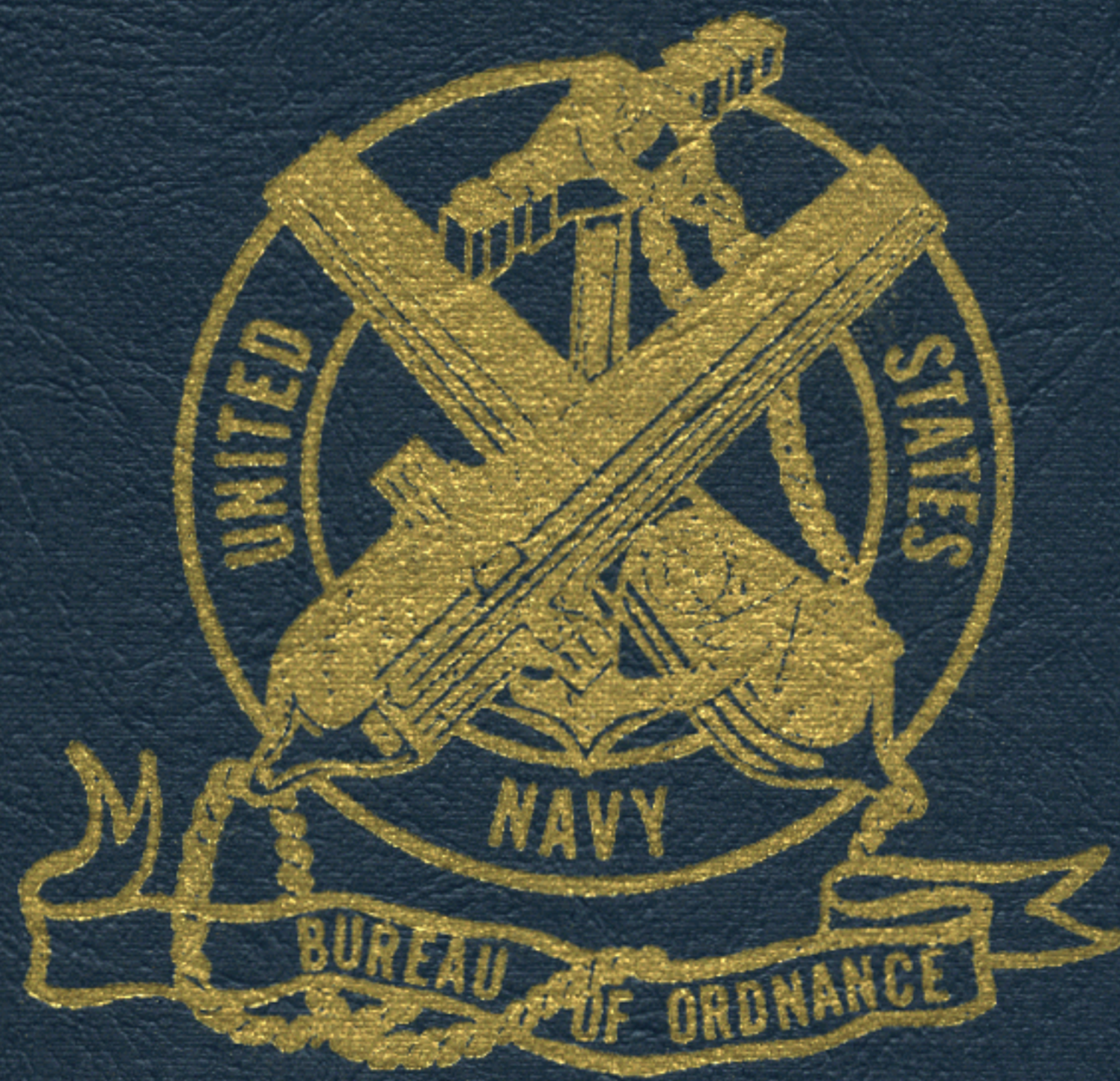


# THE MACHINE GUN

VOLUME III, PARTS VIII AND IX



A BUREAU OF ORDNANCE PUBLICATION

# THE MACHINE GUN

VOLUME III, PARTS VIII AND IX

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*George M. Blinn*

# THE MACHINE GUN

Development During World War II and Korean Conflict  
by the United States and their Allies,  
of Full Automatic Machine Gun Systems and  
High Rate of Fire Power Driven Cannon

by

**George M. Chinn**

COLONEL, USMC (Retired)

**Volume Three of Four Volumes**

PREPARED FOR THE BUREAU OF ORDNANCE

Department of the Navy

1951

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## PREFACE

The series of books entitled "The Machine Gun" has been prepared with the belief that the next best thing to actual knowledge is knowing where to find it. The research summarized within the covers of these volumes has been compiled by the Bureau of Ordnance, Department of the Navy, in order to place in the hands of those rightfully interested in the art of automatic weapon design, the world's recorded progress in this field of endeavor.

The primary purpose of Parts VIII and IX of Volume III is to make available to those in authority pertinent data on the experimental work carried on to improve the design of automatic aircraft cannon by the United States and other major powers during and since World War II. Through data given in Volume III, personnel reporting for duty in research and development activities can acquaint themselves with certain phases of developmental work that already have been accomplished.

The information in most instances was compiled by the originators of the mechanisms and is presented in substantially the same form as when first prepared. The claims, recommendations, and conclusions represent the opinions of responsible personnel at the time the reports were submitted. No editorial comment has been included; accordingly, opinions formed by the reader will be based solely on authenticated source material.

For purposes of clarity and uniformity, the topics within chapters have been arranged in as nearly the same order as possible. Because the goal of this book is to present the case history of each gun in the form the cognizant activities chose, deviations from their arrangement of material have been made only where the original reports were organized so differently that rearrangement for consistency of presentation seemed desirable.

Parts VIII and IX of Volume III, unlike Part I through VII of Volumes I and II, deal strictly with technical aspects of the mechanisms; therefore, charts are included to give specific engineering data in condensed form. It is hoped that these graphic presentations will aid in the quick location of facts when this volume is used as reference material during a conference or other similar situation.

To show the evolution of some of our most advanced automatic firing mechanisms, it was necessary to illustrate several weapons that are so outmoded that they are not listed in the chapter entitled "Automatic Gun Designations." Accordingly, it was thought appropriate to introduce them pictorially in order to establish proof of the existence of the parent design.

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The untiring personal interest, guidance and professional advice of Mr. Henry E. Marschalk, Head, Publications Branch, Administration Division, Bureau of Ordnance, is largely responsible for whatever measure of success the three volumes of "The Machine Gun" have achieved.

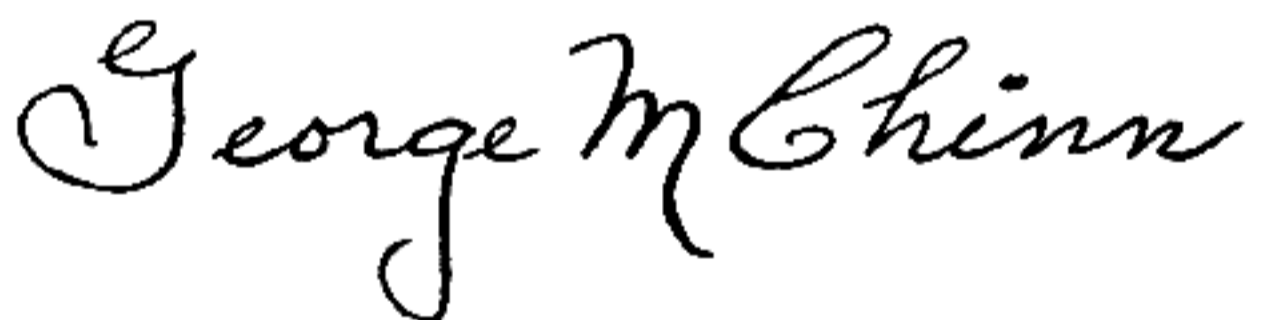
The meticulous reading of the manuscript by Comdr. Jack J. Hinman III, USN, and his valuable suggestions based on an extensive knowledge of automatic weapons added greatly to the completeness of this work.

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*Lieutenant Colonel, USMCR.*

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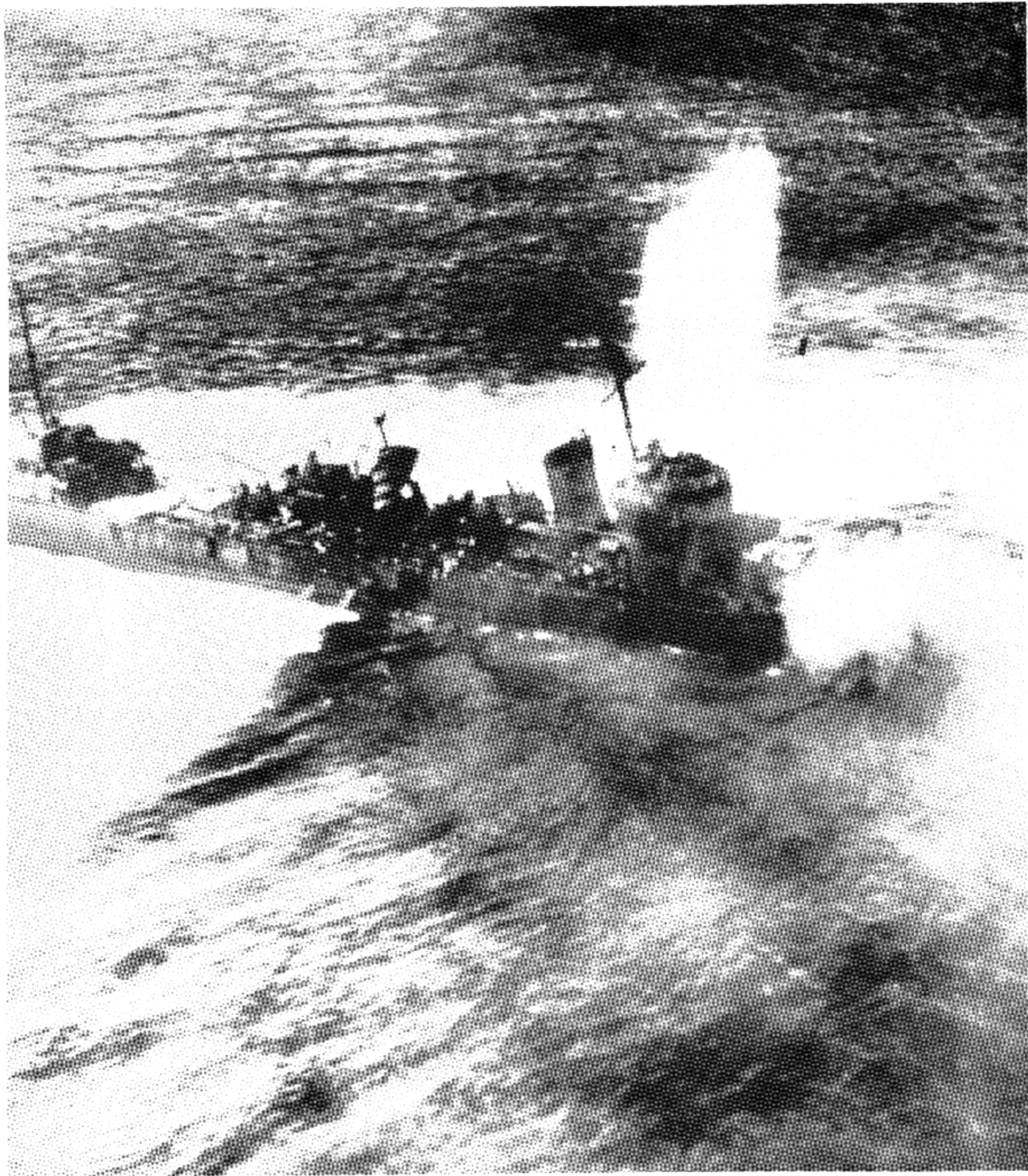
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Frontispiece. In World War II, Japanese warship receiving a fatal shot from a 75-mm aircraft cannon.

CONFIDENTIAL

PART VIII  
AUTOMATIC WEAPON DEVELOPMENT  
DURING AND AFTER WORLD WAR II  
BY THE UNITED STATES

CONFIDENTIAL

## Chapter 1

# AUTOMATIC GUN DESIGNATIONS OF THE ARMED SERVICES

## SECTION 1. INTRODUCTION

Automatic weapons for the Armed Forces of the United States are procured, with minor exceptions, by two agencies, the Ordnance Corps of the Army, and the Bureau of Ordnance of the Navy. When a project is set up to develop a new item or modify a standard piece, a distinctive designation is assigned to identify it.

The Army method prior to 1925 was to assign a designation of model and year to each design. Since that time, model has been abbreviated with a capital M and consecutive numbers are assigned. Items in the development stage are given numbers with a capital T prefixed. To indicate changes in the development stages, the capital letter E may be suffixed to the T number followed by an Arabic numeral. Experimental changes to standard, or M-numbered items are also indicated by suffixed E numbers. Standard, or M-numbered items with approved changes, or standardized alterations, are identified by suffixed A numbers.

When a Navy ordnance item is approved for testing, it is assigned a Mark number. It retains this Mark number whether finally approved for service use or rejected. Modifications to the original Mark design are treated likewise. At the present time a proposal is under consideration to use EX numbers for Navy aircraft ordnance items while they are still in the development stage.

To identify an automatic gun completely, the caliber must be mentioned, then the correct letter and number designations. In some cases it is necessary to name the gun or mechanism, for example:

"Gun, Machine, Caliber .50 M2," and "20-mm Machine Gun Mechanism Mk 2 Mod 0." Complete identifications of this type are needed since T numbers, M numbers, and Mark and Mod numbers begin with No. 1 for each of various types of ordnance and other military equipment. In addition to reuse of numbers, there is some difference of usage of letter designations. For example: the Chemical Warfare Service has used E and R designations for experimental items instead of the T and E numbers of the Ordnance Department.

One of the most confusing things associated with the official designations of weapons is the prefix "AN", extensively used during World War II. This, when found attached to a model number, sometimes has caused the erroneous impression that there is a physical difference between a weapon so marked and one that bears only the model number, for example, "Gun, Machine, Caliber .50, AN-M2," and "Gun, Machine, Caliber .50 M2." The "AN" means that the weapon was adopted by both the Army and the Navy, and no difference exists between a gun so marked and the basic design.

On the front end papers of this book is a list of United States large-caliber automatic guns. In this chapter, the distinguishing characteristics of these guns are summarized. The reader should note that not all these designs were fabricated in metal. Some were made as wooden "mockups" and others were discarded while still on the drawing board. Weapons firing rifle, pistol, or carbine ammunition have been omitted purposely.

METHOD OF ASSIGNING T NUMBERS TO  
AUTOMATIC AIRCRAFT GUNS

OLD

From 1926 to 1950 there were four separate lists from which T numbers were assigned to automatic aircraft guns.

NEW

The following examples represent the first assignment under the new system for various sizes of automatic or machine guns.

Low# High# Bore

T1	T65	Cal.30	} GUN, MACHINE	} After March 1950 numbers were drawn from a single index which is generalized as <b>"WEAPONS"</b> This weapons index includes all howitzers, guns and mortars regardless of bore, function, or use.	GUN, AUTOMATIC,	Cal.60	T130
T1	T60	Cal.50			GUN, AUTOMATIC,	27mm	T150
T17	T66	Cal.60			GUN, MACHINE, TANK	Cal.30	T152
T54	T56	20mm			GUN, AUTOMATIC,	15mm	T154
T1	T129	20mm	} GUN, AUTOMATIC		GUN, AUTOMATIC,	20mm	T160
T120	T121	30mm			GUN, MACHINE,	Cal. 50	T164
T1	T4	Cal. 90	GUN, Cal. 90		GUN, AUTOMATIC,	37mm	T172
T1	T49	37mm	GUN, 37mm		GUN, AUTOMATIC,	30mm	T182

In the future all bore sizes of new guns will be stated in mm.

All numbers between the low and the high were not necessarily assigned to machine or automatic guns. Some were proof, sub-caliber, or other types.

UNDER THIS SYSTEM ANY T NUMBER HIGHER THAN 130 WILL BE ASSIGNED ONLY ONCE TO A 'WEAPON' but there are other classifications such as 'RIFLE' and 'LAUNCHER' which will have a similar number

Figure 1-1. Method of assigning "T" numbers to ordnance items.

SECTION 2. CHARACTERISTICS OF UNITED STATES  
LARGE-CALIBER AUTOMATIC GUNS

Caliber .50 Machine Guns

*Gun, Machine, Caliber, .50, Model 1918.* In April 1918 the AEF, in a cable to the War Department, expressed an urgent requirement for a high-powered, large-caliber machine gun and ammunition primarily for aircraft, with second priority for ground use. Available knowledge on the perform-

ance of a German 13.2-mm rimmed antitank cartridge, as well as information on the British development of a caliber .50 cartridge, led to a decision to develop a caliber .50 machine gun and ammunition. Guns were designed under the supervision of John Browning at the Colt's Patent Fire Arms Manufacturing Co. (ground type) and at the

Winchester Repeating Arms Co. (aircraft type). (See *The Machine Gun*, vol. 1, p. 335.)

*Gun, Machine, Caliber .50, Model 1921.* This series of Browning guns were the first standard machine guns of caliber .50 to be adopted by the United States Government. There were variations for ground, air, and naval use. All this material is now obsolete.

*Gun, Machine, Caliber .50 T1.* An early design in the program to modify the Browning caliber .50 gun to permit right and left-hand feed. Both air- and water-cooled guns were made.

*Gun, Machine, Caliber .50 T2.* An intermediate stage in the development of the caliber .50 M2 series.

*Gun, Machine, Caliber .50 T21.* The Browning T21 was a collaborative effort by Colt and Springfield. This weapon underwent tests at Aberdeen Proving Ground from 1940 to 1942 with unfavorable results. The importance of that project was the establishment of a standard of performance for an acceptable high-speed gun. One breakage and five malfunctions were to be permitted in 5,000 rounds of firing at 1,200 rounds per minute.

*Gun, Machine, Caliber .50 T22.* Early in 1942 the High Standard Manufacturing Co. designed a high cyclic rate caliber .50 Browning machine gun and made two models. These guns, designated T22, were submitted to the Aberdeen Proving Ground for test 10 August 1942. One gun was fired on that date, 554 rounds at a cyclic rate of 1,066 rounds per minute, during which five stubbed rounds and two failures to feed occurred. Both guns were returned to High Standard for modification. A total of 10 guns were made.

*Gun, Machine, Caliber .50 T22E1.* This was a version of the T22 tested February 1943 which failed after firing 111 rounds. Failure was due to a broken sear.

*Gun, Machine, Caliber .50 T22E2.* Tested in March 1943 this gun fired 3,700 rounds at cyclic rate of 1,219 rounds per minute. There were 43 malfunctions and 7 breakages.

*Gun, Machine, Caliber .50 T22E3.* The records do not indicate the history of the T22E3.

*Gun, Machine, Caliber .50 T22E4.* Tested in August 1943 this gun fired 5,000 rounds at a cyclic rate of 1,108 rounds. There were 36 malfunctions and 2 breakages.

*Gun, Machine, Caliber .50 T22E5.* Modification of T22E4. Two guns were produced but when fired at Aberdeen their rate of fire was less than 1,000 rounds per minute.

*Gun, Machine, Caliber .50 T22E6.* Tested late in 1943 the T22E6 first gave poor results. In the development of this gun an effort was made to hold to a minimum the changes from the standard Browning M2 gun. Because of defects inherent in the mechanism it was decided that further development could not be expected to produce a completely acceptable weapon. Accordingly, further development of the T22E6 gun, as such, was not undertaken by the Ordnance Department although certain features of the weapon were incorporated in the T36 (M2A1) and T25E3 (M3) guns.

*Gun, Machine, Caliber .50 T25.* In the development of the T25 by Frigidairc no restriction was placed on the number of changes from the M2 gun, and the contractor was permitted to proceed by making all changes necessary to provide reliable functioning at a rate of fire of 1,200 rounds per minute. For example, the backplate buffer, barrel buffer, and receiver were redesigned. It was not until 10 March 1944 that the first T25 gun was submitted to Aberdeen Proving Ground for test. The gun gave a fair performance for 2,000 rounds, but from that point on excessive breakages and mal-

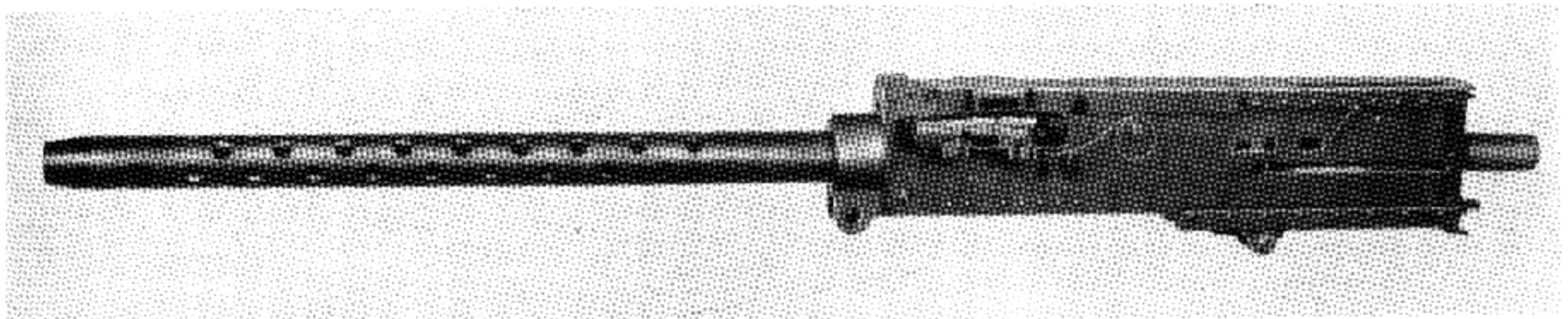


Figure 1-2. Gun, Machine, Caliber .50 T22E6.

functions occurred, and at 3,100 rounds the test was discontinued because of the breakage of the backplate buffer.

*Gun, Machine, Caliber .50 T25E1.* Work was immediately started on a second gun, the T25E1, which was tested at Aberdeen 10 May 1944. This gun was completely unsatisfactory. Nine breakages and three malfunctions occurred in 770 rounds and the test was stopped. Satisfactory functioning had not been obtained with the T25 series guns but certain features of those guns were considered very desirable.

guns, and to expedite procurement of this weapon, the Army Air Forces requested its standardization in April 1945. Ordnance Committee action was immediately taken to standardize the T25E3 gun as Gun, Machine, Caliber .50 M3, Aircraft, Basic.

*Gun, Machine, Caliber .50 T26.* Modification of the Browning M2 gun produced and tested at Aberdeen. Included a short-round device submitted by the Army Air Force and the cover assembly of the T22E5. The extractor assembly was also taken from the T22 series as was the backplate assembly. A muzzle booster with a 0.65-inch hole

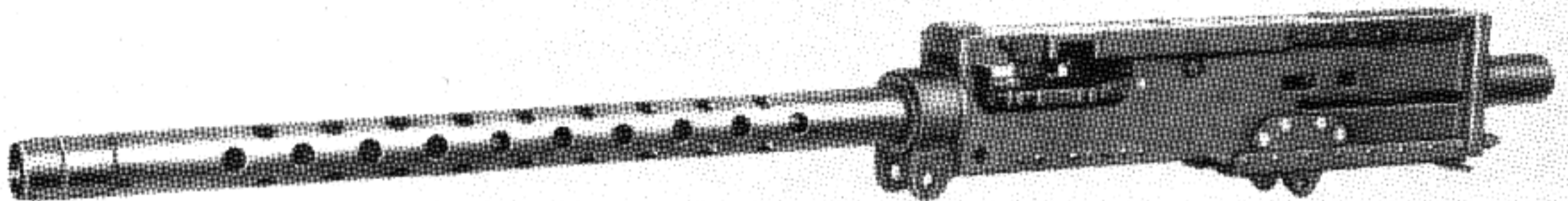


Figure 1-3. Gun, Machine, Caliber .50 T25E1.

*Gun, Machine, Caliber .50 T25E2.* To permit further study of the causes of this unsatisfactory functioning, the T25E2 gun was made up by substituting the bolt, top cover and recoil booster of the T22E6 gun for corresponding components of the T25E1 gun. This gun was fired at Aberdeen Proving Ground in June 1944. Functioning continued unsatisfactorily, and the test was stopped at 1,800 rounds. A careful examination indicated that the nested helical springs in the backplate buffer were breaking and causing extreme impact forces on the gun component.

*Gun, Machine, Caliber .50 T25E3.* The first T25E3 gun was tested at Aberdeen 19 July 1944. The functioning of this gun was greatly improved over that of the T25E1, and the cyclic rate averaged 1,250 rounds per minute. Eight malfunctions occurred, but for the first time in the development, it was possible to determine the specific cause of each malfunction. A projecting corner on the bolt was responsible for "shorting" rounds in the feedway and causing failures to feed; the remainder of the malfunctions were caused by fatigue of the sear spring. After the satisfactory tests of the T25E3

was used and a pneumatic buffer and a modified sideplate switch.

*Gun, Machine, Caliber .50 T27.* This was a Browning developed by High Standard to provide a kit of parts which could be used to convert the standard M2 gun to a high-speed weapon. The test was stopped before completion in January 1944.

*Gun, Machine, Caliber .50 T27E1.* Unsatisfactory performance, since one of the two guns made blew up. Test discontinued about February 1945.

*Gun, Machine, Caliber .50 T27E2.* The records do not indicate that the history of the T27E2 extends beyond the blueprint stage.

*Gun, Machine, Caliber .50 T27E3.* Tested in March 1944; numerous malfunctions.

*Gun, Machine, Caliber .50 T27E4.* Fired at a rate of 1,330 rounds per minute when tested in April 1944 but suffered numerous breakages and malfunctions.

*Gun, Machine, Caliber .50 T27E5.* Tested in June 1944; excessive malfunctions terminated the test after the one gun blew up.

*Gun, Machine, Caliber .50 T27E6.* Tested early in 1945, it successfully fired 5,000 rounds at a rate

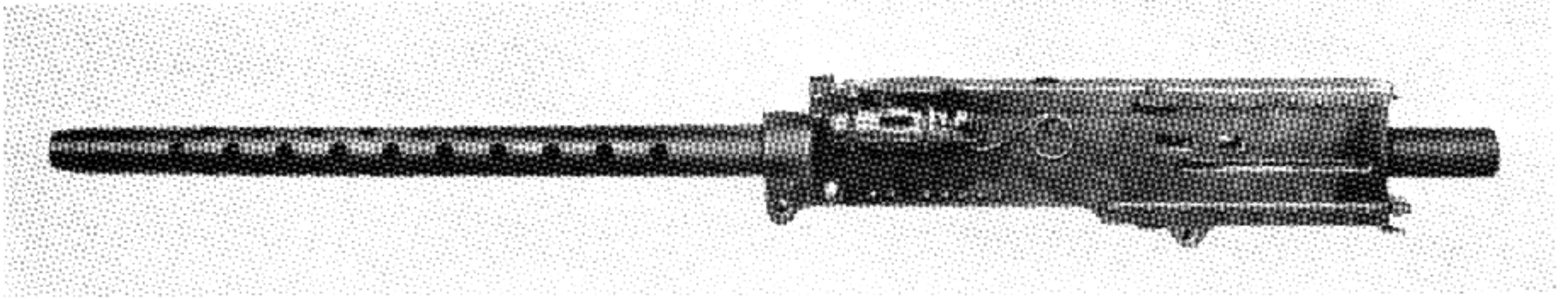


Figure 1-4. Gun, Machine, Caliber .50 T27E6.

of over 1,000 rounds per minute with only one breakage of major parts but 1 of the 4 guns tested had 11 malfunctions.

*Gun, Machine, Caliber .50 T27E7.* In March 1945 the last version was tested and successfully completed the 5,000 round test without going beyond the numbers of acceptable malfunctions but suffered excessive breakage of minor parts. In the overdevelopment of the T27 series, unsatisfactory performance and danger to personnel and equipment caused by the unusual number of breakages and explosions were responsible for the decision in March 1945 that no further consideration would be given this weapon.

*Gun, Machine, Caliber .50 T28.* Developed by Springfield Armory to produce a high cyclic rate gun. Specifications called for 1,200 rounds per minute without breakages.

*Gun, Machine, Caliber .50 T34.* Air Force requirement for the fabrication of a gun which would have a cyclic rate of 1,500 rounds per minute. Project assigned to Springfield. This was to be an entirely new mechanism, operating on a principle suitable for very high-speed operation. Preliminary drawings of this gun were received in August 1945,

and after careful study, the Springfield Armory was requested to supply additional drawings.

*Gun, Machine, Caliber .50 T35.* To fulfill the Air Force requirement for a gun with a cyclic rate of 1,500 rounds per minute, a project was set up to modify the M2 Browning.

*Gun, Machine, Caliber .50 T36.* During the development of a high speed caliber .50 machine gun, certain very valuable improvements were made which were applicable to the standard M2 caliber .50 aircraft gun. In September 1944, it was decided to incorporate immediately into the M2 gun these features which had been proven in tests of various experimental high speed guns. This improved gun, designated T36, was designed to accomplish limited objectives, compared to the M2 gun, namely: (1) reduction in recurrent malfunctions; (2) increase in cyclic rate of approximately 100 rounds per minute; and (3) increase in belt lift capacity to 30 pounds minimum consistent with the accomplishment of these objectives.

*Gun, Machine, Caliber .50 T38.* A further development of the M3 by Frigidaire in 1945. This design was also in response to the Air Force requirement for a 1,500 round per minute gun. Limited

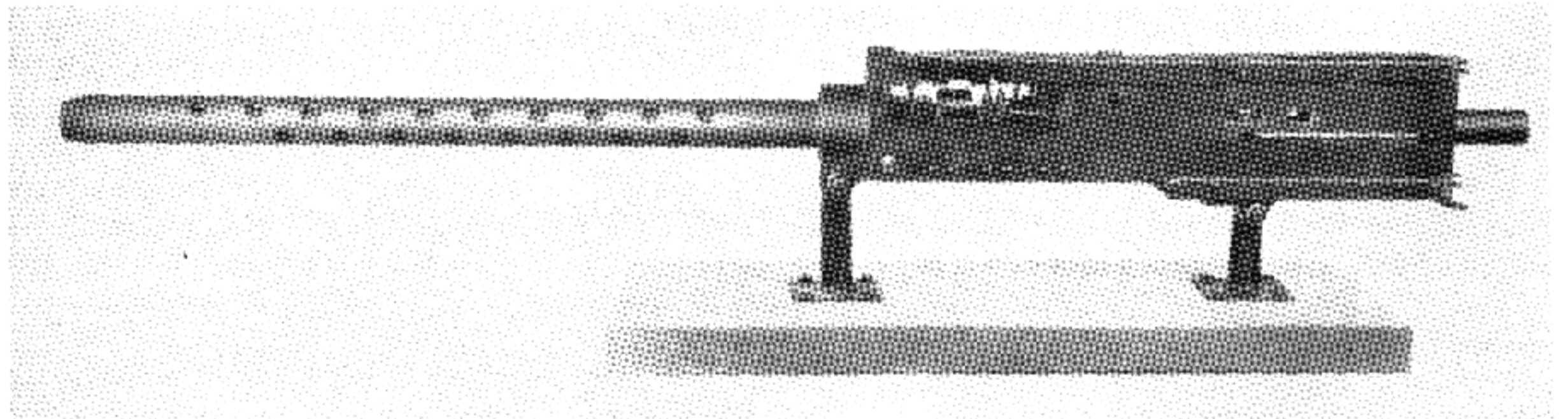


Figure 1-5. Gun, Machine, Caliber .50 T36.



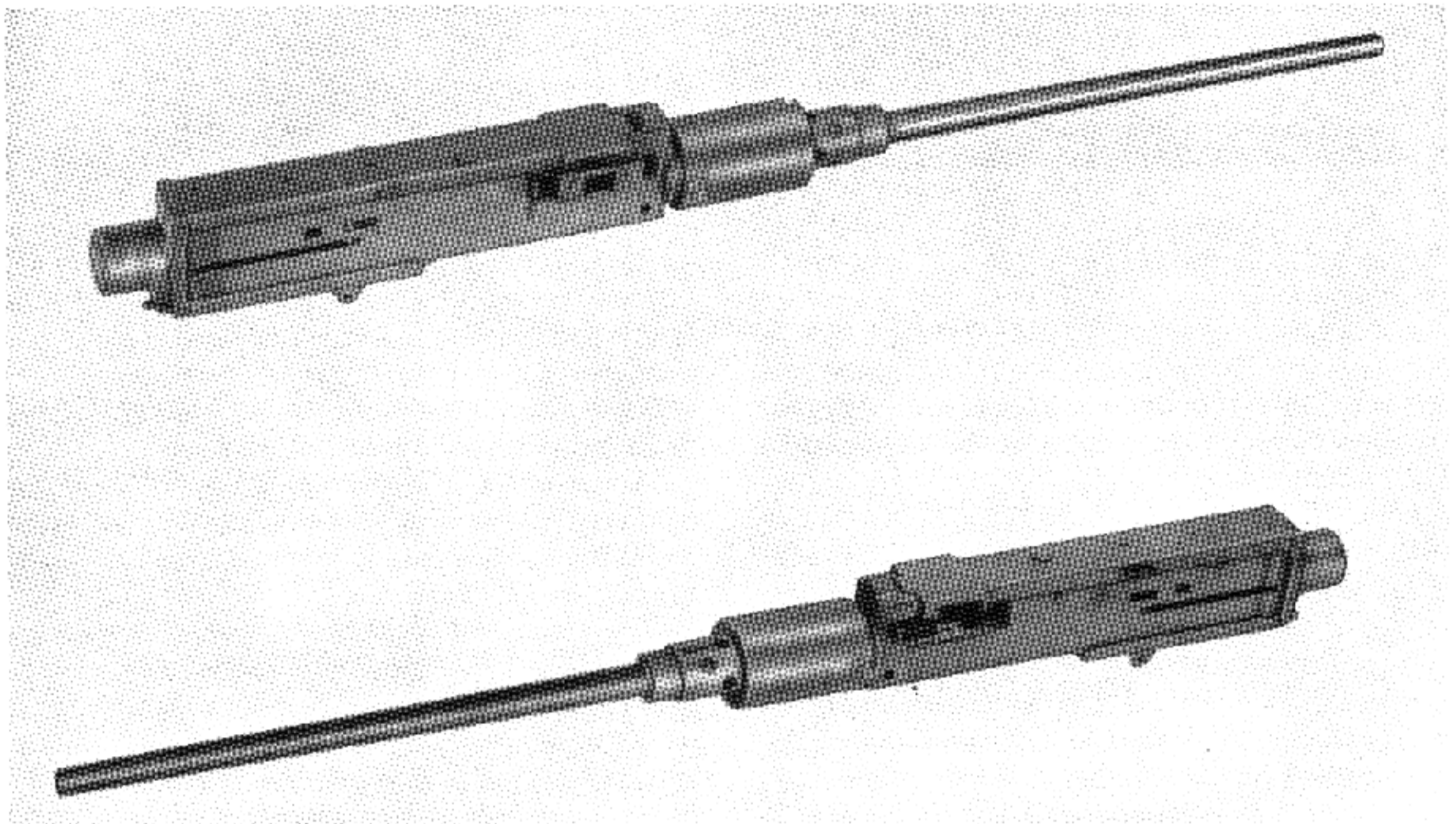


Figure 1-6. Gun, Machine, Caliber .50 T42.

firing was conducted at rates up to 1,450 rounds per minute by Frigidaire.

*Gun, Machine, Caliber .50 T42.* Intended for use as an anti-aircraft weapon with a rate of fire of 700 rounds per minute. Similar to the Browning M3 but uses heavy barrel and short barrel support.

*Gun, Machine, Caliber .50 T60.* This was a project set up in 1948 to develop an aircraft gun with a rate of fire 2,000 rounds per minute.

*Gun, Machine, Caliber .50 T164.* The armored force established a requirement for a caliber .50 machine gun for use on tank turrets with the provision that it must incorporate a short receiver. Springfield Armory built a revolver type based on the 20-mm T74 and this is designated the caliber .50 T164.

*Gun, Machine, Caliber .50 T175.* Similar to the T176, except barrel energy is transmitted by hydraulic means. Also intended for tanks.

*Gun, Machine, Caliber .50 T176.* The T176 was designed in response to the requirement for a short receiver tank gun. It is a nonconventional type in which the barrel energy is used to operate the mechanism indirectly through Belleville springs. It

was designed for alternate use at a high and low rate of fire.

*Gun, Machine, Caliber .50 M1.* The experimental Browning T2 caliber .50 machine gun was standardized for cavalry and infantry without modification as the M1. This model never went into production.

*Gun, Machine, Caliber .50 M2.* Further development of the Browning system produced the M2 series which was standardized in 1933. The three principal versions were water-cooled, aircraft, and heavy barrel. The three guns utilized the same basic receivers. The water-cooled gun was for anti-aircraft use; the heavy-barrel gun was intended for use by and against armored vehicles, and the aircraft gun with its 36-inch air-cooled barrel was for use in aircraft. Later, several other varieties were standardized, all of which used the same basic receiver. An important characteristic of the M2 series is the ability to convert from one type to another.

*Gun, Machine, Caliber .50 M2A1.* In 1944, the limited procurement of 31,336 of the T36 guns was authorized. This procurement was discontinued

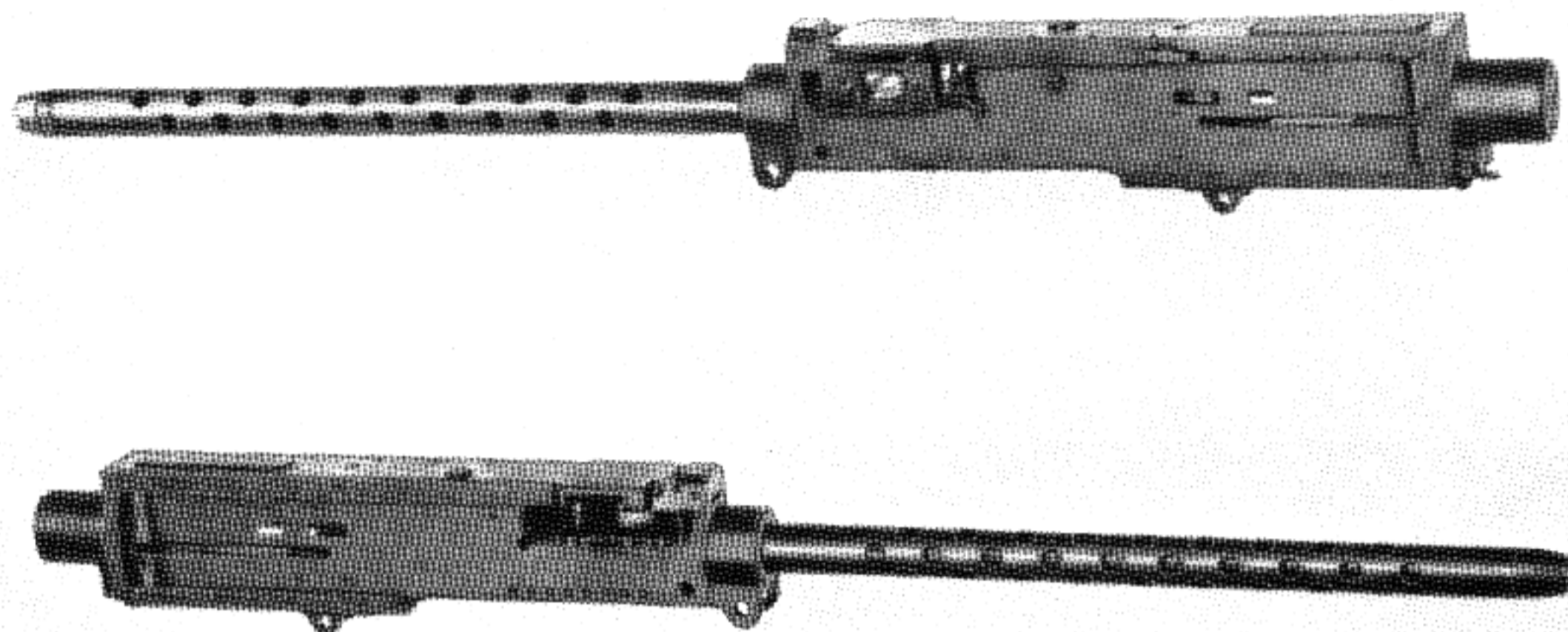


Figure 1-7. Gun, Machine, Caliber .50 M3.

after approximately 8,000 guns had been produced because of the unexpected progress made in the development of the T25E3 high-speed gun, which led to its standardization as the M3 earlier than had been thought possible. Following the standardization of the M3 gun, the T36 gun was reclassified as limited standard, and redesignated Gun, Machine, Browning, Caliber .50, M2A1, Aircraft, Basic.

*Gun, Machine, Caliber .50 M2E1.* The records do not indicate the history of the M2E1.

*Gun, Machine, Caliber .50 M3.* In 1945 the caliber .50 Browning T25E3 was standardized as the M3. There are slight variations in guns of early and later manufacture. The M3 gun is based upon the caliber .50 aircraft machine gun M2 and has essentially the same exterior dimensions, except for the increased diameter of the backplate buffer, and the length added by the recoil booster. It fires at a cyclic rate of approximately 1,200 rounds per minute with standard ammunition and links. Nearly all parts of the M3 gun differ in detail from

those of the M2, having been improved in design and metallurgy.

### Caliber .60 Machine Guns

*Bendix 15-mm Machine Gun.* The first attempt to meet the characteristics for the caliber .60 aircraft machine gun was to modify a 20-mm Hispano-Suiza automatic cannon. The receiver was identical and parts of the gun were interchangeable with the 20-mm, M1. The chief difference was in the barrel, which was chambered for the 20-mm case, bored and rifled for the 15-mm bullet and fixed in relation to the mount. The whole gun was rigidly mounted and the muzzle brake and recoil mechanism used on the 20-mm gun were eliminated.

*Gun, Machine, Caliber .60 T17.* In September 1942, a project was initiated to convert the 15-mm German aircraft gun, MG 151, a recoil-operated, air-cooled, and belt-fed gun, to use the caliber .60 cartridge. In October 1942, Colt's Patent Fire Arms Manufacturing Co. undertook this conversion.



Figure 1-8. 15-mm Bendix Machine Gun. Top view.

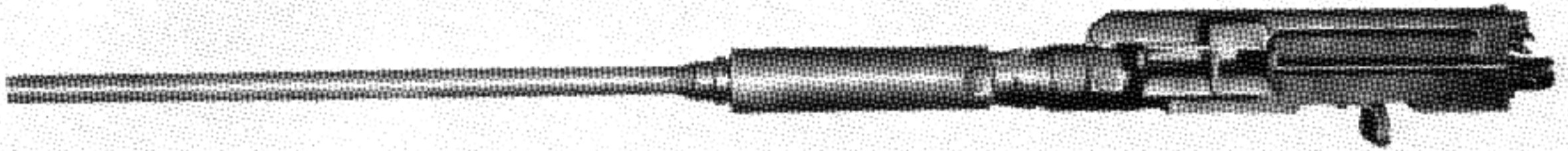


Figure 1-9. Gun, Machine, Caliber .60 T17E1.

The gun was designated Caliber .60 Machine Gun T17. It was found necessary to rechamber the barrel, lengthen the receiver, feedway, bolt, cam tube, and cover, and to make a few other minor design changes. New links were provided by the Autoyre Co.

*Gun, Machine, Caliber .60 T17E1.* The Frigidaire division of the General Motors Corp., Dayton, Ohio, undertook in January 1943 to provide 10 pilot models of the aircraft machine gun, caliber .60 T17E1. The model was to be essentially the same as the T17, except that the rate of fire was to be increased to 800 rounds per minute and the high trunnion reactions were to be lowered by incorporating in the design a recoil adapter developed by the Edgewater Steel Co. at the request of the ordnance officer at Wright Field. Links for the gun were developed by the Autoyre Co. of Oakville, Conn. Complete drawings of the T17 gun were prepared by Frigidaire and an engineering study was made to redesign the weapon for cheaper mass production.

*Gun, Machine, Caliber .60 T17E2.* The Frigidaire division was then asked to prepare two additional models which would use strengthened components and a barrel with a thicker walled chamber as the chamber had expanded during tests of earlier models. SAE 1060 steel was used in the T17E1 wherever possible. In the T17E2 this policy was abandoned and SAE 4640 steel was substituted. Fabrication of these models involved the use of sheet metal stampings and hydrogen brazing. This gun was designated the T17E2. In May 1943 the General Electric Co., Bridgeport, Conn., accepted a contract to develop an electric charger for the T17E2 gun. It appeared at this time that the most profitable development of this item would be a charger integral with the gun. Two T17E2 machine guns were delivered to Aberdeen Proving Ground for test on 25 August 1943. Each was equipped with

manual charging and firing equipment and recoil adapters. Electrical charging and firing solenoid were provided as alternate components. One gun was fired 557 rounds. Ejection difficulties developed, but after modification of the ejector the gun functioned fairly satisfactorily with a rate of fire of 600 rounds per minute. The second gun with the General Electric charging mechanism was fired 143 rounds. A combination gun was built from parts of guns No. 1 and 2 and fired 327 rounds at 658 rounds per minute and a maximum muzzle velocity of 3,696 feet per second. Numerous malfunctions were encountered which indicated that considerable further development work was needed.

*Gun, Machine, Caliber .60 T17E3.* Beginning in September 1943, attention was concentrated upon the manufacture of seven T17E3 guns with both percussion and electric ignition. On 15 December 1943 this order was increased to 10 guns. The electrical ignition mechanism was modeled upon that of the German 20-mm gun. A program was also initiated for the development of a bolt with the sear forward. It was expected that this, together with electrical ignition, would permit synchronization of the gun when either electrical or percussion primed ammunition was used. On 16 November 1943 Frigidaire was requested to develop four auxiliary gun chargers to be used as a standby device in case of failure of the electric charger. Because of a requirement placed with the Ordnance Department by the Navy Bureau of Ordnance for delivery of 2,500 caliber .60 aircraft machine guns with auxiliaries and spare parts in 1944, limited procurement of the T17E3 was initiated 2 December 1943 and approved 16 December 1943. Rock Island Arsenal was commissioned to make these guns. This gun weighed 135 pounds, including recoil mounting adapter, electrical charger and solenoid, and feed mechanism. The rate of fire was 600 rounds per

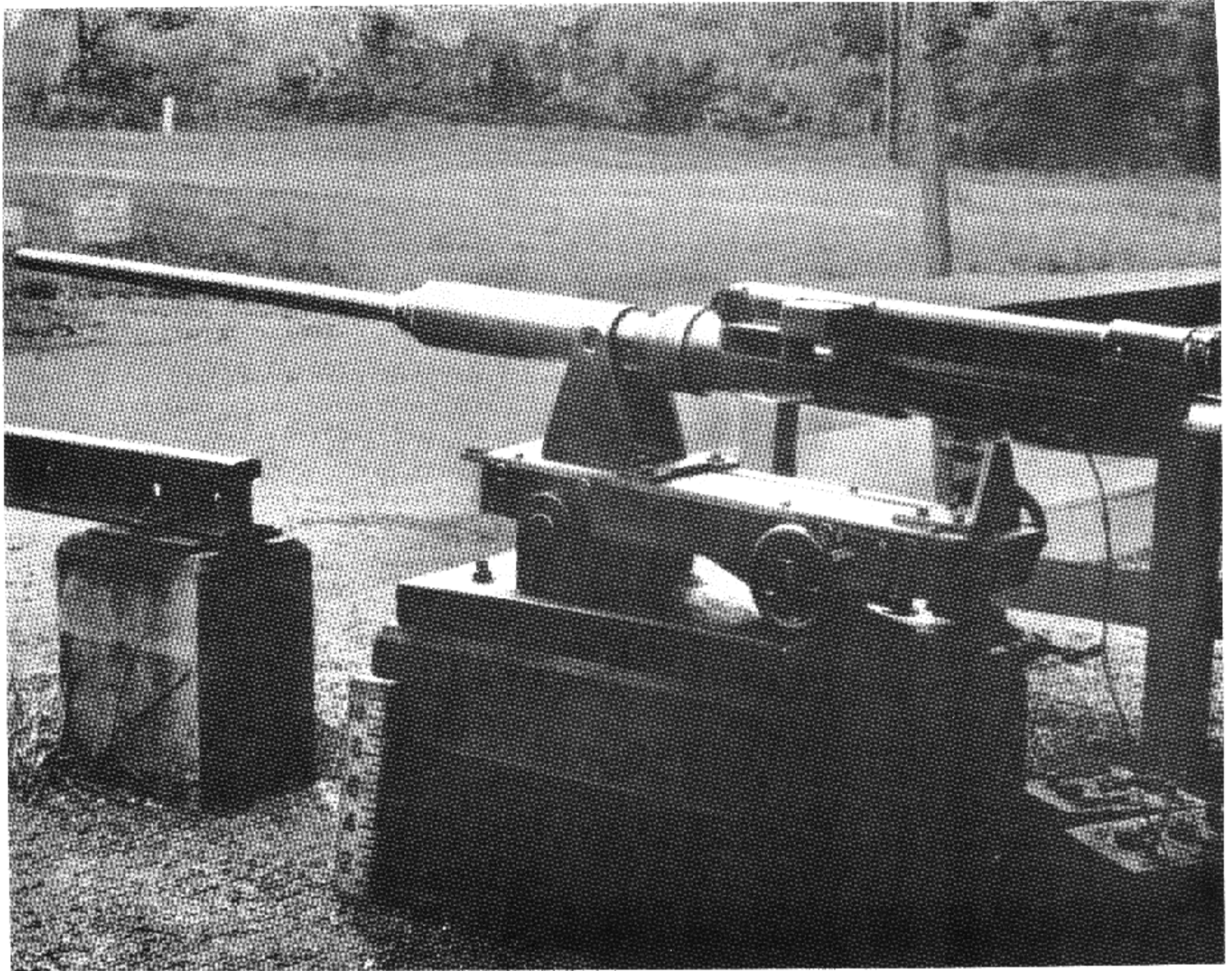


Figure 1-10. Gun, Machine, Caliber .60 T17E2.

minute, and the muzzle velocity was 3,500 feet per second. The gun was 92 inches long and had a maximum trunnion reaction of 3,500 pounds. At the request of the Army Air Forces the original procurement was increased to 5,025 guns by Ordnance Committee action on 23 December 1943.

*Gun, Machine, Caliber .60 T17E4.* Similar to the T17E3 with modification of the mechanism to use ammunition belted in a new link. Developed by Sanford Engineering Co.

*Gun, Machine, Caliber .60 T17E5.* Similar to the T17E3 with modification of locking lugs on bolt-head and breech ring and change in design of locking and unlocking cams. Developed by the Frigidaire division of General Motors.

*Hispano-Suiza Caliber .60 T18 Machine Gun.* A second modification of the 20-mm Hispano-Suiza cannon was made by rechambering the barrel for caliber .60 case and boring and rifling for the caliber .60 bullet. Corresponding changes were made in the bolt and extractor. This gun was fired a small number of rounds (not more than 50) automatically. Official designation of the gun was Caliber .60, T18. Since radical redesign of the Hispano-Suiza cannon appeared necessary if this gun was to meet aircraft requirements, work on this model was discontinued.

*Gun, Machine, Caliber .60 T18E1.* After approval by Headquarters ASF, it was recommended that further investigation of caliber .60 mechanisms

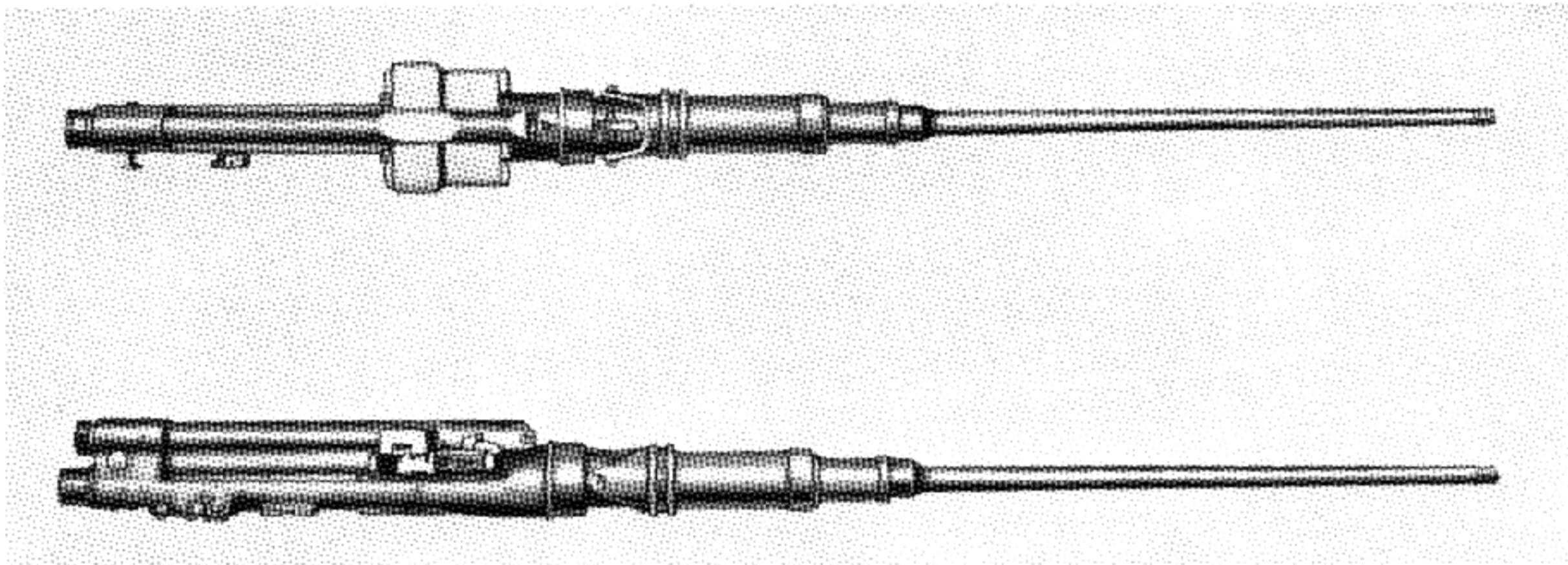


Figure 1-11. Gun, Machine, Caliber .60 T17E5.

be conducted with a modification of the 20-mm Hispano-Suiza automatic cannon, M2. This modified 20-mm weapon was designated T18E1 because there had previously been made a gun called T18 which was a 20-mm automatic cannon, M1, modified to fire the caliber .60 cartridge. The earlier

gun was fed from a five-round magazine and served only to show that the action was sufficiently strong to fire the cartridge.

*Gun, Machine, Caliber .60 T19.* This designation was assigned to an experimental design to be developed by the High Standard Manufacturing

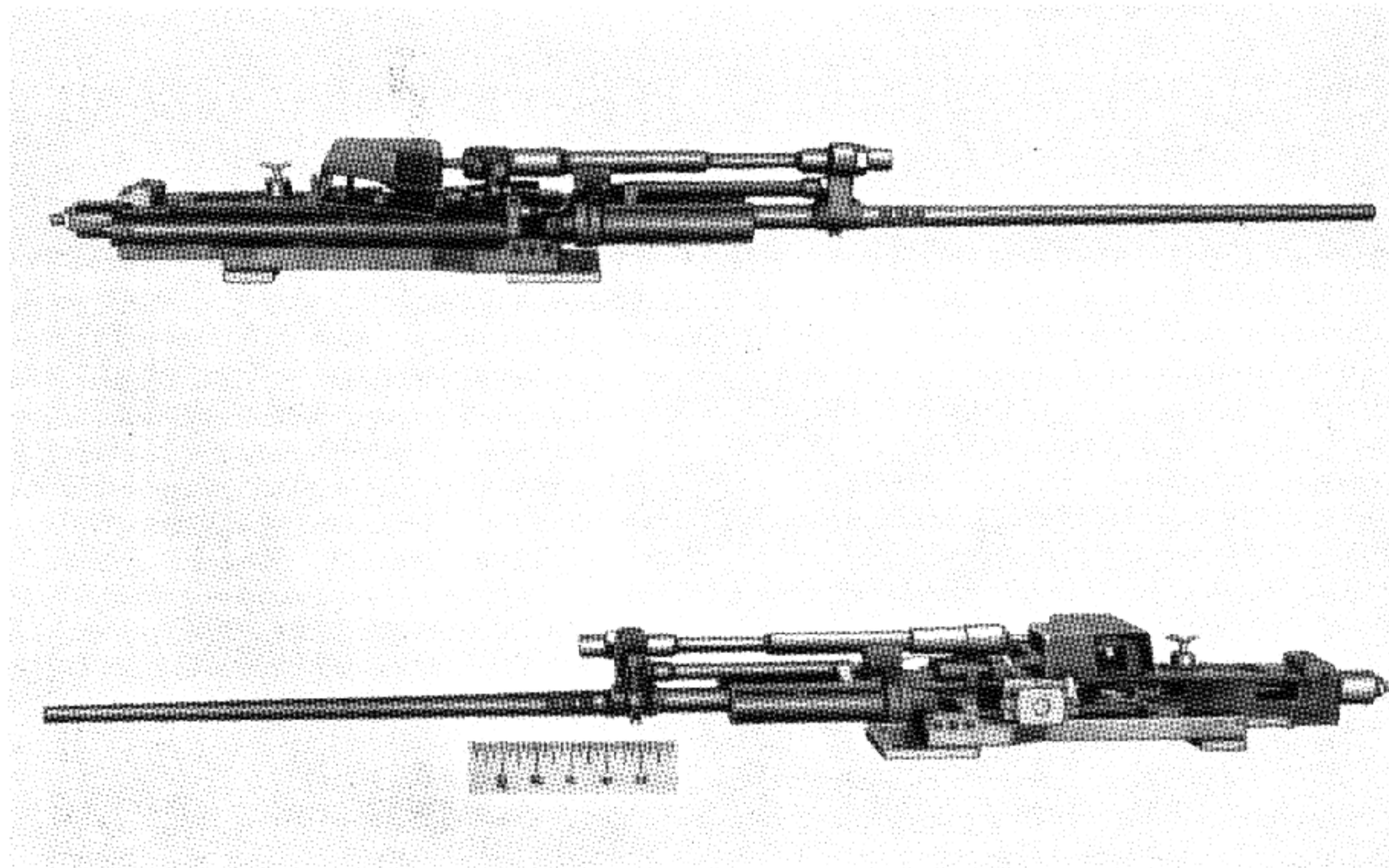


Figure 1-12. Gun, Machine, Caliber .60 T18E1.

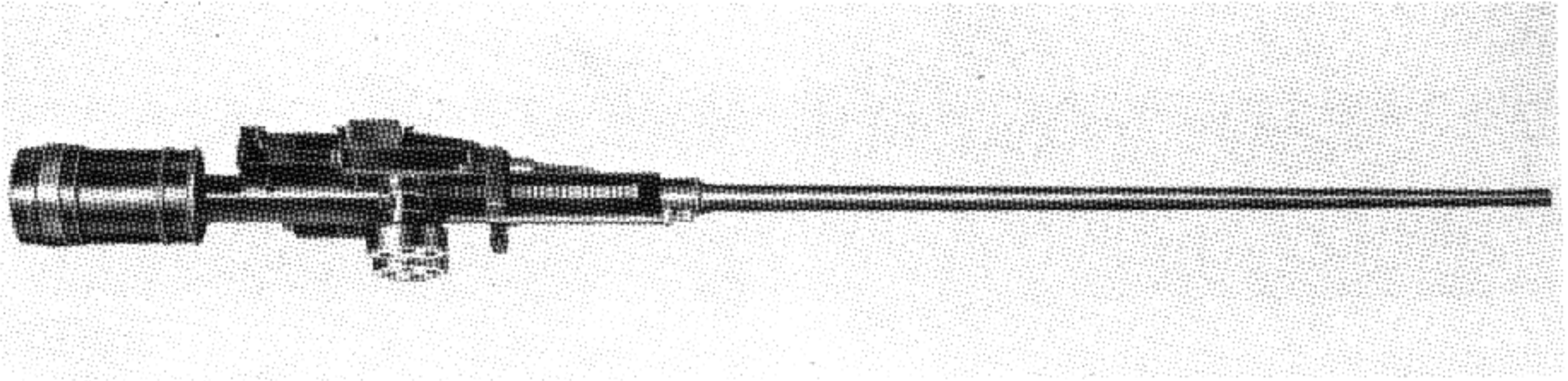


Figure 1-13. Gun, Machine, Caliber .60 T31.

Co. The design apparently went no further than the drawing board stage.

*Gun, Machine, Caliber .60 T31.* On 1 July 1944 Gazda Engineering Co. contracted to develop a gun along the lines of the 20-mm Oerlikon machine gun, but with the added features of "flywheel inertia locking," continuous belt feed, and a rate of fire in excess of 1,000 rounds per minute and capable of fire interruption (fired from a closed bolt). This gun was designated the T31. By 1 November 1944, manufacture of the gun parts had begun. On 16 January 1945, receipt of the last assembly drawing of the gun parts was acknowledged; but a complete set of detail drawings on all parts was never received. The gun, as shown by these drawings, was a composite which used a modified 20-mm Oerlikon bolt buffer, a modified 20-mm Oerlikon receiver, the T17E3 feed box and feed system, and a quick release barrel similar to the MG 151 (German). The gun was charged by a 20-mm (T2) Bendix hydraulic charger. In June 1945, the T31 was fired forty rounds by Gazda Engineering at its plant and broke a rack which connects the drive springs to the bolt. About 25 September 1945, this gun was fired again in the presence of a representative of the Office, Chief of

Ordnance, and after a few rounds a number of other parts broke.

*Gun, Machine, Caliber .60 T39.* The Caliber .60 T39 Machine Gun differs from the T17E3 only in that it has an electric bolt and bolthead, interchangeable with the percussion bolt, and a contact switch with the necessary wiring to an external power source to fire electrically primed ammunition. It is expected that this model will meet all of the Army Air Forces requirements for synchronization and fire interruption. The first electrical bolt, the E1, was a copy of the German MG 151. This bolt gave excellent ignition time and was remarkably free from "contact bounce," but the contactor which passed through the bolt and bolthead cam broke with great frequency. This design was complicated and required major modification of the bolt, bolthead and bolthead cam, and receiver.

*Gun, Machine, Caliber .60 T41.* This caliber .60 gun is a version of the caliber .60 T17E3, with two new and three modified components to provide a gas assist to the short recoil method of operation. Purpose was to provide a weapon which would function reliably, using T41 ammunition at a cyclic rate approximately equal to T17 ammunition (ball) in the basic T17E3 gun.

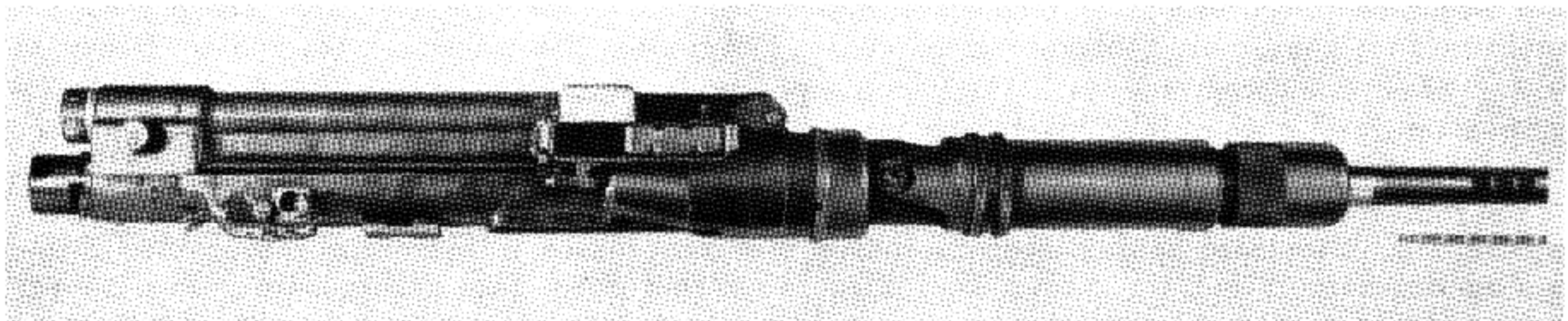


Figure 1-14. Gun, Machine, Caliber .60 T41.

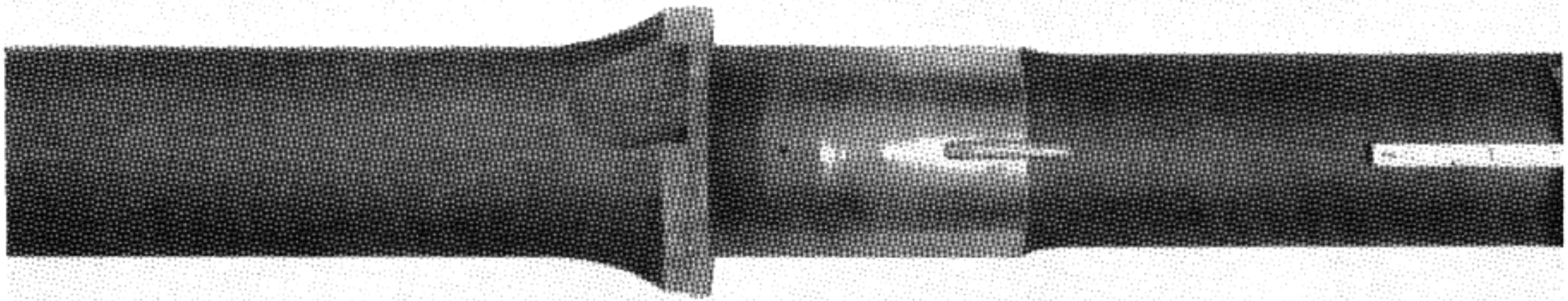


Figure 1-15. Gun, Machine, Caliber .60 T41. Closeup view of modified barrel showing gas assist port.

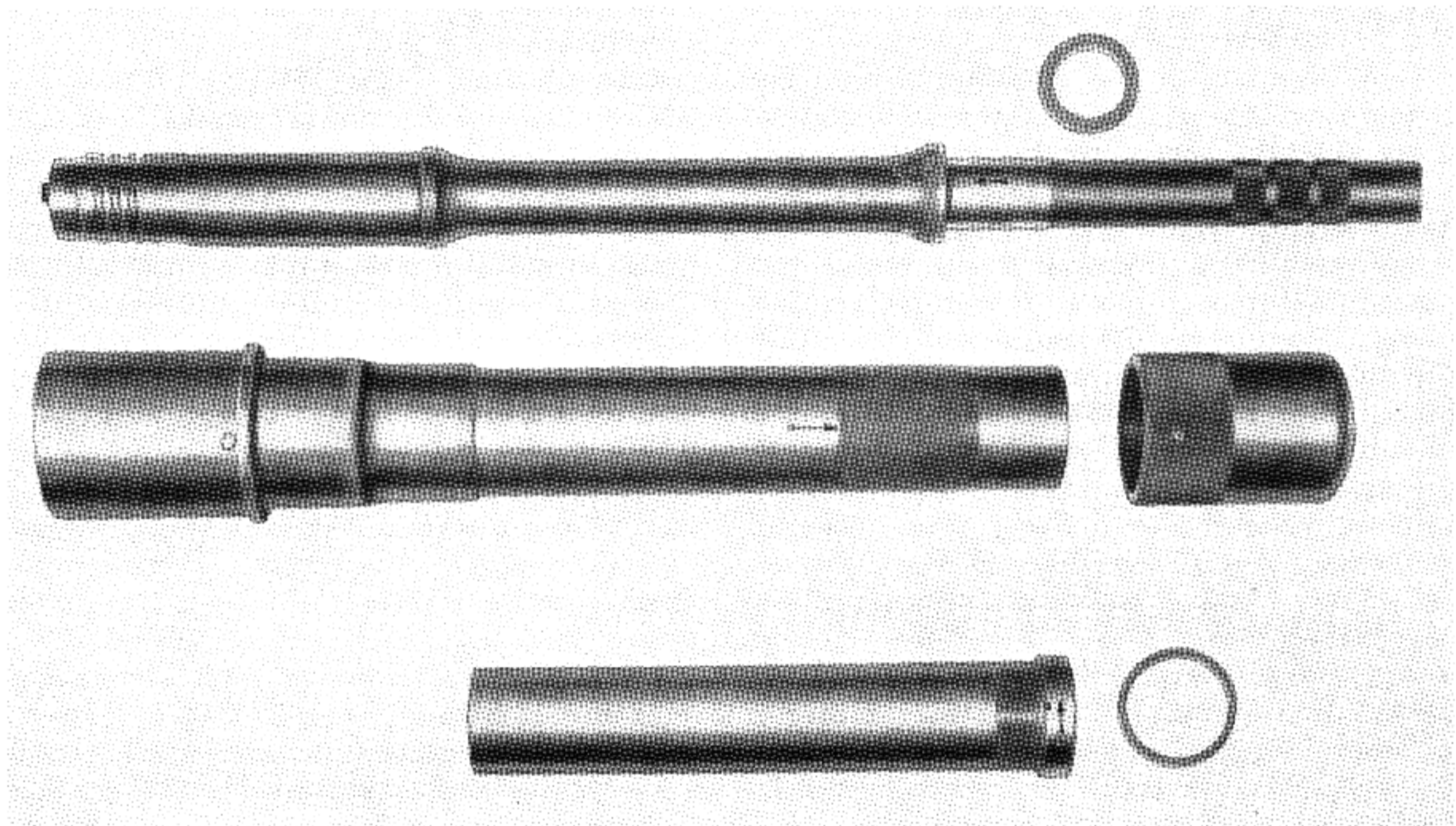


Figure 1-16. New or modified parts used in the conversion of the Caliber .60 T17E3 gun to the Caliber .60 T41.

*Gun, Machine, Caliber .60 T45.* Motor-driven machine gun with several barrels based on the Gatling system developed by the General Electric Co. under the supervision of the Ordnance Corps. Rate of fire 6,000 rounds per minute. Weight of gun approximately 427 pounds with 60-inch barrels.

*Gun, Machine, Caliber .60 T46.* Modification of the T17 series to permit synchronization by using a front sear. Developed by the Frigidaire division of General Motors.

*Gun, Machine, Caliber .60 T47.* Developed to demonstrate the problems and practicability of radi-

cally relocating gun components from their traditional position. Developed by the Frigidaire division of General Motors to use the existing caliber .60 cartridge. Designed to fire at a rate of 1,000 rounds per minute and to weigh 130 pounds including recoil adapter and feed. Length to be 70 inches with a maximum of 10 inches behind breech face of barrel.

*Gun, Machine, Caliber .60 T49.* Short 52-inch aircraft gun. Uses the standard .60 caliber cartridge, requiring changes in design and configuration of certain parts of the 20-mm version. Limited

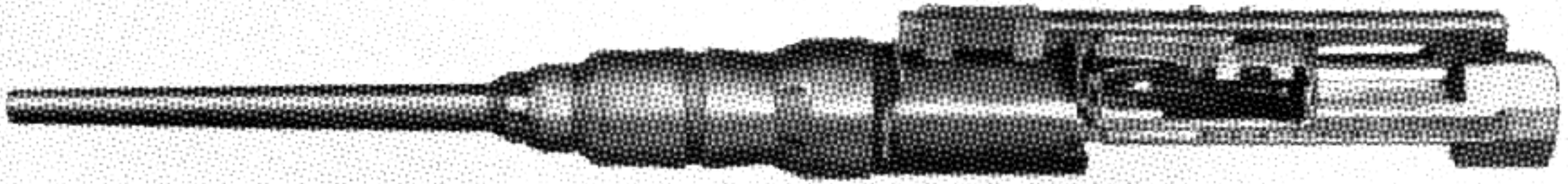


Figure 1-17. Gun, Machine, Caliber .60 T51.

development was conducted by Armour Research Foundation.

*Gun, Machine, Caliber .60 T50.* Short aircraft cannon based on the T17E5, with firing solenoid removed from rear of gun and placed on side or bottom, removal of electric charger, shortening of buffer. Developed by Naval Gun Factory.

*Gun, Machine, Caliber .60 T50E1.* Modification of the T50 with leaf type buffer springs replacing Belleville type.

*Gun, Machine, Caliber .60 T51.* Short aircraft gun based on the T17 series with firing solenoid and electric charger removed from rear of gun to side or bottom; buffer mechanism, receiver, and bolt shortened to maximum possible extent; and barrel cutoff to give 52 inches maximum overall length. Developed by Frigidaire division, General Motors.

*Gun, Machine, Caliber .60 T58.* Short aircraft gun with barrel and bolt action similar to the T17 series but having an externally driven feeder for electric primed ammunition. Proposed rate of fire 1,000-rounds-per-minute minimum.

*Gun, Machine, Caliber .60 T59.* Modification of the caliber .60 T39 gun to install in it the firing mechanism of the T17E5 gun for electric primed ammunition.

*Gun, Machine, Caliber .60 T59E1.* Version of the T59 gun having electrical charger with remote control box; spring loaded nonretractable firing pin; cam actuated extractor for ejection purposes.

*Gun, Machine, Caliber .60 T62.* An experimental weapon primarily for aircraft turrets with six barrels and same mechanism as Gun, Machine, caliber .60 T45, but with barrels shortened to give gun an overall length of 52 inches. Developed by General Electric Co.

*Gun, Machine, Caliber .60 T63.* Modification of the T17 series to increase the cyclic rate and to reduce the length and weight. An experimental percussion-fired weapon with 900 rounds per minute, cyclic rate of fire, recoil operated with integral feed mechanism, 78-inch length and 110-pound weight.

*Gun, Machine, Caliber .60 T64.* Modification of the T59 series to increase the cyclic rate and to reduce the weight. An experimental electric-fired weapon with 1,000-round-per-minute cyclic rate, recoil operated with external powered feed mechanism, 78-inch length and 140-pound weight.

*Gun, Machine, Caliber .60 T130.* Gas-operated revolver gun based on the 20-mm T74 and the German MG 213 which includes improvements over

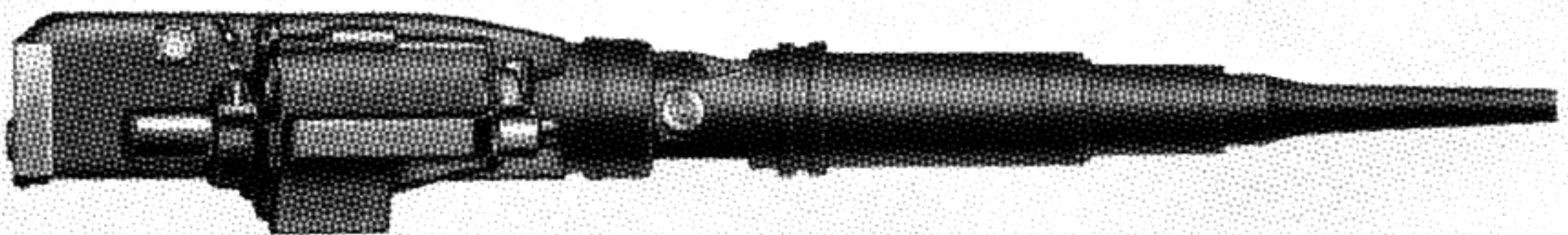


Figure 1-18. Gun, Machine, Caliber .60 T58.



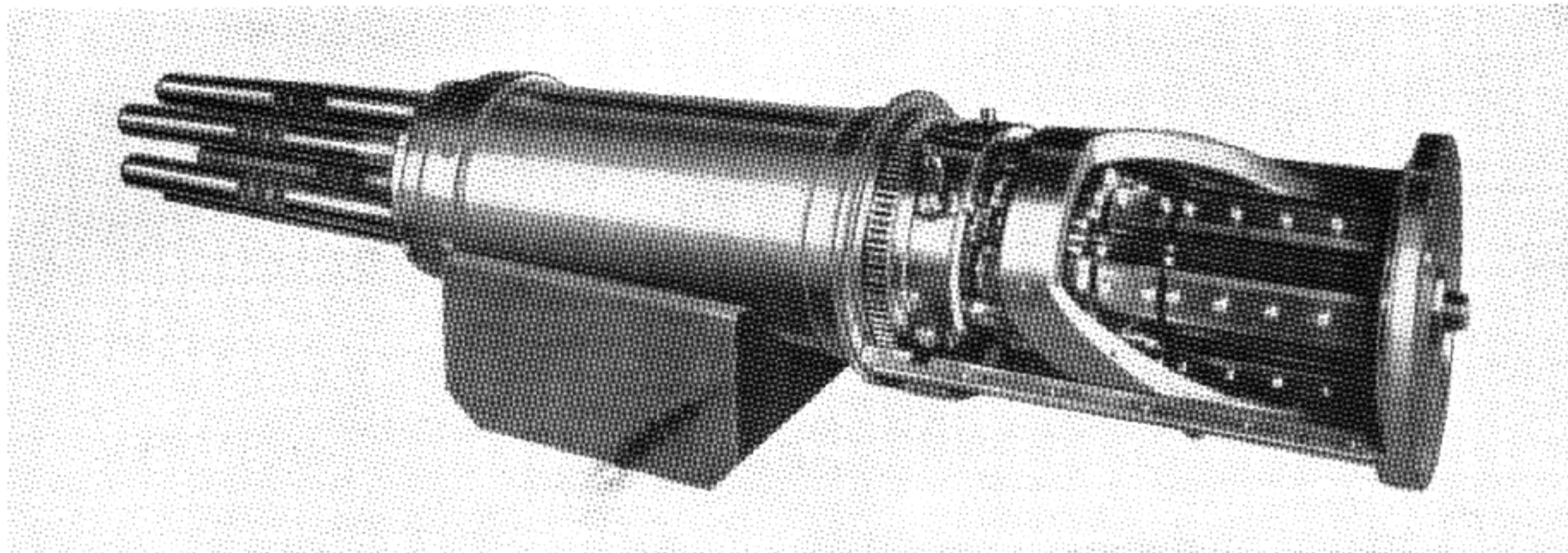


Figure 1-19. Gun, Machine, Caliber .60 T62.

the German gun consisting mostly of a rearrangement of components to secure small profile, lighter weight, improved accessibility of parts for servicing, and a general shortening of components to keep gun length to a minimum, the latter being an important advantage of this type of mechanism. The gun is of the gas-operated type with a rate of fire of 1,600 rounds per minute. Development by Armour Research Foundation.

*Gun, Machine, Caliber .60 T130E1.* A version of the caliber .60 automatic gun T130 to utilize a closed link and associated feeder.

*Gun, Automatic, 15-mm T154.* (This gun does not fire the caliber .60 rounds as normally loaded.) In response to an Air Force requirement for a shorter gun action it was proposed to construct a twin-barrel alternate firing gun using separate loading ammunition. The cartridge case to be removed from the conventional location. Ammunition development by Frankford Arsenal and Remington Arms Co., gun by Frigidaire.

*Gun, Machine, Caliber .60 T173.* An improved version of the T17 series for use as an antiaircraft gun in the ground forces. Fires a percussion primed caliber .60 ammunition.

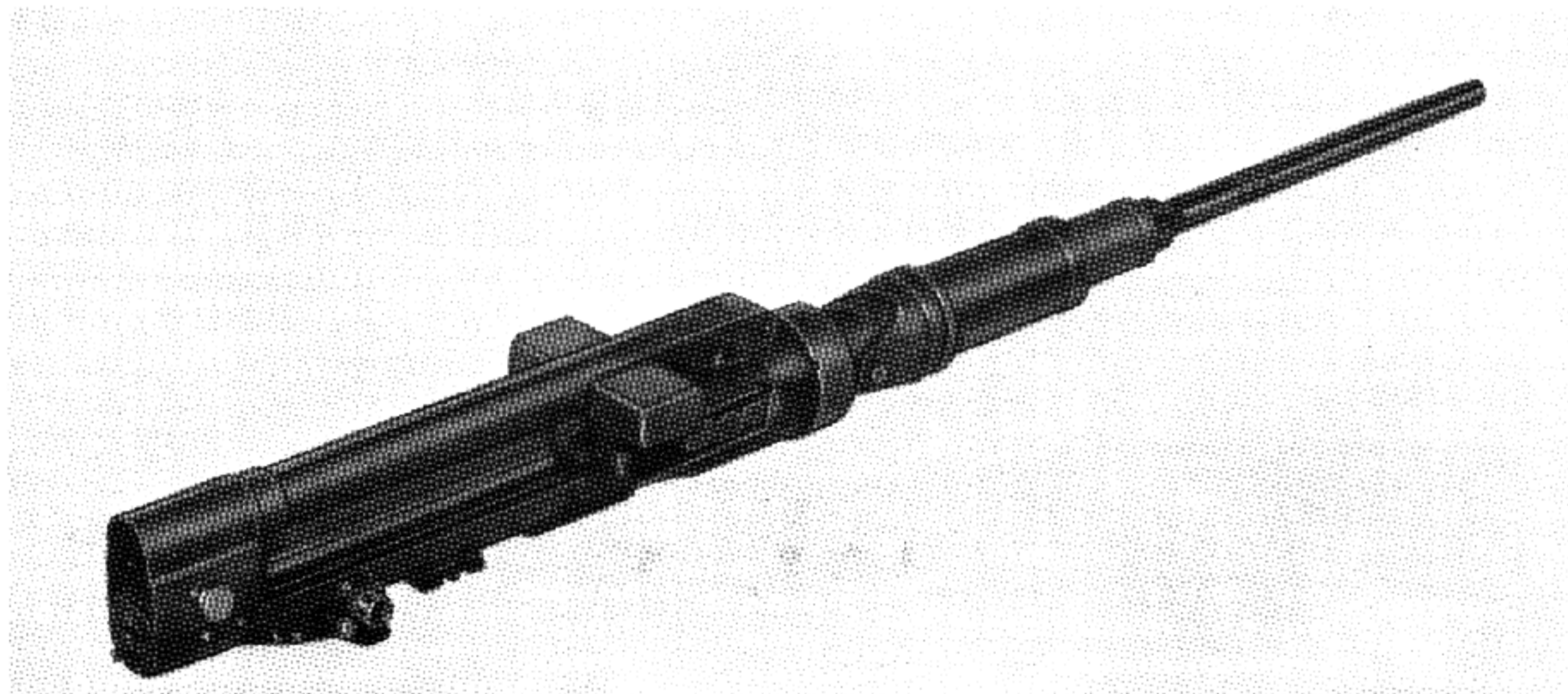


Figure 1-20. Gun, Machine, Caliber .60 T63.

## 20-mm Automatic Guns with T and M Numbers

*Gun, Automatic, 20-mm T1.* The Hispano-Suiza type 404 was tested in the United States beginning in 1938 and was officially designated the 20-mm T1.

*Gun, Automatic, 20-mm T9.* Standard Hispano M2 gun with modified chamber.

*Gun, Automatic, 20-mm T10.* Standard Hispano M2 gun with a different modification to the chamber.

*Gun, Automatic, 20-mm T12.* Standard Hispano M2 guns with another chamber design.

*Gun, Automatic, 20-mm T14.* Standard Hispano M2 gun except chamber and origin of rifling 1-mm short.

*Gun, Automatic, 20-mm T15.* Standard Hispano M2 gun with chamber modified to the design used on the British Mark II gun.

*Gun, Automatic, 20-mm T16.* Developed by the United Shoe Machinery Corp. Has the same ballistics as the M1 and M2. Project was canceled in August 1944.

*Gun, Automatic, 20-mm T18.* The T18 gun was the Hispano M2 which used, instead of the gas cylinder, a mechanical unlocking means, actuated by the recoil of the gun. The mechanical unlock was supplied with two cams, the slopes of which were 40° and 30°, respectively. Preliminary tests showed that such a device might be practical, but, after thorough tests at Aberdeen Proving Ground on a flexible mount, in July 1944 it was decided to cancel this development since the unlocking mechanism lowered the cyclic rate of the weapon.

*Gun, Automatic, 20-mm T19.* Developed by the Draper Corp. Lighter and more compact than any

previous 20-mm gun, the T19 employed the use of gas to operate the integral feed mechanism. The receiver body was a modified M2 inverted with a double key arrangement. A key plate strengthened the side of the receiver which had been weakened by the removal of the charging cylinder. The buffer had both inner and outer preloaded concentric springs, which provided a yielding instead of a solid stop in case of occasional excess force of the blow-back. The tube had an additional gas port for the gas-operated feed so located that it came in the next rifling groove ahead of the regular port.

*Gun, Automatic, 20-mm T20.* Developed by Colt. The 20-mm automatic gun T20 development was undertaken to apply a gas-operated feed to a Hispano 20-mm gun to overcome the difficulties encountered in recoil-operated feed mechanisms. One pilot model of the T20 was produced and proved successful in test at the manufacturer's range. The feed mechanism developed was gas operated and fed the belt by a reciprocating pawl similar to that on the caliber .50 machine gun.

*Gun, Automatic, 20-mm T21.* The records do not indicate the history of the 20-mm T21.

*Gun, Automatic, 20-mm T22.* The Ordnance Corps contracted with the Colt Co. to develop a gun based on the German MG151 but using a different locking system. The standard 20-mm round was used, loaded for a higher velocity.

*Gun, Automatic, 20-mm T23.* Developed by Colt. Hispano gun unlocked by recoil instead of gas pressure. In adapting the mechanical unlock unit the following modifications were made to the M2 gun: The gas port was plugged and the gas cylinder bracket removed; the gas tube attachment lug was modified at the rear by cutting a slot in it;

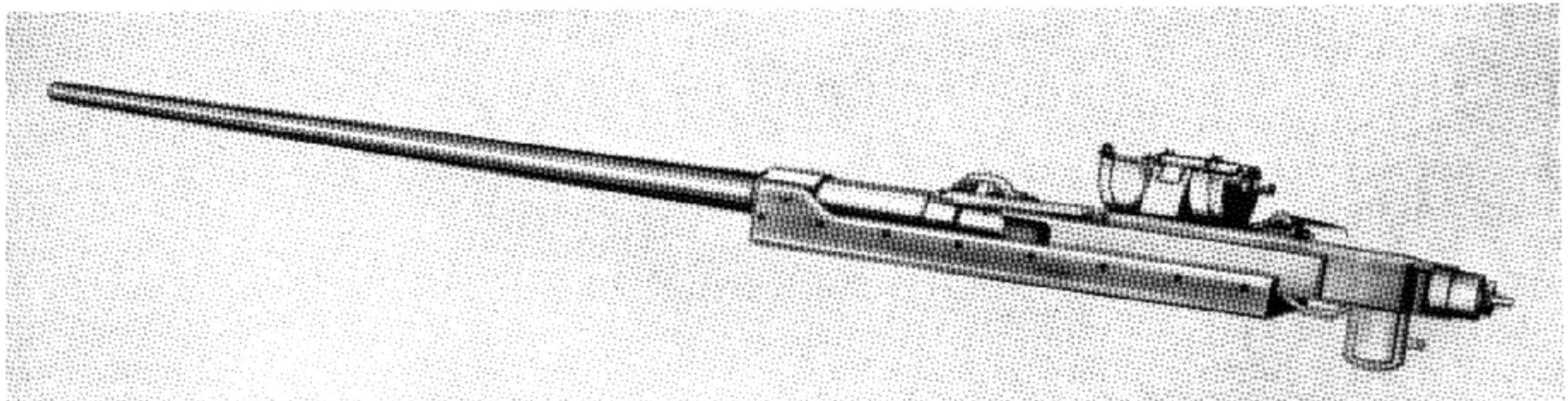


Figure 1-21. Gun, Automatic, 20-mm T18.

the push rod holes were increased in depth by  $1\frac{1}{16}$  inches, and two new push rods  $4\frac{5}{8}$  inches long were supplied. The action of the mechanical unlock mechanism was simple. On firing a round, the gun recoiled, turning the actuating levers so that the ball end of both levers made contact with and moved the two push rods. The push rods in turn acted upon the breech lock slides. From this point on, action on unlocking the bolt was the same as in the standard gas-operated gun.

*Gun, Automatic, 20-mm T24.* Redesign of the T22 to use a larger cartridge case. Built by Colt.

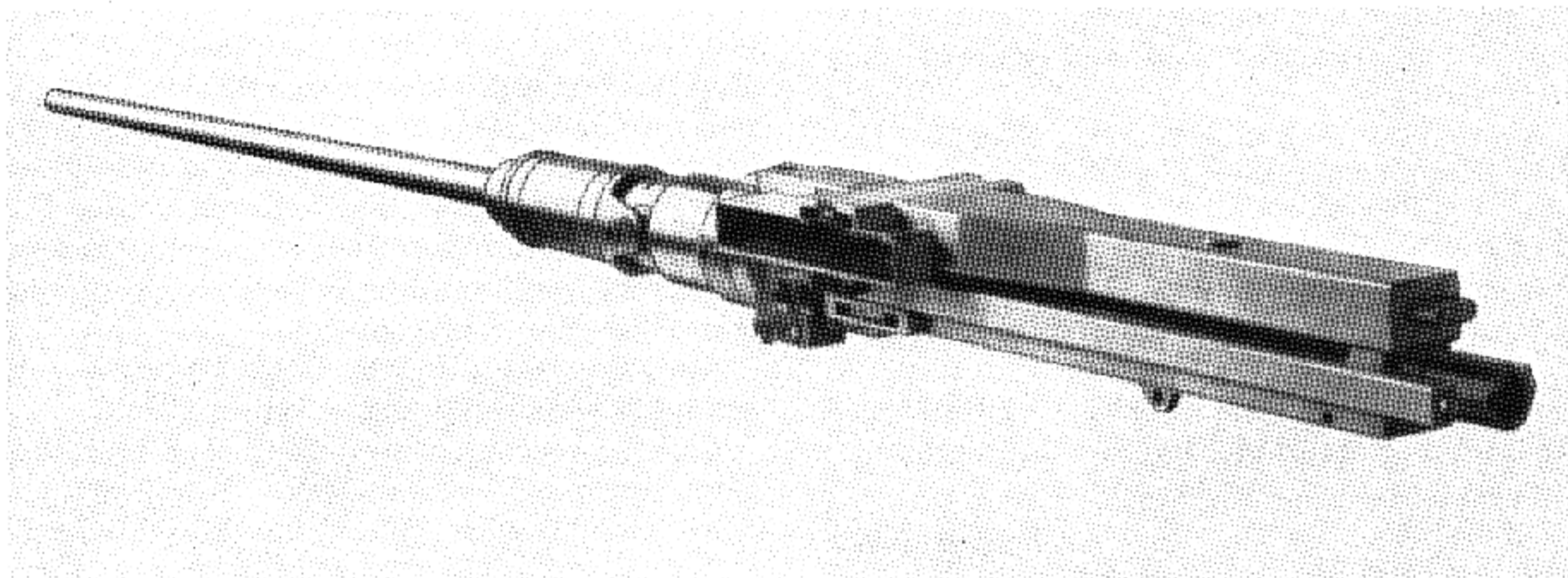


Figure 1-22. Gun, Automatic, 20-mm T24.

*Gun, Automatic, 20-mm T24E1.* Modification of the T24 having 0.006 chrome plate in bore.

*Gun, Automatic, 20-mm T24E2.* Modification of the T24 having a 0.010 chrome plate in bore.

*Gun, Automatic, 20-mm T25.* Developed by the United Shoe Machinery Corp. A conventional M2 bolt was modified with a searing arrangement that would prevent the firing pin from striking the primer when the bolt slides had reached the battery position. When firing, the sear was actuated by means of a solenoid, releasing the firing pin which was carried into the primer by action of a separate firing-pin spring. As the round was fired and the bolt unlocked by the conventional means of the Hispano-Suiza type guns, the firing pin was cocked by the slides and held on sear position until the bolt was again returned to battery and the sear released as described above. However, in December 1944, T25 development was considered complete because

of the advanced state of the T31 gun and its pending service test by the Army Air Force.

*Gun, Automatic, 20-mm T26.* Developed by Oldsmobile. To determine to what extent the standard 20-mm automatic guns M1 and M2 could be lightened without adversely affecting the life of parts or without increased hazards in connection with the firing, it was decided, during August 1943, to modify a number of 20-mm automatic guns M1 and M2. They were to have the following characteristics: A reduction in weight of approximately 25 pounds; a decrease in barrel length of 15 inches:

they must be capable of using a nonadjustable ring-spring adapter; have a muzzle velocity reduction of not more than 80 feet per second; have a cyclic rate of about 750 rounds per minute; and be capable of firing with the bolt closed and locked. The modified gun was designated 20-mm Automatic Gun T26, which, complete with T14 feed mechanism, weighed about 110 pounds, approximately the weight of the German MG 151/20 provided with the same accessories. Although the T26 gun was not capable of synchronization, it provided fire interruption in battery position by a solenoid operated plunger.

*Gun, Automatic, 20-mm T27.* M2 gun redesigned by Oldsmobile for firing with bolt closed and locked. The mechanism of 20-mm automatic gun T27, similar to that of the T25 gun, was completed and tested with the T26 gun, and consideration was given to its application to the M2 gun. The T27 gun was incapable of synchronized fire. A later re-

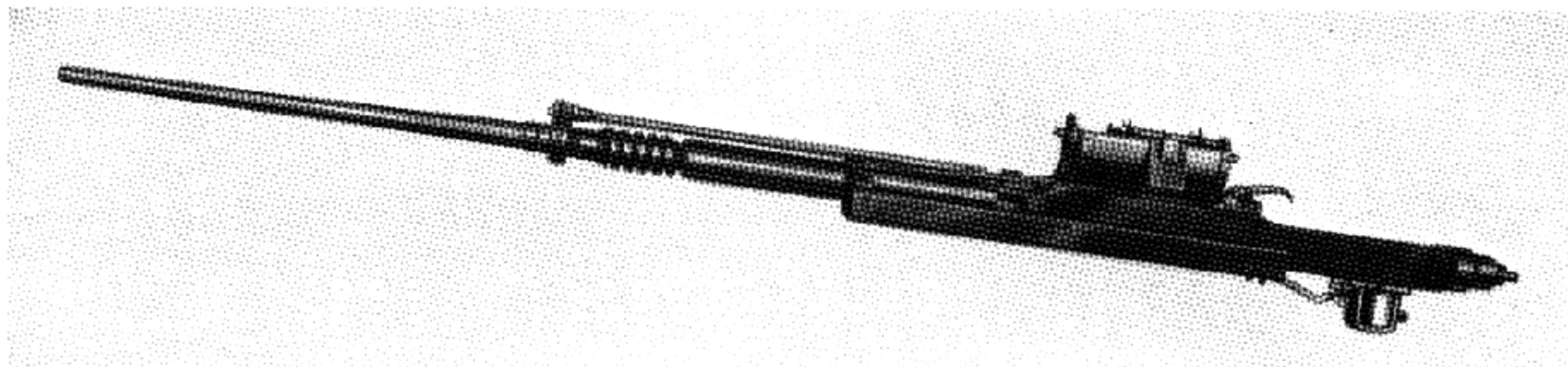


Figure 1-23. Gun, Automatic, 20-mm T26.

quirement by the Army Air Force for a new design of a 20-mm gun that could provide synchronous fire through the propeller arc of an airplane, using both electric and percussion primed ammunition, as well as the selection by the using services of the T31 gun for these purposes, caused cancellation of the development of the T27 gun in August 1944.

*Gun, Automatic, 20-mm T28.* M2 gun redesigned by Watervliet for firing from battery position.

*Gun, Automatic, 20-mm T29.* Same as T28 but for electric firing. Watervliet Arsenal developed both the 20-mm automatic gun T28, capable of mechanical synchronization, and the 20-mm automatic gun T29, capable of electrical synchronization. Both guns fired with the bolt forward in a closed and locked position. A pilot model incorporating the features of the T28 and T29 guns was completed. Firing was accomplished by changing the bolt. To simplify nomenclature these developments were combined, together with the desirable features of the T26 gun, to become the 20-mm automatic gun T31.

*Gun, Automatic, 20-mm T30.* Six inch shorter tube. The records do not indicate the history of the T30.

*Gun, Automatic, 20-mm T31.* This is an automatic blowback and gas-operated aircraft weapon. The basic difference between the 20-mm AN-M2 and the 20-mm T31 is that the T31 is a light-weight high-speed gun having the recoil system and cradle built into the gun, whereas the AN-M2 gun uses the Edgewater adapter, and the mount is a part of the airplane to which the gun is attached. The basic concept of this cradle and recoil system came from Oldsmobile and design and development of the weapon was done at Oldsmobile. The T31 gun complete with feeder, cradle, recoil system, and

solenoid weighs 116 pounds while the AN-M2 basic gun without mounts or solenoid weighs 115 pounds. The T31 gun has an overall length of 77.75 inches and the AN-M2 is 92.8 inches overall. The rate of fire of the T31 gun is approximately 720 rounds per minute, while that of the AN-M2 gun is about 100 rounds per minute less. This gun was produced in quantity at Oldsmobile. The T31 combined features of the T26, T28 and T29. This project was supervised by Watervliet. T31 indicates the rear-seared gun. This was standardized as the M3.

*Gun, Automatic, 20-mm T31E1.* This number was assigned to the forward seared mechanical percussion bolt design.

*Gun, Automatic, 20-mm T31E2.* This number was assigned to the forward seared electric ignition design which was standardized as the M24 series.

*Gun, Automatic, 20-mm T32.* The feed mechanism of this gun was to be operated by the same gas piston used to unlock and accelerate the bolt. The operation of this gas piston is as follows:

1. High-pressure gases flow through the gas orifice when the projectile uncovers the orifice on its forward travel through the bore of the gun.

2. The high-pressure gases pass through the valve, completely filling the chambers.

3. As the projectile moves down the bore, the pressure in the tube recedes and since there is a larger piston area on the forward end of the piston than on the rear end, the high-pressure gases in chambers move the piston to the rear closing the valve.

4. With the valve closed, the pressure in chamber continues to move the piston to the rear until the end of the piston uncovers the orifice so that the gas in the chamber can exhaust through the bore.

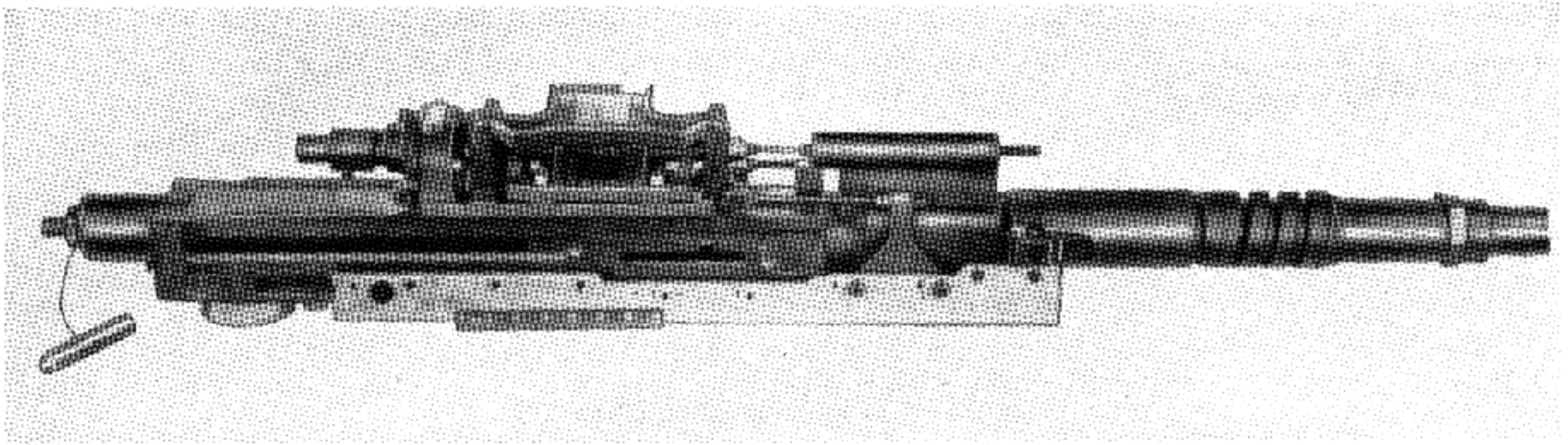


Figure 1-24. Gun, Automatic, 20-mm T32.

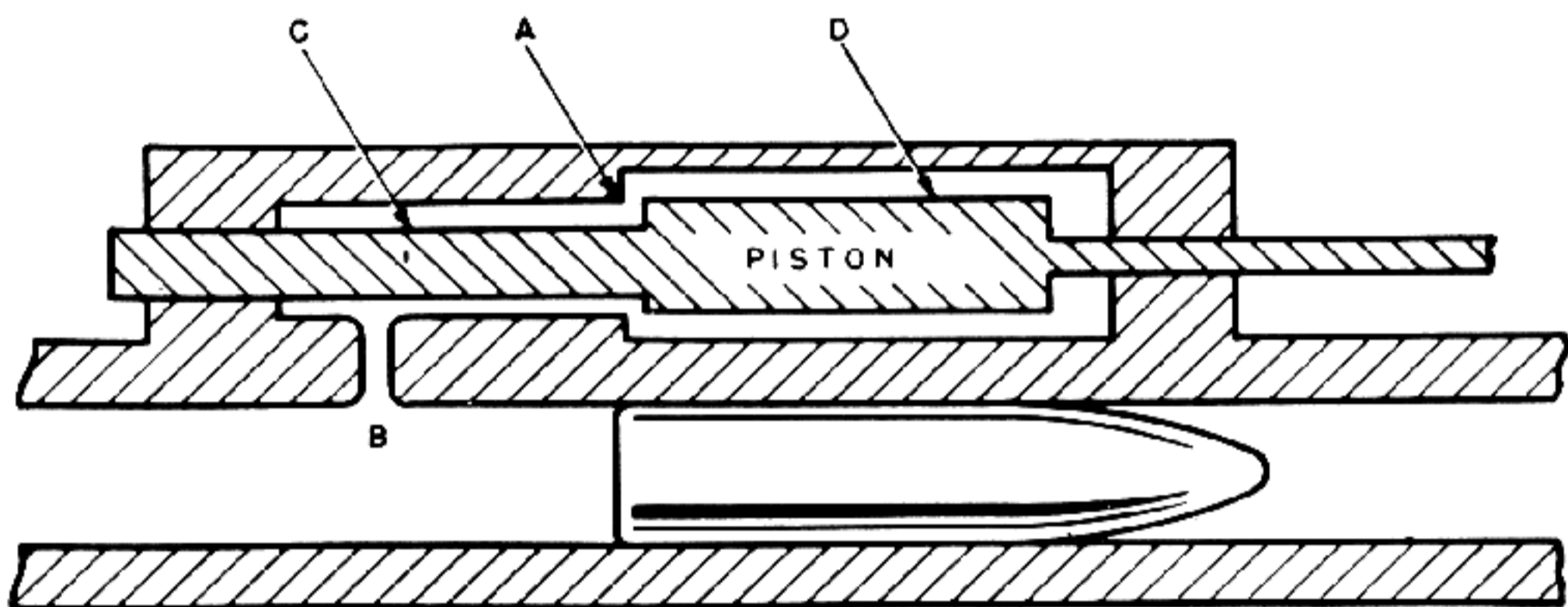


Figure 1-25. Gun, Automatic, 20-mm T32. Gas system.

5. The bolt returns the piston to the right upon its return to the in-battery position and the cycle is repeated when the next round is fired.

The bolt is locked in battery by a sliding block that moves upward as the bolt assembly enters the in-battery position. The gas piston cams the sliding block down and accelerates the bolt rearward. The stroke of the piston also operates a helical spline on the feed mechanism, keeping the sprocket wound. There are no drive springs in the gun and the gun is charged by firing a caliber .30 blank cartridge. There are two rails in the receiver of the gun that have two cam paths, one for guiding the round into the chamber and one for ejecting the extracted cartridge case. The gun is designed for electrically fired ammunition. The bolt assembly telescopes the bolt buffer thus allowing a shorter receiver design. There has been no change in the tube design to allow for the increased heating due to the higher cyclic rate, however, placing the gas operating pis-

ton near the cartridge chamber of the tube adds more metal at the "hot spot" giving a better hold-over for the heat.

*Gun, Automatic, 20-mm T33.* This assignment called for the design and development of a 20-mm gun, capable of handling new special high-velocity (3,500 feet per second) ammunition. The following features were stipulated: Integral crossfeed capable of lifting a 100 pound load of ammunition, right or left feed by interchangeable components, 750 rounds per minute minimum firing rate, 5,000 pounds maximum trunnion load. Design work was started late in 1944 and not quite completed by June of 1945 at which time the contract was terminated at Oldsmobile and turned over to Armour Research Foundation, Chicago, for completion. A wood mockup was made. The bolt has a lock on each side, similar to the bolt in the German 30-mm automatic gun, MK 103.

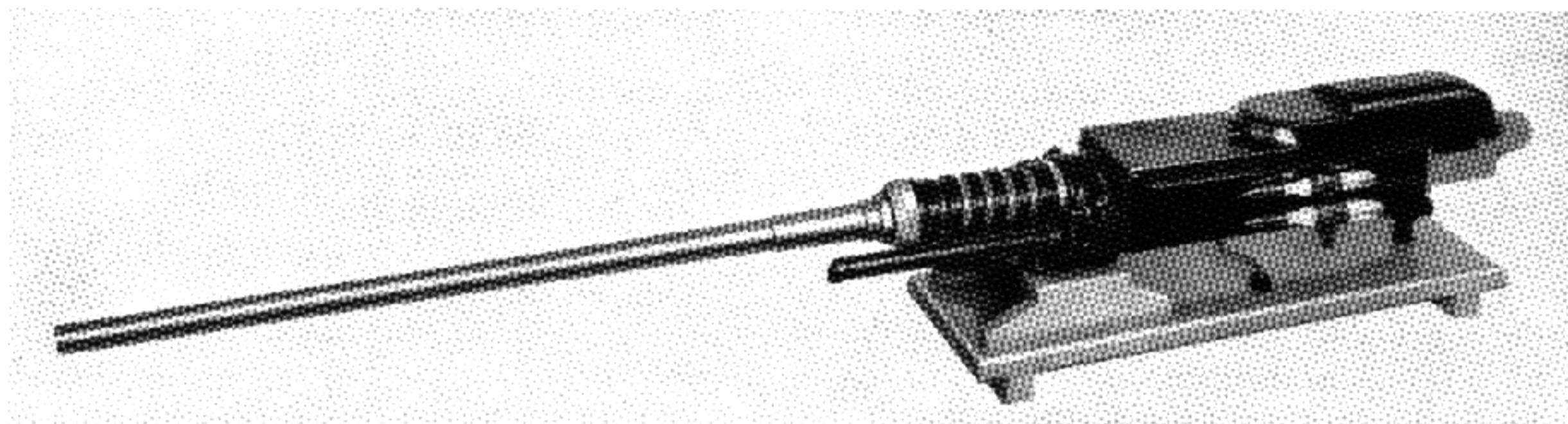


Figure 1-26. Gun, Automatic, 20-mm T33.

*Gun, Automatic, 20-mm T33E1.* Modification of the T33 which included 0.006 chrome plating in bore.

*Gun, Automatic, 20-mm T33E2.* Modification of the T33 which included 0.010 chrome plating in bore.

*Gun, Automatic, 20-mm T33E3.* Two versions of this T33E3 were made. The first, model A, used pivot locks in the barrel extension and was chambered for the large T7 case. One gun was built and tested. Model B, designed by Armour and built by the Naval Gun Factory, incorporated a new bolt

and rotary locks, a rammer actuated by bolt recoil, a gas-operated feeder utilizing feed pawls instead of sprocket, and design features which greatly simplified manufacture, assembly, and servicing. For some components there were alternate designs for the model B gun. Although the T33 series was originally based on a study of a Rheinmetall gun, changes made by the several design facilities involved have produced a weapon which does not readily classify in any of the well-known systems.

*Gun, Automatic, 20-mm T34.* Developed by Oldsmobile and based on 20-mm M3 gun with modi-

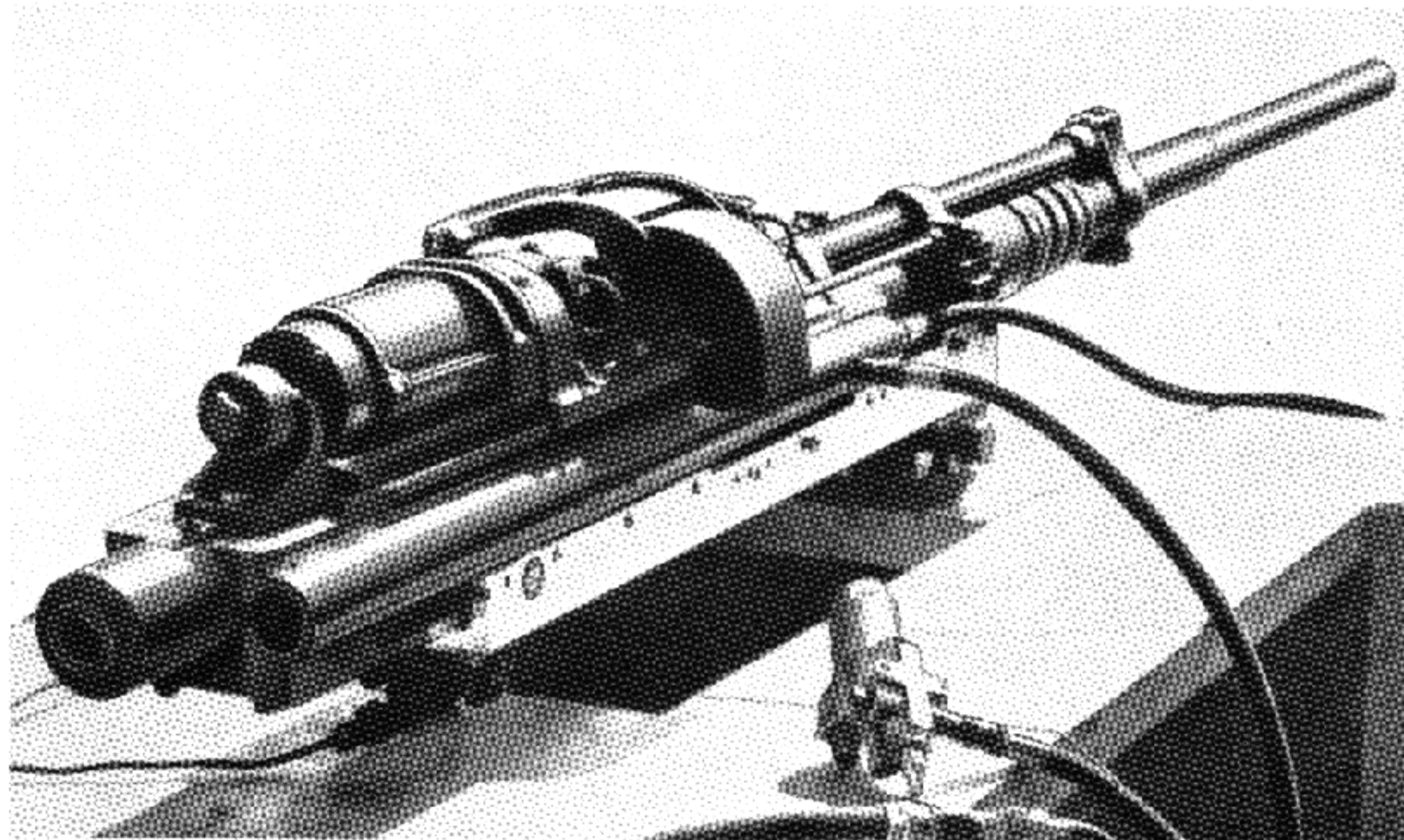


Figure 1-27. Gun, Automatic, 20-mm T34.

fications to increase the cyclic rate of fire to 1,000 rounds per minute. The four modifications are: The installation of a new type breechblock buffer stronger recoil spring, lighter recoiling parts, and installation of a higher pressure gas operating system. As originally designed, it was chambered for the large T5 case, but in April 1945 it was converted to standard ammunition to fulfill a Navy need for a high cyclic rate shipboard defense against suicide planes. By V-J Day, when the project was suspended temporarily, 12 T34 guns, with a claimed parts life of 1,500 rounds, had been delivered. Tests revealed numerous deficiencies, chiefly short-lived parts such as driving spring, firing pins, gas piston rings, receiver, slides, and slide key.

*Gun, Automatic, 20-mm T34E1.* This is the electric-fired version of the T34 gun, development of which was commenced in March 1948. The purpose of the project was to meet a Navy requirement for a high cyclic rate, electric-fired gun. Early changes eliminated two of the most serious T34 defi-

ciencies; the receiver weakness was eliminated by utilizing a modified M2 receiver of which large stocks were available, and the driving spring was removed by utilizing a double-acting pneumatic charger fitted into the new receiver.

*Gun, Automatic, 20-mm T34E2.* The T34E1 gun when modified to fire 1,600 grain projectiles.

*Gun, Automatic, 20-mm T35.* High cyclic aircraft gun using supersonic ammunition, with matched projectiles and two types of mechanical bolts and one type of electrical bolt. Designed by Oldsmobile division of General Motors.

*Gun, Machine, 20-mm T54.* This gun is the Navy Mark 10 Mod 0. It is designed as a double-barrel, low-silhouette weapon, containing its own feed mechanism driven by means of the bolt extension. It contains a pneumatic charging mechanism. Two rounds are extracted from the belt on the recoil stroke and two rounds are fed during counterrecoil. A unique feature is the method employed to feed two barrels from one belt of ammunition. The as-

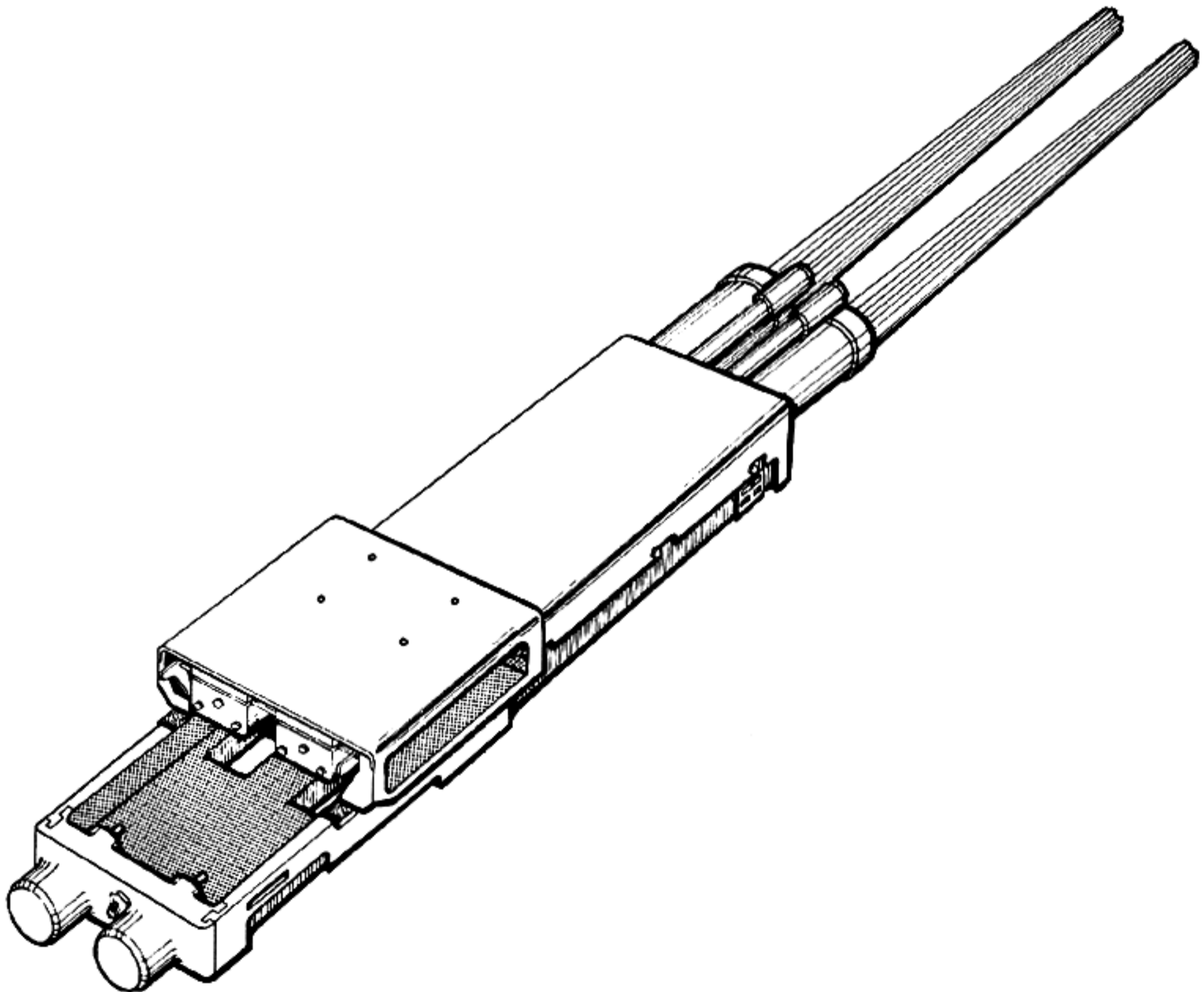


Figure 1-28. Gun, Machine, 20-mm T54.

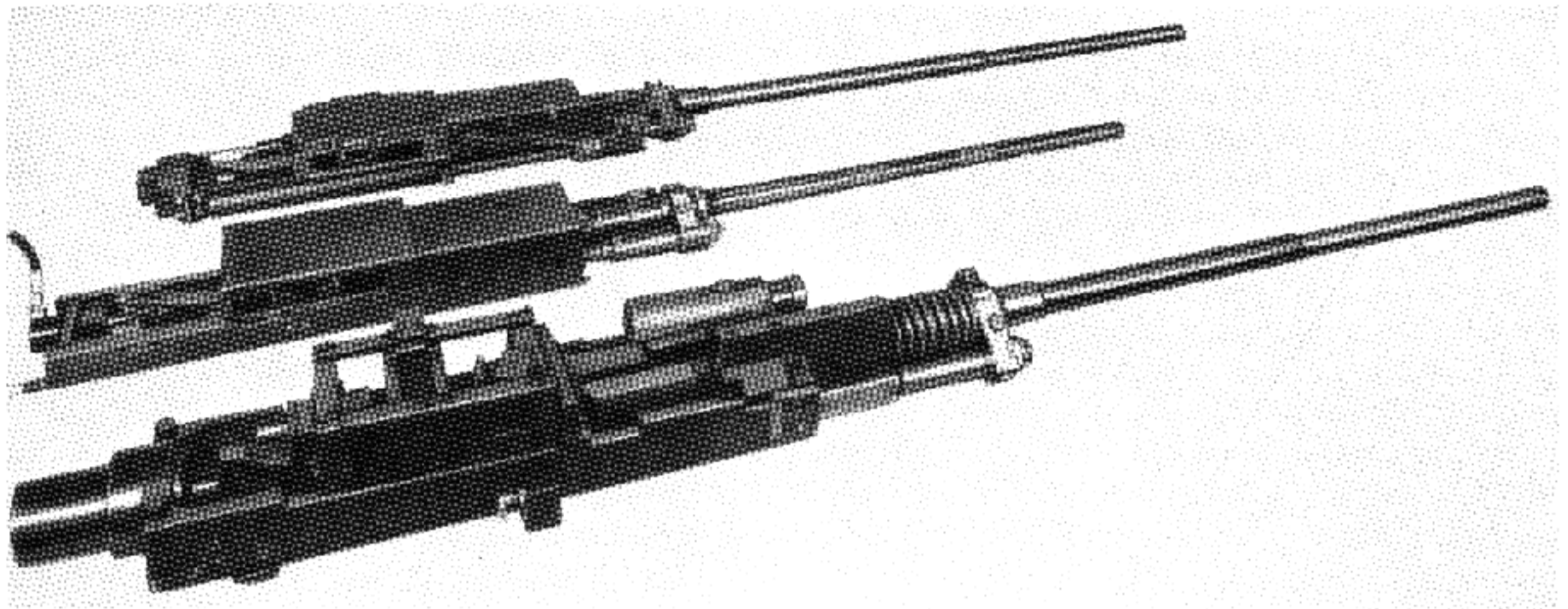


Figure 1-29. Stages in the development of the T55 gun. Front to rear: EX 1 Type 1; Mk 9 Mod 0; EX 1 Type 2.

signment of Ordnance Corps T numbers to Naval developments is done merely to facilitate identification to Army activities.

*Gun, Machine, 20-mm T55.* This designates a series of guns which were developed by the Navy and the Shirgun Corp. These guns also have Navy nomenclature. The latest version to which T55 was applied is known in the Navy as the Mk 9 Mod 0. The gun is a single-barrel, low-silhouette weapon, with a high belt-pulling capacity. It has an easily detached, integral-feed mechanism driven by the bolt extension. Pneumatic pressure is required for charger, bolt buffer, and sear operation. The charger and sear are controlled by solenoid operated valves mounted externally. The gun fires 20-mm M90 series ammunition, belted in M7 or M8 links.

These guns were later modified and known as T128 guns.

*Gun, Machine, 20-mm T56.* Actually designated Gun, Machine, 20-mm T56. Modification of Gun, Machine, Caliber .60, T17E5 to use a 20-mm cartridge. The gun can be prepared for either left- or right-hand feed. Firing is by means of a solenoid. A shock-absorbing adapter serves as a front mounting. The gun is charged by an electric charger mounted in the cover and fired from an open bolt. The gun is changed from a caliber .60 to a 20-mm by simply inserting the proper barrel.

*Gun, Automatic, 20-mm T57.* This gun is basically the 20-mm T31 aircraft gun with a lightened bolt assembly, a long-stroke Belleville spring buffer, and high-pressure gas-operating pistons. The rea-

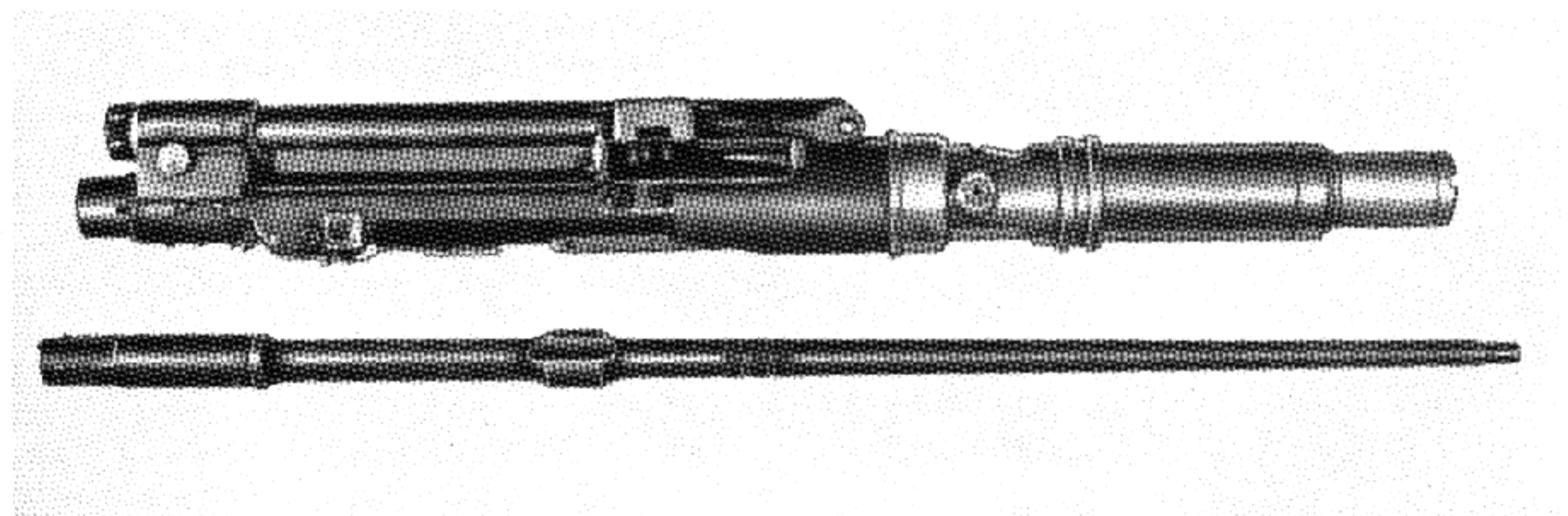


Figure 1-30. Gun, Machine, 20-mm T56.



son for operating the gun off the high gas pressures was to take advantage of the fact that a differential in pressure of 5,000 p. s. i. at gas pressures around 45,000 p. s. i. has less effect on the operation of the gun than a differential in pressure of 5,000 p. s. i. at gas pressures around 30,000 p. s. i. A large part of the erratic firing of the 20-mm T57 gun was due to the differences in pressure curves caused by bleeding the high-pressure gases off near the rotating band of the projectile. The design of gas-operating pistons caused early unlocking of the bolt with a resultant increase in the amount of flashback. Firing of the T57 gun at Salisbury Beach on 2 July 1945 disclosed the fact that the whole feed mechanism was engulfed with flame when the gun fired. No difficulty seemed to be experienced with early extraction of the cartridge case, but a number of cartridge cases showed marks of the ejectors cutting completely through the base of the cartridge rims due to the high velocity of the bolt.

*Gun, Automatic, 20-mm T67.* Navy development. Modification of M3 gun to incorporate a small oil pump to lubricate the chamber, thus eliminating necessity for lubricated ammunition. Bolt parts changed to provide for earlier firing on firing pin stroke to overcome effects of slide bounce.

*Gun, Automatic, 20-mm T74.* Gas-operated revolver-type weapon based on the German MG-213 firing a special cartridge case.

*Gun, Automatic, 20-mm T109.* This gun was developed by Armour Research Foundation.

*Gun, Automatic, 20-mm T110.* This is a variation of gun, automatic, 20-mm T74 with the barrel at the bottom of the receiver.

*Gun, Automatic, 20-mm T115.* Experimental weapon based on Mauser action. No record of having been produced.

*Gun, Automatic, 20-mm T116.* Experimental weapon based on Mauser action. No record of having been produced.

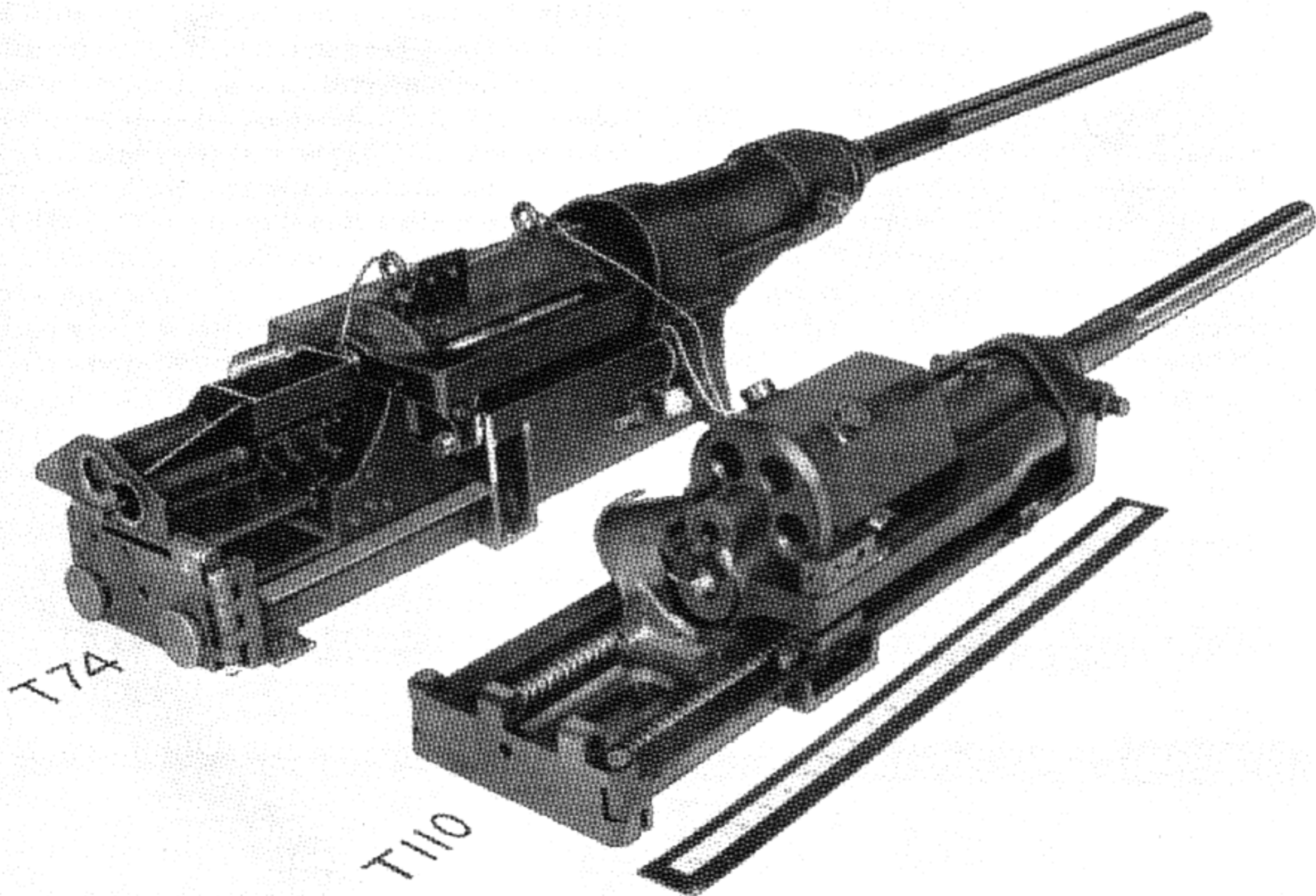


Figure 1-31. Gun, Automatic, 20-mm T74 and Gun, Automatic, 20-mm T110.

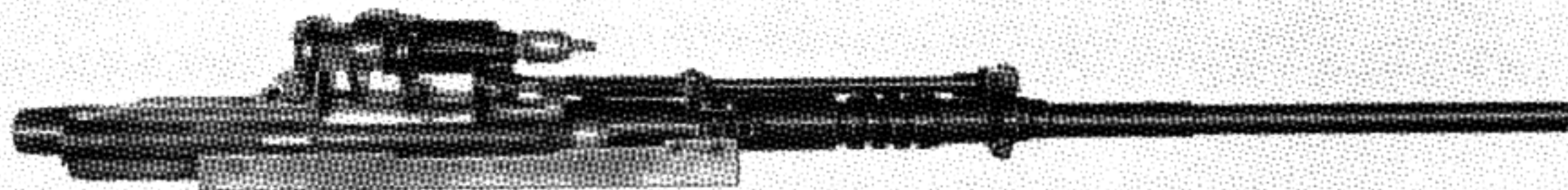


Figure 1-32. Gun, Automatic, 20-mm T118.

*Gun, Automatic, 20-mm T117.* This is the Navy Mk 11 gun. The gun is a double-barrel, two-belt feed, recoil driven weapon with revolver type breech. The electrically primed ammunition is carried to the gun by wire linked, electrically fired projectors which serve to load the ammunition in the revolving chamber and also to carry the fired cases and duds away from the gun. The gun is designed to clear duds automatically and to continue firing without releasing the firing switch. One of the unique features of the gun is the method employed for loading the firing chambers by means of the primed ammunition projectors.

*Gun, Automatic, 20-mm T118.* This nomenclature was established in the latter part of 1948 to identify a T34E1 gun rechambered and modified to fire a 1,600-grain projectile using the caliber .60 cartridge case. Approximately 20,000 rounds had been fired in tests of the T118 gun and feeder up to 30 June 1950. Subsequently the Navy adopted the T130 round for use in the T118 gun. This round consists of a 1,700-grain caliber .60 case but approximately 0.266 longer in the body than Army ammunition. This gun was adopted into the Navy as the Mk 12. However, the Navy guns are chambered for ammunition approximately one-quarter inch longer than the Army ammunition.

*Guns, Automatic, 20-mm T122 and 20-mm T123.* The designations 20-mm T122 and 20-mm T123 have appeared in some documents. These numbers were given in error for 20-mm T128 and 20-mm T129, respectively. No 20-mm guns were ever designated T122 or T123.

*Gun, Automatic, 20-mm T126.* An experimental percussion-fired weapon with 900-rounds-per-minute cyclic rate, recoil operated with integral feed mechanism, 78-inch length and 110-pound weight. Differs from the weapon designated as

Gun, Machine, 20-mm, T56 in increased cyclic rate and reduced length and weight.

*Gun, Automatic, 20-mm T127.* An experimental electric-fired weapon with 1,000-rounds-per-minute cyclic rate, recoil operated with external-powered feed mechanism, 78-inch length and 140-pound weight. Fired electric-primed ammunition employing a caliber .60 cartridge case and 20-mm projectile. Differs from gun, automatic, 20-mm T116 in increased cyclic rate and reduced length.

*Gun, Automatic, 20-mm T128.* This is Navy 20-mm gun mechanism Mk 9 Mod 1.

*Gun, Automatic, 20-mm T129.* This is Navy 20-mm gun mechanism Mk 13 Mod 0.

*Gun, Automatic, 20-mm T160.* This is a version of the caliber .60 T130 gun firing the 60/20-mm Army cartridge.

*Gun, Automatic, 20-mm T171.* This is a conversion of the caliber .60 T45 gun to fire the 60/20-mm Army cartridge. These guns operate on the Gatling principle.

*Gun, Automatic, 20-mm M1.* This was the standardized version of the T1 (Hispano-Suiza 404). It was never in active service. Designed as a motor-mounted gun, it was fed by a drum magazine. The receiver was 7 pounds lighter in weight than that of the M2.

*Gun, Automatic, 20-mm M2 Series.* This is the standard gun as used in World War II. The M2E1 used a special tube having a twist of 1 in 10 calibers, right hand; M2E2, 1 in 40 calibers, right hand; M2E3, 1 in 60 calibers, right hand; M2E4, 1 in 100 calibers, right hand. The designation, Gun, Automatic, 20-mm M2, had earlier been applied to a Solothurn antitank gun but that action had been rescinded.

*Gun, Automatic, 20-mm M3.* Standardization of the T31.

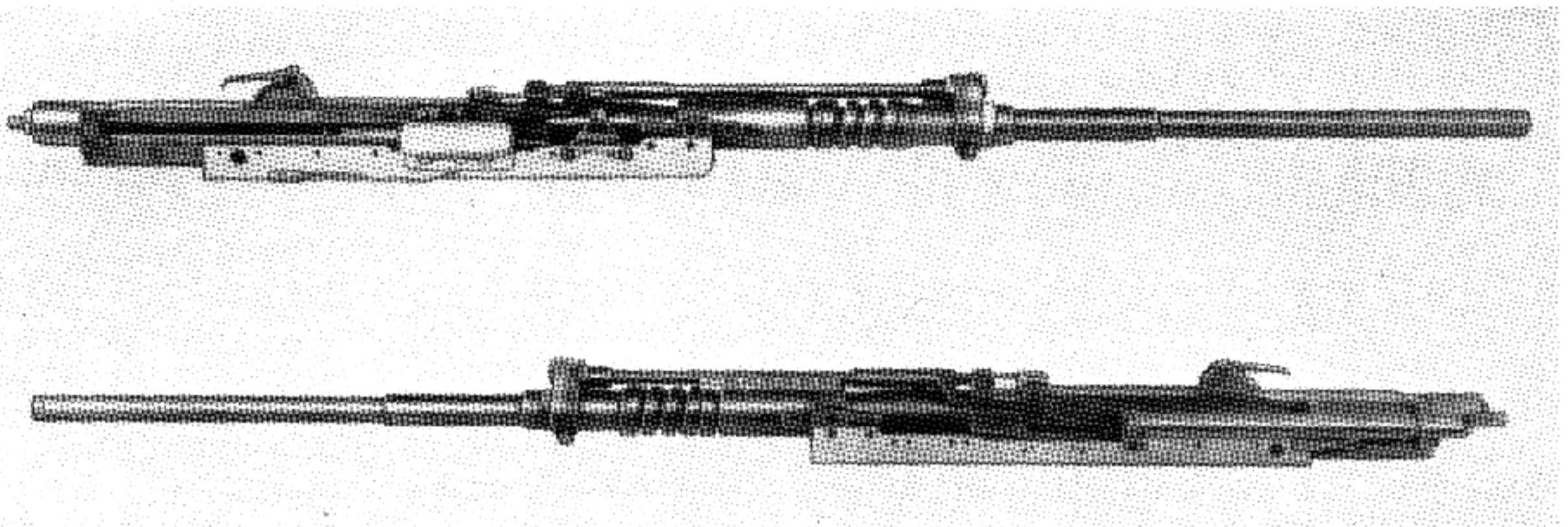


Figure 1-33. Gun, Automatic, 20-mm M23.

*Gun, Automatic, 20-mm M23.* For synchronized firing or fire interruption from the battery position, using percussion-primed ammunition.

*Gun, Automatic, 20-mm M24 Series.* The M24 is a standardization of the T31E2. The M24E1 differs in size of gas vent hole to maintain 750 rounds per minute cyclic rate for use of the 1,600 grains projectile, practice, 20-mm T61E1. In the M24E2 the bolt is modified to permit the incoming round to assist in controlling extraction and ejection of complete round in chamber. The M24A1 incorporates a barrel plunger and modified gas system. This was followed by an improved version known officially as the M24A2.

### 20-mm Automatic Guns with Mark and Mod Numbers

*20-mm Machine Gun Mechanism Mk 1.* No Mk 1 assigned to United States equipment. British Oerlikon.

*20-mm Machine Gun Mechanism Mk 2 Mod 0.* Manufactured from drawings prepared for production of the British Mark II Oerlikon.

*20-mm Machine Gun Mechanism Mk 2 Mod 1.* Refinement of the Mk 2 Mod 0.

*20-mm Machine Gun Mechanism Mk 3.* No Mk 3 assigned to United States equipment. British.

*20-mm Machine Gun Mechanism Mk 4 Mod 0.* Oerlikon manufactured from drawings prepared by NOP Centerline. Same as Mk 2, except tolerances. Limited interchangeability with Mk 2.

*20-mm Machine Gun Mechanism Mk 4 Mod 1.* Oerlikon, differs from Mk 4 Mod 0 in having new

breech casing rear cap and shortened trigger needed for use on mounts Mk 20, Mk 21, and Mk 24.

*20-mm Machine Gun Mechanism Mk 4 Mod 2.* The Mk 4 Mod 0 changed as follows:

1. Breechbar cam is attached to right breech bar.
2. Special trigger for use with Solenoid Mk 29.
3. Solenoid Mk 29 replaces trigger cover plate.
4. Uses back cover without handgrips; this permits the use of R. H. recoil operated belt feed.

*20-mm Machine Gun Mechanism Mk 4 Mod 3.* The Mk 4 Mod 0 changed as follows:

1. Breechbar cam is attached to left breech bar.
2. Special trigger for use with Solenoid Mk 29.
3. Solenoid Mk 29 replaces trigger cover plate.
4. Uses back cover without handgrips; this permits the use of L. H. recoil operated belt feed.

*20-mm Machine Gun Mechanism Mk 4 Mod 4.* Differs from Mk 4 Mod 0 in that trigger, breechbar securing bolt retaining pins, handgrip, and magazine catch lever are redesigned or modified to suit mount Mk 15.

*20-mm Machine Gun Mechanism Mk 4 Mod 5.* Eliminates machining for double-loading stop on Mk 4 Mod 0.

*20-mm Machine Gun Mechanism Mk 4 Mod 6.* Eliminates machining for double-loading stop on Mk 4 Mod 1.

*20-mm Machine Gun Mechanism Mk 5.* No Mk 5 assigned to United States equipment. British Oerlikon.

*20-mm Machine Gun Mechanism Mk 6 Mod 0.* Experimental Oerlikon design by Pontiac. Similar to Mk 4.

*20-mm Machine Gun Mechanism Mk 7.* No Mk 7 assigned to United States equipment. Reserved for British gun.

*20-mm Gun Mk 8 Mod 0.* The 20-mm T31 (M3) adapted to Mark 25 mount by Emerson Electric Co., St. Louis, Mo. This was an attempt to use the Hispano as an anti-aircraft defense against suicide planes.

*20-mm Gun Mk 8 Mod 1.* The 20-mm T31 (M3) adapted to Mark 22 mount for shipboard anti-aircraft use.

*20-mm Gun Mechanism Mk 9 Mod 0.* Developed from EX 1, designed by Shirgun Co. 20-mm self-fed, feed operates off bolt travel. There were improvements in the pneumatic system and the firing pin was scared. With the 52½-inch barrel a muzzle velocity of 2,680 feet per second was obtained at a rate of fire of 1,000 rounds per minute. Built at the Naval Gun Factory. There were two guns of this type made.

*20-mm Machine Gun Mechanism Mk 9 Mod 1.* Modified from Mod 0, these guns use Hispano electric primed ammunition at a rate of 1,100 rounds per minute. The feed is operated by a camway on the bolt extension. The pneumatic sear was removed. Two guns of this type were produced by modifying the Mod 0 units.

*20-mm Gun Mechanism Mk 10 Mod 0.* This was a proposed twin-barrel gun to feed from a single belt. Early design work by Shirgun Co. was based on the Hispano round. The Naval Gun Factory later made studies for the use of 60/20 electric primed ammunition. Only a wooden model has been made.

*20-mm Gun Mechanism Mk 11 Mod 0.* 20-mm double barrel, revolving breech, self-fed gun. Uses aluminum 60/20 mm cartridge cases. Uses two belts and relinks the cases.

*20-mm Gun Mechanism Mk 12 Mod 0.* An improved version of the T118 with chamber lengthened to take the 60/20 mm Navy round.

*20-mm Gun Mechanism Mk 12 Mod 1.* Short barrel version for use in the turret.

*20-mm Gun Mechanism Mk 12 Mod 2.* Includes modification to improve parts life and permits standardization for mass production.

*20-mm Gun Mechanism Mk 13 Mod 0.* This gun resembles the Mark 9, Mod 1, but is chambered for the short 60/20 round of the Army Ordnance Corps. The 60-inch barrel gives a muzzle velocity of 3,300 feet per second. There is no driving spring and ignition is electric. Built at the Naval Gun Factory, only two of this Mark have been made.

*20-mm Gun Mechanism Mk 14 Mod 0.* 20-mm version of 30-mm Mark 1. Mechanism is same except chamber and barrel. High-velocity ammunition.

*20-mm Gun Mechanism Mk 15 Mod 0.* Modification of 20-mm T110 to use Navy 60/20 round.

*20-mm Gun Mechanism Mk 15 Mod 1.* Refinement of the Mk 15 Mod 0.

*20-mm Gun Mechanism Mk 16 Mod 0.* 20-mm M3 gun modified by NGF to use Mk 8 feed.

*20-mm Gun Mechanism Mk 17 Mod 0.* 20-mm M24 gun modified by NGF to use Mk 8 feed.

## 20-mm Machine Guns with EX Designations

*20-mm Gun Mechanism EX 1, Type 1.* This project was placed on contract with the Shirgun Corp. by the Bureau of Ordnance. The weapon was developed into the Mk 9 Mod 0.

*20-mm Gun Mechanism EX 2.* This project was initiated in July 1942 to develop an integral feed 20-mm aircraft gun which could utilize 20-mm Oerlikon ammunition. The proposed gun was to replace the current 20-mm aircraft gun which had been experiencing excessive malfunctioning of the feed mechanism and presented installation difficulties in various planes. The Navy contacted the NDRC and outlined its desires for a new 20-mm gun. The NDRC in turn contacted Johnson Automatics, Inc. to develop the proposed weapon. The Johnson gun was gas operated, belt-fed, and first used Oerlikon ammunition, later being modified to use Hispano rounds.

*20-mm Machine Gun Mechanism EX 3.* This was the project which developed into the Mk 10 Mod 0.

*20-mm Machine Gun Mechanism EX 4.* This project developed into the Mk 11 Mod 0.

*20-mm Machine Gun Mechanism EX 5.* Based on the Mark 13 Mod 0 with major improvements. Feed operates off barrel extension and twin locks are used instead of single locks.

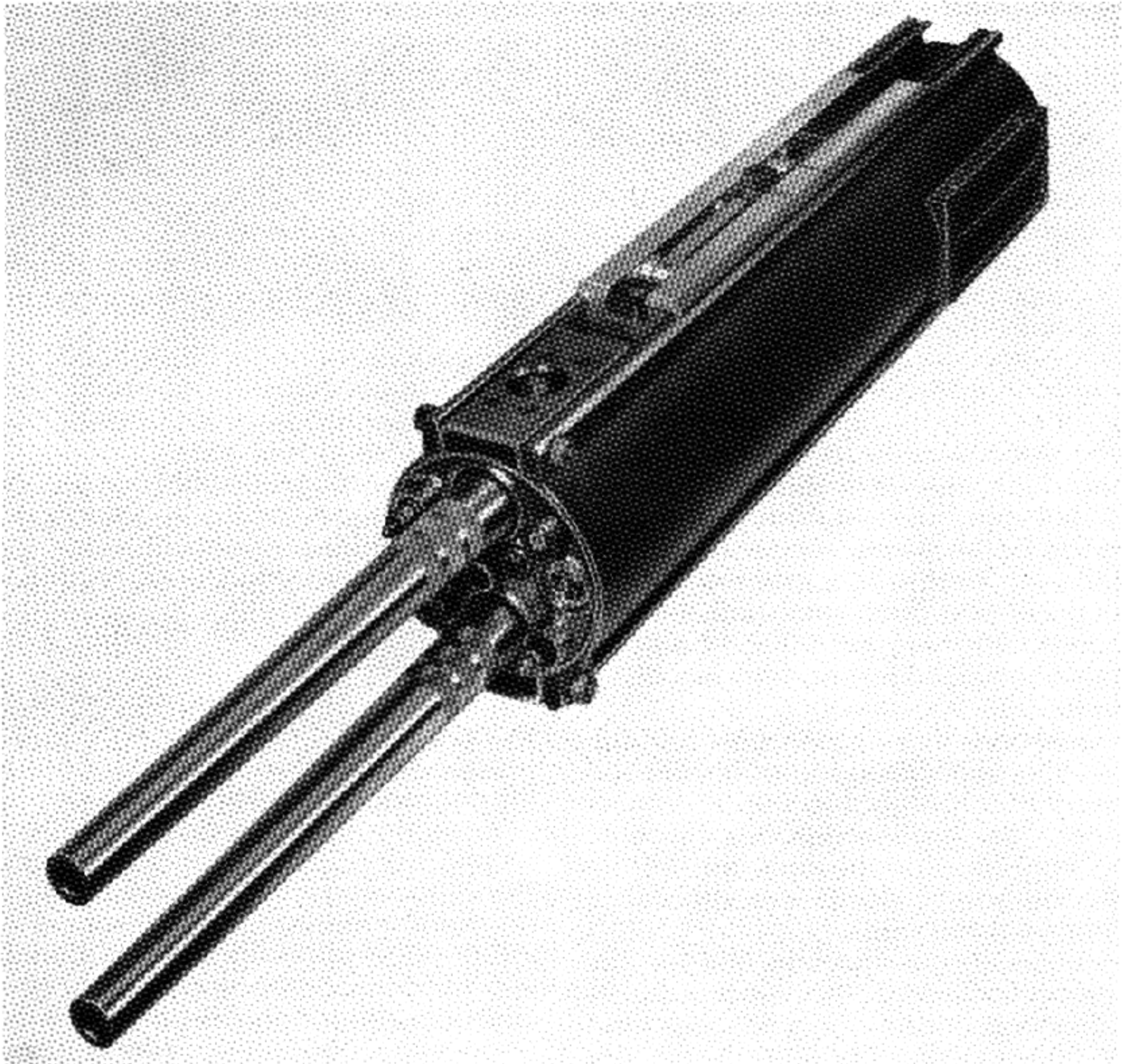


Figure 1-34. 20-mm Machine Gun Mk 11 Mod 0. Three-quarter front view.

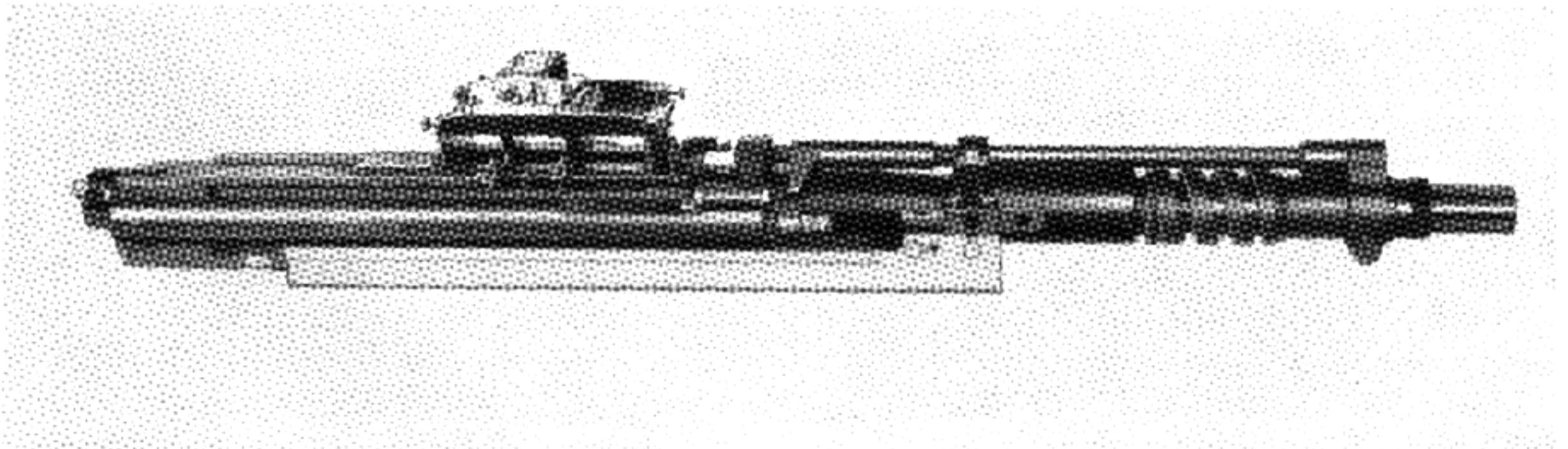


Figure 1-35. 20-mm Gun Mechanism Mk 12 Mod 1.

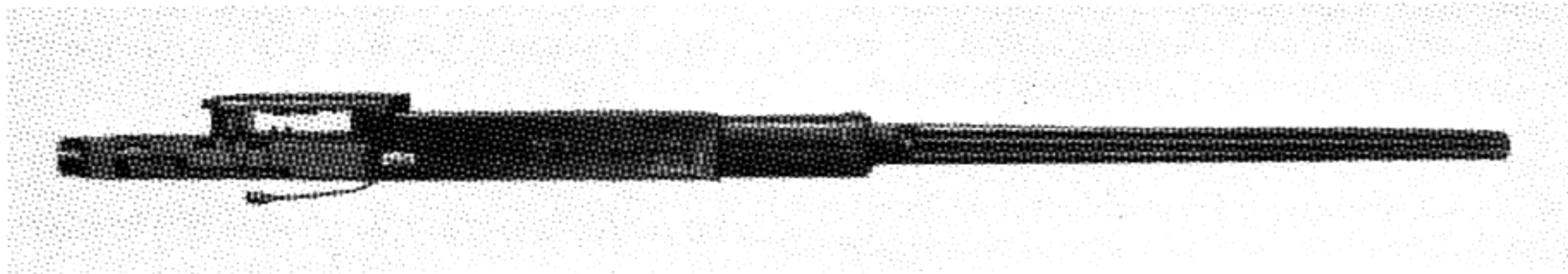


Figure 1-36. 20-mm Gun Mechanism Mk 13 Mod 0. This weapon is also known as the T129.

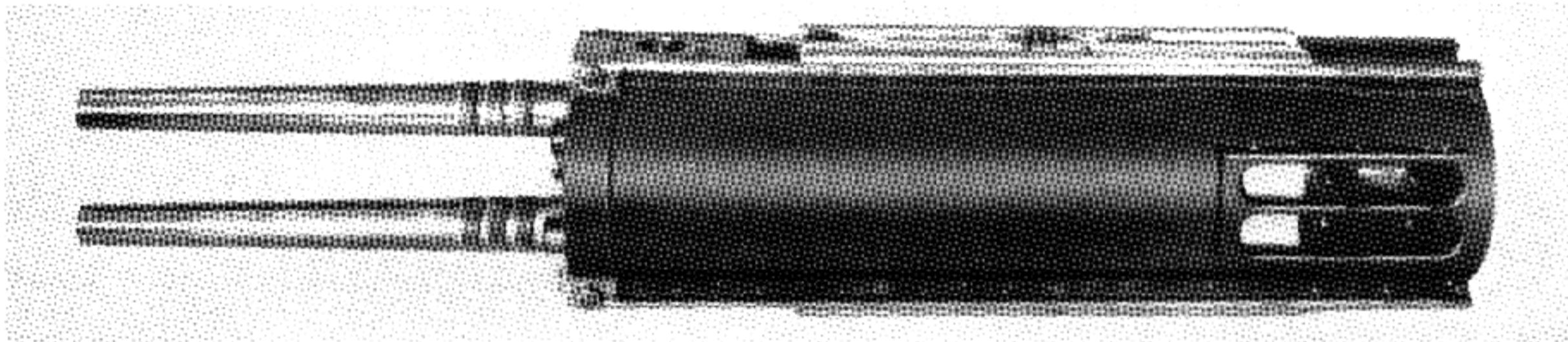


Figure 1-37. High-velocity 20-mm Machine Gun Mk 14 Mod 0. Side view.



Figure 1-38. 20-mm Gun Mechanism Mk 16 Mod 0.

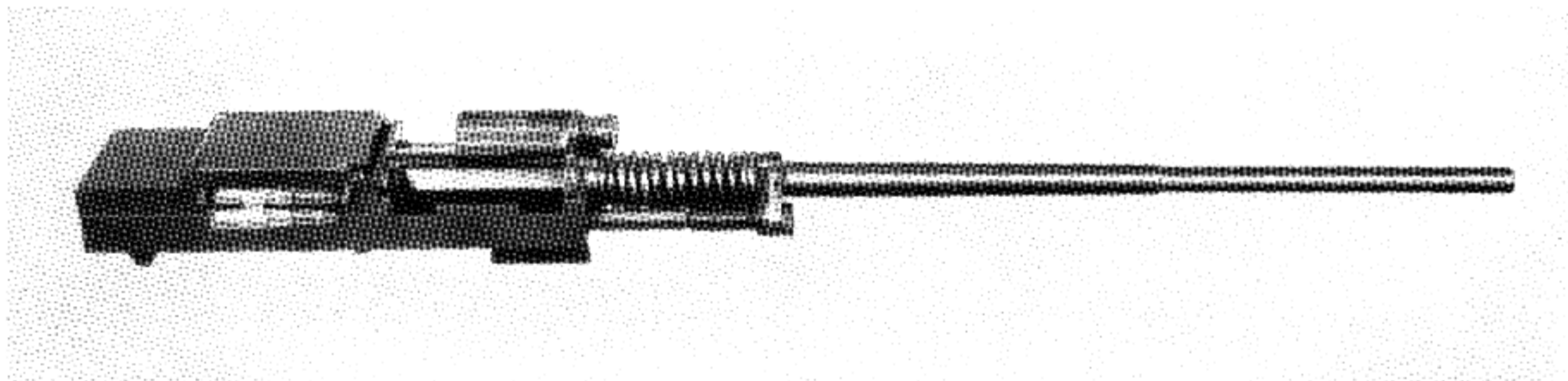


Figure 1-39. 20-mm Aircraft Cannon EX 1 Type 1. Prototype.

Redesign under direction of Dr. Walter F. Grasse, Dr. Richard H. Braun, and Mr. Theodor Rakula.

*20-mm Machine Gun Mechanism EX 6.* Utilizing short recoil, blowback, and gas for its operating power for both breechblock and feeder. Double roller locks used for securely holding breechblock and barrel extension together during moment of firing. Cammed unlocking. This version is to furnish engineering design data for use in construction of a 30-mm gun. Responsibility for design given to Lt. Col G. M. Chinn, USMCR.

### Caliber .90 Machine Guns with T Numbers

*Gun, Machine, Caliber .90 T1.* This gun was built at Rock Island Gun Arsenal and used a necked-down 1.1-inch cartridge case. The muzzle velocity was 2,850 feet per second and the rate of fire was 150 rounds per minute.

*Gun, Machine, Caliber .90 T2 Series.* The T2 series were built by Watervliet and based on the Oerlikon design. Refinements of the caliber .90 T2 were made in Gun, Machine, Caliber .90 T2E1 and Gun, Machine, Caliber .90 T2E2.

*Gun, Machine, Caliber .90 T3.* Similar to the T2 but included a blowback retarding device.

*Gun, Machine, Caliber .90 T4.* Built by the Colt Co. and based on the design of the Browning long-recoil cannon. Although the T4 was developed to provide an automatic aircraft weapon of great striking power, the need for an antitank gun more powerful than the caliber .50 machine gun but lighter and more mobile than the 37-mm gun M3, caused serious consideration of the T4 for this purpose.

### 27-mm Automatic Guns with T Numbers

*Gun, Automatic, 27-mm T150.* Modification of the caliber .60 T45 to permit use of a 27-mm projec-

tile from the same basic cartridge case. The mechanism is based on the Gatling principle.

*Gun, Automatic, 27-mm T151.* Gas operated revolver similar to the caliber .60 T130. These guns are American improved designs based on the German MG213.

### 30-mm Automatic Guns with T Numbers

*Gun, Automatic, 30-mm T120.* This is a conversion of the 20-mm T109 to 30-mm and is the equivalent of the Navy 30-mm Mk 5 Mod 0.

*Gun, Automatic, 30-mm T121.* Similar to the 20-mm T110 but fires the 30-mm round. Gas-operated revolver gun.

*Gun, Automatic, 30-mm T182.* Similar to the 30-mm T121 but fires a higher-velocity round.

### 30-mm Machine Guns with Mark and Mod Numbers

*30-mm Machine Gun Mechanism Mk 1 Mod 0.* Modification of 20-mm Mk 11 to fire low-velocity 30-mm ammunition.

*30-mm Machine Gun Mechanism Mk 2 Mod 0.* Modification of 20-mm T110 to fire low-velocity 30-mm ammunition.

*30-mm Machine Gun Mechanism Mk 3 Mod 0.* Modification of 20-mm Mk 13 to fire low-velocity 30-mm ammunition.

*30-mm Gun Mechanism Mk 4 Mod 0.* Modification of 20-mm Mk 12 to fire low-velocity 30-mm ammunition.

*30-mm Gun Mechanism Mk 4 Mod 1.* Shortened Mk 4 Mod 0 for turrets to fire low-velocity 30-mm ammunition.

*30-mm Gun Mechanism Mk 5 Mod 0.* Modification of the 20-mm T33 series to fire low-velocity 30-mm ammunition.

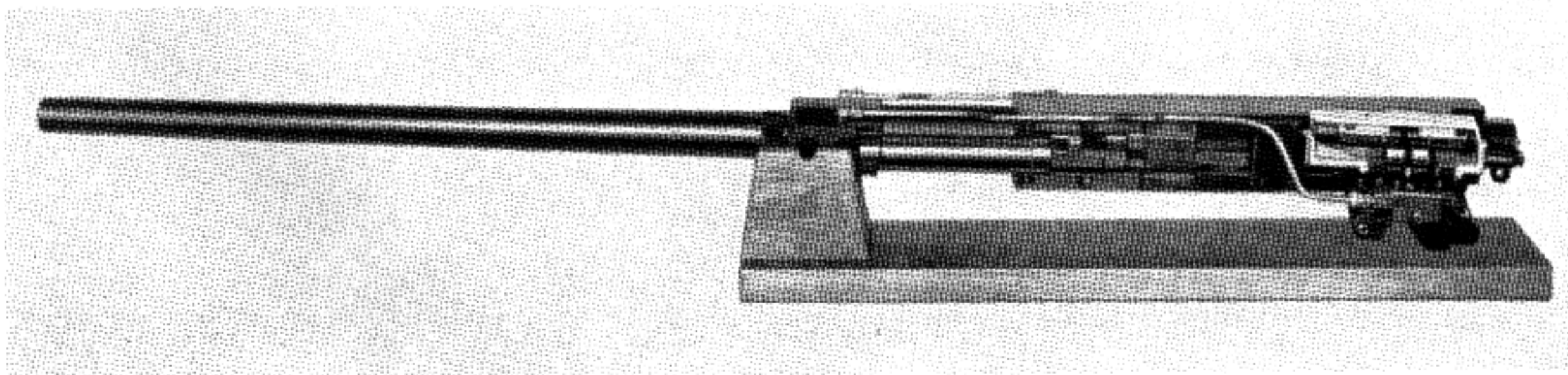


Figure 1-40. 30-mm Gun Mechanism Mk 5 Mod 0.

## 1.1-inch Machine Guns with Mark and Mod Numbers

*1.1-inch Machine Gun Mechanism Mk 1 Mod 0.* The recoil operated anti-aircraft machine gun designed by the Bureau of Ordnance for shipboard use. Used in World War II and declared obsolete upon demobilization.

*1.1-inch Machine Gun Mechanism Mk 1 Mod 1.* Variation of the Mk 1 Mod 0.

*1.1-inch Machine Gun Mechanism Mk 1 Mod 2.* Another variation of the Mk 1 Mod 0.

*1.1-inch Machine Gun Mechanism Mk 2 Mod 0.* Gas-operated, experimental machine gun.

## 37-mm Automatic Guns

*Gun, Automatic 37-mm T1.* Built about 1924 and based on a design by Col. Thomas Jervey, United States Army Ordnance.

*Gun, Automatic 37-mm T2.* The T2 Browning was tested at Aberdeen in June 1925. It was designed for muzzle velocity of 3,057 feet per second.

*Gun, Automatic 37-mm T2E1.* This modification increases weight of barrel to overcome weakness of T2 barrel. This gun has a water jacket.

*Gun, Automatic 37-mm T3.* This was a Browning design with a muzzle velocity of 1,350 feet per second.

*Gun, Automatic 37-mm T5.* Designed by the Ordnance Department and built at Rock Island Arsenal.

*Gun, Automatic 37-mm T5E1.* In September 1938 the subcommittee on aircraft cannon recommended that the 37-mm automatic gun T5 of Ordnance design be turned over to the Air Corps for further test after the completion of tests under way at Aberdeen Proving Ground. After modifications making the gun lighter, the designation was changed

to 37-mm automatic gun T5E1. Preliminary tests at Aberdeen Proving Ground were made in January 1939. The results demonstrated that the weight of the gun was excessive, the cyclic rate of fire comparatively low, and the feed mechanism unsatisfactory. The Ordnance Committee in June 1939 directed that the project be canceled and the pilot weapon sent to Watervliet Arsenal for use in connection with the study and design of automatic weapons.

*Gun, Automatic 37-mm T9.* The T2 gun was modified as a result of the experience gained from the various tests, until eventually a gun designated T9 was ready for test. In September 1939 this gun was mounted first in the nacelle of an A-20A attack plane, and later in P-38 and P-39 fighter planes. Further modifications of the experimental T9 gun, utilizing the knowledge gained from the extensive tests it had undergone, led to an acceptable weapon which was standardized as the M4. This gun was to be employed by fighter planes in attacks from the rear at long range against single large bombers and for ground strafing.

*Gun, Automatic 37-mm T19.* Actually no 37-mm automatic gun T19 was ever made. The designation was used to set up the characteristics of the ideal gun. Early in 1942 intensive efforts were made to establish the necessity for a high-velocity 37-mm automatic cannon for aircraft use. The primary mission of this piece was to be the attack of mechanized ground forces, a task for which the ballistic characteristics of the ammunition used by the 37-mm automatic gun M4 was inadequate. Experience gained with a 37-mm anti-aircraft gun M1A2 mounted in an airplane determined the desired military characteristics. The weight, including gun, tube, and feeding device, was not to exceed 400

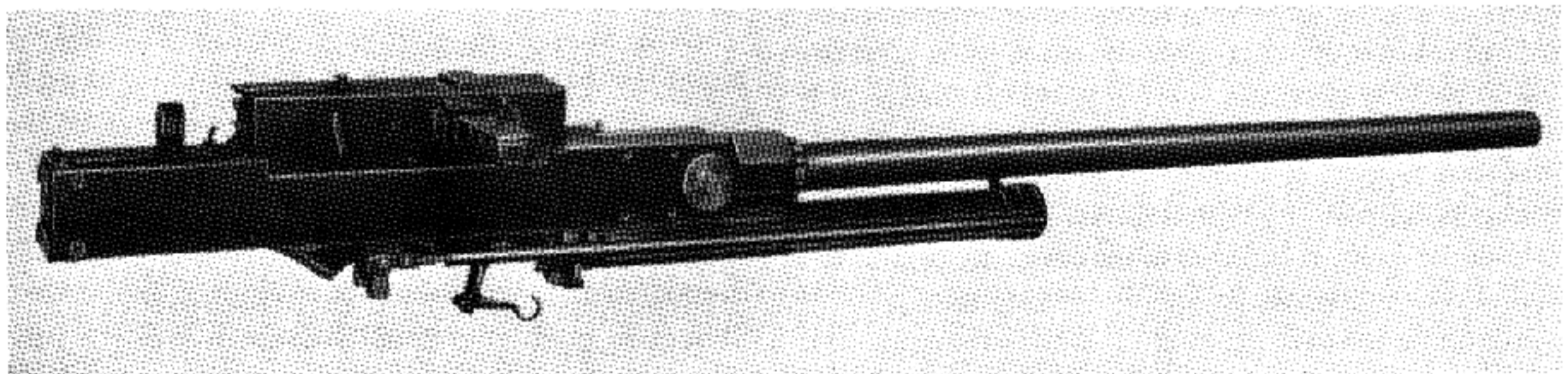


Figure 1-41. 37-mm Browning Gun T9 showing ejection chute for the five-round feeder. Right side view.



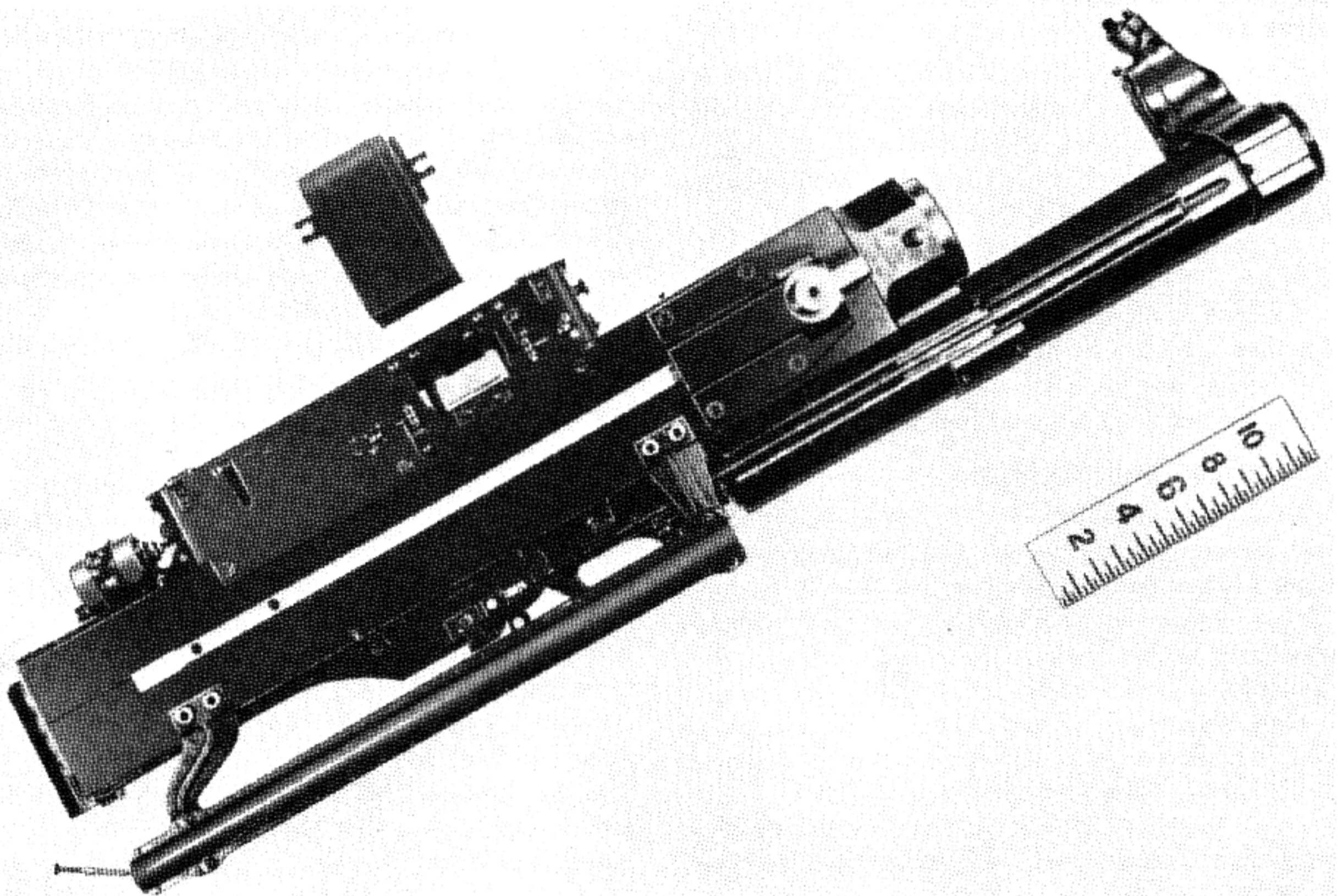


Figure 1-42. 37-mm Browning Gun T20 with barrel removed. Right side view.

pounds. Both charging and firing gun were to be by remote control and the feed was to be by a disintegrating link belt, or, as a second choice, the belt or magazine. Firing was to be at the highest cyclic rate possible.

*Gun, Automatic 37-mm T20.* In the spring of 1942 Oldsmobile under Ordnance Department contract instituted a study of the redesign of the 37-mm antiaircraft automatic gun M1A2 to adapt it to fulfill the characteristics of a high velocity 37-mm automatic gun for aircraft installation. Designation of the new gun was 37-mm automatic gun T20. Substantially, this gun was the M1A2 gun, modified to incorporate a disintegrating belt feed, with a change in the external barrel dimensions and external recoil mechanism dimensions to permit installation of this gun in the P-39 airplane.

*Gun, Automatic 37-mm T20E1.* Because the installation in the P-39 airplane of the new high-velocity 37-mm automatic gun T20 had not yet

been set up by the Army Air Corps, it was considered desirable, in December 1942, to eliminate the special barrel and recoil system needed for this installation. This change involved using the barrel and recoil system of the M1A2 antiaircraft gun. The gun, as modified, was designated 37-mm automatic gun T20E1, and embodies fewer changes from the M1A2 than the T20, thus facilitating production.

*Gun, Automatic 37-mm T20E2.* The development and standardization of the T20E1 gun as 37-mm automatic gun M9, for left-side feed resulted in the development of the 37-mm automatic gun T20E2, a right-hand feed weapon. The principal difference between the left-hand feed and the right-hand feed was in the construction of the feedbox. The gun could be changed from a left-hand to a right-hand feed, and vice versa, by replacing the feedbox and the carrier bearing brace.

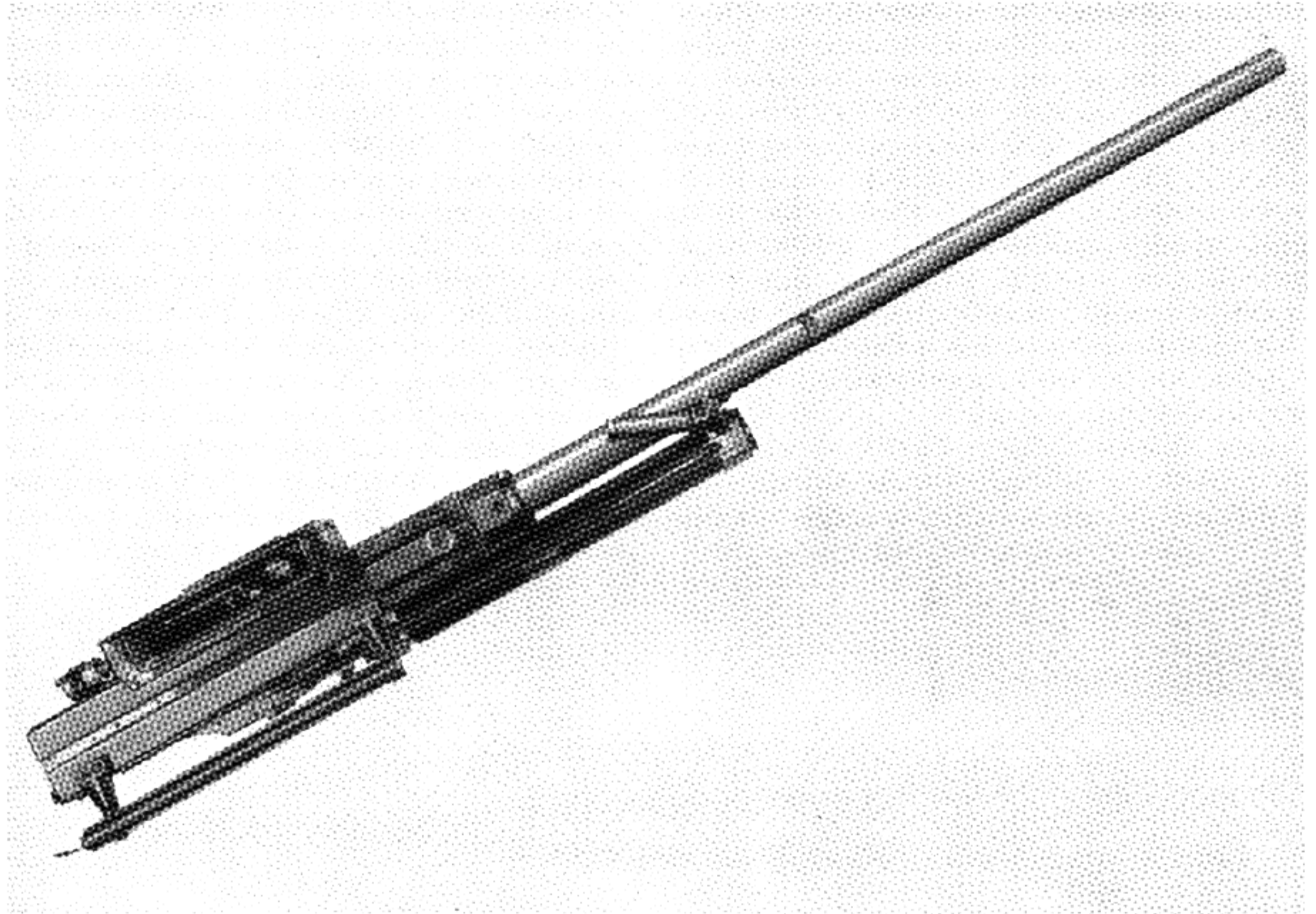


Figure 1-43. 37-mm Browning Gun T20E2. Right side view.

*Gun, Automatic 37-mm T37.* Designed by the United Shoe Machinery Corp. It includes a recoil operated integral feed, an integral charger and electric ignition. The first pilot model of this weapon was completed in November 1945. The first test resulted in several broken parts. This gun will be used to gain information for a complete redesign of a 37-mm weapon. This gun operates on the German Mauser principle. The receiver of the gun has two rails with two cam paths, one for ejecting the extracted cartridge case, and the other for guiding the round into the chamber. The gun is designed for electrically fired ammunition. The breech end of the tube has gear teeth machined on the top surface that operate the feed mechanism. A sprag type clutch is used to transmit the energy from the recoiling tube to the feed mechanism. The rotating bolthead is tied to the bolt body through a helical spline. There is no provision for

buffing the picking up of the bolthead by the bolt body during the recoil stroke. The bolthead changes from a rotational velocity to a translational velocity in a very small interval of time on the recoil stroke and from previous experience with the cal. .60 Mauser action gun, which has a buffer between the boltbody and bolthead, it is believed excessive forces due to high accelerations will result in short life and breakage of parts. There are four sets of interrupted locking lugs on the bolthead and upon examination of the detail drawing for the bolthead, it is noticed that the internal spline removed a large portion of the metal locking lugs. Failures of the metal supporting the locking lugs of the caliber .60 boltheads, proved the necessity for supporting the locking lugs with sufficient metal. A very ingenious mechanical buffer has been developed for buffing the bolt as it comes into battery on the counterrecoil stroke. Energy is absorbed by vi-

brating a mass of steel between two saw-tooth surfaces. It is claimed that this mechanical buffer will change the velocity of the bolt from about 25 feet per second to about 6 feet per second. The gun will be started in motion by use of a cartridge charger. The bolt buffer consists of a series of helical compression springs distributed around the periphery of a cup enclosing the boltbody thus minimizing the length of the receiver. The parts of this gun were completed except for the final machining of the bolthead and boltbody and it was stated that the gun would be assembled at the earliest practicable date.

*Gun, Automatic, 37-mm T37E1.* The records do not indicate the history of the T37E1. The T37E1 gun changes the T37 from a gas-operated

light reciprocating bolt and recoiling barrel, should make a very high cyclic rate gun. A unique design of ammunition loading, accomplished during counterrecoil of the barrel, had not been completed because of the difficulty in designing a satisfactory means of diverting power from the recoil barrel to the ammunition carrier, which must travel at slightly greater than twice the barrel speed. Design was still at the rough layout stage when canceled.

*Gun, Automatic, 37-mm T46.* Developed by Production Methods, Inc. The preliminary designs utilized several features common to guns of the Solothurn type and in their existing form showed considerable promise. No guns were ever made.

*Gun, Automatic, 37-mm T49.* High cyclic rate automatic aircraft gun firing new high-velocity am-

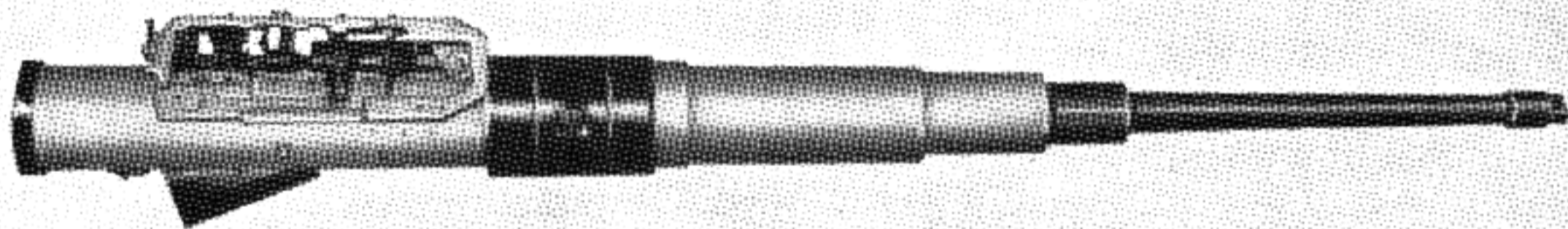


Figure 1-44. Gun, Automatic, 37-mm T37E1.

to a recoil-operated gun. Rollers operating in a stationary cam path induce rotary motion to a cylinder which in turn transmits lateral motion to the bolt operating slides through helical splines machined in the inside of the cylinder and the outside of the two slides. A hydraulic bolt operating system which operates from the hydraulic pressure obtained from the recoil cylinder was designed but not built.

*Gun, Automatic, 37-mm T44.* Developed by the Colt Co. to satisfy the same requirement as the T37. The records indicate that no gun was ever constructed to this design.

*Gun, Automatic, 37-mm T45.* This was an unconventional design by the Bartelt Engineering Co. It used a hinge-type sliding shutter to replace the conventional breechblock. This, combined with a

munition, with the matched projectiles. Developed by Bartelt Engineering Co., Rockford, Ill. This was a modification of the Hispano-Suiza 20-mm gun M2 with a forward firing bolt. An integral recoil feed mechanism was under construction according to this design.

*Gun, Automatic, 37-mm T172.* Believed intended for radar jamming by firing shells loaded with tinfoil strips.

*Gun, Automatic, 37-mm M1.* A 3,000-feet-per-second antiaircraft gun designed by Browning. It was tested at Aberdeen Proving Ground on 23 June 1925 and was considered a success, although it gave some trouble: the muzzle end of the barrel, beyond the water jacket, was too thin and overheated badly; there were numerous stoppages resulting from failure to eject the empty cartridge cases. After fur-

ther experimenting by Colt (Mr. Browning had died in 1926) a second pilot was built and then standardized as the Browning 37-mm automatic antiaircraft gun, M1, in May, 1927.

*Gun, Automatic, 37-mm M1E1.* In 1937 the M1 guns were modified and improved and redesignated M1E1.

*Gun, Automatic, 37-mm M1A1.* In October 1938 the gun was standardized as the M1A1 but without water jacket. In addition to improvements in the functioning of the mechanism, there was another change in the gun: the velocity was dropped from the hoped-for-but-not obtained 3,000 feet per second to the more realistic 2,800 feet per second. This reduction also cut down erosion.

*Gun, Automatic, 37-mm M1A2.* The accuracy of the M1 had always been unsatisfactory and investigation showed that the projectile was unstable in flight. In 1939 an increase was made in the twist of the rifling from 1 turn in 35 to 1 in 30 calibers. The modified gun was designated the M1A2. A year later, a final change was made in the characteristics of the gun—the muzzle velocity was reduced again, to 2,600 feet per second.

*Gun, Automatic, 37-mm M1A2E1.* The 37-mm gun M1A2 was tested at high altitudes to determine whether it would be satisfactory as an aircraft gun. As results of the tests were favorable, in May 1942

the Army Air Corps initiated a project to mount it in the nose of the A-20A airplane, requesting that an endless articulated belt magazine be furnished with the gun. Designed for this installation, the 37-mm endless belt magazine T9 was similar to the M6 magazine on the 37-mm gun M4 on the P-39 plane, except that the thrust of the loaded belt on the short turns was taken on wheels instead of on the magazine trackway. To accommodate the magazine T9, the M1A2 gun was modified with a loading handle and a lock frame embodying a carrier lifter cam, and designated 37-mm Automatic Gun M1A2E1. It was subsequently discovered, from extensive firing tests in a "bathtub" installation projecting below the bomb bay, that the blast from the two guns was so severe that the lower part of the fuselage was damaged, particularly in the area around the hatch for the front landing wheel. Since this condition could only be overcome by extensive reinforcement of the structure, it was decided to use the T20E1 gun and not the M1A2E1. As the T20E1 gun used a disintegrating link belt type feed, the requirement for the T9 magazine no longer existed. Therefore, although the 37-mm endless belt magazine T9 functioned satisfactorily, its development was cancelled in October 1943.

*Gun, Automatic, 37-mm M4.* The modifications made on the T9 model to produce the M4 effected

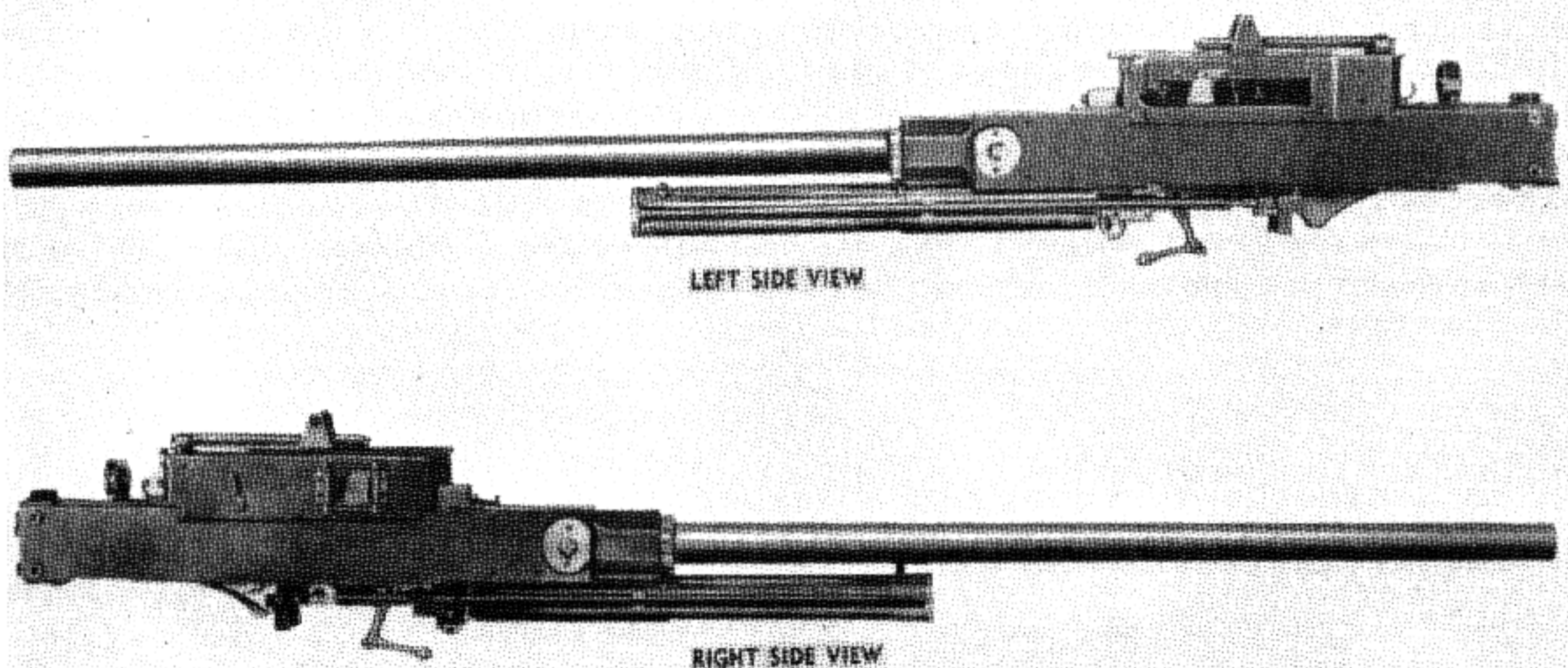


Figure 1-45. Gun, Automatic, 37-mm M4.

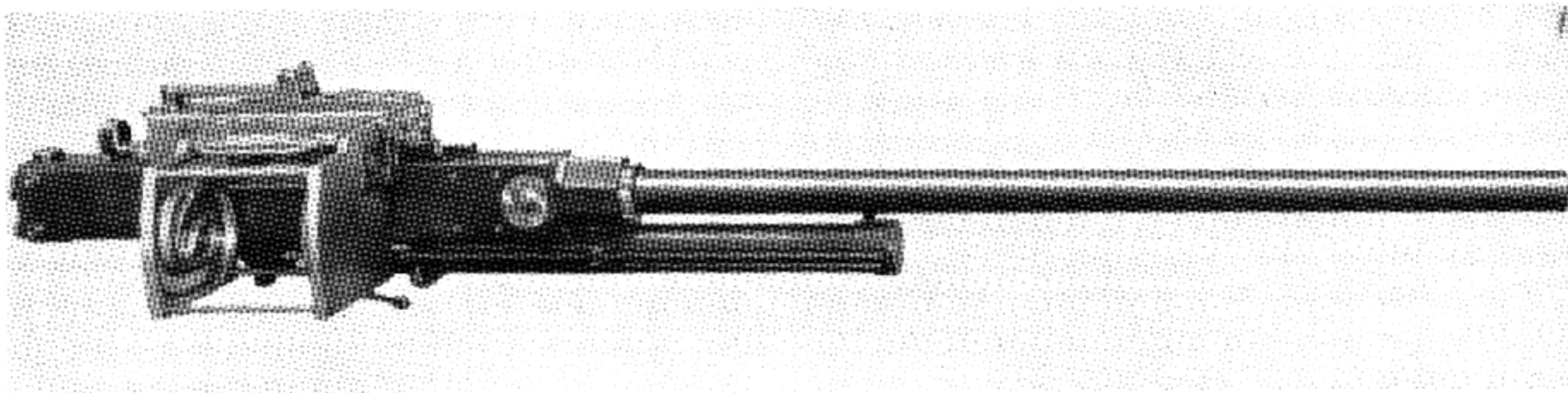


Figure 1-46. 37-mm Browning Gun M4E1. Right side view.

a number of important improvements. The backplate of the M4 was reinforced and the buffer on the backplate assembly was changed; the recuperator bushing ports of the recuperator cylinder were enlarged to increase the rate of fire; a stronger carrier catch spring enabled the carrier catch to return faster to its normal position; the trigger extension mechanism on the T9 lock frame was placed on the tube extension of the M4; and helical springs on the buffer of the M4 replaced the Belleville springs of the T9.

*Gun, Automatic, 37-mm M4E1.* In 1941 the Army Air Corps, in order to increase the armament of certain planes, established requirements for planes with wing-mounted 37-mm automatic guns fed from the fuselage. This requirement made it necessary to develop a gun with right-hand feed to pair with the left-hand feed of the 37-mm automatic gun M4. To supply this need the M4 gun was modified to feed from the right and was designated 37-mm automatic gun M4E1.

*Gun, Automatic, 37-mm M4E2.* The M4E2 gun had a modified feedbox and tube extension; the left-side plate was slotted to receive the feed assembly lever when the gun was fed from the right

side. The M4E2 gun was changed from a right- to a left-hand feed by shifting the following parts of the feedbox mechanisms. The feed slide lever was taken from the right bracket, turned upside down, and placed in the left bracket; the feed crank was rotated 180° so that the opposite feed crank stud engaged the slot in the feed slide lever; the feed slide was taken from the right side of the feedbox frame, turned around, and inserted in the left side of the feedbox frame; and the stops in the pawl assembly were turned upside down and interchanged. The complete assembly was shifted to the left.

*Gun, Automatic, 37-mm M4E3.* This was simply the M4 modified for use with a disintegrating link belt feed mechanism to feed from the left side. The method of feeding was the same as that of the standard feedbox, except in the shape of the parts, and in the operation of the stop and holding pawls. Attached to the forward end of the recuperator was a cylindrical expansion chamber, closed at the top, into which the oil could flow as it expanded. The development of the M4E3 was given a low priority to permit earlier development of the high velocity 37-mm automatic gun with a disintegrating link

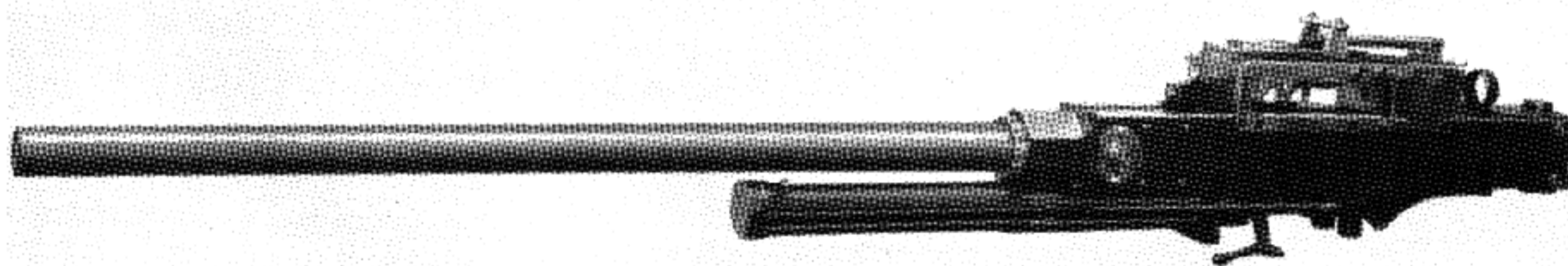


Figure 1-47. 37-mm Browning Gun M4E2 showing the M4 converted to feed from either side.

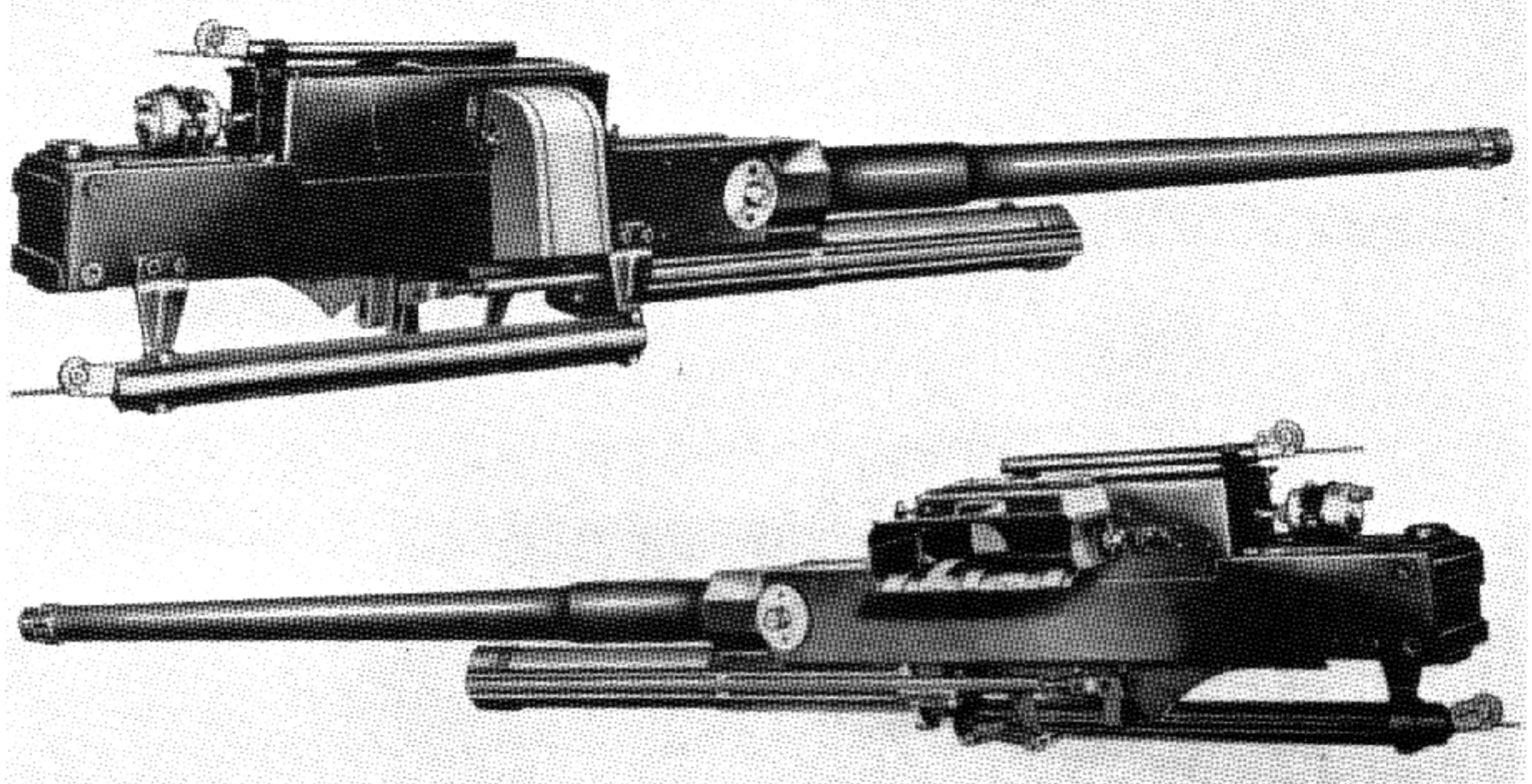


Figure 1-48. 37-mm Automatic Gun M4E3.

belt feed mechanism. As soon as this latter development was completed and the gun standardized as 37-mm automatic gun M9, the development of 37-mm automatic gun M4E3 was assigned higher priority because of the increasing difficulty in providing endless belt feed mechanisms for the M4 gun.

*Gun, Automatic, 37-mm M4E4.* Similar to the M4E3 except that it incorporated a right-hand feed.

*Gun, Automatic, 37-mm M9.* After tests of the T20E1 gun at Aberdeen Proving Ground and at Eglin Field, Fla., recommendations resulted in minor modifications to improve the functioning of the gun for use in aircraft. It was approved in January 1943 for standardization as a 37-mm gun M9. The 37-mm automatic gun M9 was basically the same as the 37-mm antiaircraft gun M1A2 in general appearance and functioning. The chief differences in the appearance of the two guns were in the shape of the recuperator expansion tube socket and the position of the recuperator expansion tube. The M9 gun socket was built with a filler screw and bracket on each side, while the gun socket of the M1A2 gun had a single filler screw and bracket on the right side only. In the M9 gun the expansion tube was placed to the rear of the socket and extended upward at an angle. In the M1A2 gun the

expansion tube was in front of the socket and parallel with the gun tube. Unlike that of the M1A2 gun, the M9 gun tube had splines machined at its muzzle end. The flats machined at approximately the middle of the M1A2 gun tube for application of the tube wrench were not incorporated in the M9 gun tube. The cartridge tray for the M1A2 gun feedbox was not used with the M9 gun, as the M9 gun used an inlet feed chute and a link ejection chute attached to the feedbox by eyebolts and wing nuts. The lower end of the operating lever on the M9 gun had a round hole to admit a charging pin, while the M1A2 gun's operating lever had a triangular hole to permit use of a priming rod. A sighting slot was incorporated in the trunnion block of the M9 gun, near the tube lock depressor, but the M1A2 gun had no such slot.

*Gun, Automatic, 37-mm M9E1.* In November 1943 the Army Air Corps requested the Ordnance Department to modify a 37-mm M9 gun so that it could be installed in the P-63 fighter plane. The following January a project was authorized for this purpose with the designation 37-mm automatic gun M9E1. The requirements outlined by the Army Air Corps called for reduction of the tube diameter and modifications of related parts to allow

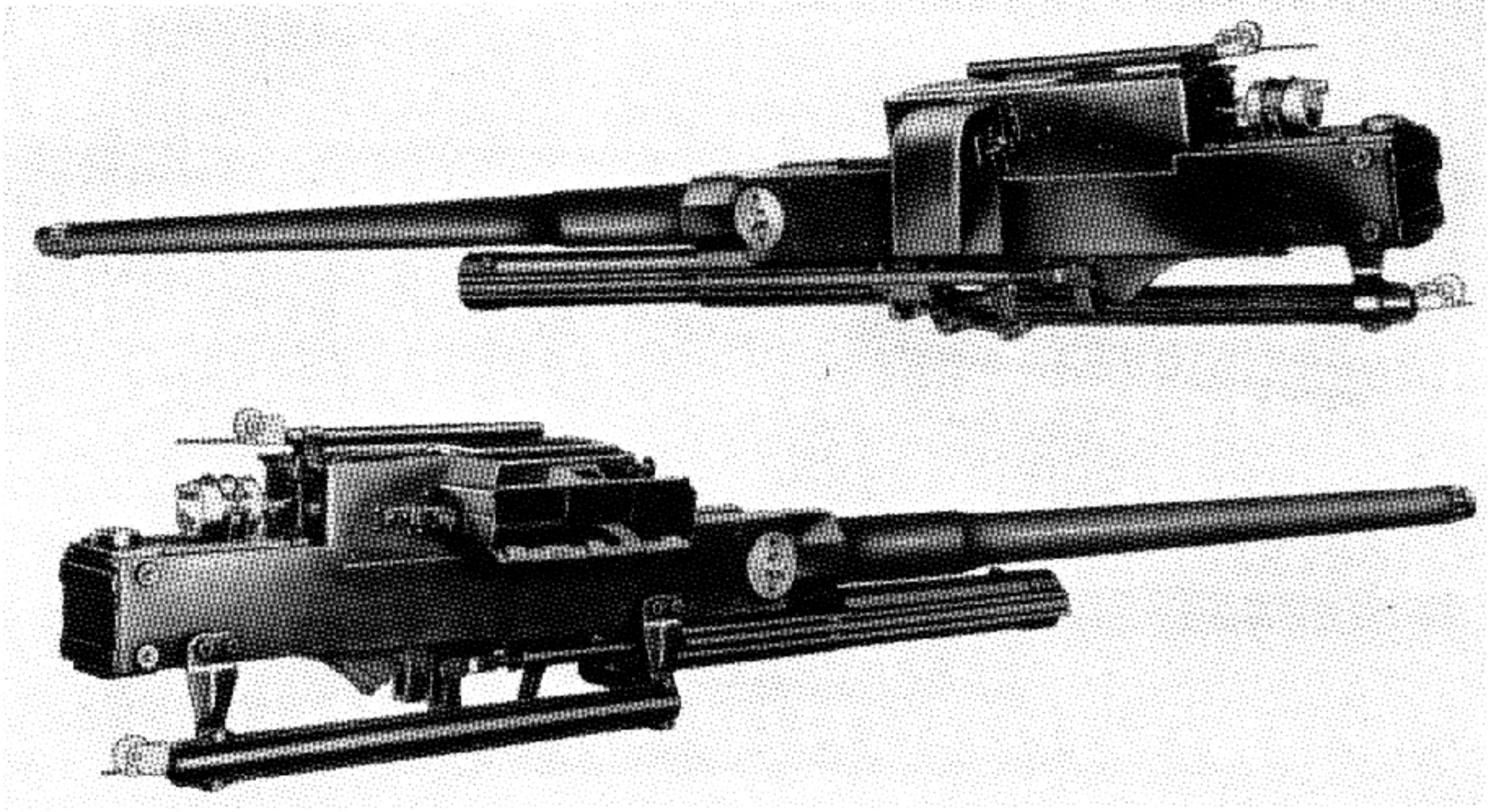


Figure 1-49. 37-mm Automatic Gun M4E4 with right-hand feed box assembly.

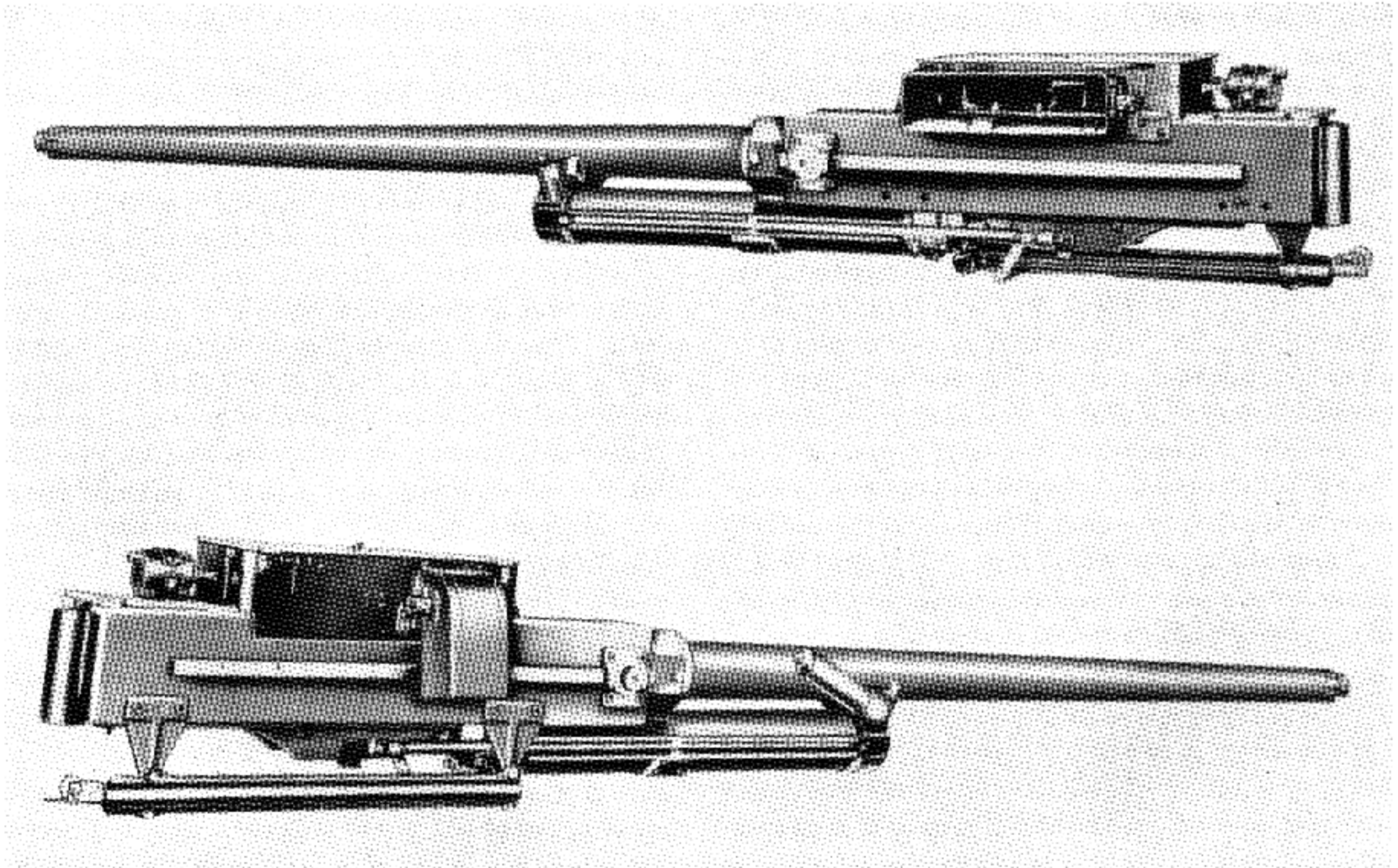


Figure 1-50. Gun, Automatic, 37-mm M9, with parts positioned for left-hand feeding.

removal of the gun through the propeller hub. Weight added at the tapered section in front of the bearing allowed a reduced section near the muzzle for freedom of movement in bore sighting.

*Gun, Automatic, 37-mm M9A1.* Firing tests of M9E1 models conducted at Aberdeen indicated that the operation of the gun was completely satisfactory. An HE shell was detonated in one M9E1 tube to determine the characteristics of the tube and material. Results of this test were also completely satisfactory and indicated that the tube was sufficiently strong to withstand any firing that would be encountered in service. In September 1944 the M9E1 gun was standardized as 37-mm automatic gun AN-M9A1.

*Gun, Automatic, 37-mm M9A1E1.* This was a project to utilize M9 tubes to supplement production of M9A1 guns.

*Gun, Automatic, 37-mm M10.* The Army Air Corps, which was kept fully informed of the progress of Ordnance development of the 37-mm automatic guns M4E3 and M4E4, at this juncture directed that the M4E4 be placed in the P-63 fighter plane. This action was taken because the M4E4 fired 25 to 30 shots faster and had double the ammunition capacity of the 37-mm automatic gun M4. However, the M4E3 and M4E4 were not yet ready for standardization, since minor modifications to the feedbox were necessary and the gun had not been service tested.

It was expected that the first 400 guns would differ from the standard gun in minor details: therefore they would require modification at a later

date. It was also expected that by December 1943, when the first 400 guns would be completed, all modifications would have been approved and standard drawings would be available according to which the remaining guns of the initial procurement could be produced. Consequently, in August 1943, the procurement of the M4E3 gun was increased to 2,500. By March 1944, all ground tests and aerial tests of the modified gun had been satisfactorily performed, and 37-mm automatic gun M4E3 and 37-mm automatic gun M4E4 were standardized as 37-mm automatic gun M10, with separate stock numbers issued for right and left side feed.

### 37-mm Automatic Guns with Mark and Mod Numbers

*37-mm Automatic Gun Mk 1 Mod 0.* This is the Army 37-mm M9 left-hand feed for wet use as the submarine antiaircraft gun.

*37-mm Automatic Gun Mk 2 Mod 0.* This is the Army 37-mm M9 right-hand feed for wet use as the submarine antiaircraft gun.

*37-mm Automatic Gun Mk 3 Mod 0.* This is the Army's 37-mm antiaircraft gun M1A2 for wet use.

### 40-mm Automatic Guns with T and M Numbers

*Gun, Automatic, 40-mm T1.* The Ordnance Committee had, on 6 February 1941, expressed its approval of the Bofors light antiaircraft gun. Manufacturing rights were to be sought, drawings were to be prepared, components and major assemblies

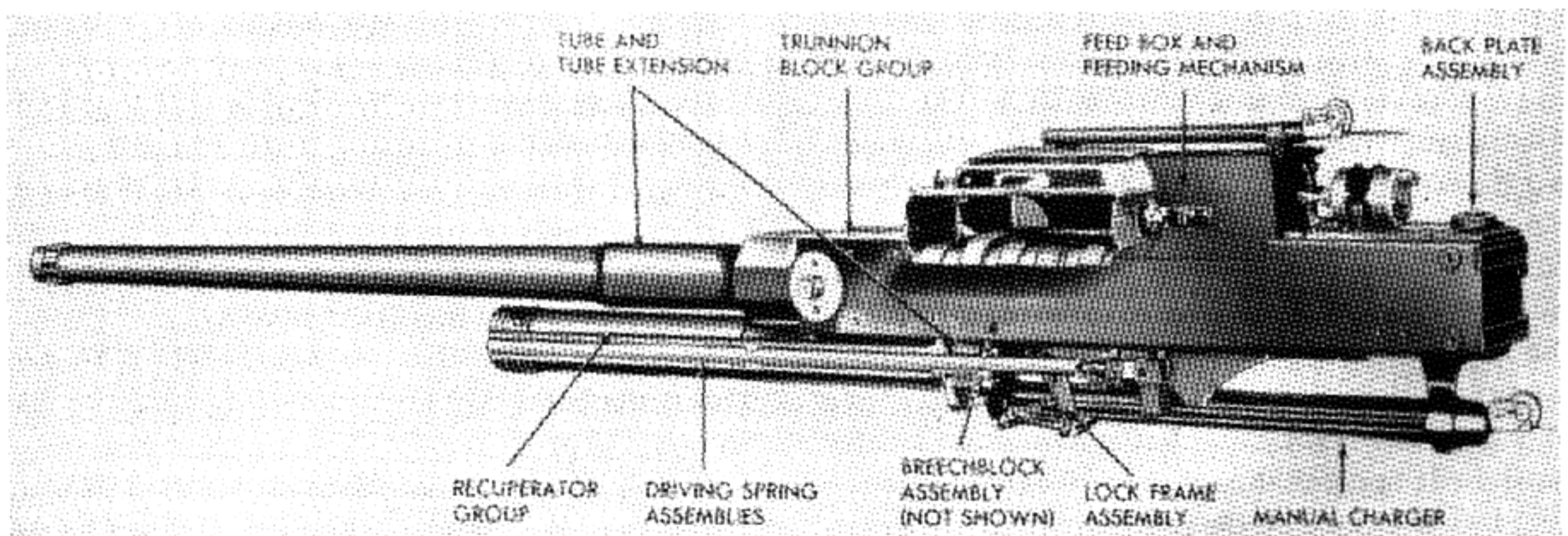


Figure 1-51. 37-mm Gun M10, left-hand feed.



were to be interchangeable as between British and United States Army Ordnance-made units, 2 complete pilot units were to be manufactured, 2 guns and carriages with 2 spare barrels and all equipment were to be procured from the British.

*Gun, Automatic, 40-mm T2.* Right-hand loader for twin 40-mm gun mount. This material is standardized with T3 without modification as Gun, Dual Automatic, 40-mm, M2.

*Gun, Automatic, 40-mm T3.* Left-hand loader for twin 40-mm gun mount. This material standardized with T2 without modification as Gun, Dual Automatic, 40-mm, M2.

*Gun, Automatic, 40-mm T4.* Standard M1 gun modified for use with two caliber .50 machine guns and computing sights on combination gun mount. Requires drilling of special holes and machining of bases on sideplate.

*Gun, Automatic, 40-mm M1.* Standardization of the T1.

*Gun, Automatic, 40-mm M1A1.* Modification of M1 for application of certain computing sights.

*Gun, Automatic, 40-mm M1E1.* Left-hand twist, increasing 1 turn in 45 calibers at breech to 1 turn in 30 calibers at muzzle.

*Gun, Automatic, 40-mm M1E2.* Never beyond blueprint stage.

*Gun, Dual Automatic, 40-mm M2.* To adapt the 40-mm gun M1 to twin mounting, a new gun mount, T12, was developed. This consisted of a left-hand gun T3 and a right-hand gun T2. T3 is essentially a standard 40-mm gun M1 slightly modified so the extractor lever could be installed on the bottom side of the gun. The extractor spindle was modified so as to permit installation from the left side. The right gun, T2, is similar to the Navy 40-mm gun, right hand. It differs from the standard 40-mm gun, M1 in the following respects: It has right-hand feed features; its hand-operating lever is on the right side; the firing mechanism is on the right side of the inner breech casing; right-hand frame of the top carriage is modified; the extractor lever is on the bottom of the gun; the breech closing spring and the outer crankshaft closing spring are located on the side opposite that of the M1 gun; the breech ring lock is located on the right side; and the elevating scale is on the right side.

## 40-mm Machine Guns with Mark and Mod Numbers

*40-mm Machine Gun Mechanism Mk 1 Mod 0.* The design of these mechanisms and barrels is essentially that of the Swedish Bofors 40-mm antiaircraft gun. The design provides for a rapid fire, recoil operated, automatic mechanism, with a maximum cyclic rate of approximately 160 rounds per minute. The Mk 1 Mod 0 is a left-hand mechanism manufactured by York and is water cooled.

*40-mm Gun Mechanism Mk 1 Mod 1.* Left-hand mechanism manufactured by Chrysler.

*40-mm Gun Mechanism Mk 1 Mod 2.* This is a Mk 1 Mod 0 with feed improvements.

*40-mm Machine Gun Mechanism Mk 1 Mod 3.* This is a Mk 1 Mod 0 with feed improvements.

*40-mm Machine Gun Mechanism Mk 1 Mod 4.* This is the Mk 1 Mod 0 with additional modifications.

*40-mm Machine Gun Mechanism Mk 1 Mod 5.* This is the Mk 1 Mod 1 with further changes.

*40-mm Machine Gun Mechanism Mk 1 Mod 6.* Modifications of the Mk 1 Mod 0.

*40-mm Machine Gun Mechanism Mk 1 Mod 7.* Modifications of the Mk 1 Mod 1.

*40-mm Machine Gun Mechanism Mk 2 Mod 0.* Right-hand mechanism built by York.

*40-mm Machine Gun Mechanism Mk 2 Mod 1.* Right-hand mechanism built by Chrysler.

*40-mm Machine Gun Mechanism Mk 2 Mod 2.* Mk 2 Mod 0 with improved feed.

*40-mm Machine Gun Mechanism Mk 2 Mod 3.* Mk 2 Mod 1 with improved feed.

*40-mm Machine Gun Mechanism Mk 2 Mod 4.* Additional modifications of the Mk 2 Mod 0.

*40-mm Machine Gun Mechanism Mk 2 Mod 5.* Additional modifications to the Mk 2 Mod 1.

*40-mm Machine Gun Mechanism Mk 2 Mod 6.* Further changes to the Mk 2 Mod 0.

*40-mm Machine Gun Mechanism Mk 2 Mod 7.* Further changes to the Mk 2 Mod 1.

*40-mm Machine Gun Mechanism Mk 3 Mod 0.* This is the Mk 1 Mod 0 with feed modified by the Shirgun Corp.

*40-mm Machine Gun Mechanism Mk 3 Mod 1.* This is the Mk 1 Mod 1 with feed modified by the Shirgun Corp.

*40-mm Machine Gun Mechanism Mk 4 Mod 0.* This is the Mk 2 Mod 0 with feed modified by the Shirgun Corp.

*40-mm Machine Gun Mechanism Mk 4 Mod 1.* This is the Mk 2 Mod 1 with feed modified by Shirgun Corp.

*40-mm Machine Gun Mechanism Mk 5 Mod 0.* The 40-mm single-gun mechanism M1 installed on mounts M3 for Navy use was procured for the War Department from Chrysler Corp. Slight modifications, such as difference in paint and buffer fluid were made to the mechanism M1 to adapt it to Navy use. The arrangement required that the Navy procure mechanism M1 for the War Department, deliver them to Army activities for single-mount assembly. During the period of production of 40-mm single mounts M3 and guns M1, numerous Ordalts were prepared by the Naval Gun Factory to better adapt the equipment to Navy use. The major portion of these Ordalts was incorporated into production of the equipment. Close liaison was maintained between the design sections of the Gun Factory and the War Department and Army drawings were modified as necessary to cover changes in design requested by the Navy. Even though the drawings and specifications for the manufacture of this equipment were exclusively under control of the Army, the Navy was able to modify the equipment in production as desired. The Army Transportation Corps had a few requirements for the mount M3 for transport vessels. However, it ac-

cepted the assembly with all Navy modifications and spare parts sets. Modifications to the mechanism finally required that it be given a new designation. This was done in March 1945 and the designation was changed from M1 to Mk 5 Mod 0. By letter of 29 November 1944 the War Department was requested to change the designation of the mount stand to Mk 3 Mod 1. In reply dated 30 April 1945 the War Department advised that it could not comply in that the stand was classified as Army standard material and model numbers are not assigned to Army gun mount subassemblies. Therefore, the mount is still designated as 40-mm mount M3.

*40-mm Machine Gun Mechanism Mk 5 Mod 1.* This is a modification in the sight adapter.

*40-mm Machine Gun Mechanism Mk 5 Mod 2.* Modification for wet use in a submarine.

*40-mm Machine Gun Mechanism Mk 5 Mod 3.* Additional slight changes.

*40-mm Machine Gun Mechanism Mk 5 Mod 4.* Another slight variation.

*40-mm Machine Gun Mechanism Mk 6.* Mk 6 was never assigned.

*40-mm Machine Gun Mechanism Mk 7 Mod 0.* Mk 1 Mod 0 modified to air cooled by Shirgun.

*40-mm Machine Gun Mechanism Mk 8 Mod 0.* Mk 2 Mod 1 modified to air cooled by Shirgun.

### 57-mm Automatic Guns

*Gun, Automatic, 57-mm T78.* Design copied directly from the German MK 112.

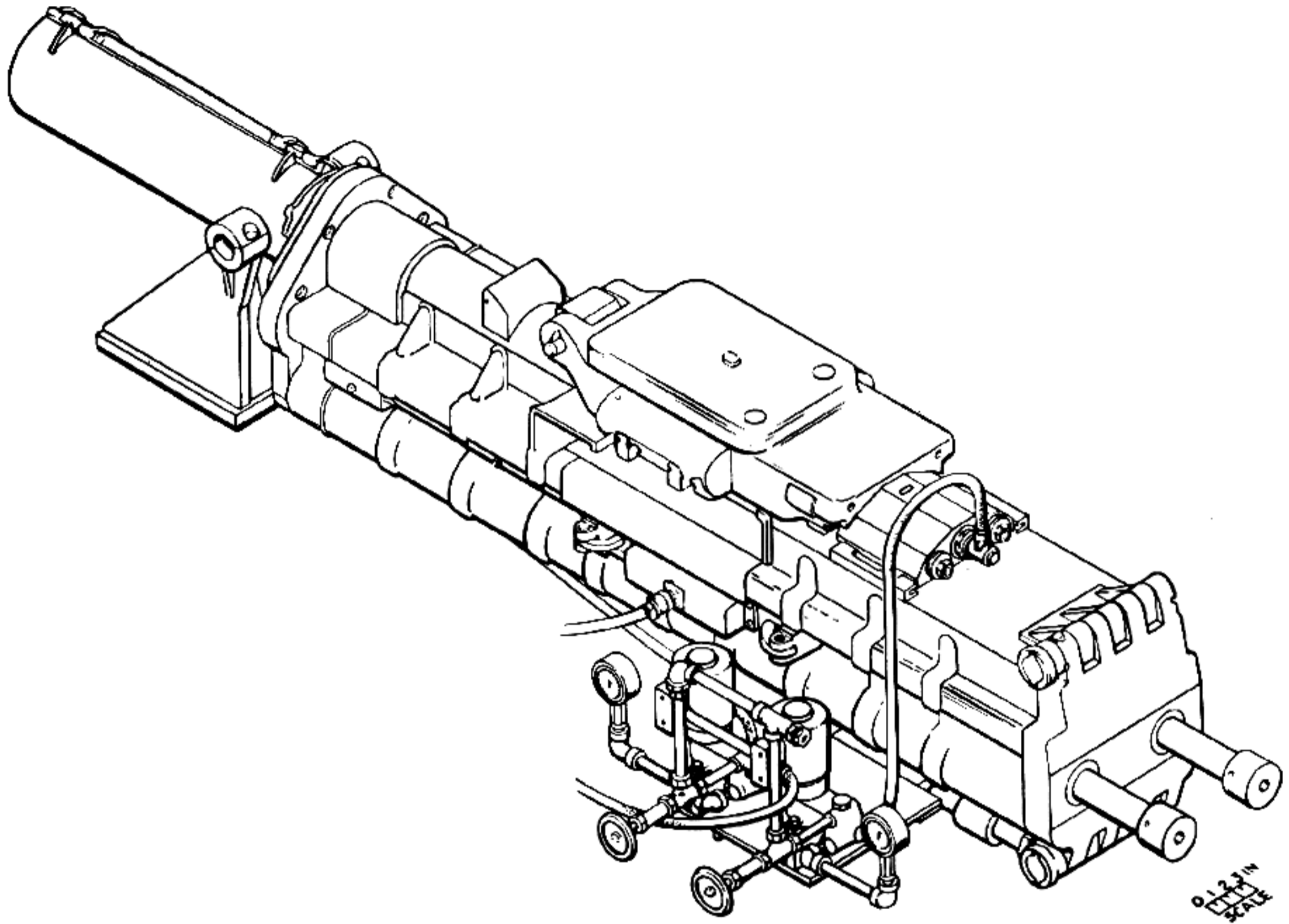


Figure 1-52. Gun, Automatic, 57-mm T78. This weapon is a conversion of the German MK-112.

Chapter 2

# ORDNANCE CORPS GAS-OPERATED REVOLVER CANNON

## SECTION 1. HISTORY AND BACKGROUND

The Ordnance Corps has originated a group of gas-operated revolver cannons using a mechanism based on a captured German revolver cannon known officially as the Mauser MG-213. The accompanying table includes an identification of the weapons that used this type of mechanism.

An MG-213 No. V6/10 was brought to the United States in a badly burned condition in 1945 and was restored to operating condition by the

United States Naval Gun Factory. American-made ammunition was used for a series of tests. Evidence indicates that the British obtained a specimen of the MG-213 earlier than 1945 and shipped it secretly to England.

The revolver principle had been employed in cannon such as the De Brame as long ago as the American Civil War, but the Germans were the first to build a type in which the drum is reloaded

MG-213 Revolver Type Guns

Designation	Developed by	Description
MG-213.....	Mauser.....	Automatic, revolver type, high-speed, aircraft machine cannon made in both 20-mm (high velocity) and 30-mm. 20-mm gun No. V6/10, a captured gun, was rebuilt by U. S. Naval Gun Factory.
T74 model A.....	ARF (Armour Research Foundation).	20-mm. Second rebuilding of the captured gun intended to secure information needed for a United States version. Some changes were incorporated. Rebuilding accomplished in 1947.
T74 model B.....	ARF.....	20-mm. Ordnance Corps design based on the captured gun. The barrel position was changed from the top to the bottom of the cylinder.
T74 model C.....	ARF.....	20-mm. Design emphasis was placed on reduction of weight and reduction of overall dimensions to meet limitations specified by the Ordnance Corps. This design was later redesignated T110.
T110.....	ARF.....	This weapon is the T74 model C redesignated in 1948.
T121.....	ARF.....	Designation assigned to 30-mm caliber of this type of gun. In preliminary study phase in 1949.
T130.....	ARF.....	Same mechanism as T110 except chambered for caliber .60 ammunition.
T151.....	ARF.....	Same mechanism as T130 except chambered for 27-mm ammunition.
T160.....	ARF.....	Same mechanism as T130 except chambered for 60/20 small round.
T164.....	ARF.....	Caliber .50 version of the T130 built at Springfield Arsenal.

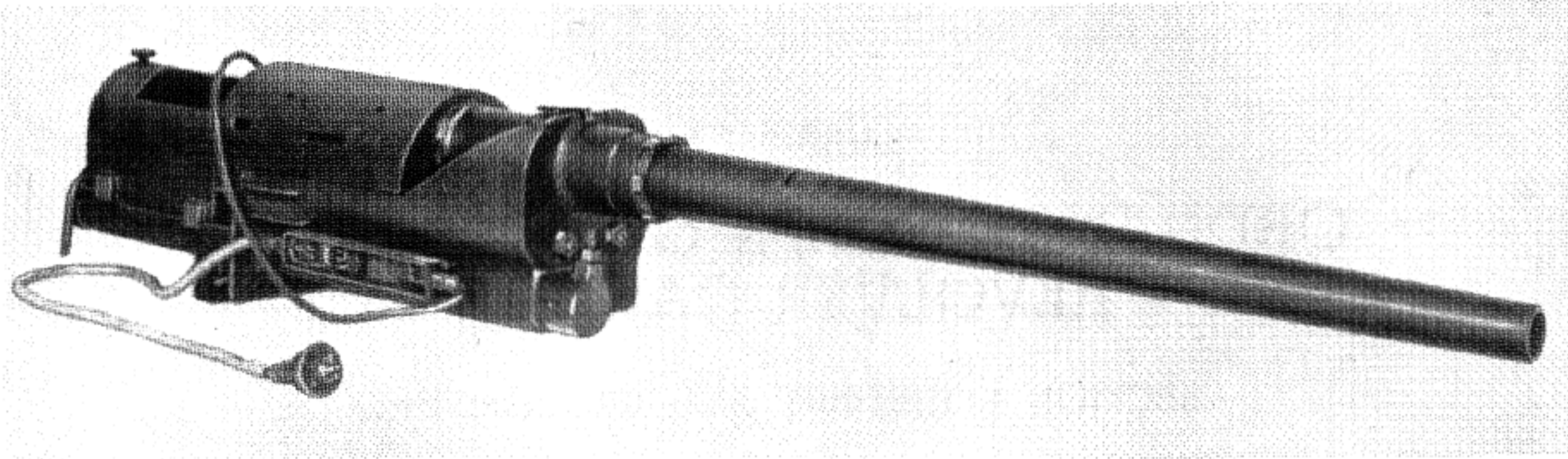


Figure 2-1. German MG-213. Right front view.

during firing. It is curious that the German gun had its barrel near the top, away from the center of gravity, since the barrel of the 1862 American De Brame gun was on the bottom.

### Background of the MG-213 in its Various Stages of Development

Late in 1942 the Luftwaffe desperately faced a need for a 20-mm aircraft gun of superior performance. Specifications were issued calling for a gun having a rate of fire of 1,000 rounds per minute with a minimum muzzle velocity of 1,000 meters per second. Since it was obviously impossible to meet such a requirement with the existing types of ammunition, the firm of Hasag was selected to develop the needed round.

It was known that the firm of Heinrich Krieghoff Waffenfabrik in Suhl, Germany, had a very promising gun design under development, but this weapon was not based on the revolver principle. This firm, which before World War II had worked mostly on sporting arms, did not have facilities to push the project to a quick conclusion. The Luftwaffe, therefore, ordered the development, transferred to Waffenfabrik Mauser A. G. The mechanism was improved by the Mauser plant to a point where it gave the required performance, but parts breakages were excessive.

Because of the difficulties with the original weapon, a simultaneous attempt was made to develop another reciprocating action type of gun proposed by a Mr. Linder, one of the Mauser engineers. It was first called the MG-215 but later received other designations; within the company, it was sometimes referred to as the MG-213M. There

were also references to it in German reports calling it the 7-43. When the need for clarifying the designations of the several guns in the series became apparent, this design became standardized as the MG-213B. This designation was retained until work on the model was stopped in favor of the revolver principle. The original designation, MG-215, was eventually assigned to another mechanism which has no relation to the present 213 series.

The gas-operated revolver-type weapon we know today as the MG-213 was the idea of another Mauser engineer, named Politzer, who appears to have been considerably influenced by the feed system of the Russian Shkas gun. The Mauser Co. was so impressed with his idea that it took up the matter with the German High Command and obtained permission to make a prototype. It was originally called MG-216. Subsequently, it became the MG-213C; still later, when converted to 30-mm bore, it was known as the MK-213C.

When it became obvious in early 1945 that it was but a matter of time before Germany collapsed, United States ordnance specialists were sent into the field to find anything of value in experimental weapons that the Germans had under test or in contemplation. After the surrender of Germany, several of the high ranking technicians at the Mauser plant revealed that an intensive program was under way on the MG-213 series of guns.

It was claimed by these technicians that with their latest development 150 rounds could be fired in 1 continuous burst without overheating or undue wear, and that 250 rounds could be expended at a single flight when simulated combat conditions were fol-

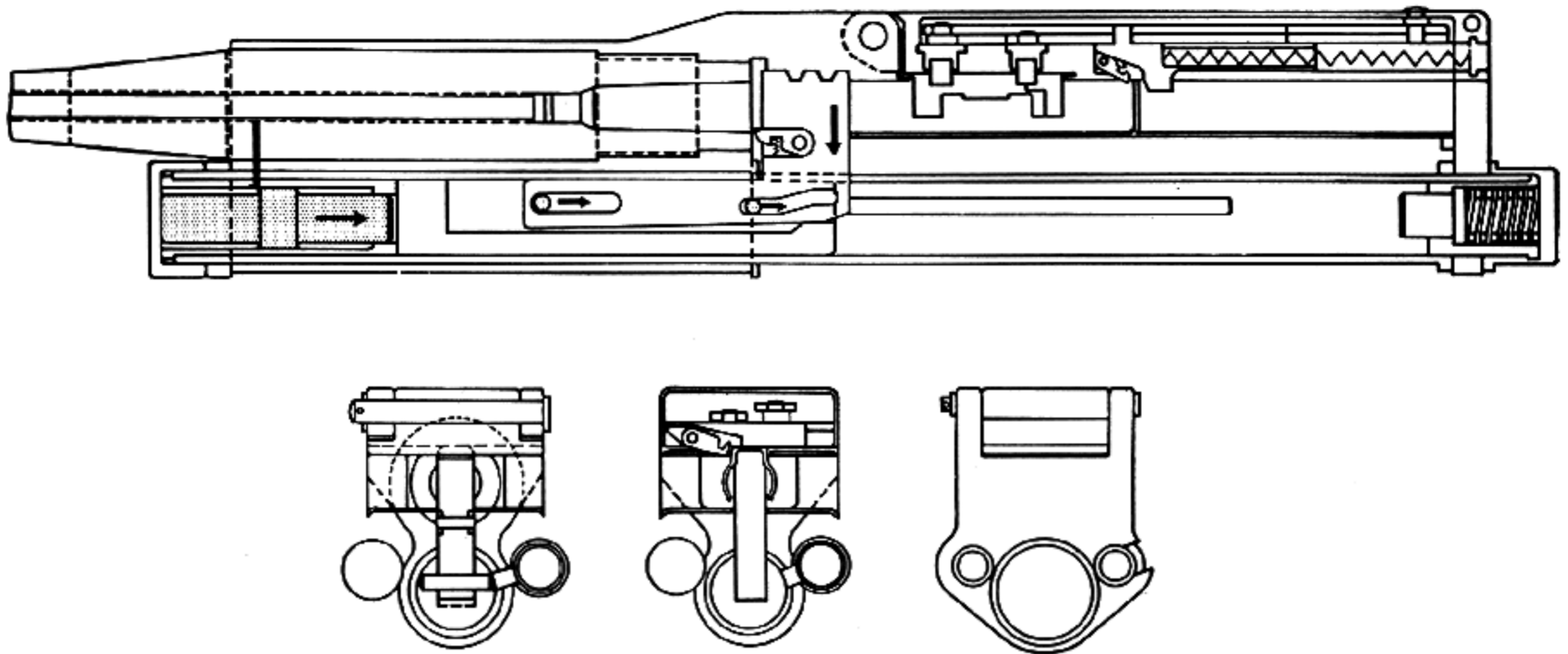


Figure 2-2. German Mauser MG-213B, designed by Linder. Sectional view. The design was also called MG-213M, MG-215, and 7-43. Arrows indicate direction of travel of parts during unlocking.

lowed. Greatly improved barrel life was the result of a special process used in polishing the bore and chamber.

The first successful pilot model of the 20-mm MG-213 was constructed by the Mauser Works as early as 1943. By the time Germany was overrun by the Allies, 5 prototypes of the final design had been fabricated, and 10 more, numbered V6/1 to V6/10, were in various stages of completion. One of the development models, No. V6/10 which had been damaged by fire, was captured at the end of

the war along with some 20-mm ammunition and shipped to the United States.

#### First ARF Development Program

This captured gun formed the basis for the development program initiated under contract W-11-022 ORD-11053 with Armour Research Foundation (ARF).

The program was conducted in four major phases which overlapped with respect to time, as shown in the accompanying table.

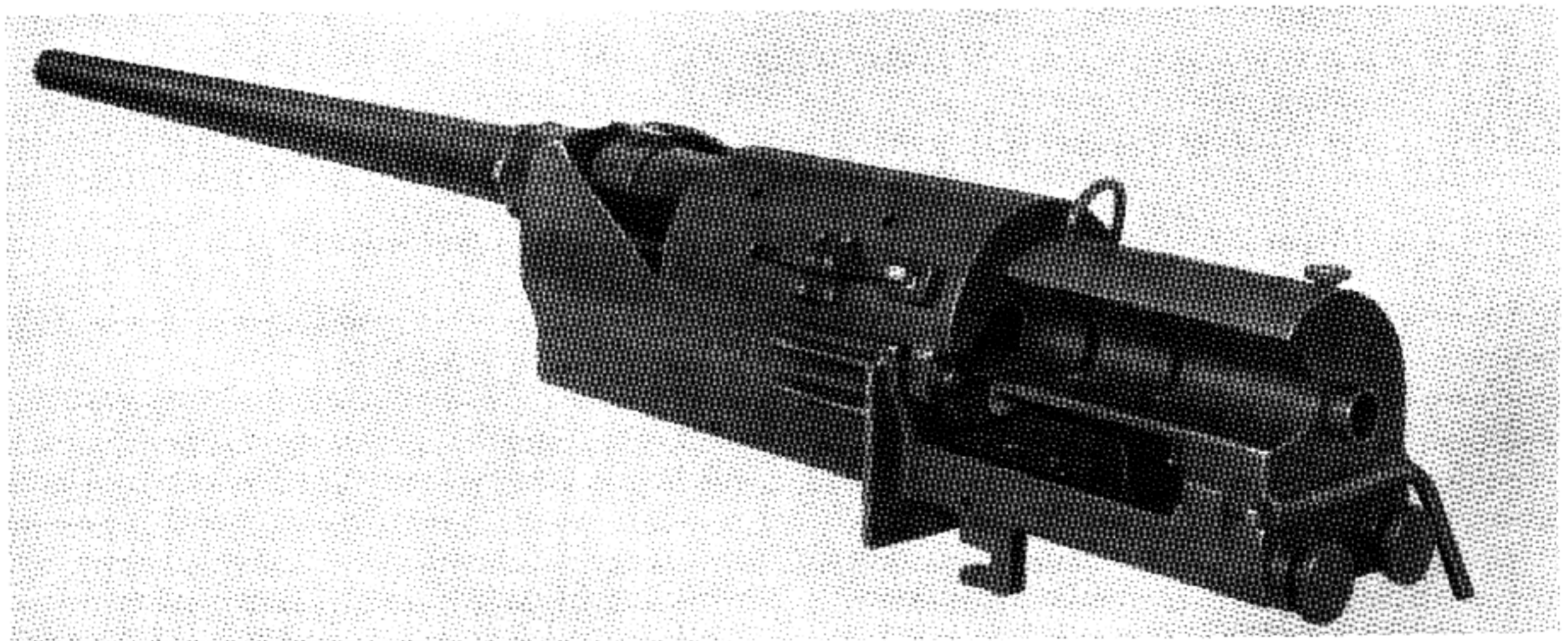


Figure 2-3. German MG-213. Left rear view.

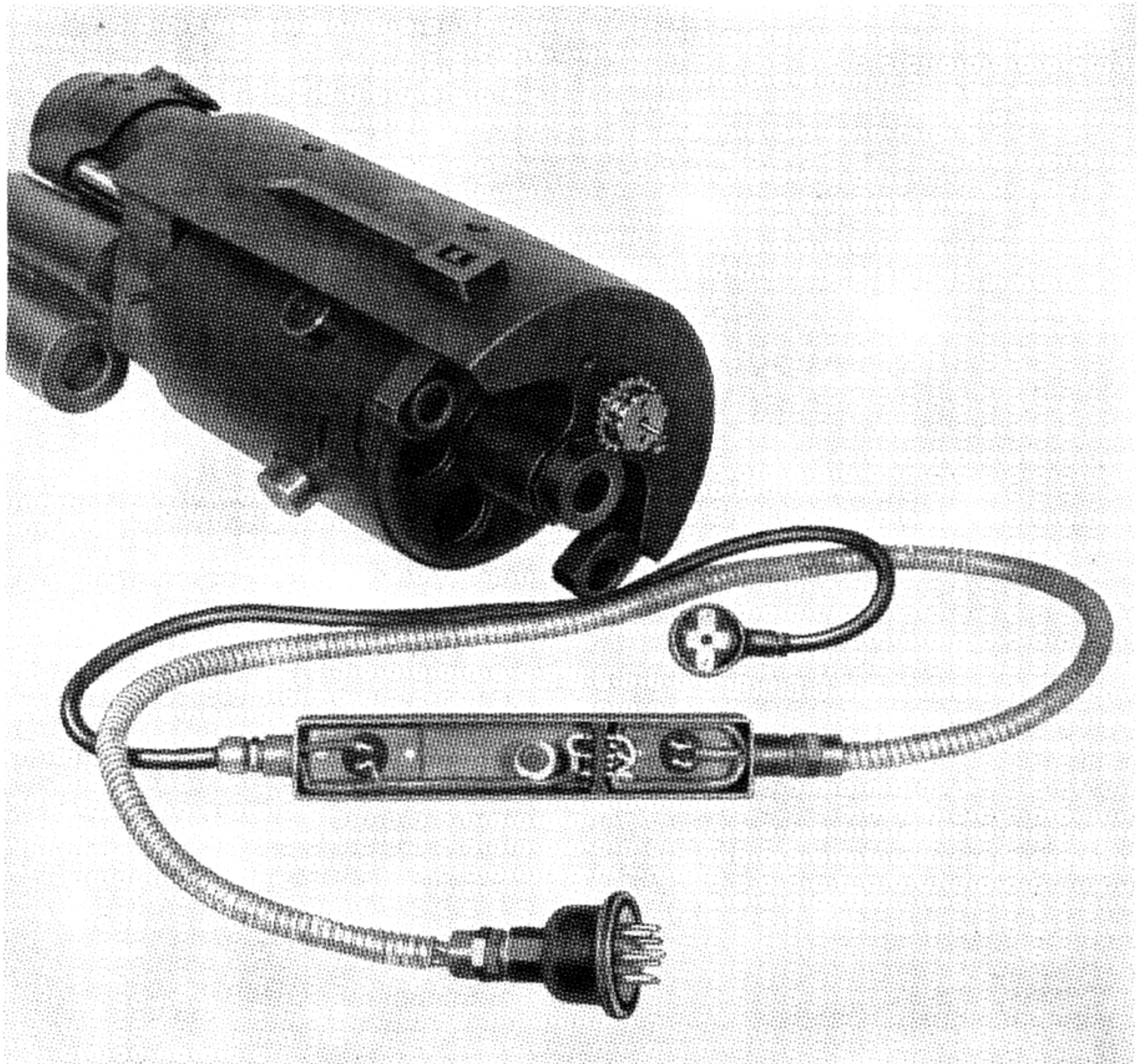


Figure 2-4. Drum, drum housing, and electric trigger connection of the German MG-213.

Under phase 1, the captured German 20-mm automatic gun MG-213 was studied and analyzed to determine the advantages of its design features and principles of operation. The weapon was reconditioned, assembled in its 20-mm form, and fired to obtain preliminary performance data.

Under phase 2, the captured German weapon was reworked and modified to permit more extensive study and analysis of operating principles and design features, and to permit more extensive firing for per-

formance data. This reworked weapon was designated 20-mm T74 Model A.

Under phase 3, a new model was designed and built, duplicating to a large extent the features of the 20-mm automatic gun T74 Model A, and incorporating design improvements based upon the knowledge gained from the studies, analyses, and tests made of this weapon. This second model was designated 20-mm Automatic Gun T74 Model B.

Under phase 4, another new model was designed

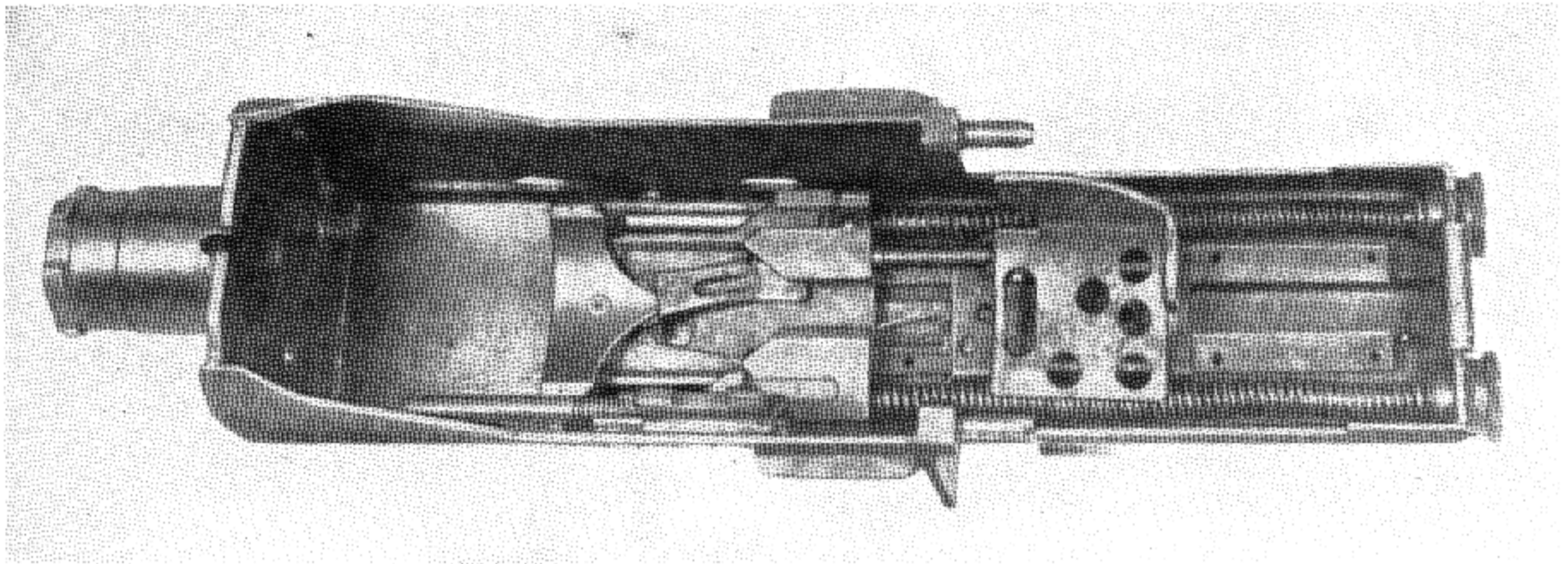


Figure 2-5. Slide, drum revolving mechanism, rammer, and driving spring of the German MG-213.

and built which incorporated major design changes to effect reduction in weight and overall dimensions; to make assembly, disassembly, and servicing easier; and to improve cyclic rate and performance. This model was designated 20-mm Automatic Gun T110.

The difficulties encountered in each model, the design changes made to overcome difficulties in pre-

ceding models, the results of kinematic and stress analyses, and photographs and assembly drawings of each model were studied.

In December 1949, the Ordnance Corps decided to terminate the contract and to continue the development of the 20-mm automatic gun T110 under a new contract with the Armour Research Foundation.

**Research and Development Time Schedule for Armour Research Foundation Project**

Phase	I	II	III	IV
Gun	MG-213	T74 A	T74 B	T110
Study, analysis, and design.	April 1946 to October 1946.	November 1946 to June 1947.	November 1946 to September 1947.	December 1947 to March 1949.
Manufacture and rework.	.....	January 1947 to September 1947.	November 1947 to May 15, 1948.	October 1948 to July 1949.
Test and modification...	September 1946 to October 1946.	June 14, 1947 to May 1948.	May 15, 1948 to August 1949.	May 15, 1949 to December 1949.

**Description of the MG-213**

The German gas-operated gun MG-213, upon which the development of all models of the revolver-type of automatic cannon developed by the United States was based, is a gas-operated, belt-fed, electrically fired, pneumatically charged weapon which fires at a rate of approximately 1,200 rounds per minute. By changing certain parts, it may be con-

verted from a 20-mm to a 30-mm weapon; by reversing certain components, it may be changed from left-hand to right-hand feed.

The distinguishing feature of this weapon is its revolving drum containing five cartridge chambers parallel to its axis of rotation and mounted upon a shaft within a housing so that each chamber is brought into alinement with the bore of the barrel



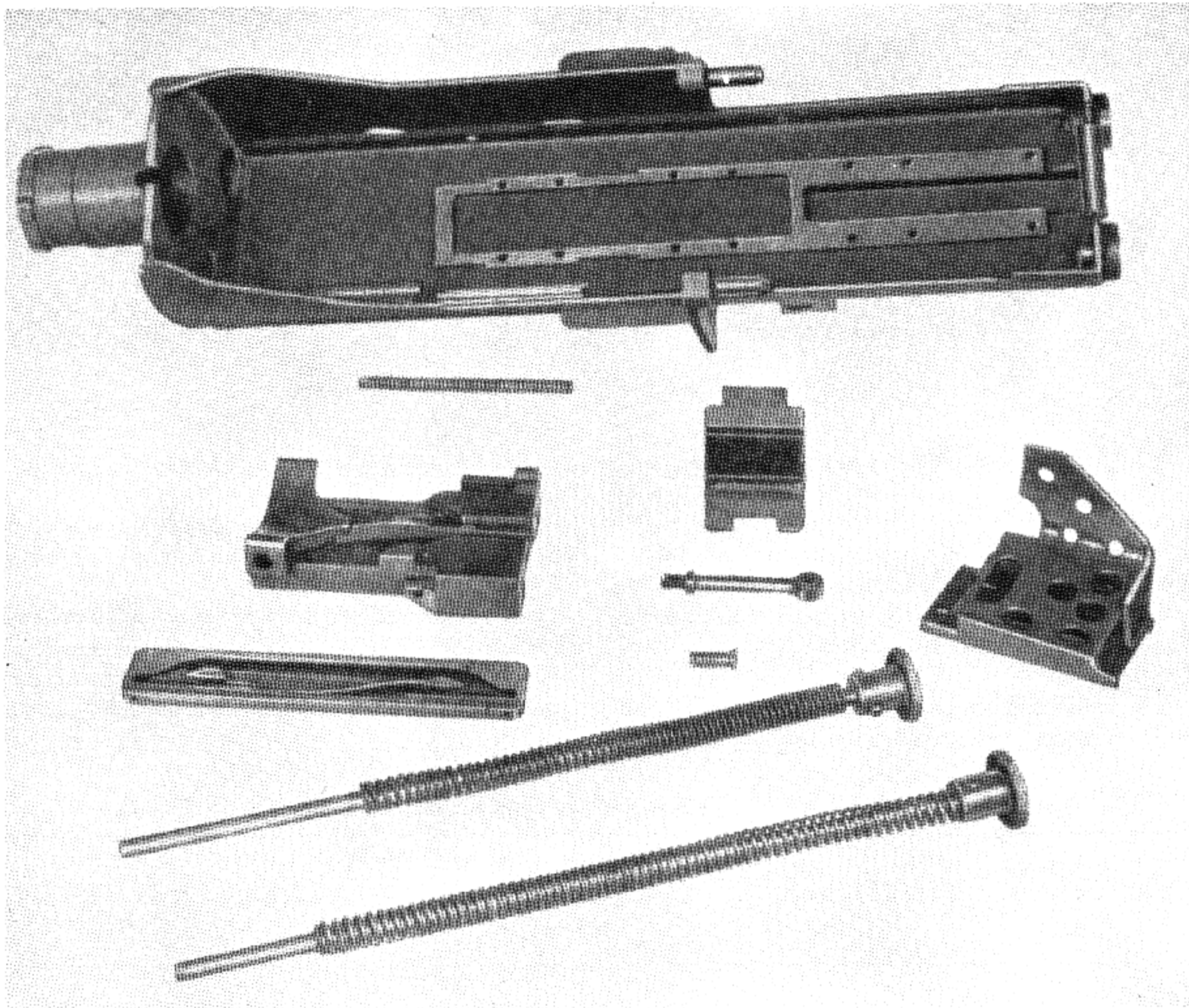


Figure 2-6. Slide, drum revolving mechanism, and rammer of the German MG-213. Disassembled view.

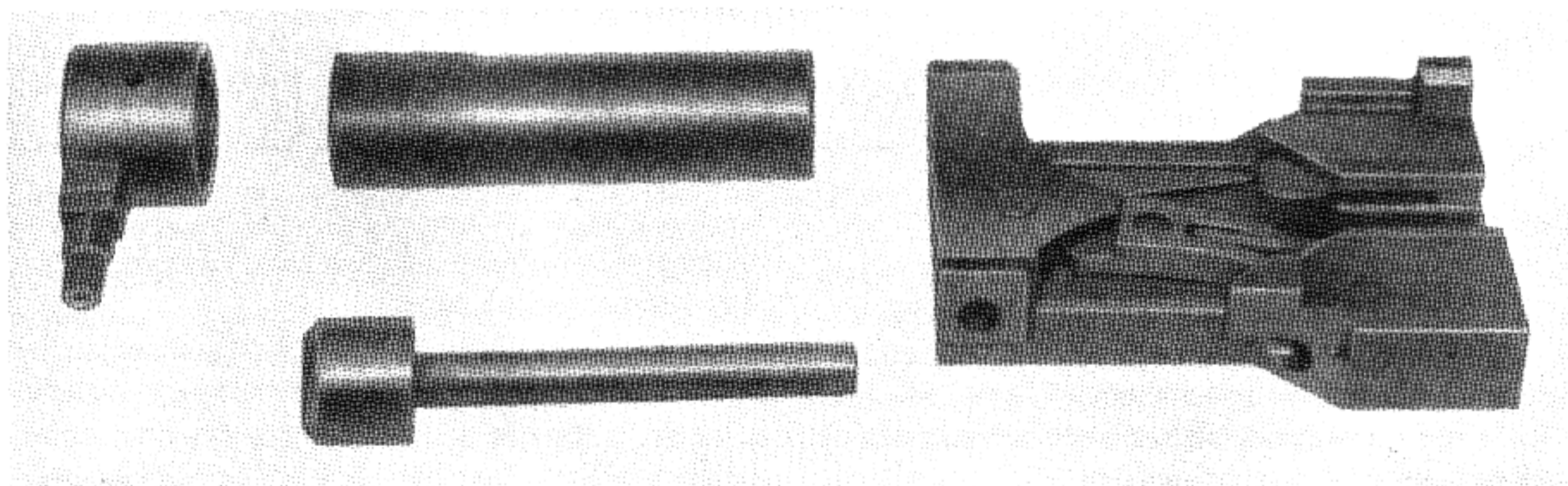


Figure 2-7. Drum revolving mechanism and charging piston of the German MG-213.

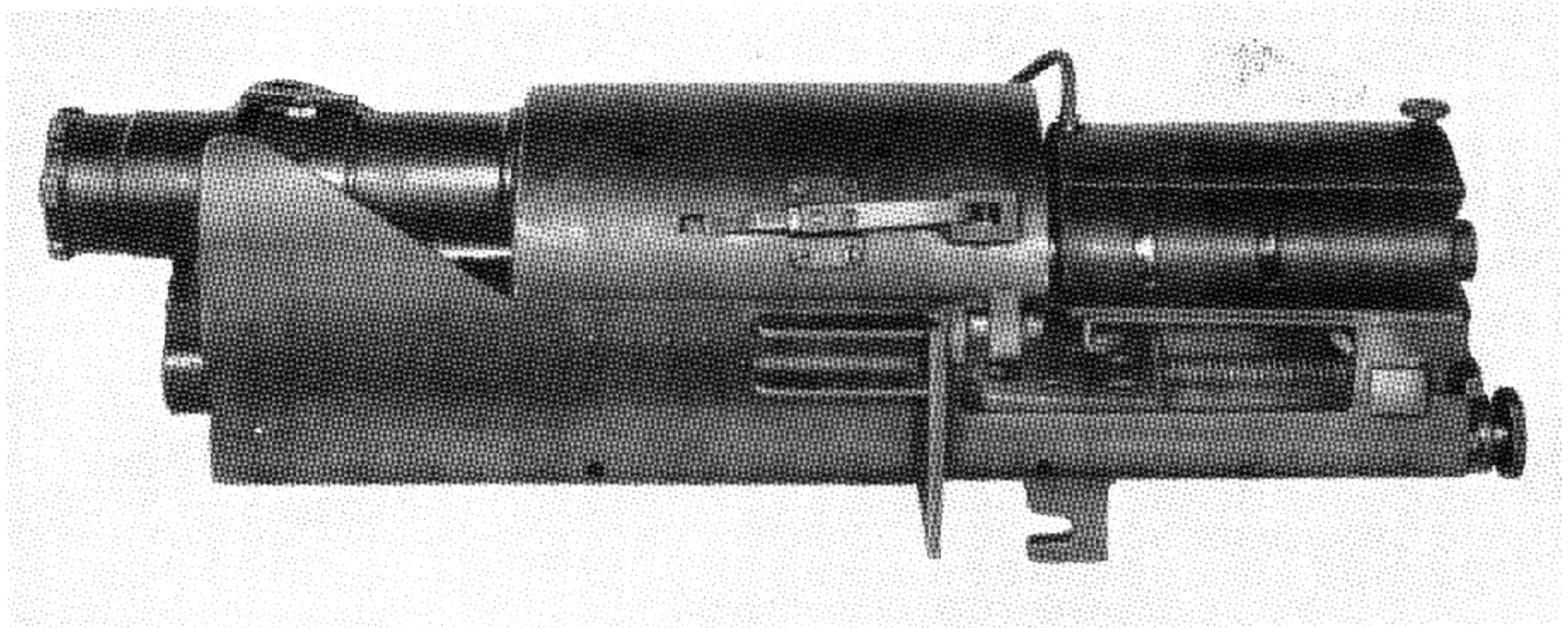


Figure 2-8. Receiver assembly of the German MG-213.

when it reaches the 12 o'clock position during drum rotation. The barrel is housed in a tube support attached to the front end of the drum support and is retained by interrupted screw threads and a key lock. When assembled, the receiver, the barrel, and the front end of the tube support extend through and are supported by a sleeve at the front end of the receiver. The rear end of the drum support is supported by two pins extending from each side of the receiver through holes in the drum support. The barrel, drum, drum support, and other parts attached to the drum support constitute the recoiling parts of the weapon and are guided in recoil by the tube support within the sleeve at the front end of the receiver and by two pins extending from the receiver through each side of the drum support.

Recoil and counterrecoil forces are limited by ring springs housed in the recoil cylinders at the front end of the drum support and are transmitted to the receiver by piston rods which are attached to the front end of the receiver.

The drum is held in alignment with the barrel during firing and indexed to bring the next chamber in alignment with the barrel by means of the five rollers on the periphery of the drum, which engage a cam track on an actuating slide in the bottom of the receiver. The actuating slide is moved rearward by a piston which receives its energy from powder gases bled from the barrel into a cylinder which is attached to the front end of the drum support. The slide is returned to its forward, or in-battery, position by two springs in the rear of the

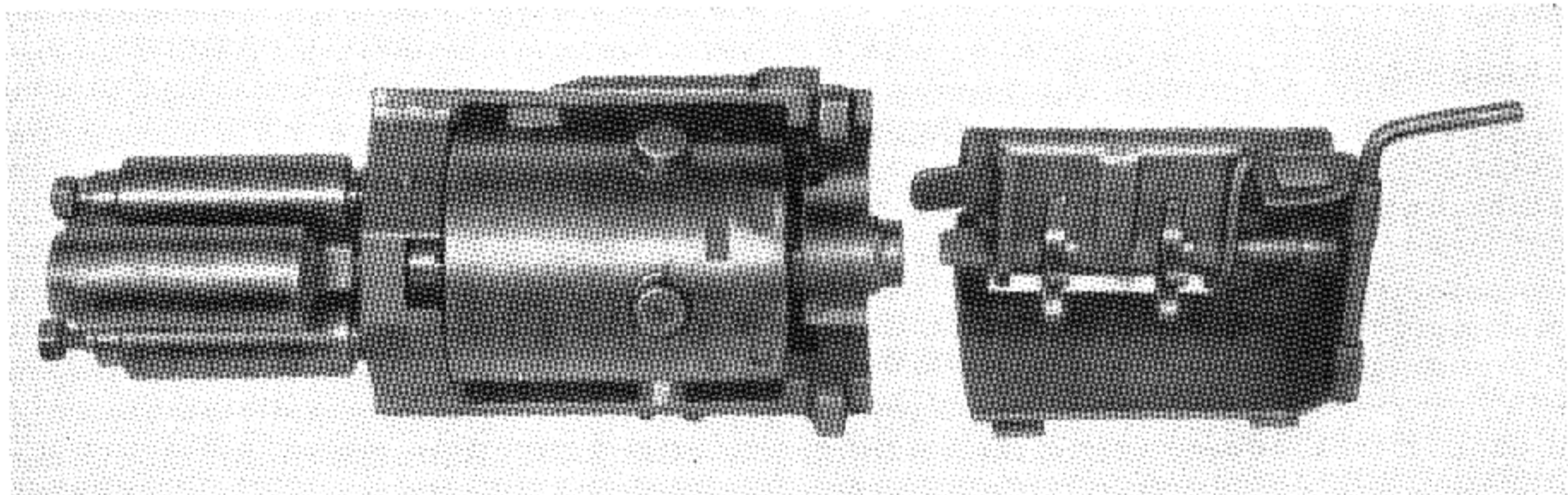


Figure 2-9. Parts of the German MG-213. Drum, drum housing, feed guide, and feed wheels.

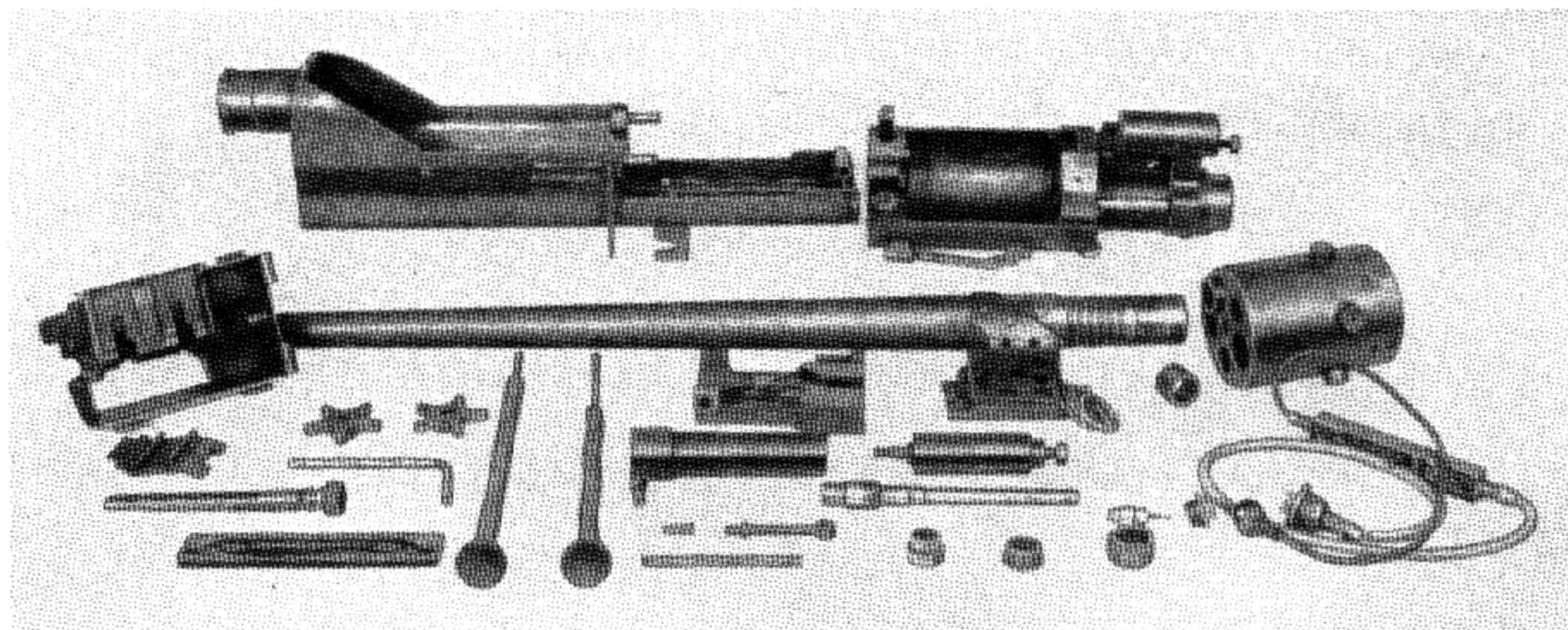


Figure 2-10. German MG-213. Disassembled view.

slide. The slide has a switch tongue which pivots about a pin through its forward end to change the cam path. The switch tongue is moved from one side to the other during slide travel by a pin extending through the slide and engaging a stationary cam in the bottom of the receiver.

*Parts.* The parts listed here constitute the components of the MG-213 automatic gun: drum support; drum; drum guide roller; drum actuating slide; switch tongue; rammer; slide drive springs; charger; gas cylinder; recoil spring housing; recoil spring housing sleeve; feeder; cartridge retaining detent; scaling sleeve; extractor; receiver; extractor actuator; switch tongue actuating cam; extractor linkages; ratchet notch (right-hand feed); ratchet notch (left-hand feed); firing pin; ejection gas orifice; drum counterrotation plunger hole; guide pins.

## Operation of the MG-213

*Preparation for Firing.* Remove the drive springs and pull the slide back to its rear position. Fit the feeder shaft tool into the back end of the feeder shaft and, while holding up the drum shaft latch, pull the shaft rearward until the shaft is disengaged from the drum at the dog-face clutch.

Feed the ammunition belt with the first link empty into the feeder, engaging the link with the sprockets in the guide track. Rotate the feeder shaft with the feeder shaft tool until the empty link is in the first rammed position. Push the feeder shaft forward

engaging the dog-faced clutch. Be sure the drum is engaged.

Push the slide into battery position and replace the drive springs. Charge the gun three times using the percussion charger to bring the first round into firing position.

*Cycle of Operation.* When the gun is ready to fire, the slide is in its forward position, the switch tongue is on the left side, and a drum roller is engaged by the straight portion of the cam path at the rear end of the slide, which maintains alignment of the chamber with the bore.

When the round is fired, the slide is driven rearward by the gas piston, and the drum roller, in following the cam path to the right, causes the drum to rotate in a counterclockwise direction. As the active roller emerges from the right side of the cam, the next roller enters the cam track on the left side, and at the same time the switch tongue is cammed to the right to permit the roller to move into the straight portion of the cam as the slide returns to its forward position under pressure of the drive springs. This brings the next chamber in alignment with the barrel. When the roller passes the rear end of the switch tongue, the switch tongue is cammed to its left position again.

Ramming is accomplished in two stages by means of a rammer, which is attached to the rear of the actuating slide. A five-pronged feeder sprocket in the feeder, located to the rear and in alignment with the drum, is driven by the drum through a shaft ex-

tension and maintains the rounds in alinement with the chambers in the drum, as the linked ammunition is pulled into the feeder from the right side of the gun.

As the slide moves forward, the rearward ramming face of the rammer engages the base of the cartridge, pushes it part of the way through the link into the third chamber counterclockwise from the round which has just fired. At the same time, the forward ramming face of the rammer contacts the base of the cartridge which was partially rammed on the previous cycle and completes chambering it in the fourth chamber counterclockwise from the one which has just fired. Also, at the same time, the round in the fifth chamber, counterclockwise from the round which has just fired, moves into alinement with the barrel and the round which has just fired moves into engagement with the extractor.

The rear end of the drum support serves as an anvil for the round during firing and houses the firing pin assembly. When an empty case is in engagement with the extractor and a completely chambered round is in engagement with the detent retainer, the round is kept from moving rearward until the drum moves it in front of the anvil.

The extractor is actuated through the mechanical linkage which is engaged by the spring-loaded ex-

tractor actuator. The extractor actuator is struck by the slide on its forward stroke immediately after the drum ceases rotating, and the empty case is engaged by the extractor.

Ejection is accomplished by propellant gases from the next round, which are bled from the barrel and directed into the mouth of the empty case through the front end of the chamber by the gas orifice. (The orifice on the opposite side is used when the weapon is assembled for right-hand feed.) Firing occurs when the slide reaches its in-battery position and closes the electrical firing circuit.

Obturation between the forward end of the chamber and the end of the barrel is accomplished by means of sealing sleeves which are held against the face of the barrel by the pressure of the propellant gases acting on the rear end of the sleeve.

There are two sets of five notches located around the periphery of the drum. One set is used for right-hand feed, the other set for left-hand feed. The notches are engaged by a spring-loaded plunger in a hole, which prevents counterrotation of the drum during the firing cycle.

The weapon is charged by a pneumatic piston and cylinder which is actuated by gas from an external source. The piston charges the weapon by forcing the actuator slide to the rear.

## SECTION 2. ARF PHASE 1: 20-MM MG-213 (MAUSER)

### Examination, Analysis, and Study

*Metallurgical Study.* Spectroscopic and wet chemical analyses were made to determine the type of steel used in the various parts of the weapon. Steel used in different parts of the 20-mm version corresponded approximately to United States specifications as follows:

Cartridge drum: SAE 1045.

Cartridge drum roller: SAE 1020, carburized.

Barrel: SAE 1350.

Belleville spring: Silicon manganese 0.90 percent carbon.

Switch tongue cam: SAE 1020.

Driving spring: SAE 1090.

Switch tongue: SAE 1045.

Other parts: Plain carbon steel.

*Hardness Examination.* Since the weapon had been damaged by fire, various parts were tested for hardness to determine the degree of softening of

hardened parts. The following values were obtained:

Belleville springs: 30 Rc to 34 Rc.

Gas cylinder piston: 32 Rc.

All other parts (including barrel and cartridge drum for 20-mm gun)

*Soft:* 85 Rb to 105 Rb.

Links for 20-mm ammunition: 47 Rc.

*Thermodynamic Investigation.* Because of the reported high cyclic rate of this weapon, 1,200 rounds per minute, it was believed that the temperature rise in the barrel and cartridge drum might be a very serious one. A theoretical study of the temperature distribution in the drum and barrel, therefore, was made to determine the number of rounds that could be fired before reaching the propellant "cook-off" temperature in the cartridge drum. The calculations were based on two main assumptions.

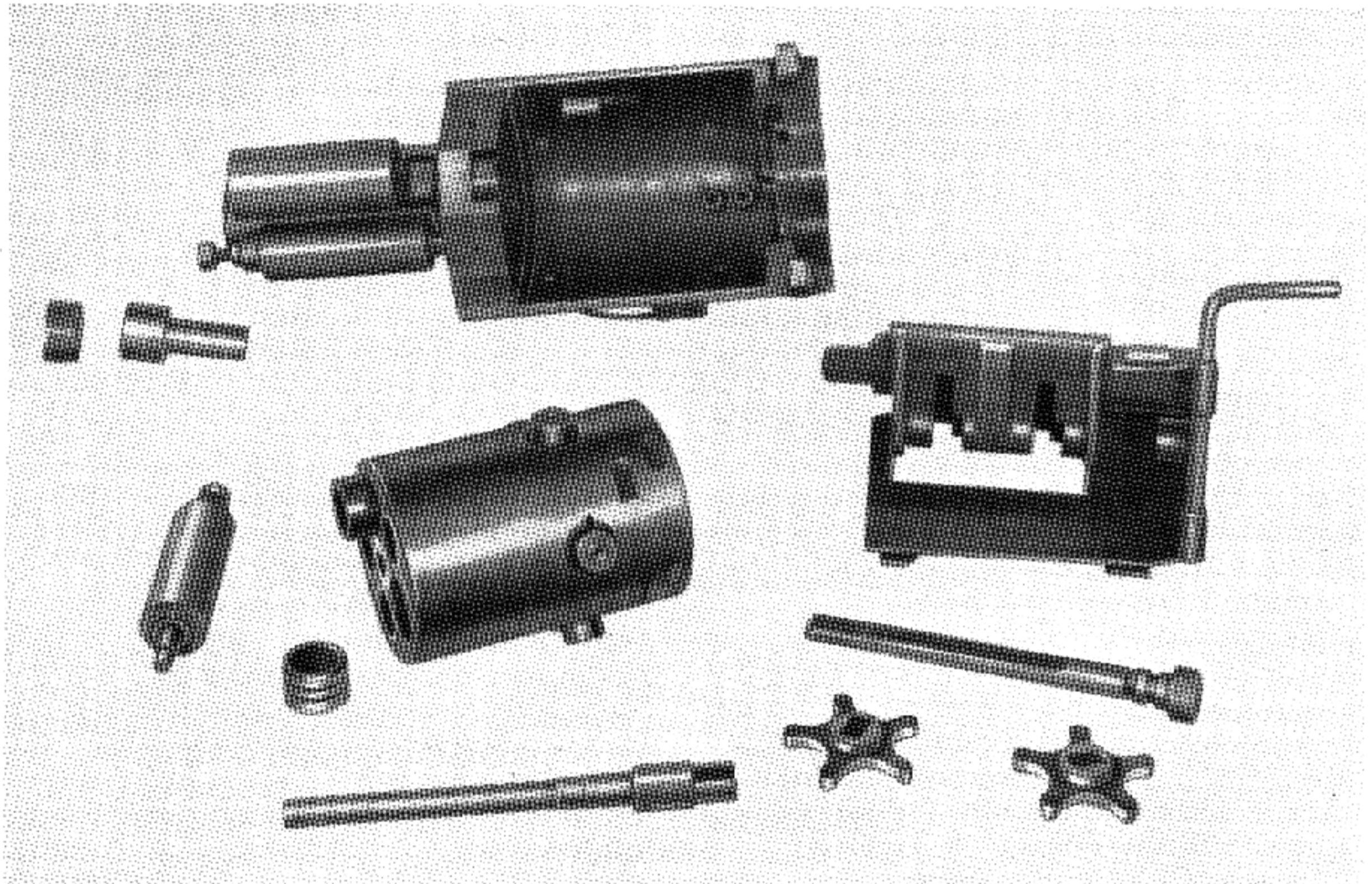


Figure 2-11. Drum and feed mechanism of the German MG-213. Disassembled view.

1. That 25 percent of the heat generated is given off to the gun (according to Cranz's Interior Ballistics), and that the total heat given to the gun is uniformly distributed along the length of the barrel and the chamber.

2. That the physical properties of the gun material remain constant.

The analysis was made by two methods, the "approximate method" and the "cylindrical heat source method". On the basis of the assumptions made, it was concluded that after 200 rounds the temperature rise of the drum would not reach the "cook-off" temperature of the cartridge, and that the average temperature rise of the barrel would be less than 500° C., at which temperature the barrel would still have sufficiently high tensile strength.

*Reconditioning of Weapon.* Before the weapon could be fired, it was necessary to:

1. Replace all springs which were damaged by fire.
2. Replace or repair worn or damaged parts.

3. Straighten the barrel.

4. Restore the hardness to parts softened by heat of the fire.

5. Manufacture cartridge drum gas cylinder seals.

6. Manufacture 50 cartridge links.

7. Modify the feed mechanism for use with the new links.

8. Build an electrical ignition circuit.

*Initial Firing Tests and Modification.* During the period 24 September through 26 October 1946, five firing tests were conducted. Numerous minor changes in firing circuit and gun components had to be made before a short burst could be fired without major malfunctions. The rate of fire was determined to be approximately 1,000 rounds per minute. Results of these preliminary tests showed that:

1. The ratchet arrangement for preventing rotation of the drum in the wrong direction could be removed without affecting the functioning of the weapon.

2. The cam plate for operating the cam switch tongue could be replaced with a leaf spring and a short cam.

3. The slide drive springs were overstressed.

4. Interference between the ejected cases and the

feeder sprockets would require close timing and rapid ejection of cases.

5. The links would require redesigning to attain sufficient strength to prevent spreading in order to avoid jamming from interference with the rammer.

### SECTION 3. ARF PHASE 2: GUN, AUTOMATIC, 20-MM T74 MODEL A

#### Modification and Rebuilding of Mauser MG-213

It was decided to rebuild the German weapon, to replace badly worn or damaged parts, and to incorporate design changes found desirable as a result of the preliminary firing tests, in order that more extensive firing tests and engineering studies could be conducted. After the following design changes and part replacements were made, the weapon was designated 20-mm Automatic Gun T74 Model A.

1. A new barrel, duplicating as closely as possible the German barrel, was made. It followed the exact rifling twist as measured in the German barrel.

2. The receiver was modified to provide greater rigidity.

3. A new tube socket, which is integral with the drum support, was made longer than the original, and the bearing for the tube socket was modified to receive it. This was done to eliminate looseness and to provide support for approximately one-fourth of the barrel length.

4. The rear drum support guide pins and bearings were badly worn and were replaced.

5. The drum shaft was badly worn and was replaced with a new one.

6. The drum support was bent beyond machining limits. The piece was straightened and reinforced.

7. The ratchet arrangement on the drum was eliminated.

8. The guideways with the actuating slide were replaced to provide closer fit and more accurate alignment of the drum chambers with the barrel.

9. Six-inch-longer driving springs were made to eliminate permanent set which occurred on the shorter springs, and the spring sockets were extended to provide for the extra length of spring.

10. A new firing-pin assembly was made to replace worn parts.

11. New rollers and pins were made for the drum to replace badly worn parts.

12. A new gas cylinder and a new piston were made. This was necessary because of the muzzle modifications. A gas exhaust port was incorporated in the cylinder, and the piston rings on the piston were replaced with grooves. Gas leaving the exhaust port was expected to produce a scavenging action and result in less fouling of the piston. Omission of piston rings was expected to result in less possibility of the piston jamming from powder gas fouling.

13. A new feeder and link were designed to transmit the belt pull through the center of gravity of the round. The feeder was designed also to deflect the ejected cases sideways, thus permitting a decrease in the effective overall length of the gun.

#### Tests and Modifications

The weapon was subjected to limited proof firing tests, then shipped to Springfield Armory on 26 June 1947 for testing to obtain performance data. A variable port opening in the gas cylinder was installed, and single-shot tests were performed with openings varying from 0.082 to 0.187 inch diameter to determine the relation between gas port opening and cyclic rate. Time displacement records were obtained and cyclic rates were determined from the time of individual cycles. These tests showed no significant change in cyclic rate as a result of changing the size of the gas port opening.

The time displacement record also showed that the slide was recoiling from 4.6 to 5.2 inches instead of the normal 5.6 inches. The short slide travel, the irregular time-displacement curve, and the badly battered counterrecoil surface of the cam, caused by roller impact, indicated that the drum rollers were leaving the cam surface during the recoil travel of the slide, instead of smoothly following the cam contour. This condition was probably the reason for the small effect of the gas orifice size upon cyclic rate.

The cam then was modified to reduce the steepness of the cam curves. This resulted in smoother action, normal slide travel, and increased cyclic rates.

Tests were then conducted with the feeder and new experimental links, manufacture of which had just been completed. The initial test resulted in only 3 inches of slide travel and jamming of the mechanism caused by interference between the rammer and the third link. Inspection of the links revealed that they did not conform to the drawings. The links were modified to eliminate interference,

and damaged slide and feeder were then repaired.

High-speed motion pictures of ejection during bursts of two rounds, hand loaded, showed that ejected cases were striking the feeder sprocket. The gas port of the ejection chamber, therefore, was increased from one-thirty-second to one-sixteenth inch diameter to obtain faster ejection.

Subsequent tests and high-speed motion pictures showed that the ejected cases were clearing the sprocket but were missing the deflector lug by approximately one-half inch. However, to prevent

Comparative Data: Several 20-mm Automatic Guns

Characteristic	MG-213	T74, Model A	T74, Model B	T110
Weight.....pounds..	180	200	225	130
Overall length.....inches..	75.1	.....	74 <sup>5</sup> / <sub>32</sub>	52
Overall width.....do.....	8.75	.....	9 <sup>3</sup> / <sub>32</sub>	8 <sup>1</sup> / <sub>8</sub>
Overall height.....do.....	9.65	.....	9 <sup>1</sup> / <sub>32</sub>	7 <sup>3</sup> / <sub>4</sub>
Approximate rate of fire.....rounds/minute..	1,200	1,200	1,200	1,200
Approximate muzzle velocity.....feet/second..	3,280	3,280	3,120	2,950
Charger.....	(1)	(2)	(2)	(2)
Extraction and ejection.....	(3)	(3)	(4)	(4)
Length of barrel.....inches..	54 <sup>7</sup> / <sub>8</sub>	54 <sup>7</sup> / <sub>8</sub>	54 <sup>7</sup> / <sub>8</sub>	33
Distance from muzzle to face of chamber.....do.....	62 <sup>3</sup> / <sub>8</sub>	62 <sup>3</sup> / <sub>8</sub>	62 <sup>3</sup> / <sub>8</sub>	40 <sup>19</sup> / <sub>32</sub>
Bore:				
Number of grooves.....	8	8	8	9
Width of lands.....inches..	0.097	0.097	0.097	0.068
Depth of grooves.....do.....	0.011	0.011	0.011	0.015
Diameter across grooves.....do.....	0.809	0.809	0.809	0.817
Diameter across lands.....do.....	0.787	0.787	0.787	0.787
Twist.....	(5)	(5)	(5)	(5)
Length of recoil.....inches..	<sup>1</sup> / <sub>4</sub> - <sup>1</sup> / <sub>2</sub>	<sup>1</sup> / <sub>4</sub> - <sup>1</sup> / <sub>2</sub>	<sup>1</sup> / <sub>4</sub> - <sup>1</sup> / <sub>2</sub>	<sup>3</sup> / <sub>8</sub>
System of operation.....		Gas (revolver principle)		
System of locking.....		Stationary breech		
System of feeding.....		Metal disintegrating belt		
Method of headspace.....		Factory established; cannot be adjusted		
Location of feed opening.....		Lower left side		
Location of ejection opening.....		Upper right side		
Method of cooling.....	(6)	(6)	(6)	(6)
Barrel weight (approximate).....pounds..	42	42	42	27 <sup>1</sup> / <sub>2</sub>
Rate control.....		Can be controlled by rheostat		
Barrel removal.....		Not considered quick disconnect		
Pitch.....		1 turn in 40 inches increasing to 1 turn in 30 inches		

- 1 Electropneumatic.
- 2 Manual.
- 3 Mechanical and gas.
- 4 Mechanical.
- 5 Progressive.
- 6 Air.

further possible damage to the gun, a hole was cut in the rear plate to permit the ejected cases to travel straight to the rear, as in the original weapon, instead of being deflected to the side.

Cyclic rates in excess of 1,200 rounds per minute were obtained. However, these rates were based upon time of cycle for individual rounds and were obtained without any ammunition belt load and without satisfactory ejection of empty cases. On the basis of the results of these tests, it was decided

that the following design changes should be incorporated in the model B weapon.

1. A mathematically calculated cam path in the drum actuating slide.
2. An extractor mechanically operated from the counterrecoil travel of the slide.
3. A firing pin with ball contact to prevent jamming or short circuiting.
4. A sliding contact, electric ignition switch for greater dependability.
5. A guide in the feeder for the extracted cases.

### SECTION 4. ARF PHASE 3: GUN, AUTOMATIC, 20-MM T74 MODEL B

#### Design and Description

The model B weapon was the first model completely designed and manufactured by Springfield Armory with designs furnished by Armour Research Foundation. This model utilized the basic principles of the previous models and followed the same general arrangement of components. However, it incorporated numerous design changes based upon the experience gained from the previous models and upon analysis made by using the performance data from the model A weapon.

Following is a list of the major design features in which the model B weapon differs from the original German weapon.

1. Means of replacing the 20-mm tube with a 30-mm tube were eliminated. The gas port in the barrel was located at the position of the port for the 30-mm tube in the original weapon.
2. The drum support was designed to minimize bending due to non-uniform distribution of mass.
3. The receiver was designed for greater rigidity. The rear end was made removable to permit easier

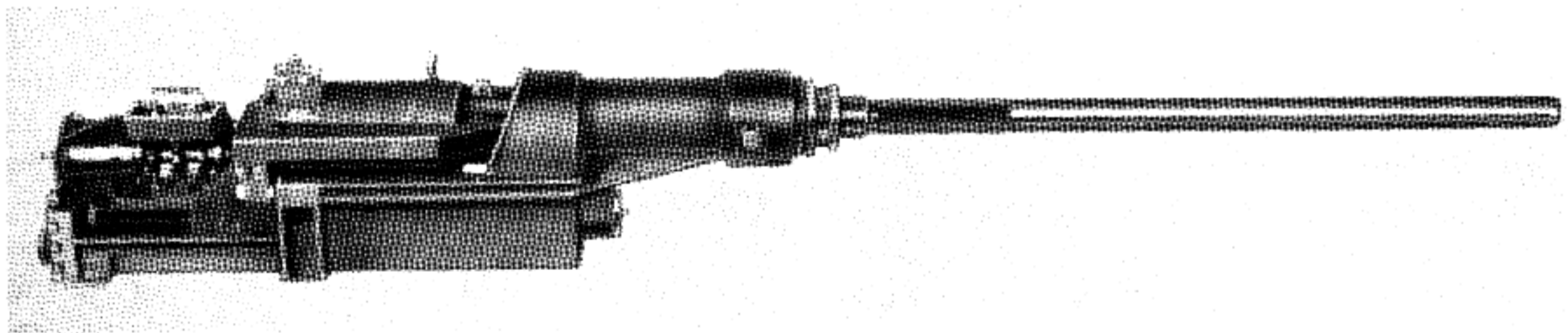


Figure 2-12. United States Ordnance Corps 20-mm. Automatic Gun, T74, Model B.

#### Comparative Data: MG-213 and 3 Designs of the 20-mm T110

Characteristic	MG-213	20-mm T110		
		Design No. 1	Design No. 2	Design No. 3
Weight.....pounds..	180	150	160	170
Length.....inches..	75	54	54	54
Height.....do....	9 <sup>5</sup> / <sub>8</sub>	7 <sup>3</sup> / <sub>4</sub>	7 <sup>1</sup> / <sub>8</sub>	8
Width.....do....	8 <sup>3</sup> / <sub>4</sub>	8 <sup>1</sup> / <sub>2</sub>	10 <sup>1</sup> / <sub>8</sub>	8 <sup>3</sup> / <sub>4</sub>



removal of the slide and rammer. The tube support was extended forward to support the tube for approximately one third of its length. Conventional trunnions were incorporated in the tube support section in the plane of the bore centerline.

4. To provide more accurate alignment, greater strength, and easier assembly, the drive coupling between the drum and feeder shafts was changed from tongue-and-groove to spline construction.

5. The rings on the slide actuating piston were replaced with grooves. An exhaust port was incorporated in the gas cylinder, and the gas orifice was made replaceable to permit testing with orifices of various diameters. The gas cylinder, instead of being made integral with the drum support, was made removable and was mounted in the receiver where it was more accessible for possible use with a percussion charger.

6. The bearing area of the slide guideways was increased to reduce wear.

7. The slide drive springs were relocated to positions along the outer edges of the slide to permit the springs to bear against lugs at the front end of the slide instead of against the rear. This permitted the length of the springs to be increased by an amount approximately equal to the length of the slide without increasing the overall length of the weapon.

8. The connection between the slide and rammer was made adjustable for determining the optimum head space.

9. A ball-type firing contact was used in place of the conventional pin type in order to avoid shorting out the primer by scraping metal across the base of the case.

10. The gas-ejection system was eliminated, and a new mechanical extractor was designed to operate on the forward motion of the slide. The original system utilizing gas ejection with a mechanical extractor was not reliable.

11. The sliding contact firing switch was made adjustable for determining the optimum firing position.

12. The recoil and counterrecoil system, consisting of two sets of Belleville springs mounted below the bore centerline, was changed to a system consisting of ring springs mounted concentrically with the barrel in order to obtain a more balanced system.

13. The pneumatic charger incorporated in the original weapon was eliminated. However, space was provided for a charger to be incorporated later.

14. The drum roller cam path in the operating slide was redesigned in accordance with a mathematical analysis of the forces and motions involved. The design provided a closed cam path which eliminated the necessity for the ratchet arrangement for preventing rotation of the drum in the wrong direction.

15. Ammunition links and feeder were redesigned to give more reliable performance.

## Analytical Studies

*Recoil Calculations.* Recoil calculations were made to determine the trunnion reaction, recoil travel and recoil time for various values of recoil spring rate. These calculations were based on the following data:

Weight of projectile: 0.3 pound.

Weight of powder: 900 grains equal 0.1283 pound.

Weight of recoiling parts: 105 pounds (estimated).

Muzzle velocity: 3,090 feet/second.

Gas pressure at the muzzle: 16,000 p. s. i.

Length of barrel: 41 $\frac{1}{4}$  inches.

Area of bore: 0.502 square inch.

At the time these calculations were made, it was intended to limit the length of the weapon to 52 inches and to design ammunition with the same ballistic characteristics as the German ammunition. The calculations, therefore, were based on the use of a short barrel (41 $\frac{1}{4}$  inches) and the ballistics of the German ammunition. Later it was decided that manufacture of a short barrel would delay the program too much, and the weapon was designed for use with a long barrel (54 $\frac{7}{8}$  inches) already available from the previous model. The weight of the projectile used was in error and should have been 1,800 grains, or 0.257 pound.

*Determination of Cam Profile and Forces Acting on the Cam.* As a result of calculations, it was concluded that an elliptical cam path should be used in designing the cam for indexing the cartridge drum. A method was used for calculating the forces acting on the cam in moving a variable drum mass in which the effect of friction and of the slide drive spring was neglected. An intensive program was

initiated to alleviate difficulties that had been encountered in the past from this miscalculation.

*Stress Analysis of Cartridge Drum.* In designing the model B weapon, difficulties were encountered when an attempt was made to analyze the stresses in the cartridge drum. Since this component was a heavy-walled shape of nonuniform thickness, it was not susceptible to good mathematical analysis. The problem, therefore, was approached experimentally, and the brittle-material method was selected as the one offering the most practical approach, although some development of technique was necessary before quantitative results were obtainable.

A replica of the drum was made from Aridized No. 1 pottery plaster and tested under internal air pressure, simulating statistically the effect of firing a cartridge in one of the chambers. The specimen broke when the initial pressure was 125 p. s. i. The ultimate strength of the material measured in simply loading beams of the same plaster was 426 p. s. i. If all the material properties were as assumed (the stress-strain relationship is linear to failure, and failure is a function of maximum tensile stress only), this would mean that when the internal pressure in the drum chamber is 10,000 p. s. i., the maximum stress is  $426 (1,000)/125$ , or 3,408 p. s. i.

*Gas Resistance to Slide Motion During Return of Slide to Battery Position.* One of the factors which conceivably retards the slide during its return to battery position is the gas resistance encountered as the slide pushes the gas piston ahead of it. During this motion, the gas-air mixture retained in the cylinder is compressed in the space forward of the piston and flows back into the barrel through the orifice. The built-up pressure, which retards the piston motion, depends upon (1) the residual pressure remaining in the cylinder from the previous rearward movement of the slide, and (2) the escape of gas through the orifice while the piston returns to battery. Calculations were made to evaluate these effects.

1. The residual pressure remaining in the gas cylinder at the time the slide, during its return to battery position, contacts the piston rod, is expected to be very close to atmospheric, so that no slowing down of the slide may be expected because of it.

2. The pressure rise in the gas cylinder during return of slide and piston to battery position is negligible. The pressure is not expected to increase to more than 3 p. s. i. above atmospheric pressure, and the corresponding force on the piston is not sufficient to cause appreciable deceleration.

*Investigation of Gas-Piston Bounce.* One of the causes for deceleration of the actuator slide during its return to battery is the impact and subsequent bouncing between the slide and the gas piston rod. This bounce had been observed on high-speed movie films on which slide motion and piston motion were recorded simultaneously. A mathematical and experimental investigation of this condition was made at ARF to correct this. The following conclusions were reached:

1. During its return to battery position, the actuator slide is decelerated as a result of impact with the gas piston.

2. Depending on whether the process takes place inelastically or elastically, the reduction in slide velocity may be slight (8 percent of the velocity before impact) or so great that, as a result of repeated impacts, the slide never reaches battery position.

Test results confirmed the existence of at least one bounce. However, further experimentation would be required before final conclusions concerning the details of these impact phenomena could be drawn. Since there was no evidence that gas piston bounce had appreciable effect on cyclic rate, continuation of the investigation was not considered to be warranted.

## Tests and Modifications

During the firing test of the weapon, a number of parts failed or deformed, and numerous difficulties (concerning the functions of extraction, feeding, ramming, and ignition) occurred. These problems were solved, or partially solved, as follows:

*Firing Pin.* The firing pin broke on the initial firing test where the smaller diameter anvil portion joins the larger diameter base portion. By chamfering the bore in the drum support and adding radius at the point of stress concentration in the firing pin anvil, this difficulty was eliminated.

*Gas Piston.* One failure occurred where the rod joins the piston. This was attributed to severe load imposed when the slide jammed because the

switch tongue pin dropped out of place. No modification was made and no subsequent failure occurred.

*Actuating Slide Switch Tongue.* The switch tongue cam surfaces were being deformed continually by impact of the drum rollers, and on one occasion the switch tongue broke. Also, the switch tongue cam-follower pin frequently failed. To reduce breakage of the switch tongue cam-follower pin, the solid steel cam in the receiver for switching the tongue at the end of the slide recoil was spring-loaded in the direction of slide travel. Breakages still occurred, so the spring-loaded cam was replaced with a leaf-spring cam. This greatly reduced the impact forces between the drum rollers and the switch tongue, but did not eliminate breakage of the switch tongue pin.

It was then concluded that breakage of the switch tongue pin was caused also by impact of the pin against the forward solid steel cam which returns the tongue on forward travel of the slide. The forward cam then was replaced with a leaf-spring cam, but the spring leaves could not withstand the impact loads, and they failed. A cam made of Micarta also failed. A steel cam was used for the remainder of the tests.

The switch tongue frequently dropped out of position because of failure of its snap ring retainer. This failure caused the mechanism to jam and the pin to break. This was a design weakness which was overcome in a later model.

*Recoil Springs.* During one firing test, the recoiling parts failed to return to battery because several elements of the recoil ring springs seized in the compressed position and did not disengage. Lubrication of the mating surfaces of the springs with Dixon XP190 graphite grease and packing with Dixon XP271 graphite grease, as recommended by the ring spring manufacturer, eliminated this difficulty.

*Drum Roller Studs.* Two failures of drum roller studs occurred due to stress concentration at the two diameters. New studs with a larger radius in the corner were made and installed, and no further difficulty with this part was experienced.

*Actuating Slide, Extractor Lug.* This lug sheared off once. It was decided, however, that

the extractor set back against the return spring on recoil and permitted the extractor lever to rotate into such a position as to permit the lug on the slide to jam against it on its rearward travel. This trouble was eliminated by increasing the preload on the extractor return spring.

*Ejection Difficulties.* An empty case, upon extraction, is thrown rearward into the feeder ejection chute where the base of the case strikes an inclined surface which deflects it to the side. If the case does not clear the chute before the next round is fired, the feeder sprockets rotate with the drum and engage the extracted case. The case is mashed or cut through, and the mechanism becomes jammed. This calls for a very fast acting ejector and a feeder ejection throat which offers a minimum of interference.

The energy for ejection is obtained from the kinetic energy of the slide on its counterrecoil stroke and from the force of the slide drive springs. Since the reduction in slide velocity due to extraction reduces the cyclic rate, it is desirable to keep the energy requirements for extraction to a minimum. The energy required with the original extractor was so high that the slide frequently failed to return to battery position to fire the next round. This occurred with a 20 pound per inch extractor return spring. With a weaker spring, however, the extractor frequently failed to return in time to engage the next case and extract it. Furthermore, the spring took a permanent set of as much as one-half inch after several rounds. In conjunction with this problem, the extractor buffer springs, consisting of Belleville washers, also took a permanent set after a few rounds. High-speed motion pictures showed that the extractor was being displaced rearward about one-half inch on recoil because of its inertia.

The return spring was replaced with a stranded wire spring, 20 pounds per inch, to dampen the oscillations, and its initial load was increased to 30 pounds by adding a spacer. The extractor lever was changed to reduce the positive travel of the extractor from  $1\frac{3}{4}$  inches to  $1\frac{1}{4}$  inches, and the moving parts of the extractor were reduced in weight about 20 percent. The Belleville buffer spring was replaced with a Fabrecka buffer one inch long. Modifications improved the performance of the ex-

tractor, but jamming of the cases in the ejection chute still occurred at cyclic rates of over 1,000 rounds per minute.

Other attempts to improve ejection were made by enlarging the feeder ejection throat and by installing a deflector at the rear end of the throat to deflect the cases to the side. Various deflector angles were tested. A deflector mounted against Fabreeka also was tested. Although these modifications of the extractor and of the feeder extraction throat improved extraction performance, the problem was never completely solved on the model B weapon.

*Ramming Difficulties.* High-speed motion pictures of the Model B weapon showed that the rounds were being stripped free of the links during initial ramming. Since the round was not completely chambered until after the second ramming stroke, the round was out of control between the two ramming cycles. Attempts were made to improve this condition by increasing the "push through" resistance of the link from 50 pounds to 70 pounds by embossing detents into the forward holding fingers of the links, and by reducing the effective stroke of the first ramming cycle.

High-speed motion pictures taken during subsequent tests showed that the rounds were still being stripped completely from the links on the first ramming stroke. An attempt was then made to control the stripped round by installing a spring-loaded retainer on the drum support. High-speed motion pictures showed that this retainer functioned as expected, preventing the round from falling out of the chamber until fully chambered by the second ramming stroke.

Occasionally a round was not sufficiently chambered by the second ramming stroke to clear the face of the anvil, possibly because of an oversize case and insufficient kinetic energy of the rammer: this condition resulted in jamming of the mechanism when the drum rotated. To prevent firing under these circumstances, an electric contact was connected into the firing circuit and arranged to operate in conjunction with the cartridge detent located in the rear end of the drum support. This change made it necessary for the switch to be closed by pressure of the detent in its undepressed position behind the completely chambered round before firing could occur.

*Ignition Difficulties.* Occasionally primer insulation was blown from the base of the cartridge onto the firing pin and prevented electrical contact with the primer of the next cartridge. This occurred only when firing German ammunition. It never occurred when United States ammunition was fired.

*Cyclic Rate.* The time of the firing cycle is the sum of: primer ignition time; time for rearward motion of operating slide; and time for forward motion of operating slide.

Time-displacement records of the slide show that the forward velocity of the slide is decreased greatly after the slide contacts the extractor. Attempts were made, therefore, to reduce the kinetic energy taken from the slide by improving the mechanical operation of the extractor. As previously described, the extraction and ejection problems were not overcome to the extent that sustained bursts could be fired.

Attempts were also made to reduce the energy required for extracting the case by lubricating the ammunition. When the ammunition was lubricated with a 5-percent solution of Ceresin wax in carbon tetrachloride, there was an apparent increase in the cyclic rate of approximately 100 rounds a minute.

Various gas orifices were tested to determine the effect of orifice diameter upon cyclic rate. Time-displacement records of slide movement indicated that the size of gas orifice does have some effect upon cyclic rate. However, there were so many other variables affecting cyclic rate which were so difficult to control that the quantitative data were not considered reliable. Tests were conducted to determine the effect upon primer ignition delay of increasing the ignition voltage from 45 volts to 170 volts. No effect was apparent.

### Tests of Components for Model C Weapon

Since much of the model C weapon design had been completed while the model B weapon was undergoing tests, some of its design features were tested in the model B weapon.

The gas operating cylinder was reduced from 1½ inches in diameter to 1¼ inches in diameter in order to approximate the piston area in the model C gun. Comparison of the time-displacement rec-

ords of the slide showed no significant difference in performance and indicated that a 1 $\frac{1}{16}$  inch diameter was sufficient.

**Performance Data**

The following data were obtained during the firing tests conducted:

- Length of recoil:  $\frac{1}{4}$  to  $\frac{1}{2}$  inch.
- Cyclic rate: Over 1,200 rounds/minute.

Maximum pressure in gas cylinder:

- With  $\frac{1}{2}$ -inch orifice: 1,380 p. s. i. (average of two tests).
- With  $\frac{1}{8}$ -inch orifice: 2,440 p. s. i. (average of five tests).
- With  $\frac{3}{16}$ -inch orifice: 5,200 p. s. i. (average of eight tests).

Slide velocity during recoil: Approximately 40 feet/second.

**SECTION 5. ARF PHASE 4: GUN, AUTOMATIC, 20-MM T110**

**Design and Description**

While the 20-mm Automatic Gun T74 Model B was being manufactured, design of another model was initiated. This model was initially designated T74 Model C and later redesignated T110.

In designing this weapon, emphasis was placed upon reduction of weight and reduction of overall dimensions to meet the following limitations specified by the Ordnance Corps:

- Overall length: 52 inches.

Overall width: 8 inches.

Overall height: 8 inches.

In order to meet the maximum silhouette requirements, major changes in the arrangement of components were made, and whenever possible these changes were also made to facilitate assembly, disassembly, and servicing. Layouts of three different arrangements of components were prepared. Weight and overall dimensions for these three designs were estimated. These data have been tabulated for comparison with the original MG-213.

**Comparison of Weight and Overall Dimensions of the MG-213 and 3 Designs of the 20-mm T110**

Characteristic	MG-213	Design No. 1	Design No. 2	Design No. 3
Weight in pounds.....	180	150	160	170
Length in inches.....	75	54	54	54
Height in inches.....	9 $\frac{5}{8}$	7 $\frac{3}{4}$	7 $\frac{1}{8}$	8
Width in inches.....	8 $\frac{3}{4}$	8 $\frac{1}{2}$	10 $\frac{1}{8}$	8 $\frac{3}{4}$

All three designs incorporated the same principles of operation. However, design No. 1 was selected on the basis of weight, silhouette dimensions, number of parts, ease of assembly, and accessibility for cleaning.

A list of the major T110 design features which are different from those of the T74 model B follows.

1. The barrel was relocated with respect to the drum for firing from the chamber at the bottom position instead of from the top of the chamber, as in the German method. This arrangement reduced the overall height and brought the line of action of the recoil force closer to the center of mass. This made it necessary, however, to relocate the drum rollers

from positions between the chambers to positions opposite the chambers; this, in turn, made it necessary to make the roller studs an integral part of the drum.

2. The front bearing of the drum support was redesigned. The rifling torque and the torque produced by the force of the drum roller on the slide actuating cam was transmitted directly to the trunnion yoke instead of to the receiver. This change was accomplished by making the front end of the tube support and the mating portion of the trunnion yoke hexagonal.

3. The recoil springs were located in two nests in the drum support in a horizontal plane through the

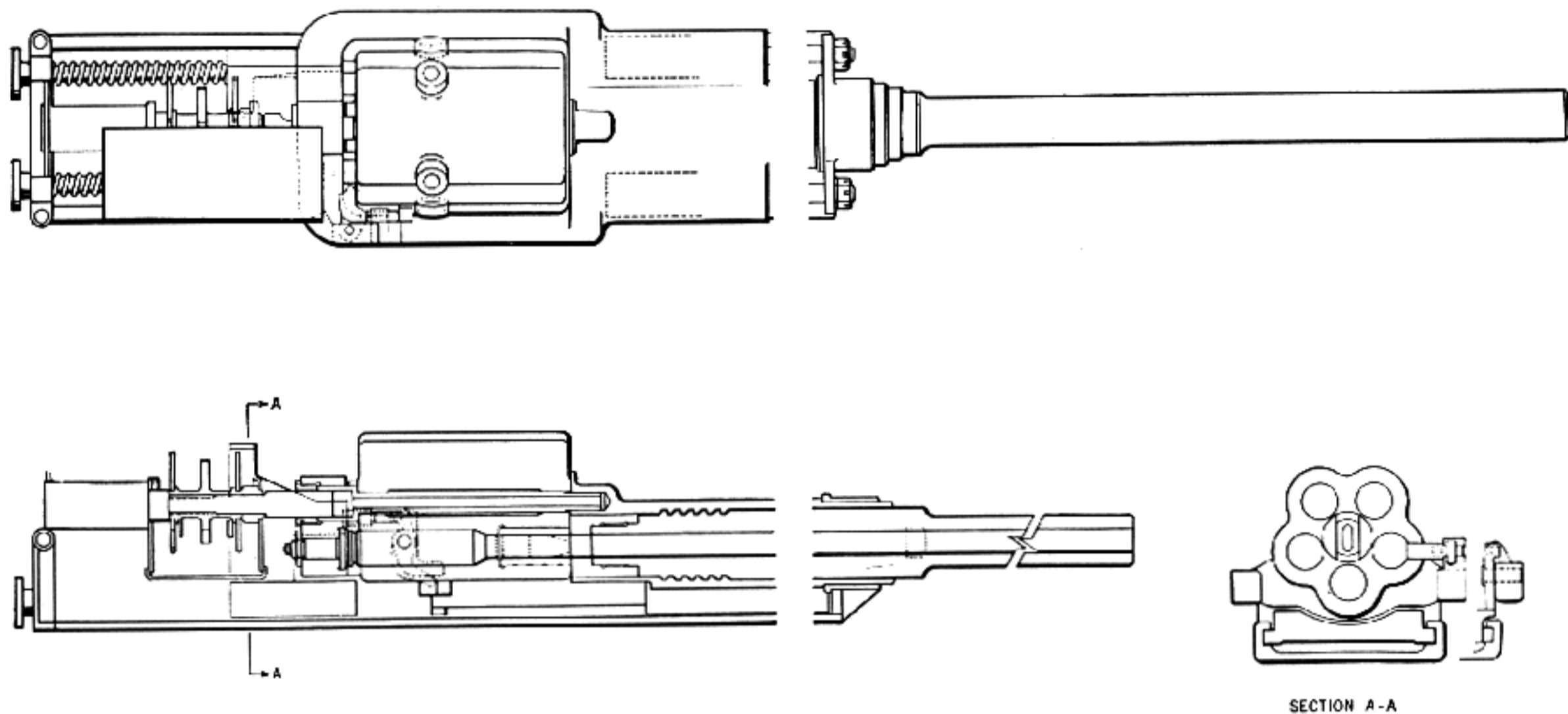


Figure 2-13. United States Ordnance Corps 20-mm Automatic Gun, T74, Model C. Assembled view.

bore centerline. This permitted connecting the recoil rods to the trunnion yoke so that the recoil force was transmitted directly to the trunnion yoke rather than to the receiver.

4. The gas cylinders were made integral with the drum support. Since the drum support is a part of the recoiling mass, the reaction of the slide against the action of the piston absorbs recoil energy and reduces the forces acting on the recoil springs.

5. The gun barrel was shortened to comply with the 52-inch overall length requirement.

6. Items 1, 2, 3, and 4 greatly reduced the strength requirements of the receiver and permitted considerable weight reduction. Additional weight reduction was realized also by the use of an aluminum alloy casting.

7. The feeder was redesigned; feeding and ejection of cases and links from the same side was changed to permit multiple installations in a minimum of space.

8. The extractor was redesigned to incorporate the features of the extractor on the British gun, aircraft, 30-mm Aden.

9. The rammer and actuator slide were made in one piece to provide greater rigidity. These adjustable parts in the model B weapon frequently became loose and caused binding in the slide guides.

**Analytical Studies**

*Determination of Cam Profile and Forces Acting on the Cam.* Forces acting between the drum roller and the cam on the slide were investigated for the following cam profiles and gas piston strokes:

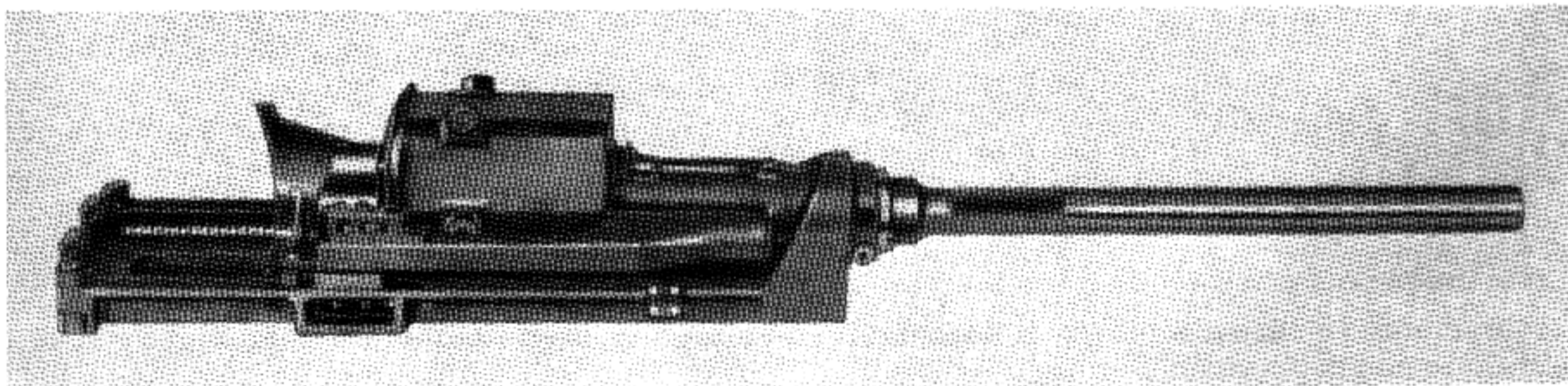


Figure 2-14. United States Ordnance Corps 20-mm Automatic Gun, T110.

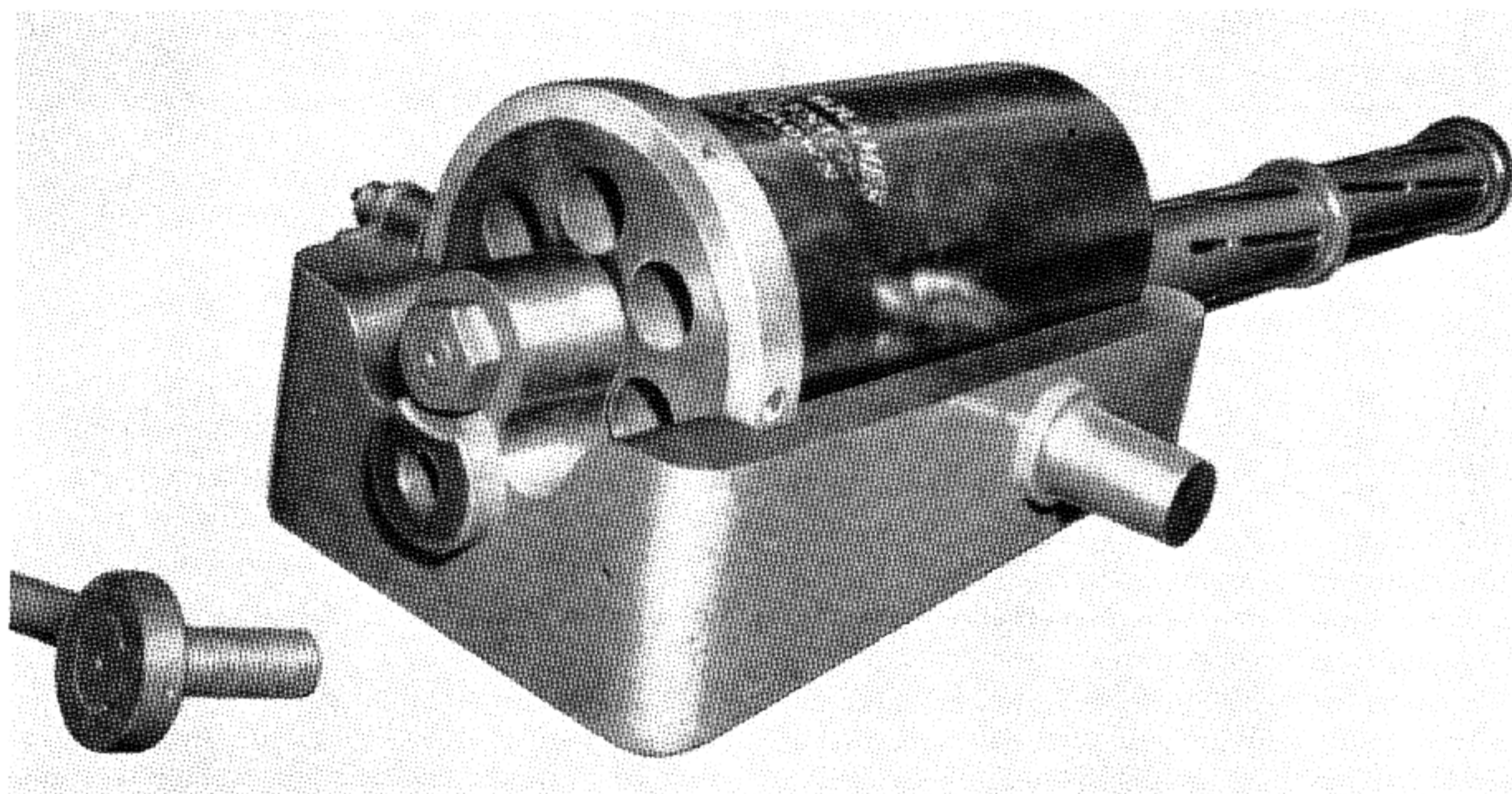


Figure 2-15. The American DeBrame Cannon of the Civil War Era. This weapon is hand operated and resembles modern, gas-operated revolver cannon.

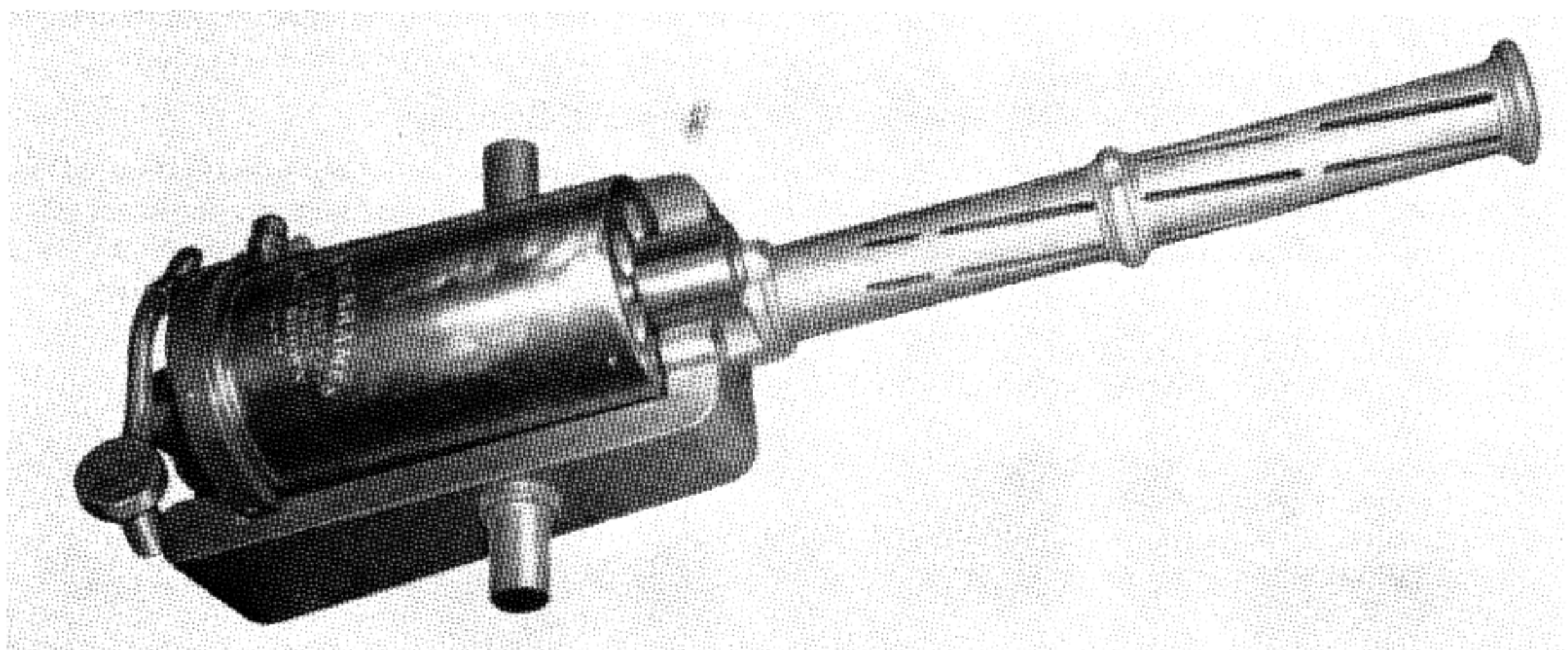


Figure 2-16. The DeBrame Gun. View from above, showing the patent date.

**CASE A: ELLIPTICAL ARC.** This profile was used in the T110. Three different periods of operation were considered for the gas piston:

Case A1. Pressure system operative for a short interval following the firing stage.

Case A2. Pressure system operative until the drum roller approaches the curved portion of the cam.

Case A3. Pressure system operative during the entire rearward travel of the slide.

**CASE B: PARABOLIC ARC.** The pressure system is considered effective during the entire rearward travel of the slide.

**CASE C: CIRCULAR ARC PLUS STRAIGHT-LINE TANGENT.** The pressure system is considered effective during the entire rearward travel of the slide.

**CASE D: TWO TANGENTIAL PARABOLIC ARCS.** This cam profile is approximately the same as that used in the German MG-213. The pressure system is considered inoperative until the drum roller approaches the curved portion of the cam.

Equations of motion of cam slide and drum were derived from the various conditions listed, neglecting friction. Solutions were presented showing the components of forces of the cam face perpendicular to the direction of slide motion. The components of the forces in the direction of slide motion were small for all cases considered.

The maximum forces acting between the drum roller and the cam face during the rearward travel of the slide are of the order of 16,000 to 17,000 pounds for the cases considered. The high value is due to cam profiles with severe discontinuity in the radius of curvature. For the elliptic cam selected for the T110 weapon, the maximum force is of the order of 7,000 pounds.

Further analytical study also indicated that for a given cyclic rate the effect of varying the interval during which the pressure-driving system is operative has little effect on the forces acting on the cam faces. Increasing the duration of the pressure stroke, however, permits the use of a smaller diameter piston.

*Analysis of Forces on the Receiver.* A study of the forces acting on the receiver indicated that the section of the receiver between the trunnion and the points of mounting (directly under the T-slots for guiding the rear end of the drum support) would be subjected to a torque of 7,500 inch-pounds or

less. In this study it was considered that the critical forces transmitted to the receiver were those resulting from drum rotation. The maximum force between the drum roller and the cam was computed to be approximately 700 pounds, and this value was used in computing the torque acting on the receiver.

*Analysis of Forces on the Drum Support.* A study of the forces acting on the drum support indicated that the drum support would be subjected to an axial tension of approximately 80,000 pounds. In this study, it was considered that the critical force acting on the drum support was the force produced by a maximum powder pressure of 65,000 p. s. i.

## Tests and Modifications

During the firing tests the following difficulties, failures, and deformation of parts were encountered.

*Firing Pin.* The anvil of the firing pin failed where the body joins the larger diameter anvil. Increasing the thickness of the anvil eliminated this difficulty.

*Slide Guideways.* The slide guideways in the aluminum receiver deformed under the force of the drum roller on the cam, causing the slide to bind in the ways. A steel plate was set into the receiver between the guideways to increase their lateral stiffness.

*Gas Pistons.* Impact of the gas piston against the end of the cylinder upset the end of the cylinder around the piston rod, causing it to seize. Replacing the chamfer around the piston rod hole with a counter bore eliminated this difficulty. The piston rods also bent and failed where they join the pistons. To reduce this weakness, the length of the piston rods was decreased by increasing the length of the cylinder.

*Rammer.* High-speed motion pictures showed that the rammer vibrated excessively during ramming. Reinforcing ribs were added to reduce this vibration.

*Receiver.* High-speed motion pictures showed that the rear end of the receiver deflected downward about the rear point of support an excessive amount at the end of the counterrecoil stroke of the drum support. Since there is no force acting directly on the rear end of the receiver which could cause such a deflection, it was attributed to the force of impact of the recoiling parts upon the trunnion yoke, which, acting below the center of mass, produces a couple



in the weapon which causes the receiver to bend upward between the trunnions and rear points of support. This deflection indicates the necessity of designing the receiver for greater rigidity. For all subsequent firings, the rear end was clamped firmly to the firing mount to prevent deflection.

*Switch Tongue.* The cam surfaces of the switch tongue upset near the pivot end from impact of the drum roller. To eliminate this condition, the slide and switch tongue were modified by shortening the length of the cam surface on the switch tongue and adding to the slide the portion of the cam surface removed from the tongue. This allowed more time for switching the tongue before the roller contacted it; the additional switching time permitted switching by the switch tongue cam and not by impact of the drum roller. Also, it was necessary to increase the hardness of the switch tongue from 40 Rc to 50 Rc to prevent deformation of the cam surface by the pressure of the drum roller.

The stop pad on the under side of the switch tongue and the surface of the slide contacted by the stop pad deformed also. This condition was eliminated by increasing the thickness of the pad from three thirty-seconds of an inch to seven thirty-seconds of an inch.

In an attempt to eliminate the various difficulties experienced with the switch tongue and switch cam in the three 20-mm models tested, a different type of slide and drum actuating cam was conceived. A wood model of this cam, called the "butterfly" cam, was made. The beveled edge on each side of the slide forms a cam surface for the drum rollers. These two surfaces, sliding between two rollers, maintain alignment of the drum with the bore during the time the rollers are in contact with the straight portions of cam.

On each side of the slide, at the curved portions of the cam track, is a movable piece, referred to as a cam wing, which pivots about a shaft running parallel to the direction of slide travel. The two wings are connected with a cross link which causes them to move together. The left wing is spring loaded in such a way as to cause it to be normally depressed while the other wing is held in alignment with the beveled cam surface of the slide proper.

As the slide moves rearward, the left cam roller clears the depressed wing and enters the curved cam path while the other roller follows the active cam

surface of the opposite wing to cause the drum to rotate in a counterclockwise direction. As the drum continues to rotate and the slide reverses direction, the roller in the cam path depresses the active wing and follows the curved cam surface on the slide. At the same time the left wing moves up into alignment with the cam surface of the slide proper just as the next roller of the drum moves into engagement with it.

As the slide returns forward to battery position, the straight portions of the cam surface moving between the two drum rollers maintain alignment of the drum chamber with the bore.

This slide arrangement appeared to have the following advantages over the switch tongue type of slide.

1. It was expected that impact of moving parts of the cam would be reduced greatly.

2. The drum rollers were mounted between chamber openings instead of directly over them. This permitted the roller studs to be attached to the drum rather than to be made an integral part of the drum and simplified drum construction.

Development of a cam of the butterfly type for the 20-mm automatic gun T110 was not undertaken during this period of the contract.

*Extractor.* The main difficulty encountered during the firing test was the same as that encountered in the previous model; that is, insufficient extraction velocity of the empty cases to clear the feeder sprocket. Various modifications of the extractor were made in an attempt to increase this velocity. The leading edge of the extractor pawl was sloped so that the drum rotated into extraction position, the pawl cammed the case out of the chamber and broke it loose before extracting. Also, the extractor was more rigidly attached to the drum support to eliminate vibration and to provide greater resistance to the forces of extraction. A new extractor lever and various pickup lugs designed to give a greater extraction velocity, by increasing the mechanical ratio, were made and tested.

These changes did have some beneficial effect but did not improve the extraction velocity sufficiently to insure that the cases would always clear the feeder sprockets. The changes resulted also in a decrease in cyclic rate, because more energy was taken from the slide by extraction, thus decreasing the average velocity of the slide after extraction

began. Other methods of extraction and ejection, therefore, were investigated.

Schematic drawings were made that showed an extractor which utilizes an air spring restoring energy taken from the propellant gases. Release of the air spring sear by forward motion of the slide permitted the piston to move rearward under the action of the air spring and actuate the extractor. Such a system allowed the storing of as much energy as is needed for extraction. Since it required merely that the slide trip the sear, it had no effect on cyclic rate.

ARF engineers designed an extractor which utilized hydraulic fluid to transmit kinetic energy from the slide to the extractor. This system, like the mechanical system installed on the weapon, affected the cyclic rate of the weapon.

A type that showed the most promise, however, was a mechanical extractor very similar to the British type. It had a mechanical ratio of 3 to 1, whereas the British type had a mechanical ratio of 2½ to 1. Also it was designed to have less friction than the British type.

The use of a nondisintegrating ammunition belt with links designed to receive the ejected cases was considered also as a means of overcoming the ejection problem. Such an arrangement would require only sufficient case velocity to seat the empty case in the link before the feeder rotates to eject the link with the empty case. With a lower extraction velocity required, the British type extractor probably would be satisfactory.

The use of nondisintegrating belt links had other advantages. The ejected belt and cases could be confined within the gun compartment. Also, a force could be applied, through sprockets, to the ejected belt to prevent jamming of the gun when an acceleration force opposing ejection was applied during maneuvering of the aircraft. The ejected belt could be fed to a position where it would best maintain the weight distribution within the aircraft.

A pilot model link and test feeder were made, and tests of this type of feeder and link arrangement proved very promising. Development of a link and feeder for the weapon was then initiated.

By this time, a new contract for continuation of work after 31 December 1949 had been written.

This included further development of extractors and nondisintegrating links.

*Cyclic Rate.* In an effort to improve cyclic rate, firing tests were conducted with larger orifices and stronger slide drive springs mounted on extension rods through the rear of the receiver. These tests indicated that the heavier drive springs produced a shorter cyclic time due largely to a better carry-through of the slide during extraction. However, tests to determine the optimum orifice diameter and slide drive spring rate were not completed during the period of this contract.

### Performance Data

*Cyclic Rate.* Because of ejection difficulties, very few bursts of more than five rounds were fired during the period of the contract. (The longest burst fired was 12 rounds.) Therefore, cyclic rate data obtained were based upon the time of cycle for individual rounds or, at best, for several rounds.

The accompanying table lists cyclic rates obtained under various conditions but without any ammunition belt load. These data indicate the desirability of a large gas orifice, heavy slide drive springs, and lightweight slide for high cyclic rates.

Cyclic Rates of 20-mm Automatic Gun T110 Under Various Conditions

Orifice diameter (inches)	Drive spring rate (pounds/inches)	Weight of slide (pounds)	Approximate cyclic rate (rpm)
0.093.....	5	*9.6	1,040
.093.....	5	**11.2	886
.093.....	13.2	***13.7	1,230
.110.....	13.2	13.7	1,350

\*Original weight of slide.

\*\*Weight increased to determine effect of slide weight on cyclic rate.

\*\*\*Weight increase due to modification of slide for use with heavier springs.

*Recoil, Time-Displacement, and Trunnion Reactions.* From a typical time-displacement record for two rounds, the cyclic rate was computed to be 1,206 rounds per minute. On the first round, the slide velocity during recoil was of the order of 48 feet per

second, and during counterrecoil it was of the order of 16 feet per second. After the slide struck the extractor lever, the slide velocity was reduced to approximately 12 feet per second.

One test was conducted to determine the trunnion reactions. A special firing mount was constructed to obtain this measurement by means of strain gages mounted on linkages which transmitted the trunnion

reactions. This single test indicated a total reaction of the order of 8,000 pounds.

*Extraction.* Velocity of extracted cases determined from high-speed motion pictures was of the order of 40 to 45 feet per second. This velocity was not sufficient for the case to clear the feeder sprockets except at case-extraction velocities of approximately 85 feet per second.

## SECTION 6. GUN, AUTOMATIC, CALIBER .60 T130 MODEL D

In the late 1940's, there was a demand for a higher-velocity projectile which apparently could be fulfilled only by employing the existing caliber .60 round of ammunition. The official designation T130 was assigned on 1 December 1950 to a specific type of weapon employing the conventional caliber .60 round of ammunition. Shortly thereafter the Armour Research Foundation was given a contract to develop the gun.

### General Description and Principles of Operation

The caliber .60 automatic gun T130 is a gas-operated, belt-fed, electrically fired, percussion-charged weapon. By changing certain parts, it may be changed from left-hand to right-hand feed. The following description applies to the weapon when assembled for right-hand feed.

The distinguishing feature of this weapon is a re-

volving drum, containing five cartridge chambers parallel to its axis of rotation and mounted upon a shaft within the drum support, so that each chamber is brought into alignment with the bore of the barrel and momentarily stopped when it reaches the 6 o'clock position during drum rotation.

The barrel is housed in a tube support attached to the front end of the receiver and is retained by interrupted screw threads and a latch in the front end of the drum support. When assembled to the receiver, the hexagonal front end of the drum support engages a hexagonal socket in the rear end of the tube support.

The rear end of the drum support is supported at each side by an L-slotted block attached to the receiver. The barrel, drum, drum support, and other parts attached to the drum support constitute the recoiling parts of the weapon and are guided in recoil by the tube support at the front end of the

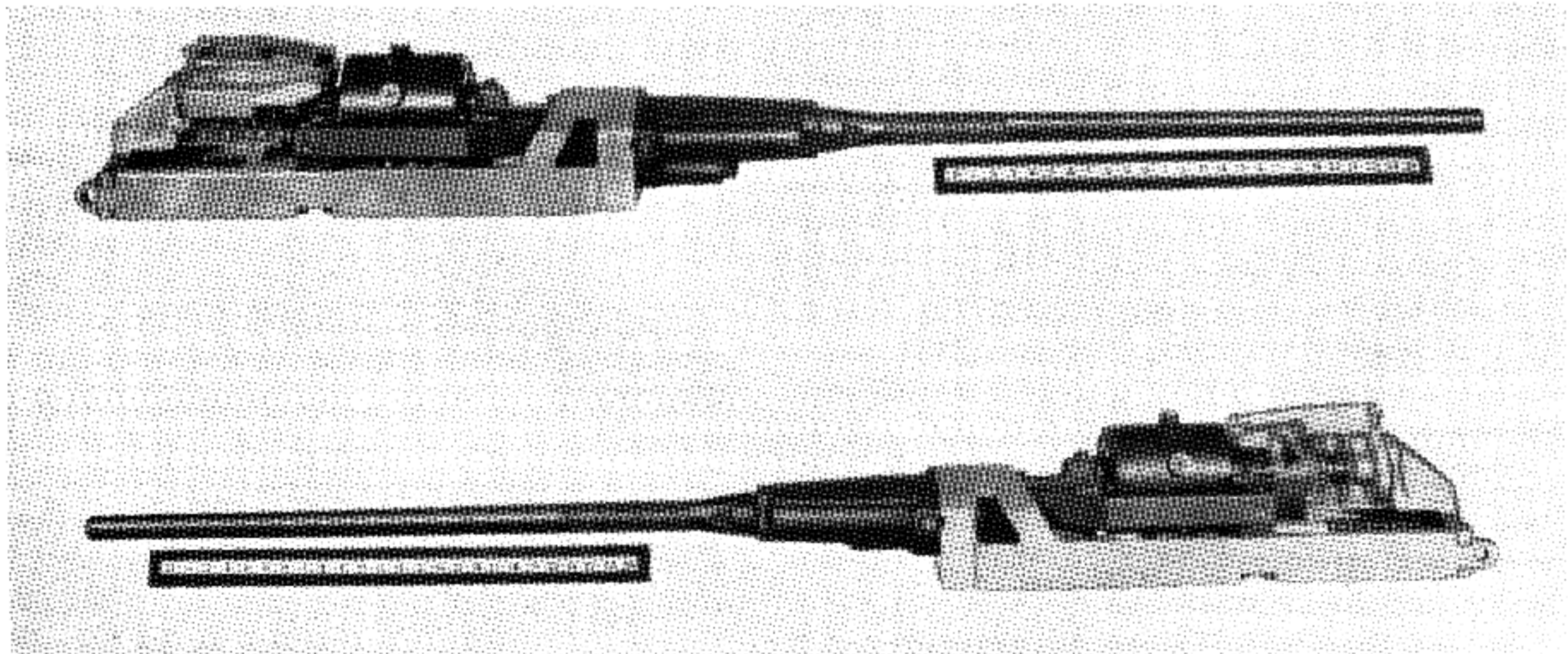


Figure 2-17. United States Ordnance Corps Caliber .60 Automatic Gun, T130, Model D.

receiver and by the L slots at each side of the rear end. Recoil and counterrecoil forces are limited by two sets of ring springs housed in the tube support, one on each side of the tube, and are transmitted to the springs by rods which are attached to lugs on the front end of the drum support.

A chamber in the drum is held in alinement with the barrel during firing and is indexed to bring the adjacent chamber in alinement with the barrel by means of five rollers on the periphery of the drum

which engage a cam track on an actuating slide in the bottom of the receiver. The actuating slide is moved rearward by a piston which receives its energy from powder gases bled from the barrel into the cylinder in the front end of the drum support. The slide is returned to its forward, or in-battery, position by interaction between the rotating drum and the cam in the actuating slide, assisted by two stranded wire drive springs. The slide has a switch tongue which pivots about a pin through its forward

### General Data: Caliber .60 T130 Model D

Gun length, overall: 72 inches.  
 Gun weight: 187 pounds.  
 Rate of fire: 1,200-1,300 rounds/minute.  
 Muzzle velocity: 3,400 feet/second.  
 System of operation: Gas rotation of cylinder.  
 System of locking: Revolver principle.  
 System of feeding: Disintegrating metallic link.  
 Method of headspace: Factory established (cannot be adjusted).  
 Location of feed opening: Left hand rear.  
 Location of ejection opening: Right hand.  
 Method of charging: Cartridge.  
 Method of cooling: Air.  
 Weights of major subassemblies:  
 Receiver and tube support assembly (including switch cam, charger bracket, recoil springs, ways): 41.9 pounds.  
 Drive springs, guide rods, end gate: 2.6 pounds.  
 Feeder and drum shaft assembly: 9.9 pounds.  
 Drum assembly: 22.2 pounds.  
 Drum support assembly (cast): 29.1 pounds.  
 Actuator slide assembly: 11.8 pounds.  
 Total weight of major subassemblies without charger T10, charger cylinder, and gasline: 148.8 pounds.  
 Charger cylinder and piston assembly: 4.1 pounds.  
 Charger T10: 7.5 pounds.  
 Gasline: 1.6 pounds.  
 Total weight of major subassemblies including charger T10, charger cylinder, and gasline: 162.0 pounds.  
 Weights of recoiling parts:  
 Drum assembly. (See above.)  
 Drum shaft: 1.3 pounds.  
 Feeder shaft: 0.6 pound.  
 Drum support assembly. (See above.)  
 Barrel: 31.3 pounds.  
 Recoil springs ( $\frac{1}{2}$  weight): 0.8 pound.  
 Recoil rods and nuts: 1.6 pounds.  
 Switch cam: 1.5 pounds.  
 Total weight of recoiling parts: 88.4 pounds.

Barrel length: 53.56 inches.  
 Barrel weight: 31.3 pounds.  
 Rate control: None.  
 Barrel removal: Not quick change type.  
 Bore:  
 Number of grooves: 8.  
 Groove depth:  $0.016 \pm .002$  inch.  
 Groove width:  $0.150 \pm .010$  inch.  
 Pitch: 1 turn in 18 inches.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Weight of parts moving with actuator slide:  
 Actuator slide assembly: 11.7 pounds.  
 Drive springs ( $\frac{1}{2}$  weight): 0.4 pound.  
 Total weight of parts moving with actuator slide: 12.1 pounds.  
 Overall width: 8 inches.  
 Overall height:  $7\frac{7}{8}$  inches.  
 Distance from muzzle to rear end of chamber: 59.90 inches.  
 Diameter across grooves: 0.604 inch.  
 Diameter across land: 0.588 inch.  
 Gas piston diameter: 1.125 inches.  
 Gas piston stroke: 1.625 inches.  
 Length of recoil springs for 1,250 pounds preload: 7.24 inches.  
 Free length of slide drive spring:  $15\frac{5}{8}$  inches.  
 Miscellaneous design data:  
 Type of charger: Percussion.  
 Type of firing: Electrical.  
 Preload in recoil spring: 1,250 pounds.  
 Total drive spring load, slide forward: 80 pounds.  
 Total drive spring load, slide rearward: 187 pounds.  
 Performance data:  
 Length of recoil:  $\frac{1}{2}$  inch, approximate.  
 Slide stroke:  $5\frac{1}{2}$  inches.  
 Recoil force: Less than 5,000 pounds.  
 Counterrecoil force: Less than 5,000 pounds.  
 Velocity of extracted cases: 80 feet/second, approximately.

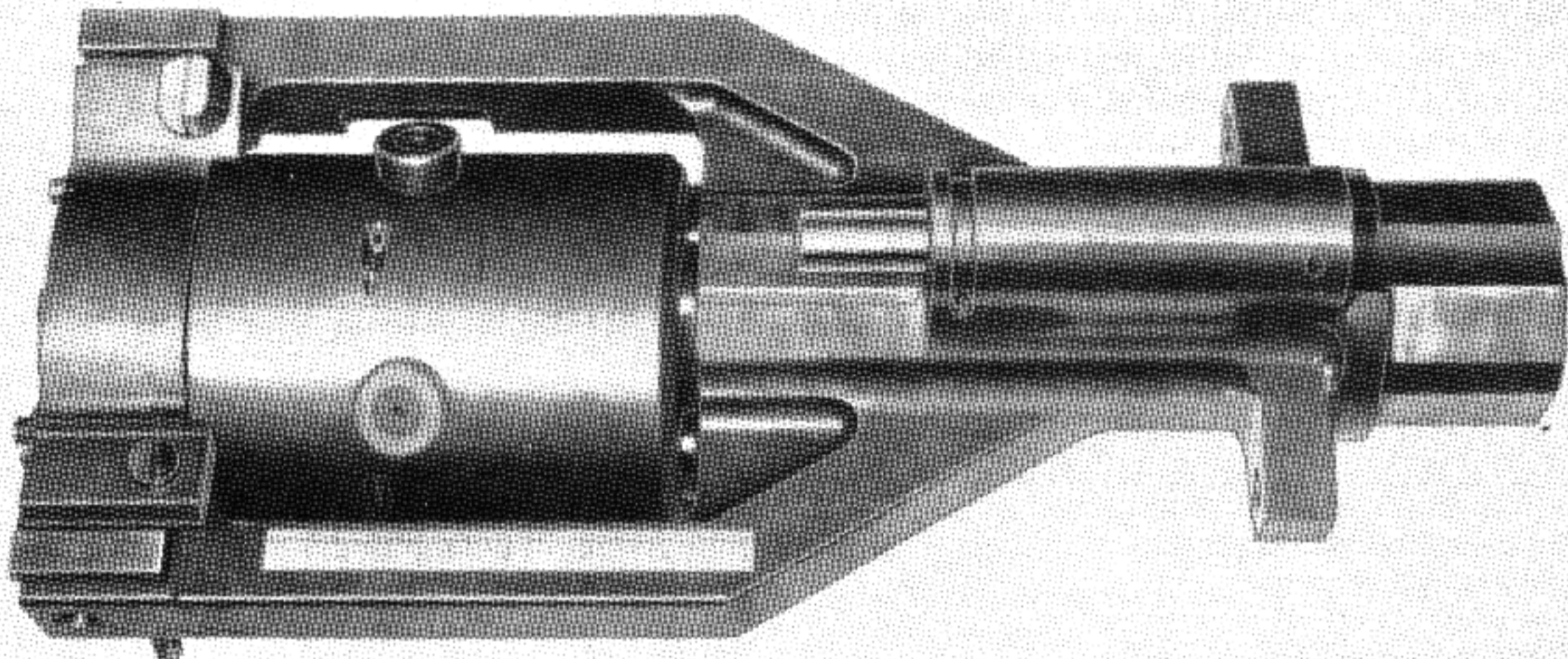


Figure 2-18. Automatic Gun, Caliber .60, T130. Drum and drum support assembly.

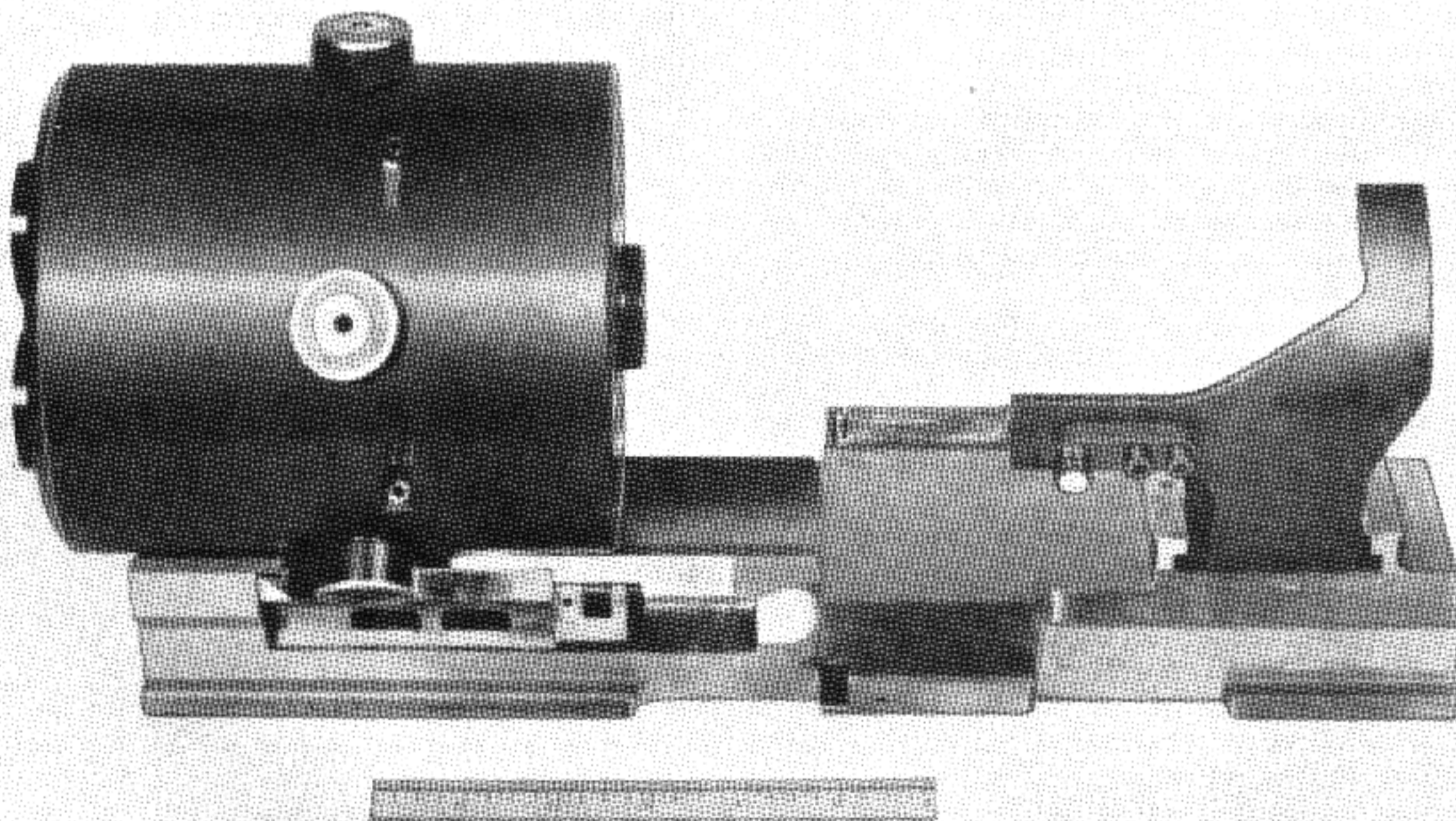


Figure 2-19. Automatic Gun, Caliber .60, T130. View showing engagement between drum rollers and actuating slide. (Slide in forward travel after exciting roller has depressed the right butterfly cam wing and caused the left wing to rise into engagement with the oncoming roller.)

end to change cam path. The switch tongue is moved from one side to the other during slide travel by a pin extending through the slide and engaging a switch cam in the bottom of the receiver. The switch cam is attached to the drum support by ears on the front end of the cam which engage a groove around the gas cylinder. The switch cam recoils with the drum support in slideways attached to the bottom of the receiver.

When the gun is ready to fire, the slide is in its forward position, the switch tongue is on the left side, and a drum roller is engaged by the straight portion of the cam path at the rear end of the slide, which maintains alinement of the chamber with the bore.

When the round is fired, the slide is driven rearward by the gas piston. The drum roller, in following the cam path to the right, causes the drum to rotate in a counterclockwise direction (when looking from the rear toward the muzzle). As the active roller emerges from the right side of the cam, the next roller enters the cam track on the left side. At

the same time, the switch tongue is cammed to the right to permit the roller to move into the straight portion of the cam as the slide returns to its forward position by kinetic energy transferred by the drum and by pressure of the drive springs. This brings the next chamber in alinement with the barrel. When the roller passes the rear end of the switch tongue, the switch tongue is cammed to its left position again.

Ramming is accomplished in two stages by means of a rammer, which is attached to the actuating slide. A five-station feeder sprocket in the feeder, located to the rear of and in alinement with the drum, is driven by the drum through a shaft extension and maintains the rounds in the ammunition belt in alinement with the chambers in the drum, as the linked ammunition is pulled into the feeder from the right side of the gun. Upon firing, the gas piston drives the slide rearward.

On the forward, or return, stroke of the slide, the upper ramming face of the rammer engages the base of a cartridge and pushes it through the link and partially into the chamber in line with the cartridge.

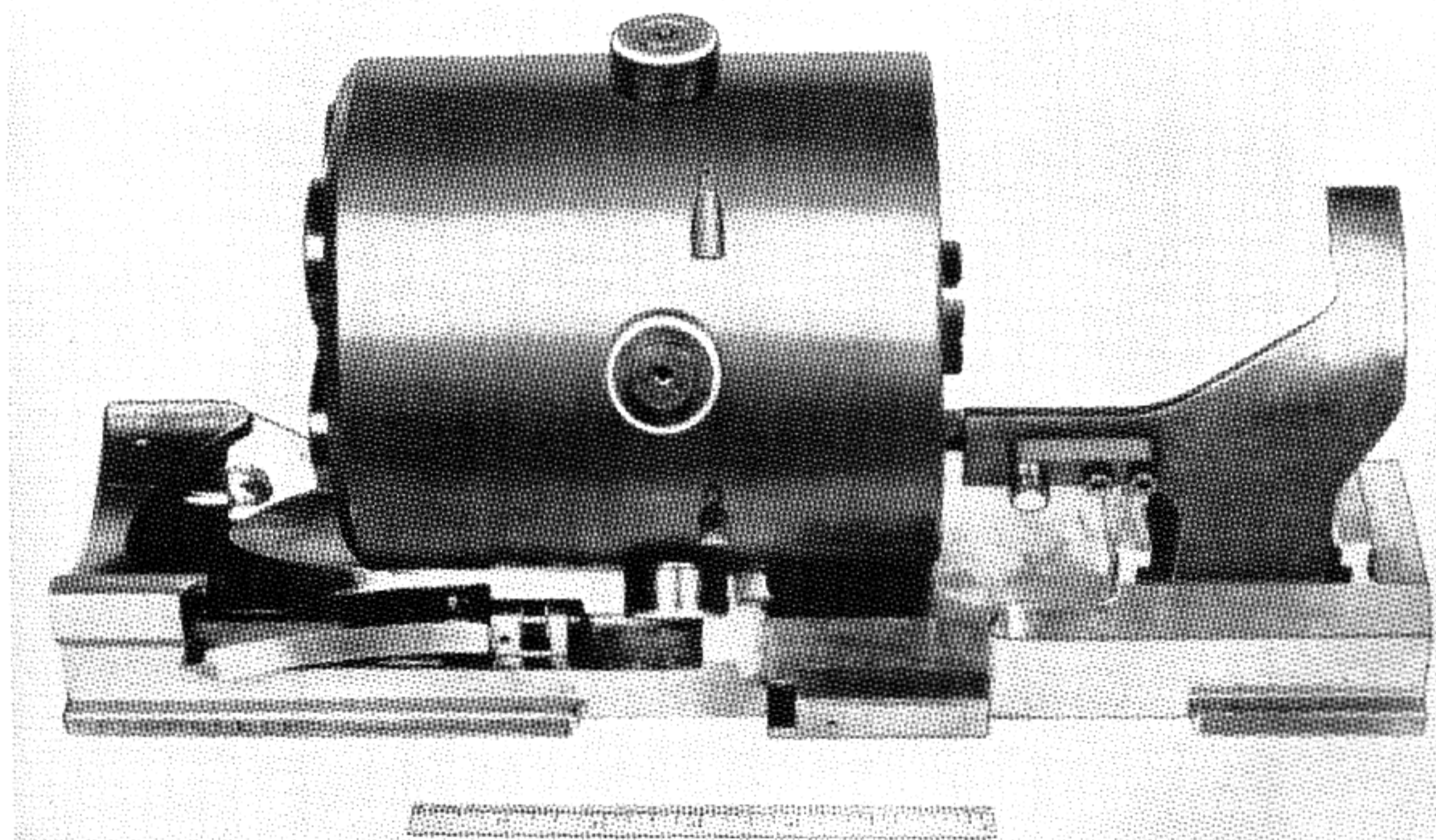


Figure 2-20. Automatic Gun, Caliber .60, T130. View showing engagement between drum rollers and actuating slide (Slide forward.)

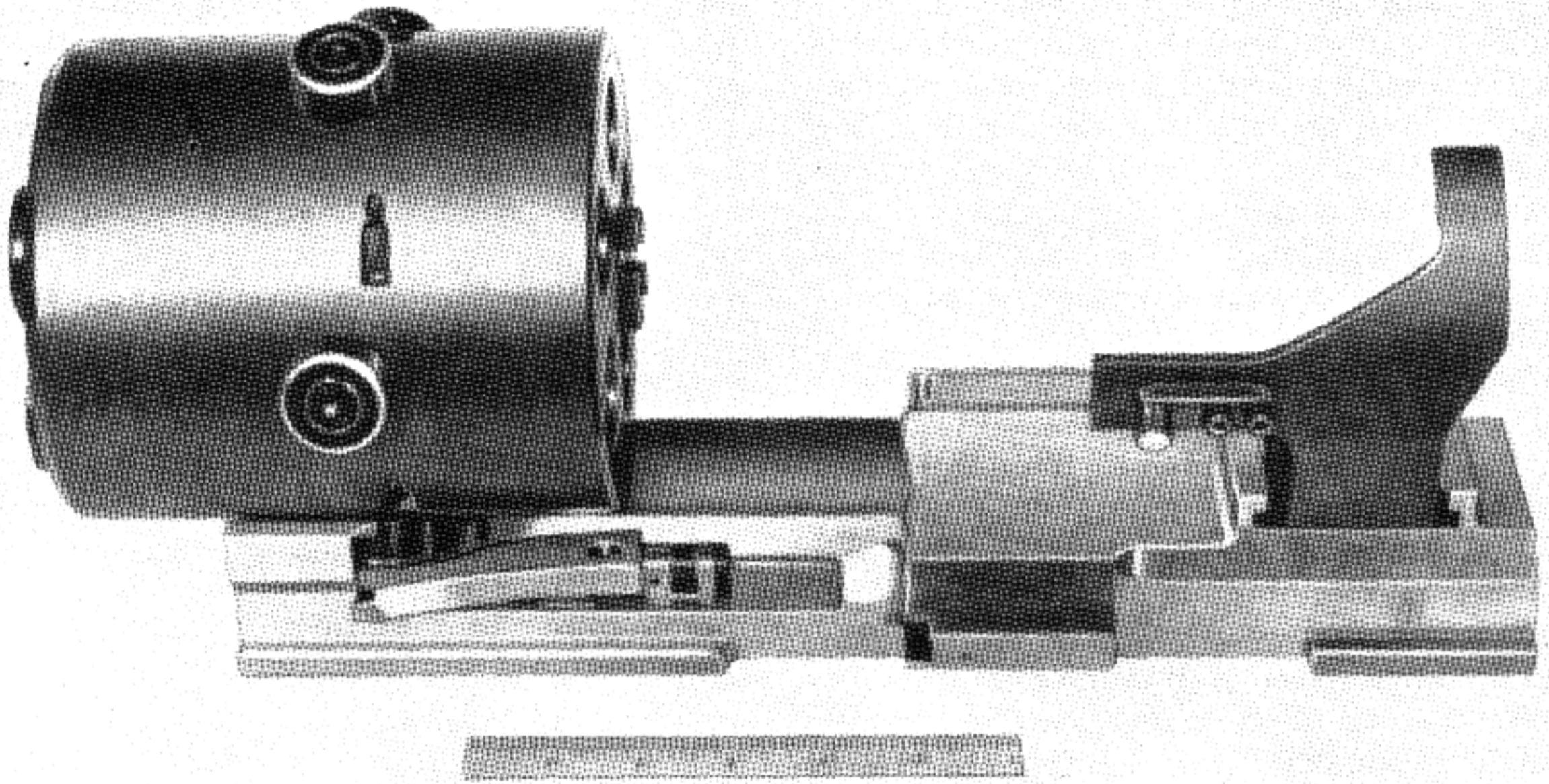


Figure 2-21. Automatic Gun, Caliber .60, T130. View showing engagement between drum rollers and actuating slide. (Slide rear.)

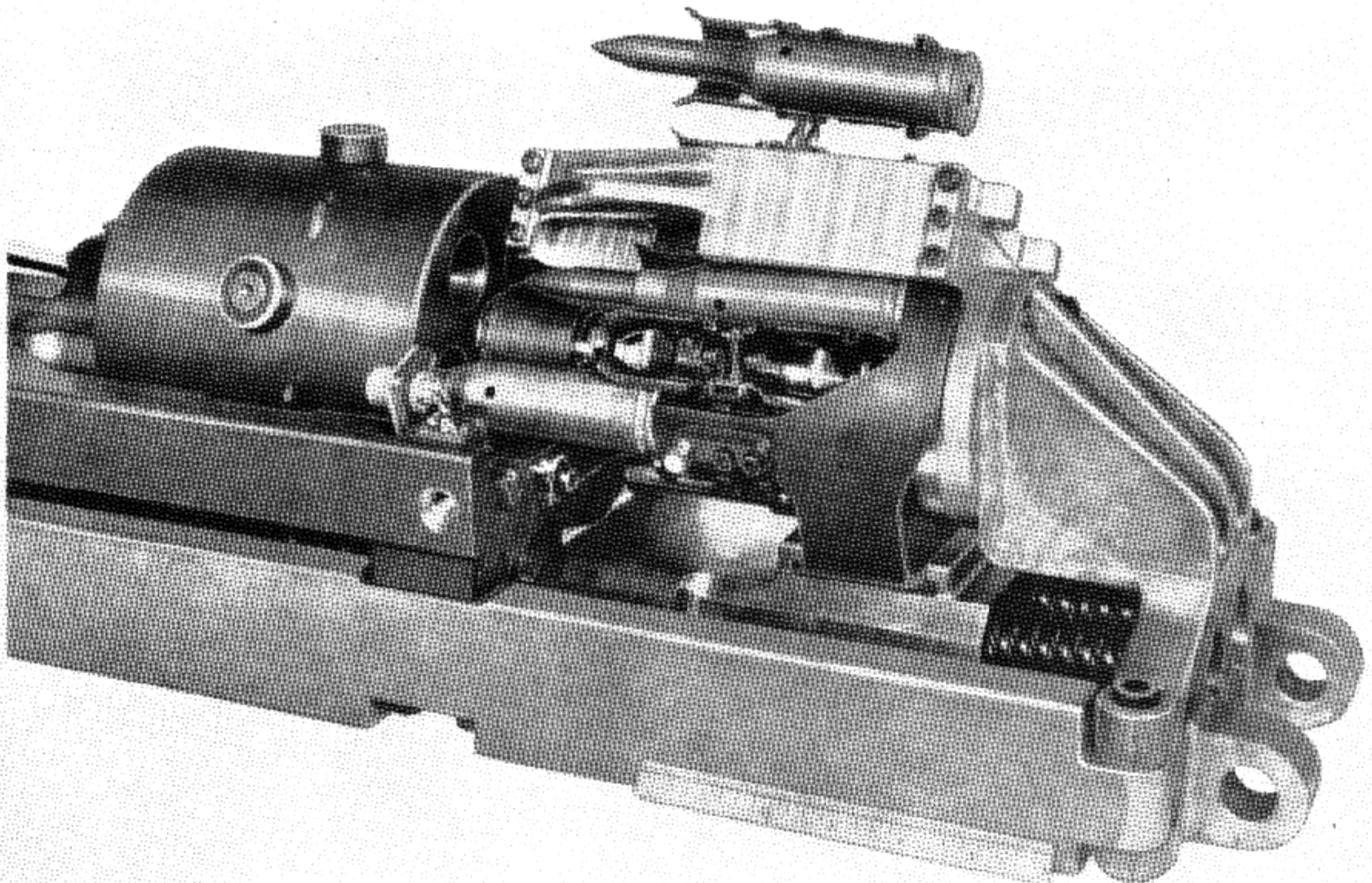


Figure 2-22. Automatic Gun, Caliber .60, T130. View showing start of ramming stroke.

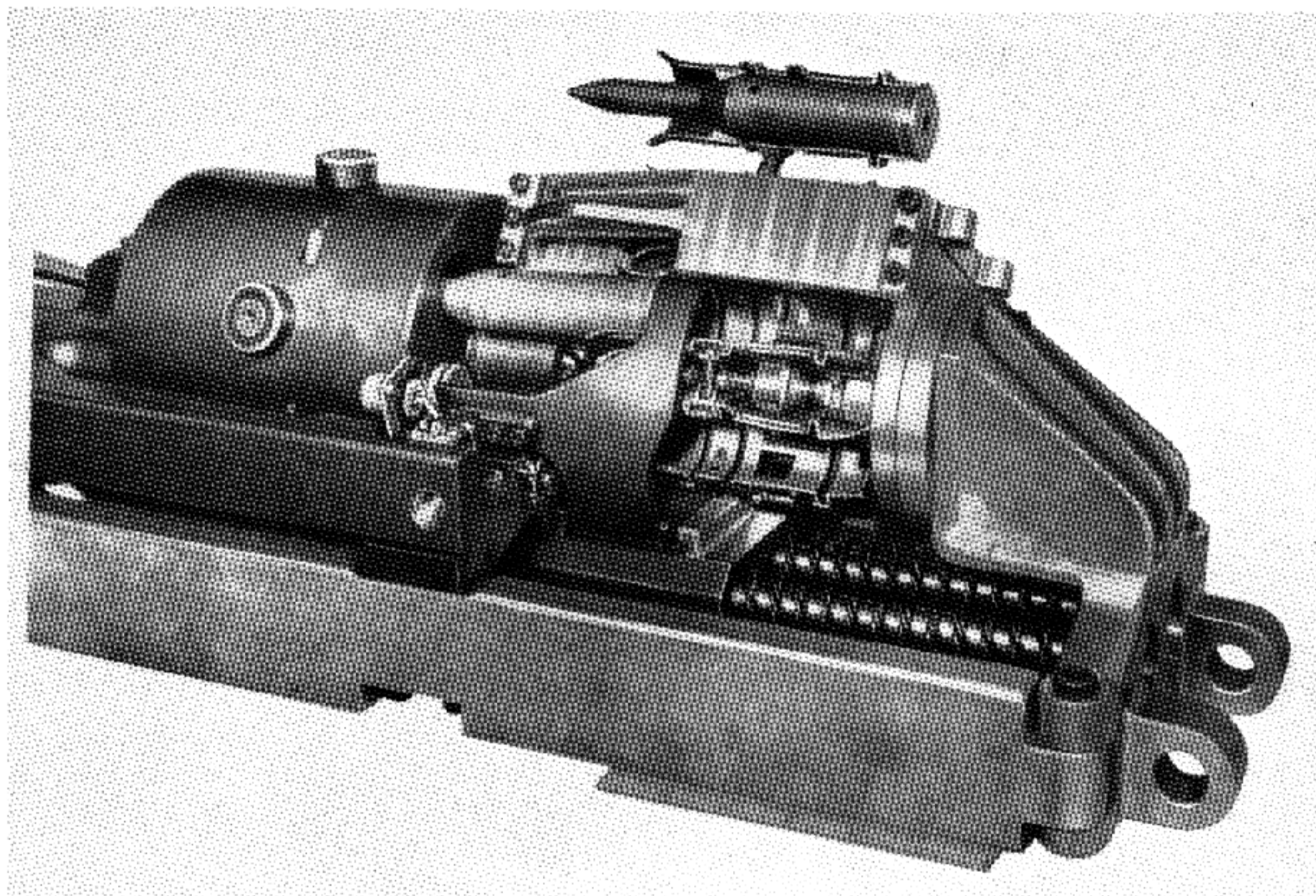


Figure 2-23. Automatic Gun, Caliber .60, T130. View showing completion of ramming stroke.

At the same time, the lower ramming face of the rammer contacts the base of the cartridge which was partially rammed on the previous cycle and completes chambering it. A spring-loaded detent in the rear end of the drum support retains the rammed cartridge in the chamber.

Simultaneously with the ramming action just described, the round which was completely chambered on the previous cycle moves into alignment with the barrel and into contact with the firing pin, and the expended case of the round which was fired at the start of the cycle moves into engagement with the extractor, located on the right side of the drum support.

The extractor is actuated by a striker located in a lug on the right side of the slide, which strikes a lug on the lower end of the extractor shaft and causes it to rotate. This occurs on the forward stroke of the slide when it is about 2 inches out of the battery immediately after the drum has ceased rotating and

the empty case has been engaged by the extractor.

Firing occurs just as the slide reaches its battery position. Firing is initiated electrically by the engagement of a male contact on the slide with a female contact on the rear end of the drum support. Closing of these contacts permits an electric current from an external power source to flow through the firing pin into the electric primer.

Two types of feeders are provided for this weapon: the disintegrating type and the relinking type. The disintegrating type ejects the empty links through the lower opening on the right side of the feeder and deflects the extracted cases to the right as they are ejected rearward. Without cases or rounds in them, the links are free to separate. The relinking type feeder positions the empty links in line with the extraction station, where they receive the extracted case. Cases and links are then ejected in a continuous belt through the lower opening on the right side of the feeder.



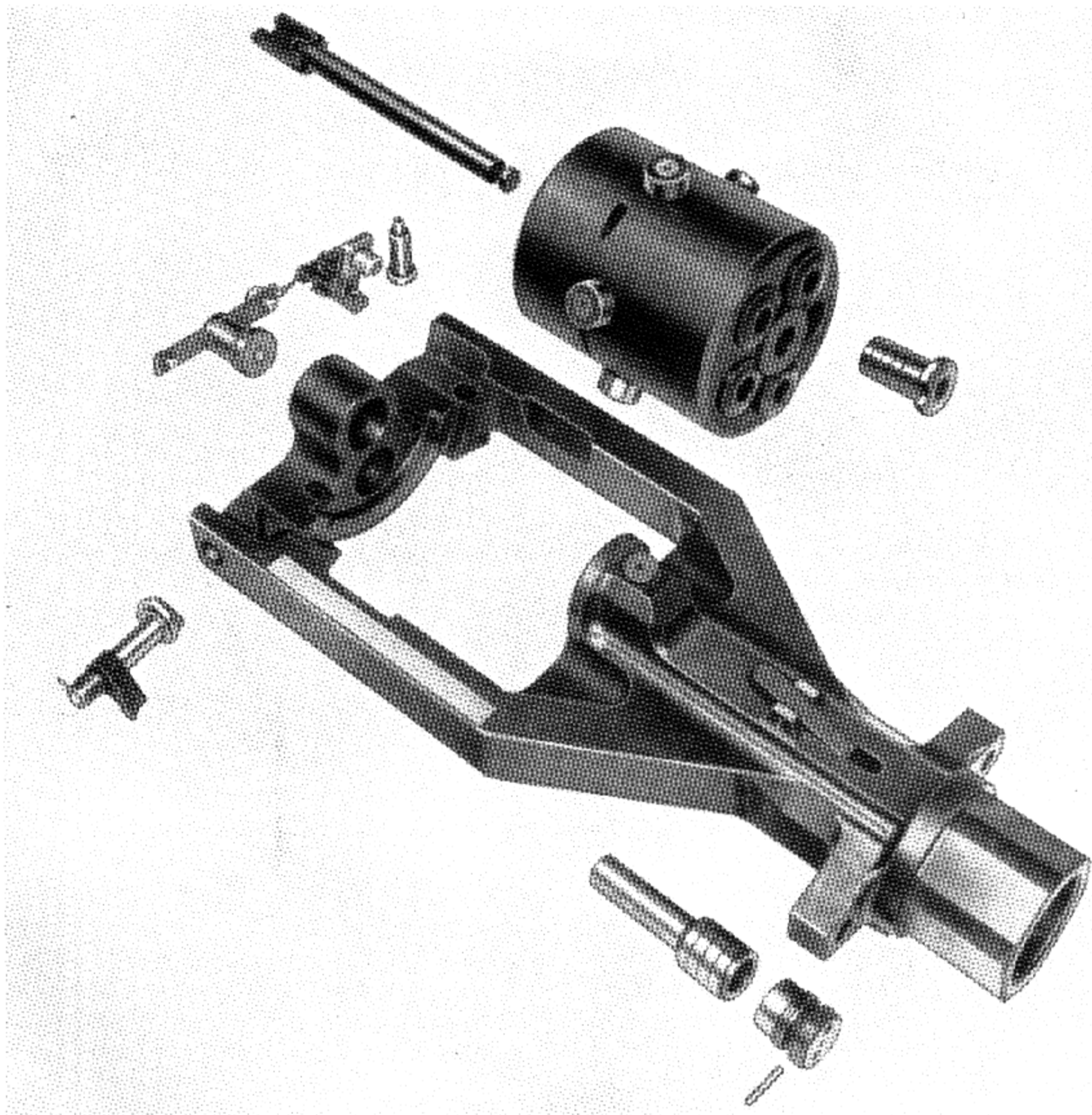


Figure 2-24. Automatic Gun, Caliber .60, T130. Drum and drum support, disassembled.

Obturation between the forward end of the chamber and the end of the barrel is accomplished by means of sealing sleeves, which are held against the face of the barrel by the pressure of the propellant gases acting on the rear of the sleeve. The weapon is charged by a gas piston in a cylinder housed in the receiver and tube support. It is actuated by gas pressure from the firing of a caliber .30 grenade cartridge M3 in the percussion charger T10. The pis-

ton charges the weapon by forcing the actuating slide to the rear. The percussion charger T10 and the charger cylinder were developed under a contract separate from the caliber .60 gun T130 model D.

#### Description of Design and Construction Features

The weapon is designed for transmission of the recoil forces through trunnions cast integrally with the steel tube support, which also houses the recoil

springs. The rifling torque and the torque produced by the force of the drum roller on the actuating slide cam are transmitted through the trunnions by means of the hexagonal bearing at the front end of the drum support and the mating hexagonal socket in the rear end of the tube support. However, because of flexure of the sidearms of the drum support, some of the torque produced by the force of the drum roller on the actuating slide cam is transmitted to the receiver through the L-slot connections at the rear end of the drum support. This torque can be transmitted directly to the gun-mounting structure by changing the location of the rear mounting points to directly under the drum support L slots. This latter position was made possible by providing a hole in each slide of the receiver under the drum support L slots, allowing engagement of the points with a supporting trunnion on the gun-mounting structure. Similar holes have been provided near the rear end of the receiver; however, it is recom-

mended that the gun be supported at the drum support L slots, as this location subjects the weapon to minimum stress, and results in minimum dispersion when firing from a rigidly supported structure.

Because of the arrangement just described, it was possible to design the receiver for minimum loads and cast it from an aluminum alloy. At points where the receiver engages moving parts, steel mating members (drum support L-slot supports, actuating slideways, switch cam slideways), have been bolted to it. The receiver and tube support are held together with six socket-head cap screws and are aligned by the engagement of horizontal and vertical keys on the rear end of the tube support with mating key ways in the front face of the receiver.

The recoil ring springs are assembled to the recoil rods within sleeves, in the form of a cartridge unit, and have been tightened to a preload of 1,250 pounds. A cotter pin through the preload nut prevents loosening during firing. When assembled in

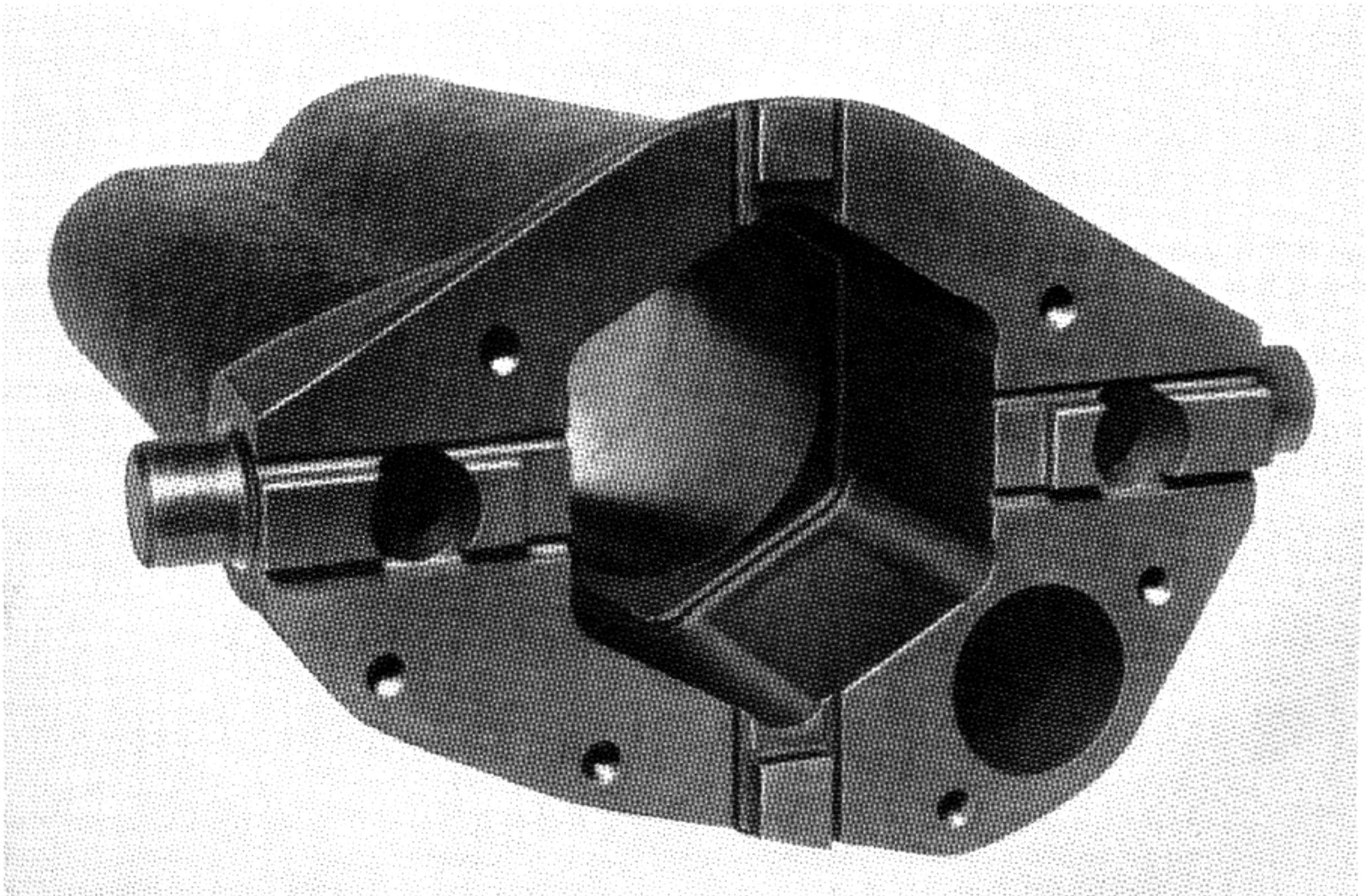


Figure 2-25. Automatic Gun, Caliber .60, T130. Trunnion.

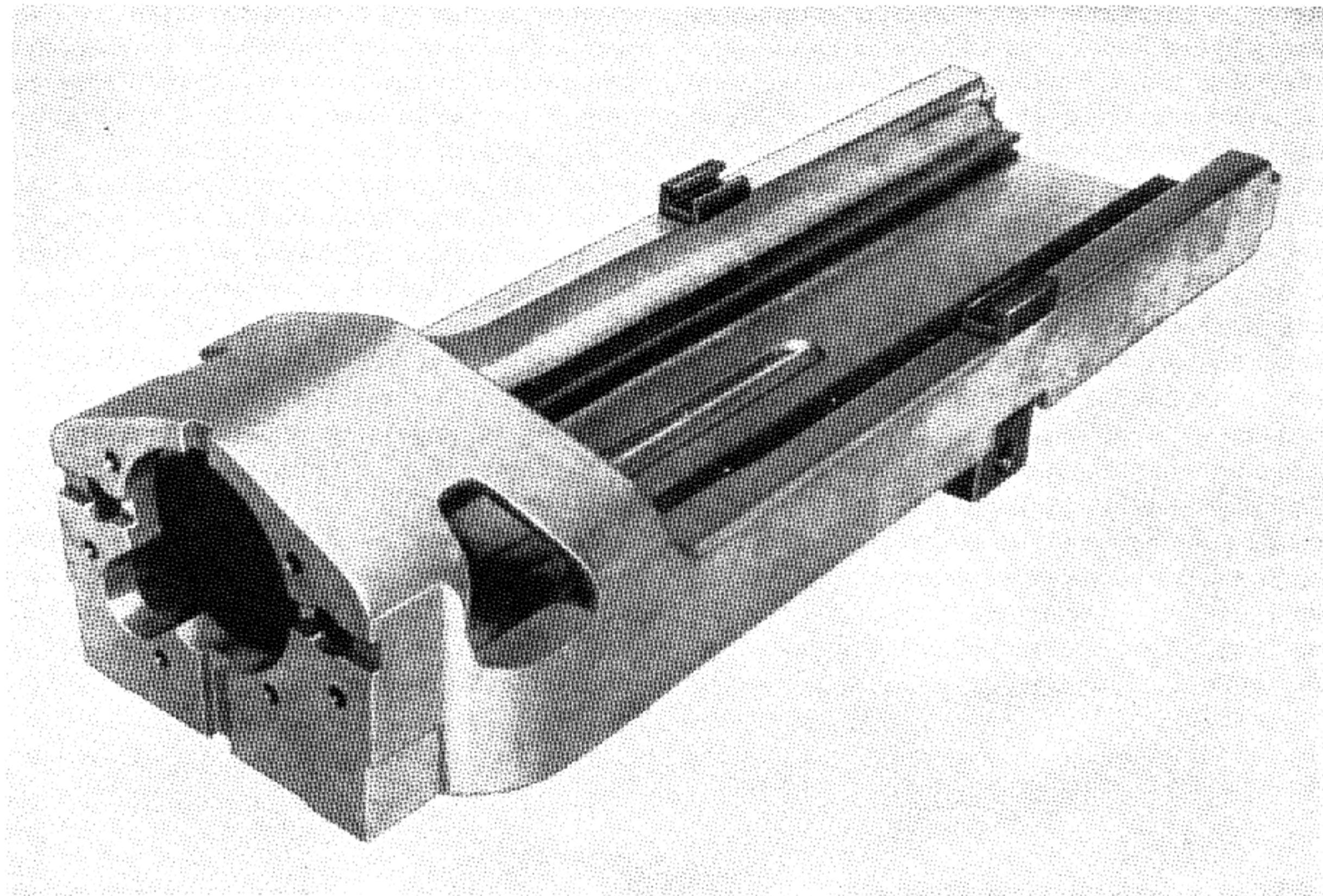


Figure 2-26. Automatic Gun, Caliber .60, T130. Receiver assembly.

the tube support, the recoil rods extend through holes into the receiver and attach to ears on the front end of the drum support. Plugs, screwed into the front end of the tube support against the front collar of the recoil spring assembly, position the springs against the rear ends of the cylinders, in such a way that there can be no free movement of the recoiling

parts in either direction without compression of the springs. Accordingly, the springs are double acting, and limit the counterrecoil forces as well as the recoil forces.

The tube is supported at two points, by a close fitting bore within the drum support and by a similar bore at the end of the tube support.

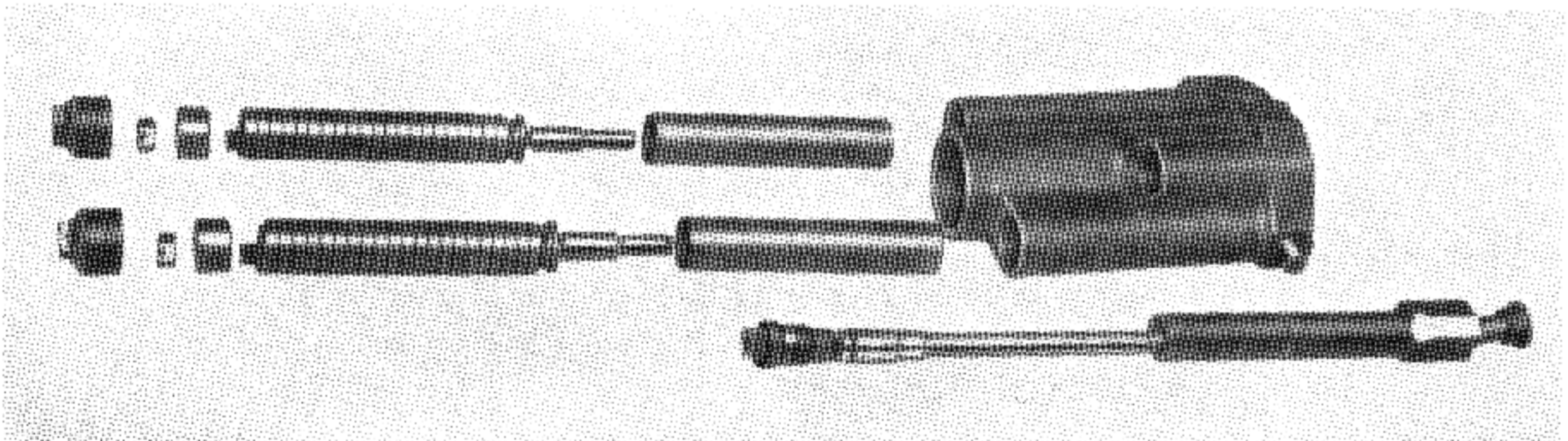


Figure 2-27. Automatic Gun, Caliber .60, T130. Trunnion group, disassembled.

Considerable force is exerted on the rear of the tube by the sealing sleeve on the rear end of the tube (approximately 38,000 pounds). To resist this force as well as the forward frictional force of the projectile, two sets of four interrupted threads have been provided on the tube, which engage mating threads in the front end of the tube support.

The gas cylinder which contains the piston for actuating the slide forms an integral part of the drum support. This arrangement permits bleeding gas from the tube through a straight passage leading directly from the tube into the gas cylinder. Since the gas cylinder is a part of the recoiling mass, the force exerted by the gas piston on the slide opposes the recoil force and reduces the load on the recoil springs by an amount dependent upon the size of the gas orifices.

Leakage of gas from the tube gas port between the tube and the mating bore of the drum support has been minimized by machining six labyrinth grooves in the tube, three on each side of the gas port.

Leakage of gas past the gas piston is prevented by three labyrinth grooves around the piston.

The rear end of the drum support houses the firing-pin assembly which serves as the anvil for supporting the case during firing. The firing pin assembly has been made small in diameter in order to provide for maximum strength in the rear end of the drum support. This strength is necessary because of (1) the concentrated load imposed on the drum support by the gas pressure acting on the cartridge case and (2) the distributed load imposed by the gas pressure acting on the bottom of the sealing sleeve recess in the drum.

The drum is machined from a forged steel billet. It contains five equally spaced chambers, with a gas sealing sleeve at the front of each chamber. Sealing against gas leakage between the sleeve and the sleeve recess in the drum is accomplished by four grooves around the sleeve, and by longitudinal grooves around the rear end of the sleeve at 90° spaced intervals. Gas pressure acting on the rear end of the sleeve forces the sleeve out against the face of the tube and prevents serious leakage of gas between the end of the sleeve and the face of the tube during firing. Around the periphery of the drum and radial with the chambers are five rollers mounted on studs and retained by blind snap rings. The studs are

integral with the drum, thus providing adequate strength in the outside chamber walls.

The drum is mounted upon a shaft supported in the drum support and is keyed to it by dogs machined on the rear end of the shaft. The shaft rotates with the drum and causes the feeder shaft to rotate with it by means of a universal joint connecting the two. This universal joint provides for any misalignment caused by deflections during firing. A spring-loaded latch pin in the front end of the drum support engages a groove in the end of the drum shaft to prevent axial motion.

The actuating slide fits in guideways in the bottom of the receiver and moves backward and forward beneath the drum and drum support under the action of the gas piston and the drive springs. Its stroke is 5½ inches. Machined into the slide are two cam paths which engage the drum rollers and cause the drum to rotate as the slide moves through its cycle. These two cam paths consist of curved portions 3½ inches long which curve in toward the longitudinal axis of the slide and merge into a central straight portion 2 inches long. A part of the inside edge of each cam path is formed by a movable member, called the switch tongue, which pivots about its forward end. The position of this switch tongue determines which cam path is made continuous throughout its length.

Underneath the slide is a cam which engages a stud on the switch tongue or a spring-loaded pin within the stud. This cam is designed so as to cause the switch tongue to move from one side to the other at the proper time in the cycle, thus changing the continuity of the cam path in the slide from one side to the other and causing the drum to move in one direction on both the rearward and forward stroke of the slide. The straight portion of the slide cam keeps the drum stationary for the first 2 inches of the rearward travel. Thus the chamber is aligned with the barrel while the projectile is in the bore during the first 2 inches of slide travel, and the empty case is at the extraction station during the last 2 inches of slide travel.

Variable relative motion between the drum and switch cam from round to round cannot be tolerated, as the switch tongue must be switched precisely at the proper position of the drum roller in the cam path. Therefore, since the drum is a recoiling part, and since the recoil cycle does not follow a consistent

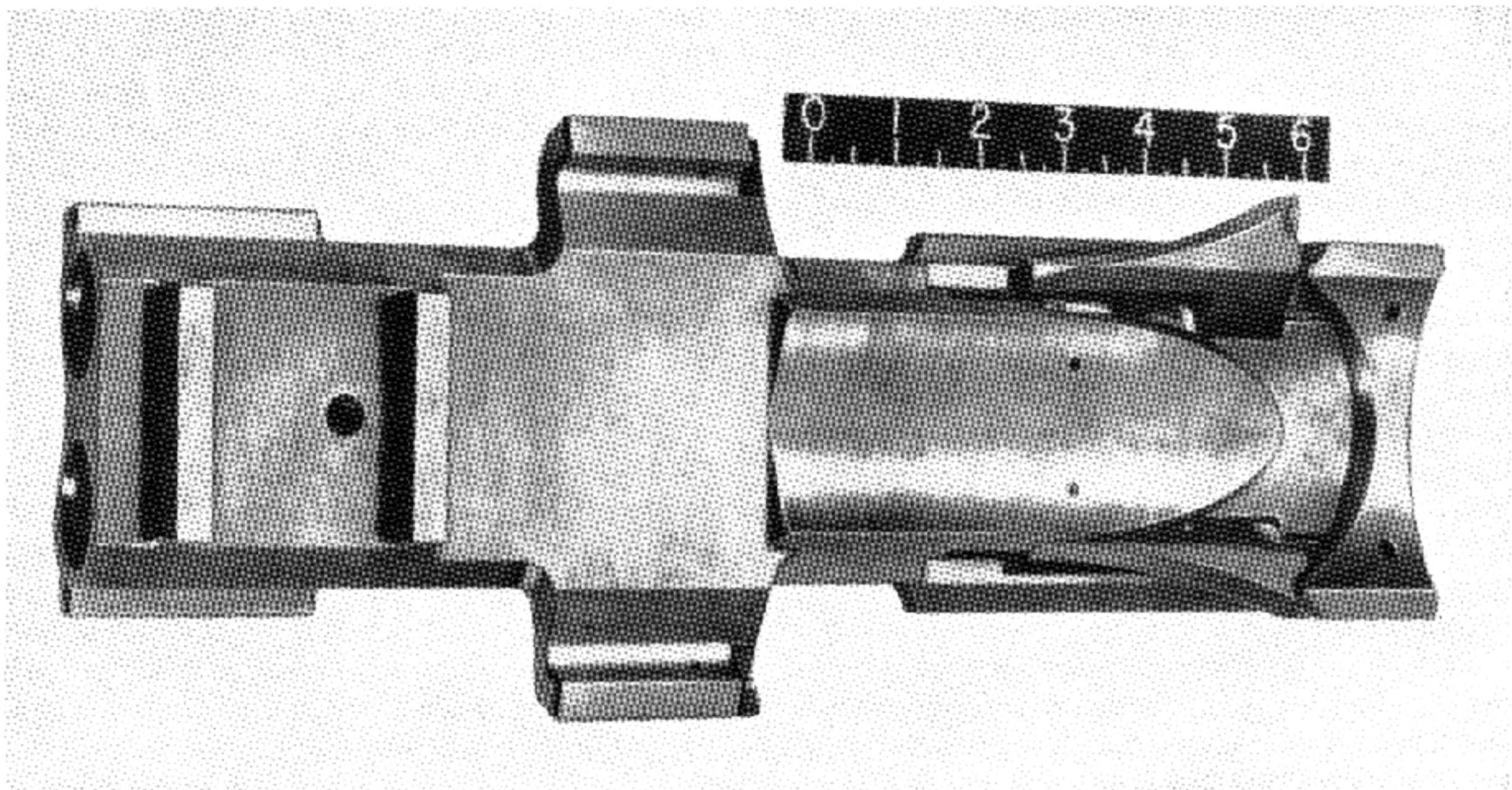


Figure 2-28. Automatic Gun, Caliber .60, T130. Actuating slide assembly.

pattern, it was necessary to make the switch cam a recoiling part. This was done by machining a groove around the outside of the gas cylinder on the drum support to engage ears machined in the front end of the switch cam. The guide plate, attached to the bottom of the receiver, guides the cam during its recoil travel.

In addition to actuating the drum, the slide actuates the extractor and carries the rammer which rams the rounds from the links and chambers them.

The extractor, located in the rear end of the drum support, is kinetically one piece. It consists of a shaft with a striker face on its lower end and an extractor pawl on its upper end.

As the slide returns to battery, a replaceable striker housed in a lug on the right side of the slide strikes a face on the lower end of the shaft, causing the shaft to rotate and allowing the slide to continue to battery. The extractor pawl is held in a retracted position after extracting the case, until the slide moves rearward again. When the lug on the side of the slide clears the end of the extractor shaft, a torsion spring on the upper end of the extractor shaft returns the extractor to extraction position with the pawl against the face of the drum.

The torsion spring returns the extractor with sufficient force to cause the pawl to bounce rearward from the face of the drum and to miss frequently the rim groove of the oncoming case to be extracted. Therefore, an antibounce device was incorporated in the extractor to reduce the amount of bounce and prevent failure to extract.

This device consists of a spring-loaded detent housed in the drum support which engages a shallow hole in the hub of the extractor pawl when the pawl is against the face of the drum. The ratio of movement of the end of the extractor pawl to the movement of the point struck by the slide is approximately 1.67 to 1. Case extraction velocities are of the order of 80 feet per second.

The rammer consists of a single piece mounted in guide slots at the rear end of the slide and held in place with a cap screw. For right-hand feed, the rammer curves outward to the left to clear the feeder sprocket and the edges of the open-sided links presented to the rammer by the feeder. The two slide-drive springs are of stranded wire construction. They engage holes in the rear end of the slide and are held in position at the rear by guide rods which engage bayonet locks in the receiver end

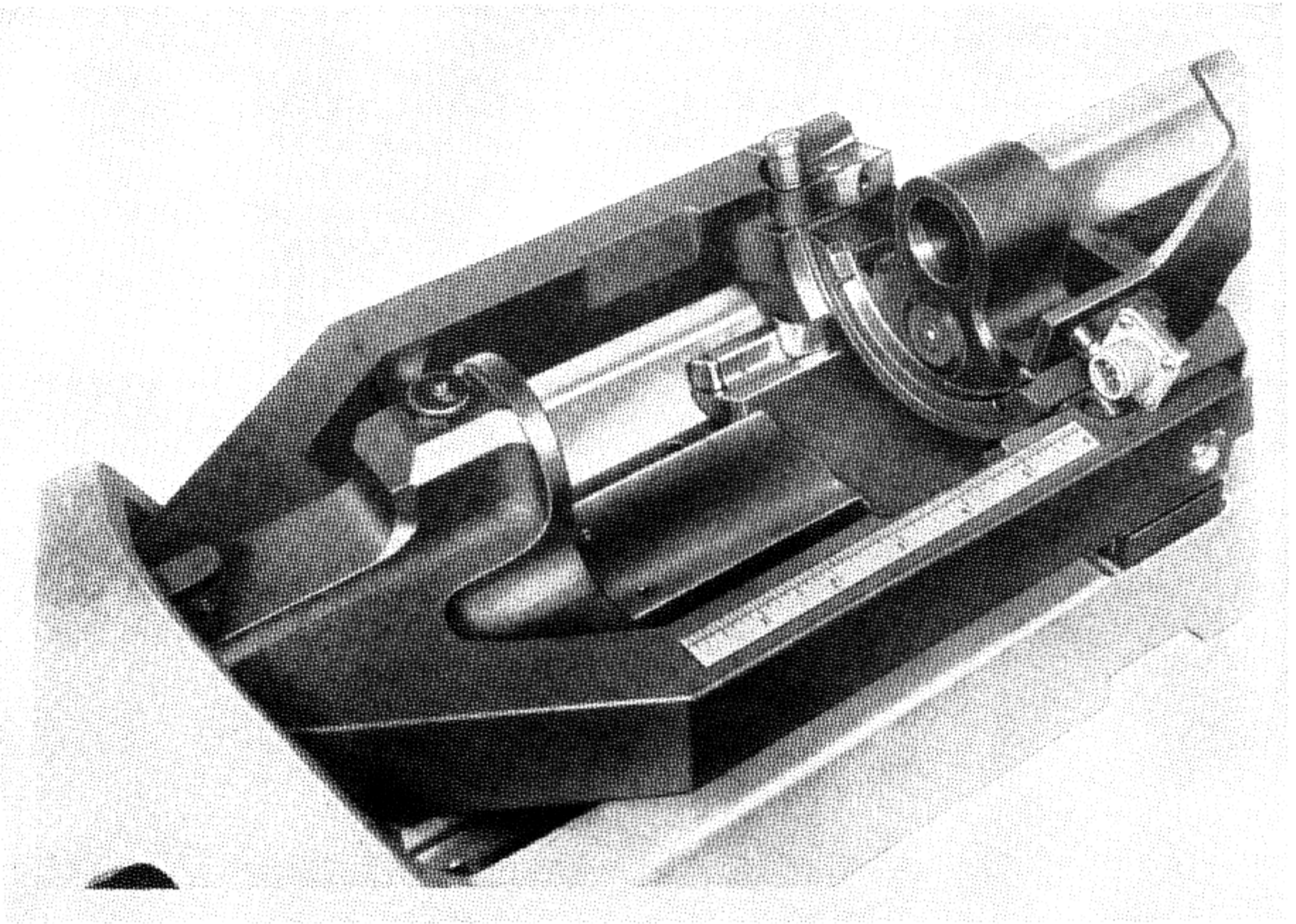


Figure 2-29. Automatic Gun, Caliber .60, T130. View showing extractor and extractor striker on slide. (Drum removed.)

plate. The springs exert a total force of 80 pounds when the slide is forward, and 187 pounds when the slide is rearward.

The disintegrating belt feeder consists of a cast magnesium-aluminum alloy frame which houses the sprocket, sprocket shaft, link guides, and case deflection chute. The elements of the sprocket, which are splined to the shaft, consist of the following:

1. One drive sprocket, which engages the ammunition belt links at the link connectors.
2. Two sprockets, one on each side of the drive sprocket, which force the link connectors out to their proper distance from the center of rotation.
3. One guide sprocket ahead of the front connector spacing sprocket, which bears against the side of the link, and keeps the link aligned with the chamber.

4. Front guide sprocket, which controls the round after it is rammed from the link into the chamber.

5. Rear ramming stop sprocket, which engages the link on the front side of the rib at the rear, and prevents the link from moving forward under the force of ramming. This sprocket also assists in keeping the link aligned with the chamber.

Also mounted on the shaft are two guide tracks, which engage the two ears on the ammunition belt link and hold the first and last links of the ammunition belt on the sprocket against centrifugal force acting on the link and round during sprocket rotation. The intermediate links in a belt are held in the sprocket by their adjacent links.

The ammunition belt enters the feeder horizontally from the right through an opening at the top and engages the sprocket tangentially as the ears enter the guide tracks. After ramming, the empty

links continue around the sprocket and leave the feeder through an opening on the right side; then they are free to disintegrate.

Mounted in the right side of the feeder and opposite the extraction station is a curved deflection chute which deflects the ejected cases out of the feeder to the right, clear of the sprocket.

The feeder assembly is held to the top of the receiver by two headed studs on each side of the receiver which engage slots in the sides of the feeder frame. Two spring-loaded pins, one on each side of the receiver, engage holes in the feeder frame and prevent forward or rearward movement of the feeder.

The relinking feeder is similar to the disintegrating belt feeder with respect to the drive sprocket and method of mounting on the receiver. It also has a cast magnesium-aluminum alloy frame; however,

the belt entrance is at an angle of 25 degrees with the horizontal. The empty links are carried on around the sprocket further than in the disintegrating belt feeder to a position in line with the extraction station, where the extracted case reenters the link and is stopped by the end of the feeder frame.

The relinked case and link then leave the feeder through an opening on the right side under the belt entrance opening. With the ejected cases in the links, the belt cannot disintegrate.

The gun firing circuit components consist of the firing pin assembly mounted in the rear end of the drum support, a female contact consisting of two steel leaves and insulating strips mounted on the rear end of the drum support, a male contact and insulating strip mounted on top of the slide at the rammer mounting screw, and an external power receptacle mounted on a bracket on the rear end of

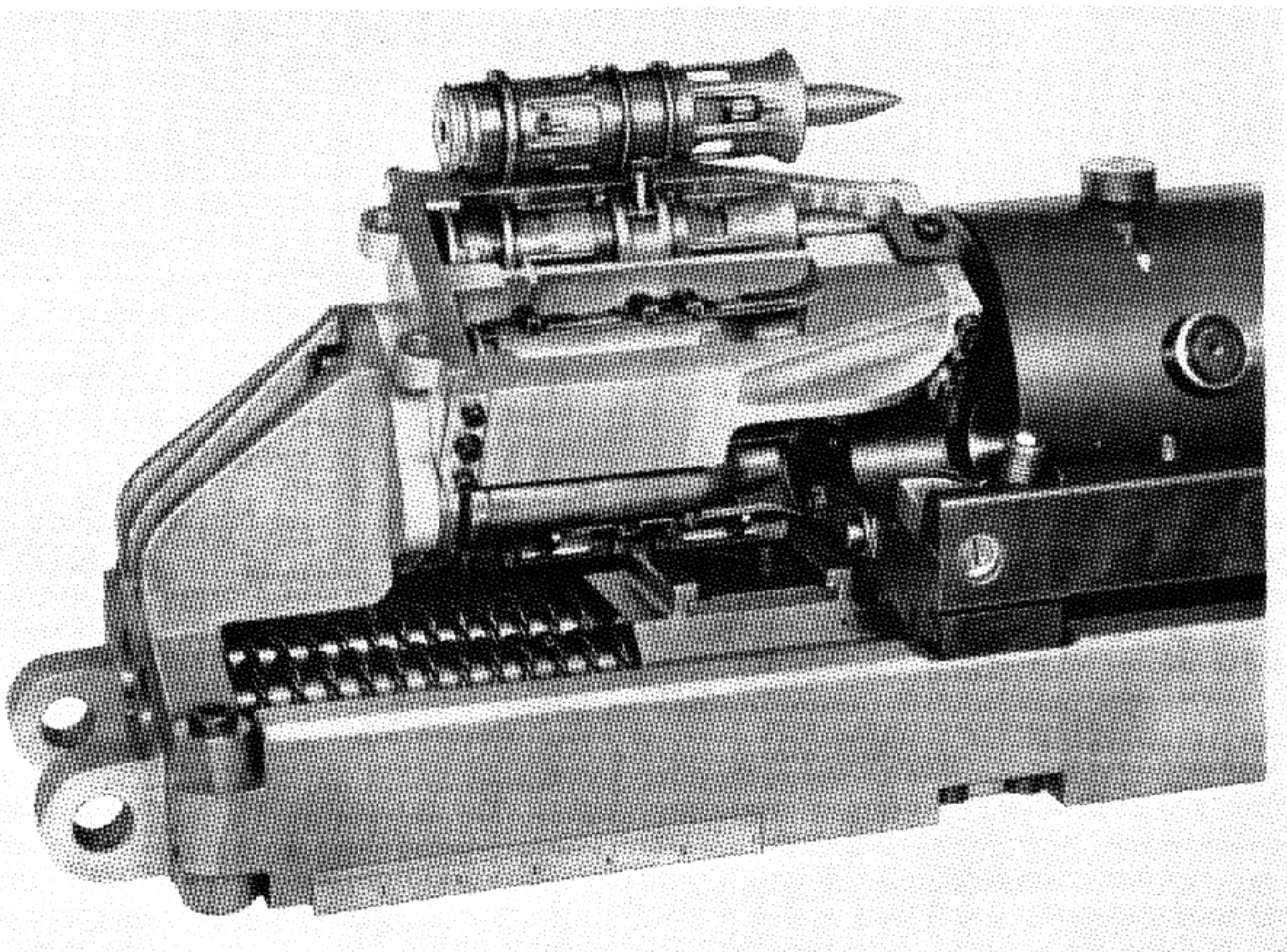


Figure 2-30. Automatic Gun, Caliber .60, T130, showing the fired case returned to the link for ejection.

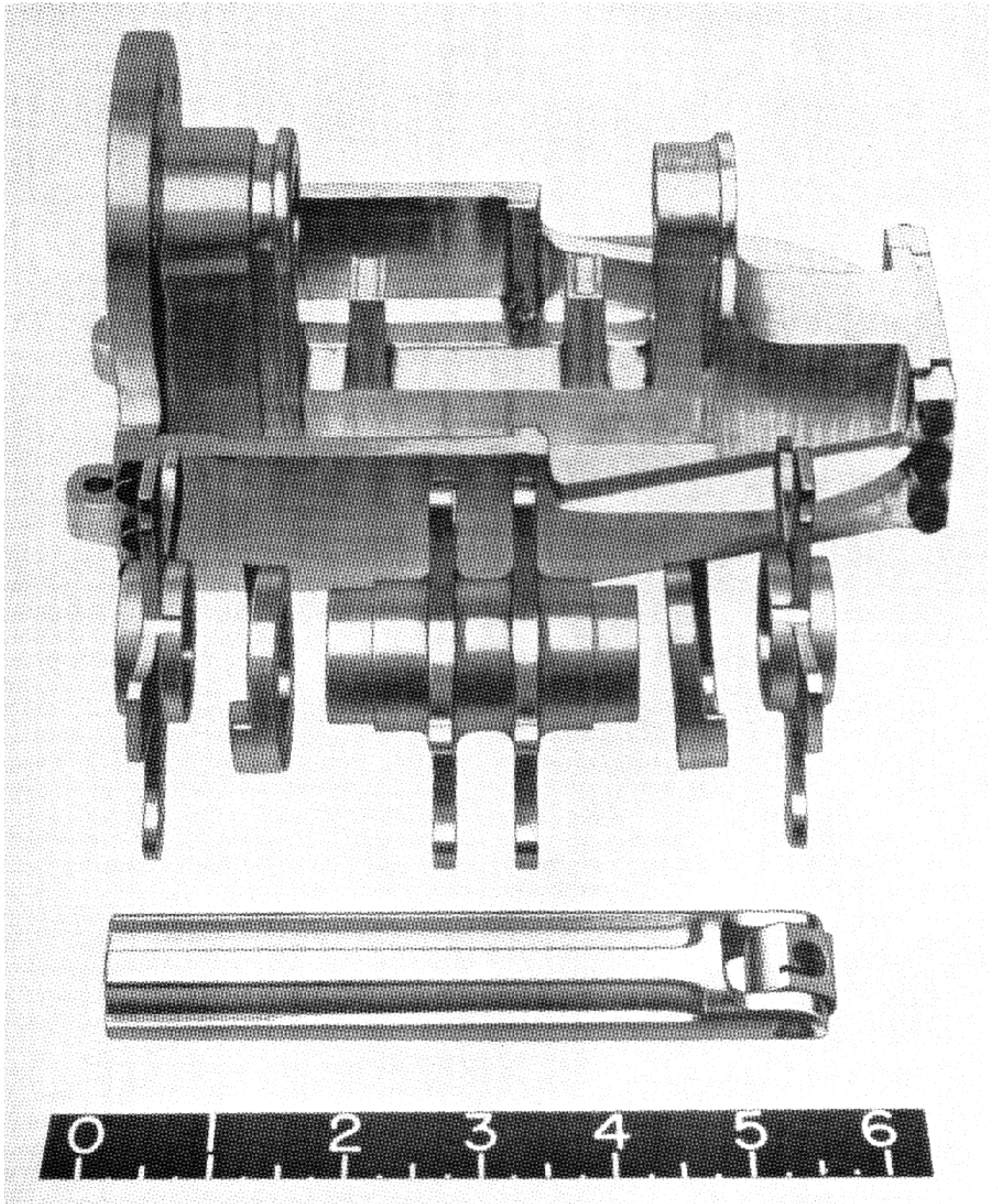


Figure 2-31. Automatic Gun, Caliber .60, T130. Feeder, disassembled.



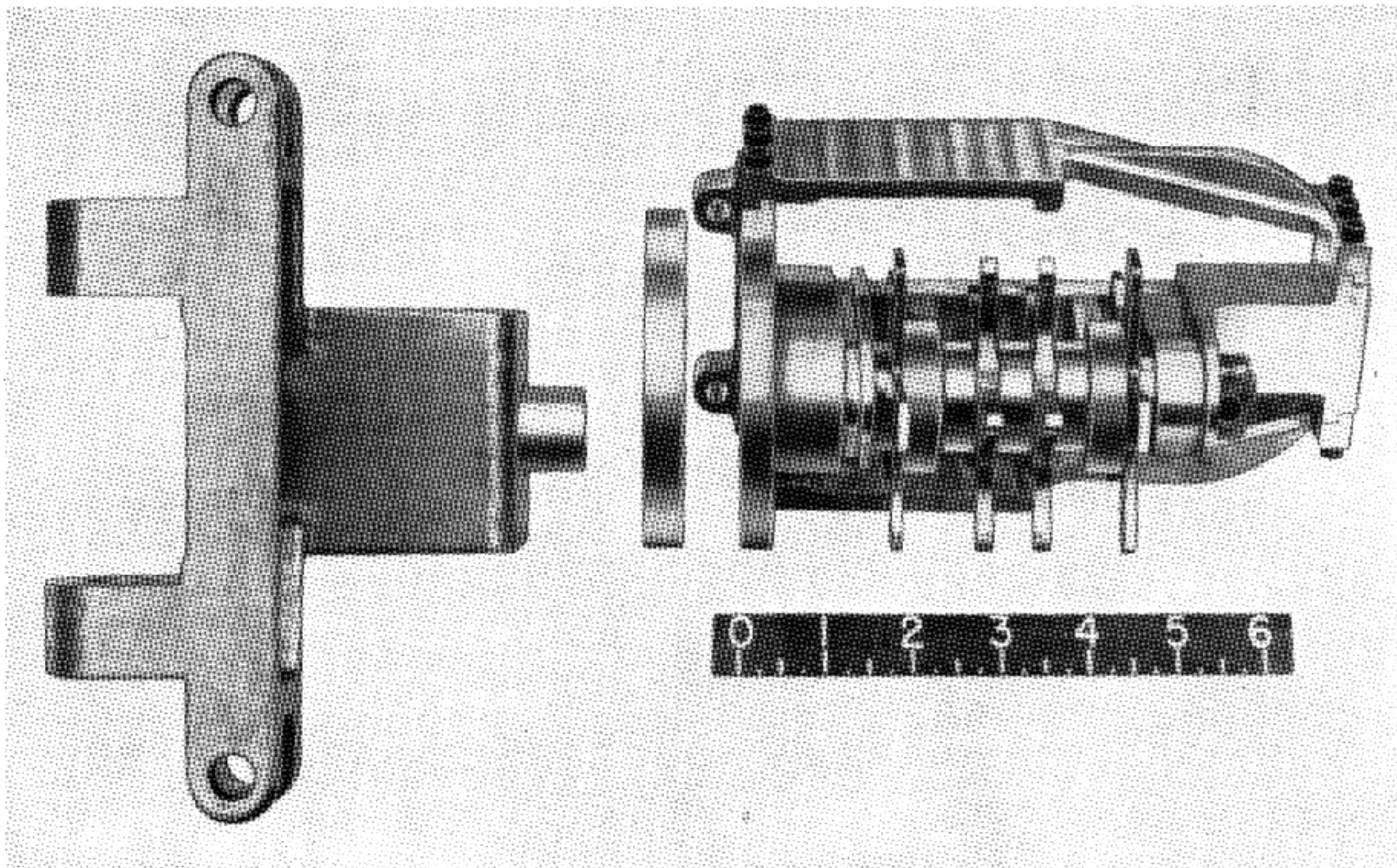


Figure 2-32. Automatic Gun, Caliber .60, T130. Feeder and tail gate assembly.

the drum support on the side opposite the extractor. The two leaves of the female contact and the insulated firing pin are connected in series to one side of the power receptacle when the female contact is engaged by the male contact. The other side of the power receptacle is connected to ground.

When the slide is in battery, the male contact is pressed between the two leaves of the female contact, which completes the circuit to the primer when it is in contact with the firing pin. Thus, when external power is applied to the receptacle, the gun fires automatically on successive rounds when the slide reaches battery position and brings the male contact on the rammer in engagement with the stationary female contact.

The charging system, developed by Norman McDonald Co. consists of percussion charger T10, the charger cylinder assembly, and the U-shaped gasline connecting the charger to the cylinder.

The charger is mounted in a bracket which fits over the end of the tube support and over the end of the right recoil spring retainer.

A large-headed screw which screws into the end of the recoil spring retainer holds the bracket in position. The charger cylinder assembly is housed in the tube support and extends through the end of the receiver on the right side in such a way that the end of the piston is against the end of the actuating slide. It is held in position by an adapter screwed into its front end.

Gas pressure produced by the firing of a caliber .30 grenade cartridge M3 in the charger actuates the charger piston, which forces the slide rearward. The forward stroke of the slide returns the charger piston.

### Mounting

Mount the gun on a rigid structure which supports it at the trunnions and at one of the two sets of receiver mounting holes. For minimum dispersion, use the receiver mounting holes located under the rear end of the drum support. The rear mounting must restrain the receiver in a vertical plane and provide freedom of movement in a longitudinal

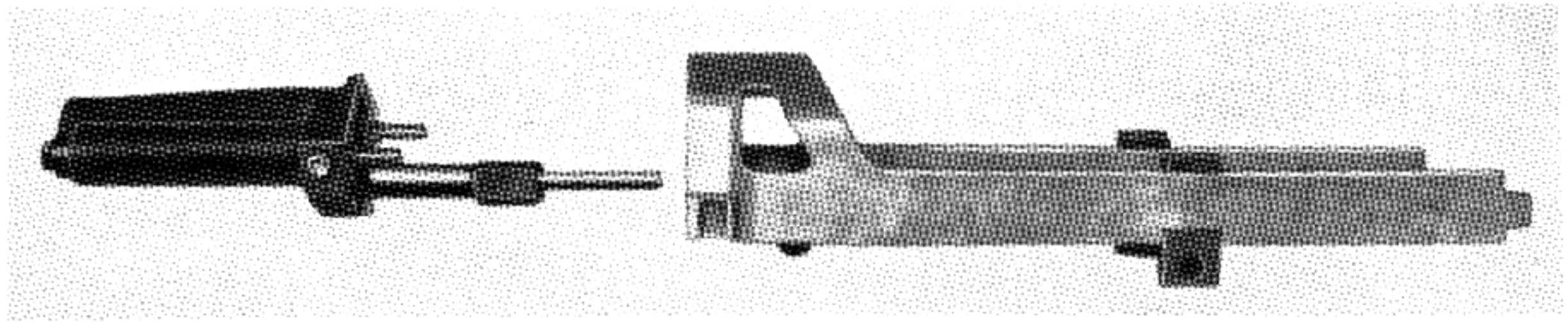


Figure 2-33. Automatic Gun, Caliber .60, T130. Trunnion and receiver.

plane so that the front trunnions take all the longitudinal load. The mounting structure must be sufficiently rigid so that it does not deflect in torsion at either the front or rear mounting points.

### Preparation for Firing

Remove the drive springs and pull the slide back to its rear position. Fit the feeder shaft tool into the back end of the feeder shaft and while holding up the drum shaft latch, pull the shaft rearward until the shaft is disengaged from the drum at the dog clutch face. Feed the ammunition belt with the first link empty into the feeder; engaging the link with the sprockets and guide track. Rotate the feeder shaft with the feeder shaft tool until the empty link is in the first ram position. Push the feeder shaft forward engaging the dog clutch face. Be sure the drum shaft latch is engaged. Push the slide forward into battery position and replace the drive springs. Charge the gun three times, using the percussion charger to bring the first round into firing position. The loading procedure is the same for either the relinking or disintegrating belt feeder.

Connect the external firing circuit to the gun-firing circuit at the power receptacle.

### Disassembly by Groups

*Removal of Feeder.* To remove the feeder, depress the lock pin releases and pull the feeder back until the base of the feeder holds down the lock pin. Screw on the feeder shaft tool at the rear of the feeder. Pull up on the drum shaft latch and remove the feeder assembly by pulling back on the feeder shaft tool until the drum shaft is clear of the drum support.

*Removal of Drum.* With the drum shaft removed, the drum may be removed by lifting it up from the drum support with the slide fully forward.

*Removal of Tube.* Pull up on the tube latch.

Give the tube a quarter turn and pull it forward until it clears the tube support.

**CAUTION.** Do not remove the tube from the gun before the drum is removed. The scaling sleeve may slip out of the drum into the space occupied by the tube. This prevents the removal of the drum until the sleeve is pushed back into position.

#### *Removal of Drum Support.*

1. Remove the drive springs by inserting a screwdriver into the slotted head of the spring guide assembly. Push in on the assembly until it clears the recessed section of the receiver end plate. Turn the spring guide a quarter turn and remove the springs through the end plate.

2. Pull the slide back to its most rearward position. Use a  $\frac{3}{4}$ -inch open-end wrench and remove the nuts and washers which attach the recoil rods to the drum support. Pull the drum support back until it clears the front bearing and rear guides, and lift it up from the receiver.

#### *Removal of Actuator Slide Assembly and Switch Cam.*

1. Unfasten the safety wires and remove the end-plate pins and the end plate.

2. With the drive springs and end plate removed, the slide and switch cam are removed by sliding them rearward until they clear their respective guides.

#### *Removal of Charger and Charger Bracket.*

1. Remove the gasline between the charger and the charger cylinder.

2. Unfasten the safety wire and remove the  $\frac{3}{8}$ -inch hexagonal head screw holding the charger bracket to the right recoil spring retainer.

3. Slide the charger and charger bracket forward until it clears the tube support.

4. Remove the right slide guide from the receiver from the right front side of the tube support. Push the charger cylinder rearward, and remove it.

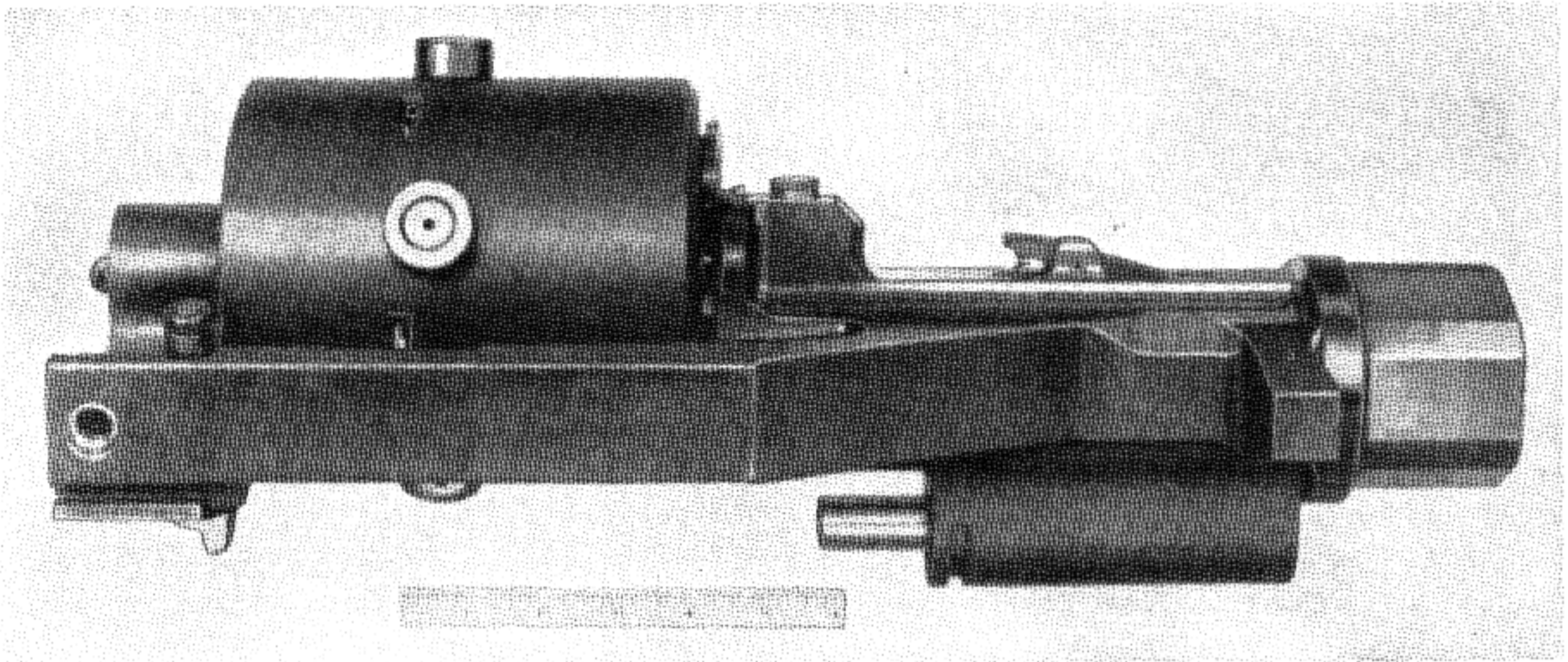


Figure 2-34. Automatic Gun, Caliber .60, T130. Drum and drum support assembly.

**Removal of Recoil Springs.** Remove the recoil spring retainer using a  $\frac{3}{4}$ -inch open-end wrench and a special spanner wrench. Push the recoil rods forward to remove the recoil spring assemblies from the tube support.

### Detailed Disassembly

#### *Feeder.*

1. **DISINTEGRATING BELT FEEDER.** Remove the feeder shaft through the front of the feeder. This releases the sprockets and guide tracks for removal. Remove the front end and the rear feeder shaft bush-

ings. The internal guides and chute may be disassembled by removing the appropriate socket-head cap screws.

2. **RELINKING FEEDER.** Remove the feeder shaft through the front of the feeder. This releases the sprockets and guide tracks for removal. Remove the front and rear feeder shaft bushings. The center and stationary guides may be disassembled by removing the necessary socket-head screws.

#### *Drum.*

1. The sealing sleeves are removed by slipping them out of the drum chambers.

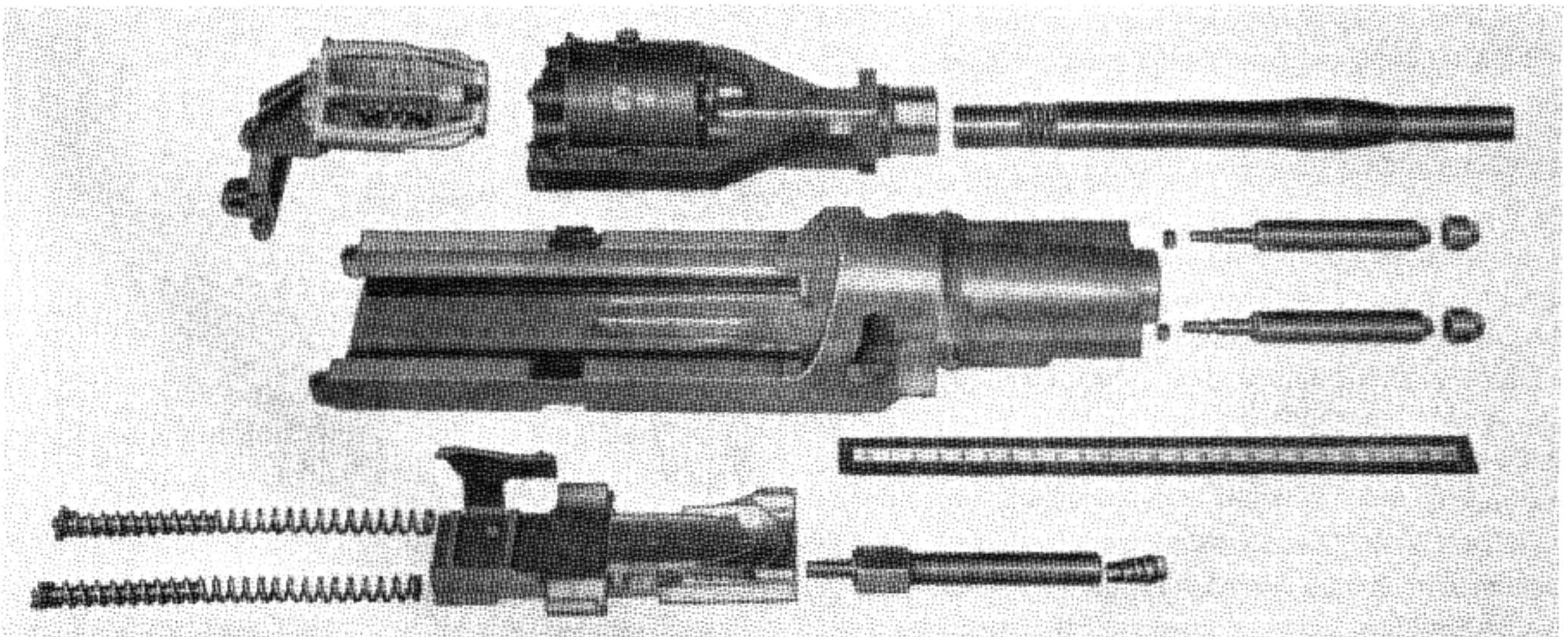


Figure 2-35. Automatic Gun, Caliber .60, T130. Major components.

2. The drum rollers are held to the drum trunnions by internal snap rings and in general should not be removed unless they are damaged and need replacement. The rollers must then be removed by hand grinding, taking special care not to damage the trunnions.

**CAUTION.** Do not attempt to pry the rollers off the trunnions. The trunnions will be damaged.

*Disassembly of Tube.* The gas orifice is the only removable part of the tube and can be withdrawn with a screwdriver.

#### *Disassembly of Drum Support.*

**REMOVAL OF GAS PISTON.** Drive out the cylinder cap retaining pin and unscrew the gas cylinder cap, using a special tool. Push the gas piston forward and out of the gas cylinder.

**DISASSEMBLY OF EXTRACTOR.** Drive out the roll pin holding the extractor cap to the extractor shaft. Remove the extractor cap, extractor spring, and extractor pawl from the extractor shaft, being careful when removing the pawl that the detent ball and spring do not fly out of the drum support. Remove the detent ball, spring, and sleeve from the inner side of the drum support and the extractor shaft from the bottom of the drum support.

Drive out the roll pin holding the extractor stop to the drum support and remove the extractor stop.

**REMOVAL AND DISASSEMBLY OF FIRING PIN ASSEMBLY.** Screw the threaded tool into the firing-pin anvil retainer pin and pull out the retainer pin. Remove the  $\frac{1}{4}$ -inch slotted nut from the rear of the firing-pin shaft. Push the shaft forward to remove the firing-pin anvil, being careful not to drop the firing-pin plunger assembly. Remove the firing-pin plunger spring, firing-pin shaft, and insulator. Remove the two  $\frac{1}{2}$ -inch socket-head cap screws holding the female contacts. Drive the contact receptacle roll pin and contact receptacle pin out and remove the female contact and the contact receptacle.

**REMOVAL OF DRUM SHAFT LATCH AND TUBE LATCH.** Drive out the drum shaft latch roll pin and remove the drum shaft latch head, allowing the drum shaft latch and spring to drop down through the hole in the bottom of the drum support. Follow the same procedure for removing the tube latch.

**REMOVAL OF ROUND RETAINER.** Drive the round retainer roll pin from the rear of the drum

support through the contact screw hole. Lift the round retainer and spring from the pocket.

**REMOVAL OF PIPE PLUG.** The pipe plug may be removed by unscrewing the top of the drum support.

#### *Actuator Slide.*

**REMOVAL AND DISASSEMBLY OF SWITCH TONGUE.** Drive the two  $\frac{1}{8}$ -inch roll pins out and remove the two serrated head shoulder screws holding down the cam insert. Remove the cam insert and lift out the switch tongue.

Depress the locking pin through the locking plate hole. Slide the locking plate out, being careful that the locking pin and locking pin spring do not fly out. Remove the locking pin, locking pin spring, and switch tongue pin from the switch tongue.

**REMOVAL OF EXTRACTOR STRIKER.** To remove the extractor striker, drive out the roll pin and pull out the striker.

**REMOVAL OF MALE CONTACT AND RAMMER.** To remove the male contact and rammer, remove the  $\frac{3}{8}$ -inch hex-head screw and lift the firing contact and insulator out. The rammer may then be removed by sliding it out of its ways.

#### *Recoil Spring Assembly.*

**CAUTION.** Under normal use, there should be no reason for the disassembly of the recoil spring assembly; however, if necessary, be sure that the ring elements are kept in their original order so that their calibration will be the same.

To disassemble the recoil springs, slide the recoil spring sleeve off. Remove the cotter pin and nut from the end of the recoil rod. The recoil spring spacer, recoil spring elements, and recoil spring seat can now be slipped off the recoil rod.

#### *Disassembly of Receiver and Tube Support.*

1. To separate the receiver and tube support, remove the six  $\frac{5}{16}$ -inch socket-head cap screws and lockwashers from inside the receiver. Pull the receiver trunnion apart, being careful not to damage the tube support key slots.

2. To remove the rear drum support guides, remove the four  $\frac{3}{8}$ -inch socket-head cap screws from the bottom of the receiver and lift the guides out.

3. To remove the switch camways, remove the six  $\frac{10}{32}$ -inch socket-head cap screws from the bottom of the receiver. Then lift the switch camways out.

4. To remove the actuator slideways, remove the twelve  $\frac{1}{4}$ -inch socket-head cap screws from the

bottom of the receiver. Then lift the slideways out.

5. To remove the feeder frame pins, drive out the  $\frac{3}{16}$ -inch roll pins and lift the pins out.

## Assembly

### *Assembly of Receiver and Tube Support.*

1. Replace the feeder frame pins into their proper holes in the receiver. Drive out the  $\frac{3}{16}$ -inch roll pins.

2. Replace the actuator slideways in the receiver base, alining the holes in the slideways with the holes in the receiver. Fasten the slideways to the receiver with the twelve  $\frac{1}{4}$ -inch socket-head screws.

3. Replace the switch camways in the receiver base, alining the holes in the camways with the holes in the receiver. Fasten the ways to the receiver with the six  $1\frac{1}{32}$ -inch socket-head cap screws.

4. Replace the rear drum support L-slot guides in their respective places in the receiver and fasten them to the receiver with two  $\frac{3}{8}$ -inch socket-head cap screws.

5. Alinc the keys at the rear face of the tube support with the key slots in the front face of the receiver. Push the tube support and receiver together, being careful not to damage the key slots. Replace the six  $\frac{5}{16}$ -inch socket-head cap screws and lock-washers, thus fastening the tube support and receiver together.

*Recoil Springs.* Replace the recoil spring seat against the shoulder at the rear end of the recoil rod. With the recoil spring elements assembled in the proper sequence and original order, slip the front end of the recoil rod through the elements, being careful not to drop them. Replace the recoil spring spacer, recoil spring nut, and recoil spring sleeve. To set in a preload of 1,250 pounds, tighten the nut until the distance between the rear face of the recoil spring seat and the front face of the recoil spring spacer is 7.24 inches. With this distance set, lock the nut in place using a cotter pin. Replace the recoil spring assemblies in their housing in the tube support.

**CAUTION.** Be sure to lock the nut in place with the cotter pin. Operation of the gun without the cotter pin will result in loosening of the nut and changing the preload in the ring springs. This will cause erratic recoil and possible damage to the gun.

### *Charger.*

1. Replace the charger cylinder in the tube support.

2. Slide the charger and charger bracket over the front end of the tube support.

3. Replace the gas line between the charger and the charger cylinder. Make sure the fittings are tight so that there will be no gas leakage.

### *Actuator Slide and Cam Switch.*

1. Replace the switch tongue pin and the locking pin spring into position in the switch tongue. Place the locking pin on top of the locking pin spring, then depress the locking pin far enough to slide the locking plate over the locking pin until the locking pin locates itself in the locking plate. Replace the switch tongue and cam insert into their position on the slide. Replace the two serrated-head shoulder screws holding down the cam insert. Drive in the two  $\frac{1}{8}$ -inch roll pins that prevent the shoulder screws from turning.

2. Replace the extractor striker into position on the right side of the slide and lock in place by driving in the roll pin. Be sure in replacing the striker that the most forward part of the sloped face of the striker is on the outside of the slide.

3. Slide the rammer into position at the rear of the slide. Replace the male contact insulator and the male contact into position on the rammer and fasten to the slide by the  $\frac{3}{8}$ -inch hexagonal-head screw, being sure that the male contact remains insulated from the slide.

4. Place the slide on top of the switch cam, making sure the switch tongue pin is engaged in the cam surface. Slide the actuator slide and switch cam simultaneously into their respective ways in the receiver.

### *Drum Support.*

1. Replace the pipe plug on top of the drum support. Be sure this is tight so that no gas from the tube orifice will leak around the tube and out of this locating hole.

2. Replace the round retainer spring and the round retainer into the pocket at the left rear section of the drum support. Drive the round retainer roll pin forward through the contact screw hole.

3. Place the tube latch spring over the shank of the tube latch and slip them into the tube latch hole from the rear of the tube support. Use a long rod to hold the latch up in position so that the tube

latch head can be placed on the tube latch shaft. Drive in the roll pin holding the tube latch head to the tube latch.

Follow the same procedure in replacing the drum shaft latch.

4. Firing pin assembly. Place the firing-pin spring in the recessed hole of the firing-pin shaft and insulator assembly. Replace the shaft in the drum support. Place the firing-pin plunger assembly into the hole of the firing pin anvil and slide this into the large hole at the rear of the drum support. Replace the firing-pin anvil retainer pin for holding the anvil in position in the drum support. Place the female contact and insulators into position on the rear face of the drum support and replace the two  $\frac{1}{4}$ -inch socket-head cap screws and the  $\frac{1}{4}$ -inch slotted nut. Replace the contact receptacle and the contact receptacle pin, and lock in position on the drum support by driving in the contact receptacle roll pin.

5. Extractor assembly. Replace the extractor shaft in the drum support. Replace the detent spring into the blind hole in the detent sleeve, and replace the sleeve into the detent hole in the drum support. Place the detent ball against the detent spring and depress the ball until it is flush with the side of the drum support so that the extractor pawl may be replaced on the extractor shaft. Replace the extractor shaft spring and extractor shaft cap. Drive in the roll pin holding the assembly together. Replace the extractor stop on the drum support and drive in the roll pin.

6. Gas piston. Slide the gas piston into the gas cylinder of the drum support. Replace the gas cylinder cap using the special tool. Drive in the gas cylinder cap retaining pin.

7. The drum support may now be slipped into position with the receiver and tube support by first engaging the front hexagonal section of the drum support with the tube support socket, the recoil bolts with the drum support lugs, the L slot supports with the L slots, and the notch at the front bottom of the drum support with the ears of the switch cam. Next, replace the nuts fastening the drum support to the recoil rods, tightening them sufficiently to bring the rear shoulder of the recoil rod up against the drum support lug. Now pull back on the drum support so that the rear end of the recoil spring assembly is seated against the rear end of the bore in the drum support which houses the spring assembly.

Replace the recoil spring retainers, making sure that they are only hand tight. Replace the  $\frac{3}{4}$ -inch hexagonal-head screw into the end of the right recoil spring retainer to hold the charger bracket to the drum support. Place the cotter pins on the rear nuts of the recoil rods and safety wire the left recoil spring retainer and the hexagonal-head screw in the end of the right recoil spring retainer.

**WARNING.** Proper functioning of the gun requires proper assembly of the recoil spring system to the drum support and tube support. Careless and improper assembly will result in erratic recoil and subsequent damage to the gun; therefore, be sure:

1. The drum support lug is against the shoulder of the recoil rod.
2. The rear end of the recoil spring assembly is seated against the shoulder in the tube support.
3. The recoil spring retainers are replaced hand tight.
4. All nuts of the recoil system are cotter pinned and the retainers safety wired.

*Tube.* Replace the tube orifice. Slide the tube into the tube support. Lift up the tube latch and continue sliding the tube rearward until it stops. Release the tube latch and rotate the tube until the latch drops into engagement with the hole in the tube.

**CAUTION.** Be sure that the tube latch is engaged with the hole in the tube.

*Drum.* Replace the sealing sleeves in the drum with the unnotched faces forward. Place the drum in the drum support with the actuator slide fully forward. Be sure that the drum roller is properly engaged with the slide cam.

*Feeder.*

1. Replace the feeder end plate and the end plate pins. Safety wire the end plate pins.
2. Insert the guide rods in the slide drive springs, and slip the assemblies through the holes in the end plate in the holes in the rear of the slide. Engage a screwdriver with the slotted head of the drive spring guide rod and compress the spring until it clears the notched section of the end plate. Rotate the assembly  $90^\circ$  so that it is aligned with the recessed section of the end plate. Let up on the screwdriver enough to seat the drive spring guide against the end plate. Repeat the procedure for the second spring.

## 3. Assembly of feeder.

Disintegrating belt feeder. Replace the front and rear feeder shaft bushings. Replace the internal guides and chute. Safety wire all socket-head cap screws. Insert the feeder shaft through the front bushing and replace the tracks and sprockets in the following order: front guide track, front guide sprocket, link connector support sprocket, drive sprocket, link connector support sprocket, spacer, rear guide track, ramming sprocket.

Relinking feeder. Replace the four stationary guides. Insert the center guide so that the front and rear bushings may be replaced. The bushings must be replaced before the socket-head screws are replaced. Safety wire all screws. Insert the feeder shaft through the front bushing and replace the guide and sprockets in the following order: guide track with track facing center of feeder, spacer, link connector support sprocket, drive sprocket, link connector support sprocket, spacer, guide track with track facing center of feeder, ramming sprocket with hub toward the center of the feeder.

4. To replace the feeder on the gun, first slip the drum shaft through the rear drum shaft support, the drum, and the front drum shaft support. It may be necessary to hold up the drum slightly in order to align the drum and drum-shaft bearings. Lift up on the drum-shaft latch. Now push forward and down on the feeder frame until the feeder is locked into position by the feeder locking pins. Release the drum shaft latch, rotating it until it engages the groove in the drum shaft.

CAUTION. Be sure the latch is engaged in the groove.

## Conversion from Right-Hand to Left-Hand Feed

The following parts are either changed or reversed in assembly for conversion from right-hand feed to left-hand feed.

*Switch Cam.* A different switch cam is used for left-hand feed to provide clockwise rotation of the drum.

*Rammer.* The right-hand feed rammer must be replaced with one made for the left-hand feed. For left-hand feed, the rammer is located on the right side of the slide.

*Extractor Striker.* The extractor striker is replaced with one made for left-hand feed. Its position for left-hand feed is on the left-hand side of the slide, with the most forward part of the striker face on the outside of the slide.

*Extractor Assembly.* The right-hand feed extractor must be replaced with one made for the left-hand feed. Also for left-hand feed, the extractor is assembled on the left side of the drum support. The extractor stop is for either right- or left-hand feed. For left-hand feed, the stop is located on the left side of the drum support.

*Receptacle Bracket Assembly.* The receptacle bracket assembly can be used for either right- or left-hand feed, however, for left-hand feed the bracket assembly is located on the right side of the drum support.

*Round Retainer.* The round retainer must be assembled on the right side of the drum support for left-hand feed.

*Feeder.* For left-hand feed, a left-hand feeder frame and deflector must be used. The feeder sprockets and guides are the same.

## Chapter 3

# ORDNANCE CORPS POWER-DRIVEN MULTIBARREL REVOLVER CANNON

## SECTION 1. HISTORY AND BACKGROUND

Before the end of World War II, the Ordnance Corps realized that greatly increased rates of fire of aircraft guns would be required to be effective against the increasing speed of jet aircraft. In order to obtain any marked improvement in automatic weapons, it was essential that the fundamental characteristics of existing types be improved, such as (a) increase in firing rates, (b) reduction and smoothing of machine gun actions and (c) increased muzzle velocities in spite of the resultant barrel erosion problems.

The conventional types of single barrel reciprocating action weapons whose rate of fire is determined by gun energy, were approaching their design limit of rate of fire. These weapons require the reciprocating mass to be stopped at the time of locking and the direction of motion to be reversed when rebounding from the buffer during each cycle. As the velocity of the reciprocating mass reaches increasingly higher limits for the increased rates of fire, the impacts become an important problem, since they have to be absorbed by the weapon and imparted to the aircraft frame. Increasing rates of fire had caused increasing difficulties in barrel erosion and control of moving parts. It was believed that this situation would be remedied by the use of several barrels rather than one, thus securing better cooling periods for each barrel. Further, the use of a continuous power source, rather than the impulsive action of the powder gases, was expected to provide smoother action and longer life of components.

The best known progenitor of this type of weapon is the Gatling gun. While this weapon, whose operating principles were originally patented 4 November 1862, was operated by hand at a moderate

rate of fire, it was decided to investigate the possibility of using a power drive. In early 1946, an electric motor drive for a model 1903, 10 barrel, 45-70 Gatling gun was provided and operated for a short period at the rate of 5,000 shots per minute. A theoretical study of the mechanism showed that even higher rates of fire were attainable. Such a gun, to be profitable, must show a profit in terms of weight per barrel, rate of fire per barrel, and in other ways, to overcome the handicap introduced by making all the barrels subservient to a common operating mechanism.

On 18 January 1946, the General Electric Co. submitted, at the invitation of the Ordnance Corps, proposed methods for conducting a development study to work out an improved aircraft gun of increased firepower, improved ballistics, better control

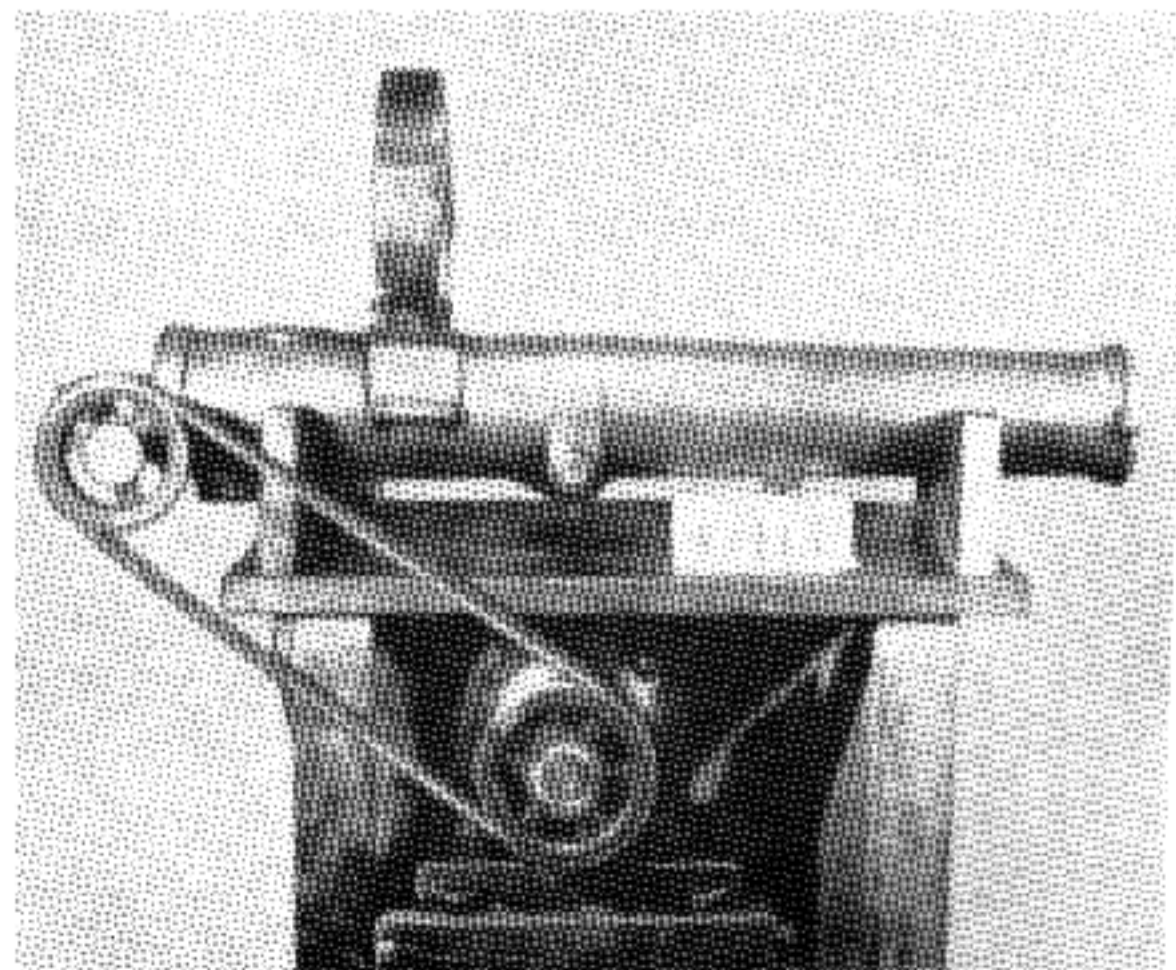


Figure 3-1. An old Gatling Gun with motor drive. This gun was used experimentally in the development of the T45.



of reciprocating components, and reduced length to improve its aircraft adaptability. The General Electric Co. was requested by the Ordnance Corps to quote on the study and development of a multi-barreled gun of the Gatling type.

In June 1946 a contract was negotiated with the General Electric Co., Schenectady, N. Y., for a preliminary design study for a gun to meet the following gun design characteristics:

**Mechanism:** A multibarrel gun, similar to the Gatling gun, driven by an external power source. The number of barrels in the initial design is not prescribed. A jam in one barrel should not affect the others.

**Caliber:** .60/50 (T41 cartridge; later changed to caliber .60 round.)

**Barrel length:** 60 inches.

**Maximum gun length:** 80 inches.

**Maximum weight:** 100 lb/barrel.

**Minimum rate of fire:** 1,000 r. p. m./barrel.

**Firing mechanism:** Electrical primers.

**Feed:** To be determined by analysis.

**Firing control:** Electrical. To permit firing without loss of time and stopping without loss of ammunition. Maximum rate of fire is desired throughout burst. Clutch or cutout may be provided to decrease up-to-speed time.

**Cook-off controls:** Provision must be made so that no cartridge remains in a chamber at the end of a burst. Barrels should remain open after firing to permit cooling by natural air draft. Provisions for fluid cooling if required.

**Reloader:** Gun to be initially loaded by armorer; necessary for reloader mechanism to be deter-

mined by possibility of normal feeding cycle being interrupted by malfunctioning.

**Mounting provision:** Spring-loaded mounting to provide for smoothing of recoil load transmitted to the airplane structure. Installation proposed for aircraft.

**Access:** Vital parts of the gun must be accessible for servicing.

### Basic Design

The design arrangement selected for the first test gun was a five-barrel model of medium size and performance suitable for construction as a development sample.

The principal parts may be designated as: Support; feed unit; housing; bolt; rotor; barrel; drive unit; lock.

The design follows the Gatling principle, which lends itself satisfactorily to the application of modern ammunition and electrical control. Where there is duplication of parts, like the bolts and barrels, other items like the recoil spring supports and general structure are common. This arrangement results in a considerable saving in weight and space. Barrels are grouped in a circle and fastened at the breech end to a single central member. There is an additional support approximately 2 feet forward of the breech. The central member, which is referred to as the rotor, carries individual bolts in guide slots which reciprocate in a conventional function under the action of a spiral cam on the outside of the housing member.

A reduction in diameter at the muzzle is achieved by bringing the barrels together at the end at an

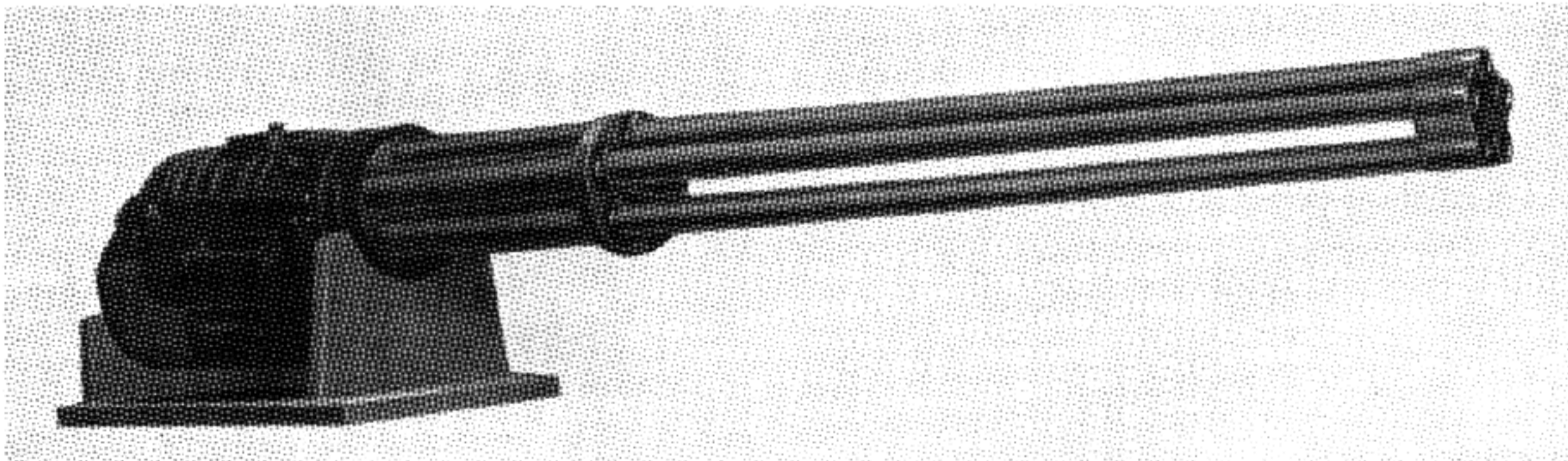


Figure 3-2. Wooden model of the early stages of Ordnance Corps Electric-Operated Machine Gun.

angle of approximately three-quarters of a degree, instead of maintaining parallel axes. The relative value of this arrangement is easy to see.

Ammunition is fed by belt from the side with links discharged before entering the gun, as in the 20-mm M2 feed mechanism. The cartridge is driven by a sprocket into the space ahead of the bolt from which point it is forced into the barrel, fired, and the case ejected in the course of the bolt's reciprocating travel. Suitable guides maintain the cartridge in position during its motion.

### Early Design Problems

The necessity of quick starting of the gun without undue stresses on the ammunition belt and the matter of clearing the gun for prevention of cook-offs have necessitated the use of certain control auxiliary which would not have been otherwise required.

It was early determined that, in a gun of the proportions that existed in this type of mechanism, it would be possible to store sufficient energy in a small flywheel to permit starting of the gun rotor in a satisfactorily short space of time, 0.1 to 0.2 second. Hence with the use of a flywheel and a quick-acting clutch and brake unit, it became possible to positively start and stop the gun every time it was so desired.

Clearing the barrels of live ammunition is more difficult. If cooling were adequate, this problem might not have arisen. At this time, however, the cooling problem was not considered sufficiently developed to say what the possibilities were.

A second rather simple expedient was to back up the gun after firing by employment of a heavy spring. This required that the bolt secure a firm hold on the cartridge at an early stage, a mechanical problem which was not solved at this time. It also implied that due provision was needed for some backward motion of the ammunition belt. In either of these methods, the feed sprocket was attached directly to the drive and moved with the gun rotor. General Electric engineers elected, however, at this time at least, to adopt a more complicated but more comprehensive method of clearing the gun. The scheme decided upon was to provide for independent stopping of the feed and gun rotor. There were variations of this cycle, but basically the feed was stopped before the gun, an arrangement which permits the gun to empty itself before stopping. A

special type of brake and clutch combination assuming precise angular engagement and disengagement had to be developed to fulfill this need.

The operating cycle based on the overall arrangement may be described briefly as follows:

As a preliminary to firing, a master switch or action switch is closed; accordingly, the electric motor with its attached flywheel is started. This part of the system is designed to operate on a continuous basis. The firing switch is now closed as desired, operating through electrical switching. The main clutch is actuated, bringing the gun rotating element up to speed. At the same time the circuit to the electric primer is energized. During this part of the cycle, the ammunition feed sprocket is locked to the gun rotor in the correct angular relationship, so that ammunition feeding commences with the starting of the gun rotor. The main clutch is so designed that the time required for obtaining full speed is between 0.1 and 0.2 second, fast enough to meet normal firing requirements but slow enough to prevent high acceleration forces on the ammunition belt. At the conclusion of the burst, the feed sprocket is stopped abruptly by the feed clutch action within approximately 30 degrees of angular rotation. This action stops the first round of ammunition with an acceleration equivalent of 40 g's; however, because of the elastic action of links and chute, the shock on succeeding rounds is reduced rapidly. Simultaneously with the feed clutch action, the main clutch is changed from driving to braking position. Since the braking action is designed to occur in the predetermined time limits of 0.1 to 0.2 second, the gun rotor continues to turn for a sufficient angular distance to clear the gun of all live rounds. Whether or not the residual rounds are fired out or discharged live is determined by the time delay or interlocking relationship of the primer circuit. It is expected that the primer will be operated from a relay having suitable time delay on dropout. Actual firing of the cartridge takes place after the bolt has pressed the cartridge into the breech and is securely locked. Firing is accomplished by the closing of the final contact to the primer button by means of a fixed contact in the fixed gun cover. An extension on the bolt strikes this contact as it passes in the course of its circular motion.

The action of the bolt in handling the cartridge, the method by which it is held securely during the

interval of high chamber pressure, the feed action and the recoil are vital functions which deserve some extended explanation and discussion. These functions must be synchronized and timed in such a way as to insure reliable working of the other component parts.

*The Locking Function.* The means by which the bolt is held forward against the cartridge butt during the firing period is important to the safety of operation. A force of approximately 50,000 pounds is developed momentarily during the combustion period, diminishing gradually to from 2,000 to 3,000 pounds at the time of extraction. The total time of the locking cycle is approximately 6 milliseconds corresponding to a linear travel of about 2 inches at a mean pitch diameter of  $5\frac{3}{4}$  seconds. Since there are five bolts, the roller lock is performing a locking operation during 50 percent of the total firing time. The forces are so great and the duty so severe that there was some question at this time of the ability of a roller of moderate size to stand up. There was a further consideration that several horsepower in friction can easily be consumed at this point. This problem presented one of the biggest obstacles to be overcome by the General Electric engineers in the construction of this unusual weapon.

While the roller lock possessed certain virtues, particularly that of simplicity, there were disadvantages of high roller stress, friction, and deflection, all of which made it difficult to predict successful operation. Roller stresses were calculated to be in excess of 400,000 pounds per square inch, and it was difficult to predict the friction developed under such conditions even where materials were able to withstand the direct loads. The maximum deflection was estimated to be as much as one-sixteenth inch. It was decided to use not the roller lock but an interrupted thread attaching the bolthead directly to the barrel extension. In this arrangement, the bolthead is rotated  $13^\circ$  at the forward end of the stroke into locking position. This motion is accomplished by means of a linkage in the barrel extension, which is operated by a drum cam on the frame.

*Bolt Action.* The bolt carries the cartridge from the feed groove into the barrel; fires the primer and blocks the breech during the combustion period; pulls out the fired case by means of springtype extractors; and holds it in position to be discharged through the case disposal chute. The reciprocating

motion by which the bolt performs these operations is obtained through contact between a driving roller and a spiral double-acting cam surface. There is a substantial dwell period at each end of the stroke, the one at the rear position being necessitated by the interval of disposing of the empty case and placing a new round in the feed slot. The dwell period at the forward end is determined by the time required (about 6 milliseconds) for the gas pressure to rise and fall during the bullet discharge. The pressure of these dwell periods is the same as steepening the cam slope of the intervening space. The cam is a critical element. It must be designed for minimum acceleration forces in three directions and must have a safe stall angle. It was believed that the cam angle of  $60^\circ$  was as high as could be safely used and that  $45^\circ$  would be much better. A smaller cam angle could be obtained by reducing the bolt stroke or by increasing the mean diameter. The diameter is determined by the number of barrels. It was decided to go to a six-barrel design, thereby reducing the cam slope from 60 to 55 with a resultant decrease in horsepower of the motor, increase in rate of fire from 5,000 r. p. m. to 6,000 r. p. m., and increase in total weight of 30 pounds, which is the weight of the additional barrel. The rate of fire per pound of weight was increased by about 10 percent.

### Firing of First Completed Model

The first firing model was completed and fired in April 1949. Considerable bench testing had been done prior to this date. One of the advantages of this gun is that it can be cycled rapidly by the motor, or slowly by hand before actual firing is done, thereby saving money and time in the development program. Rates of 2,500 r. p. m. were obtained for short bursts. There were occasional misfires due to external electrical circuits or primer misfires. Starting and stopping action was rapid and smooth.

*Conference on Electric Primers and Gun Ignition Circuits.* Personnel from General Electric, Frankford Arsenal, Springfield Armory, Ballistic Research Laboratory, and Aberdeen Proving Ground, and other interested parties were invited to a conference held in Washington on 17 March 1949, to exchange information relative to electric primers and gun ignition circuits.

Information disclosed at this meeting indicated that:

1. The primer would function satisfactorily at 50,000 feet altitude and as low as  $-80^{\circ}$  F.
2. The resistance of the wireless type primer (T59E2) could not be controlled within the limits requested by General Electric.
3. It is necessary to use a condenser discharge firing circuit.
4. Functioning of the wireless type primer is independent of resistance.
5. The application of higher voltage (180 to 250 volts) insures uniform functioning and minimum ignition time.

Based on this information, General Electric withdrew its objections until such time as further tests indicated trouble was occurring.

*Experiments Conducted With Electric Primers.* Preliminary measurements at General Electric of current and voltage requirements to fire this ammunition indicated minimum resistance of 50 ohms and a voltage sensitivity somewhat higher than the previously submitted Remington sample lots that required 50 and 100 volts for firing. In order to use this ammunition, currents of at least 0.2 ampere were employed. General Electric stated that they believed that the use of this ammunition could be expected to lead to early failure of presently designed firing components by arcing and serious erosion of contacts, especially at high altitude, and they thought this might jeopardize the development of the T45 gun.

Primer leakage was encountered with ammunition containing T59E2 primers, as shown by dark ring deposits on bolt face coinciding with the primer diameter. This evidence indicated that the primer had ruptured and the powder gases had discolored the bolt face. It was also concluded that the link stripping arrangement, together with the feed and guide systems, needed further refinement to establish reliability. Careful examination was made of all parts with only slight corrections being found necessary before further firing tests were satisfactorily conducted.

*Other Results of Firings.* Mounting and recoil did not appear to be serious problems. Due to the high-firing frequency, it would be possible to realize the low forces obtainable with single-barreled guns,

but in relation to weight and fire power, the figures should be as good or better.

By June 1950, 20 round belts had been fired at average rates of 4,000 rounds per minute, with a maximum in excess of 5,000 rounds per minute with dispersion of  $3\frac{1}{2}$  mils for 100 percent of shots. All firing was conducted from a fixed mount, using a standard capacitor circuit. By September 1950, maximum rate of fire of 6,000 rounds per minute had been obtained. Work progressed slowly due to fund restriction.

The first model used a handmade link of the 20-mm type. A two-piece link previously developed for the caliber .60 round with further development, appears to be more practicable. The second gun fabricated to use this link was completed and fired in July 1950.

### Designations and Characteristics of Various Models

In September 1950 four more "A" prototype guns were proposed to be used by the Ordnance Corps and Air Force for engineering tests and installations. Two additional models, designated B1 and B2, to include refinements due to testing of the "A" models, were to be made. Twenty-five additional models, designated "C", to be made with temporary production tools were scheduled.

An ammunition booster mounted on an ammunition container of 200 rounds capacity was designed and fabricated. The booster was driven directly from a gear takcoff on the gun through a flexible shaft. This booster functioned satisfactorily and a burst of 157 rounds was fired without trouble. With the exception of a single round, all shots fell within a 3-mil diameter.

As of May 1952, 7 "A" model guns had been delivered, were under test, and had been fired a total of 75,000 rounds, one gun having fired 7,300 rounds without a stoppage. Three additional "A" models were scheduled for completion by June 1952. These are all prototype guns with experimental features, consequently, their weights are excessive. A detailed description of the "A" models is given in section 2. The rate of fire on these models is being held between 4,000 and 4,500 r. p. m. although this model has been fired at 6,000 r. p. m. These guns have the flywheel feature described earlier. Twenty-seven "C" models were scheduled to be built as

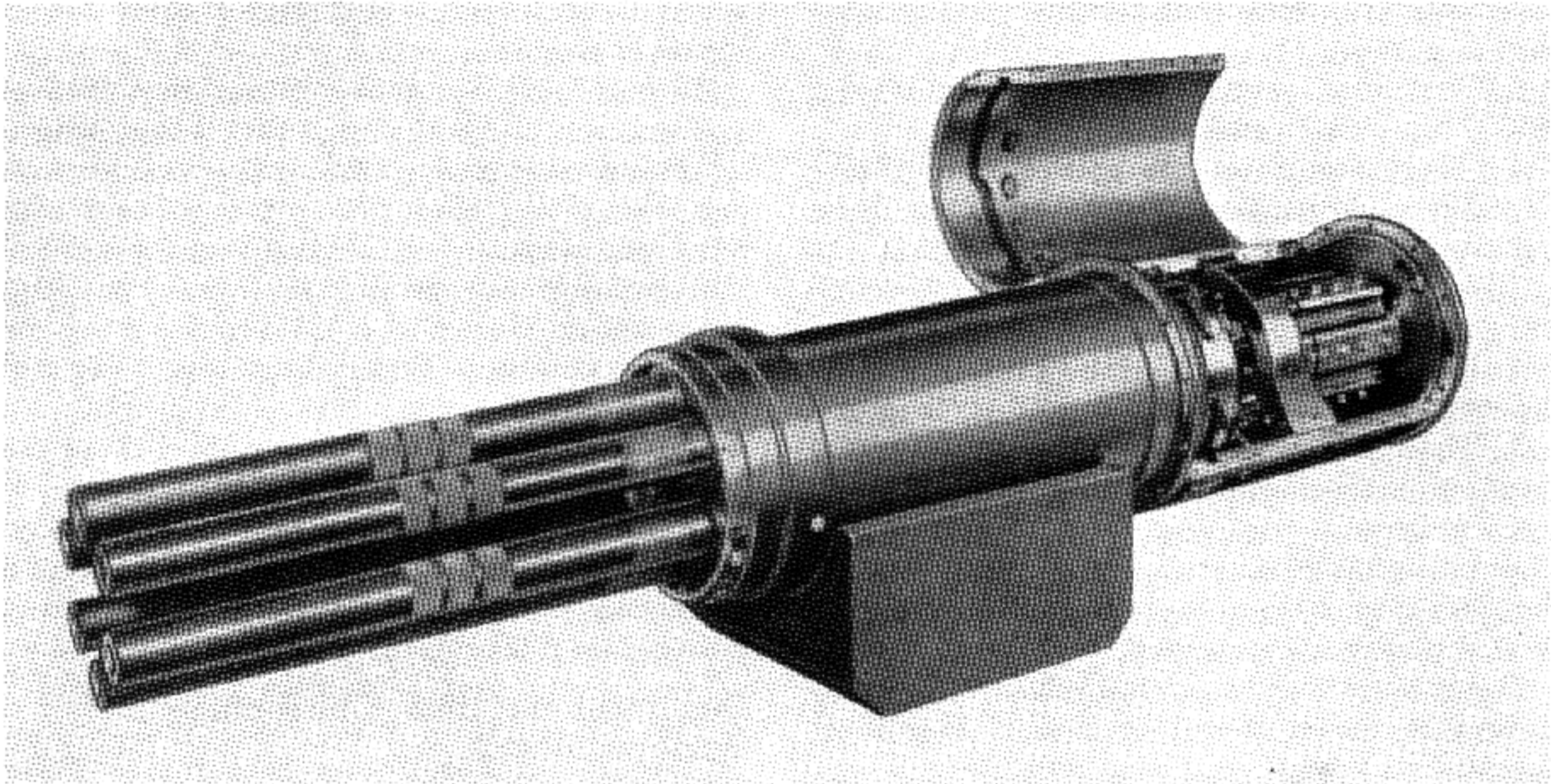


Figure 3-3. Ordnance Corps Electric-Operated Machine Gun, Caliber .60, T62. Receiver cover open.

20-mm T171 guns, delivery starting in August 1952. These guns are lighter in weight, weighing about 365 pounds of which 180 pounds are barrels. Six conversion kits to convert to T45, caliber .60 guns, and five kits to convert to T150, 27-mm will be provided. The 27-mm guns will weigh about 330 pounds because of shorter barrels. These conversion kits will consist of barrels, barrel clamp and front sprocket and stripper in the feeder. Calibers of the guns may be changed quickly by removing barrel clamps, replacing barrels which are of the quickly removable type, and changing to a feeder containing the appropriate parts. A further model, designated "D", is contemplated, which will be

materially reduced in weight, weighing about 300 pounds and will fire at an average rate of 6,000 r. p. m. There was a T62 model, intended to meet a requirement of 52 inches overall and a barrel length of 38 inches. The requirement for this model has been withdrawn.

The varying characteristics for the different calibers in the "C" models may be summarized as shown in the accompanying chart. All "C" models are intended for aircraft use.

The general design of the "C" models will follow that of the "A" models, with improvements in design. Therefore, the general data given for the "A" models are applicable to the "C" models.

	T45	T150	T171
Weight:			
without barrels.....pounds..	185	155	185
with barrels.....pounds..	365	335	365
Muzzle velocities.....ft./sec..	3,550	3,300	2,000
Primer.....	(1)	(1)	(1)
Length of round.....inches..	6 $\frac{3}{8}$	6 $\frac{5}{8}$	6 $\frac{3}{8}$

<sup>1</sup> Electric.

## SECTION 2. "A" MODEL T45 CALIBER .60 MACHINE GUN

## Design Data and Specifications

Type: Electrically operated, rotating, multiple barrel.

Weight:

Without barrels: 256 pounds.

With barrels: 427 pounds.

Length: 74 inches.

Approximate profile dimensions: 14 by 14 inches.

Number of barrels: 6.

Rotation: Clockwise when viewed from muzzle end.

Power sources:

Motor: 24 volts, d. c. power, 300-350 amperes.

Firing circuit: 250-350 volts, d. c. power, 100 ma.

Firing rate: 4,000 rounds/minute at 668 revolutions/minute and 24 volts at motor.

Suggested maximum safe firing time (continuous burst): 7 seconds.

Dispersion: 3 to 4 mils (80 percent circle).

Time interval to obtain full firing rate: 0.2 to 0.4 second.

Recoil reaction: 4,000 to 8,000 pounds on 250,000 pounds/inch firing platform. 18,000 to 20,000 pounds on rigid mount.

Location of cartridge and link ejection: Bottom.

Location of feeder: Right side at 45°.

Recommended maximum ammunition belt pull at feeder: 50 pounds.

Recommended maximum length of belt without booster: 5 feet horizontal or 4 feet vertical.

Feed is by belt, with disintegrating link of strip-off type.

Belt speed corresponding to above rate of fire: 500 feet/minute, with maximum acceleration of 1.5 g.

## General Description

The T45 gun is an electrically operated, multi-barreled, caliber .60 machine gun, designed for handling belted electric-primed ammunition at speeds

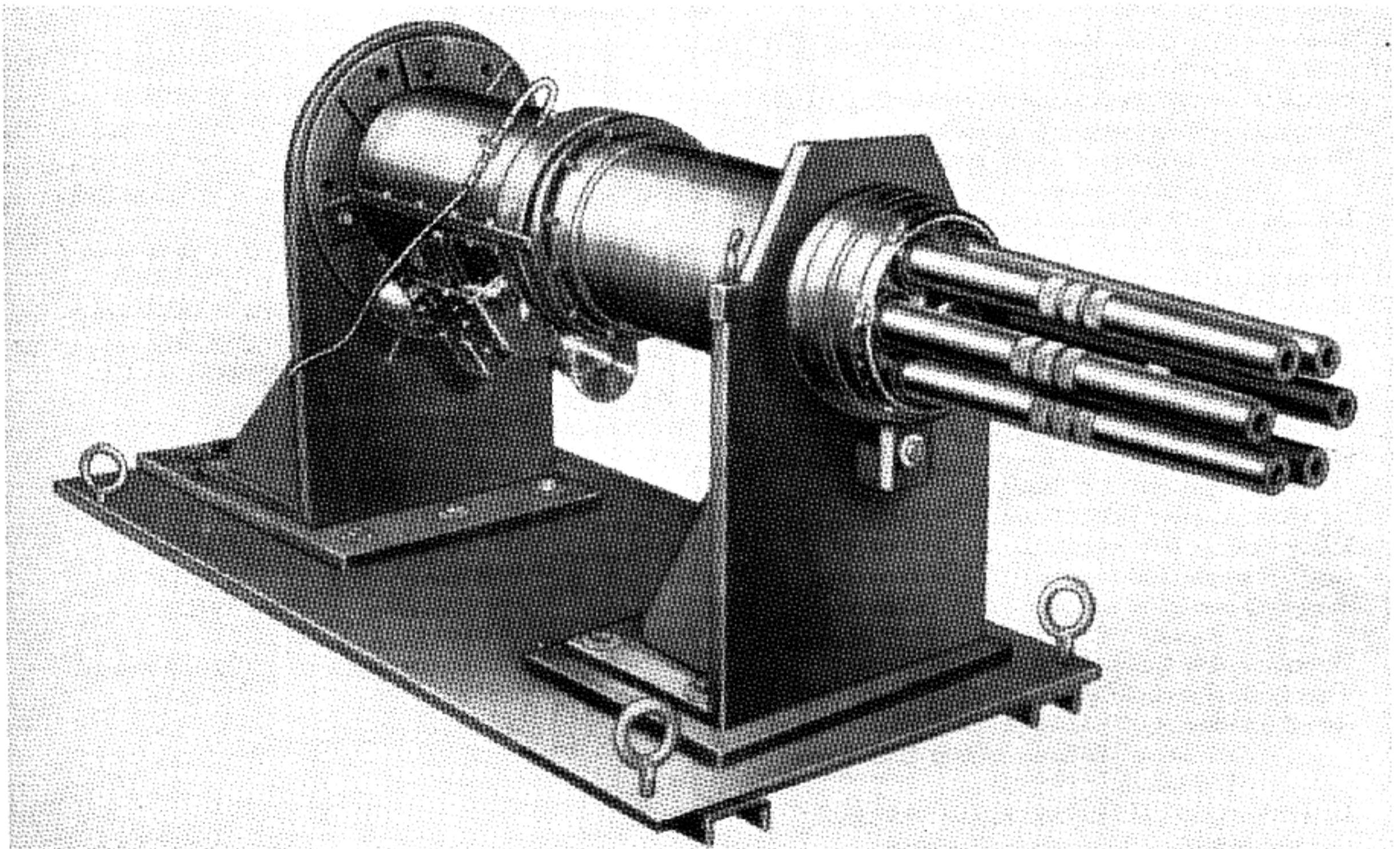


Figure 3-4. Ordnance Corps Electric-Operated Machine Gun, Caliber .60, T62. Mounted on test stand.

up to 4,000 rounds per minute. The gun is driven by a 24-volt d. c. drive motor. The associated solenoids require a 24-volt d. c. power supply and a firing circuit, a minimum of 250 volts d. c. power. No separate charger is required.

The T45 gun consists of a rotating firing mechanism with six 60-inch barrels. The weapon will operate satisfactorily with caliber .60 electric-primed ball ammunition belted by means of T44E4 links.

*Firing Mechanism.* The firing mechanism consists essentially of a stationary member which encloses a rotating member. The stationary member is made up of an end cover, upper and lower housings, forward casing, drive unit, feeder, and main cam. The rotating member consists of a rotor assem-

bly (rotor and connection block), rotor extension, six slide assemblies, and the forward bearing block. The rotating member is supported in the stationary member on two sets of bearings. Five thrust bearings, in the rear of the rotor, transmit recoil forces to the housing by means of a shaft through the back cover. Six bearing and roller assemblies in the forward bearing block support the front end of the rotating member in the forward casing.

Recoil adapters, one on each side of the casing, provide the two primary mounting supports.

The drive and feeder assemblies are mounted to the outside of the lower housing, one on each side of the gun. The main cam is fastened to the inside of both the upper and lower housings. In addition,

#### General Data Caliber .60 T45 Machine Gun

Gun length: 74 inches.  
 Gun weight:  
     With barrels: 477 pounds.  
     Without barrels: 306 pounds.  
 Rate of fire: 4,500-5,000 rounds/minute.  
 Muzzle velocity: 3,000 feet/second.  
 System of operation: Power-driven multibarrel (Gatling principle).  
 System of locking: Each barrel has own locking device.  
 System of feeding: Disintegrating metallic link.  
 Method of headspace: Factory established (can be adjusted if necessary).  
 Location of feed opening: Upper right-hand side at 45 degrees.  
 Location ejection opening: Bottom of receiver.  
 Method of charging: Electric.  
 Method of cooling: Air.  
 Approximate profile dimensions: 14 inches x 14 inches.  
 Number of barrels: 6.  
 Rotation: Clockwise when viewed from muzzle end.  
 Power sources:  
     Motor: 24 volts, d. c. power, 300-350 amps.  
     Firing circuit: 250-350 volts, d. c. power, 100 ma.  
 Firing rate: 4,000 rounds/minute at 568 revolutions/minute and 24 volts at motor.  
 Suggested maximum safe firing time (continuous burst): 7 seconds.  
 Dispersion: 3 to 4 mils (80 percent circle).  
 Time interval to obtain full firing rate: 0.2 to 0.4 second.  
 Recoil reaction: 4,000-8,000 pounds on 250,000 pounds/inch firing platform; 18,000-20,000 pounds on rigid mount.  
 Location of cartridge and link ejection: Bottom.  
 Location of feeder: Right side at 45 degrees.

Barrel length: 38 inches.  
 Barrel weight: 28½ pounds each (38-inch barrel).  
 Rate control: Rheostat.  
 Barrel removal: Not quick disconnect.  
 Bore:  
     Number of grooves: 8.  
     Groove depth: 0.016 inch.  
     Groove width: 0.150 inch.  
     Pitch: One turn to 18 inches.  
     Direction of twist: Right-hand.  
     Form of twist: Constant.  
 Recommended maximum ammunition belt pull at feeder: 50 pounds.  
 Recommended maximum length of belt without booster: 5 feet horizontal or 4 feet vertical.  
 Feed is by belt, with disintegrating link of strip-off type.  
 Belt speed corresponding to above rate of fire: 500 feet/minute with maximum acceleration of 1.5 g.  
 Ammunition:  
     Ball T77 caliber .60 cartridge.  
     Weight per pound: 0.52 pound.  
     Weight per link: 0.12 pound.  
     Primer: Electric.  
     Diameter of case: 1½ inches.  
     Length of round: 6⅝ inches (normal).  
     Links (GFE): Modified T44E2 or T44E3.  
     Number of rounds per foot of belt: 1.  
     Barrels (GFE): Supplied from Springfield Arsenal.

the upper housing carries a locking cam and the firing contact, while the lower housing supports a set of 12 guides.

The rotating group is turned by the drive assembly through a gear machined on the connection block. The feeder, located on the opposite side of the gun, is driven from this gear. The rotor of this group carries the six slide assemblies which move back and forth in slots. The connection block supports six locking levers which are actuated by the locking cam.

The six barrels of the T45 machine gun are arranged circumferentially in the rotating member and are supported by the connection block and the forward bearing block. The barrels are held in the connection block by three sets of teeth located on the outside of the barrels. Spring locks on the forward bearing block, one for each barrel, lock the barrels in place. The barrel clamp is fastened to the muzzle end of the six barrels to give rigidity to the 60-inch barrels when the T45 machine gun is operated at high speed.

**Slide Assembly Bolt.** The slide assemblies are made up of a body, a cam follower, firing pin assembly, bearing shoes, and a bolthead. The bolt has teeth for locking the bolt in the connection block. It also carries a single-tooth gear, the extractor springs, and part of the interlock switch. The remainder of the interlock switch is a spring mounted on the side of the bolt body. The firing pin assembly is spring loaded inside the bolt body to insure proper contact with the primer on the round. The cam follower is fastened to the bolt body by an eccentric shaft to permit adjusting headspace.

**NOTE.** Headspace of the firing mechanism refers to the distance between the back of the teeth in the connection block and the back of the teeth on the bolthead at the instance that the bolthead starts to lock.

**Feeder and Gear Box Assembly.** The feeder assembly is made up of a fabricated housing containing gearing, a shaft carrying two sprocket wheels, link guides, stripper fingers, and the link discharge. The feeder sprockets are driven through a gear train by a gear on the connection block. The feeder is so designed that the sprocket wheels and link guides position a belted round of ammunition so that the link passes under the stripper finger while the round passes over it. The feeder also contains stationary fingers to cam the spent cases out of the bottom of the lower housing.

**Drive Assembly.** The drive assembly comprises a 24-volt d. c. drive motor, a flywheel for energy storage, a double-action solenoid, a clutch, a brake, and the necessary reduction gearing.

The flywheel is mounted near one end of the drive unit housing. It is supported on two radial bearings and is driven directly by the output shaft of the motor by engaging flats on the drive shaft with the socket on the flywheel. This permits relative axial motion of the flywheel, which is absorbed by thrust washers at each end of the flywheel. Two sets of pressure plates are mounted near the front end of the drive unit. One set is driven by the flywheel through planetary gearing. The other set is held stationary. A disc on the output shaft is located between the sets of pressure plates. The disc is moved axially by an actuator connected to

Comparative Data: Caliber .60 T45 Machine Gun

Characteristic	Gun Length (inches)	5 Barrel	6 Barrel
Total weight, 60-inch barrel (weight per barrel, 30 pounds).	74	368 pounds.....	402 pounds.
Total weight, 38-inch barrel (weight per barrel, 22 pounds).	52	328 pounds.....	354 pounds.
Weight per barrel.....	74	73½ pounds.....	67 pounds.
Do.....	52	65¼ pounds.....	59 pounds.
Height.....		14½ inches.....	14¾ inches.
Width.....		11¾ inches.....	12¼ inches.
Rate of fire rounds-minute.....		5,000.....	6,000.



the plunger of the solenoid assembly. The solenoid assembly is made up of two coils. When both solenoids are de-energized, the actuator holds the disc in a neutral position between the pressure plates. Neither the clutch nor the brake are engaged, and the output gearing is free to turn. When energized, the rear solenoid moves the top of the pivoted actuator to the rear. This causes the disc on the drive shaft to engage the stationary pressure plates, locking the output gearing. De-energizing the rear solenoid and energizing the front solenoid causes the top of the actuator to move forward; the output shaft disc is pushed against the rotating pressure plates and the motor is clutched to the output gearing.

**NOTE.** The two solenoids should not be energized at the same time.

*Main Cam.* The main cam is essentially oval in shape with a groove for the bolt cam follower on the inside. The cam is made with a small removable segment at the back to permit removing the bolts from the rotor.

## Cycle of Operation

The T45 machine gun is operated in two steps: (1) closing the master switch and (2) closing the firing trigger. Closing the master switch energizes relays which set the brake and start the drive motor.

**NOTE.** These relays are not an integral part of the T45 machine gun, although they may be supplied in a test control box.

The motor brings the flywheel up to speed. After the motor and flywheel combination are brought to speed, the gun is ready for firing. On closing the trigger, the solenoids operate to release the brake and to clutch the drive to the rotor. At the same time, the firing circuit is closed to the firing contact at the top of the gun. The "stored energy" in the flywheel accelerates the rotor. The six bolts on the rotor are moved forward and backward by interaction between the bolt rollers and the main cam.

As the rotor is turned, the feeder sprockets draw the belted ammunition into the gun. The sprockets pull the ammunition so that the link passes under the stripper finger while the round rides over the top. Guides in the feeder hold the link parallel to the bottom of the feeder. Continued rotation of the feeder sprockets cause the round to ride up on the stripper finger lifting it out of the link. The link is

then ejected out of the link discharge opening at the bottom of the feeder. As the round is carried around in the feeder, it is cammed out of the sprocket wheels into the rotor bolt groove ahead of a bolt by guides on the inside of the casing. For each revolution of the rotor, the feeder supplies 6 rounds, 1 to each of the 6 rotor slots.

Further rotation of the rotor causes the bolt to be moved forward by the main cam. As the bolt advances along the lugs in the rotor, it pushes the round ahead of it. Additional guides inside the housing direct the round into the chamber. When the rotor and main cam combination have pushed the round into the chamber, the extractor fingers on the bolthead engage the cannellure of the round. At the same time, the firing pin in the bolt comes into contact with the primer on the round; however, the round will not fire until the bolt interlock contact is closed and moved against the firing contact.

After the bolthead is pushed all the way into the connection block, additional rotation of the rotor causes a finger on the bolthead to engage a locking lever on the connection block. This lever is actuated by a follower in the locking cam in the top of the housing. Motion of the locking lever rotates the bolthead with respect to the bolt body. This rotation causes the teeth on the bolthead to enter mating recesses in the connection block, locking the bolt to the rotor. At the same time, the rotation of the bolthead closes the firing-pin interlock contact on the bolt.

Continued rotation of the rotor brings the interlock switch into contact with the firing contact, closing the firing circuit and firing the cartridge. The recoil forces are transmitted through the teeth on the bolt to the rotor, then through the back cover, and finally to the casing. The recoil adapters on the casing absorb much of the force of recoil and of counterrecoil.

During firing, rotation continues with the bolt locked through the dwell period; then the locking cam actuates the locking lever to unlock the bolthead. The main cam then forces the bolt to the rear. As the bolt moves rearward, the empty case is withdrawn from the chamber by the extractor fingers. Additional guides in the housing keep the case in the rotor slots as the bolt withdraws. When the empty case reaches the ejection position, stationary fingers on the feeder cam the case out of the

extractor fingers and eject it through the case discharge opening. The bolt is then carried around the rotor to come behind the next round fed into that rotor slot by the feeder.

The firing mechanism continues to strip, fire, and eject until the firing trigger is released. When the firing trigger is released, the solenoids on the drive unit actuate to declutch the motor from the rotor. At the same time, the brake is applied to rapidly stop the rotor.

**NOTE.** It is recommended that the firing circuit be kept energized until rotation of the unit stops. A time delay relay is used in the test line to accomplish this.

**Control Box.** The control box contains the relays, switches, capacitors, and connectors used in operating the firing mechanism during the test. For wiring, use only approved procedure.

**Links.** The link being used with the "A" model guns is a two-piece disintegrating type designated T44E4.

### Advantages of the T45 Gun

Advantages of the external power driven gun over the normal type of gun mechanism are:

1. No gun charger is required and gun stoppage does not result from misfires, round being extracted automatically.

2. As gun mechanism does not start and stop at each cycle and uncontrolled reciprocating parts are eliminated, the resulting impact loads occurring in normal type guns are eliminated. The majority of gun failures are caused by impact.

3. The use of springs is reduced to a minimum. Failure of gun springs subjected to repeated impacts at high frequencies is one of the main troubles with standard type guns.

4. As the belt of ammunition is not subject to the repeated starting and stopping occurring in standard type guns, the belt is not as subject to separations.

### Operation Precautions

1. Be sure that the access opening on the main cam is fully seated and the screws tight before operating the gun. A slight misalignment will damage the cam rollers.

2. Be sure to use only links of approved dimensions.

3. Dummy rounds having open primer holes will strain or break the firing pins on the slide assemblies.

4. Load a single belt of ammunition into the feeder of the gun from the right side with the single loop first.

5. When loading, be sure that the first round is fully engaged by the feeder sprocket before applying appreciable torque.

6. The firing rate of 4,000 rounds per minute is obtained at 22 to 24 volts at the motor terminals. Higher potentials will produce greater speeds which are above the present safe operating limits.

7. Do not allow brake coil of solenoid to remain energized for more than 5 minutes at a time, to prevent overheating.

8. Do not run the motor for extended periods, as the heat rating is critical.

9. If starting or stopping is sluggish, a slight adjustment of the drive unit solenoid may be necessary.

### Cleaning, Lubrication, and Inspection: General

Proper functioning and the accuracy of firing depend largely upon care, cleaning and oiling. The weapon should be checked daily for cleanliness and lubrication. The following instructions should be carefully observed. Relubricate after cleaning to prevent subsequent rusting.

#### Cleaning

All parts should be checked to insure that they are clean and lubricated. If not, clean according to the directions in the following paragraph.

Thorough cleaning after firing is extremely important and should be performed as soon as possible. The bore and other portions exposed to primer fouling should be thoroughly cleaned of primer salts, using rifle bore cleanser. The corrosive primer salts are water soluble but are not soluble in petroleum distillates.

**Barrels.** Except in emergencies, barrels should be removed for cleaning to avoid accumulation of deposits in connector block. Barrels are cleaned by running wet patches impregnated with bore cleaner through the bore. After the bore is thoroughly coated with bore cleaner, the barrels should be allowed to sit a minimum of one-half hour or overnight if possible. After allowing the barrels to sit, clean the bore cleaner out of the bore with a dry clean patch. Loosen the foreign particles in the bore by running a wire brush through it several times. Using warm soapy water and a clean patch,

thoroughly clean the bore. Follow this procedure with dry patches run through the bore until they come out clean and dry. Barrels are then ready for use. However, they should be coated inside and outside with a thin coat of Navy specification U51 oil if they are to be left standing more than 2 hours. Before firing, all oil should be removed from the barrel bore.

**NOTE.** If barrels are to be stored, the preceding operation should be repeated on three separate days.

*Slide Assemblies (Bolts).* Slides are wiped clean after removing them from the gun. The heads should be immersed in bore cleaner to permit free action of the solvent.

*Rotor and Connection Block.* If there appears to be an excessive accumulation of dirt in the rotor and/or connection block, remove the upper and lower housings and clean with brushes.

## Lubrication

Lubrication is required according to a chart furnished with the weapon. Use lubrication sparingly.

## Inspection and Checks

A thorough systematic inspection at regular intervals is essential. These inspections should include (1) preventive maintenance and (2) determining whether replacement of parts is necessary because of ordinary wear and defective parts.

## Prefiring

1. Be sure ammunition and links are in acceptable condition: clean, free of burrs, and within drawing dimensions.

2. Be sure that access plate is securely bolted in place. Failure to seat properly will damage cam roller and may cause failure of gun.

3. Check all sliding parts and bearing guides for burrs or abrasive foreign matter.

4. Be sure that the firing contact pin completely engages each of the six slide contact pins and that the interlock contacts engage with approximately one-eighth inch interference. The engagement must be positive but not excessive. Since wear may take place on the contact pin, it may be necessary to replace it. The recommended contact dimension is 0.010 to 0.020 inch interference.

5. Check to see that ejection openings for spent cases and links are not obstructed. Also make sure

that they cannot bounce back into the ejection openings.

6. Check condition of feeder and ejection arms for looseness of parts, breakage, or wear. The feeder must be in excellent shape at all times.

7. Make sure that the feeder chutes are installed correctly and that there is no interference.

8. Before loading the gun, check the operation of the motor and clutch unit to insure proper functioning.

9. Run a belt of at least six dummy rounds through by hand. If any binding or sluggish movement is noted, determine the cause and make the necessary checks and repairs.

10. Check all bolts for looseness or breakage of safety wires.

11. Be sure that recoil adapter bolts are snug and suitably locked.

12. Check extractor springs for tension or mechanical defects. All extractor springs should have one or more pounds of preload and should have an initial resistance to lifting by the finger.

13. Check extractor clamp screws. If loose, either replace or restake.

14. Check bearing shoes for deep scratches or wear.

15. Make sure the firing pin is free and centered with suitable electrical clearance. Make occasional ground resistance checks at some elevated potentials such as 500 volts.

16. Be sure that the ammunition chute (not furnished) is securely fastened and accurately aligned.

## Performance

1. Check the condition of the bearings occasionally by turning the gun by hand.

2. Take headspace reading frequently. Values should read 0.0025–0.005 inch.

3. Inspect the slide assemblies after every 200–300 rounds according to prefiring instructions, just given.

4. Check firing contact pin frequently according to prefiring instructions.

## Removal, Disassembly, and Installation

The multibarrel gun should be disassembled only to the extent described in applicable manuals. In cases where a component is faulty, it should be removed, repaired, and replaced in the gun in accord-

ance with the appropriate instructions. Some units cannot be removed without prior removal of other subassemblies.

**NOTE.** It is recommended that the six slide assemblies be removed prior to the removal of any subassembly.

With the exceptions noted, the reassembly of each subassembly is the reverse of the disassembly and therefore is not included.

#### *Barrels—REMOVAL.*

1. To remove the barrel clamp, remove the six nuts which hold it in place and slide it off the ends of the barrels.

2. Pry up the barrel lock springs on the bearing block. Turn the barrel one-sixth of a revolution counterclockwise (when looking into the muzzle) and pull the barrel out.

**REPLACING THE BARRELS AND BARREL CLAMP.** Reverse the procedure just given. Care should be taken to see that the barrel clamp nuts are pulled up evenly.

*Slide Assembly (Bolt).* Any of the parts of the slide assembly may be replaced when necessary.

**NOTE.** All slides are numbered and should be inserted in the correct rotor slot.

#### **REMOVAL.**

1. Using an Allen-head wrench, reach into the access opening on the end cover, and remove the two screws from the cam insert located in the main cam. Turn the rotor until a rotor guide appears directly above the insert. Pull the insert out.

2. Turn the rotor one-twelfth of a revolution either way and pull out a slide assembly through the opening. Continue by turning the rotor one-sixth of a revolution and removing each slide assembly in turn.

#### **DISASSEMBLY.**

1. Remove head from body by turning head clockwise until it unlocks, and pull it off.

2. Remove contact pin, insulation, roller, and washer from head.

3. Remove the two extractor springs from the head by removing the three screws and clamp.

4. Pull off four bearing shoes.

5. Using an adjusting locknut wrench, unscrew the locknut on the bottom of the roller assembly. Be sure to note the position of the mark on the shaft in relation to the body of the slide assembly. In reassembly, the shaft must be aligned correctly with

the slide body in order to give proper headspace. Push out the shaft and roller assembly. Remove the washer and roller from the shaft if necessary.

**NOTE.** In reassembly, be sure that one of the teeth of the locknut lies over the center of the hole in the slide body. If this cannot be done, use another nut.

6. Remove the contact assembly by removing the 2 screws, retainer, insulation, 2 contact springs, 2 insulation washers, and insulation.

7. Tap out the split dowel pin, using a pin punch and a hammer.

8. Push out the firing pin assembly.

**INSTALLATION.** When installing a slide assembly in gun, reverse the procedure for removal. Be sure to check headspace according to procedure in test section.

*Feeder and Gearbox Assembly.* The feeder housing is riveted together. Do not remove the rivets. Replace with a new assembly if the housing is not usable. Each guide and stripper assembly is individually fitted to each feeder. Therefore, if something is wrong with the guide and stripper assembly, replace the entire feeder. During reassembly of feeder and gearbox assembly, be sure to conduct tests noted later in this section.

#### **REMOVAL.**

1. Remove 3 screws and 3 washers holding ammunition chute to feeder. Remove chute.

2. Remove 10 screws, 10 lockwashers, and 2 dowel pins holding feeder to housing, and 3 screws, 3 lockwashers, and dowel pin holding gearbox to housing. Lift the assembly off the housing.

#### **DISASSEMBLY.**

1. Remove gearbox from feeder by removing 3 screws, 3 lockwashers, 2 dowel pins, which hold gearbox to feeder. Slide gearbox away from side of feeder housing.

2. Disassembly of gearbox: Remove retaining ring and spacer. Slide shaft out. Shaft fits fairly tight, and it may need to be tapped out. Be careful of Woodruff key. Press out needle bearings if bearings are bad.

3. Disassembly of feeder: Tap taper pins out of sprockets. Slide shaft out. (Do not lose the two spacers.) Remove gear. Do not lose Woodruff key. Drive taper pin out of gear. Press out needle bearings if necessary.

**INSTALLATION.**

1. Reassemble gearbox to feeder: Slide end of gearbox into feeder housing, making sure the gears on the feeder and the gearbox mesh correctly. Fasten gearbox to feeder with 3 screws, 3 lockwashers, and 2 pins.

2. Fasten feeder and gearbox assembly to gun. Be sure to check for backlash and clearance.

**NOTE.** Before reassembly, refer to later section for timing of feeder.

*Drive Unit.* The drive unit should not be completely disassembled. Only the pinion, the drive gear, the solenoid, and the motor should be removed from the drive unit and disassembled as far as stated here.

**REMOVAL.**

1. Remove 4 screws, 4 lockwashers, and 2 dowel pins holding bracket to gun assembly, and 3 screws and washers holding flange to gun assembly. Remove drive unit from gun. Be careful of wires.

**DISASSEMBLY.**

1. Pinion: Remove three screws holding gear cover to drive unit and remove cover. Remove nut and lockwasher. Slide stud assembly out of bracket. Remove two thrust washers and pinion from stud. Press needle bearings out of pinion if necessary.

2. Drive gear: Remove retaining ring. Pull off gear. Be careful of Woodruff key.

3. Solenoid: During reassembly, be sure to adjust position of solenoid. Remove solenoid by removing 4 screws and 4 lockwashers holding solenoid to drive unit. Remove end covers after removing the 4 screws and 4 lockwashers located on both covers. Take top and bottom covers off after removing the 2 screws and 2 lockwashers located on both covers. Pull out solenoid coils.

4. Motor: Remove 4 bolts and 4 lockwashers holding plate and motor assembly to clutch mechanism. Lift off plate and motor assembly. Remove 4 bolts and 4 lockwashers holding motor to plate. Lift off motor.

**INSTALLATION.** After reassembly, install drive unit on gun. Be sure to check backlash.

*Contact Assembly.*

**REMOVAL FROM GUN.** Remove 4 screws and 4 lockwashers holding contact assembly to gun. Remove contact assembly.

**REASSEMBLY.** Be sure to adjust contact pin.

*Housing.* Either half of the housing may be removed at any time during disassembly. The main cam must be supported when both halves of the housing are removed.

**UPPER HOUSING.**

1. Removal: Remove the 18 screws, 18 washers, and 4 pins holding upper housing to lower housing and end cover. Remove 4 screws, 4 lockwashers, and dowel pin holding housing to main cam. Remove six lockwashers holding housing to casing and extension assembly. Lift off housing.

2. Replacing locking cam: Remove upper housing. Remove 3 screws and 3 washers holding cam to housing. Carefully tap locking cam out of housing.

**LOWER HOUSING.**

1. Removal: Remove drive unit and feeder and gearbox assemblies. Remove the 18 screws, 18 washers, and 2 dowel pins holding lower housing to upper housing and end cover. Remove 6 screws and 6 lockwashers holding housing to main cam. Remove 6 screws and 6 lockwashers holding housing to casing and extension assembly. Lift off housing.

2. Replacing guides: There are 12 graduated guides, 6 on each side of the lower housing. The guides may be removed from the housing after removing the housing from the gun assembly. If any of the guides are worn, a complete set should be replaced. Be sure they are replaced in the correct order. After replacing guides, run a dummy round through the firing mechanism and check to see that the round does not bind between the rotor and the guides. If the round binds, the position of the guide should be shifted slightly. (1) Remove guides individually or as a set by removing screws and lockwashers holding guides to housing.

*End Cover.* Do not remove the end cover before removing at least half of the housing. Be sure the rotor is supported when removing end cover, as gun assembly will be top-heavy.

**REMOVAL.**

1. Remove one half of housing.  
2. Remove 6 screws and 6 lockwashers holding other half to housing end cover.  
3. Remove end cover after removing locknut, nut, and washer from rear of gun assembly.

*Main Cam.* Extreme care should be taken when removing main cam from gun assembly. Be sure

to remove the six slide assemblies before removing the main cam from the firing mechanism.

#### REMOVAL.

1. Remove upper housing.
2. Remove end cover. Support the rear gun assembly as it will be top-heavy.
3. Remove 6 screws and 6 washers holding cam to lower housing.
4. Carefully slide cam off of rotor.

#### INSTALLATION.

1. Carefully slide cam over rotor, being careful to support the cam when it is positioned.
2. Replace screws holding cam to housing.
3. Replace end cover.
4. Replace upper housing.

#### Rotor Assembly.

**REMOVAL.** Be sure to remove the six slide assemblies before removing the rotor assembly from the firing mechanism.

1. Remove gun barrels, forward bearing block, casing, and extension according to instructions that follow.

2. Roll gun over until it rests on the upper housing.

3. Remove lower housing. (The feeder and gearbox assembly and the drive unit may be replaced if desired.)

4. Remove end cover, using extreme care not to let the rotor drop on the upper housing.

5. Slide the rotor assembly (rotor and connection block) and rotor extension out of the main cam and upper housing.

6. Remove the six screws and washers holding the rotor extension to the connection block and remove the extension. (The rotor and connection block have been fitted together in manufacture and require a special key. If it is necessary to replace a rotor or a connection block, they should be replaced as a unit.)

#### REPLACING ROTOR AND CONNECTION BLOCK COMPONENT.

1. Guide plates: Certain rotors have removable plates: If the guide plates on these rotors become damaged in operation, they may be removed and replaced. To remove guide plates, take out the screws and lift the plate off. When replacing a guide plate, use extreme care to be sure it is properly lined with the other plates in the set. Improper alignment will

leave protruding corners which will be struck by the slide assembly.

2. Bearings: The after bearings may be removed and replaced without removing the rotor from the gun. To do this, remove the end cover. Remove the bearing retainer and bearings per instructions below, and replace them. Replace the after bearings as a complete set of five. To replace the bearings, remove the six screws and lockwashers which hold the bearing retainer in place and lift the retainer off. Using the bearing shaft for a grip, pull the bearings out. To install the bearings, line the set up so that the lines on the outer race form a V, then insert them in the bearing bore with the sharp end of the V entering first.

3. Locking lever assembly: Remove the 2 screws and 2 washers and lift the locking lever bracket off the connection block. The dowel pins will remain in the bracket. Lift the locking lever off the connection block. Press the pivot pin out of the lever. Replace the damaged part or parts and reassemble by reversing the above instructions.

#### Forward Bearing Block—REMOVAL.

1. Remove barrels.
2. Remove locknut, nut, and washer, which hold the bearing block to the rotor extension.
3. Using a bearing puller, pull bearing block off of rotor extension.

#### REPLACING BEARINGS ON BEARING BLOCK.

1. Remove pin on back side of roller assembly.
2. Pull out roller shaft. Roller will drop off as shaft slides out.

3. Press needle bearings out of rollers if necessary.

**NOTE.** If needle bearings are removed from the rollers, new bearings should be installed.

#### Casing and Extension—REMOVAL.

1. Remove barrels and bearing block.
2. Remove 12 screws and lockwashers which hold the casing and extension to the upper and lower housing.
3. Slide casing and extension off.

**Recoil Adapters.** To remove the recoil adapter from the gun, take out the eight screws and lockwashers which hold it in place. Remove the four dowel pins and lift the adapter off.

## Headspace Adjustment

#### Checking Headspace.

1. Bring slide assembly up to fire position.

2. Connect headspacing gage. There are 5 pieces (2 with a bushing attached) and 4 bushings (counting 2 attached bushings).

3. Slide rod into top barrel.

4. Attach end fitting. Bring it against the end of the barrel. Tighten the thumb screws. Center as well as possible.

5. Slide the dial indicator into the hole in the end fitting and fasten in place by tightening the nut. The dial indicator should be positioned so that it is approximately in the center of travel.

6. Remove the rotor in a counterclockwise direction (facing the forward end of the barrels) until the high spot on the cam is located. Stop the rotor with the cam follower on the high spot and zero the dial indicator.

7. Move the rotor in a clockwise direction until a follower clears the high spot. Read the headspace from the dial indicator.

NOTE. Headspace should be 0.0025–0.005 inch. If it is not, adjust headspace as directed below.

8. After reading headspace on the locking side, zero the dial indicator before revolving the rotor further.

9. Revolve the rotor in a clockwise direction until the high spot on the unlocking side of the cam is located. With the cam follower on the unlocking high spot, read the unlocking headspace directly from the dial indicator.

NOTE. Locking and unlocking headspace should be within  $\pm 0.001$  of each other.

10. Continue to check headspace on all slide assemblies.

#### *Adjusting Headspace.*

1. Remove the slide assembly from the gun.

2. Remove the slide roller assembly, taking care to note the position of the shaft with respect to the body.

3. Turn the shaft so that it rotates a distance of one spline tooth with respect to the body. Fasten a roller assembly in place.

NOTE. If the headspace is too high, rotate the shaft so that the small hole in the shaft moves toward the slide head. If the headspace cannot be adjusted to within limits by turning the shaft, a new shaft should be installed. Two types of shaft are made: one with the high spot located between two teeth,

the other with the high spot located on one tooth. Either type shaft may be used.

## Feeder Timing

Feeder-timing marks and holes have been put in the completed feeder and gearbox assembly to facilitate timing. However, timing should be carefully checked each time the feeder and gearbox assembly is removed from the gun.

#### *Timing the Feeder and Gearbox Assembly.*

1. Rotate the rotor so that the number one barrel is on top and the lines marked "T" are lined up.

2. Rotate the feeder sprockets so that the line (on the sprocket tooth) marked "T" lines up with the upper support. Clamp or hold the sprockets in this position.

3. Rotate the gears in the gearbox so that a  $\frac{1}{8}$ -inch dowel pin will slide into the holes in the gearbox and the gear.

NOTE. If new gears or sprockets are installed, holes or lines should be added to them in the same position as the holes or lines are on the replaced parts.

4. Assemble gearbox and feeder.

5. With the rotor, feeder, and gearbox locked in the above positions, slide the feeder and gearbox assembly into place on the lower housing and insert the dowel pins. Install several screws to hold the feeder in place while checking timing. After timing is checked, install rest of screws and lock-washers.

#### *Checking Timing.*

1. Remove the cam insert.

2. Remove the number one slide (all slides may be left out if desired).

3. Turn the number one barrel to the "Fire" position, and insert a dummy round in the feeder.

4. Slowly revolve the rotor in the clockwise direction (viewing from the front), at the same time watching the round through the opening in the end cover.

5. If the feeder is properly timed, the round should just clear the leading edge of the rotor slot (0.001–0.005-inch clearance).

6. If the feeder is not properly positioned, re-adjust the feeder and gearbox assembly so that the

gear in the gearbox mates with the next tooth in the connection block or so that the gearbox pinion mates with the next tooth in the internal feeder gear.

### Contact Assembly Adjustment

#### *Checking Travel.*

1. Remove the electrical fitting.
2. Remove the insulation washer, spring, and stop from the contact.
3. Insert a 1/4-inch dowel pin into the contact and place a dial indicator on the housing such that it will read the travel of the dowel pin.
4. Rotate the rotor in the running direction noting the reading on the dial indicator as each slide passes under the contact. This travel should read 0.010–0.020 inch. If not, remove a shim from under the contact or replace the contact button.

### Solenoid Adjustment

The solenoid should be positioned so that the movement fore and aft is approximately the same, measured from the free or midposition. This should produce a starting and stopping time of from 0.2–0.4 second.

1. Loosen the four screws holding the solenoid to the drive unit.
2. Slide the solenoid forward to decrease starting time or aft to decrease stopping time.

The gun should at all times be supported by a suitable cradle. The firing stand may be used as a support for the shop servicing. The main frame of the firing mechanism is sufficiently strong, but the total weight should not be supported by the external auxiliaries, such as the firing contact, the feeder bracket, or the drive motor. Barrels are normally removed for handling.



## Chapter 4

# ORDNANCE CORPS SHORT-RECOIL-OPERATED AUTOMATIC MACHINE GUN

## SECTION 1. HISTORY AND BACKGROUND

During the first year of American entry into World War II, the Army Ordnance Corps, in anticipating the needs for a machine gun for aircraft use having a bore of larger diameter and higher muzzle velocity than the universally used Browning caliber .50 machine gun, started development of a caliber .60 aircraft machine gun.

The first attempt to meet the characteristics for the caliber .60 aircraft machine gun was to modify a 20-mm M1 Hispano-Suiza automatic cannon. The receiver was identical, and parts of the gun were interchangeable with the 20-mm M1. The chief difference was in the barrel, which was chambered for the 20-mm case, bored and rifled for the 15-mm bullet and fixed in relation to the mount. The whole gun was rigidly mounted and the muzzle brake and recoil mechanism used on the 20-mm gun were eliminated.

The Eclipse machine division of the Bendix Aviation Corp. undertook the modification and fabrication of the modified gun. A type of feeder known as the "Burgess," which was operated by the recoil

of the weapon, was tried at first but was not successful. The pilot model was equipped for a 47-round magazine, to be mounted rigidly on the gun. This magazine was similar in appearance to the 60-round drum which was standard on the 20-mm M1 gun. The pilot weapon was fired more than 800 rounds, but further testing was discontinued after it was found that the velocity obtainable from the cartridge used was approximately 150 to 200 feet per second less than could be obtained with the caliber .60 cartridge case.

A second modification of the 20-mm Hispano-Suiza cannon was made by rechambering and boring and rifling the barrel for the caliber .60 case and bullet. Corresponding changes were made in the bolt and extractor. This gun was fired a small number of rounds (not more than 50) automatically. Official designation of the gun was caliber .60 T18. Since radical redesign of the Hispano-Suiza cannon appeared necessary if this gun was to meet aircraft requirements, work on this model was discontinued.

### General Data: Caliber .60 T18 Machine Gun

Gun length: 100.625 inches.  
Gun weight: 115 pounds.  
Rate of fire: 650-700 rounds/minute.  
Muzzle velocity: 3,000 feet/second.  
System of operation: Gas unlocking, blowback actuating.  
System of locking: Swinging lock.  
System of feeding: Drum and spring-wound feeder.  
Method of headspace: Governed by component manufacturing tolerance.  
Location of feed opening: Top of receiver.  
Location ejection opening: Bottom of receiver.  
Method of charging: Air, hydraulic, or manual.  
Method of cooling: Air.

Barrel length: 67.52 inches.  
Barrel weight: 47.8 pounds.  
Rate control: None.  
Barrel removal: Not designed for field removal.  
Bore: Number of grooves: 8.  
Groove depth: 0.016 inch.  
Groove width: 0.150 inch.  
Pitch: One turn in 18 inches.  
Direction of twist: Right hand.  
Form of twist: Constant.

NOTE: Modification of 20-mm Hispano-Suiza cannon by using barrel chambered for cal. .60 (see Fig. 1-12, p. 12).

After approval by Headquarters, ASF, it was recommended that further investigation of caliber .60 mechanisms be conducted with a new design (T31) and a modification of the 20-mm Hispano-Suiza automatic cannon M2. This modified 20-mm weapon was designated T18E1 because there had previously been made a gun called T18, which was a 20-mm automatic cannon M1 modified to fire the caliber .60 cartridge. The earlier gun was fed from a five-round magazine and served only to show that the action was sufficiently strong to fire the cartridge.

In August 1944, it was decided to reopen this phase of the development in order to determine whether a caliber .60 gun could be produced from the 20-mm M2 weapon by replacing or modifying a small number of parts. It was hoped that a satisfactory weapon could be produced rapidly by utilizing several thousand 20-mm guns which were on hand and for which there existed no immediate military requirement.

A contract was placed with the Autoyrc Company. The specifications called for a gun with a quickly detachable barrel, a feeding mechanism, a front (synchronizable) sear, and a recoil adapter. A new link was also developed to facilitate the design of the feed mechanism.

It was decided to retain the existing gas-operated means of unlocking the bolt. An extension was fastened to the forward end of the receiver to provide for the quickly removable barrel. The feed mechanism was operated by an additional gas piston and cylinder mounted above the unlocking cylinder. This upper piston was arranged so that gas pressure would compress the feed springs which would then expand and feed the belt as rapidly as the timing of the gun permitted. The cartridge was forced from the bottom of the feed link and was not

pushed through it. The caliber .60 cartridge was larger in diameter than the 20-mm cartridge and, accordingly, the height of the bolt was increased so that the extracted case would not be pushed off by the following round. The link used with the new ejector proved to be one of the major causes of trouble.

Modifications were made to the firing pin and locking slides so that the gun could be fired with the bolt in the forward position. This was done by placing the plunger of the firing solenoid in the path of one locking slide.

Functioning of the gun was believed good, considering the short time which had elapsed since the development had started. However, difficulty was encountered with ejection, with stubbing of the cartridge, and with failures to fire. It was found that the latter were caused by the bolt rebounding from the breech face, a malfunction which was corrected by the use of brass impact surfaces. The feeding difficulties were traced to slowness of feed and faulty design of the feedway opening. The ejector troubles required complete redesign of the ejector assembly.

Because of the heavy workload at Aberdeen Proving Ground, Md., the development program was transferred to Springfield Armory and final tests were conducted there. It was found that the sear release time was slow due to the large mass of the firing parts. This characteristic, together with the extensive modifications which had to be made to the 20-mm gun, made it impossible to achieve the original aim.

Had all the malfunctions been corrected, the product would still have been a conversion, but the amount of work required to change or replace existing parts would have justified an entirely new start. Accordingly, the project was dropped.

## SECTION 2. CALIBER .60 T17 MACHINE GUN

### Summary of Development

In September 1942, the Ordnance Corps initiated a project to convert the German Mauser MG 151/20 to a caliber .60 machine gun. The MG 151/20 was a 20-mm short-recoil-operated, air-cooled, belt-fed weapon. A German gun had been shot down in the Battle of Britain and turned over

by the British authorities to the United States for study and development.

In October 1942, the Colt Patent Fire Arms Co. of Hartford, Conn., undertook this conversion. The Ordnance Corps designation was caliber .60 machine gun T17. It was found necessary to rechamber the barrel, lengthen the receiver, feedway, bolt, cam tube, and cover, and also to make a few other

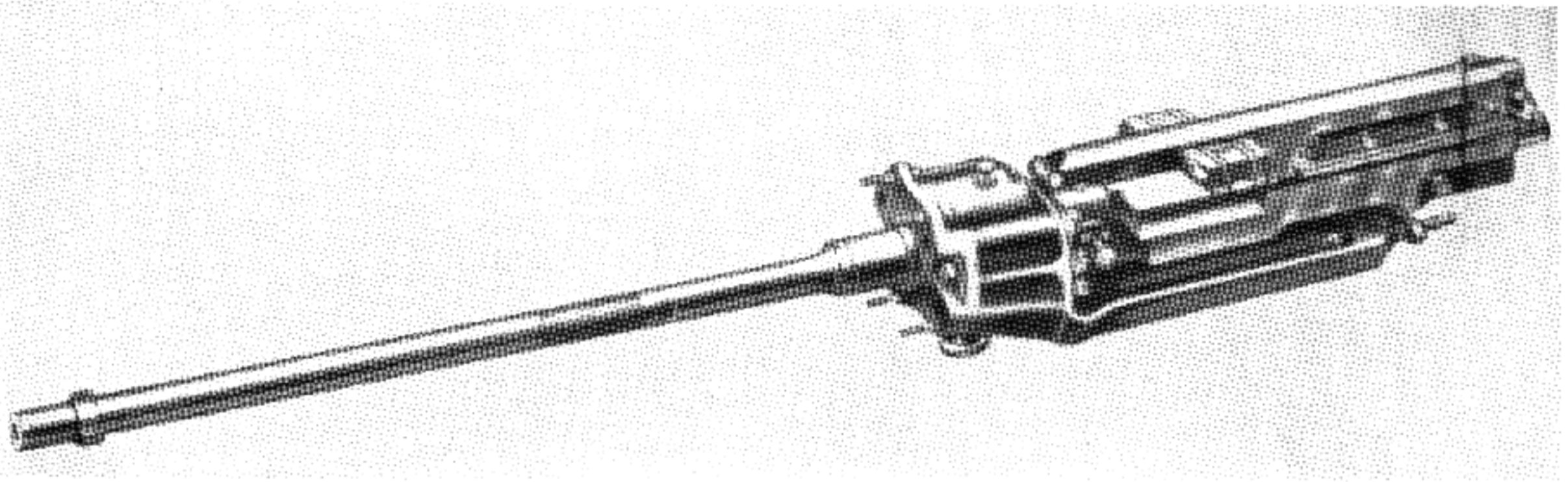


Figure 4-1. German Mauser 20-mm Automatic Gun MG-151/20.

minor design changes. New links were provided by the Autoyre Co.

The first test firing of the gun was at the Colt plant on 23 November 1942. It was found that the recoil was very heavy and that extraction was too early as evidenced by expanded cases. It was assumed by the designer that the rate of fire was much above the desired rate, and a recoil brake was added to the muzzle. However, this did not reduce the rate of fire as much as expected. The gun was then sent to the Aberdeen Proving Ground, Md., where it was fired approximately 350 rounds. The rate of fire was then determined to be approximately 700 rounds per minute. Bursts of four rounds were fired satisfactorily. A barrel 51 inches long, the same length as the German gun barrel, was used. A muzzle velocity of 3,000 feet per second was obtained.

Unlocking and extraction occurred early, as evidenced by expanded shoulders of the cases. It was discovered that minor modifications should be made to strengthen certain portions of the bolt and to provide for later unlocking in extraction. Further development at Colt's was discontinued as the Colt plant was not suitably adapted for continuing this development as speedily as was desired.

### Basic Barrel Development

Development work on the gun barrel has been carried on by Springfield Armory and Frankford Arsenal. The initial requirement for the T17 gun

called for a quickly detachable and replaceable barrel. This feature, suggested by Frigidaire, had earlier been taken from the German MG 151/20 design. Springfield Armory made the first barrels and integrated the barrel design. After the initial barrels were fired, Springfield Armory worked on improvements in metal strength characteristics and heat treatment problems. Frankford Arsenal developed the original data on bore diameter and depth of rifling, and it determined that 590 grains of powder (IMR 4996) would yield an instrumental velocity at 78 feet of  $3,500 \pm 30$  feet per second with a 1,200-grain projectile.

In March 1944, a groove diameter of  $0.604 \pm 0.002$  and a land diameter of  $0.588 \pm 0.002$  with one caliber of free travel were adopted. Data presented by Frankford Arsenal showed that one caliber of free travel reduced the peak chamber pressure approximately 2,000 pounds per square inch and the initial muzzle velocity by approximately 100 feet per second. The standardized depth of rifling of 0.007 to 0.009 inch was an increase of 0.004 inch in depth over the first barrels used.

At approximately the same time, it was desired to increase the capacity of the cartridge case and to make it more nearly cylindrical to facilitate manufacture and stowage. Accordingly, modified chambers and cartridge cases were designed and tested. The old cartridge (T1) was characterized by a 0.050 body taper, the new (T22) by a 0.035 body taper.

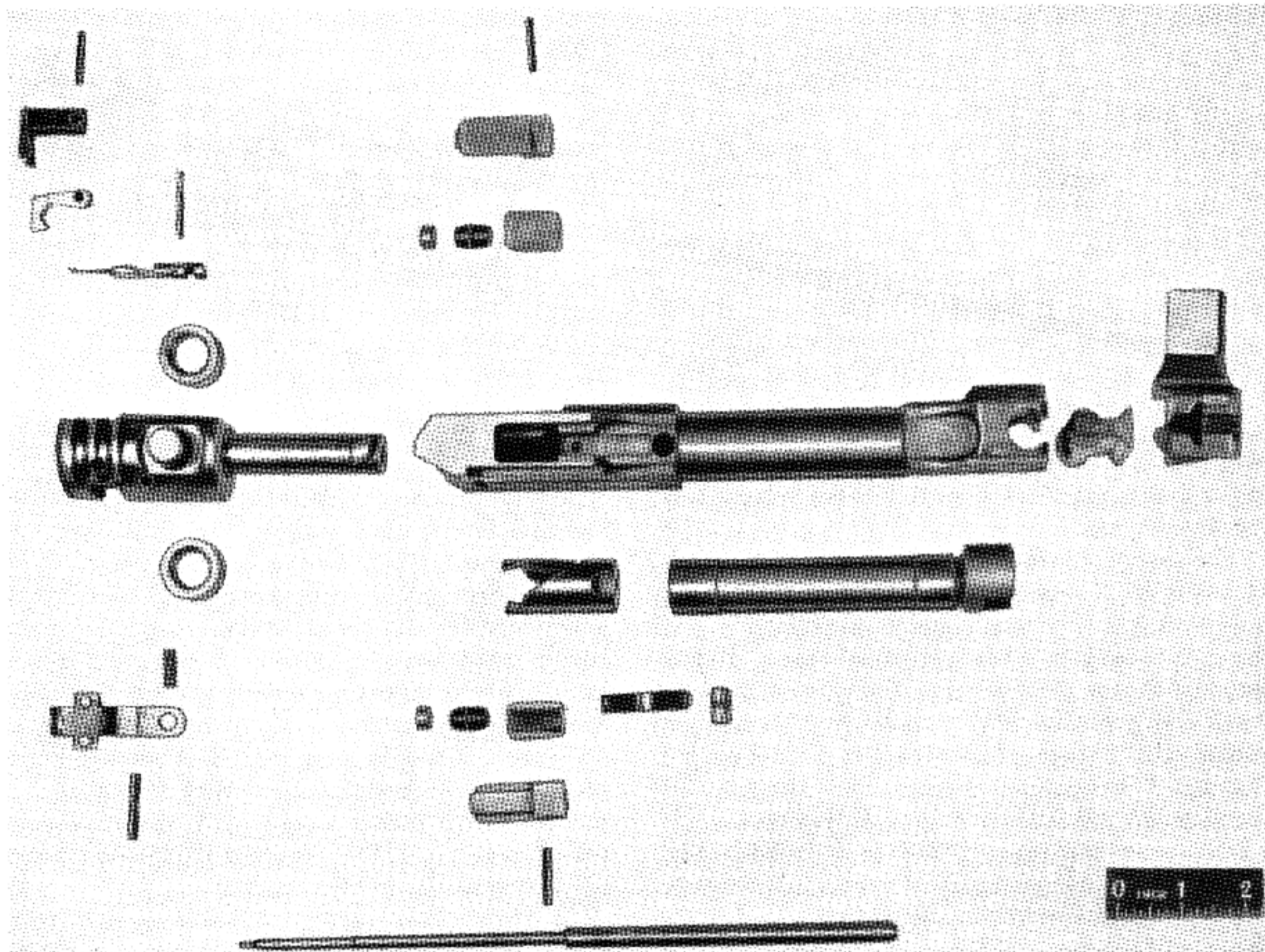


Figure 4-2. Gun, Machine, Caliber .60, T17. Bolt components.

### SECTION 3. CALIBER .60 T17E1 MACHINE GUN

#### Summary of Development

In January 1943, the Frigidaire division of the General Motors Corp., Dayton, Ohio, undertook to provide 10 pilot models of the aircraft machine gun, caliber .60, T17E1. The model was to be essentially the same as the T17 except that the rate of fire was to be increased to 800 rounds per minute and the high trunnion reactions were to be lowered by incorporating in the design a recoil adapter developed by the Edgewater Steel Co. at the request of the Ordnance Officer at Wright Field. Links for the gun were developed by the Autoyre Co. of Oakville, Conn. Complete drawings of the T17 gun

were prepared by Frigidaire and an engineering study was made to redesign the weapon for cheaper mass production.

The pilot model T17E1 was delivered to Aberdeen Proving Ground for test on 2 May 1943. Tests indicated that the bolt either was made of improper material or had been overhardened, as the locking lugs and a section of the bolt face were broken after only a few rounds had been fired. New components were made and after firing 70 rounds on 24, 25, and 26 May 1943, an explosion occurred which ruptured the cartridge case and destroyed all of the operating parts of the gun.

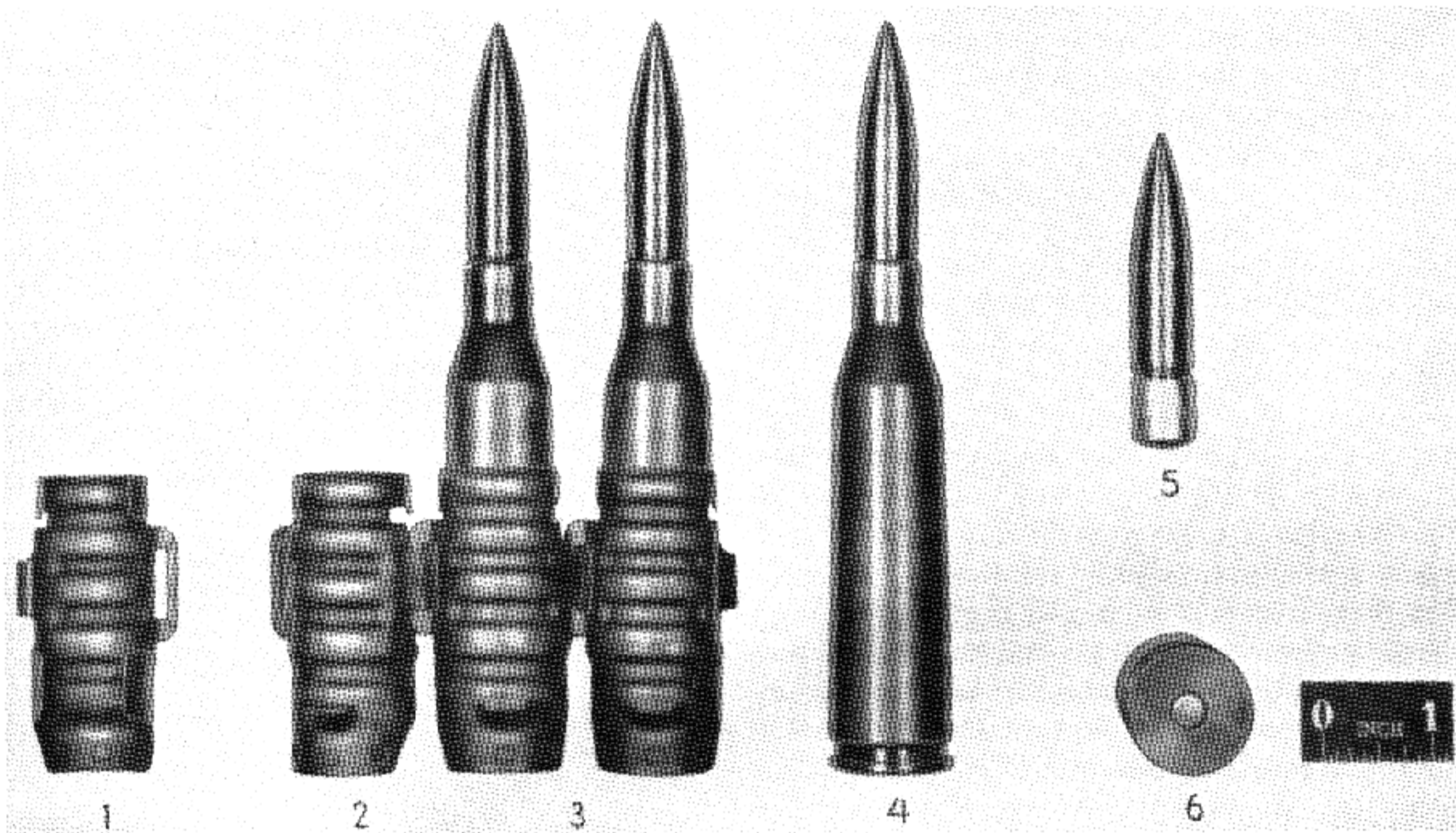


Figure 4-3. Ammunition and links for Caliber .60 Machine Gun T17.

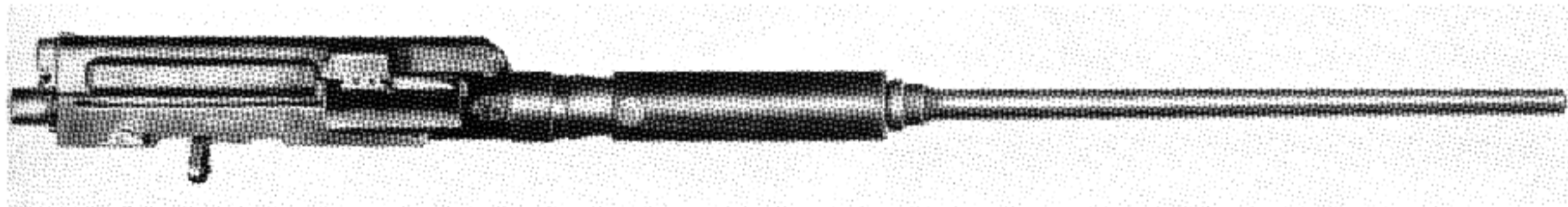


Figure 4-4. Gun, Machine, Caliber .60, T17E1. This design was derived from the German MG-151.

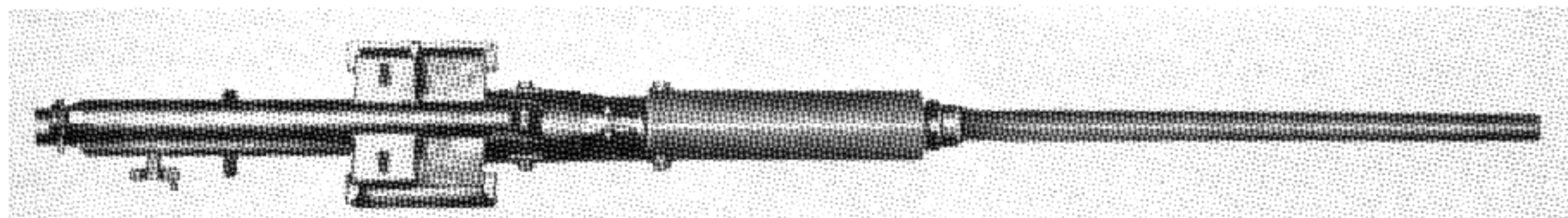


Figure 4-5. Gun, Machine, Caliber .60, T17E1. Top view.

## SECTION 4. CALIBER .60 T17E2 MACHINE GUN

## Summary of Development

The Frigidaire division was then asked to prepare two additional models which would use strengthened components and a barrel with a thicker wall chamber, as the chamber had expanded during tests of earlier models. SAE 1060 steel was used in the T17E1 wherever possible. In the T17E2 this policy was abandoned and SAE 4640 steel was substituted. Fabrication of these models involved the use of sheet metal stampings and hydrogen brazing. This gun was designated the T17E2.

In May 1943, the General Electric Co., Bridgeport, Conn., accepted a contract to develop an electric charger for the T17E2 gun. It appeared at this time that the most profitable development of this item would be a charger integral with the gun. The electric reloader drive unit is composed of an electric motor which drives a lead screw, a ball nut assembly which travels on the lead screw and moves an adapter group, and mechanical and electrical controls to govern the operation of the motor. The adapter group picks up the drive bushing as it moves to the rear down the lead screw and retracts the bolt to the rear. The lead screw passes through the center of the drive spring and drive bushing. The drive bushing engages the bolt. As the bolt passes over the sear, it depresses a device that determines the rotating direction of the charger motor, called the telltale, which actuates a switch and reverses the rotation of the motor. The adapter group travels forward into the cam tube lock and is forced against

the rear of the cam tube lock. Since the ball nut cannot turn, this pressure forces the lead screw to the rear; and in this way, the switch arm is actuated, the current to the motor is broken, and the circuit to the solenoid is closed.

The mechanical linkage between the solenoid and the sear is so arranged that it retracts the telltale when the sear is retracted, but the telltale may be retracted by the bolt without retracting the sear. The solenoid was mounted as an integral part of the gun. By this method an integrated unit assembly was provided which, it was believed, would be superior to the previous practice of developing the gun separately and then attaching the charger as an appendage.

Two T17E2 machine guns were delivered to Aberdeen Proving Ground for tests on 25 August 1943. Each was equipped with manual charging and firing equipment and recoil adapters. Electrical charging and firing solenoids were provided as alternate components. One gun was fired 557 rounds. Ejection difficulties developed, but after modification of the ejector, the gun functioned fairly satisfactorily with a rate of fire of 600 rounds per minute. The second gun with the General Electric charging mechanism was fired 143 rounds. A combination gun was built from parts of guns numbered 1 and 2 and fired 327 rounds at 658 rounds per minute with a maximum muzzle velocity of 3,696 feet per second. Numerous malfunctions were encountered which indicated that considerable further development work was needed.

## SECTION 5. CALIBER .60 T17E3 MACHINE GUN

## Summary of Development

Beginning in September 1943, attention was concentrated upon the manufacture of seven T17E3 guns with both mechanical and electrical ignition. The electrical ignition mechanism was modeled upon that of the German MG 151/20. A program was also initiated for the development of a bolt with the sear forward. It was expected that this arrangement together with the electric ignition would permit synchronization of the gun with either electric or percussion primed ammunition.

On 15 December 1943, because of increased interest by the U. S. Navy, this order was increased to 10 guns.

On 16 November 1943, Frigidaire had been requested to develop four auxiliary gun charges to be used as a standby device in case of the failure of the electric charger.

Because of a requirement placed with the Ordnance Corps by the Navy Bureau of Ordnance for the delivery in 1944 of 2,500 caliber .60 aircraft machine guns with auxiliaries and spare parts, limited procurement of the T17E3 was initiated 2 De-

ember 1943 and approved on 16 December 1943. This procurement was begun immediately even though preliminary service tests of the T17E3 had not been held.

When the decision was made to rush the preparation for manufacture of the caliber .60 machine gun at Rock Island Arsenal, it was recognized that the expenditure of large sums of money would be required to put changes in design of the components into production. However, it was felt that a major portion of the tooling for the gun would ultimately be usable, and that the plan followed would save priceless time in getting fully developed guns into the hands of the Air Force and the Navy. The Rock Island Arsenal was commissioned to make these guns.

Up to this time, the only unit to fail consistently was the bolthead. Redesign of this unit was immediately undertaken. The breech ring, firing pin, bolthead buffer springs, and a few minor components had broken, but it was believed that improved metallurgy of these components would satisfactorily increase their life.

This gun weighed 135 pounds including recoil mounting adapter, electrical charger and solenoid, and feed mechanism. The rate of fire was 600 rounds per minute, the muzzle velocity was 3,500 feet per second. The gun was 92 inches long and had a maximum trunnion reaction of 3,500 pounds.

At the request of the Army Air Force, the original procurement was increased 5,025 guns by Ordnance Committee action on 23 December 1943. Twenty-five guns of this procurement were allotted to the Ordnance Corps for experimental purposes.

Two T17E3 machine guns manufactured by Frigidaire were delivered to Aberdeen Proving Ground on 29 December 1943 for test. The breech ring on gun number two broke after a few hundred rounds, severely damaging the gun. Gun number one successfully fired several thousand rounds. The gun fired erratically with frequent and long hesitations. These hesitations were later found to be caused by stubbing of the bullet point against the breech face of the barrel. A 25-round burst was considered good.

During January 1944, a research project was established with the Battelle Memorial Institute, Columbus, Ohio, for the purpose of making recommendations on heat treatment and other metallurgi-

cal operations of the caliber .60 machine gun. Battelle recommended a longer draw temperature and larger fillets in the breech ring. These proved successful.

During February and March 1944, Frigidaire engineers decreased the weight of the bolt to 5 pounds, increased the diameter of the bolthead roller trunnions to 0.656 inch, removed the link stripper from the feedway since it was found unnecessary and added a cartridge holddown lever and a feed pawl control lever to the feed box. The feed pawl control lever prevents a round from being fed into the feedway by the feed pawls while another round is already over the feed slot in front of the holding pawls. This is accomplished by a linkage attached to the feed pawl control lever, which lifts the feed pawls and prevents them from engaging the feed belt when a round is already over the feed slot and forward of the holding pawls. The cartridge hold-down lever positions the round in the feed slot and holds the round down as the bolthead drives it forward.

In April and May in 1944, this gun was tested. It fired 100 rounds at a uniform cyclic rate without a stoppage and the cyclic rate was estimated to be approximately 600 rounds per minute. Malfunctions were reduced to 1 percent and breakages to 0.3 percent.

On 13 March regular weekly conferences were initiated by the Small Arms Development Division, Research and Development Service, United States Army, to integrate all information on the progress of the project. This conference series was attended by representatives from Field Service, Industrial Service, Office of the Air Ordnance Officer, Navy Bureau of Ordnance, Frankford Arsenal, and occasionally by representatives from Aberdeen Proving Ground, Rock Island Arsenal, and Frigidaire. In these meetings, all changes in the gun design were discussed and transmitted to the Industrial Service, which in turn sent the information to Rock Island Arsenal. The minutes of these meetings, which were held weekly until 15 January 1945, biweekly until 27 August 1945, and monthly thereafter, were filed in the Small Arms Development Division, Research and Development Service, and in other Ordnance establishments.

By June 1944, Rock Island Arsenal through the Industrial Service had been furnished complete

drawings for the caliber .60 T17E3 machine gun and all accessories developed up to that time except the bore-cooling device. Tooling at Rock Island Arsenal was approximately 80 percent completed. Every effort was made to cooperate and assist Rock Island Arsenal in this tooling and to modify components and assemblies and simplify design to assist manufacture. The weekly meetings were almost entirely devoted to this work.

Rock Island Arsenal had completely assembled three caliber .60 T17E3 machine guns from parts made at the Arsenal and by its subcontractors. These guns were test fired approximately 100 rounds each. Ammunition did not feed properly. The cam tube was redesigned by Rock Island Arsenal as a two-piece construction without prior firing tests. This was not satisfactory, as the forward locking end became separated from the remainder of the tube. This was corrected by Rock Island Arsenal as soon as observed.

Further firing tests disclosed that these guns fired erratically with a cyclic rate of approximately 600 rounds per minute. Frequent bolthead and breech ring breakages were encountered. Rock Island Arsenal breech rings failed at an approximate average of 1,000 rounds each, while Frigidaire breech rings were failing at approximately 5,000 rounds average life. Later, one Frigidaire breech ring was fired more than 20,000 rounds. Difficult extraction was encountered with frequent breakages of extractors. As a result of this performance, manufacturing operations were reduced.

An invitation from Army Ordnance brought Navy, Rock Island, Industrial Service, and Army Ordnance representatives to Aberdeen Proving Ground on 15 August 1944 to witness a firing demonstration of the Frigidaire manufactured gun. It was fired 1,000 rounds with one malfunction and no breakages. A few days later, a firing test was conducted at the Frigidaire plant. Frigidaire personnel fired another Frigidaire manufactured gun 2,138 rounds without a malfunction. An intensive development study was initiated to correct the differences between the Frigidaire division and Rock Island manufactured guns.

At the end of World War II, the development picture as a whole was considered very promising. Manufacturing difficulties had been overcome to an extent, and the drawings had been entirely stabil-

ized. With a continued delivery of uniform production parts, performance of the gun became truly predictable, the malfunctions were localized, and their number and occurrence were reduced.

In March 1946, the average malfunction rate was one per thousand rounds. This was based upon the firing of not more than 5,000 rounds in any single gun and required replacement of parts according to the schedule below.

Component	Replacement required after round			
	1,000	2,000	3,000	4,000
Firing pin.....	X	X	X	X
Drive spring.....	X	X	X	X
Bolthead.....		X		X
Bolthead cam.....		X		X
Bolthead rollers.....		X		X
Bolthead buffer spring.....		X		X
Bolthead buffer blocks.....		X		X
Extractor cushions.....		X		X
Extractor.....		X		X
Roll pins A7160389.....		X		X
Roll pins A7160220.....		X		X

More than 309 T17E3 guns had been manufactured and more than 950,000 rounds of ammunition of various types had been fired in them. Tests were continued to ascertain the life of the various components and to reduce the malfunctions. The principal components requiring early (1,000 round) replacement are the firing pin and the drive spring. Several types of these were then under development and test. Because the major components of the gun appeared to be serviceable for much more than 5,000 rounds, work was started to establish a 10,000 round life for the gun by replacing a few parts at 5,000 rounds and by continuing the replacement table beyond that point. Ground tests in several aircraft and Eglin Field Air Force Proving Ground tests were completed. The Ordnance Corps certified to the Air Force that it believed the gun to be operational. Consideration was being given to use of the gun as an antiaircraft weapon in armored vehicles.



## General Description of the Model

A general description of the T17E3 machine gun is as follows. It consists of a receiver supporting a cover, breech ring and barrel. Within the receiver slide a bolt and bolthead. In the cover is a cam tube with a helical slot cut in it. Riding within the cam tube, guided by a helical slot, is the drive bushing which encloses one end of a drive spring. On the outside of the cam tube near its forward end is cut a spur gear which engages the rack that operates the feeding mechanism. When the cover is closed, a stud on the drive bushing engages a raised portion of the bolt and in operation the bolt, bolt-head, and drive bushing travel together. The firing pin is fastened in the front of the bolt and projects into the bolthead. The charger retracts the drive bushing which in turn pulls the bolt back to the sear which is located at the rear of the receiver. When the sear is released, the bolt goes forward, and the bolthead is rotated and locked by the cams on the breech ring and bolt. As the bolt head rotates, the bolt moves forward in relation to the bolthead. This causes the firing pin to protrude, ready to fire the primer.

A buffer spring and a buffer plate are mounted in the buffer block at the rear of the receiver. This assembly arrests the rearward movement of the bolt assembly and with the assistance of the drive spring returns the bolt assembly to battery during automatic fire.

## Component Development

*Development of a New Type Electric Reloader.* The electric reloader developed by the General Electric Co. for the T17E3 gun is an apparatus designed to replace the manual reloading mechanism in the T17E2 gun with equipment that will clear stoppages automatically and reload the gun when required. The standard 27.5-volt d. c. system for airplanes is used as the power source for the operation of this charger and its controls.

This reloader includes all parts and assemblies necessary for its operation. The cable and cross pin in the cover (used in manual reloaders) are replaced by the reloader drive unit which consists of a motor, lead screw, and adapter group, plus other miscellaneous connecting and mounting parts.

The adapter group houses a ball-bearing thrust nut which rides on the lead screw. As the lead

screw is rotated by the motor, the adapter group is driven to the rear along the screw, picking up the drive bushing and retracting the bolt until it engages the sear. This operation also compresses the drive spring. The adapter group is then returned to the front of the lead screw ahead of the bolt by reversing the direction of rotation of the motor by means of a telltale and switch located in the receiver.

The electric operation of the sear is accomplished by the firing solenoid, which is bolted to the back of the buffer block. The armature in the solenoid is attached to a lever arm, which actuates the link bar. The bar, in turn, is fastened to the sear mechanism. When the solenoid is energized, the link bar is moved to the rear. This action depresses the sear and frees the bolt, which is forced forward by the drive spring and fires the gun.

The motor of the drive unit is series wound with a reversing field and is rated at 0.4 horsepower at 10,000 r. p. m. at 25 amperes and 24 volts d. c.

*First Bolt for Electrically Primed Ammunition.* During April 1944, two T17E3 machine guns were completed at Frigidaire and fitted with bolt assemblies to fire electrically primed ammunition. These bolt assemblies were adapted from the bolt used in the German MG 151/20 to fire electrically primed ammunition. The electrical connector between the outside power source and the bolthead passes through the right side of the receiver opposite the case ejection chute. During the firing of a few rounds of electrically primed ammunition at Frigidaire, a bolthead was severely damaged by primer failure. This experimental work was continued on the caliber .60 machine gun T39.

*Preformed Strand Wire Spring Development.* In the initial test firing of the T17E3, the drive spring set severely at approximately 50 rounds. This drive spring was of the conventional type. It was believed that the very short life of this component was due to surges set up in the spring by the high cyclic rate. Helical coil springs made from three-strand preformed wire were then tried. These springs had been used successfully by foreign gun manufacturers as drive springs on machine guns. The usage was confined to applications requiring relatively long, soft springs capable of large amounts of deflection with a minimum change in loading, as is generally required in machine gun drive springs and frequently in firing pin springs.

The first springs of the multiple-strand preformed wire type were observed in Russian machine guns used during the Spanish Civil War. This type spring had also been used for driving and ejector springs in the British Hispano-Suiza automatic 20-mm cannon Mark II. Springs of this type were adopted and were in actual use in the early part of 1940 by the French and British. The preformed wire spring is not claimed to be interchangeable with conventional springs.

A project to develop multistrand preformed wire springs was initiated by the William D. Gibson Co., Chicago, Ill., in November 1942. Trouble was experienced in obtaining wire from the wire manufacturers and in coiling the wire. A quantity of springs of various wire sizes were made and various tests conducted. The following information was obtained:

1. The overall diameter of the stranded wire after coiling remained very close to what it was before coiling.
2. The outside diameter of the coil increased greatly when the spring was compressed.
3. Under static loading there was very little energy absorption due to friction.
4. It was indicated that these springs gave longer life under dynamic loading.
5. It was not possible to coil these springs on production coiling machines.

In June 1944, the Gibson Co. stated that they could not continue the research on this project as their facilities were occupied with work on aircraft valve springs and other vital war production.

The Eaton Manufacturing Co., Detroit, Mich., was given a contract to develop a number of springs suitable for small arms, particularly drive springs for the caliber .60 machine gun, and to design and construct a fatigue testing device capable of testing these springs under conditions similar to those encountered in machine guns.

The company started on the assumption that the motion imparted to one end of the spring is propagated along the longitudinal axis with infinite velocity. Actually, the spring has a finite velocity of propagation; but so long as the velocity of propagation is quite high in comparison with the velocity of displacement, no great errors result from the design assumption based on the concept of infinite propagation velocity. If the velocity of displace-

ment exceeds the velocity of propagation, a condition inherent in conventional machine gun drive springs and firing pin springs together with almost all types of counterrecoil springs, the resulting motion produces higher stresses in the end coils than in the more centrally located intermediate coils.

The beneficial damping effect of the friction provided by the use of preformed wire strands and helical springs is influenced by the number of elements in the strand and by the pitch angle of the elements. For a small number of elements, the strains set up in the stranding are greater than those for larger numbers of elements. It is important in preformed wire springs to coil the helix in such a manner that the twisting moments tend to produce frictional binding on the strand elements. It is vitally necessary to coil these springs to a helix opposite in direction to that in which the strand elements are twisted.

A comprehensive fatigue schedule permitted the conclusion that the optimum preformed wire-strand spring would be made from music wire material using three elements in the strand, the elements being twisted at a helix angle of approximately  $73^\circ$  and the elements of the strand in the coils of the spring being formed as helices, in opposite directions to one another. On the average, such springs were indicated as having a life expectancy of three and one-half times that of the equivalent conventionally designed single-wire spring.

A fatigue testing machine was developed which would vibrate the spring at its resonant frequency and would induce in it the wave motion which is characteristic of the duty imposed on the spring. This machine is similar to a conventional crank-rig testing machine in that it consists of an electric motor, a variable speed control unit, a belt drive, flywheels, adjustable throw crank, and a vertical crosshead which is connected to a means for actuating the spring under test.

The most important difference concerns the rotational speed of the crank. In a conventional machine, the crank rotates at such a low speed that one can assume an infinite velocity of propagation of the distribution along the coils of the spring grinder test, and one can therefore base stress computations on ordinary "static" formulas. In the machine constructed, the rotational speed of the crank is relatively high and is adjusted for each test so that the spring is substantially in resonance, in

which case, the velocity of propagation is approximately equal to the velocity of displacement. In consequence of this condition, the motion imparted to the coils is a wave motion of extreme amplitude, substantially like the wave motion imparted to the coils of the spring in the actual gun or other mechanism which the spring was designed to actuate.

Another difference found in the use of this machine, compared with a conventional machine, concerns the lives of the springs tested in the ordinary low speed tests. Where failures are generally found to occur in hundreds of thousands and millions of strokes in the resonant machine, failures occur in thousands and tens of thousands of strokes. This is an important consideration, because the springs in service under highly vibratory conditions generally fail in the latter order of number of strokes.

The location of failures in the coils of the springs is another characteristic difference found when testing in the respective machines. Failures occur in any coil when a conventional machine is used, but in the resonant machine failures occur invariably in the region of the end coils. This latter location is typical of actual failures in service under highly vibratory conditions. Fatigue failures were obtained in this machine which duplicated in appearance and location those which occurred in service. Hence, results obtained from the fatigue test could be counted upon as indicative of the service life expectancy.

After several trials the Eaton Co. furnished a three-strand preformed wire drive spring which satisfactorily met the requirements as to life except the end coil would spread and creep out over the conical surface on the motor mount seat, thus interfering with the drive bushing. To prevent this, five coils were wound solid on this end and the end of the last coil brazed to its adjacent coil.

*Bolt Assembly.* In June 1944, 10 boltheads made at Rock Island Arsenal by production methods were received at Frigidaire for test in the original Frigidaire guns. Five were broken with a maximum life of 287 rounds. Examination revealed that production boltheads were made of WD 4340 steel instead of the recommended WD 4640 steel, from which the Frigidaire boltheads were made.

It was observed that the finish on these boltheads was not as good as the finish on those that Frigidaire manufactured. The undercut at the base of the

locking lugs had not been finished round to a fine finish. Metallurgical examination revealed in the bolthead surfaces a decarburized layer approximately 0.010 inch deep, caused by improperly controlled furnace atmosphere.

With these refinements completed along the lines observed for Frigidaire boltheads, the life of the bolthead increased to approximately 2,000 rounds. However, when the cyclic rate of the gun was increased to 750 rounds per minute, the frequency of breakage again increased and the average life decreased to less than 1,000 rounds. With a decrease in bolt weight and an increase of the locking cam angle on the breech ring to  $101^\circ$ , the trunnions broke less frequently and locking lug failures remained as the predominant form of breakage.

Various heat treatments were tried on WD 4340 metal. The most successful was the "Martempering" operation submitted by the Battelle Memorial Institute. Because the entire lot of WD 4340 steel had been purchased for the manufacturer of the boltheads, only a few heads were made of WD 4640 steel for limited tests. Many types of patented tool steels were tried without success.

In June 1945, Rock Island Arsenal submitted for test three boltheads made of WD 4820 steel. These boltheads were fitted with replaceable trunnions and had a carburized and ground finish. These boltheads failed in the locking lugs at approximately 3,500 rounds. Early investigations had established that no increase in life in the bolthead is obtained by using removable trunnions if breakages are occurring elsewhere on the bolthead, so this bolthead with integral trunnions was established as standard.

About 15 February 1945, Frigidaire was requested to design a bolthead and breech-ring combination which would consistently fire 5,000 rounds without breakage. No restrictions on redesigning the gun were applied. In April 1945, Frigidaire submitted their first model made from WD 4640 steel, together with drawings of the required gun modifications, to Aberdeen Proving Ground for test. The bolthead fired approximately 1,000 rounds when the trunnion broke. This bolthead was then returned to Frigidaire and equipped with a removable trunnion made of WD 3312 steel and returned for further test. The bolthead fired an additional 5,000 rounds without breakage.

Three more additional bolthead breech-ring combinations were delivered for test. The breech rings were all fired more than 9,000 rounds without breakage, and the boltheads fired more than 6,000 rounds each with replacement at approximately 1,000 rounds of the original trunnions with trunnions made from WD 3312 steel. This design called for a longer bolthead with a different style locking lug and required that the barrel and barrel recoil ring springs be moved forward seven thirty-seconds inch to compensate for the increased length of the bolthead. The design required retooling and could not be incorporated in the first production lot of guns.

**BOLTHEAD ROLLER GUIDE.** In the early T17E3 model, the bolthead rollers were held onto the bolthead trunnions by a **C** ring, which fits into a groove in the center of the trunnions and the center of the rollers. The **C** ring was compressed into the groove in the trunnion, the roller slipped over the **C** ring and released. The **C** ring expanded into the groove in the roller and prevented the roller from coming off.

By leaving the **C** ring off, it was observed that the rollers moved out and rolled along the full surface on the unlocking cam, thus greatly reducing the pressure on the cam surface and increasing the life of the unlocking cam. To assure that the bolthead rollers would remain on their trunnions while they were returning to battery and locking the bolthead, Frigidaire added a recoil spring sleeve between the unlocking cam and the breech ring. This guide limits the distance that the rollers can leave the trunnions at that time. By the addition of the bolthead roller guide, the bolthead rollers were confined to the trunnions of the bolthead at all times, thus making possible the removal of the **C** clips as suggested by Rock Island Arsenal and greatly increasing the life of the unlocking cam.

**BOLTHEAD BUFFER SPRINGS.** At the beginning of recoil, the bolthead is in a retracted position in relation to the bolt body with substantially zero velocity. As recoil proceeds, the bolthead is unlocked as it passes through the unlocking cam. Its velocity and acceleration to the rear are the same as that of the recoiling barrel while the bolt travels rearward as a free body at an increasingly greater velocity.

Soon after the bolthead is unlocked from the

breech ring, the bolt body picks up the bolthead, the system now having been forced into an extended position during the unlocking. The bolt then imparts additional energy to the bolthead, and this energy is transmitted through the bolthead buffer spring assembly. On the early T17E3 guns and earlier models, this assembly consisted of a **U**-shaped piece of spring steel with a steel plug inserted in the **U** to limit the travel of the spring. As the cyclic rate was increased from 450 to 700 rounds per minute, the amount of energy per round transmitted through this assembly increased as the velocity of the bolt group increased. Breakages became more frequent until they were excessive. The **U**-shaped spring assembly was removed and a small steel block containing a very stiff helical steel spring was substituted.

When the cyclic rate was increased to 800 rounds a minute, this spring became highly stressed with the increased load, and the tips of the ends frequently broke when the spring was ground flat. This tip would fall into the bolthead cam and jam the bolthead. The manufacturer of these spring ends was then changed from a "grind flat" to a special end, which gave the wire a square cut ground only one quarter flat on top. This proved highly satisfactory.

**EXTRACTOR AND EXTRACTOR SPRINGS.** The first T17E3 and subsequent models gave difficult extraction and frequent failures to extract. The extractor spring set quickly. As the cyclic rate was increased, the failures to extract and broken extractors became as frequent as 20 per 100 rounds. Experience showed that the extractor spring was not heavy enough to move the extractor lip up behind the rim of the case in the time required. A double spring assembly with one spring placed outside the other was substituted. This arrangement did not prevent the extractor from slipping over the rim of the case and only increased the number of broken extractor lips.

In June 1944, a widened extractor with a heavy lip was tried at Frigidaire. These extractors would extract several thousand rounds but gave rim shears and continued to slip from the rim of the case. Some rounds were so difficult to extract that noticeable hesitations occurred during automatic fire.

Space limitations prevented the use of a higher rate spring, so a solid rubber plug was used. This

proved to be quite satisfactory and entirely eliminated failures to extract caused by the extractor not engaging the rim of the case. To reduce the operations required of the extractor and improve its service life, a slot the width of the base of the cartridge was cut from the top of the bolthead; accordingly, when the bolthead drove the cartridge into the chamber, the base of the round would follow across the bolthead face and force the rim into the entrance groove without the extractor snapping over the rim of the case when the bolthead closed. To strengthen the lip of the extractor, the extractor was increased 0.020 inch in length and the breech face of the barrel shortened 0.020 inch for clearance. This permitted the design of an extractor with a heavy lip. This proved to be the first entirely satisfactory extractor lip. This slotted bolthead, together with the rubber extractor spring, was found to be a real improvement.

There was also tried an extractor design with the extractor hole the same size in both the extractor and the bolthead. A solid steel pin was used. The pin sheared or the extractor broke in a few rounds in all models tested. The clearance between the extractor and the extractor pin allowed movement forward of the extractor when load is applied so the load is taken on the extractor wings.

Aberdeen Proving Ground submitted a bolthead with a projection on the lower edge into which was milled a slot that served as an extractor.

Frigidaire tested a bolthead with an extractor welded into the bolthead. These designs were not thoroughly tested because the extractor slot in these designs would not engage the rim of the case if the round chambered with the rim in advance of the extractor slot, a condition which would not exist except under unusual circumstances. Preliminary tests conducted on these designs gave good results.

Excessive rim shears and erratic firing caused by difficult extraction were not eliminated until fluted barrels were adopted.

**BOLT.** In May 1944, an effort was made to increase the cyclic rate of the T17E3 gun from an average of approximately 615 rounds to 800 rounds per minute. The bolt body weighed  $3\frac{3}{4}$  pounds. A series of bolt bodies, weighing from  $3\frac{1}{4}$  pounds to  $2\frac{1}{4}$  pounds were made at May's Auto Parts, Inc., and tested. The cyclic rate increased approximately 75 rounds per minute for a  $2\frac{1}{2}$  pound bolt

and substantially eliminated bolthead breakages in the rear around the cam lugs. It also greatly increased the life of the bolthead buffer spring assembly. The bolt was standardized after discussion at the caliber .60 meeting of 1 May 1944 at  $2\frac{3}{4}$  pounds with a center cross section which was square on three sides and round on the bottom. The  $2\frac{1}{4}$ -pound bolt produced at May's Auto Parts, Inc., had a hollow center circular cross section with additional holes drilled at right angles through the bolt to remove weight. Preliminary tests on this design showed it to be entirely satisfactory.

**FIRING PIN.** The firing pin designed for the T17 series of guns originated with the German MG 151/20. The tip of the firing pin was 0.078 inch in diameter with a 0.038-inch radius point. The primer used in the caliber .60 round is the same as that used in the caliber .50 round. Because of pierced primers and firing pin tip breakages, the point was changed to 0.90 inch in diameter with a 0.045-inch radius point. Firing pin breakages were still excessive. The firing pin frequently broke forward of the shoulder which passes through the bolthead cam. This breakage was found whenever a gun accidentally fired out of battery.

The major redesign was done on the firing pin. The clearance was greatly increased between the firing-pin hole in the bolt, and the firing pin. The bolthead cam in the firing pin, had a large fillet placed on the shoulder which is forward of the bolthead cam. The firing-pin hole in the rear of the bolthead was chamfered to accommodate this fillet. The firing pin point was increased to 0.110 inch in diameter with a 0.045-inch spherical radius blended with a  $90^\circ$  conical cut. Firing-pin breakages were so numerous, there were times that, if a few hundred rounds were expended per firing pin, it was considered excellent firing.

After extensive firing tests with different firing-pin point diameters and designs, it was conclusively shown that a 0.090 inch diameter tip with a 0.045-inch radius spherical point gave the best results and fewer pierced, plugged, and blown primers. However, this design did not entirely eliminate the condition. Firing pins with chrome-plated tips of the preferred dimensions were then tried with success.

**Mounting Supports.** The rear support used on the T17E2 and the earlier models was designed from the German MG 150/20. This support was quite

difficult to manufacture and was difficult to fit on a mount or cradle. Originally beneath the gun, it was raised on the T17E3 to provide a more nearly axial mounting.

Soon after mockups were furnished the Navy Department, a proposal was submitted by it to change this feature to a rear mount which would be more convenient to use and a front mounting scheme which would give less dispersion than the trunnions with which it was originally provided. The Navy built a number of cradles which used both type rear mounts and a new annular ring type front mount and furnished them to Aberdeen Proving Ground for test.

Based on the results of this test, the Navy type rear mount (flat slide type) and the annular rings about the rear of the ring spring adapter were adopted as AN standard. The Air Force insisted that the forward mounting trunnions be retained, so both types of front mounting were included in the approved design.

*Feed System.* On models previous to the T17E3 the feedway was held in place by the cover and latterly by two small tabs on each side which slipped over the outside of the receiver. On the early T17E3 guns, the cover rose during firing. This allowed the feedway to rise and the bolt missed the rim of the cartridge which was to be fed into the chamber. When this condition was established, Frigidaire was requested to design a feedway which would remain down against the receiver at all times regardless of the position of the cover.

The first model submitted had pins attached to the receiver over which slipped hooks that were welded to the rear of the bottom of the feedway. These hooks had a slight interference with the auxiliary charger bracket and were not very wide. Two holes were placed in the front of the feedway into which slipped two dowel pins that were mounted in the receiver just above the unlocking cam.

Rock Island Arsenal took this design and produced a feedway with wider lugs and with the interference eliminated. This feedway arrangement was adopted as standard and all guns manufactured by that date were modified accordingly.

As the rate of fire increased and the belt pull was improved, the cartridge stop became tattered and loose in a few thousand rounds and permitted the cartridge to carry over the feed slot. Rock

Island Arsenal began extensive tests on an improved method of securing the cartridge stop. Bolting the stop to the feedway was tried but was found unsatisfactory because of sheared bolts.

After extensive trials during which high speed motion pictures were taken, it was discovered that the feed pawl spring did not depress the feed pawls fast enough for the feed pawls to catch the round, thus causing failures to feed. Also it was believed that the feed pawl control lever and its linkage, plus the cartridge holddown lever, required enough energy to reduce the belt pull as much as 50 rounds.

The Autoyre Co. was engaged to design a feed system which would be more easily manufactured and have an increased belt pull. The Autoyre Co. designed the belt feed slide which replaces the cartridge holddown lever and the feed pawl control levers and its linkage. This slide was fired approximately 35,000 rounds with good results.

*Ejector Development.* The ejector on all the T17 models prior to June 1944 was located in the bolthead. The ejector formed a portion of the top of the bolthead face and was pivoted about a pin which passed through the bolthead. The top of the ejector was struck during recoil by a projection of the feed tray which forced the ejector downward, displacing the case from the bolt face.

If the projection on the feed tray was too high or moved upward when the gun recoiled, it would either fail to strike the ejector or strike it across the very top, thus giving poor ejection. If the projection was too low, it interfered with the movement of the bolthead and reduced the cyclic rate. Manufacturing tolerances and wear in a few hundred rounds often caused ejection to pass from the latter to the former condition.

Boltheads having an integral ejector were often cracked back of the front locking lugs where the ejector slot passed. The recoil plate used had to be thin to prevent cracking between the recoil plate hole and the vertical ejector slot. To improve the strength of the bolthead and reduce manufacturing costs, a project was initiated to improve the ejector.

Rock Island Arsenal submitted a model which consisted of a large leaf spring attached to the rear of the feed way and bent in a loop so that the end rode in the horizontal ejector slot in the bolthead. This model was not successful because of excessive breakage in the spring.

Frigidaire submitted two models. The first one, submitted in August 1944, was a bar hinged in a pin attached to the rear of the feedway and confined by a slot in the cover, which limited its movement upward and rearward. The bar was further guided by a pin attached to the feedway and which passed through a long slot in the end of the bar opposite the hinge. On the bottom of the bar, a second bar, the ejector bar, was welded perpendicular to the first. This second bar rode in the horizontal ejector slot in the bolthead. A small spring mounted between the guide pin and the first bar held the ejector down against the bolt and bolthead. This model was difficult to adjust to proper height, and the upper bar soon bent the cover slot until it was impossible to make an adjustment. To make this adjustment last the life of the gun, a bar was welded across the cover slot which served as an ejector stop. This arrangement was entirely successful except that it required hand fitting to each ejector and made the cover and feedway of each gun not interchangeable. The ejection was entirely satisfactory. Because of the improved ejection, all T17E3 guns manufactured at that time were fitted with this ejector.

Frigidaire continued development, and in May 1945 a full floating self-adjusting ejector was submitted for test. This ejector fired 15,000 rounds without adjustment or failure. This ejector was guided by two pins which were attached to the feed tray and passed through two slots in the ejector bar. Two small helical springs held this bar away from the face of the feedway and against the slot in the cover. The vertical movement of the bar was regulated by an angular stopping surface cut at the bottom of the cover which engaged two angular shelves on the face of the ejector bar. These surfaces were at a 45° angle with the vertical, and parallel with the ejector surface on the bar which rode in the ejector slot of the bolthead and ejected the case during recoil. All T17E3 guns manufactured after 1 November 1945 were fitted with the latter design.

*The Sear.* The sear used in the T17 and T17E1 were copies of the sear used by the German MG 151/20. The development of a satisfactory sear to be operated by a solenoid was undertaken by the General Electric Co. The solenoid should be as small as possible; therefore, the sear must have as low a release load as possible.

The General Electric Co. based its design on the roller-type sear which would give minimum frictional loads on the searing surface. Three designs were tested extensively and several others failed in preliminary tests. The "roll and counterweight" type designed to maintain balance and prevent accidents on rough landings of aircraft carriers, was used on the T17E2 and the T17E3 models. This sear would not always stop the gun and even if it did it was often several rounds after release. High-speed motion pictures showed that the sear assembly had too much mass to recover and remain in a position to stop the bolt after the bolt bounced off the buffer. Also, the force required to stop the bolt was too great to be accomplished without some type of shock absorbing mechanism. When the mass of the sear was decreased so that it would operate properly, breakage was caused in the sear frames and roller trunnions.

The final design adopted was the "block type" sear, which has a light sear frame and a shock absorber to take the load when the bolt is seared. This construction has been entirely satisfactory and is unique in machine gun sear design. In this design the sear roller, when released, is moved upward by a spring under the sear frame and engages a projection on the bottom of the bolt, which drives the sear roll and frame upward and forward. A pin which passes through the sear frame and sear block is carried forward against the spring which is housed in the sear block and which absorbs the initial shock. This pin also guides the sear roll and the sear roll stop on the rear of the sear block.

Several other designs were tested. One was a roller which replaced the projection on the bottom of the bolt. Another had a spring-operated projection attached to the bottom of the bolt, which dropped down after passing over the sear roll and engaged the sear roll on its return from the buffer. These designs were discarded because the adopted design gave better performance.

*Electrical Controls.* To operate the reloader automatically, it was necessary to build into the gun and synchronize with the sear, a telltale device to ascertain the position of the bolt in relation to the sear, and to operate the switch that controlled the reloader. This device operated in parallel with the sear and was actuated by the sear bar. The adjustment of this arrangement due to tolerance buildup

and wear became the major problem. An adjustable telltale was designed, but even then some guns could not be adjusted properly.

In the new sear assembly, a double bar replaced the single bar. This design permitted independent adjustment of that portion of the mechanism connecting the solenoid to the sear. It was not necessary simultaneously to adjust the part which connected the telltale with the motor control switch. Both parts were operated in parallel by the sear solenoid. This arrangement proved quite satisfactory. In the T17E2 design a double switch and cam were operated by the telltale, but the second switch, which was in series with the solenoid control side of the first switch, was found to be unnecessary because of the rapid charger operation in production chargers.

*Breech Ring.* The original breech rings developed by Frigidaire and fired in Frigidaire guns gave satisfactory performance and life. The original breech rings manufactured by Rock Island Arsenal did not meet these standards. Many of the first lot of Rock Island breech rings failed at less than 1,000 rounds. Careful inspection and examination revealed that the heat treatment of the breech rings was not as recommended by Frigidaire and that the finish on the interior working surface was not adequate.

Examination of a Frigidaire breech ring disclosed that the generation of the locking cam began at  $100^{\circ}50'$ , while the Frigidaire and Ordnance drawings specified  $96^{\circ}30'$ . The Rock Island Arsenal breech rings were made to  $96^{\circ}30'$ . This error occurred when the Frigidaire drawings were first made. After many layouts and conferences, a quantity of breech rings was fabricated, having an improved heat treatment, finer ground internal and external surfaces, and a locking cam angle of  $102^{\circ}30'$ . Samples with locking angles of  $103^{\circ}30'$  and  $105^{\circ}30'$  were also tested. These were unsatisfactory as they had an average life of only 1,500 rounds.

A third lot was made with heat treatment recommended by Frigidaire. This lot also had additional metal added under the locking cam and at the rear of the recoil spring shoulder. These breech rings proved satisfactory, firing 5,000 rounds without failure.

The Bureau of Ordnance, Navy Department, submitted a design, and later samples, for firing tests of a breech ring with new locking and stop cam surfaces, and which operated with a special unlocking cam and bolthead cam design. Two of these combinations were tested and found to give a marked improvement in gun performance, longer life of operating parts, and a higher cyclic rate. Because of the expense and difficulties in retooling for this design, it was not used in the T17E3 machine gun.

*Bolt Buffer Assembly.* All models prior to the T17E3 and the first T17E3 guns had a nest of three high-rate helical springs made of wire with a rectangular cross section. These springs were found to be satisfactory when used in a low cyclic rate gun, but at cyclic rates in excess of 700 rounds per minute, these springs set quickly and broke after a few hundred rounds.

In January 1945, Frigidaire made and submitted for test several sets of Belleville bolt buffer springs. Rock Island Arsenal had earlier suggested the use of Bellevilles to avoid a difficult manufacturing problem. These springs decreased the cyclic rate of the gun approximately 15 rounds per minute, but provided springs which would last the life of the gun. These were adopted as standard, and manufacture was begun by Rock Island Arsenal.

*Bore Cooling Devices.* Research on a bore cooling device for the caliber .60 machine gun was actively pursued at Purdue and Frigidaire. The average barrel life for this gun was less than 400 rounds when fired in 25 round bursts with a 2-minute cooling interval between bursts.

In February 1944, the fundamental studies were completed at Purdue University and in March 1944, research and development projects were accepted by the Bendix Aviation Corp. and the Diesel Engineering and Manufacturing Corp. It was found that a bore cooling device for this weapon was highly desirable to increase the barrel life.

Concurrently other methods of increasing barrel life were being investigated and before a satisfactory bore cooling device was obtained, the life of the barrel had been considerably increased by the use of chromium plating and stellite liners. Because of the success of the liner and plating program,



the bore cooling project soon became of minor importance.

*Barrel Development.* Because of difficult extraction, an extensive barrel chamber investigation was launched. Barrel chambers were honed, horizontally lapped, or fine ground, for test firing. None of these consistently gave "easy" extraction. Experiments in headspace and "crush-up" were conducted but failed to give conclusive data. The Oldsmobile division of General Motors Corp. was engaged to flute the chambers of the trial lot of barrels by an extrusion process which used a mandrel. The initial requirements were for 16 flutes .010 inch deep running from forward of the bullet seat to two-thirds the length of the body of the case. The initial barrels were delivered about 15 November 1944 and proved a great success. For the first time, the gun fired at long bursts at a uniform cyclic rate. The cyclic rate increased 75 rounds a minute and no other trouble was experienced with difficult extraction. Barrel chambers having 12, 16, 20, and 24 extruded flutes 0.006 inch and 0.012 inch deep were test fired, but unfortunately the flutes did not carry forward of the bullet seat. Chambers having 16 extruded flutes 0.012 inch deep but running various lengths down the chamber from forward of the bullet seat were tried.

Three-fourths of the length of the case was found to be optimum. These were the first fluted chamber machine gun barrels adopted for use in the United States.

*Forward Sear Bolt.* The military characteristics for the caliber .60 gun called for automatic synchronized fire. Two concurrent developments were initiated: A bolt to fire electrically primed ammunition, and a bolt with a mechanical forward sear to be operated by a trigger motor.

In June 1944, the first models of the forward sear bolt were fired at Frigidaire. Because this bolt had to replace the standard bolt, the design was greatly handicapped by limitations imposed by these space requirements. Nine models were prepared by Frigidaire, four entirely different designs were tested. Three of these designs were mechanically perfect, but only one design had sufficient life of parts to warrant extensive test. This design had a cocking

lever similar to the caliber .50 machine gun which operates in a slot in the receiver and which is interrupted by using a standard trigger motor.

The mechanism was quite complicated and required a complete new bolthead and bolt design. Adequate tests were conducted to determine the frequency of the breakage of parts.

*Heater Development.* Since most aircraft machine guns are equipped with gun heaters when they are used in combat, a program for the development of a heater was initiated about 1 October 1943 with the Pioneer Products division of the General Electric Co. Most aircraft gun heaters manufactured at this time were of the "sandwich" type. They were bolted onto the receiver where the heat was required. Since the heat would be required the full length of the track on which the bolt travels, it was believed that the sandwich-type heater would be inadequate. One-quarter-inch tubing was brazed beneath the bolt tracks in the receiver with ends protruding from the rear. General Electric initiated a project to develop a "Calrod" unit to fit into these heater tubes.

Several units were installed in receivers and tested at Aberdeen Proving Ground. Two units had the Calrod heater element inside the heater tube of the gun. These units failed at the rear end where the electrical conductor joined the Calrod unit. The vibration of firing flexed the joint until it broke after a few hundred rounds. Four receivers were submitted with Calrod units in the annular space between the two brazed sections of the receiver outside the heater tubes. Each unit was one continuous Calrod tube, grounded at one end and fastened to an amphenol connector on the other. These units broke after less than 50 hours and 3,000 rounds, either at the ground or at the amphenol connector. When statically tested, without firing, one heater unit was operated for 1,400 hours and was still operating successfully when the test was discontinued. No satisfactory connection was made between the Calrod unit and the amphenol connector on the gun.

No sandwich-type heating elements were tried, but one unit was being prepared for tests when V-J Day was proclaimed and the project was discontinued with the General Electric Co.

## SECTION 6. CALIBER .60 T17E5 MACHINE GUN

## Description

The gun standardized as the caliber .60 T17E5 aircraft machine gun is a recoil-operated, air-cooled, belt-fed weapon. The belt is of the metallic link disintegrating type. The gun can be prepared for either left- or right-hand feeding. Firing is by means of a solenoid, but a manual release for the sear is also provided. The weapon is provided with a shock absorbing adaptor which also serves as a front mounting. The gun is charged by an electric

charger mounted in the cover and fired from an open bolt.

The gun is composed of several groups of parts: barrel, cover group, bolt group, feedway and ejector group, receiver and barrel support group, and adaptor group.

*Barrel.* The function of the barrel is to direct the discharged projectile. The rifling in the bore (8 grooves, 1 turn in 18 inches) causes the projectile to rotate.

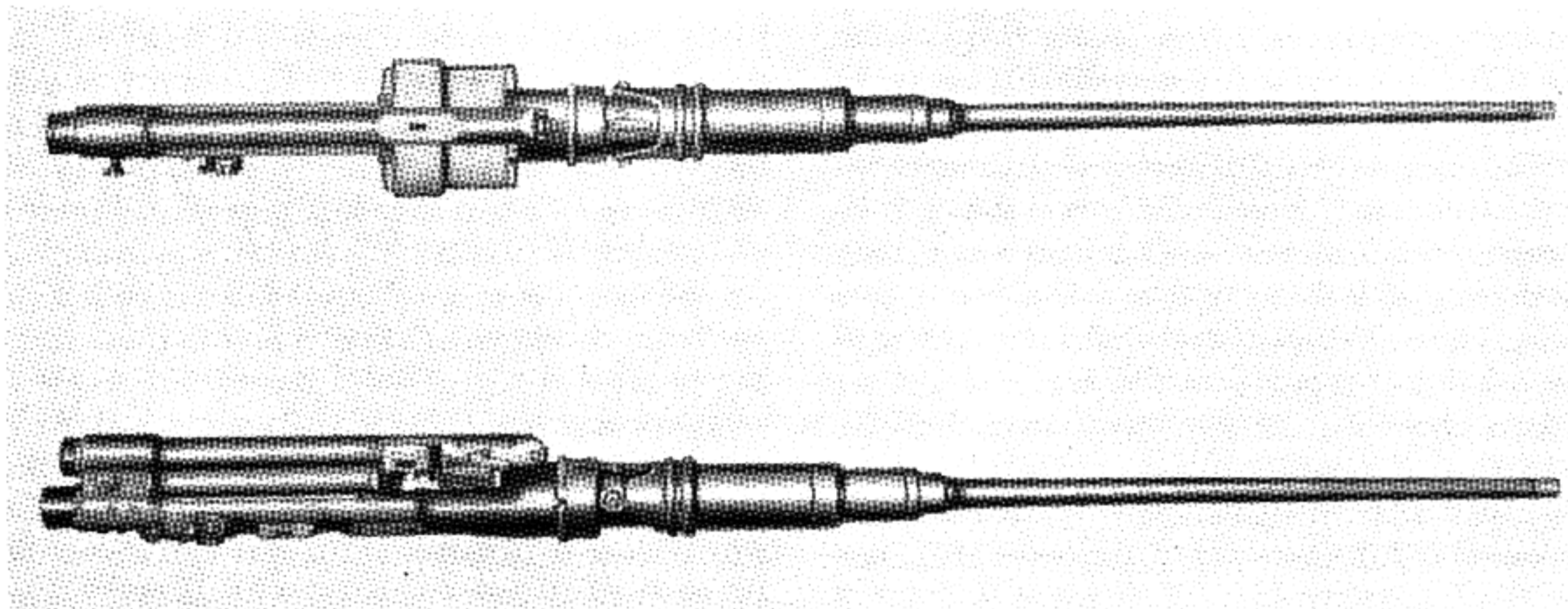


Figure 4-6. Gun, Machine, Caliber .60, T17E5.

## General Data: Caliber .60 T17E5 Machine Gun

Gun length: 91.7 inches.  
 Gun weight, complete with charger: 127 pounds.  
 Rate of fire: 700-750 rounds/minute.  
 Muzzle velocity: 3,400-3,500 feet/second.  
 System of operation: Short recoil.  
 System of locking: Rotating bolthead.  
 System of feeding: Disintegrating metallic link belt.  
 Method of headspace: Factory established.  
 Location of feed opening: Right or left hand.  
 Location of ejection opening: Bottom.  
 Method of charging: Electric.  
 Method of cooling: Air.  
 Overall width at feed assembly: 8 inches.  
 Overall height of gun: 6.5 inches.

Barrel length: 60 inches.  
 Barrel weight: 30.25 pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect.  
 Bore:  
 Number of grooves: 8.  
 Groove depth: 0.016+0.002 inch.  
 Groove width: 0.150+0.010 inch.  
 Pitch: 1 turn to 18 inches.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: '177.  
 Weight of round plus 1 link: 0.607 pound.  
 Muzzle velocity: 3,510 feet/second.  
 Weight of projectile: 1,150 grains.  
 Range, maximum: 5,520 yards.

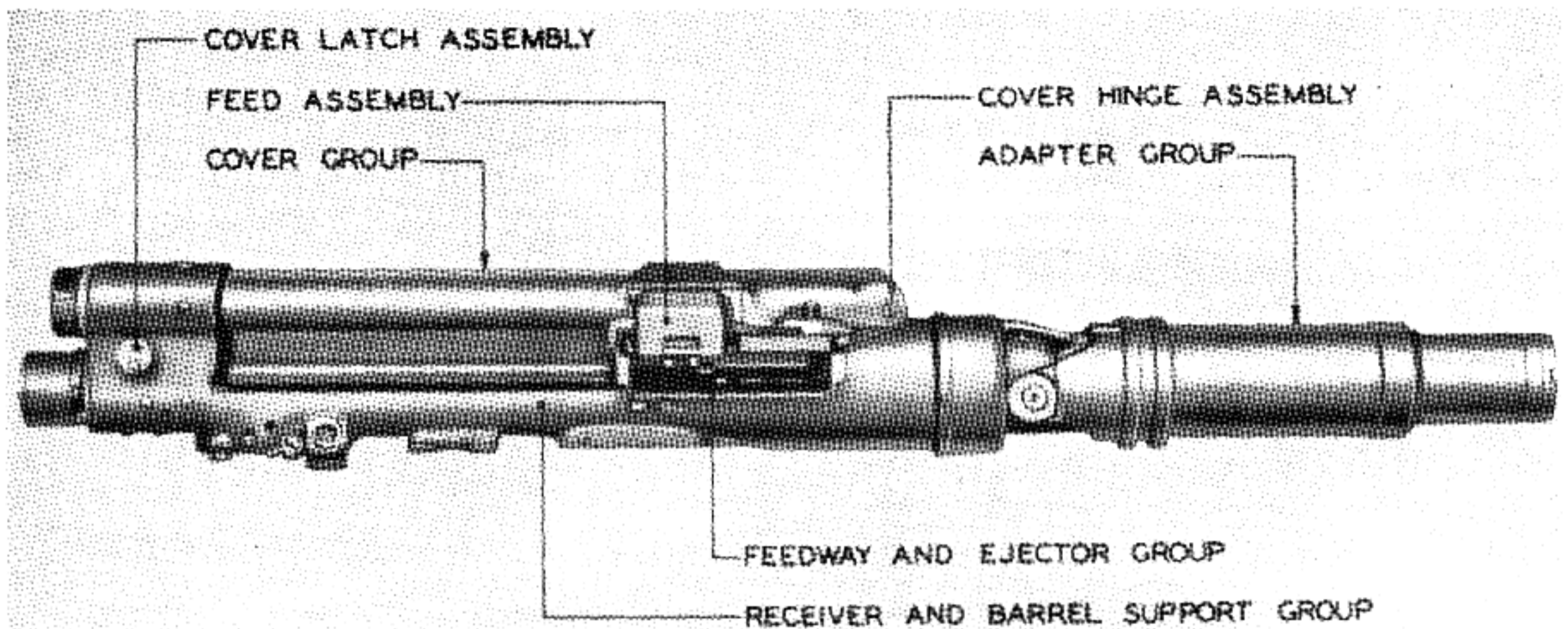


Figure 4-7. Gun, Machine, Caliber .60, T17E5. General assembly of groups.

A hardened barrel liner has been provided to lengthen the life of the barrel. Three knurled bands down the middle provide a convenient gripping surface when assembling the barrel. An enlarged fluted section to the rear of these knurled bands slides within the barrel, bearing the recoil and counterrecoil of the barrel.

The barrel flares outward to a shoulder, to the rear of the fluted section. This shoulder contacts the barrel buffer thrust collar near the end of recoil to stop the rearward travel of the barrel.

Buttress locking lugs around the outside of the barrel, at the breech end, engage mating lugs in the breech ring to lock the barrel in the breech ring assembly. Two small projections, which extend from the breech end of the barrel, are partial safety devices which will interfere with the bolthead if the barrel is not turned to at least two-thirds of its fully locked position. If the bolthead interferes with these projections, but cannot move the barrel forward, as when the barrel is turned less than two-thirds of its locked position, the bolthead will not lock and the firing pin will not strike the primer to fire the cartridge. However, if the barrel is not fully inserted in the breech ring, or if the bolthead interferes with these projections but moves the barrel forward, as when the barrel is fully inserted but not turned at all, then the firing pin can protrude to strike the primer and fire the round if the extractor is holding the cartridge against the face of the bolt.

At the top of the barrel, near the breech end, is a longitudinal locking groove which engages the barrel lock. If the gun is fired with the barrel rotated beyond two-thirds of its locked position, but not locked, it will rotate progressively to the left until the barrel lock engages the locking groove.

*Cover Group.* The cover group includes an electric charger as well as those parts and assemblies whose function is to feed ammunition into the gun.

The front end of the cover is attached to the receiver by means of a cover hinge assembly, which engages the hook projection on top of the receiver.

This cover hinge is designed to permit the removal of the cover when the gun is mounted in a limited space. The design also permits removal by raising the rear end of the cover and pushing it forward. When the cover is closed, it is secured by the cover latch which engages the cover latch block on the receiver. The cover latch spring maintains pressure on the cover latch handle to keep the latch closed. The rolled machine edges of the cover form an upper guide for the bolt.

The belt feed tube is mounted in the top part of the cover and is held in place at its forward end by the belt feed tube lock.

The electric charger, which is assembled inside of the belt feed tube, has a motor assembly with a set of electrical contacts which engage a matching set of contacts in the receiver when the cover is closed. The motor rotates in either direction de-

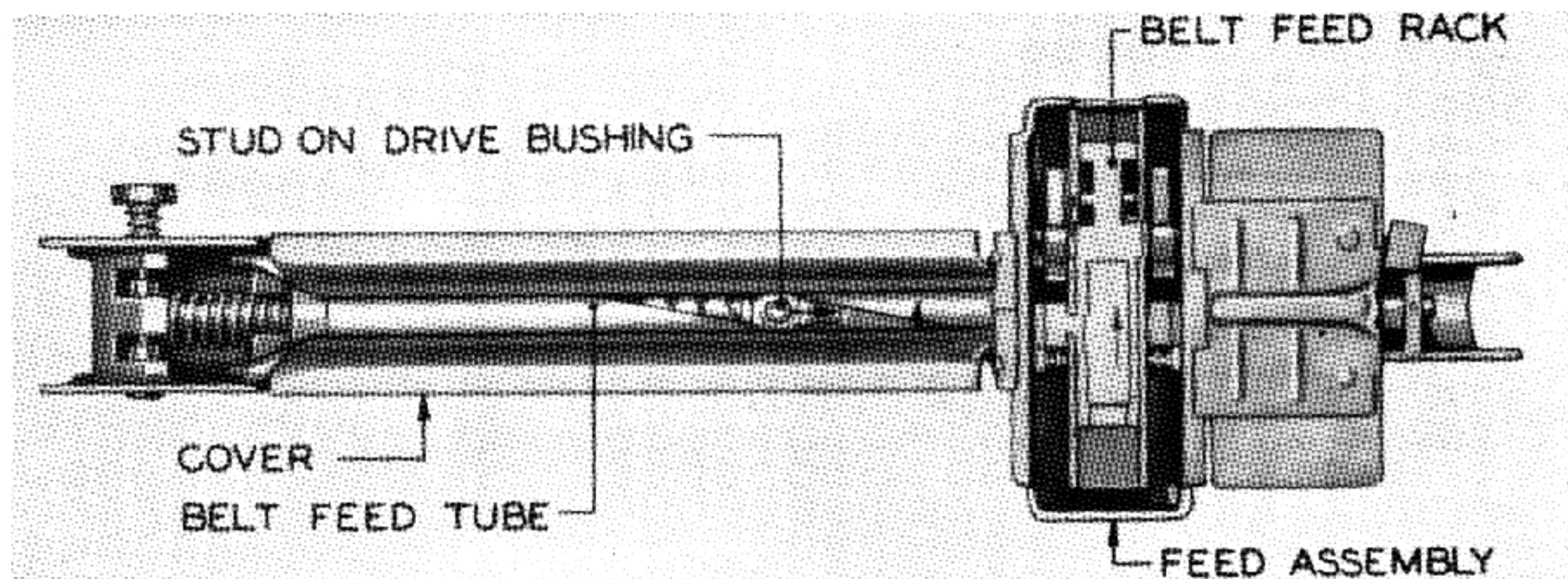


Figure 4-8. View showing how belt feed rack is moved outward during counterrecoil.

pending on the duty required. The motor contains a locking plunger which engages a mating hole in the cover for retaining the charger. The motor mount also provides the housing for the lead screw which is rotated by the motor through the friction drive assembly.

The feed assembly is mounted on the under side of the cover and is secured to the cover by two feed body locks. The stripper rack assembly includes the belt feed rack, universal stripper and belt pawl, as well as minor parts. The belt feed tube moves the stripper and rack assembly back and forth in a sidewise direction to feed the ammunition. The purpose of the stripper is to position the cartridge for feeding and to hold the link during stripping.

Ammunition may be fed into the gun from either side, depending on which belt feed tube is used and the installation of the feed assembly. (Both right- and left-hand belt feed tubes are supplied to provide movement in the proper direction for feeding ammunition from either side of the gun.)

The drive bushing assembly slides inside the belt feed tube. A stud projects downward from the drive bushing and engages a socket in the top of the bolt. A roller on this stud rides in a track formed by the sides of the cover to keep the drive bushing assembly from turning in the cover. Hardened cam surfaces at the base of the stud contact a spiral slot in the belt feed tube. During the forward movement of the bolt assembly and the drive bushing as-

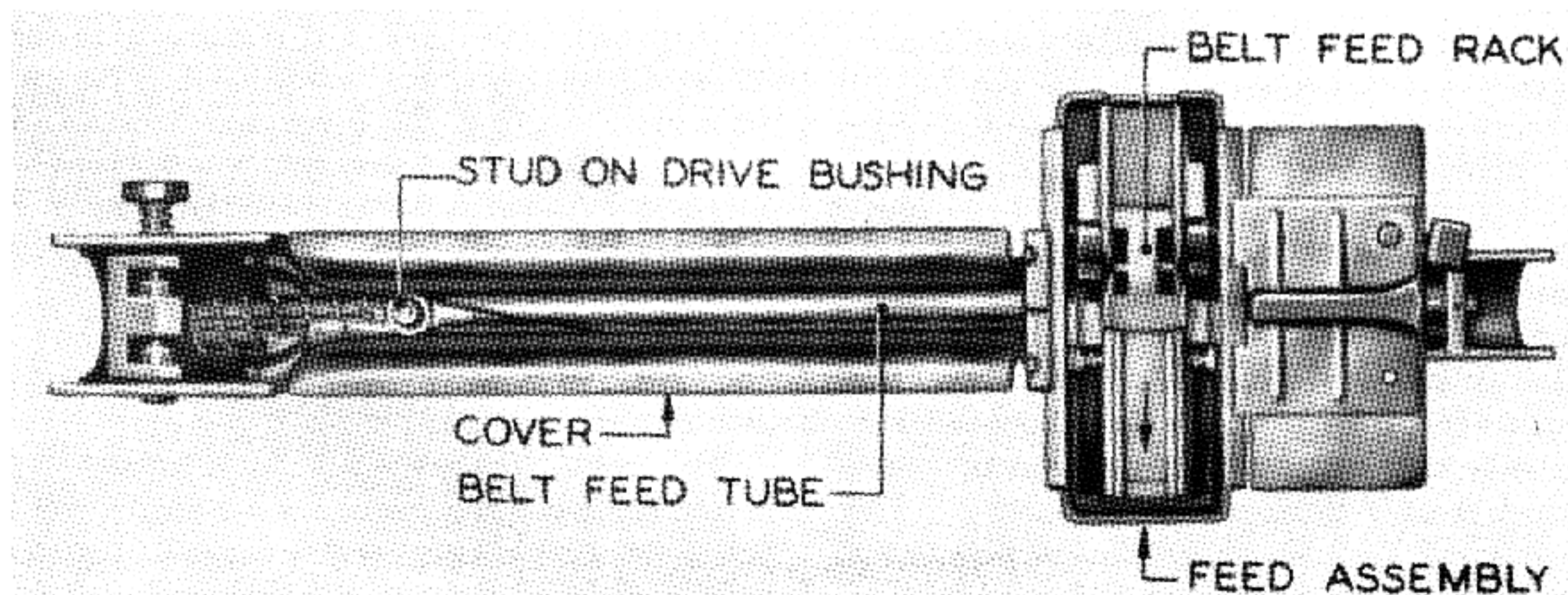


Figure 4-9. View showing how belt feed rack is moved inward during recoil.

sembly, these cam surfaces cause the tube to rotate about half a turn, thus moving the belt feed rack out towards that side of the gun into which ammunition is being fed. This movement of the rack with the tube is a result of the tube being geared to the rack. As the bolt assembly and the drive bushing assembly move rearward, the cam surfaces on the drive bushing cause the belt feed to rotate in the opposite direction.

This movement forces the belt feed rack inward and pulls a cartridge toward the center of the cartridge belt feedway.

When the gun is ready to fire, the bolt assembly is held rearward and a cartridge is centered in the cartridge belt feedway by the universal stripper.

As the bolt assembly moves forward, the cartridge is forced out of the link by the top front edge of the bolthead and the belt holding pawls continue to retain the cartridge belt in position by holding the empty link. At the same time, the belt feed rack is moved outward and the belt feed pawl hinges upward to ride over the link of the next cartridge.

At the completion of the forward movement of the bolt assembly, the belt feed rack has been carried still farther outward, and the belt feed pawl snaps down behind the next cartridge.

As the bolt assembly recoils, the belt feed rack and the belt feed pawl draw the belt into the gun.

The belt holding pawls hinge outward to clear the entering cartridge.

As the bolt assembly reaches the rearmost position, the belt holding pawls snap downward against the link to hold the cartridge and the universal stripper holds the cartridge down in the slot of the cartridge belt feedway so that it projects below the feedway where it can be engaged by the top front edge of the bolthead.

The cartridge guide assembly is slid onto the cover and retained by the contact of the cartridge guide spring with the cover. Attached to the cartridge guide assembly is a spring loaded cover safety catch, which is positioned under the edge of the cover. Whenever it is in a raised position, to prevent the cover from accidentally closing on the hands of the operator, this cover safety catch must be swung out of the way before the cover can be closed.

*Bolt Group.* The bolt group includes the bolt, bolthead, bolthead roller, bolthead cam, bolthead buffer bodies, volute springs, extractor, extractor spring, firing pin, recoil plate, and minor parts.

The recoil plate is pressed into the front end of the bolthead. The extractor spring exerts pressure against the rear end of the extractor, which is pivoted to the bolthead by a double roll pin. This pressure, at the rear of the extractor, forces the front end firmly into the extractor groove of the cartridge and

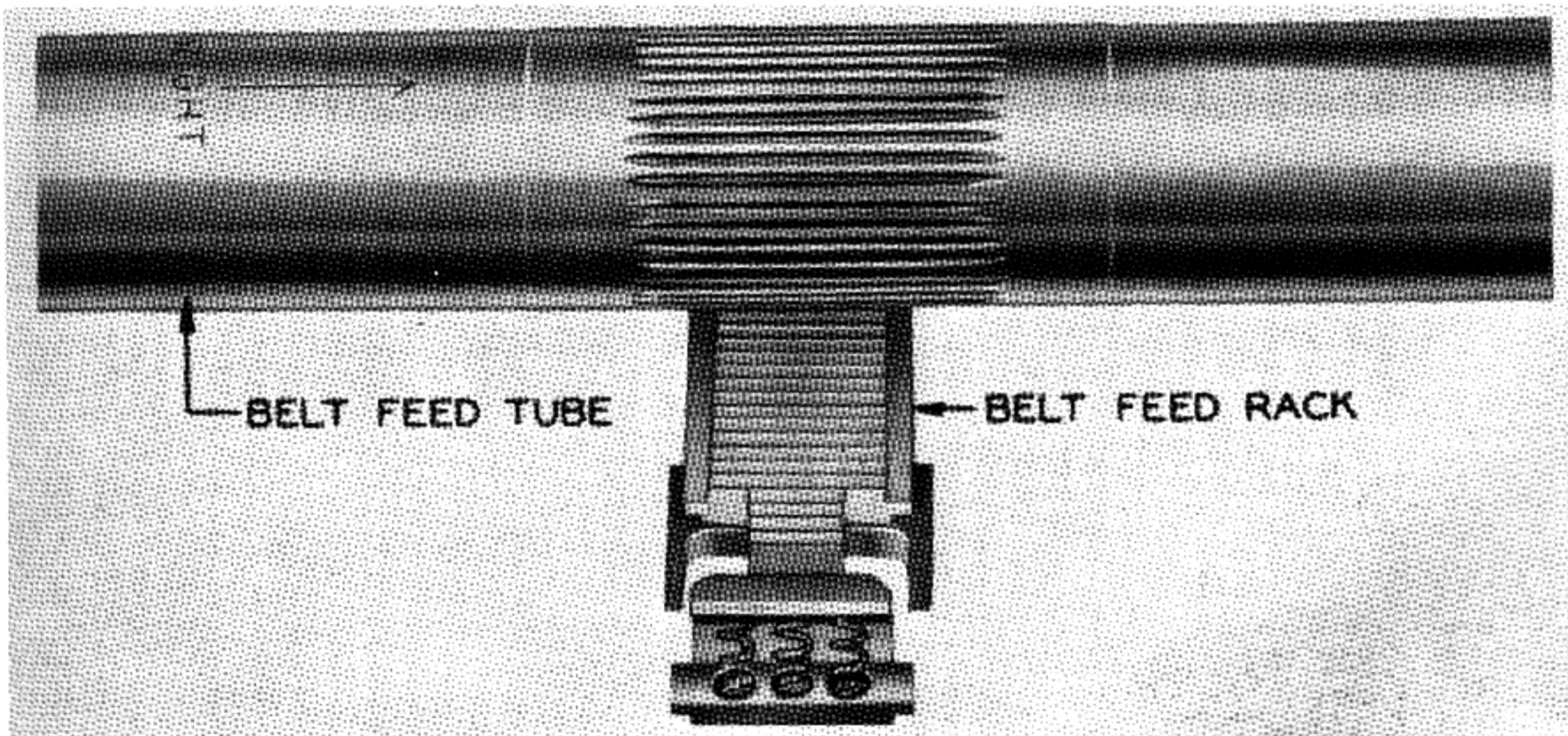


Figure 4-10. View showing engagement of belt feed tube and rack.

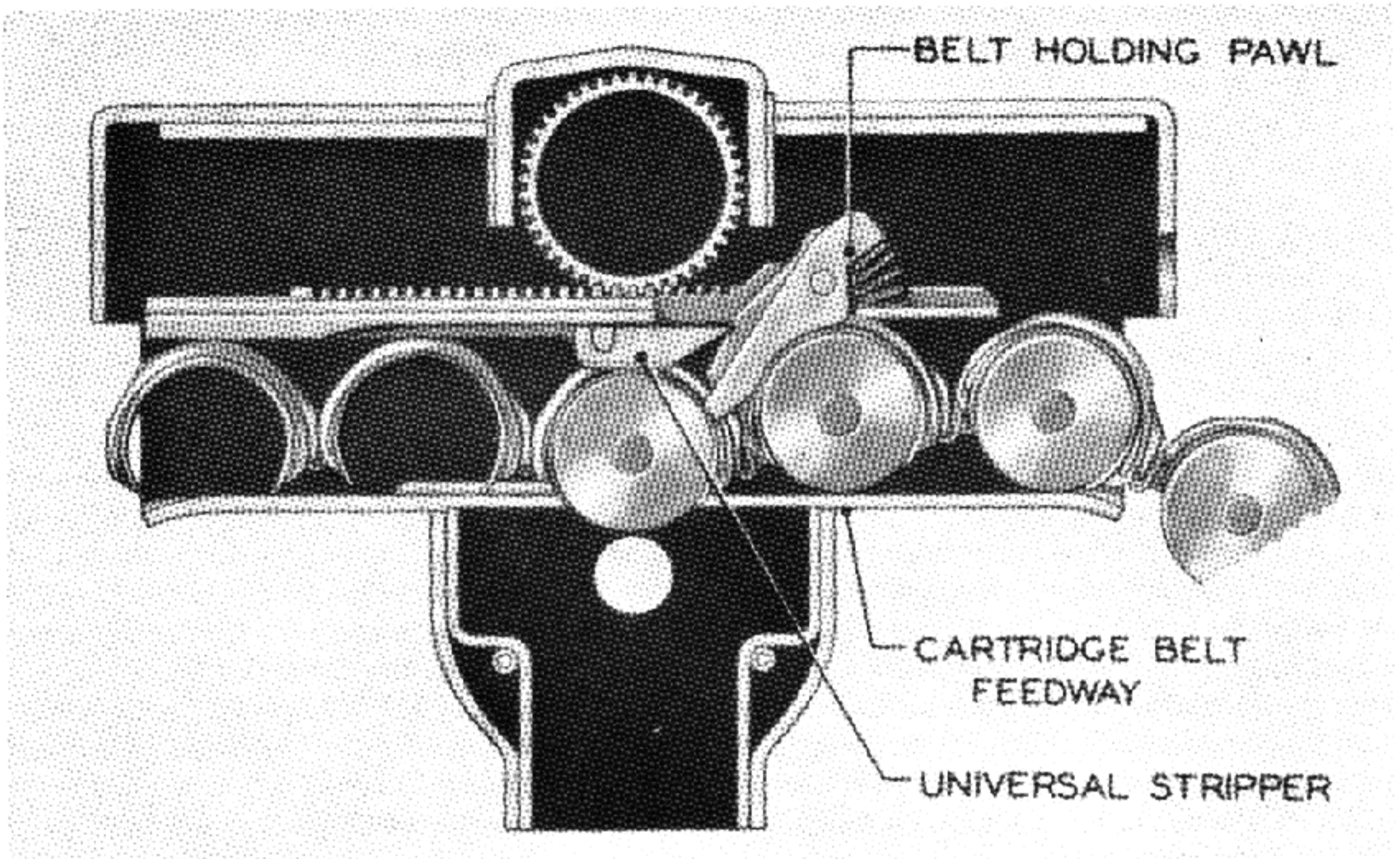


Figure 4-11. View showing how cartridge is held alined in feedway.

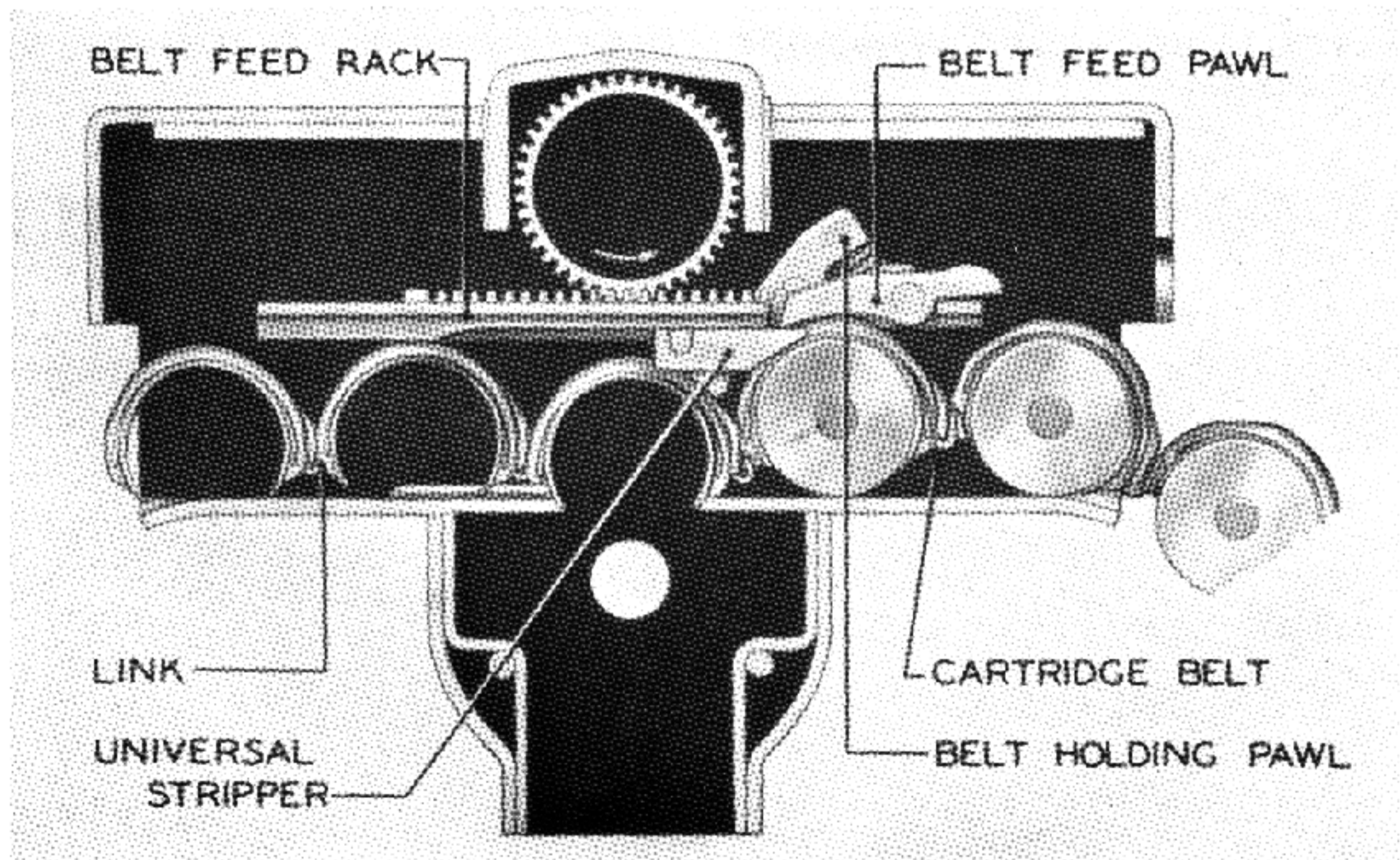


Figure 4-12. View showing how backward movement of belt is prevented when rack shuttles.

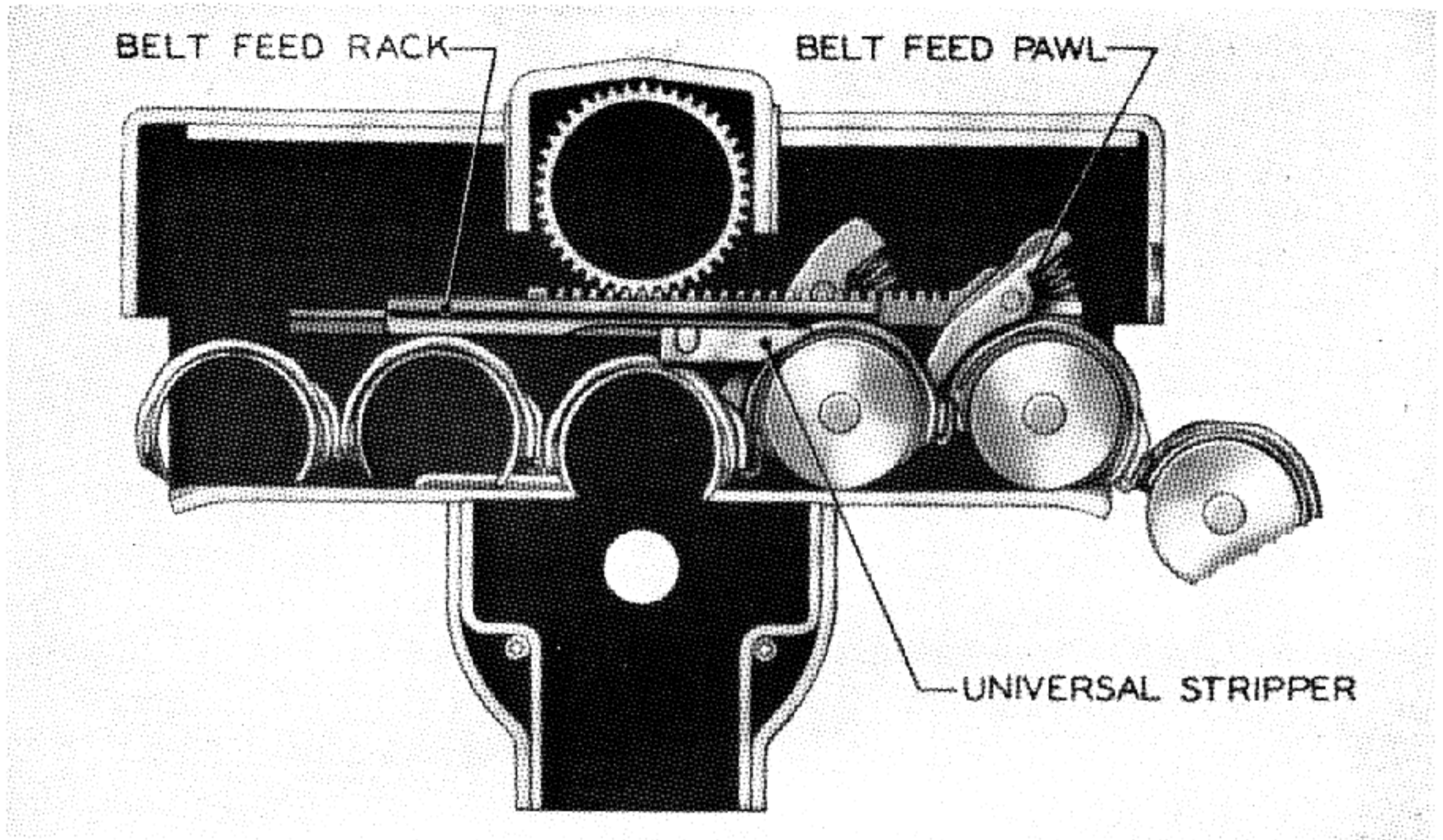


Figure 4-13. View showing how belt feed pawl grasps next cartridge.

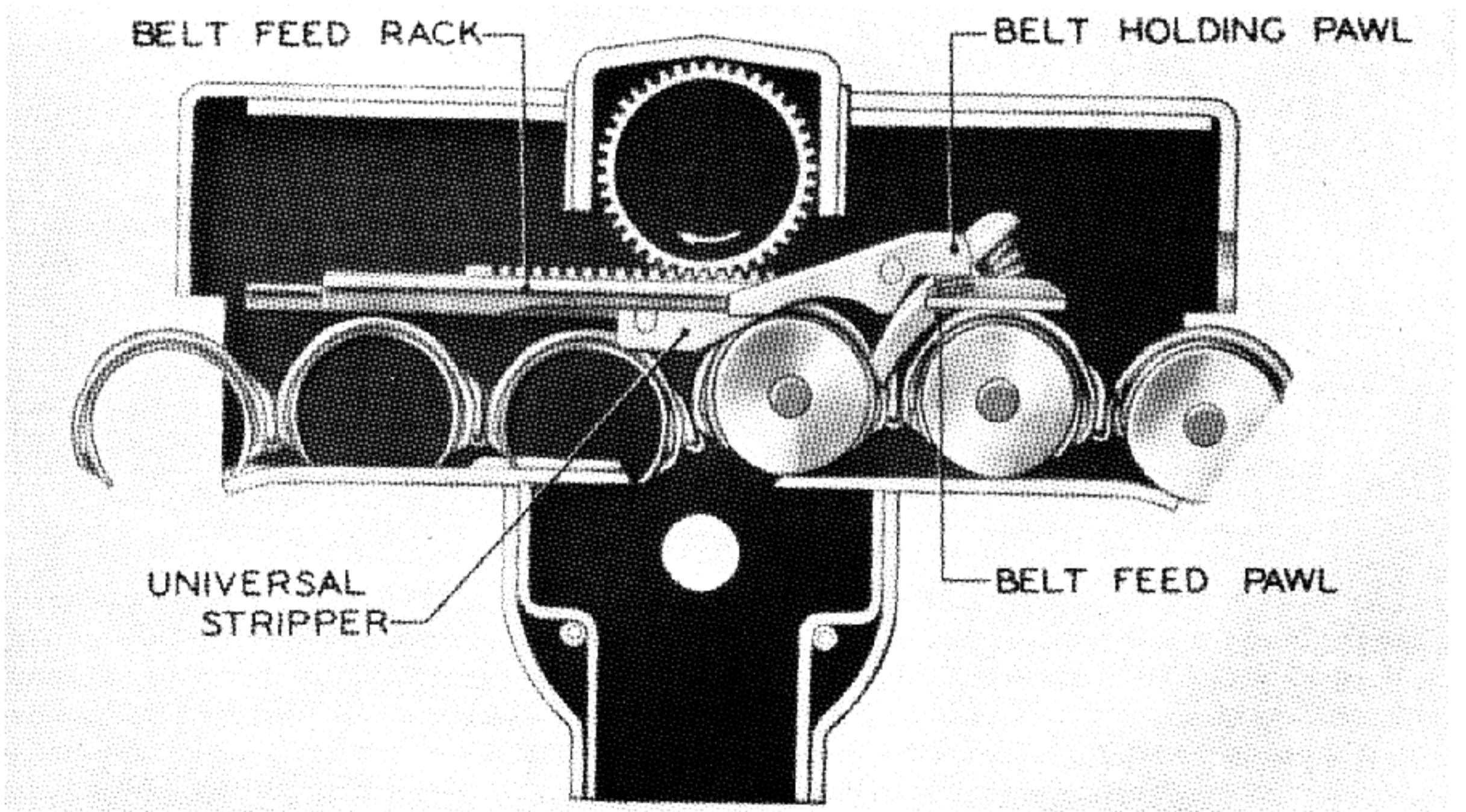


Figure 4-14. View showing how belt feed pawl positions next round in feedway.

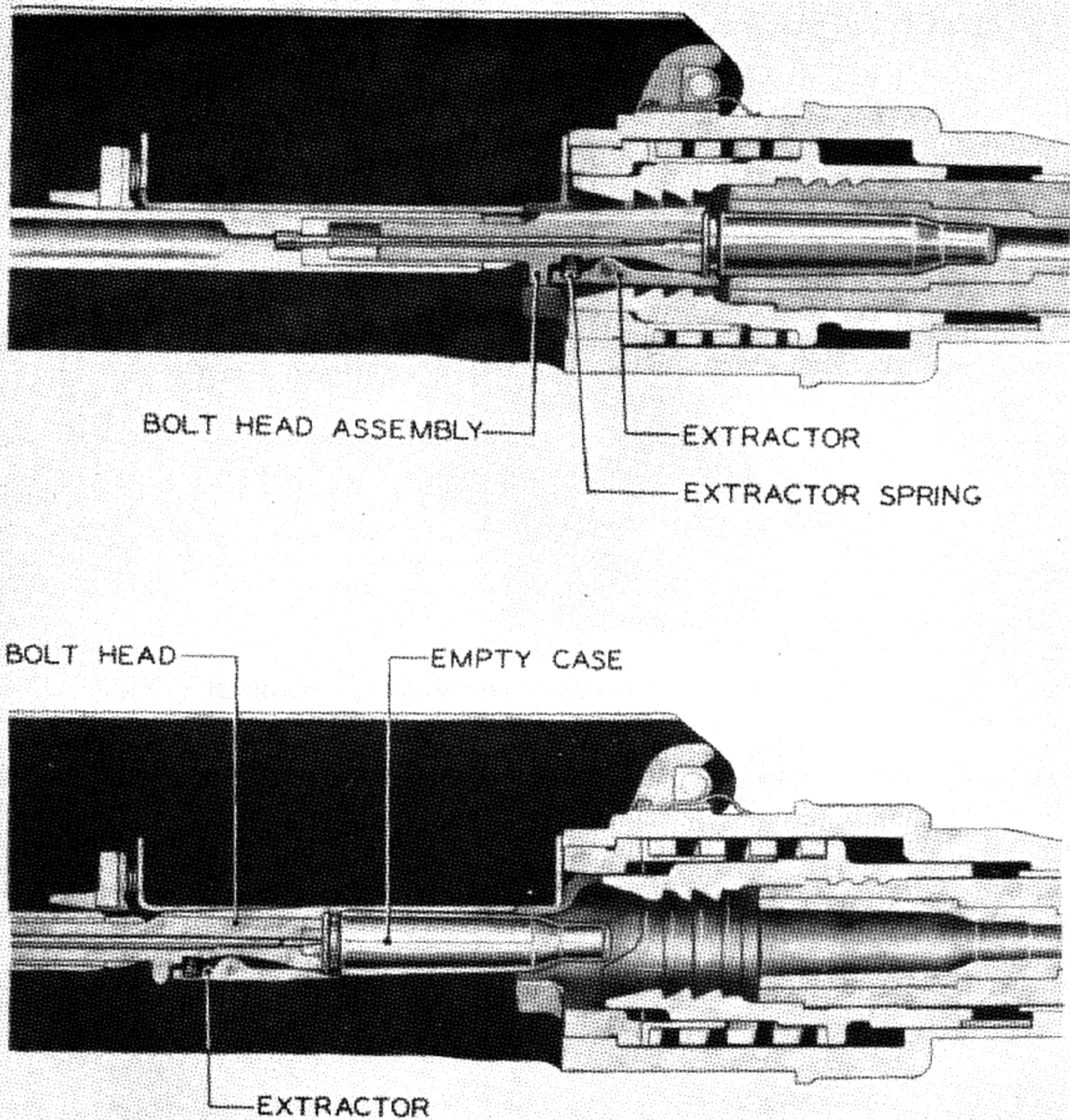


Figure 4-15. The extracting phase in the operating cycle of the Caliber .60 T17E5 Machine Gun.

pulls the empty case loose from the chamber. The extractor is provided with projections to take the extraction and ejection load instead of the load being transmitted to the pin.

As the recoil continues, the extractor holds the empty case in the recess of the bolthead and bolthead rollers operate against cams to cause the locking and unlocking of the bolthead during the firing cycle.

These rollers ride on the track in the receiver during the forward and rearward travel of the bolt assembly.

Cam lugs on the sides of the shank of the bolthead operate in spiral grooves in the bolthead cam assembly, which is recessed in the bolt. The cam is positioned, during assembly, by the bolthead cam pin. While the gun is being cocked, prior to firing, the travel of the spiral cam grooves past the lugs



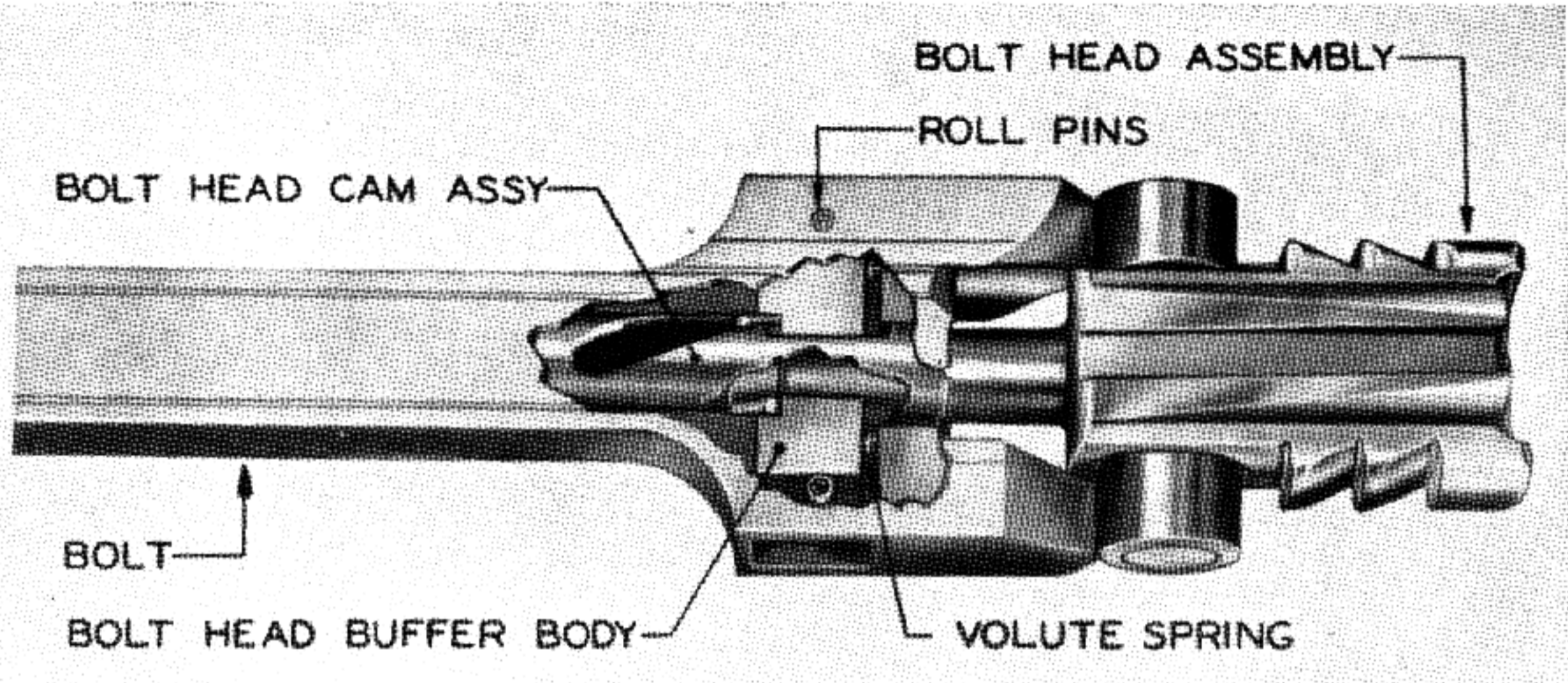


Figure 4-16. Cutaway view of bolt of Caliber .60 T17E5 Machine Gun, showing buffer between bolt body and bolthead.

causes the bolthead to turn and unlock from the breech-ring assembly. This makes it possible to cock the gun without compressing the recoil spring or contacting the unlocking cam. The bolthead cam assembly also holds the firing pin rearward in its recess in the bolt.

The bolthead buffer bodies and volute springs are assembled into each side of the bolt. The rounded inner surfaces of the buffer bodies bear against the shank of the bolthead. Double roll pins hold the buffer bodies in position. The buffer bodies project into the squared section of the slot in the bolthead

cam to keep it from turning and prevent it from moving forward. The buffer springs cushion the shock as the accelerated bolt pulls the bolthead rearward after being unlocked from the breech ring assembly. The forward surface of the cam lug on each side of the shank of the bolthead is driven against the rear surface of the bolthead buffer body.

The under surface of the wider section, at both front and rear of the bolt, slides on the track of the receiver. A lug, which projects outward from each side at the rear of the bolt, rides in a slot between the receiver and the cover. A horizontal hole

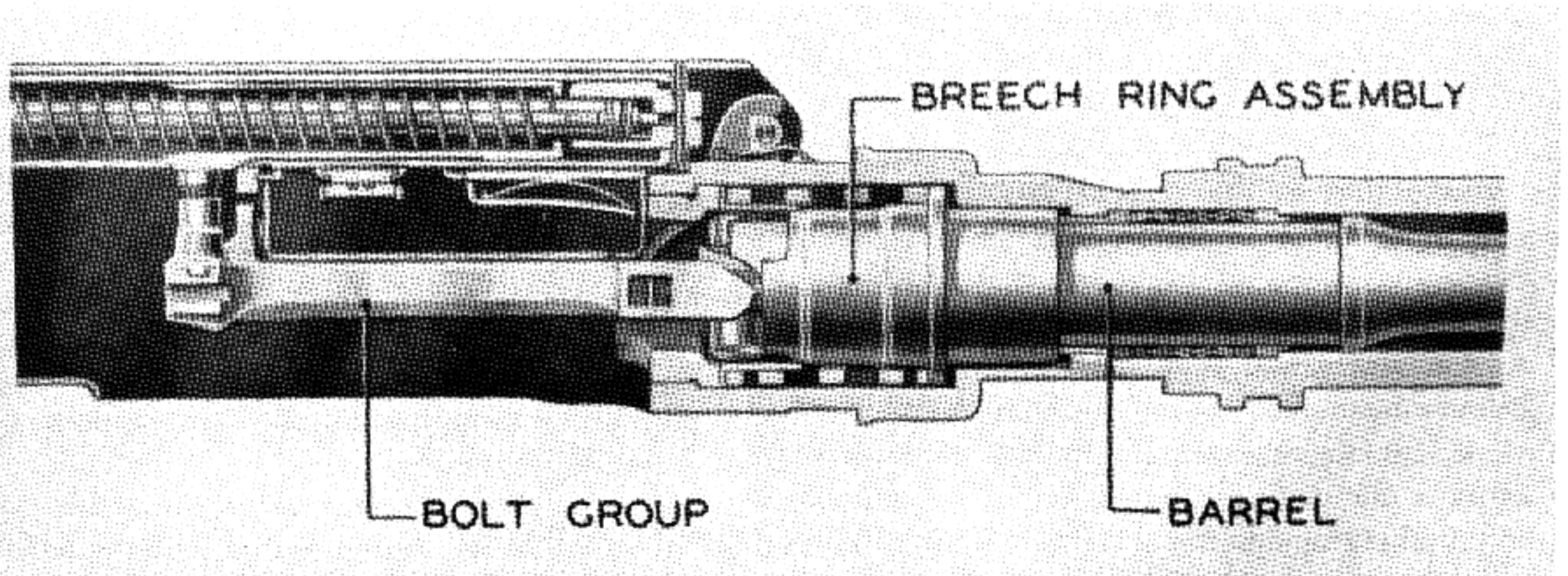


Figure 4-17. Recoiling mass of Caliber .60 T17E5 Machine Gun.

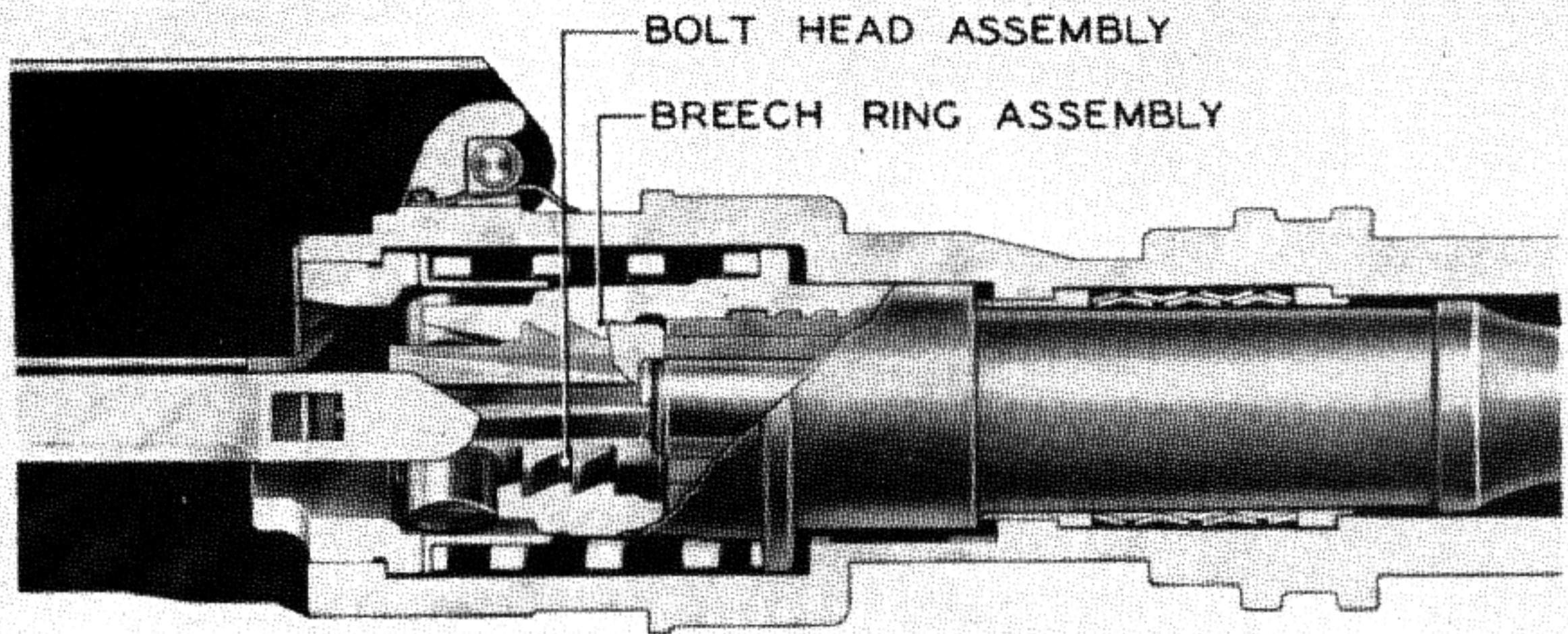


Figure 4-18. Bolt head locking lugs of Caliber .60 T17E5 Machine Gun.

through the projection at the rear of the bolt is to provide clearance for the ejector when the bolt assembly is in its forward position.

The complete cycle of the recoiling portion of the gun, which takes place as each cartridge is fired, consists of the recoil stroke, when certain parts of the gun move rearward, and the counterrecoil stroke, when these same parts move forward. At the instant of firing, the recoiling portion is in the forward position of the gun. At this time, the bolt head is locked in the breech ring assembly against the base of the cartridge. Buttress locking lugs on the inner surface of the breech ring assembly are engaged with mating lugs on the outer surface of the bolt head.

As the cartridge is fired and the projectile travels out of the barrel, the force of recoil drives the recoiling portion rearward. After recoiling about  $\frac{7}{16}$  inch, the bolt head rollers engage the cam surfaces of the unlocking cam. Continued rearward travel of the recoiling portion causes the bolt head to rotate and unlock from the breech ring assembly.

As the bolt head is thus rotated, the rearward movement of the bolt, which has been nested with the bolt head, is accelerated and the bolt moves rearward from the bolt head by action of the bolt head rollers pushing against the bolt nose cams. This acceleration occurs as the bolt head is being unlocked from the breech ring assembly. The firing pin,

which is retained in the bolt, is withdrawn from the surface of the bolt head during this action.

The recoil spring is being compressed throughout the rearward travel of the barrel and breech ring assembly. Following the unlocking of the bolt head from the breech ring assembly, the barrel and breech ring assembly continue to travel rearward, until stopped by the snubbing action of the barrel buffer spring inside the barrel support assembly. The total recoil distance of the barrel and breech ring assembly is approximately  $1\frac{1}{4}$  inches.

During the rearward travel of the bolt assembly, the drive spring assembly is compressed by the bolt acting through the drive bushing assembly. The rearward stroke of the bolt assembly is finally stopped as it strikes the buffer plate which is cushioned against the Belleville buffer springs.

While the bolt assembly is still recoiling and recocking the gun, the barrel and breech ring assembly are forced forward in counterrecoil by the energy stored in the recoil spring. When the barrel has moved forward into firing position, the barrel buffer spring inside of the barrel support again comes into action to stop the barrel and breech ring assembly.

If the sear roller has been held down, either manually or electrically, the bolt assembly rebounds from the buffer plate and is driven forward on another firing cycle by the energy stored in the drive spring

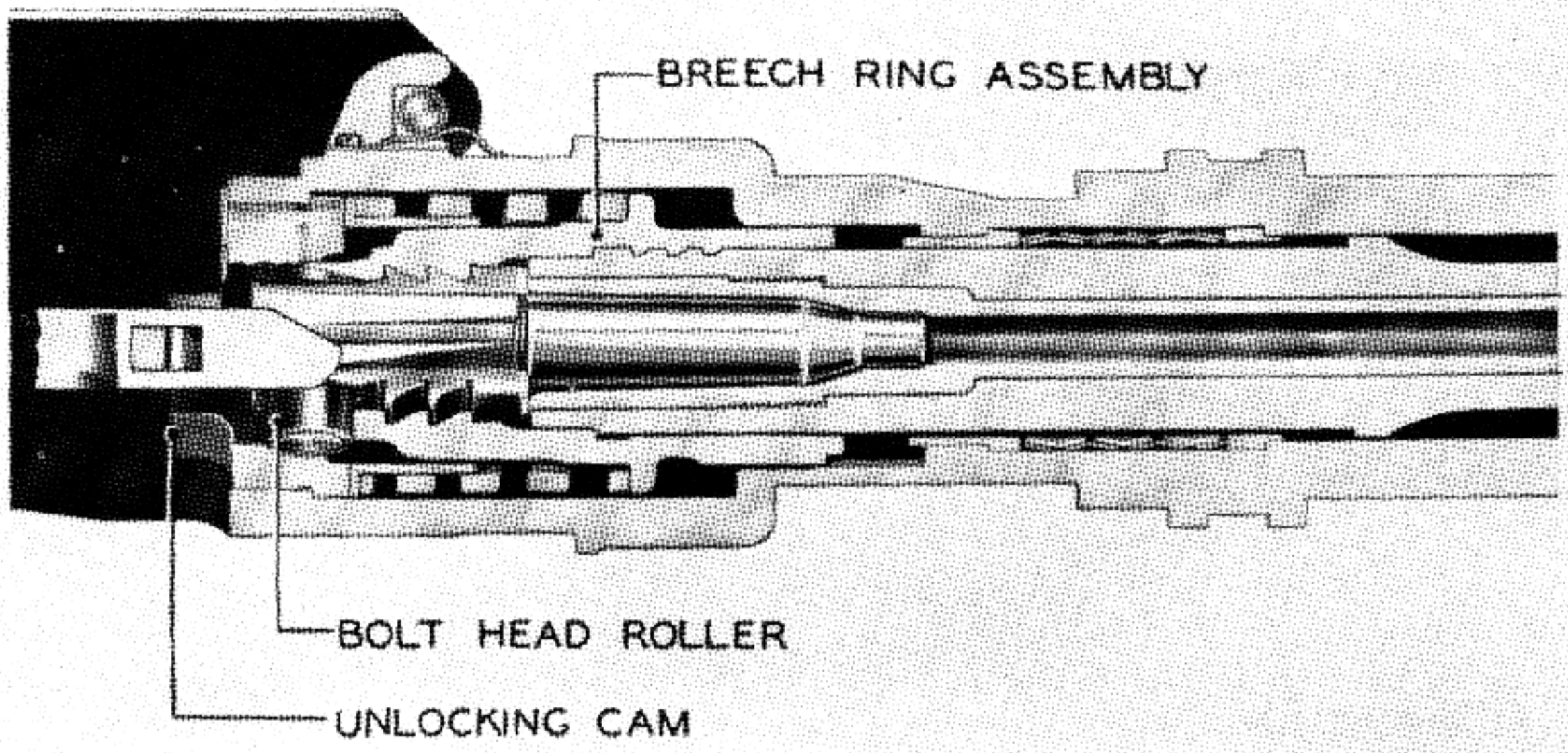


Figure 4-19. Unlocking action of Caliber .60 T17E5 Machine Gun.

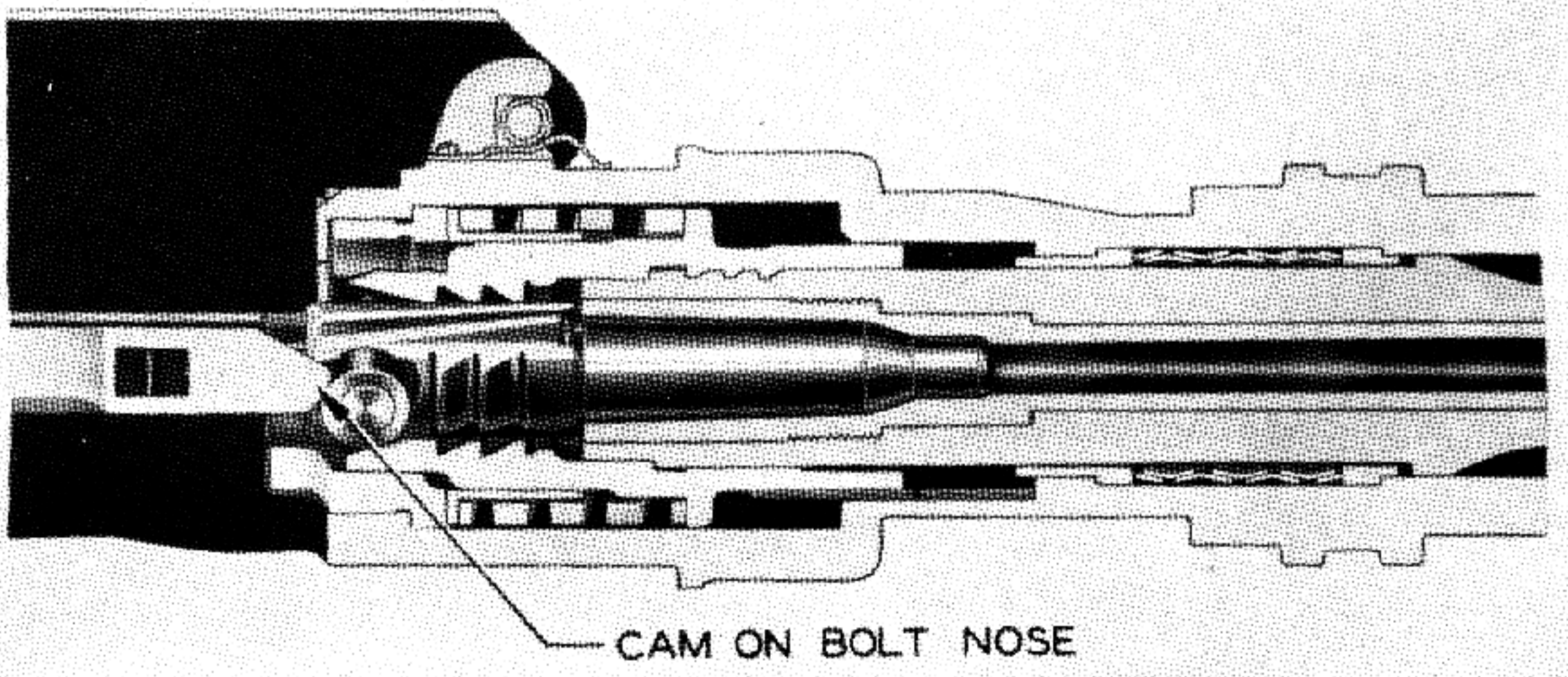


Figure 4-20. Method of accelerating bolt.

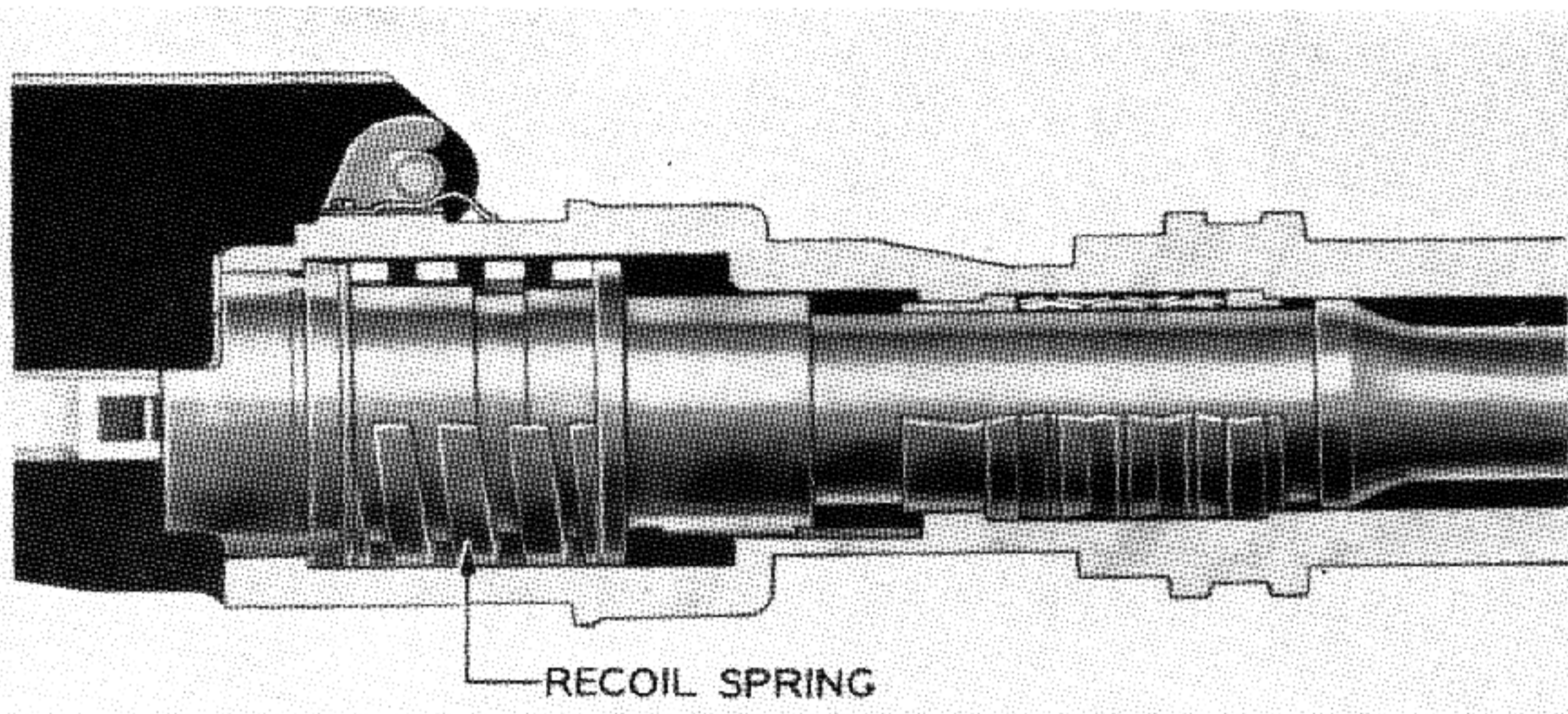


Figure 4-21. View showing recoil spring compressed.

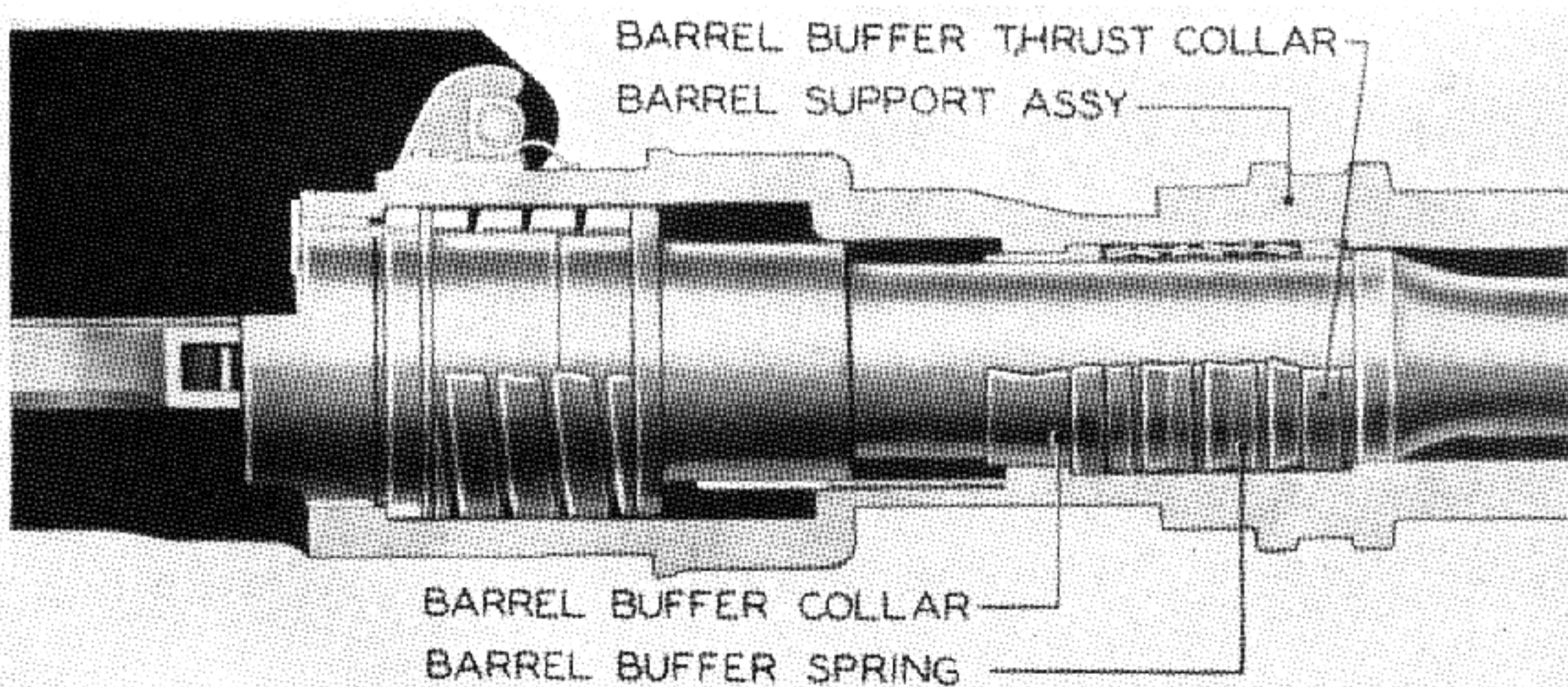


Figure 4-22. View showing how barrel buffer stops barrel recoil.

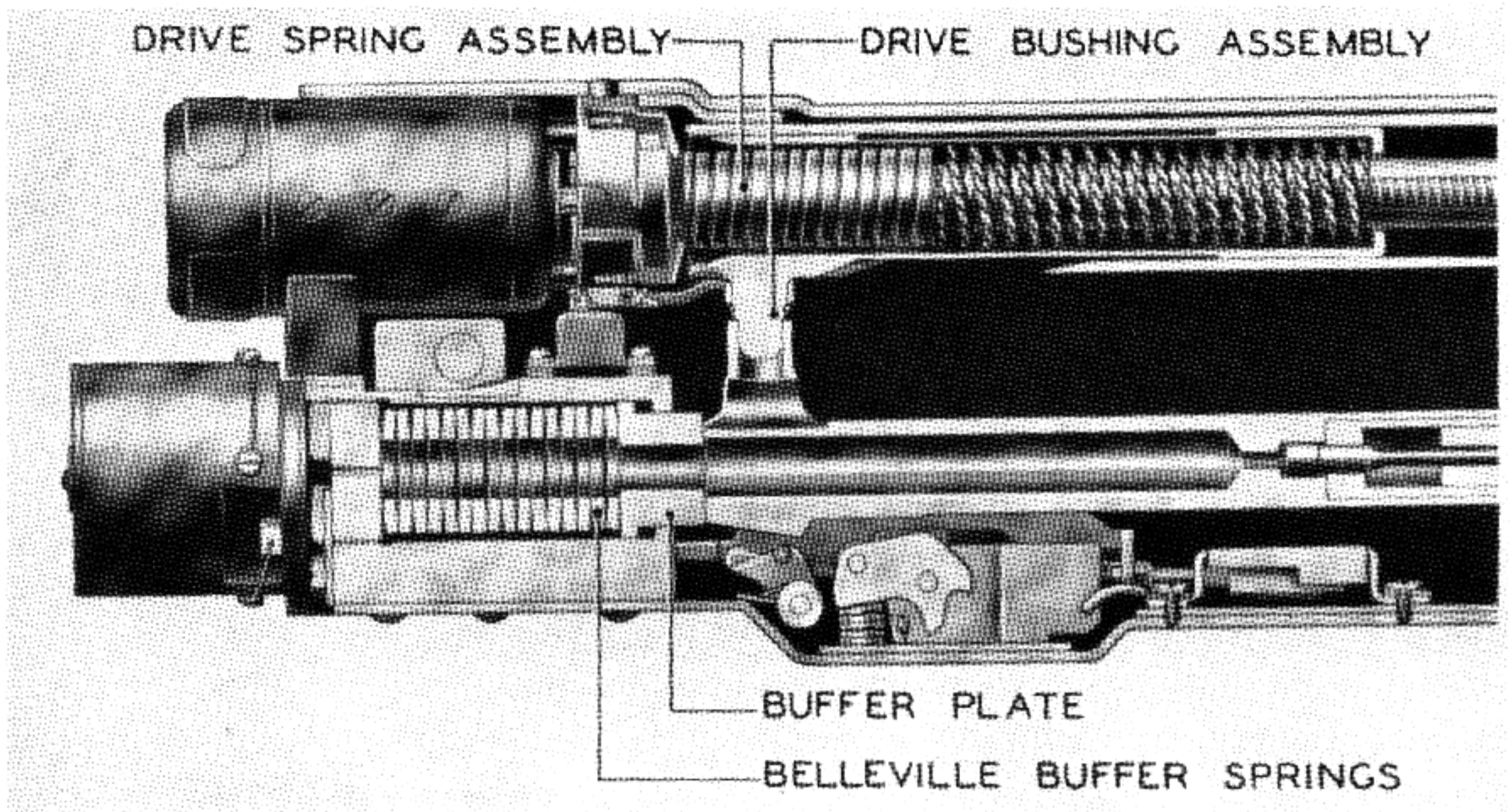


Figure 4-23. View showing how bolt buffer stops bolt recoil.

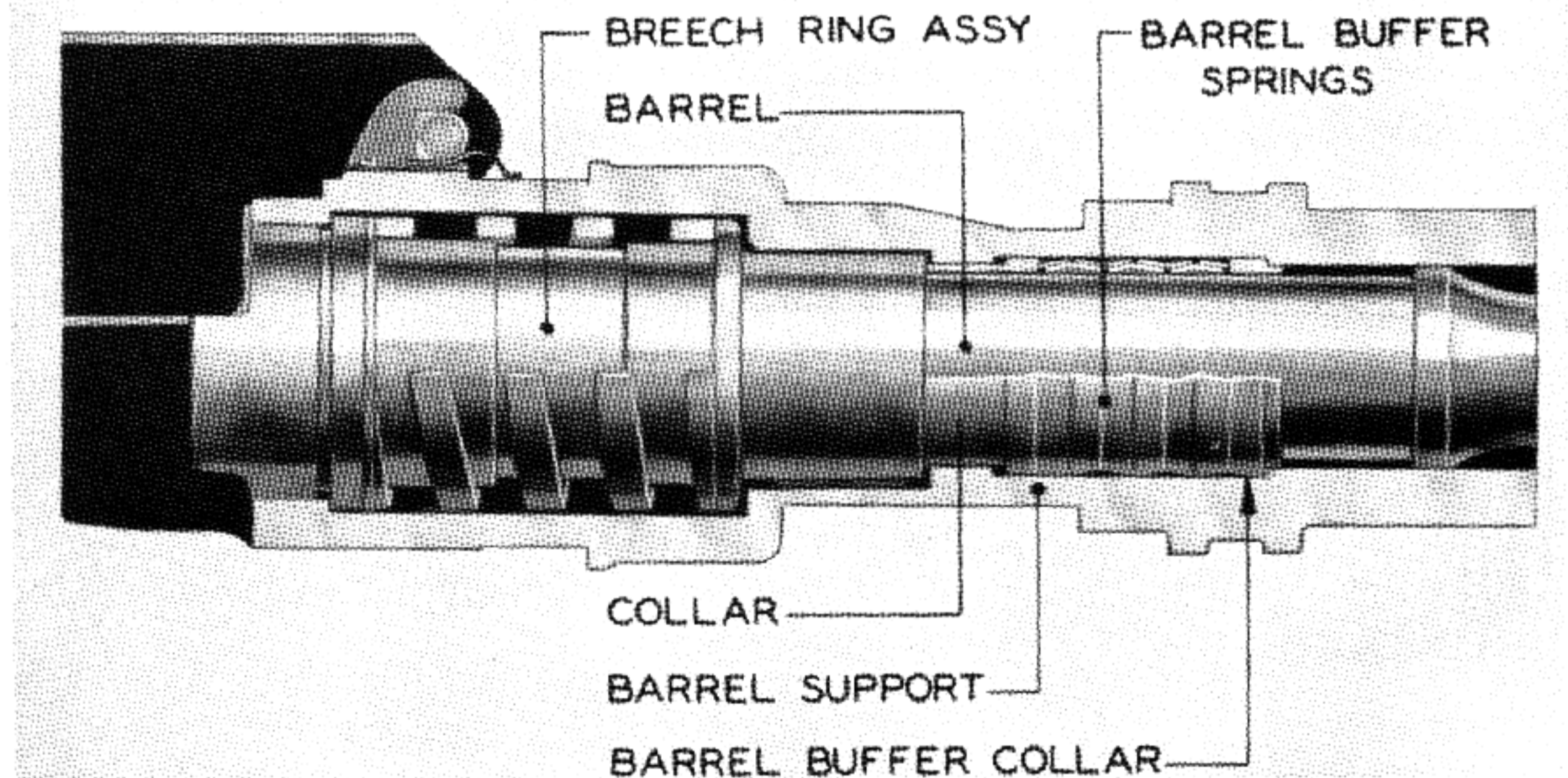


Figure 4-24. View showing how barrel buffer stops barrel counterrecoil.

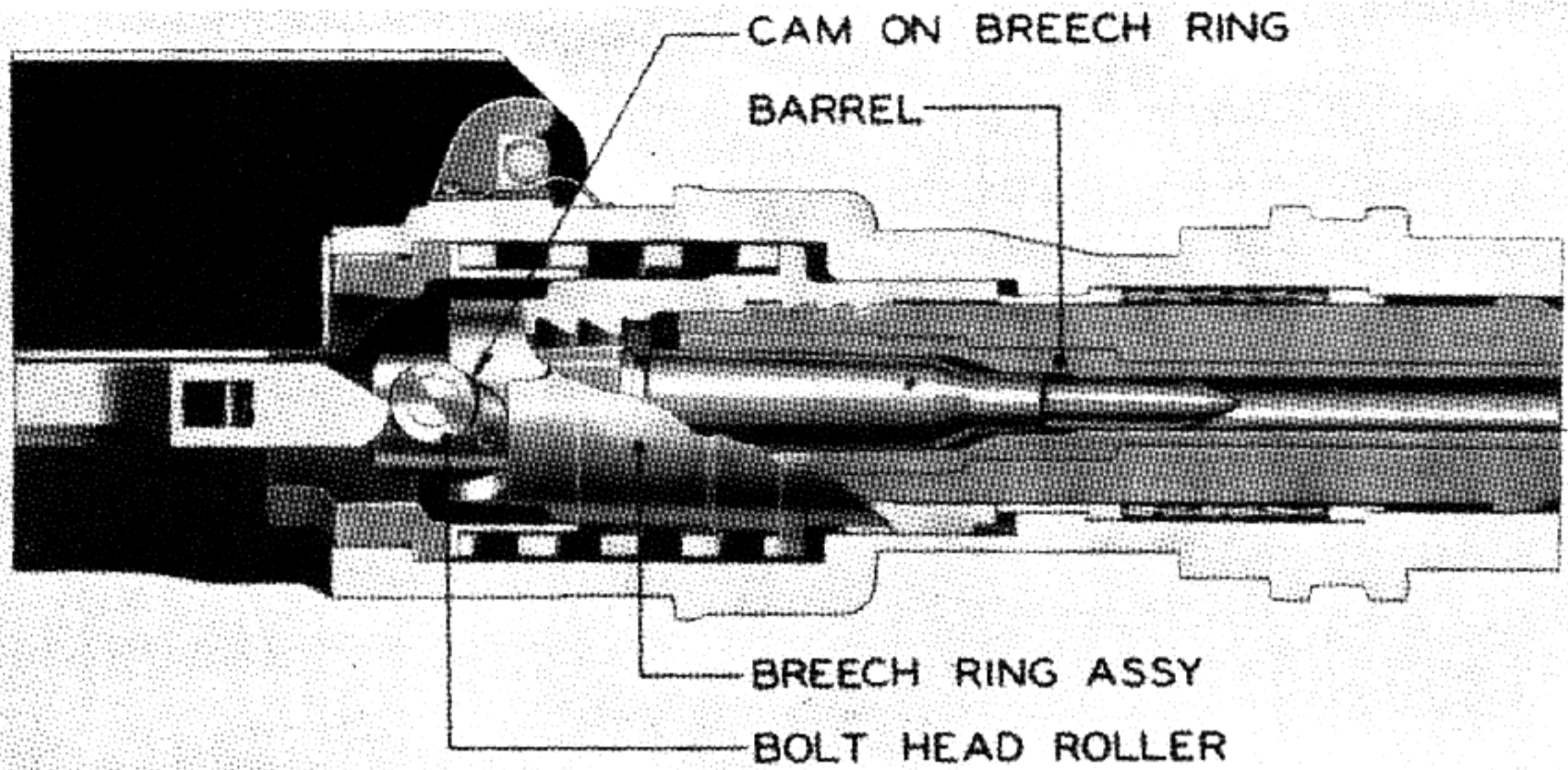


Figure 4-25. Beginning of locking action.

assembly and buffer spring, thus producing automatic firing.

When the next cartridge is within about  $\frac{5}{16}$  inch of being chambered, the bolthead rollers contact the breech ring cams. This gives the bolthead a chance to begin rotating in preparation for locking to the breech ring assembly.

While being rotated by the breech ring cams, the bolthead continues its forward travel and chambers

the cartridge. After the cartridge is fully chambered and the forward motion of the bolthead has stopped, the rotation of the bolthead continues through the action of the bolt nose cams against the bolthead rollers. This locks the bolthead to the breech ring assembly.

During this locking action, the bolt continues to move forward and nest around the bolthead. The final forward movement of the bolt pushes the firing

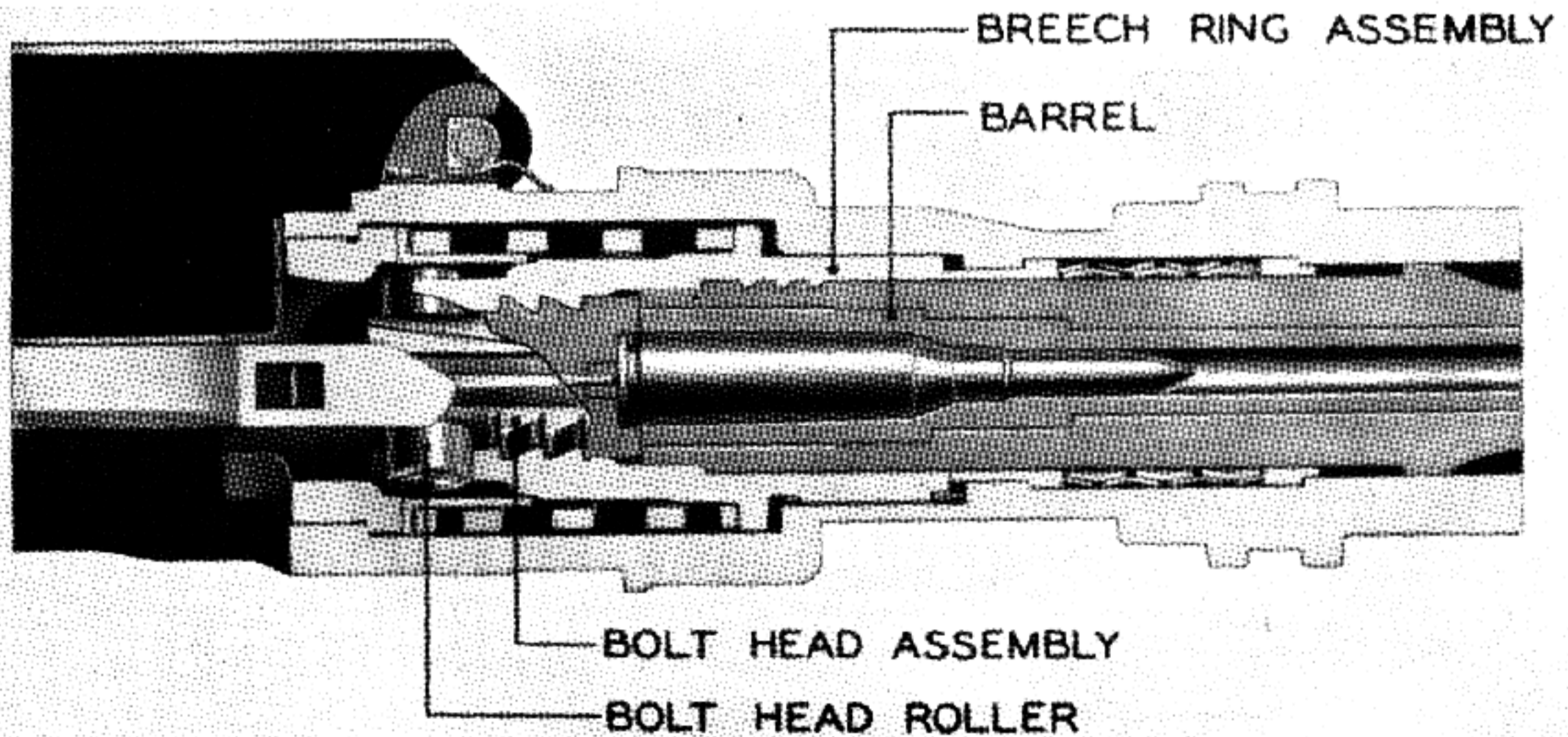


Figure 4-26. Completion of locking action.

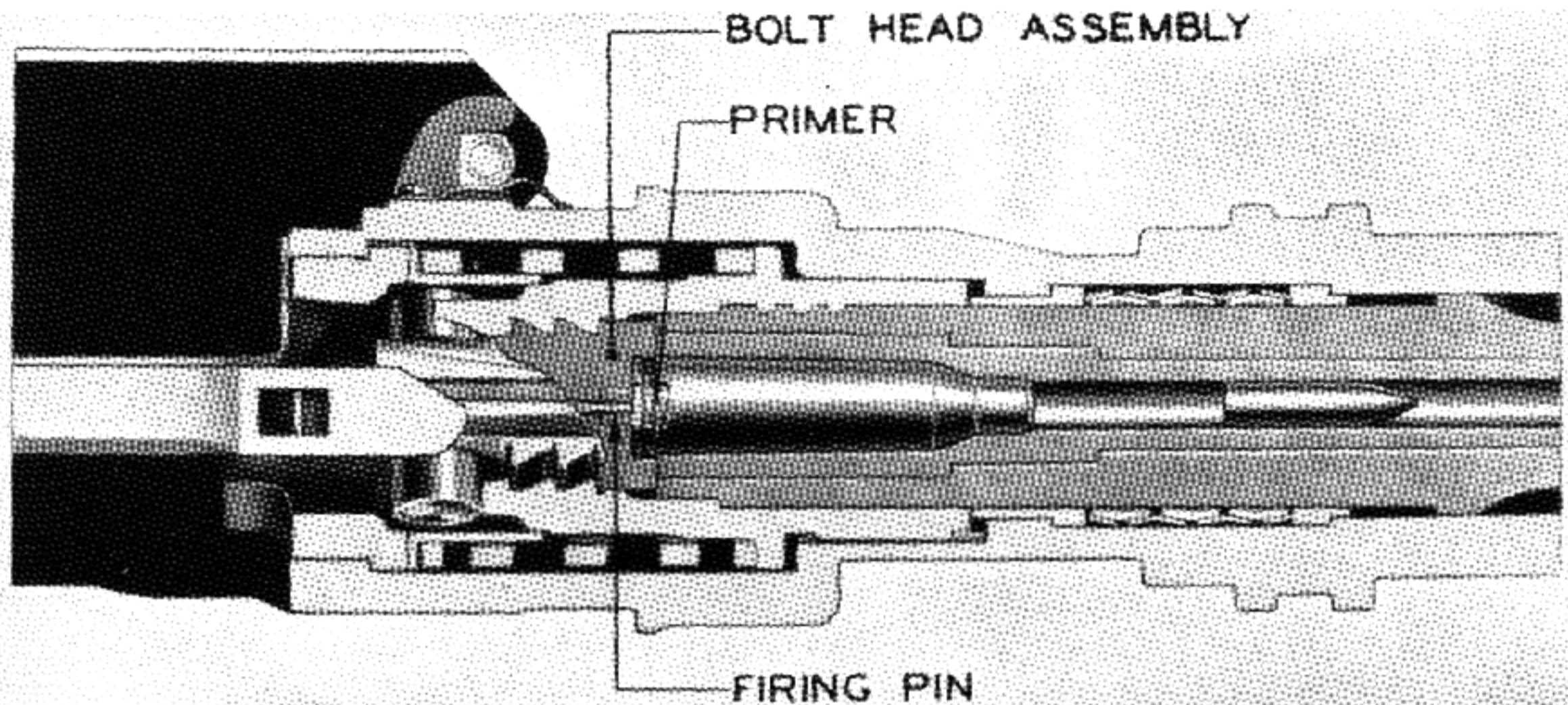


Figure 4-27. Ignition phase.

pin beyond the face of the bolt head to strike the primer and fire the cartridge.

*Feeding and Ejector Group.* The feedway and ejector group is mounted in the top forward portion of the receiver and is held firmly in position when the cover is closed. The group consists of the feedway and ejector assembly and the cartridge stop assembly. When the empty case is extracted from the

chamber and carried rearward by the bolt assembly, it strikes the ejector, which is mounted on the rear of the feedway. This causes the case to hinge downward over the extractor, ejecting it through the opening in the bottom of the receiver. The cartridge stop assembly prevents the cartridge from overriding the slot in the feedway and guides the empty links as they are forced from the feedway.

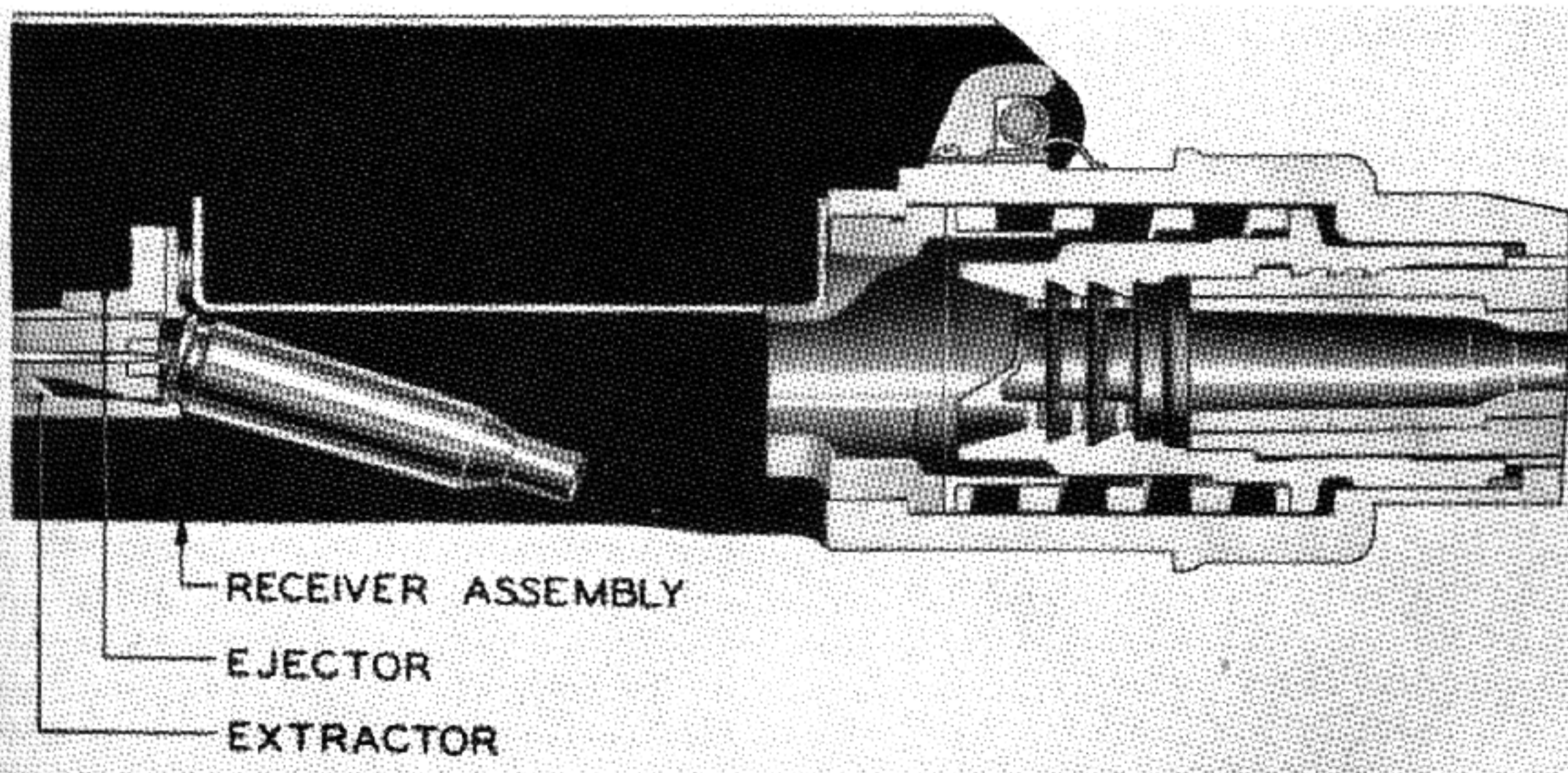


Figure 4-28. Ejection of empty case from gun.

*Receiver and Barrel Support Group.* The receiver assembly provides a housing for the buffer group, solenoid assembly, lower contact group, switches, telltale group, sear assembly and sear manual release group, and minor parts.

The buffer housing is located at the rear of the receiver and houses the buffer group. This group is composed of the buffer plate, Belleville buffer springs, buffer housing screw, and buffer housing screw retainer. These parts cushion the recoil with the bolt assembly when the rear of the bolt strikes the buffer plate. The energy is transmitted to the Belleville buffer springs which are positioned by the buffer housing screw. This screw is held in adjustment by the buffer housing screw retainer. The energy stored in the buffer springs starts the bolt assembly forward on the counterrecoil stroke.

The solenoid assembly, which is used to electrically operate the sear, is fastened to the rear of the buffer housing with two solenoid mounting screws. The solenoid assembly is composed of the solenoid coil assembly, armature, solenoid arm, solenoid shield plate, solenoid mounting plate, and minor parts. The solenoid arm is attached to the armature by the solenoid hinge pin. The arm is held stationary at the upper end by the pivot pin, causing the lower end of the arm to move through a distance greater than the travel of the armature. The electrical contact is made by the solenoid contact plug engaging the solenoid contact receptacle located in the rear end of the buffer housing.

The lower contact group is mounted above the rear end of the buffer housing. When the cover is closed, the three contacts mate with corresponding contacts on the electric charger and provide for two electrical circuits, namely, the power stroke circuit and the return stroke circuit.

The shroud switch assembly is located above in the front end of the buffer housing and includes the switch, switch shroud, switch shroud insulator, and shroud shims. The insulator lines the inside of the shroud and the switch is fastened in the shroud with two screws. There is an opening in the top of the shroud to allow the lower switch arm and switch arm shoe, located in the motor mount of the charger, to operate the switch. The switch assembly is fastened to the receiver with four screws and is properly spaced with the shroud shims. The switch opens and closes the return stroke circuit of the

charger, and opens and closes the firing circuit. When the return stroke circuit is open, the firing circuit is closed; and vice versa.

The telltale group, located forward of the buffer housing, determines the rotating direction of the charger motor. This group is composed of the telltale spacer, telltale, telltale spring, telltale spring capstan, capstan pin, and telltale pivot pin. The spacer, telltale spring, and capstan, respectively, fit over the pivot pin which is positioned by holes in the side walls of the receiver. One end of the spring engages the hole in the telltale, and the other end is connected to the capstan. The capstan is turned until the correct forward pressure is put on the telltale, and the capstan is then fastened by inserting the capstan pin into one of the holes in the capstan and allowing the capstan to turn back until the pin is stopped by the bottom of the receiver.

The sear assembly is mounted in the bottom of the receiver, forward of the telltale group. The sear assembly includes the sear block assembly, sear frame assembly, sear frame pin, sear roller, sear roller pin, sear yoke, sear locating spring, sear spring, and minor parts. The sear block is fastened to the receiver by the sear block screw and two sear block valve screws. The sear frame is mounted to the sear block by the sear frame pin. The sear roller is held in the sear frame by the sear roller pin. The sear frame and the sear roller are normally held upward by the sear spring. The sear roller and related parts hold the bolt assembly in the rearward position by engaging the shoulder on the bottom of the bolt. The sear yoke and the sear locating spring serve to cushion the initial shock as the sear roller engages the shoulder on the bottom of the bolt at the start of counterrecoil stroke of the bolt assembly.

The sear manual release group is located on the right side of the receiver. This group is composed of the sear manual release lever, sear manual release shaft, sear manual release retainer, and the sear manual release spring. The lever is used to manually depress the sear roller. Normally, the lever is held out of engagement by the spring.

The switch housing assembly, located forward of the sear assembly, is composed of the housing switch, switch housing, cam rod, cam, switch cam adjusting nut, and minor parts. The switch is fastened in the switch housing with two screws. The cam rod, on which is mounted the cam that operates the switch,



passes through one side of the housing. The switch assembly is fastened to the receiver by the two switch housing screws. The telltale bar is positioned on the cam rod by the switch cam adjusting nut. The sear bar extends through a hole in the buffer housing and is connected, at the rear end, to the solenoid arm. The switch is controlled by the position of the telltale. The power stroke circuit is closed through the switch when the telltale is in the upward position. The return stroke circuit is closed through the switch when the telltale is in the downward position.

A connector is fastened to the right side of the receiver with four screws. The purpose of this connector is to provide means of making electric connections to the gun.

To the inside of the receiver are the tracks on which the bolt assembly rides. The heater tubes, which are underneath the tracks, are used to house electric resistance heaters with which to heat the tracks to avoid congealing of oil at low temperature, which would cause sluggish operation of the bolt assembly.

The bolt holding keys are attached to the receiver in front of the buffer housing. The bolt slides underneath the keys as it nears the end of the recoil stroke. These keys serve to prevent the bolt assembly from being forced upward over the sear by the pressure of the drive spring assembly when the cover is raised with the bolt assembly in its rearward position.

The rear support slide, which is welded to the under side of the receiver, provides a rear support for the gun.

The hook-shaped projection on which the cover hinges is located on the front end of the receiver. The cover hinge spring serves to hold the cover rearward when the cover is in a raised position.

The unlocking cam is located in the forward part of the receiver and serves to unlock the bolthead during firing.

The barrel support assembly provides a housing for the breech ring assembly, recoil spring, barrel buffer spring assembly, barrel buffer retaining sleeve assembly, barrel lock, and various parts.

The breech ring assembly is located at the junction of the receiver and barrel groups and serves to couple the bolthead to the barrel. Near the forward end of the breech ring are internal buttress locking lugs which retain the barrel, and near the

rearward end are similar lugs which retain the bolthead during firing. Cam surfaces at the rearward end of the breech ring bear against the bolthead rollers to start the rotating motion which locks the bolthead to the breech ring for firing. Following the initial rotation, the breech ring cam serves to stop the forward motion of the bolthead as the bolt nose cam bears against the bolthead rollers to turn the bolthead approximately one-sixth turn and complete the locking action. Tangent to the surfaces which stop the forward motion of the bolthead are surfaces which bear against the bolthead rollers to stop the rotation of the bolthead after locking has been completed.

The recoil spring surrounds the rear section of the breech ring assembly and is compressed between the unlocking cam in the receiver and the shoulder on the breech ring. The recoil spring cushions the recoil of the barrel and returns the barrel to its forward position. The bolthead roller guide, which is assembled to the rear of the recoil spring, prevents the bolthead rollers from flying off as the bolthead moves into the locked position.

The barrel buffer spring assembly, which is composed of a series of buffer springs, exerts a snubbing action to keep the movement of the barrel uniform on both the recoil and counterrecoil stroke. Near the end of the recoil stroke, the shoulder on the barrel strikes the barrel buffer thrust collar and compresses the buffer spring against the barrel buffer collar assembly which, in turn, contacts the shoulder on the barrel support and stops the rearward movement of the barrel. Near the end of the counterrecoil stroke, the front of the breech ring strikes the barrel buffer collar assembly, compressing the buffer spring against the barrel buffer thrust collar which, in turn strikes the barrel buffer retainer sleeve assembly and stops the forward movement of the barrel.

The barrel buffer retainer sleeve assembly performs two functions, namely: it holds the barrel buffer thrust collar, buffer spring, and barrel buffer collar assembly in position against the shoulder on the barrel support; and it contains the barrel bearing, to support the bearing surface of the barrel.

The barrel lock is located near the rear end of the barrel support. The front end of this lock is forced downward by the barrel lock spring to engage a slot in the top of the barrel to keep the barrel from turn-

ing out of engagement with the breech ring assembly. The rear end of the lock engages a notch in the barrel support coupling to prevent the coupling from turning out of engagement with the receiver.

A key which projects upward from the barrel support, forward of the barrel lock, rides in the key way in the adapter assembly to keep these parts properly in line as the barrel support assembly moves back and forth inside the adapter assembly.

The barrel support coupling provides a means of fastening the barrel support assembly to the receiver assembly and provides the means of supplying the initial compression to the recoil spring.

*Adapter Group.* The adapter body assembly provides a housing for the adapter spring assembly, which is composed of a series of adapter rings and two adapter thrust rings, one on each end. The function of the adapter spring assembly is to exert a snubbing action to stop the movement of the gun on both the recoil and counterrecoil strokes.

The trunnions at the rear of the adapter assembly are provided for mounting the gun in the cradle. A groove in the yoke also serves for mounting in the cradle as well as for installation in aircraft.

## Operation

### *Loading.*

1. The cover should be closed before any firing is attempted. This also includes loading. Make certain that before the cover is closed, the bolt assembly is in its foremost position. This will insure that the stud on the drive bushing engages the socket in the top of the bolt. As a check on the correct position of the bolt assembly before closing the cover, the rear end of the bolt should be approximately five-sixteenths inch rearward of the end of the ejection

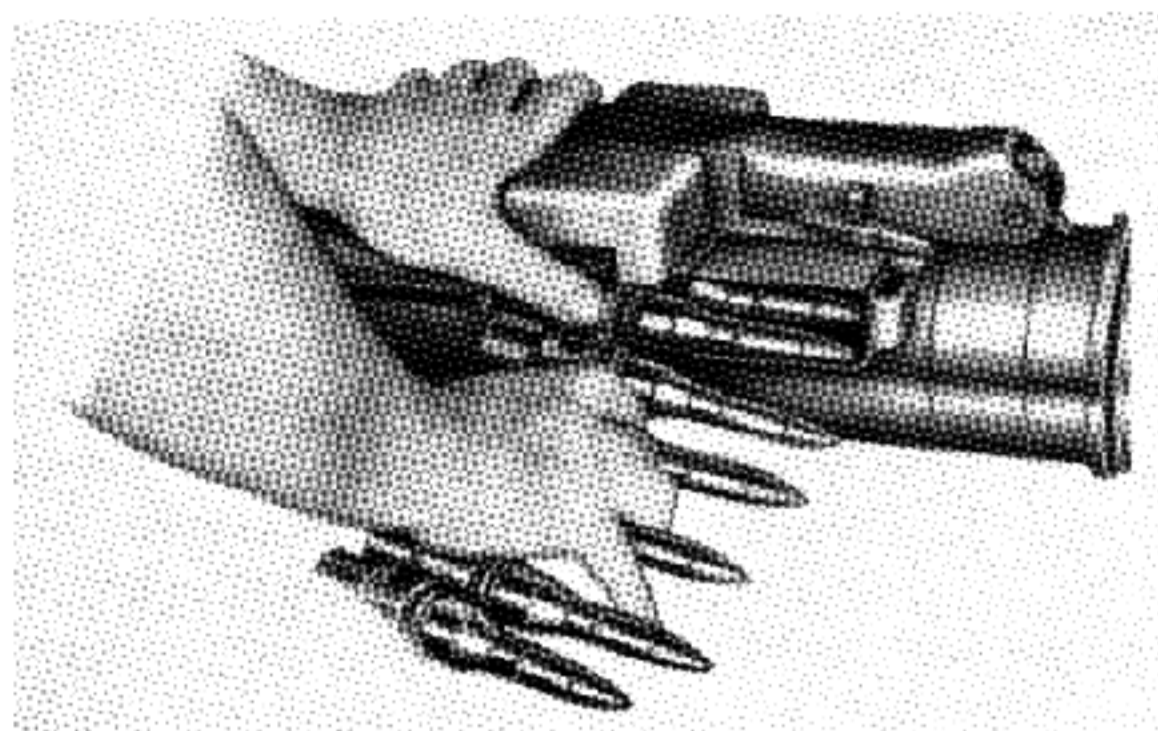


Figure 4-29. Method of inserting ammunition belt.

tor. Never load the gun when the bolt is being held by the sear roller in the cocked position.

2. Insert the ammunition belt with the open side of the links down against the feedway. Push in on the belt until the second cartridge is well inside the edge of the feedway. Pull outward on the belt to make certain that the belt is properly engaged by the belt holding pawl.

### *Firing.*

1. When the ammunition belt is started into the gun, the cocking of the gun places the mechanism in a ready to fire position with the bolt assembly held rearward and the cartridge positioned for chambering in the feedway.

2. To fire the gun, the sear roller must be depressed either manually or electrically. To depress the sear roller manually, push in on the sear manual release lever until it engages the sear frame assembly. Then turn the lever downward about one-sixth turn.

To depress the sear roller electrically, close the firing switch. This energizes the solenoid, pulling the sear bar rearward and depressing the sear roller.

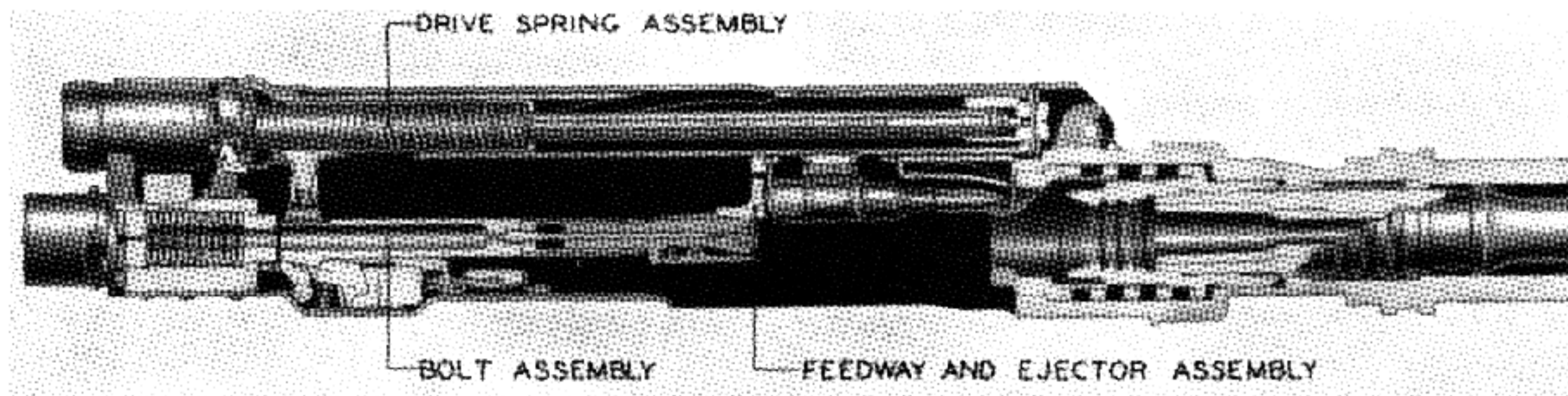


Figure 4-30. Caliber .60 T17E5 Machine Gun ready to fire. Longitudinal section.

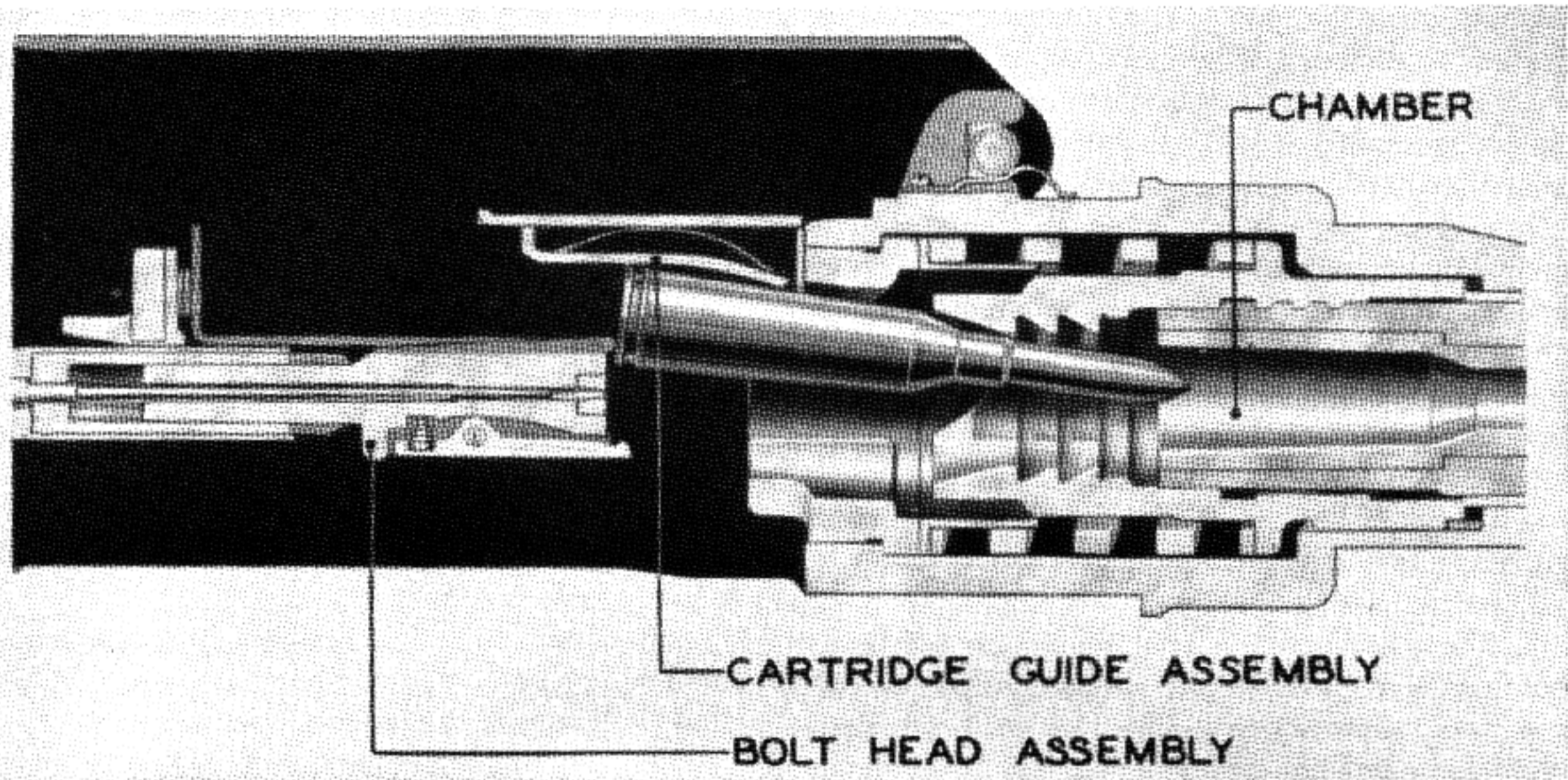


Figure 4-31. Guiding the cartridge toward the chamber.

With the sear roller depressed, the bolt assembly moves forward. The top front edge of the bolt head hits the base of the cartridge and moves it forward, stripping it from the link. The cartridge is guided downward toward the chamber through the front end of the slot in the feedway assembly by means of the cartridge guide assembly.

3. When the forward motion is completed and the cartridge is held securely in the chamber by the bolt head assembly, the bolt pushes the tip of the firing pin beyond the face of the bolt head to strike the primer and fire the cartridge.

4. The gun will then fire automatically, until the sear roller is permitted to spring upward, either manually or electrically, so that it engages the shoulder on the bottom of the bolt. The telltale, however, is still held downward by the bolt which is directly above it.

5. Combat firing is unrestricted, but bursts of longer duration than 150 rounds (12-second bursts) may lead to a stoppage due to overheating. Non-combat firing should be restricted with the duration of bursts and cooling governed by the "life expectancy" of the barrel.

**CAUTION.** In case of misfire with a hot barrel, the gun should be cleared within 10 seconds after the stoppage. If the gun cannot be cleared within 10

seconds, the round should be allowed to remain in the chamber a minimum of 10 minutes, making sure the gun is aimed in the opposite direction from personnel and equipment. If the gun is cleared between the 10 seconds and 10 minute period, the extracted cartridge may explode outside the weapon causing serious injury to personnel or equipment.

#### *Unloading.*

1. To unload the gun, the cover must be raised. Before raising the cover, carefully note the position of the bolt assembly. If the bolt assembly is in the extreme forward position, the cover can safely be raised. However, if the bolt assembly is held rearward by the sear roller or jammed ahead of the sear assembly, extreme caution must be exercised when raising the cover.

**CAUTION.** The bolt assembly must positively be held rearward using a screwdriver or some such tool while the cover is being raised. On guns which are provided with a slot in the cover, a screwdriver or some similar tool should be used to jam down into the rear of the feed rack.

2. After the cover is raised, remove the ammunition belt. Depress the sear roller with the sear manual release lever and move the bolt assembly slightly forward to clear the bolt holding key. Remove the bolt assembly and also the feedway and ejector

assembly from the gun. Then make a careful inspection to determine whether or not there is a cartridge in the chamber and if there is, the barrel should be removed. Then the cartridge can be easily removed from the chamber.

**CAUTION.** Never permit the bolt assembly to move forward to the locked position with the cover open if a live cartridge is, or can be, chambered.

3. Replace the parts that have been removed from the gun. Push the bolt assembly into its extreme forward position. Close and latch the cover. During periods of storage or nonuse, the gun parts should be left in this position as all operating springs will be under their normal initial compression.

#### *Changing Feed.*

1. The gun may be assembled so that ammunition may be fed into it from either the right- or left-hand side. In order to change the gun from right-hand feed to left-hand feed or vice versa, the proper belt feed tube must be installed, the position of the feed assembly must be reversed and the cartridge stop assembly must be repositioned in the feedway and ejector assembly. The correct position of the various parts for both the right- and left-hand feed are furnished in an instruction manual that is sent with each gun.

2. The following description explains in general terms the change from right-hand feed to left-hand feed. By reversing the process, the gun may be changed from left-hand feed to right hand.

#### **COVER GROUP:**

1. Remove the cover.
2. Remove the cartridge guide assembly.
3. Remove the electric charger.
4. Remove the stripper and rack assembly.
5. Remove the feed assembly.
6. Remove the right-hand belt feed tube and replace it with the left-hand belt feed tube.
7. Reinstall the feed assembly in a reversed position.

**NOTE.** The opening for the stripper and rack assembly should always be on the side from which the ammunition is to be fed.

8. Assemble the stripper and rack assembly to the feed assembly.

**NOTE.** Be sure that the feed body locks are all the way out in their locked position, otherwise they will interfere and prevent the

stripper and rack assembly from being moved into position.

9. Install the cartridge guide assembly.

**NOTE.** The cover safety catch may be located on either side of the cartridge guide assembly.

10. Install the electric charger.

#### **FEEDING AND EJECTOR GROUP:**

1. Remove the feedway and ejector assembly.
  2. Detach the cartridge stop assembly.
  3. Install the cartridge stop assembly on the right-hand side of the feedway and ejector assembly.
  4. Remove the cartridge belt feedway pad.
- NOTE.** Used with right-hand feed only.
5. Place the feedway and ejector assembly in position on the receiver.
  6. Push the bolt assembly into the extreme forward position.
  7. Assemble the cover to the receiver.
  8. Test the feed mechanism by operating the charging mechanism to be sure that the parts work freely without binding, and that they have been correctly reassembled.

### **Disassembly by Groups**

The major groups of the gun are the barrel, cover group, bolt group, feedway and ejector group, adapter group, and receiver and barrel support group. It is assumed that the gun is set up for right-hand feeding.

**CAUTION.** Before starting to disassemble the gun, make certain that it is not loaded. Follow the instructions sent with each gun giving procedure and detail for assembly and disassembly.

*Barrel.* Depress the rear end of the barrel lock and turn the barrel about one-fourth turn counterclockwise. Then pull the barrel forward out of barrel support.

*Cover Group.* Press inward on the cover latch handle and raise the cover just enough to disengage the cover latch and then allow the rear end of the cover to rest upon the rear end of the receiver. Using a screwdriver, turn the cover hinge plug as far as it will go. Then raise the rear end of the cover at least 2 inches to permit the disengagement of the drive bushing from the bolt, which should be in the forward position, and slide the cover rearward from the receiver.

*Bolt Group.* Pull rearward on the bolt to unlock the bolt head from the breech ring assembly. Then

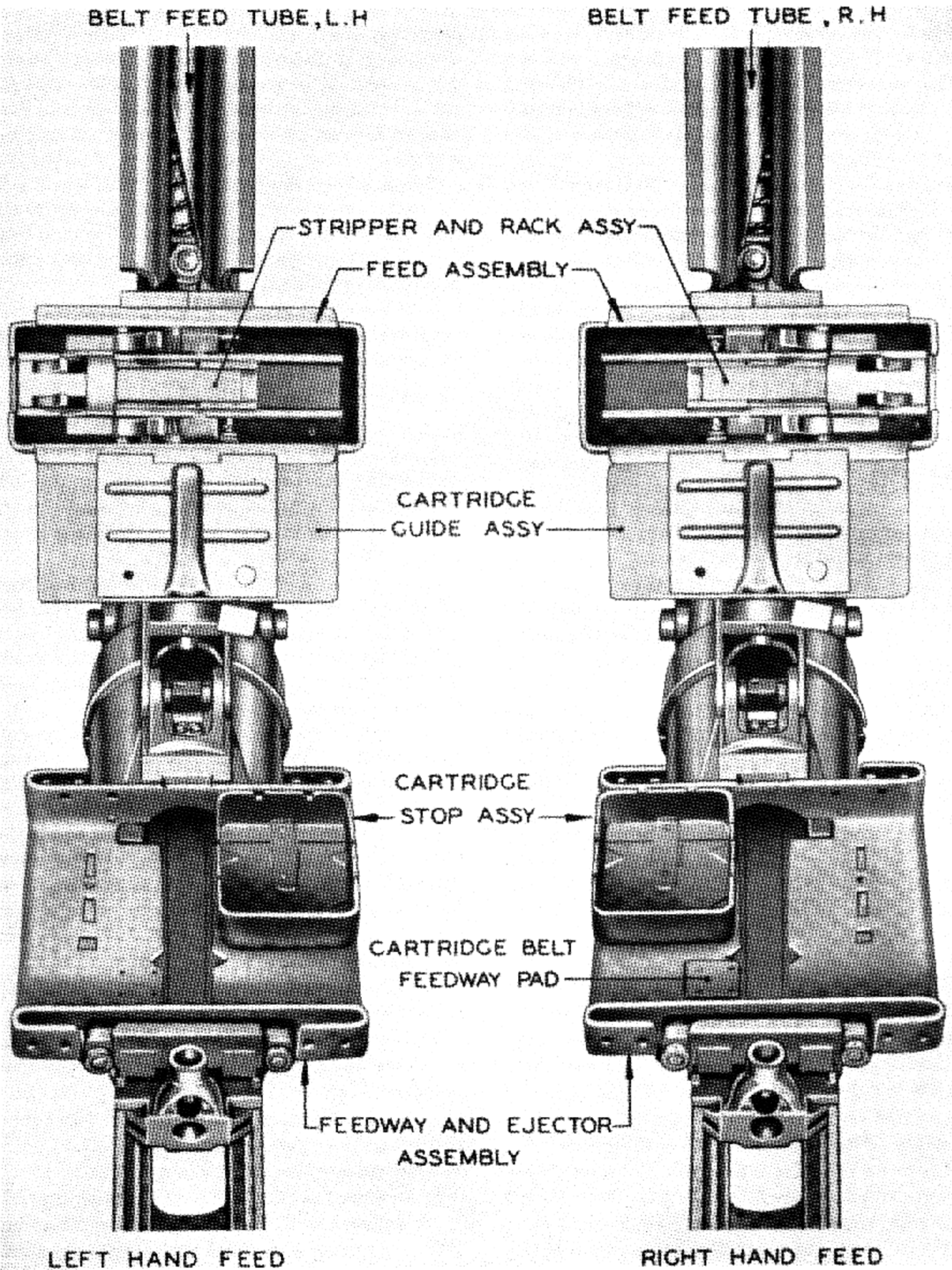


Figure 4-32. Comparison of feed assemblies for left-hand and right-hand feeds.

grasp the bolt firmly and lift it from its ways in the receiver. If the bolt is pulled too far back before it is lifted up, the rear end will engage the bolt holding keys, making it impossible to lift it out until the sear roller is depressed and the bolt slid forward enough to clear the keys.

*Feedway and Ejector Group.* Pull the feedway and ejector assembly rearward about three-eighths inch and then lift it from the receiver. This rearward movement is to clear the feedway retaining studs and locating pins.

*Adapter Group.* To remove the adapter assembly from the barrel support, drive out the roll pin and then unscrew the adapter retainer nut at the front end of the adapter, using the combination wrench. With the adapter retainer nut removed, the adapter can be slipped forward off the barrel support.

### Assembly by Groups

*Adapter Group.* Slip the adapter assembly on over the front end of the barrel support, with the trunnions toward the rear of the gun. Line up the keyway in the adapter with the locating key on the barrel support, and slide the adapter back until the full length of the locating key in the barrel support is covered by the adapter. Then start the adapter retainer nut on the threads at the front end of the barrel support and draw it up tight with the combination wrench. The adapter retainer nut should be just flush with the adapter ring retainer nut. Line up the pinholes and drive the roll pin in place.

*Feedway and Ejector Group.* Place the feedway and ejector group in position with the ejector to the rear. Raise the ejector as high as it will go. Slide the feedway and ejector assembly forward until the feedway retainers engage the feedway retaining studs.

*Bolt Group.* Start the bolt assembly into the top opening in the receiver, directly to the rear of the feedway and with the bolthead toward the front of the gun. With the bolt resting on the tracks in the receiver, push it forward until the bolthead locks into the breech-ring assembly. At this time, the rear end of the bolt should be approximately five-sixteenths inch rearward of the end of the ejector.

*Cover Group.* Place the cover group on the receiver and barrel support group so that the hinge plug holes come into approximate alignment with the cover hinge assembly. Release the cover safety

catch and allow the rear end of the cover to rest upon the rear end of the receiver. Using a screwdriver, turn the cover hinge plug until it is as far out as it will go. Press in on the cover latch handle, and push down on the cover until the cover latch is engaged.

*Barrel.* Start the breech end of the barrel into the barrel support with the indicating arrow at the top. Push the barrel in as far as it will go and then turn it in the direction indicated by the arrow stamped on the barrel.

**CAUTION.** The front end of the barrel lock must snap down into the locked position to insure that the barrel is locked in place.

### Detailed Disassembly and Assembly

#### *General.*

1. In the following description of the detailed disassembly and assembly of the gun groups, it is assumed that the ordnanceman is familiar with the operations involved in removal and installation of groups as a whole.

2. In disassembling the gun, it will be found helpful to place the parts neatly in order as they are removed.

3. Place disassembled parts on a clean, flat surface and guard against loss of pins, springs, and other small parts.

4. Parts for each gun should be kept intact and separated from those of other guns. Although parts are interchangeable, they will work best in their original combination.

5. When two roll pins are used, one inside the other, they should be driven out together and then separated one from the other before reassembly. In assembling the roll pins, each pin should be driven separately, care being taken that the openings in the pins are opposite.

6. Before assembling, clean all parts thoroughly and oil lightly.

7. When assembling the gun, always line up the parts carefully and insert the roll pins properly before attempting to drive the pins into place. Seat springs correctly, replace and spread cotter pins, and install locking wire where prescribed.

#### *Disassembly of the Cover Group.*

1. Remove the cartridge guide assembly by sliding it forward until it disengages from the cover. The cover safety catch and the cover safety catch

spring may then be removed, if necessary, by driving the roll pin out and then removing the pin retaining collar and the cover safety catch pin.

2. To remove the electric charger from the cover, first depress the motor mount locking plunger, which engages a hole in the top of the cover, and keep it depressed while starting to turn the charger in a counterclockwise direction. Grasp the motor and turn it about one-eighth turn, at which time the charger will be pushed back one-quarter inch by the compressed drive spring. Turn the cover in an upside down position. The removal of the charger may then be started from the cover. In order to provide clearance for the drive bushing as the charger is pulled rearward, the charger must be turned clockwise about one-eighth turn, so that the stud on the drive bushing will line up with the notch in the cover. The charger assembly can then be drawn out of the cover.

3. Depress the belt feed pawl and pull the stripper and rack assembly out of the feed body.

4. The removal of the stripper and rack assembly permits movement of the feed body locks. Pry the lock nearest the front end of the cover rearward so as to release the feed assembly. The feed assembly can then be removed by raising the front edge of the assembly.

5. To disassemble the feed assembly, the following operations are necessary.

(a) To remove the feed body locks, remove the cotter pins from the locks and withdraw the locks from the feed body.

(b) To disassemble the belt-holding pawls, remove the cotter pins from the belt-holding pawl studs and unscrew the studs. Then remove the belt-holding pawls, belt-holding pawl springs, and holding pawl spacers.

6. To disassemble the stripper and rack assembly, the following operations are necessary.

(a) Remove the three belt feed-pawl springs by compressing them with a small screwdriver.

(b) Remove the belt feed pawl pin.

(c) Hold the stripper and rack assembly in one hand and insert a slender drift or piece of drill rod (.100 diameter) into the spring channel until its end pushes the spring follower out of the notch in the lockpin. Tap the lockpin in about  $\frac{3}{16}$  inch, using a drift. Insert the drill rod or drift in the second spring channel and drive out the lockpin.

(d) Slide the universal stripper back and remove the springs and followers.

CAUTION. As the stripper is moved back, the spring and follower will fly out and a hand should be placed so as to catch them to prevent loss.

(e) The universal stripper can now be slid back until it is clear of the rack.

7. To remove the belt feed tube, place the cover in a vertical position with the front end up, and rotate the tube until the arrow on the tube is centered in the opening in the cover. (Precaution should be taken that the end of the tube is not battered when dropped from the cover.) The belt feed tube will then fall, or can be moved, out of engagement with the tube lock and can be removed from the cover.

8. To disassemble the belt feed tube lock from the cover, remove the roll pin and turn the lock one-quarter turn in either direction. Then push the lock rearward from the cover.

9. To disassemble the cover latch, drive the roll pin out of the cover latch handle. Then the handle, cover latch pin, and cover latch spring can be removed from the cover.

#### *Assembly of the Cover Group.*

1. Place the cover in a vise and clamp firmly. Assemble the cover latch and cover latch spring into the cover and line up the cover latch pin with the hole in the cover. Also line up the hole in the cover latch handle with the hole in the cover latch. Insert and drive the roll pin home.

2. Push the belt feed tube lock into the hole in the cover and turn it  $\frac{1}{4}$  turn so that the cutout in the lock is up. Insert and drive the roll pin home.

3. Place the cover in a vertical position with the rear end up. Insert the belt feed tube into the cover, with the slotted end up, and carefully let it drop into place. Rotate the tube until the arrow on the side of the tube is centered in the opening in the cover. The tube will then drop enough to engage the belt feed tube lock. After engaging the lock, the tube should be turned slightly in either direction to complete the locking action.

4. To assemble the feed assembly, the following operations are necessary.

(a) To assemble the feed body locks, insert the locks in the holes in the feed body, and insert and spread the cotter pins.

(b) To assemble the belt holding pawls, partially insert the holding pawl stud, assemble the holding pawl spacer on the threaded end of the stud, and insert the belt holding pawl spring in the recess in the pawl. Hold the two pieces together and start the upper end of the spring on the stud on the under side of the holding pawl spring support. Lift up the pawl in such a manner as to compress the spring and push it into the feed body until the spring is in a vertical position. In order to compress the spring and to raise the pawl into position, grasp the end of the pawl with pliers and raise straight up. At the same time apply pressure to the stud with a screwdriver and then shift the pawl until the stud enters a hole in the feed body. Now continue to shift the pawl slightly until the threaded end of the stud lines up with, and enters, the threaded hole in the support in the feed body. Screw the stud in securely and insert the cotter pin in such a position as to prevent the stud from turning.

(c) Assemble the remaining belt holding pawls using the same procedure.

5. To assemble the stripper and rack assembly, the following operations are necessary.

(a) Insert the universal stripper in position on the belt feed rack assembly.

(b) Aline the head of the lockpin with the notch in the stripper, and tap the lockpin into its hole to a depth of approximately  $\frac{3}{8}$  inch.

(c) Slide the stripper back approximately 1 inch, insert the first spring and follower, and slide the stripper forward.

(d) Compress the spring with a drift or piece of drill rod until the follower clears the lockpin. Drive the lockpin in until its end passes the first spring channel.

(e) Repeat steps (c) and (d), inserting the second spring and follower and driving the lockpin in until its head is flush with the surface of the stripper.

(f) Assemble the belt feed pawl to the belt feeder rack assembly.

(g) Push the belt feed pawl pin into place.

(h) Assemble the three belt feed pawl springs by compressing them with a small screwdriver.

6. Place the feed assembly in position over the cover with the opening for the stripper and rack assembly on that side of the cover into which the ammunition is to be fed. Tip the front of the feed assembly upward and engage the rear edge in the

notch in the cover, being sure that the feed body lock toward the hinge end of the cover is drawn back into the feed body. The feed assembly can then be lowered into place and locked to the cover by pushing both feed body locks outward.

7. Turn the belt feed tube until the lengthwise mark on the tube is in alinement with the assembling line on the cover. Then insert the stripper and rack assembly into the feed body, with the pawl end outward. Depress the belt feed pawl and push the stripper and feed assembly inward. If the belt feed tube is positioned correctly and if the upper belt feed tube (left-hand or right-hand) is being used, the gear teeth on the tube and the teeth on the rack will engage, and the rack can be pushed into position. It may be necessary to turn the belt feed tube slightly either right or left as required to engage the teeth. If the rack teeth engage the teeth on the belt feed tube, but the belt feed tube cannot be pushed completely into the feed body, it will usually be found that one of the feed body locks is not fully in the outward or locked position and is interfering with the rack.

8. The cover safety catch may be installed on either side of the cartridge guide assembly, but it is normally installed on the right-hand side. Insert the cover safety catch pin into its proper hole in the cartridge guide assembly. Place the cover safety catch over the pin with the long end of the catch forward. Place the cover safety catch spring on top of the catch, one end of the spring engaging the hole in the rear end of the catch. Place the pin retaining collar over the pin on top of the spring. Line up the holes in the collar and the pin, and insert and drive the roll pin flush with the collar.

9. The cartridge guide assembly should be slid rearward on the flat portion of the cover toward the feed assembly. The cover safety catch spring must be compressed forward as the cartridge guide assembly is being assembled.

10. To install the electric charger, turn the belt feed tube so that the slot at the rear end of the tube is toward the opening in the cover. Insert the charger into the cover so that the stud on the drive bushing will slide through the notch in the cover. Engage the stud in the slot in the belt feed tube, and push the charger assembly forward. The charger must then be turned slightly, counterclockwise, so that the slots in the charger housing line up with the



studs projecting inward from the cover. Push the charger completely forward, and turn it clockwise until the motor mount locking plunger snaps into position.

#### Disassembly of the Bolt Group.

1. The bolt head rollers can be readily removed, as there is nothing to retain them in place.

2. Place the bolt on a wooden block, and with a hammer and a drive punch of the proper size drive out the roll pins. Start the removal of the buffer bodies by tapping with a block of wood. Pull the bolthead out of the bolt. Then grasp the projecting firing pin and pull it forward, removing the bolt-head cam assembly with the firing pin. If the firing pin and bolthead cam assembly cannot be removed in this manner, insert a rod,  $\frac{3}{16}$  inch in diameter and about 9 inches long, into the rear recess of the bolt and through the  $\frac{3}{16}$ -inch diameter hole to the rear of the firing pin. Drive the firing pin and bolthead cam assembly forward from the bolt.

3. With the bolthead assembly, bolthead cam assembly, and firing pin removed, the bolthead buffer bodies and bolthead buffer springs can be removed by prying or pushing them out of the recesses on each side of the bolt.

4. Insert a piece of steel,  $\frac{1}{4}$ -inch square by 3 inches long, into the ejector slot in the bolthead. Then clamp the bolthead assembly firmly in a vise with protective facings. With a drive punch of the

proper size, drive out the roll pins holding the extractor and remove the extractor and extractor spring.

#### Assembly of the Bolt Group.

1. Insert a piece of steel,  $\frac{1}{4}$ -inch square by 3 inches long, into the ejector slot in the bolthead. Then place the extractor and the extractor spring in position with the larger end of the spring bearing against the extractor. Clamp the bolthead assembly firmly in a vise with protective facings. Drive the roll pins in until the ends of the pins are slightly below the surface of the bolthead.

2. Insert the firing pin into the bolt, and make sure that it seats fully back in its recess. Place the bolthead cam assembly, with the slotted end toward the front, over the firing pin and push it back into the bolt. Care should be taken that the pin in the bolthead cam assembly is in alignment with the hole in the bolt. When fully seated, the front of the cam will be approximately one-eighth inch inside the opening in the bolt.

3. Position the bolthead assembly over the firing pin so that the top surface of the bolthead lines up with the top of the bolt, and insert the bolthead shank in the bolt recess so that the lugs in the shank slide in the slots of the bolthead cam. Permit the bolthead to turn and push it rearward. Then insert the bolthead buffer springs into the recesses in the bolthead buffer bodies. The bolthead buffer spring

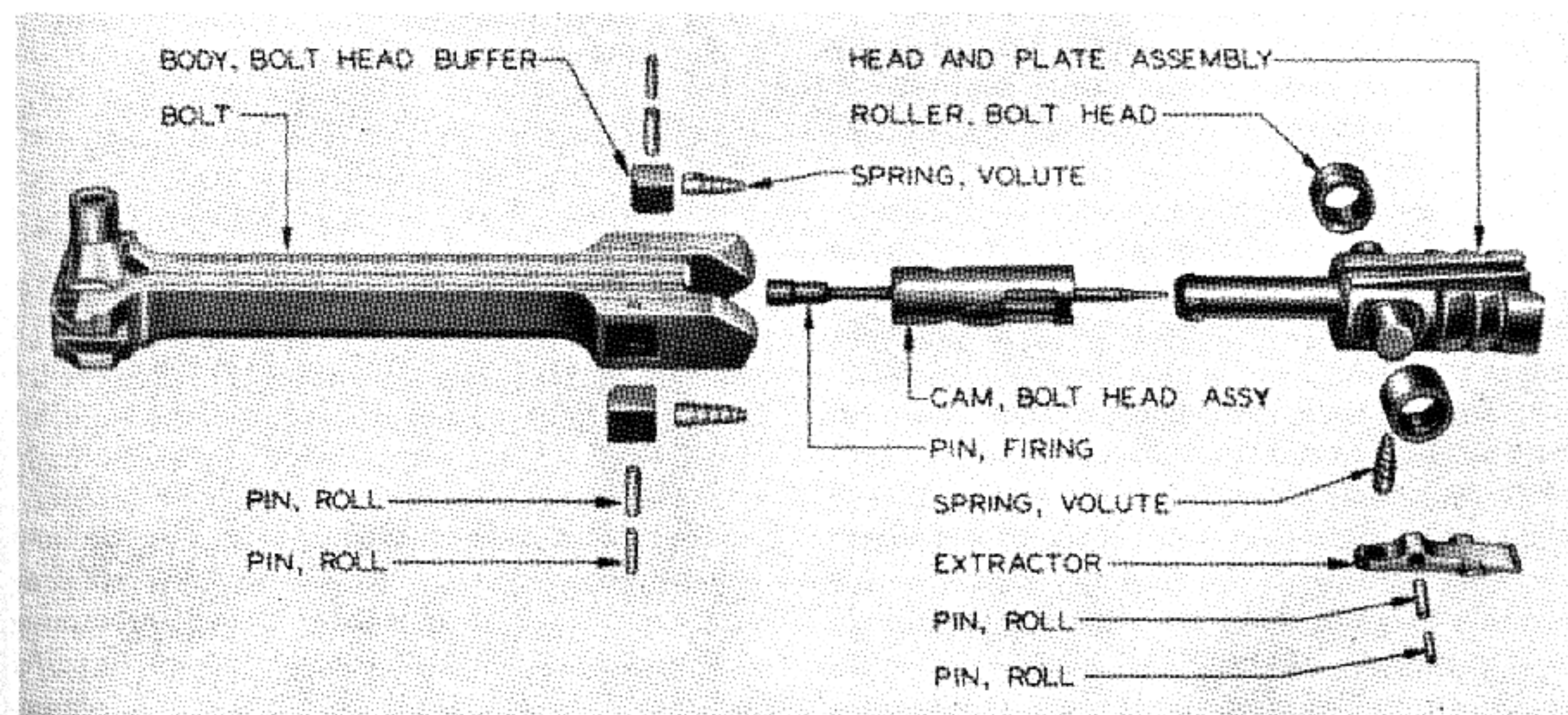


Figure 4-33. View of bolt group, disassembled.

may be compressed with pliers and the bolthead buffer bodies and spring inserted in their recesses on each side of the bolt in such a way that the curved surfaces of the bodies bear against the rounded shank of the bolthead and the small ends of the springs are toward the front of the bolthead. Then holding the bodies firmly inward against the shank, insert the roll pins and drive them flush with the top surface of the bolt.

4. In assembling the bolthead rollers, precaution should be taken that the chamfered edge of the hole is against the bolthead.

*Disassembly of the Feedway and Ejector Groups.*

1. To remove the cartridge stop assembly, hold the feedway and ejector assembly, and, with the point of a drive punch, push the cartridge stop retaining spring stud out of its hole in the feedway. The cartridge stop assembly can then be slid rearward until its lugs are disengaged from the holes in the feedway.

2. To remove the cartridge belt feed pad, remove the screws holding the pad to the feedway.

3. To remove the ejector, place the feedway and ejector assembly on a wooden block. With a drive punch of the proper size, drive the roll pins out of the ejector retaining collars and the ejector pins. The ejector and ejector springs can then be readily removed.

*Assembly of the Feedway and Ejector Groups.*

1. To assemble the ejector, place the ejector springs in the recesses in the ejector and slide the ejector onto the ejector pins. Place the feedway on a wooden block, and, with the ejector retaining collars assembled in place, drive the roll pins in flush with the collars.

2. Before attaching the cartridge stop assembly to the feedway and ejector assembly, it should be noted that the cartridge stop assembly is always attached to the side of the feedway which is opposite to that from which the ammunition is to be fed.

3. To attach the cartridge stop assembly to the feedway and ejector assembly, engage the hook which projects downward from the rear of the cartridge stop in the square hole on the proper side of the feedway. Then, holding the cartridge stop assembly forward, make sure that the lugs on the front of the assembly enter the square holes on the vertical front section of the feedway. When the cartridge stop assembly is all the way forward, the

cartridge stop retaining spring will force the stud down into the locking hole in the feedway, thus locking the assemblies together.

4. To assemble the cartridge belt feedway pad, position it in the feedway so that the beveled edge is adjacent to the feedway slot. Assemble the screws with a screwdriver.

NOTE. The cartridge belt feedway pad is used with right-hand feed only.

*Disassembly of the Adapter Group.*

1. Drive out the roll pin in the front end of the adapter.

2. Replace the adapter on the barrel support in its assembled position so that the adapter is retained from turning, and, using the combination wrench, remove the adapter ring retainer nut.

3. After removing the adapter from the barrel support, remove the adapter spring assembly, being careful to retain the spring components in their assembled position.

*Assembly of the Adapter Group.*

1. If the adapter has been disassembled for the purpose of cleaning or lubricating, care should be taken that the components of the adapter spring assembly are reassembled in their original position.

2. After the spring assembly has been installed, start the adapter ring retainer nut into the adapter, and turn it by hand as far as possible.

3. Replace the adapter on the barrel support in its assembled position so that the adapter is restrained from turning.

4. Using a combination wrench, tighten the adapter ring retainer nut until it projects approximately  $\frac{1}{16}$  inch beyond the front face of the adapter. Line up the pin holes and drive the roll pin in place.

*Disassembly of the Receiver and Barrel Support Group.*

1. Place the adapter spring compressor in position, and tighten the hexagon head on the front end until the recoil spring is compressed. Remove the barrel lock and the barrel lock spring by removing the roll pin. Using the adjustable spanner wrench, unscrew the barrel support coupling. If necessary, tap the wrench with the rawhide-face hammer until the coupling loosens. Disassemble the coupling from the receiver. Remove the adapter spring compressor and remove the coupling from the barrel support. Remove the barrel support from the receiver.

2. Remove the bolthead roller guide, recoil spring, and breech ring assembly from the barrel support. Also remove the unlocking cam from the front end of the receiver.

3. Place a block of wood against the flat surface of the cover hinge assembly and drive it from the hook-shaped projections on top of the receiver. Remove the locking wire from the two cover hinge spring screws and remove the screws. Then the cover hinge spring can be removed.

4. Clamp a steel bar,  $\frac{5}{16}$  inch by  $\frac{1}{2}$  inch by 5 inches long, in a vise. Place the front end of the barrel support so that the bar engages the slots in the barrel buffer retainer sleeve. Insert a steel rod,  $\frac{1}{2}$  inch in diameter by approximately 18 inches long, through the holes in the barrel support and turn in a counterclockwise direction until the sleeve is disassembled.

5. Remove the barrel buffer spring assembly and the barrel buffer collar, being careful to retain the spring components in their assembled position.

6. To remove the solenoid assembly, remove the locking wire from the solenoid mounting screws. Then remove the solenoid mounting screws, using the nut-and-bearing-spanner wrench from the electric charger tool set. Pull the solenoid straight back for about one-quarter inch to disengage the solenoid contact plug from the solenoid contact receptacle which is located in a 2-o'clock position in the rear end of the receiver. Then, being careful not to strain the sear bar, tilt the solenoid to the left far enough to disconnect the solenoid arm from the pin in the end of the sear bar.

7. Remove the buffer housing screw retainer screw and the buffer housing screw retainer. Place the receiver in a vise and unscrew the buffer housing screw, using one end of the combination wrench, until it can be removed from the buffer housing. Care should be taken not to damage the end of the sear bar with the handles of the wrench in removing the buffer housing screw. In order to retain the Belleville buffer springs in their assembled position, insert a rod or large screwdriver through the springs and the recoil plate, and remove them from the rear end of the buffer housing.

8. To remove the sear assembly, remove the locking wire, the sear block screw, and two sear block dowel screws from the bottom of the receiver, being

careful that the sear bar or the telltale bar is not sprung during the removal of the sear assembly.

9. Insert the drift pin from the electric charger tool set in the top hole of the telltale spring capstan and pull forward. Then remove the capstan pin from the capstan. Insert the drift pin and a similar pin alternately into the holes in the capstan, allowing the capstan to turn slowly counterclockwise, thus relieving the tension of the telltale spring. Remove the cotter pin from the end of the telltale pivot pin and remove the telltale pivot pin from the left side of the receiver. Then the telltale spring capstan, telltale spring, telltale, and telltale spacer can be removed from the receiver.

10. To remove the telltale bar, disengage the sear bar spring hook from the slot in the telltale bar. Then pull the telltale bar from the shank of the switch cam adjusting nut.

11. Remove the switch cam adjusting nut from the cam rod. Then the sear bar spring hook can be removed from the cam rod. Withdraw the sear bar from the hole in the buffer housing and remove it from the receiver. The sear bar must be turned approximately  $90^\circ$  in removing it from the hole in the buffer housing. Care should be taken not to strain the sear bar during removal.

12. If it is necessary to replace the housing switch in the switch housing, remove the two switch housing screws and the switch housing screw locks. Tilt the switch housing about  $90^\circ$ , taking care that the wires are not chafed in doing so. Remove the two screws and the switchette screw anchor. Keep the terminals sufficiently free to permit the removal of the wires. Then replace the housing switch with a new unit. Resolder the wires to the terminals, taking care that each wire is connected to its proper terminal. Replace the switchette screw anchor and the two screws, and resolder the ends of the screws on the top of the switch housing.

13. If it is necessary to replace the electrical plug connector on the right side of the receiver, remove the locking wire and four screws. Pull outward on the connector to take up the slack in the wires. Push the wire insulators back on the wires. Heat the connector terminals sufficiently to permit the removal of the wires. Replace the connector with a new unit and resolder the wires to the terminals, taking care that each wire is connected to its proper terminal. The polarity plug of the connector must

be to the rear. Replace the wire insulators in position and bend the wires downward, so as to prevent grounding on the heater tube because of pinched wires. Place the connector in the hole in the receiver, twisting it back and forth to set the wires into position. Replace the four screws and locking wire. Replace the two switch housing screws and switch housing screw locks. Also replace the ground wire under the head of the rear screw.

14. If it is necessary to replace the shroud switch, remove the locking wires and the four screws holding the switch shroud to the receiver. Then remove the two screws holding the switch to the shroud. Remove the shroud and insulator from the switch, keeping the insulator intact in the shroud. Also remove the shroud shims from the receiver. Heat the terminals on the switch sufficiently to remove the wires, preferably one at a time, and connect them to the new unit, care being taken that each wire is connected to its proper terminal. Replace the shroud and insulator on the switch and replace the screws holding the switch to the shroud. Resolder the ends of the screws to the shroud. Replace the shroud and switch groups, shroud shims, and the four screws and locking wire.

15. If it is necessary to replace the solenoid contact receptacle, remove the wire retainer by pulling it out of the buffer housing. Lift the receptacle straight up from the slot in the buffer housing. Heat the terminal on the receptacle sufficiently to remove the wire. Replace the receptacle with a new unit and resolder the wire to its terminal. Be sure that the solenoid wire insulator is positioned properly. Replace the receptacle in the slot in the buffer housing. Replace the wiring retainer by inserting it in the slot and pushing it rearward. Stake the retainer in place.

16. To remove the sear manual release, drive out the roll pin and remove the sear manual release lever and the sear manual release spring. Position the sear manual release retainer, then remove the retainer and the sear manual release shaft.

*Disassembly of the Sear Assembly.* The sear assembly may be completely disassembled by performing the following operations.

1. Place the sear assembly in a vise and remove the sear frame pin. Then the sear frame and roller assembly can be removed.

2. Place the sear block assembly in a vise and remove the double roll pin. Then remove the assembly from the vise and remove the sear locating spring support, sear locating spring, and sear yoke from the sear block.

3. Place the sear frame assembly on top of the vise and remove the sear roller pin. Then the sear roller can be removed from the sear frame assembly.

*Assembly of the Sear Assembly.* The sear parts can be assembled into a complete sear assembly by performing the following operations:

1. Place the sear frame assembly, sear roller, and vise and remove the sear roller pin. Then the sear roller pin in a vise, and press the sear roller pin being assembled.

2. Assemble the sear yoke, sear locating spring, and sear locating spring support into the sear block. The sear yoke must be so positioned that the slots in the head line up with the holes in the sear block. Place these parts in a vise and drive the roll pin into place.

3. Place the sear block in a vise and place the sear frame and roller assembly in position. Drive the sear frame pin into place. The sear frame and roller assembly should move freely after being assembled.

*Assembly of the Receiver and Barrel Support Group.*

1. Examine the sear bar before assembly to see that it is straight. In assembling the sear bar, insert the rear end of the bar into the hole in the buffer housing, allowing the front end to lie flat with the notched surface up. Push it through the hole until the rear end protrudes beyond the rear of the buffer housing. Place the sear bar spring hook on the cam rod, and screw the switch cam adjusting nut on to the cam rod until it is flush with the end of the rod.

2. To assemble the telltale bar, place the sear bar spring hook in the slot in the telltale bar. Place the front end of the bar on the shank of the switch cam adjusting nut. Then position the telltale bar on the sear bar. Take hold of the front end of the telltale bar and the rear end of the sear bar and move them back and forth to see that the sear bar moves freely in the buffer housing and also that the cam rod moves freely.

3. Insert the telltale pivot pin in the hole in the left side of the receiver. Place the telltale spacer on the pivot pin, pushing the pin in far enough to

hold the spacer in position. Assemble the telltale, telltale spring, and telltale spring capstan, in the order named and as a unit, with one end of the spring in the hole in the telltale and the other end in the hole of the capstan. Insert the telltale stud into the slots in the telltale bar and the sear bar, and rotate the unit until it is in alignment with the pivot pin. Push the pivot pin through the hole in the right side of the receiver. Insert and spread the cotter pin. Insert the drift pin from the electric charger tool set and a similar pin alternately into the holes in the capstan, turning the capstan forward until the ninth hole comes to the top. Insert the capstan pin into this hole and allow it to rest against the receiver. Push down on the telltale and observe the action of the telltale bar. The telltale bar and the cam rod must be free to operate on the tension of the sear bar spring. Also see that the sear bar operates freely on this spring.

4. Place the sear spring in place on the sear spring guide pin in the bottom of the receiver. Then place the sear assembly in position and see that the pin in the sear frame enters the slot in the sear bar without straining the sear bar or the telltale bar. Replace the sear block screw and the two sear block dowel screws. Replace the locking wire through the heads of these screws.

5. To assemble the sear manual release, insert the sear manual release shaft into the hole in the right side of the receiver, with the projection on the end of the shaft toward the front. Insert the sear manual release retainer into the slot in the shaft, and position it. Then line up the retainer with the shaft so that the prongs on the retainer are on the inside of the receiver. Assemble the sear manual release spring and the sear manual release lever into position. Insert and drive the roll pin in.

6. The Belleville buffer springs and the Belleville buffer plate should be positioned by a large screwdriver and assembled into the rear end of the buffer housing. Push the parts forward until the smaller end of the buffer plate protrudes from the front end of the housing. Screw the buffer housing screw into the housing until the buffer plate can no longer be turned with the fingers. Then, using one end of the combination wrench, tighten the buffer housing screw from three-quarter to one complete turn, until one of the locking slots is vertical. Care should be

taken not to damage the end of the sear bar with the handles of the wrench in assembling the buffer housing screw.

**CAUTION.** Do not tighten the buffer housing screw excessively so as to fully compress the buffer springs.

The rear surface of the buffer housing screw will be approximately flush with the rear end of the buffer housing when tightened properly. Place the buffer housing screw retainer in the locking slot in the buffer housing screw and fasten it in place with the buffer housing screw retainer screw. When the retainer screw is tightened, lock it in place by bending up the locking tip on the lower end of the retainer against one of the flat sides of the screwhead.

7. Hold the sear bar rearward and connect the pin in the rear end of the bar with the solenoid arm. Swing the solenoid assembly up into position. Insert the solenoid contact plug into the solenoid contact receptacle, and push the solenoid into place. Replace the solenoid mounting screws, using the nut-and-bearing-spanner wrench from the electric charger tool set. Replace the locking wire.

8. Check the height of the sear roller and check the position of the switch cam adjusting nut.

9. Place the cover hinge spring in position between the hook-shaped projections on top of the receiver. Replace the cover hinge spring screws and the locking wire. Position the cover hinge assembly and, placing a block of wood against the flat surface of the hinge assembly, drive it into place.

10. Assemble the unlocking cam into the front end of the receiver with the narrow key at the top.

11. Place the barrel support in a vertical position with the small end up. Drop the barrel buffer collar into the end of the barrel support with the large end up. See that the holes in the collar are in alignment with the holes in the barrel support. Place a screwdriver through the holes in the barrel support and the collar. Place the barrel buffer retainer sleeve in a vertical position with the threaded end down. Position the barrel buffer spring assembly on top of the sleeve with the barrel buffer thrust collar contacting the end of the sleeve. Place the small end of the barrel support over the spring assembly and the sleeve and slide it down until the thread on the end of the sleeve is engaged. Screw the sleeve into the barrel support as far as possible by hand. Retain the screwdriver in the holes in the barrel support

and the collar until the spring assembly exerts pressure on the collar and then remove it.

12. Clamp a steel bar,  $\frac{5}{16}$  by  $\frac{1}{2}$  by 5 inches long, in a vise. Place the front end of the barrel support so that the bar engages the slots in the barrel buffer retainer sleeve. Insert a steel rod,  $\frac{1}{2}$  inch in diameter by approximately 18 inches long, through the holes in the barrel support and turn in a clockwise direction until the sleeve is tightened. Line up the pinhole in the sleeve with the hole in the barrel support and drive the roll pin in.

13. Assemble the breech ring assembly in the large end of the barrel support, lining up the key on the breech ring with the keyway in the barrel support. Assemble the recoil spring against the breech ring assembly, and place the bolthead roller guide into the head of the recoil spring.

14. Assemble the large end of the barrel support into the front end of the receiver, lining up the stud in the barrel support with the slot on the bottom of the receiver. Place the barrel support coupling on the barrel support.

15. Place the adapter spring compressor in position, and tighten the hexagon head on the front end until the recoil spring is compressed. Assemble the barrel support coupling to the receiver and turn it as far as possible by hand. Using the adjustable spanner wrench, tighten the coupling. Place the barrel lock and barrel lock spring in position, and drive the roll pin in. Check the barrel lock to see that it works freely and that it engages a notch in the barrel support coupling. Remove the adapter spring compressor.

NOTE. Make certain that the barrel support coupling is fully tightened before attempting to fire the gun.

## Adjustments

It may be necessary to make various adjustments to compensate for the normal wear of certain gun parts. The following instructions for making these adjustments should be carefully followed.

### *Height of the Sear Roller.*

1. The height of the sear roller in its depressed position should be approximately flush with the top of the sear block. With the cover opened, this should be checked in two ways.

(a) Depress the sear roller with the manual release lever, and pull the bolt assembly to the rear.

With the bolt held firmly down on the receiver tracks, it should not contact the sear roller. If the bolt does contact the sear roller, examine the assembly to determine the cause. Probable cause may be a sear spring with too great a solid height, or, the sear spring stop on the sear frame may be too long. If so, replace the sear spring or file the end of the sear spring stop until the condition is corrected.

(b) Depress the sear roller by closing the firing switch and manually depressing the shroud switch. Pull the bolt assembly to the rear and with the bolt held firmly down on the receiver tracks, it should not contact the sear roller. If the bolt does contact the sear roller, remove the solenoid and add shims, one by one, between the solenoid mounting plate and the buffer housing until the bolt does not contact the roller.

2. The height of the sear roller in its released position should be approximately 0.250 inch above the sear block, and should be such that it will just contact the bottom of the bolt just forward of the sear projection.

### *Switch Cam Adjusting Nut.*

1. The proper relation of the bolt to the opening and closing of the power stroke and return stroke circuits is obtained by the adjustment of the switch cam adjusting nut.

2. Depress the sear roller with the manual sear release lever (both the sear and telltale are controlled by the firing switch and solenoid, preventing use of the firing switch for this purpose). Pull the bolt rearward, holding it firmly down on the receiver tracks until the housing switch is heard to release with an audible click. Make a reference mark on the receiver edge using one of the rear guide lugs of the bolt as a point of origin. Free the manual sear release and pull the bolt to the rear until the sear roller rises and engages the bolt. Press the bolt forward as far as the sear roller permits. Again mark the receiver edge using the same point of origin. If the distance between the two marks on the receiver edge is between three-sixteenths and one-quarter inch, the telltale setting is correct. If incorrect, adjust the switch cam adjusting nut until the correct setting is obtained.

3. The analyzer may be employed to determine the make or break point of the power circuit instead of depending on ear to hear the housing switch click. Connect the analyzer. Hold the analyzer test prod

on the power circuit contact of the lower contact assembly. Flashing of the blue (continuity) analyzer indicator will disclose the make or break point of the housing switch.

#### *Shroud Switch.*

1. Sufficient play may develop between the cover and the receiver to prevent the switch arms from properly depressing the shroud switch button. Shims should be added under the switch shroud until this condition is corrected. Spare shims are kept on the top of the switch shroud flanges.

2. Shroud switch adjustment should be made after the following check of cover clearance.

(a) Close the power switch to permit charger operation through one cycle; close and open the firing switch to release the bolt (manually operate the sear if necessary). The power switch must be left open during the succeeding operation to prevent reoperation of the charger.

(b) With the feeler gages, check the clearance between the cover and the receiver at a point immediately below the cover latch. This clearance should be the maximum at which the cover will just latch.

(c) Raise the cover and add 0.040 inch to the previous gage reading.

(d) Insert the combined gage, and close the cover. Although the cover will not latch, the solenoid circuit should be closed. Check by closing the firing switch to energize the solenoid and actuate the sear. (If the circuit analyzer is connected correctly, the green indicator should flash.)

(e) If the circuit does not close, adjust the shroud switch by adding sufficient shims under each flange of the switch shroud. This adjustment (cover 0.040 inch from closed) is sufficient to compensate for wear and no further adjustment should be needed during the normal life of the gun.

## SECTION 7. CALIBER .60 T39 MACHINE GUN

The caliber .60 machine gun T39 differs only from the T17E3 in that it has a special bolt and bolthead interchangeable with the percussion bolt, and a contact switch with the necessary wiring to an external power source to fire electrically primed ammunition. It was expected that this model would meet all the Air Force requirements for synchronization and fire interruption.

The first electrical bolt was a copy of the German MG 151/20. This bolt gave excellent ignition time and was remarkably free from "contact bounce," but the contactor which passed through the bolt and bolthead cam broke with great frequency. This design was complicated and required major modification of the bolt, bolthead and bolthead cam, and receiver.

Frigidaire was requested to redesign this bolthead, reduce the number of contactors required, and reduce the number of modifications required to convert T17 guns to T39 guns. The new assembly required no modification to the bolthead cam, but a new recoil plate in the bolthead, an enlarged firing pin hole in the bolt, and a contactor attached to the rear of the bolt were necessary. A switch attached by a bolt was added to the side of the re-

ceiver. The firing pin in this model was a WD 1090 wire 0.040 inch in diameter, which ran from the bolt contact in the rear of the bolt to the face of the bolthead when the assembly was retracted. The time of firing was controlled by the location of the switch on the receiver engaging a contact in the rear of the bolt. The firing pin used in this design failed after a few hundred rounds, and the contacts arced and chattered.

Frankford Arsenal Laboratory developed the E3 design independently. It was an improved E1 which required less modification of the T17 parts. This model failed because of excessive part breakage.

Arrow Engineering Co., Chicago, was engaged to redesign the E1. This redesign was called the E4, and it had an improved firing pin and contact mechanism in the bolt and a knife blade switch between the bolt and the receiver. The timing of the bolt was the same as in the E2.

Quality Hardware Corp. was then engaged to develop the E5.

The timing of this firing pin was accomplished by the movement of the bolt body in relation to the bolthead and is independent of the bolt switch.

This design also incorporates a chatterproof contact in the bolt. Test data on the E4 and E5 bolt assemblies was submitted and eventually accepted.

Various other experimental designs of electrical units were tested and efforts were made to modify T17E3 guns along with T39 weapons using electrical units fabricated by the Alpha Engineering & Machine Works. These guns were furnished by an order of 50 such guns at Rock Island Arsenal. Results of tests as a whole were unsatisfactory and further development of electrical firing units for this gun were limited due to the changeover to the T17E5 mechanism. Of the tests that were con-

ducted at the Aberdeen Proving Grounds to obtain data for possible use in future gun development, the designs tested did not prove to be satisfactory; however, some features in their switch and contact designs did appear desirable. The Naval Gun Factory at Washington, D. C., also built two types of bolt-heads of the T39 type.

The demand for a short aircraft gun led to a radical redesign of the T17 type guns to produce a version known as the T51. The buffer, receiver, bolt, and barrel were shortened to the minimum possible length to give an overall length of 52 inches. This development took place in 1947.

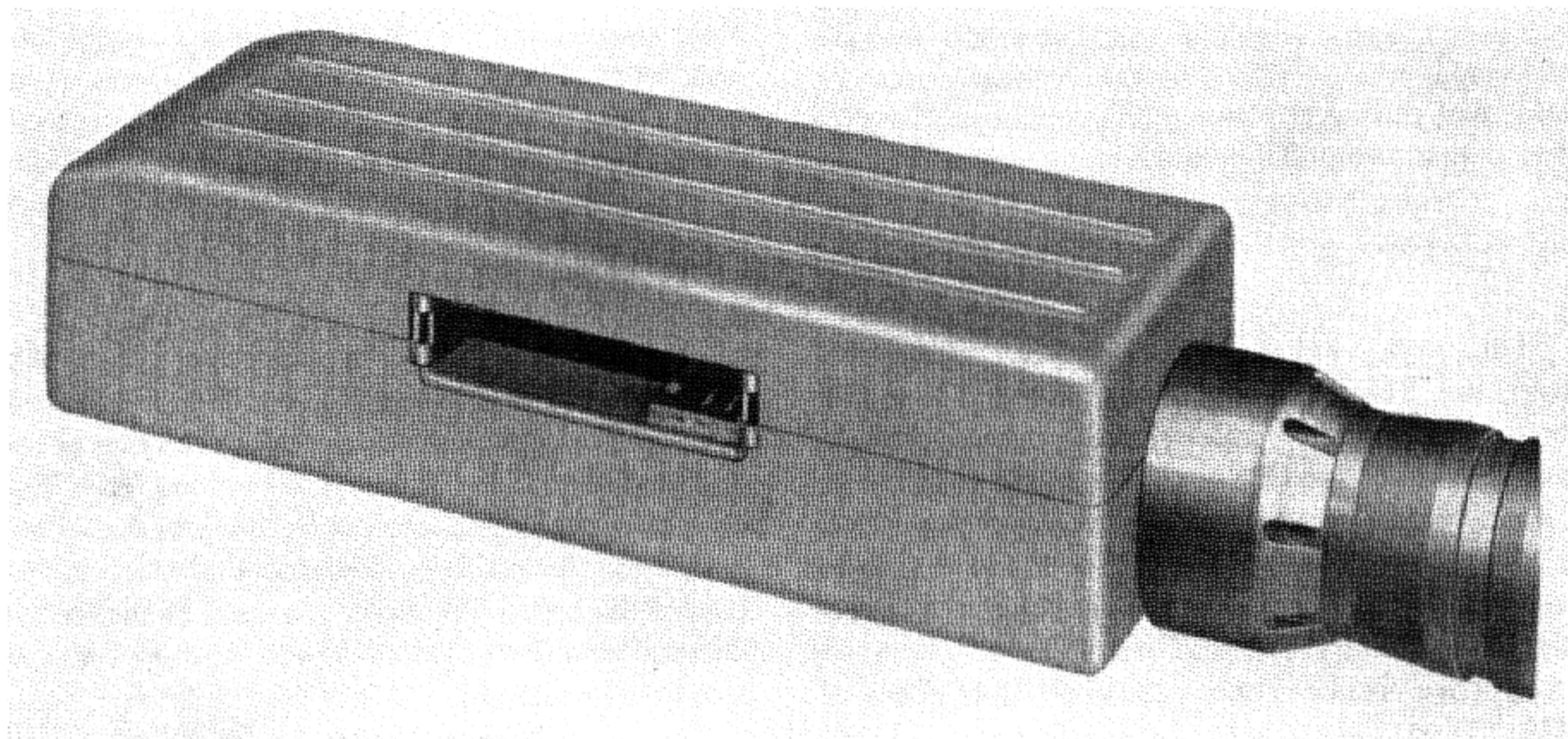


Figure 4-34. Wooden mockup of Caliber .60 T51 Machine Gun, view of receiver portion.



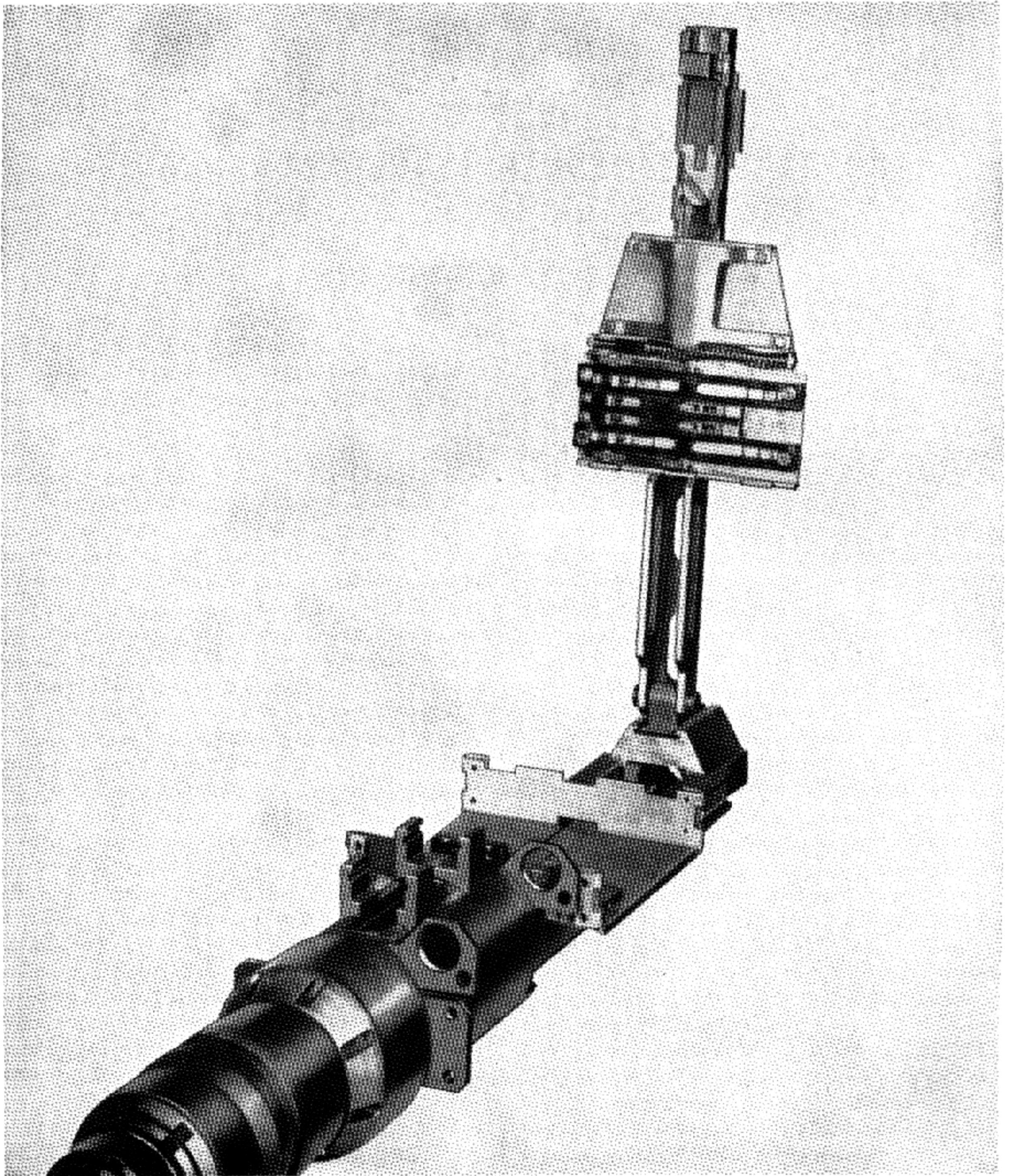


Figure 4-35. Wooden mockup of Caliber .60 T51 Machine Gun. Casing removed and feed hinged up.

## Chapter 5

# 75-MM AMERICAN AIRCRAFT CANNON DEVELOPMENT

## SECTION 1. HISTORY AND BACKGROUND

The military characteristics for airplane cannon approved in January 1937 called for an experimental cannon not to exceed a caliber of 75 mm, which would be capable of firing time and impact fused shells.

By October 1938, the Ordnance Corps expressed a desire to push with all possible speed the project for mounting a 75-mm gun and its necessary fire-control equipment in a suitable airplane. Thorough study of the problem by the Ordnance Corps revealed that the simplest possible solution should be attempted first. From an artillery point of view, this meant mounting the 75-mm as a fixed gun with limited movements in elevation and traverse. The gun should be capable of firing at a predetermined range with fuses set to burst at a chosen distance.

Two months later, a project was initiated, known as 75-mm airplane gun mount T1, for mounting a French 75-mm gun, model 1897, in a B-18 airplane together with a telescopic sight and a range finder. The Army Air Corps cooperated with the Ordnance Corps in the development of this improvised unit, which was tested by Ordnance Corps personnel on the ground and in the air. When firing tests for accuracy were conducted against aerial targets, the results obtained were far better than had been anticipated. The airplane successfully withstood the shock resulting from firing the 75-mm cannon, proving conclusively that the mounting of a 75-mm gun in an airplane was feasible from both an engineering and a tactical point of view.

The first 75-mm aircraft cannon, standardized as the 75-mm gun M4, with airplane gun mount M6, was essentially an adaptation of the 75-mm gun M3 designed for tanks. Subsequent research and development resulted in lighter guns known as the 75-mm gun M5, with airplane gun mount M9, and

the 75-mm gun M10, with aircraft gun mount M10. These installations weighed approximately 500 pounds less than the M4 gun with the M6 mount, a reduction in weight made possible by the use of high-strength alloy steel and the design of concentric recoil mechanisms. The saving in weight permitted the installation in aircraft of additional forward-firing caliber .50 machine guns.

Much of the variation in design of the 75-mm gun and its supplemental equipment was a result of space limitations and other characteristics of the airplanes into which it was to be installed. Up to the end of 1944, the M5 gun had been placed in the A-20, XA 38, XP-58, P-71, XA 26B, and B 25H airplanes, while during the same period the M5 gun was also installed in the light tank M24.

In October 1940 approval was given for the Ordnance Corps, in cooperation with the Air Corps, to proceed with the design and manufacture of a combat unit consisting of a 75-mm gun, an aircraft mount, a stereoscopic rangefinder, and a fire control system, as well as an airplane designed and built to carry this combat unit. The Ordnance Corps was to design and manufacture the gun, mount, and fire-control system immediately, while the Air Corps was to start the design and manufacture of the airplane when facilities became available, but not later than fiscal year 1942.

Plans were made to mount the 75-mm gun M2 in the nose of an XP-71 plane, with a bulkhead separating the gun and the crew. Although this type of plane was to be primarily a high-altitude fighter, requirements had also materialized for a plane with a large cannon whose primary mission was to destroy ground targets. Consequently, it was planned to mount the 75-mm Gun M3 in the XA-26B plane then under development.

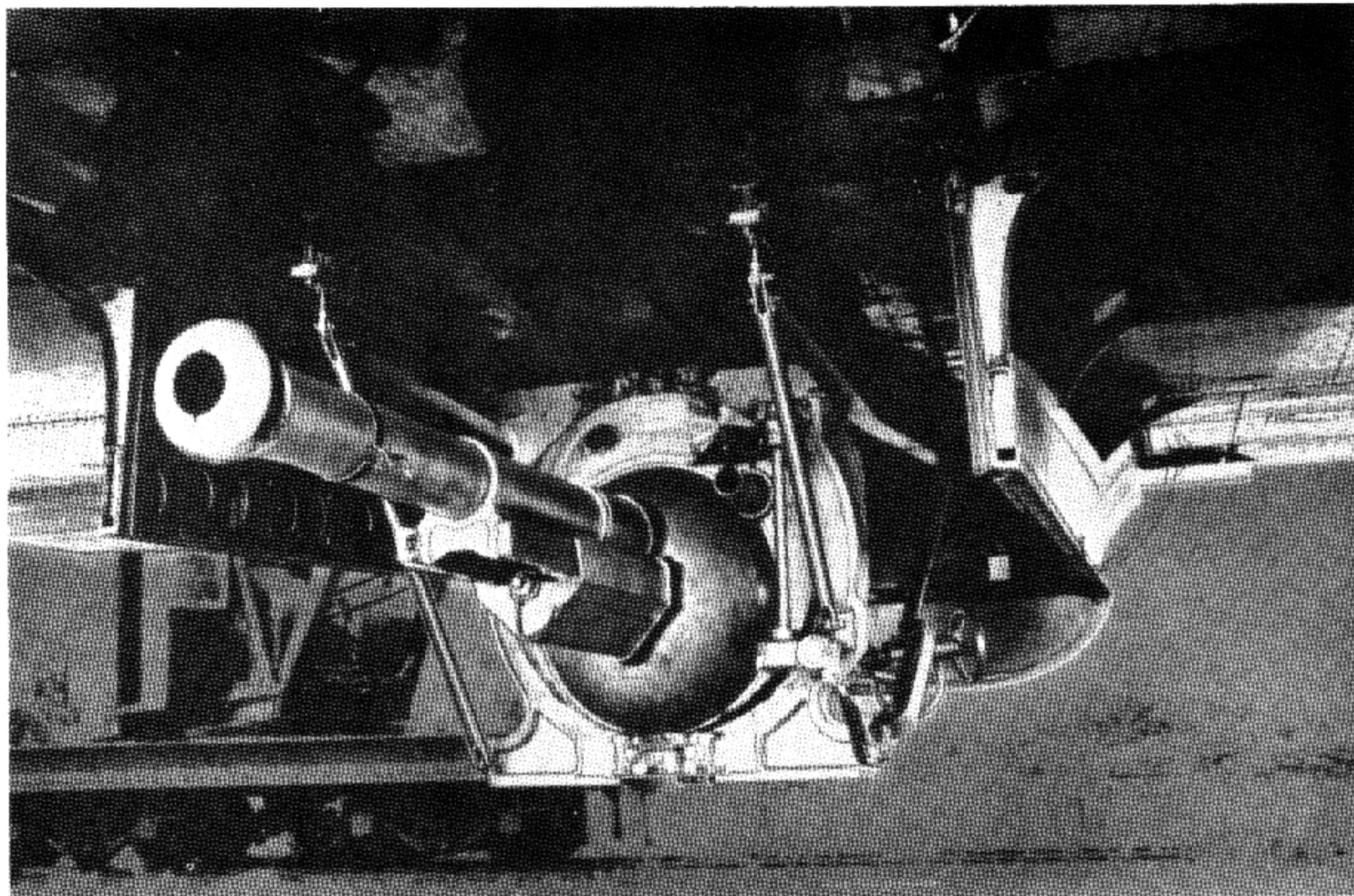


Figure 5-1. 75-mm Gun M1897A5E1 mounted in the B-18 Airplane. This mounting was used in 1939.

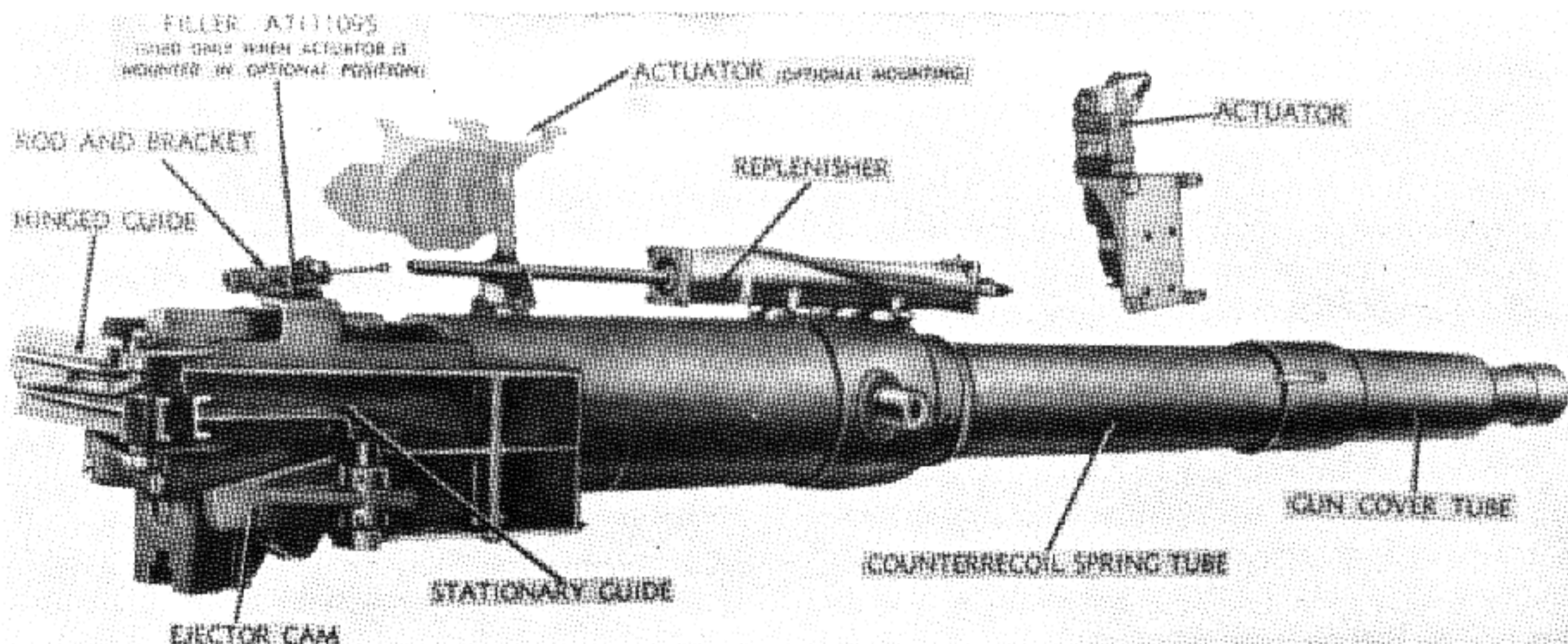


Figure 5-2. Ordnance Corps 75-mm Gun M5.

The 75-mm guns M2 and M3 were derived from the 75-mm gun T6. The Ordnance Corps originally planned to use the T6, a low-velocity anti-aircraft gun, as armament for the medium tank. Later it was found that the T6 gun would have to be modified to make it suitable for use in tanks, and the modified design was designated 75-mm gun T7.

The firing mechanism of the T7 gun used a trigger type with provision for the use of a solenoid, instead of the lanyard type of trigger actuation as used on the T6 gun. Its recoil mechanism was rotated 90 degrees about the barrel. With the addition of an operating handle for initial opening of the breech, the T7 gun was standardized in April 1941, designated 75-mm gun M2, as part of the armament of medium tank M3.

Improvements in tank design required mounting the 75-mm gun in the turret rather than in the right sponson mount. When a gyrostabilizer was installed, the gun became out of balance, because of breech preponderance; however, this difficulty was overcome by lengthening the barrel from 28.47 calibers to 37.5 calibers. This modified M2 gun was standardized as 75-mm gun M3 in June 1941.

The M3 gun required two mounts: 75-mm airplane gun mount T3 without a muzzle cover, and 75-mm airplane gun mount T3E1 with an automatic muzzle cover.

The muzzle cover was designed to prevent flare-backs caused by the action of the air blast through the open gun tube, which might carry powder gas and unconsumed particles of burning powder rear-

ward into the airplane. In addition, the muzzle cover was to aid in the loading of the gun by reducing the force caused by the air blast through the tube while the airplane was in flight.

In June 1942 at a meeting of representatives of the Air Corps and the Ordnance Corps in California, it was decided to replace the 75-mm M3 gun in the production XA-26B airplane with the 75-mm T9 gun. Pending development of the T9 gun, however, production was authorized for 750 mounts using the M3 gun. The T3E1 mount was modified to facilitate manufacture after relocating trunnions in such a way that the T9 gun could be installed without further change in the production airplane. In August 1942 this mount was standardized as 75-mm airplane gun mount M6. To fit the M6 mount, the M3 tube had a seat machined on it to accommodate the muzzle cover spline ring. Standardization of this modified M3 gun as 75-mm gun M4 took place at the same time that the M6 mount was standardized.

In the fall and winter of 1942, the M4 gun on the M6 mount underwent firing tests using M72 and M61 projectiles against an M4E2 tank hull. Firings were also conducted with a towed target representing a submarine with the deck awash. In March 1943, trunnion reactions were measured and extensive tests of the muzzle cover were made under conditions simulating a plane at rest on the ground. By April 1943, slight modifications had been made to the muzzle cover, and the gun and mount were in production. Tests conducted at Eglin Field, Fla.,

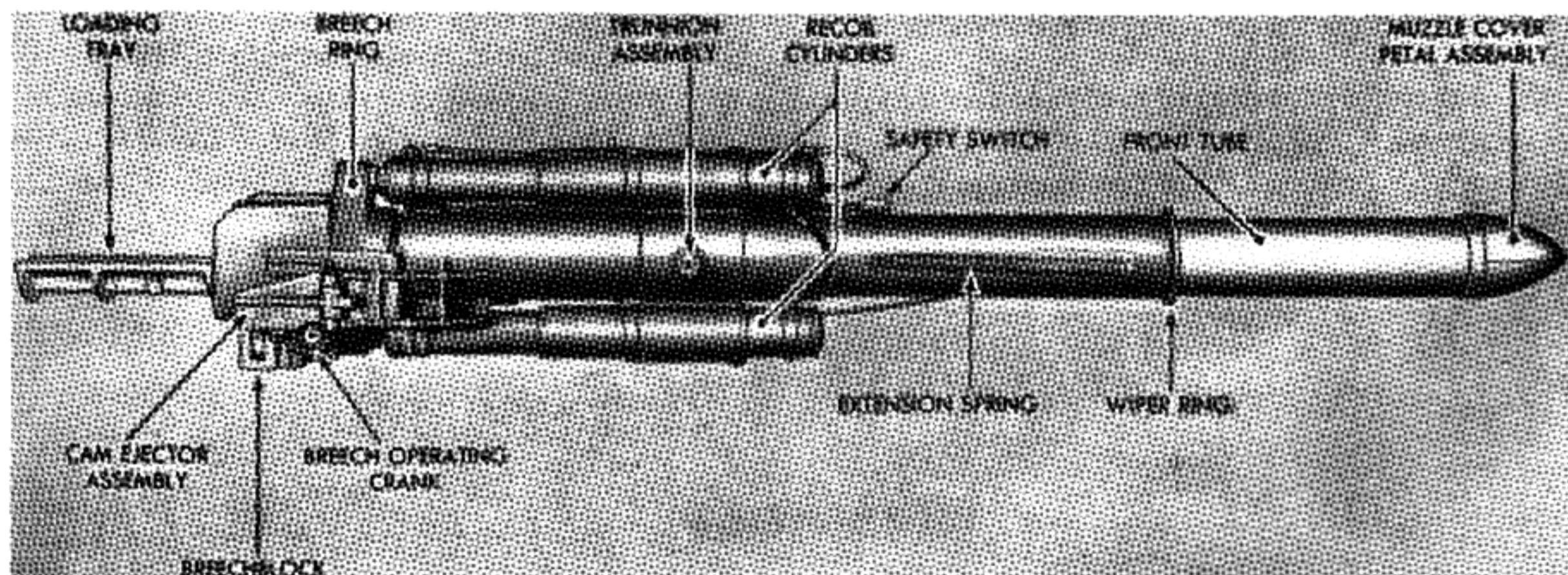


Figure 5-3. Ordnance Corps 75-mm Gun M4 on Mount M6. Right side view.

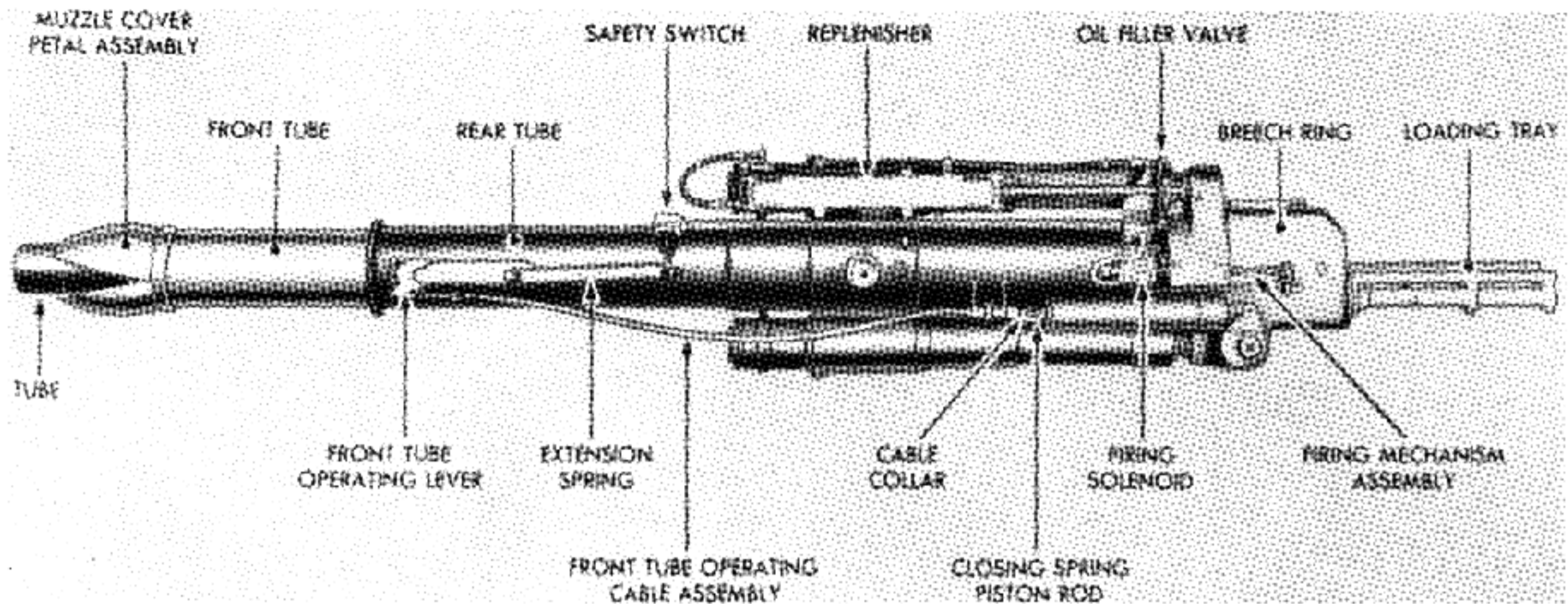


Figure 5-4. Ordnance Corps 75-mm Gun M4 on Mount M6. Left side view.

in May 1943, showed that the petals of the muzzle cover would not stay closed; accordingly, the Air Force abandoned the muzzle cover as a requirement.

Initiated in May 1942 75-mm gun T9, which was designed as a light weight 75-mm gun for aircraft use, had the same ballistic characteristics as those of 75-mm gun M4. Two pilot models were constructed; one had a closed and the other open breech ring. In December 1942 these pilots were redesignated 75-mm guns T9 and T13 respectively. The T9 gun was intended for use with mechanical loading devices and the T13 gun with hand loading installations. In November 1942 limited procurement was approved for 100 T9 guns, with 75-mm feed mechanisms T13 and 75-mm airplane gun mounts T15, all for installation in experimental aircraft.

In March 1943 during a preliminary test of the 75-mm feed mechanism T13 with the 75-mm gun T9, a power failure of considerable magnitude developed making it necessary to balance the breech

ring so that the center of gravity of the recoiling parts lay on the centerline of the bore. Because of the similarity between the breech rings of the T13 and T9 guns, this was also necessary for the T13 gun. These balanced guns were designated 75-mm guns T9E1 and T13E1.

Extensive tests were conducted at Aberdeen Proving Ground with production 75-mm guns T13E1, including extended firing at excess pressure, cold-room firing, and detonation tests. Examination of tubes at Watertown Arsenal showed that satisfactory tubes could be obtained only when the tube was heat treated after boring during the manufacturing process.

The prototype B-25H airplane with 75-mm gun T13E1 and 75-mm airplane gun mount T13E2 was subjected to service tests at Eglin Field, Fla. Following this test, standardization of the equipment at 75-mm gun M5, 75-mm airplane gun mount M9, and firing lock M15 was authorized in March 1944.

In May 1944 the Joint Aircraft Committee adopted the above unit with the nomenclature of

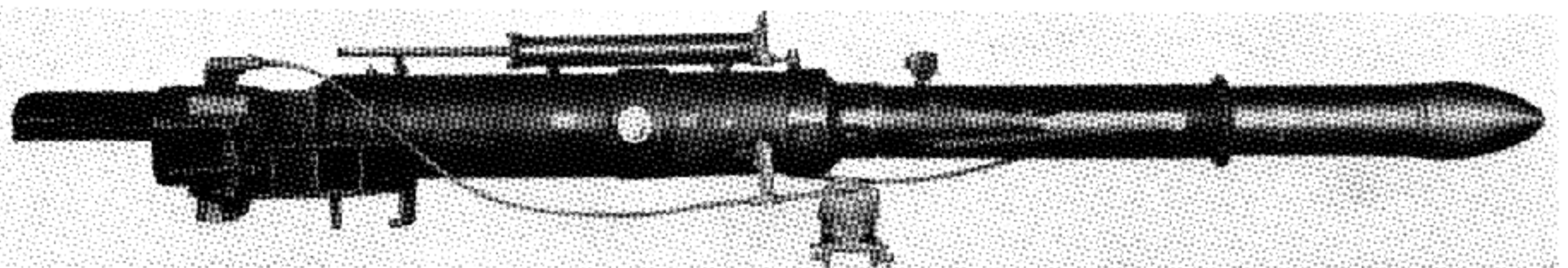


Figure 5-5. Ordnance Corps 75-mm Gun T13. Right side view.

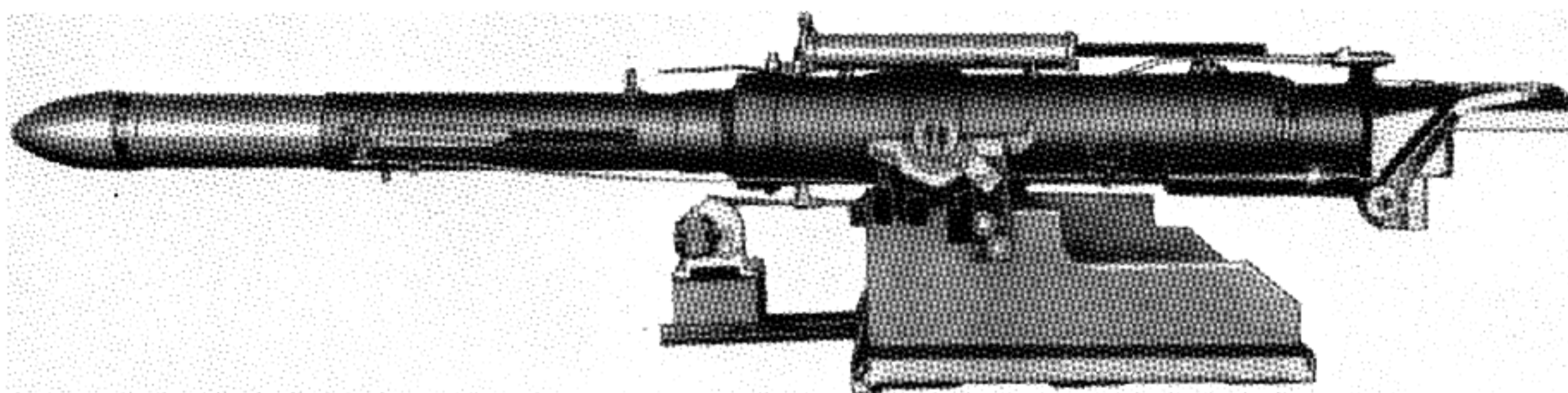


Figure 5-6. Ordnance Corps 75-mm Gun T13. Left side view.

75-mm gun AN-M5, 75-mm aircraft gun mount AN-M9, and firing lock AN-M15 as standard for use by the Army, Navy, and the British.

The 75-mm gun AN-M5 was mounted as a fixed installation in the nose of the plane. The vertical sliding wedge type breech mechanism of the AN-M5 gun was opened manually for the first round and closed by the action of the projectile, tripping the extractors and allowing the breech to close under pressure of the closing spring. During counter-recoil, the breech mechanism was opened automatically by action of the breech operating crank as it struck the breech operating cam on the mount. A collar on the forward end of the gun tube retained the counterrecoil spring.

The M9 aircraft gun mount consisted of a cradle which formed the outer cylinder of the concentric recoil mechanism. Two trunnions located on the cradle provided for mounting the gun, recoil mechanism, and cradle in the airplane. The cradle supported the replenisher and the recoil guide. The counterrecoil spring was located ahead of the cradle and was inclosed by the rear tube. A front cover was snapped in place on the front end of the rear tube. A hinged guide was provided on the rear right side of the cradle to guide the gun during recoil and counterrecoil. During inactive periods the guide could be swung across the rear face of the breech ring to conserve space.

The M15 firing lock was operated by a motor driven firing actuator, controlled by a cannon selector switch and firing button which were airplane equipment mounted in the pilot's compartment.

By the end of 1944, extensive research work had produced 75-mm guns of greater firepower than those the field artillery had used in World War I. Many differences were evident: The original field

artillery weapon weighed 1,015 pounds, but the modern airplane gun of the same bore weighed only 406 pounds. The M5 was three calibers longer than the French model. The hydropneumatic recoil system used by the French permitted a recoil of 46 inches, while the airplane gun hydrospring concentric recoil system limited the recoil to 21 to 23 inches.

The trend of 75-mm development was marked by reduction in weight and increase in firepower. Increased firepower was attained through the development of an automatic feed mechanism and a fuse setter-rammer. On 1 July 1944, for the first time, a 75-mm gun was fired automatically in bursts of three rounds from an airplane in flight. Personnel were released for other purposes than gun loading because power operation made possible use of the gun in aircraft where space was inadequate for manual operation. A cyclic rate of 30 rounds per minute and ammunition capacity of 20 rounds were achieved.

B-25G and the improved B-25H bombers armed with the 75-mm cannon sank lightly armored warships and destroyed enemy gun emplacements, shipping, and tanks. Extremely accurate attacks in the New Guinea area scored five direct hits on a Japanese destroyer, which was left in a sinking condition. In the Lanywa oil field of Burma, an oil storage tank was destroyed with 3 out of 4 shots put in the target. During operations in the Marshalls, the 75's were reported as extremely effective in silencing antiaircraft positions. In the Mediterranean, 75-mm aircraft cannon were used successfully against shipping.

While the French originated the 75 and its accompanying materiel, the Ordnance Corps adapted it to the needs of modern warfare. The 75-mm gun

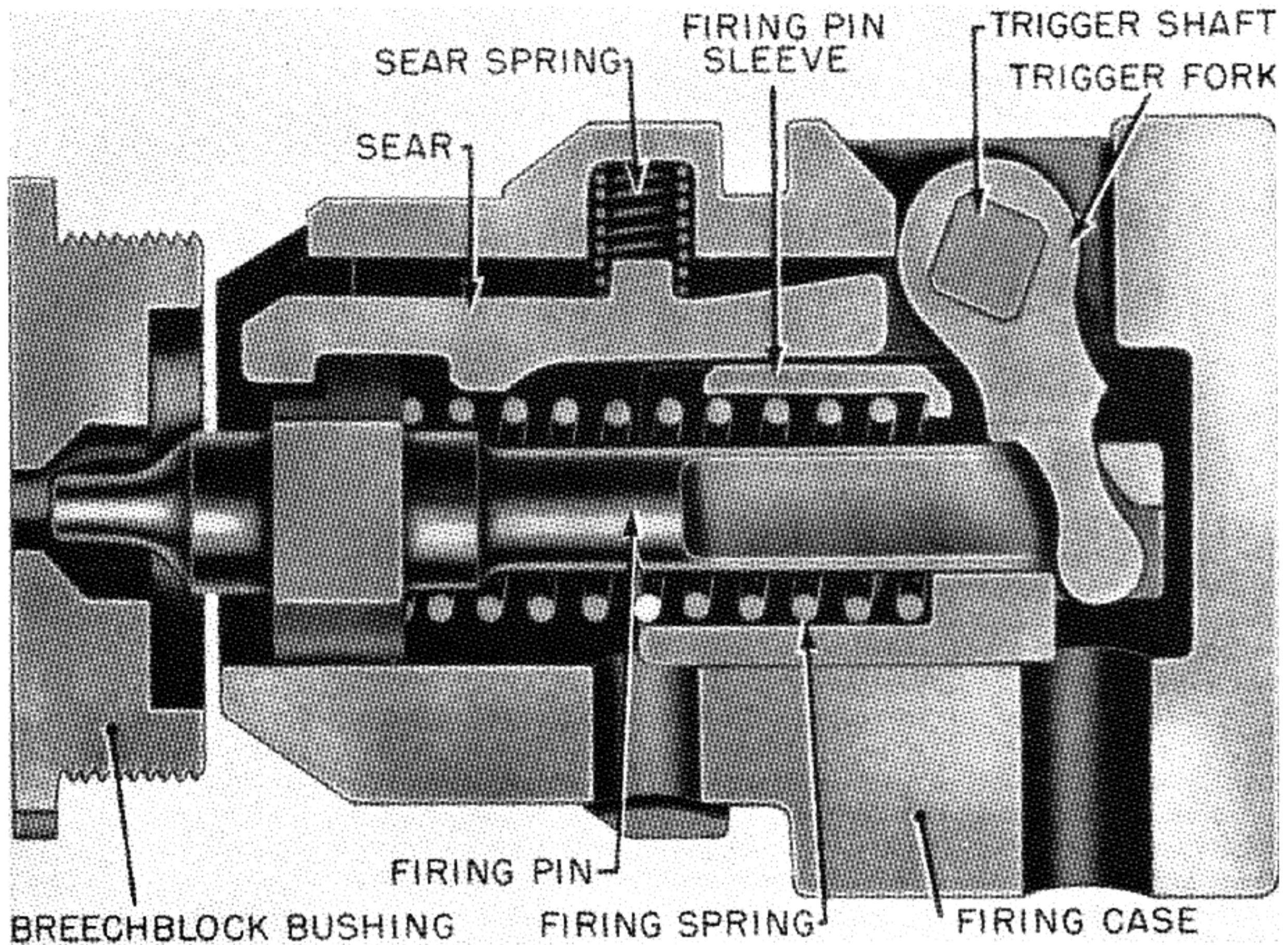


Figure 5-7. Ordnance Corps 75-mm Gun M5. Firing Lock M15 in firing position. Sectional view.

has been supplanted as a field weapon by an equally mobile 105-mm howitzer but was still an outstand-

ing weapon in World War II when used in its modern form in an airplane or tank.

## SECTION 2. 75-MM GUN M4

### General Description

The 75-mm gun M4 was a single-shot, hand-loaded, flat-trajectory weapon with an automatically operated vertical sliding wedge type of breechblock. A breech ring anchored two recoil mechanisms. The breech mechanism was composed of a breechblock percussion type mechanism, right- and left-hand extractors, breech operating shaft, breech and breechblock operating cranks, and a chain terminal crank connected to the breech closing mechanism.

The 75-mm airplane gun mount M6 consisted of a cradle in which the tube assembly was supported longitudinally in a large central boring. Bored sec-

tions of the cradle above and below the tube boring and parallel to the tube carried the two recoil cylinders. A replenisher mechanism was mounted on the left side of the upper section of the cradle; an electrical firing circuit was on the left rear side of the central section of the cradle, and a cam ejector mechanism was on the right rear side of the cradle.

The muzzle cover mechanism consisted of a rear tube, front tube, and muzzle cover petals, which opened automatically when a round was inserted in the chamber and then closed on counterrecoil of the gun. A safety switch, connected to the electrical firing device, prevented firing of the gun when the muzzle was closed.

**General Data: 75-mm Gun M4**

<p>Gun length: 129.23 inches.                  Gun weight: 893 pounds.                  Rate of fire:                      Normal: 3 to 4 rounds/minute.                      Maximum: 30 rounds/minute.                  Muzzle velocity (average velocity with new gun):                      Shell, HE, M48, with supercharge: 1970 feet/second.                      Shell, APC, M61: 2030 feet/second.                      Shell, AP, M72: 2020 feet/second.                  System of operation: Long recoil (semiautomatic).                  System of locking: Sliding vertical block.                  System of feeding: Manual.                  Location of feed opening: Rear.                  Location of ejection opening: Rear.                  Method of charging: Manual.                  Method of cooling: Air.                  Breech mechanism: Vertical sliding wedge, semiautomatic.                  Type of firing mechanism: Percussion.</p>	<p>Barrel length: 110 inches.                  Length from muzzle to rear face of breech ring: 118 inches.                  Barrel weight: 628 pounds.                  Rate control: None.                  Chamber pressure: 38,000 p. s. i.                  Bore:                      Number of grooves: 24.                      Groove depth: 0.02.                      Groove width: 0.248.                      Direction of twist: Right hand.                      Form of twist: Uniform.                      Length of bore: 37.5 calibers.                      Length of rifling: 96.2 inches.                  Type of mount: 75-mm M6.</p>
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**General Data: 75-mm Gun M5**

<p>Length of gun (muzzle to rear face of breech ring): 116.375 inches.                  Weight of gun: 406 pounds.                  Muzzle velocity:                      Projectile APC, M61: 2,030 feet/second.                      Shell, HE, M48 (supercharge): 970 feet/second.                      Shot, AP, M72: 2,020 feet/second.                  Type of firing mechanism: Continuous pull, self-cocking.                  Breech mechanism: Vertical sliding wedge, semiautomatic.                  Length of barrel: 37.5 calibers.                  Weight of gun and mount (including recoil mechanism): 763 pounds.                  Length (muzzle to rear end of hinged guide): 129.25 inches.                  Type of mount: 75-mm M9.</p>
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**Comparative Data: 75-mm M6 and M9 Gun Mounts**

Mount	M6	M9
Recoil mechanism.....	Hydrospring, two separate recoil cylinders (recoil mechanism is considered part of mount M6).	Hydrospring concentric recoil mechanism counter-recoil springs are housed in separate cylinder ahead of cradle (considered part of mount M9).
Weight of recoil mechanism.....	334 pounds.....	
Maximum allowable recoil.....	23 inches.....	
Normal recoil.....	21 inches.....	
Breech ring guide.....	Solid construction.....	Folds against rear face of breech ring.
Loading tray.....	Swings up out of way.....	None.



## SECTION 3. 75-MM GUNS M5, M5A1, AND AN-M5A1

The 75-mm gun M5 used the standard 75-mm gun rifling with a twist of 1 turn in 25.58 calibers. The stability factor of 75-mm HE shell M48 was 1.373 when fired on the ground; when fired from an airplane in flight (because of the increase in linear velocity with no increase in rotational velocity), the stability factor was reduced and reached a value of 1.000 for a true air speed of 228 miles per hour at sea level. At higher speeds, the stability factor was even less. This condition of instability precluded the application of adequate fire control and substantially reduced the effectiveness of the round.

To improve the stability of 75-mm HE shell M48 for aircraft firing, it was necessary to provide a gun with increased twist. Accordingly, two 75-mm guns M4 were made with a twist of rifling of 1 turn in 22 calibers.

With this increased twist, the stability factor for ground firing of 75-mm shell M48 was raised to 1.857, with a corresponding increase for aerial firing. Extended firings were conducted with one of these guns at Aberdeen Proving Ground, and the second gun was sent to Eglin Field, Fla., for aerial firing. The results of Eglin Field tests were in agreement with this and indicated satisfactory stability with HE shell M48 when fired from a gun with a twist of 1 turn in 22 calibers.

Two other tubes with twist of rifling of 1 turn in 22 calibers were built and tested at Aberdeen Proving Ground. One of these guns had the standard 75-mm gun form of rifling and the other, a modified 75-mm howitzer form of rifling (28 lands and grooves, 0.30 in. deep with a fillet radius of 0.03 inch).

## SECTION 4. 75-MM GUN M10 (T9E2)

In July 1944 75-mm gun T9E2, with 75-mm feed mechanism T13 and 75-mm airplane gun mount T15E2, were installed in the XA-38 airplane and fired on the ground at Tulsa, Okla. This test was essentially a proof test of the airplane structure. At the same time the unit was fired from the XA-38 airplane in flight at Great Bend, Kans. Throughout this test, the mechanism functioned satisfactorily.

The 75-mm gun T9E2 differed slightly from the 75-mm gun M5A1, but was used with the T15E2

One gun of each type was fired approximately 1,000 rounds at maximum rated pressure and ambient outdoor temperature, followed by 200 rounds at 115 percent maximum rated pressure and  $-50^{\circ}$  F. Series of shell M48 and projectile APC M61 inert were fired for recovery and examination of the rotating bands at intervals of 500 rounds. In addition, spin measurements were taken with M48 shell fired from the standard gun contour of rifling to obtain comparative results of firing from a new gun and from one which had been fired approximately 1,800 rounds.

The results of these tests indicated that there was no appreciable loss of spin in a gun which had been fired 1,800 rounds. Accordingly, it was approved in July 1944 that the twist of rifling of 75-mm gun tubes for aircraft use be increased to 1 turn in 22 calibers, retaining the standard form of rifling for 75-mm guns. These guns were then designated 75-mm gun M5A1 and 75-mm gun T9E2, and the 75-mm gun M5 for aircraft use was reduced to limited standard.

In November 1944 the Joint Aircraft Committee considered further development of the M5A1 gun. It was pointed out that although the AN-M5 gun was satisfactory for firing from aircraft, such as the B-25, at speeds up to 230 to 250 m. p. h., it was unsatisfactory on the A-26 and in other aircraft having maximum speeds above 250 m. p. h. Consequently, the M5A1 gun was standardized as 75-mm gun AN-M5A1, and the AN-M5 gun reduced to substitute standard, with the understanding that the AN-M5 gun would not be procured for airplanes having speeds above 250 m. p. h.

mount and T13 feed mechanism. It was not interchangeable with the 75-mm gun M5A1 and M9 mount. The breech rings were made from the same castings and were alike except that provision was made on top of the breech ring of the T9E2 gun for mounting the feeder mechanism which started the operation of the feed mechanism. The T15E2 mount differed from the M9 mount only in the location of the trunnions and the provision of certain

bosses and pads for mounting the feed mechanism.

Standardization of the T9E2 gun as 75-mm gun M10, the feed mechanism T13 as 75-mm feed

mechanism M4, and the T15E2 mount as 75-mm aircraft gun mount M10 was approved in October 1944.

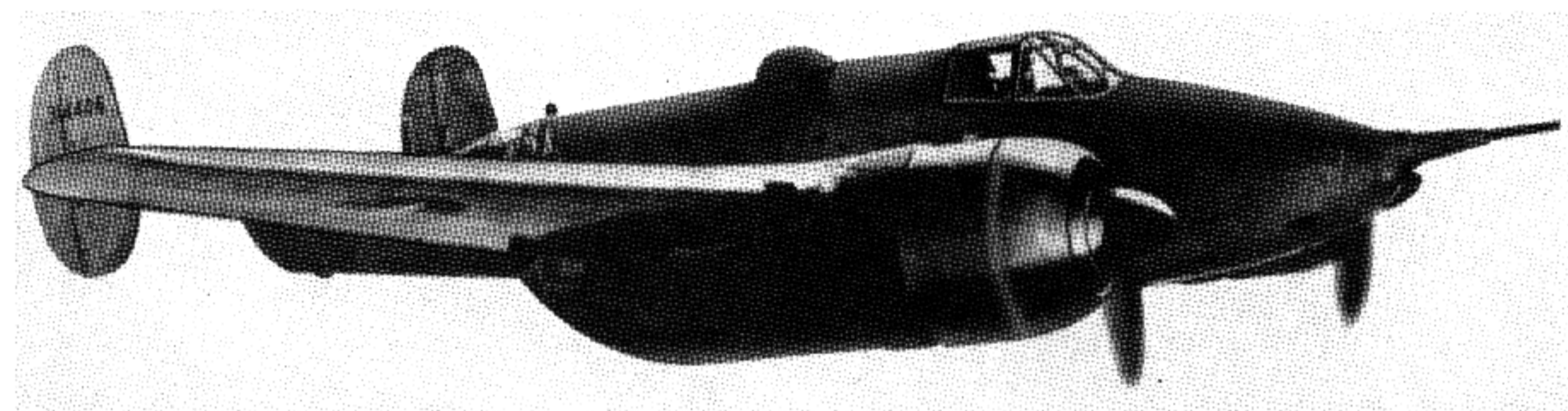


Figure 5-8. XA-38 Airplane armed with 75-mm Cannon M10.

## SECTION 5. 75-MM GUN T9E3

In August 1944 a development program was authorized to reduce the installation weight of the combination T9E2 gun, T13 feed mechanism, and T15E2 airplane gun mount in the XA-38 airplane. The new gun, designated 75-mm gun T9E3, was to be provided with suitable bearing surfaces to guide it in recoil, to mount the piston of the recoil mechanism directly on the tube, and to have the standard 75-mm gun form of rifling with a uniform right-

hand twist of 1 turn in 22 calibers. The ballistic characteristics were to be identical with the 75-mm gun T9E2.

A new mount, designated 75-mm airplane gun mount T15E4, was to be used with the T9E3 gun. This mount, unlike its predecessors which were of the hydrospring concentric recoil type, embodied a hydropneumatic concentric recoil mechanism.

### General Data: 75-mm Gun T9E1

Gun length: 116.375 inches.  
 Gun weight:  
   Without mount: 406 pounds.  
   With mount: 763 pounds.  
 Rate of fire:  
   Maximum: 30 shots/minute.  
   Average: 3 or 4 shots/minute.  
 Muzzle velocity: 2,030 feet/second (when using projectile APM61).  
 System of operation: Long recoil.  
 System of locking: Vertical sliding wedge.  
 System of feeding: Manual.  
 Method of headspace: Locking wedge designed to take up any excessive headspace.  
 Location of feed opening: Rear of breechblock.  
 Location of ejection opening: Rear of breechblock.  
 Method of charging: First round loaded by gunner.  
 Method of cooling: Air.

Barrel length: 84 inches.  
 Barrel weight: 178 pounds.  
 Rate control: None.  
 Barrel removal: Not designed for field removal.  
 Bore:  
   Number of grooves: 24.  
   Groove depth: 0.020 inch.  
   Groove width: 0.248 inch.  
   Pitch: 7 degrees. (Equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches.)  
 Direction of twist: Right hand.  
 Form of twist: Uniform.

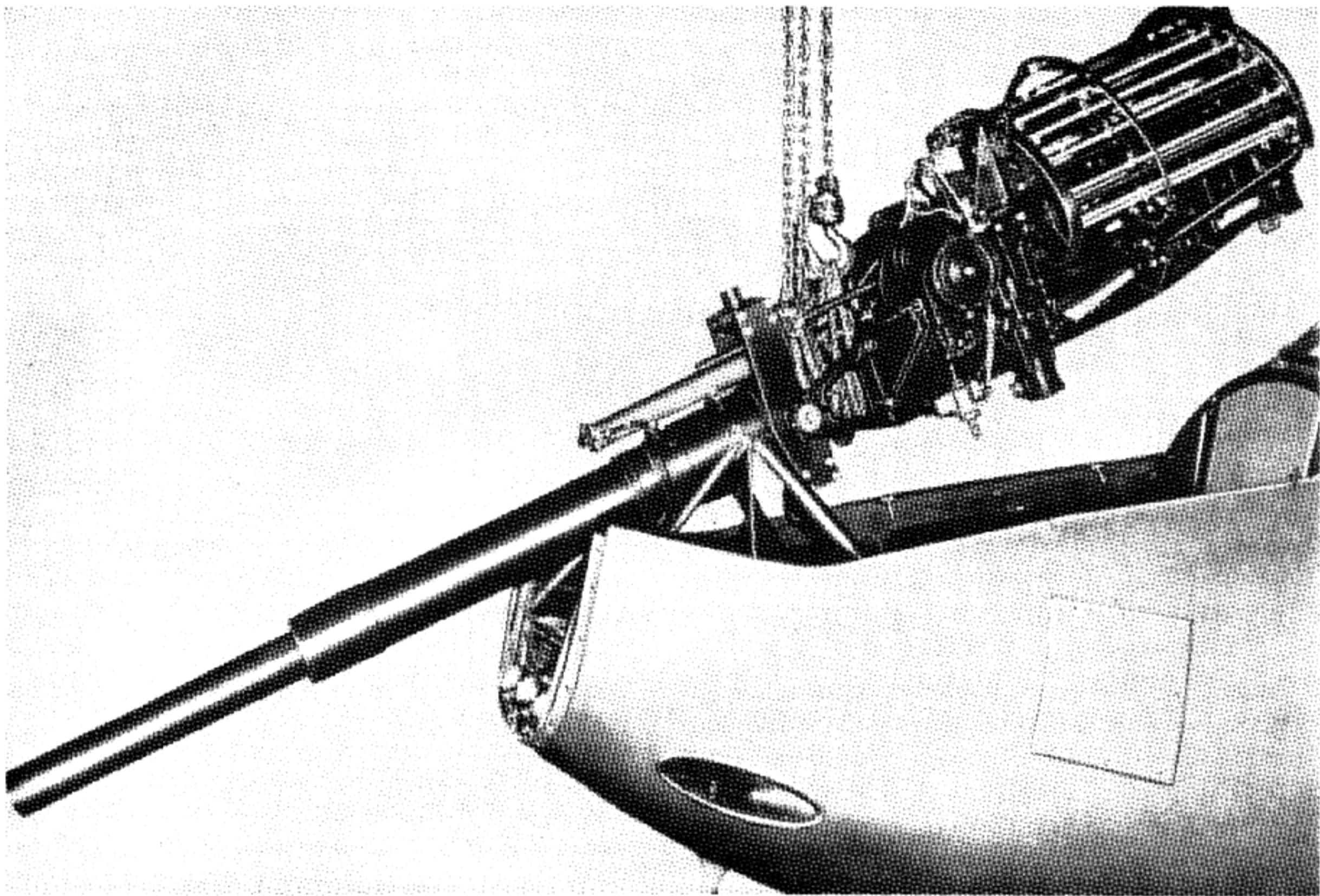


Figure 5-9. Ordnance Corps 75-mm Gun M10.

Modifications to the T13 feed mechanism were carried on with the designation 75-mm feed mechanism T13E1.

Tests of the gun, mount, and feed mechanism combination showed that excess impact load was caused by rapid ejection. A new ejector cam for the T15E4 mount was consequently required to slow

down the ejection. Before completion of this latest cam design, the Aberdeen Proving Ground was ordered to stop further testing.

The 75-mm aircraft weapon program came to a halt after the effectiveness of rockets was proved by their promoters, but not before the weapon had been successfully modified to fire full automatic.

## Chapter 6

**BUREAU OF ORDNANCE REVOLVER  
CANNON (MARQUARDT)****SECTION 1. HISTORY AND BACKGROUND**

After the end of hostilities with Germany in 1945, the Navy Department sent Frank R. Marquardt, a naval technician, to Europe to investigate German aircraft machine gun development. After reviewing the status of the German revolver gun developments, Marquardt became interested in the possibilities of obtaining high firing rates with low weight by use of a rotating chamber. He felt that the single barrel, five chamber, revolver guns under development were unnecessarily compromised to make use of conventional recoil absorbing, gas operating, and

mechanical ramming mechanisms as a result of the German anxiety to meet an urgent requirement.

Upon his return to the United States, Marquardt decided to investigate the possibilities of a rotating chamber gun and made the first sketch of his new approach to a revolver gun on 7 December 1945. Shortly thereafter, the Navy Department assigned John J. Sauber to assist Marquardt in the development of his ideas.

Numerous methods of rotating a drum were investigated for single- and double-barrel versions.

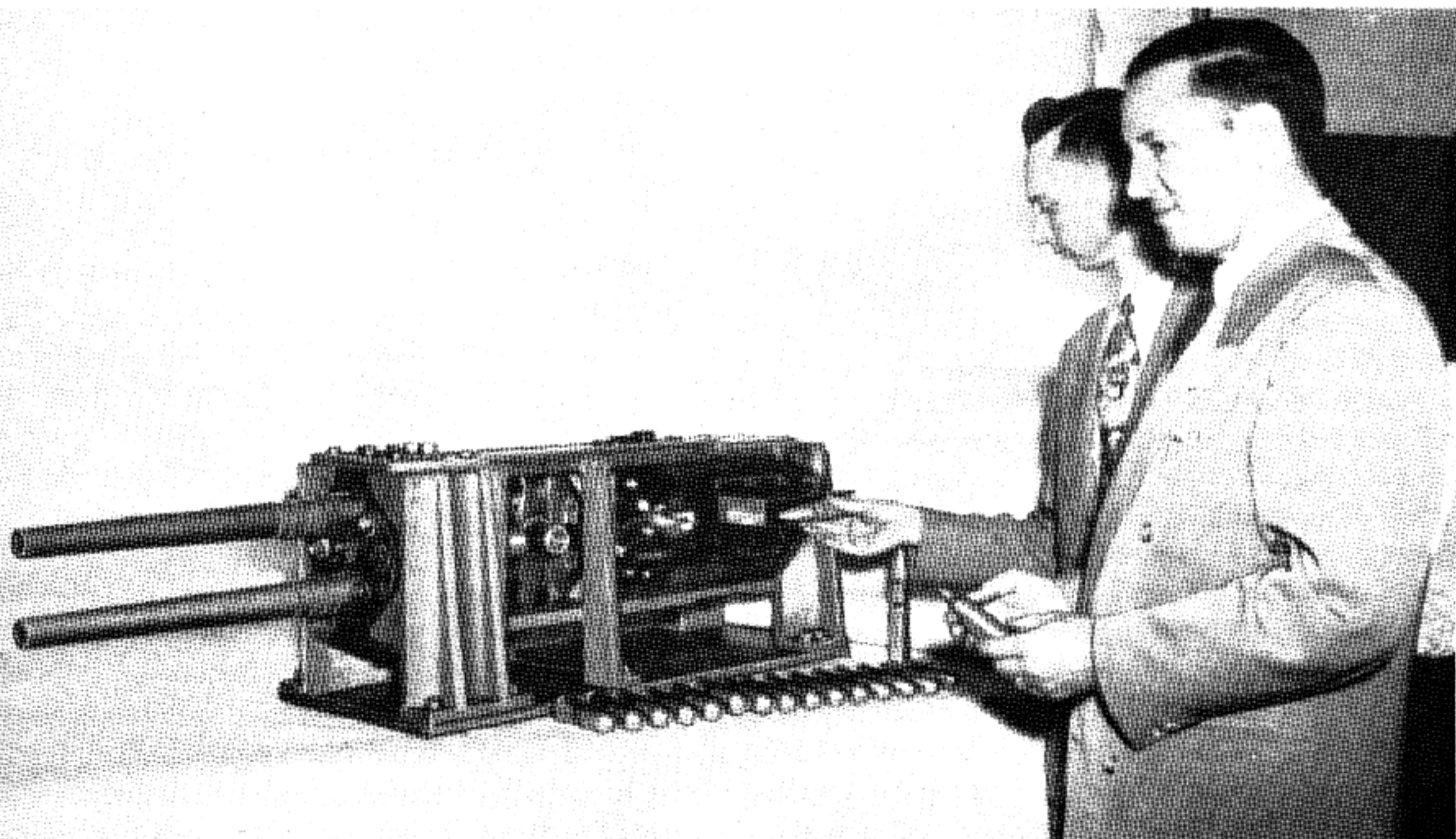


Figure 6-1. 20-mm Gun Mechanism Mk 11 Mod 0 installed in test frame. In foreground, Frank Marquardt, inventor and chief design engineer, and John J. Sauber, assistant design engineer.

One of these designs contained 2 barrels and 2 drums with 3 chambers in each drum. This design was later changed to four chambers per drum to obtain a cooling position for the obturating sleeves in addition to the positions for loading, firing, and extracting. In order to decrease the loading distance, a design was conceived whereby the projectiles were loaded from the front of the drum and the incased propellant was loaded from the rear. This design represented an attempt to obtain a balanced short-stroke rammer with the projectile weight approximately equal to the incased propellant weight.

Marquardt's efforts to reduce the rammer weight included the use of chemical energy in the form of an electric primer to move the projectile and incased propellant, thus eliminating the complicated, heavy mechanical ramming design derived from his attempts to use gun energy. In order to convince himself that ramming by chemical means was possible, he obtained a package of electrical primers being developed for the 20-mm ammunition and started experimenting at his home.

He cut off a 20-mm cartridge case about 1 inch from its base and soldered this into the end of a piece of brass pipe, the inside of which he had machined to fit the largest diameter of a complete 20-mm round. After making a firing fixture, he attempted the first projection of a round of ammunition by chemical means. Not knowing what to expect, he directed it toward the ceiling of the basement and was quite surprised to see the 20-mm round put a dent in the wooden beam. Carrying his experiments further, he moved his fixture outdoors next to a telephone pole, the height of which he had determined by measuring the length of a ball of string he threw over the horizontal wires. By standing off at a distance, he noted that the round of ammunition was projected about two and one-half times as high as the telephone pole and thus was able to determine the projection velocity.

As a result of these experiments, he changed his mechanical ramming design to explosive projection of a one-piece round from the rear of the rotating drum into the drum chambers. He continued the gun design based on this explosive projector method of loading, combining the 2 drums with 4 chambers each into 1 drum containing 8 chambers. He then worked out a firing cycle based on the firing of one

barrel to start a burst and the firing of the other barrel to stop the burst.

After the design became firm, two wooden models were fabricated at the Naval Gun Factory for demonstration and to check the arrangement of the components. Demonstrations were given using these gun models and a test fixture. On 16 December 1946, a development program was initiated for a 52-inch Marquardt gun for aircraft turret use. As the work progressed, tasks were set up with both civilian and Government contractors to carry on engineering studies and to manufacture components. Participating contractors included were: Hughes Aircraft Co., United Shoe Machinery Corp., Remington Arms Corp., Naval Gun Factory, and Frankford Arsenal.

### Chronological History

1945.

7 DECEMBER. First sketch made.

10 DECEMBER. First preliminary design drawing; five chamber cylinder, single barrel.

26 DECEMBER. Impulse system of operation investigated.

1946.

21 JANUARY. First time displacement curves using constant retarding force for single-barrel gun developed.

MARCH. First rounds projected by electric primers.

15 MARCH. First time displacement curve for double-barrel gun using constant retarding force developed.

SPRING. Investigated gas-driven cylinder.

JULY. First drawing using lever to multiply motion of recoil to turn cylinder.

JULY-AUGUST. Design of switching of roller device of cylinder.

1947.

24 FEBRUARY. Drawings made on a wooden mockup of gun to show the action of the gun.

13 MARCH. Drawings delivered to Naval Gun Factory of mockup.

16 MARCH. Development of method for calculating forces, velocities, and displacements of gun parts by graphical integration.

18 APRIL. First time displacement of gun plotted.

21 APRIL. First showing of wooden mockup and demonstration of its operation. Demonstration of projector using live primer to ram round into gun chamber. CO<sub>2</sub> used to eject case from chamber. Representatives were present from the Bureau of Ordnance, Bureau of Aeronautics, Naval Gun Factory, Dahlgren Proving Ground, and the War Department.

28 APRIL. Demonstration and explanation for Chief of Bureau of Ordnance, and other officials of the Bureau. They were interested to know when manufacture of a prototype could start and were told it would take the few BuOrd engineers available about 3 months of unbroken work to finish layouts and dimensional design drawings.

14 MAY. BuOrd letter to NGF authorized expenditure of funds for design layouts and mockups of subassemblies.

24 JULY. At a conference held at Naval Gun Factory, it was decided what items of the gun were to be patented. It was also determined what tests Naval Gun Factory was to run in connection with the development of the EX 4 gun.

7 AUGUST. Work started on CNO memo to scale up EX 4 gun to 40-mm, 3,500 feet per second muzzle velocity, high cyclic rate gun.

11 AUGUST. Finished preliminary layout and computations on 40-mm gun.

14 AUGUST. Task assignment NGF-18-Re8a-111-2 assigned to BuOrd letter of 14 May 1947. \$5,000 allotted. To be completed 1 December 1947.

18 AUGUST. A complete set of preliminary prints of EX 4 gun and one set of photographs of model were given to BuOrd Chief Engineer who was told they were not yet covered by patents and didn't want anyone else getting patents ahead of the USA. These prints and photographs were taken to England for discussion of ship defense.

19 AUGUST. First results of a series of ramming tests at 90 feet per second showed that when standard ammunition was used headspace problems became very significant. That fact was emphasized because the round was going so far into the chamber that the rifling was engraving the cartridge case.

22 OCTOBER. Design drawings finished.

26 NOVEMBER. Meeting held at Naval Gun Factory to discuss progress on the EX 4 gun. Prints of the EX 4 were delivered and branch head of

Re8 made it plain he wanted an EX 4 manufactured and ready for firing by June 1948.

1 DECEMBER. The Mark number assigned to the EX 4 gun was 20-mm gun mechanism Mk 11 Mod 0. Short barrel, 20-mm gun barrel Mk 9 Mod 0. Long barrel, 20-mm gun barrel Mk 10 Mod 0.

6 DECEMBER. First NGF drawings released to shop for manufacture of first prototype gun.

26 DECEMBER. Task NGF-18-Rc8a-111-6. Engineering detailing and manufacture of subassemblies. \$50,000 allotted. To be completed 30 April 1948.

1948.

JANUARY. Manufacture of two aluminum alloy breech forgings was begun at the NGF.

MARCH. Machining of NGF forging was begun.

6 APRIL. Change, task assignment NGF-18-Re8a-111-6, completion date to be 30 September 1948.

22 APRIL. Kinematic analysis plotted from integrated mathematical equations.

24 MAY. Design drawings signed.

3 JUNE. Task assignment NGF-18 Re8a-111-8 assigned for short length Mk 11 Mod 0, \$60,000 being allotted to manufacture five guns. Completion date, 30 September 1948.

AUGUST. Procurement of six Alcoa hand forgings initiated.

SEPTEMBER. Predetonations occurred; round primer detonated during projection.

23 SEPTEMBER. Task assignment NGF-18-Re8a-111 6. Increase by \$10,000 from Re8a-111-8 (total \$60,000).

24 SEPTEMBER. OCO letter to Remington requested 1,000 N-13 4.5 grain primers be forwarded to Naval Gun Factory for Mk 11 gun studies.

24 SEPTEMBER. OCO letter to Frankford Arsenal, discussing Mk 11 gun and projector and test fixtures and aluminum cased ammunition.

17 NOVEMBER. 200 aluminum cartridge cases from Remington Arms delivered to BuOrd.

24 NOVEMBER. OCO letter 00471.91/36 (c) dated 29 Nov. 1948 to Frankford Arsenal: (a) All previous requests for ammunition canceled; (b) 480 electric primed brass cased ammunition sent to naval proving ground; (c) 300 electric primed brass ammunition inert charge to be delivered to Naval Gun Factory; (d) arsenal to conduct development

and test program on ammunition (brass and aluminum); (e) determine possibility of premature ignition of round during projection. Authorized development of primer if necessary.

10 DECEMBER. One test mechanism sent to Frankford Arsenal for ammunition development. 1949.

10 JANUARY. OCO letter QQ 471.873/102(c) Attn: ORDTS-FA 471.8731/1770-25. (Light alloy cartridge case.)

4 FEBRUARY. Flanged rotating band projectile designed to decelerate round being rammed.

10 FEBRUARY. Re8 memo to Re3 via Re2. Practice rounds for Mk 11 Mod 0 discussed.

15 FEBRUARY. Task assignment NGF-18-Re8a-113-1 set up for 20-mm gun mechanism Mk 11 Mod 0. Cost \$50,000. Completion date 31 December 1949. Date extended to 15 June 1950 by telcon of 15 November 1949. Date extended to 30 June 1951 by telcon of 22 March 1950.

11 MARCH. Re2 memo to PLc. Budget request for development of ammunition for Mk 11 gun.

9 MARCH. Re2 conference on ammunition for Mk 11 gun conference stated requirement for immediate need of 5,000 rounds of practice ammunition.

22 MARCH. Memo from Re8 to PLc. Subj: Aircraft ammunition, responsibility for research and development.

1 APRIL. Re2 received \$240,000 to be given to the Army for development of ammunition for Mk 11 gun.

1 APRIL. Re2 memo on allotment of funds.

1 APRIL. Re8 memo to Re2, Re3, requested development of ammunition.

15 APRIL. Re2a memo to Reb requesting \$240,000 to be transferred to the Army for Mk 11 ammunition.

15 APRIL. Request for contract or fiscal action to Reb from Re2a on funds for development of Mk 11 gun ammunition.

18 APRIL. Re2 memo to Re8. Aluminum alloy cases for Mk 11 gun.

5 MAY. BuOrd letter to OCO referring to Interdepartmental Order No. 02570 on the development and providing of 5,000 rounds practice ammunition and development of matched family of rounds.

5 MAY. Re8 memo to Re3. Information on ammunition with reference to functioning of gun.

5 MAY. Letter from BuOrd to OCO. Development of ammunition for Mk 11 gun.

27 MAY. Mk 11 gun was sent to Naval Proving Ground and the first round was fired. The aluminum breech failed. The gun otherwise was undamaged. The cause of the failure was due to many factors: (1) advancing cone in the barrel was not present; (2) poor material in the breech (elongation in 2 inches was 1.5 percent); (3) excess pressure rounds were used.

JUNE. Initiated manufacture of one steel breech.

JULY. Initiated machining of Alcoa hand forging.

SEPTEMBER. Attempt at automatic fire failed. Mechanical components found to be satisfactory. Failure found to be due to electrical malfunctions. These firing attempts done with new steel breech rather than aluminum because the aluminum forgings were not finally machined.

27 SEPTEMBER. Satisfactory burst of 5 rounds out of 8 rounds loaded. Attempt at second burst in afternoon gave a burst of 4 rounds out of 8. Indicated rate of fire of the gun with steel breech was set at approximately 3,000 rounds per minute.

30 SEPTEMBER. One ammunition test fixture ordered sent to Frankford Arsenal for ammunition development. (Due 1 November 1949.)

6 OCTOBER. Memo to Re2a discussed division of funds from T117 gun for ammunition for T118 gun.

14 OCTOBER. The new aluminum alloy forged breech was fired single shot. Everything was found to be satisfactory.

21 OCTOBER. Previous attempts at eight round bursts failed. Cause was believed to be that the loaded rounds were forced forward when the gun fired, thus moving the primer out of the reach of the firing pin. In an attempt to prove or disprove this, eight rounds were loaded into the chamber while the gun was disassembled. These rounds were then pressed into the chamber four at a time with a force of 4,000 pounds to give all rounds the same head spacing to very close limits and to keep the rounds from moving into the chambers during firing. The gun was then assembled using the new alloy aluminum forged breech. Firing pins were spaced to give the proper firing contact. A burst

was attempted. Seven shots were fired in automatic fire at a very high rate. The actual rate was not obtained because of a disconnected electric power lead. The eighth round failed due to a jam on the last cycle. The roller that was cammed out of the previous cam track bounced back into the track as the gun began the next cycle so that there was a roller partially engaged in each cam track.

26 OCTOBER. (Re2a) WGS: 578-1 (20-mm)  
From: Chief, Bureau of Ordnance.

To: Chief of Ordnance, paragraph 2 referred to target date for T117 gun.

1 NOVEMBER. Gun cleaned from previous firings. The cams were stoned down at points of deformation caused by previous firing. An attempt was made to fire a burst. The gun stopped half a cycle past the starting position. The parts were in such a condition to bind the revolving and reciprocating parts. After fired case was removed, all parts worked freely in mechanism. Therefore, it appears that the case moved aft under pressure and expanded to a point where it would not return. This bound the sprocket because of the breech deformation. After disassembly, it was found that the aluminum breech was not permanently distorted. The above occurred during two attempts to fire automatically. It is also believed that possibly the rounds were forced into the chamber too tightly when they were loaded into the chamber.

8 NOVEMBER. The first time an eight round burst was obtained. (Rounds loaded by hand.)

9 NOVEMBER. Burst fired steel breech. Rate of fire approximately 2,600 shots per minute. Investigation was started into elimination of friction which was believed to be causing the low rate of fire.

10 NOVEMBER. Burst fired aluminum breech. Rate of fire approximately 3,480 shots per minute.

7 DECEMBER. One set of design drawings sent to Frankford Arsenal.

30 DECEMBER. Re2 memo to Re. Referred to Mk 11 gun, delivery of guns and development of ammunition.

1950.

JANUARY. Rough machining and heat treating of remaining 5 of original 6 hand forgings.

JANUARY. Ordered 10 Alcoa hand forgings for 5 prototypes and 5 spares.

JANUARY. Requested machining of 5 of 10 Alcoa hand forgings.

8 FEBRUARY. Four Mann barrels for Mk 11 ammunition development sent Frankford Arsenal.

MARCH. Machining of second-hand forging of first six.

1 MARCH. Task Assignment NPG-18-Re8a-113-1 allotted \$15,000 to be completed 30 June 1950 for test of Mk 11 gun.

JULY. Initiated procurement of four 30-mm Alcoa hand forgings.

AUGUST. Initiated procurement of 30 universal die forgings.

2 AUGUST. BuOrd letter to OCO forwarding of EX 2 and EX 3 projectiles for study in connection with Mk 11 gun.

4 AUGUST. Pamphlets on Mk 11 gun sent to Frankford Arsenal and Remington Arms.

OCTOBER. Rough machining of four final machining of two 30-mm Alcoa hand forgings.

30 NOVEMBER. HAC Contract Amendment No. 5 added Task 4, Mk 11 gun.

1951.

FEBRUARY. Requested complete machining of all four 30-mm breeches.

FEBRUARY. Initiated procurement of three titanium forgings.

FEBRUARY. Requested machining of 4 additional of 10 Alcoa forgings.

17 FEBRUARY. BuOrd letter to OCO. Request for ammunition for Mk 11 gun.

28 FEBRUARY. BuOrd letter to OCO. Modification of letter on Mk 11 ammunition dated 17 February 1951.

29 NOVEMBER. First assembled Mk 11 gun delivered to Hughes Aircraft Co. Representatives of NGF and BuOrd present.

30 NOVEMBER. Fired first round from gun. Difficulties encountered. Gun disassembled at Hughes Aircraft Co.

4 DECEMBER. Fired first proof rounds in gun at Hughes Aircraft Co.

6 DECEMBER. Fired first burst of 1 revolver full (8 rounds) successfully at Hughes Aircraft Co.

1952.

11 MARCH. United Shoe Machinery Corp. amendment No. 5 added task 4—30-mm Mk 1 gun (Mk 11 principle).



22 APRIL. Second aluminum breech failed at Hughes Aircraft Co. This was the first-hand forged 75ST aluminum breech to fail.

14 MAY. Third breech failed at Hughes Aircraft Co.

18 JUNE. Fourth aluminum breech failed at United Shoe Machinery Corp.

1953.

29-30 JANUARY. First coordinated meeting on 20-mm gun Mk 11 and 30-mm gun Mk 1 between all agencies involved in program.

30 APRIL. Mk 11 gun with nonrelinking feed delivered to Naval Proving Ground, Dahlgren, for burst firing from belt.

4 MAY. First attempt to load live round by primer projection from belt and fire gun in automatic fire. Two 3-round belts used. Two rounds fired.

5 MAY. Two 5-round belts loaded (10 rounds total); 2 rounds fired.

6 MAY. Two 5-round belts loaded (10 rounds total). Gun fired out 10-round burst, rounds loaded and cases ejected satisfactorily. Rate 2,667 rounds per minute.

13 MAY. Two 8-round belts loaded (16 rounds total). Gun fired out 16-round burst. The burst length was restricted to 16 rounds because that was the total quantity of projectors available for use.

## SECTION 2. DEVELOPMENT OF 20-MM GUN MECHANISM MARK 11 MOD 0.

### Gun Theory

To arrive at a compact high-firing-rate gun mechanism that would be complete within itself so that no accessories would be required other than an electrical firing control, the following items were considered necessary:

1. Use made of all available gun recoil energy to increase the firing rate.

2. A high ratio of recoiling weight to total gun weight to reduce the reaction loads.

3. Weight reduced by use of high-strength aluminum alloys.

4. The gun to contain an integral charging system containing its own operating energy.

5. All parts to be tied together mechanically to eliminate the phasing difficulties associated with high-firing rates.

6. No large quantities of highly concentrated propellant gas to be released rearward if the gun is to be used in an enclosed turret or gun compartment. (Recoil operation in place of gas operation must be used.)

### Machine Mechanism

Because of the large losses in energy in standard reciprocating guns as a result of metal-to-metal pounding of parts, all initial effort was placed on arriving at a machine type mechanism having intermittent revolving motion to accomplish the task of feeding the cartridges and ejecting the expended cases which was devoid of impact blows.

Various types of mechanism were investigated.

1. Propellant gas driven; multiple piston versus single piston and cam.

2. Recoil operated:

(a) Short recoil (this stopped most designs).

(b) All early methods of multiplying recoil motion became cumbersome.

(c) Multiplied motion with cam reciprocating and rollers on cylinder.

(d) Multiplied motion by use of a linkage with the rollers reciprocating (the most satisfactory).

The system to control recoil motion and belt feeding by use of cams on the rotating cylinder and rollers in an external guide was chosen because it gave the lowest reciprocating mass and the simplest parts construction.

### Use of Gun Energy

Rather than use an energy absorbing mechanism and throw the recoil energy away as heat, a two-barrel design was developed that would put the energy to work in reducing trunnion reactions.

The idea was to allow the gun to freely recoil for a sufficient period of time while the pressure in the barrels dropped to a safe value before the chamber was rotated away from the barrels. The method chosen was to convert recoil energy to rotating energy by revolving the cylinder and stopping the gun recoil; then to use the spinning cylinder to drive the gun back toward the battery position.

## Maximum Rate

Computation showed that the gun rate varied as a function of recoil distance, mass of the recoiling parts, and inertia of the revolving cylinder.

Actually, rate was restricted by lack of time to load rounds and eject fired cases.

Design rates of fire were calculated to be 4,500 to 5,000 rounds per minute using an aluminum breech. Actual rates of fire have run between 2,800 (for a steel breech) and 3,500 rounds per minute (for an aluminum breech). Firings at the Hughes Aircraft Co. gave rates of 4,400 rounds per minute using top barrel boosting. Test data showed that rates well in excess of 4,400 could be attained.

## Light Weight

Light weight was accomplished by use of aluminum at all points possible, such as in the breech (the structural member holding the barrels and rotating cylinder).

The basic idea for the use of aluminum in large gun components began with the need for guns of less weight. Since steel could always be used with increased weight if the aluminum failed to meet the load requirements, it was decided that aluminum should be used in the initial development to prove or disprove its effective use.

The first firing of the gun was done with a 14ST aluminum breech and resulted in a breakage of the breech. It was known prior to the firing that the properties of the breech as manufactured were very poor, but it was believed that much information could be derived from the test even if fracture did occur.

At this point, a steel breech to the same dimensions was ordered so that additional firing could be conducted until new 75ST aluminum forgings, which were on order, were delivered and machined.

The first forged 75ST aluminum breech fractured during firing on 22 April 1952 at the Hughes Aircraft Co. The second forged aluminum breech broke 14 May 1952, and the third 18 June 1952.

During this period, investigations were conducted to determine the reason for the short life and the cause of these breakages. Preliminary evidence revealed extremely high internal stresses in the material. This was verified by metallurgical tests

conducted on high-strength 75ST aluminum. To eliminate the results of the high internal stresses, and the short fatigue life, breeches from other aluminum alloys were manufactured. Also breeches of lightened steel design were under development.

The aluminum breech which failed 18 June 1952, at the United Shoe Machinery Corp. was replaced with one manufactured from titanium at the Naval Gun Factory. United Shoe Machinery Corp. began cycling the gun on 30 June 1952 using SAE No. 90 high-pressure lubricant, but the test was discontinued due to galling between slider and breech. Colloidal graphite and molybdenum disulphide were tried but seizing of parts caused stoppage. During July, the slider which carries the rollers was flash chrome plated and the gun was lubricated with "Liqui-Moly Grease". The gun was cycled a total of 172 times on 17 July. The gun first failed to return to battery on the thirty-fifth cycle with a charger pressure of 1,350 p. s. i. The gun was "freed up" and relubricated with "Liqui-Moly", but seizing became progressively worse so that after 172 cycles testing was discontinued. The slider was rechrome plated with no improvement in operation. On 21 July, the work on the titanium breech was discontinued until some lubricant or surface finish could be found to alleviate the galling.

## Impulse System of Operation

In order to eliminate the energy losses from metal-to-metal pounding inherent in most reciprocating mechanism, the gun was designed to fire out of battery after the first cycle. The reciprocating parts were free floating during a burst. The top barrel chamber is fired to start the gun in motion. Near the end of this first cycle, both barrels are fired simultaneously to return the gun in recoil before it reaches the in-battery position. This system continues until it is desired to stop the gun. The gun is stopped by firing the bottom barrel chamber. This leaves the unfired top barrel chamber in a position to start the next burst without charging.

## New Principle of Ramming Rounds

In order to move a round from a belt into a chamber and maintain a very high rate of fire, a completely new method of moving the rounds into the chamber was investigated. Marquardt believed

that an electric primer of the type that was being developed for the Army could be used to blow a round from a closed end tube into the gun chamber. These primers had been designed exclusively to ignite propellant in a cartridge in a manner similar to percussion primers.

A special test fixture was assembled from the chamber end of an M3 20-mm gun barrel and a closed end tube held in line with the barrel section by a bracket member. The first tube was closed at one end by the base end of a cartridge case soldered into place. This allowed an electric primer to be inserted into the tube. The first test using this method was conducted during March 1946.

Demonstrations were given during the spring of 1947 to describe the principle involved.

During the early fall of 1947, the Naval Gun Factory carried on the projection investigation and observed the difficulties of overcrush.

In September 1948, predetonations occurred. Predetonations are the condition where the primer in the projector or ramming tube causes the primer in the cartridge to detonate. In the case of a live cartridge, an explosion could have occurred.

In a letter dated 24 November 1948 the Chief of Ordnance authorized Frankford Arsenal to determine the possibility of premature ignition of the round during projection and authorized the development of a primer to eliminate this condition if possible. During December 1948, a projection test mechanism was sent to Frankford Arsenal from the Naval Gun Factory for ammunition development.

Tests using blast deflectors in the projectors were conducted during the spring of 1949 but were inconclusive with respect to elimination of predetonations because of the limited amount of testing.

During the summer of 1951, rounds were loaded into the revolver chamber during charging and this proved a completely feasible principle. In this test, the incased rounds were strapped to the sprocket of the feed.

Early in 1952, the first M52A3 electric primers were received at the Naval Gun Factory, and a new series of projection tests were begun. In this series of tests using no protective shield, predetonations occurred and also there were failures to fire

the primer of the rammed round due to metallic particles being blown onto the base of the round and shorting out the primer buttons.

### Ammunition and Chamber Designs

The first ammunition to be used in the development was the standard 20-mm M90 series service rounds. Considerable difficulty was encountered in overcrushing the case during ramming. Rounds of ammunition were being rammed into a chamber at velocities of 80 to 100 feet per second. The chamber from the 20-mm automatic gun M3 was used in the first tests. It was found, after a small number of tests, that the rounds were going into the chamber till the case itself was being engraved by the rifling. When the rifling was eliminated, the projectiles had nothing to stop against and would completely debullet from the case.

To assist in overcoming this situation and to get a round that gave a higher muzzle velocity, the ammunition was changed to the 0.60/20-mm round being developed by the Department of the Army. This round gave much better performance in holding the headspace to a more reasonable value but was not completely satisfactory, because debulleting was still experienced.

In a further attempt to hold the headspace to an allowable value, a special rotating band was developed which had a forward flange of a larger diameter than the main body of the band. Ramming tests of these rounds gave headspace values that were much more consistent and prevented debulleting.

After this initial period development began on another series of rounds for the 20-mm aircraft gun Mk 12. When it was known that this series of ammunition would be mass produced and issued to the fleet, a decision was reached to start investigating the use of this ammunition in the Mk 11 gun. If it could be used, it would eliminate a special series of ammunition for fleet use.

The initial studies using the T130 20-mm round were conducted at Hughes Aircraft Co. under Bureau of Ordnance contract NOrd 10496. A special chamber was designed which reshaped the case in a different manner and to a greater extent than in previous designs.

## SECTION 3. DESCRIPTION OF 20-MM GUN MECHANISM MARK 11 MOD 0

## General Description

This weapon is intended for both air-to-ground and air-to-air combat. Each installation comprises 20-mm gun mechanism Mk 11 Mod 0, 20-mm gun

barrel Mk 9 Mod 0, and 20-mm gun barrel Mk 10 Mod 0. The gun mechanism consists of the following components: receiver assembly, pneumatic tank assembly, breech assembly, sprocket assembly, and cylinder.

## General Data: 20-mm Gun Mechanism Mk 11 Mod 0

## Gun length:

With Mk 9 barrel, overall: 52 inches.

With Mk 10 barrel, overall: 70 inches.

## Gun weight:

With Mk 9 barrel (short): 162 pounds.

With Mk 10 barrel (long): 170 pounds.

Rate of fire: Variable by electrical control of 2-round bursts. 5,100 rounds/minute, maximum (instantaneous starting and stopping).

## Muzzle velocity:

Mk 9 barrel: 3,100 feet/second.

Mk 10 barrel: 3,300 feet/second.

Chamber pressure: 53,000 p. s. i.

System of operation: Recoil.

System of locking: Revolver principle.

System of feeding (integral self-fed): Sprocket.

Method of loading: Explosive projecting.

Method of headspace: "Belted" ammunition, stationary anvil.

Location of feed opening: Left and right rear of receiver; 2 belts.

Location of ejection opening: Right and left side of receiver; 2 openings.

Method of charging: Integral solenoid operated air valve and air pistons (2, left and right).

Method of cooling: CO<sub>2</sub> and liquid coolant.

## Projectile travel:

Mk 9 barrel: 37.645 inches (47.83 calibers).

Mk 10 barrel: 55.645 inches (70.71 calibers).

Recoiling weight: 120 pounds.

Recoiling distance: 1.01 inches.

Distance between barrels: 4.125 inches.

Weight of cylinder: 49.57 pounds.

Mass movement of inertia of cylinder: .0675 slug ft.<sup>2</sup>

Cylinder diameter: 7 inches.

Cylinder length: 7.094 inches.

Number of holes in cylinder: 8.

## Velocity of belt:

Average: 5.59 feet/second.

Maximum: 11.18 feet/second.

Projection velocity ammunition: 80-90 feet/second.

Ignition system: Electric (250 V condenser discharge).

Velocity of recoil (40 percent energy loss): 10.2 feet/second, maximum.

Velocity of counterrecoil (40 percent energy loss): 8 feet/second, maximum.

## Barrel length, effective:

Mk 9 barrel: 41.25 inches.

Mk 10 barrel: 59.25 inches.

## Weight of barrels:

Mk 9: 41.4 pounds (both barrels).

Mk 10: 57.4 pounds (both barrels).

Rate control: Electric rheostat.

Barrel removal: Quick disconnect.

## Removable barrel length:

Mk 9 barrel: 33.906 inches.

Mk 10 barrel: 51.906 inches.

## Bore:

Number of grooves: 9.

Groove depth: 0.015 inch.

Groove width: 0.205 inch.

Land width: 0.068 inch.

Pitch of rounds in belt: 1.579 inches.

Direction of twist: Right hand.

Form of twist: Progressive; 0 degrees to 7 degrees.

## Recoil force (250,000 pounds/inch mount):

Average: 3,500 pounds.

Peak: 6,700 pounds.

Rotational torque: 7,500 inch-pounds.

Complete round weight, aluminum case: 0.40 pound.

Projectile weight: 1,700 grains.

Propellant weight: 640 grains.

Cartridge case weight, aluminum: 655 grains.

Length of case: 4.340 inches.

Diameter of base of case: 1.165 inches.

Weight of projector and link: 0.125 pound.

Length of round: 7.22 inches, maximum.

Weight of round: 3,000 grams (.429 pound).

The weapon is a revolver type automatic gun equipped with two barrels firing simultaneously. It is served by two belts of ammunition which enter the mechanism from opposite sides, and feeding is accomplished by the sprocket assembly which operates within the mechanism. The ammunition is carried to the weapon in projectors which are linked together and from which the rounds are launched into the chambers by means of an electric primer. The projectors remain belted and continue through the mechanism, receiving the empty cases prior to emerging from the opposite side. Case ejection is accomplished by pneumatic power. Firing of both the projectors and ammunition is electrical.

*Assembled Arrangement.* The pneumatic tank, one of the nonreciprocating elements of the gun mechanism, houses the gun chargers, the ejection and coolant valve assemblies, and the hold forward valve and gun switch assembly. The tank is provided with pads for mounting the gun mechanism and is secured to the receiver by two lock pins. The receiver is the nonreciprocating element which supports and guides the reciprocating breech assembly, supports the aft end of the sprocket assembly, and houses the entire gun mechanism. The sprocket assembly extends from the aft end of the receiver, to which it is attached, into the breech. The cylinder is supported by the sprocket assembly shaft within the breech and, therefore, reciprocates on the sprocket assembly shaft together with the breech.

*Cooling.* The firing chambers are cooled by the passage of carbon dioxide through the chamber hole after the cartridge case is ejected. Since there are 8 holes in the revolving chamber, 2 rounds are fired,

2 cartridge cases are ejected, 2 live rounds are loaded, and 2 chamber holes are cooled, all at the same time. There are two shutoff valves that are controlled by the recoil of the gun in such a manner that the flow of carbon dioxide is shut off when the gun is at rest in battery, but resumes when the gun moves out of battery. Since the gun is only in battery for a short time during a burst, and since the carbon dioxide contained in the tube between the slide valve and the open chamber acts as an intermediate reservoir, a continuous flow of carbon dioxide will result during a burst. The chambers are cooled to prevent "cook-offs" at the end of a sustained burst because the gun stops firing with a live round in the chamber aligned with the top barrel and 2 live rounds in the holes adjacent to the 2 barrels. No cooling is necessary to prevent "cook-offs" if less than 800 rounds are fired per gun, however, cooling the chambers will greatly increase the life of the obturating sleeves. The gun barrels are not cooled by any means other than normal air flow over the barrels since the hottest portion of the bullet travel is contained in the revolving chamber which is cooled by means of carbon dioxide.

*Energy Balance.* The energy imparted to the recoiling mass from the firing of 1 round is approximately 158 foot-pounds, and the energy imparted to the recoiling mass from the firing of 2 rounds is approximately 316 foot-pounds. The energy taken from the gun consists of friction and the energy required for feeding. If there were no energy taken from the gun by friction and feeding, the cyclic rate would depend upon the time it takes to decelerate and accelerate the recoiling mass with a total energy

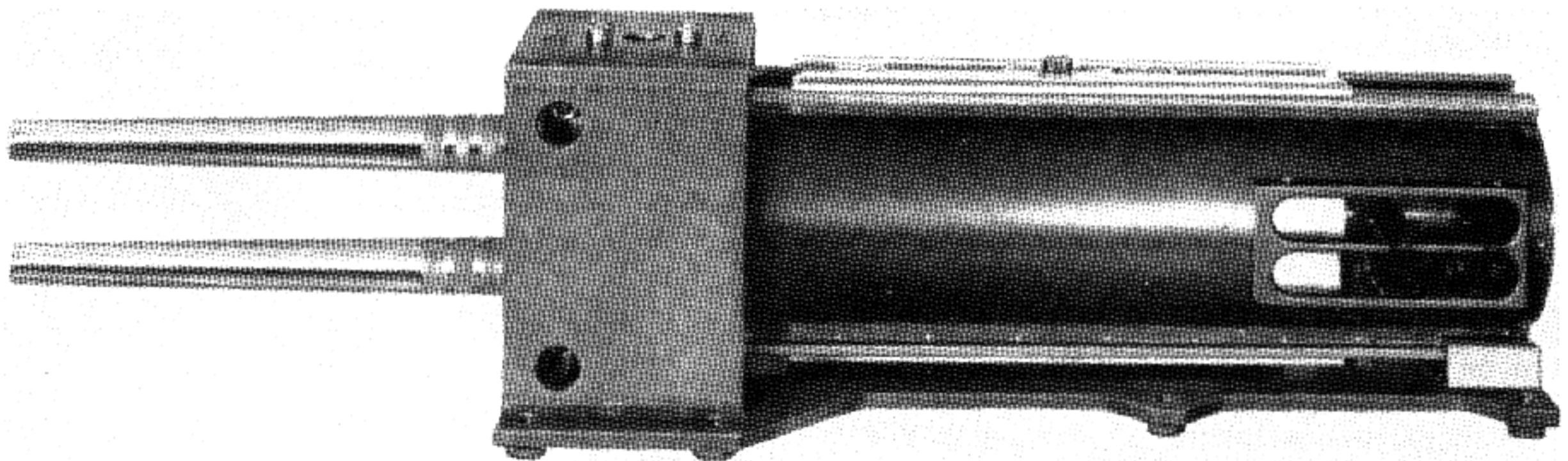


Figure 6-2. 20-mm Machine Gun Mk 11 Mod 0 mounted in test stand.

content of 158 foot-pounds by means of the cams cut on the outside of the firing chamber. Computations show that the gun would have a cyclic rate of 5,100 rounds per minute under these conditions. In order to obtain a more accurate analysis of the cyclic rate, it was assumed that the energy taken from the gun by friction and feeding was proportional to the remaining energy. The cyclic rate was computed with a 75 percent and 50 percent return of energy, and it was found that the cyclic rate remained at 5,100 rounds per minute and was not dependent upon the efficiency of the mechanism or the belt pull. This phenomenon is possible because the energy in the system creates its own balance after approximately seven cycles of operation. The figures for a 50 percent return of energy are as follows:

Cycle No.	Energy at start (ft. lb.)	Energy at end (ft. lb.)	Number of rounds fired
1.....	158	79	1
2.....	237	118	2
3.....	198	99	2
4.....	217	109	2
5.....	207	104	2
6.....	212	106	2
7.....	210	105	2
8.....	211	105	2

It will be noted that the odd cycles are slow cycles while the even cycles are fast cycles, but the difference diminishes very rapidly so that a constant cyclic time is reached in approximately seven cycles. The summation of the fast and slow cycles gives an overall cyclic rate of 5,100 rounds per minute. The energy taken out of the recoil stroke by the hold forward is returned on the counterrecoil stroke. The hold forward prevents any automatic operation through the cams with the energy that is left over at the end of a burst.

*Reversibility.* The gun is designed so that by interchanging cylinders with roller lifting cams cut on the left or right hand end of the operating cams, rotation in a clockwise or counterclockwise direction is obtainable. To change from rotation in one direction to rotation in the opposite direction, the gun is partially disassembled, the ejection and cooling

tubes interchanged, the projector firing contacts re-located, and an opposite hand firing chamber assembled into the gun. This reversibility gives two feeding arrangements for the gun so that a better arrangement of ammunition chuting is obtainable for multiple gun installations. The ammunition is fed into the top of the left-hand side and the bottom of the right-hand side when clockwise rotation is used and is fed into the bottom of the left-hand side and the top of the right-hand side when counterclockwise rotation is used. Directions are from back of gun looking forward.

*Obturation.* The breech is of the revolver closing type, where the cartridge case forms a gas seal at the after end of the firing chamber and an obturating sleeve in the forward portion of the firing chamber forms a seal with the after end of the barrel.

*Trunnion Reactions.* The gun has its own recoil mechanism to reduce trunnion reactions. The recoiling mass is gradually stopped in the rearward direction by the cam action of the rollers and is rapidly stopped in the forward direction by the impulse of the fired projectiles or is gradually stopped in the forward direction by the pneumatic buffers. The stopping and returning of the recoil mass by the impulse from the fired projectiles causes a recoil reaction on the mount because the cam follower assembly mass has its direction changed by the operating levers that are pivoted at the center of the gun. This reaction has a peak value of approximately 2,200 pounds. The maximum recoil force occurs at the end of the recoil stroke and is approximately 6,700 pounds. There is no counterrecoil force unless two duds occur simultaneously, at which time the counterrecoil force becomes approximately 4,500 pounds. The charger also causes a counterrecoil force of approximately 4,000 pounds. In addition to the recoil and counterrecoil forces, a rotational torque of approximately 7,500 inch-pounds is created at the start of rotation of the chamber. This torque is zero when the maximum recoil force occurs at the end of recoil and is approximately 6,000 inch-pounds in the opposite direction when the rotation of the chamber is stopped near the end of a cycle. The recoil force, due to the firing of the electric primers in the projectors, occurs when the recoil force due to the cam action of the rollers is small so that the maximum value of 6,700 pounds is not exceeded.

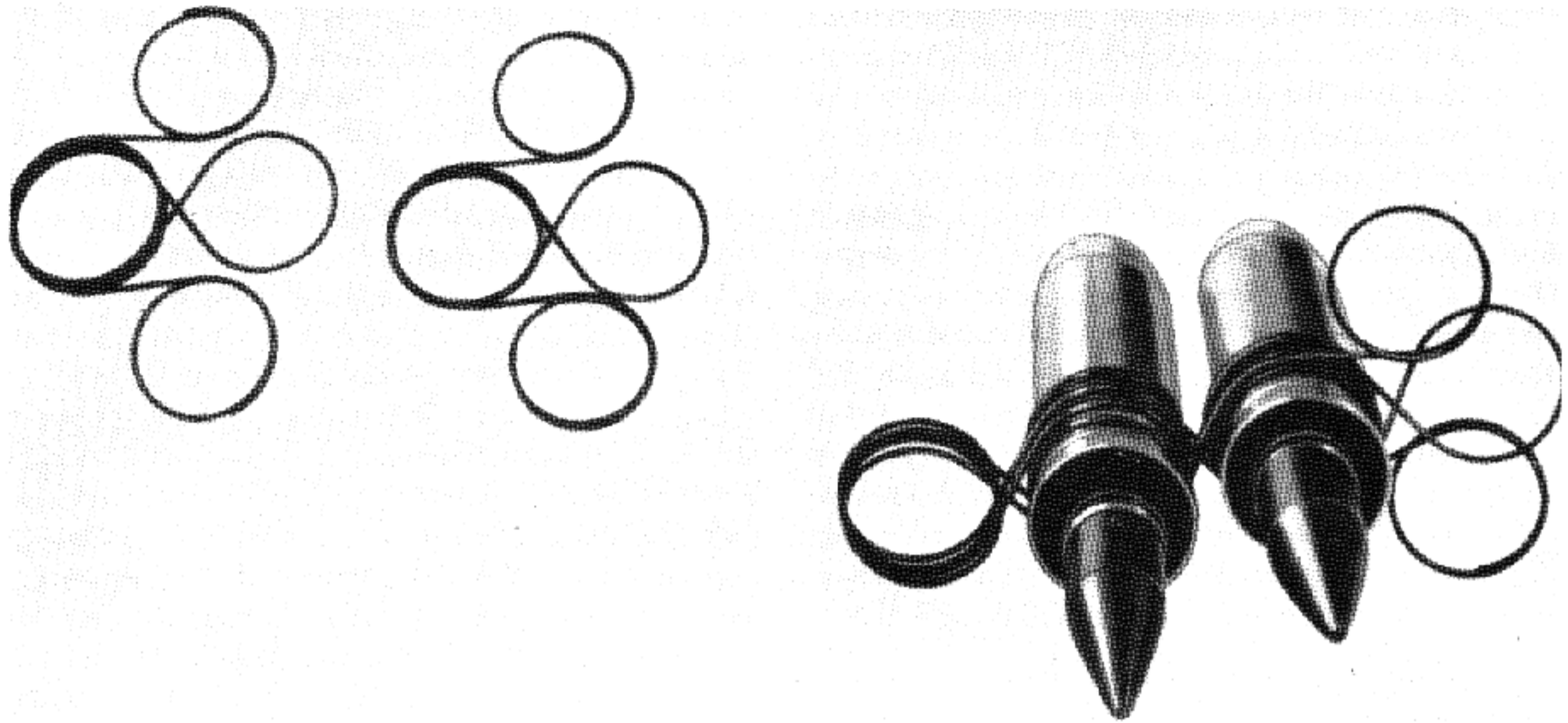


Figure 6-3. Ammunition and links for the 20-mm Machine Gun Mk 11 Mod 0. Front view.

*Mounting.* The pneumatic tank is equipped with two diametrically opposite mounting pads that serve as the main support for absorbing the trunnion reactions. The after end of the receiver is equipped with two diametrically opposite T-slots to support the gun and still allow the receiver to be

moved aft for loading and clearing ammunition jams.

*Links.* The links are of a self-locking wire type to obtain flexibility in all directions and to obtain maximum strength with a minimum weight. Any link of a closed-loop type can be used since the projectors carrying the ammunition are never separated from the link. The projectors can be manufactured with a self-connection so that no separate linking arrangement is needed; however, this method is more costly to produce and has no particular advantage. The wire type link used has a stretch of one-eighth inch per link with a 100-pound load so that the belt acts as a spring, thus allowing the gun to have a pulsating feed motion while the conveyor system is operating at constant velocity.

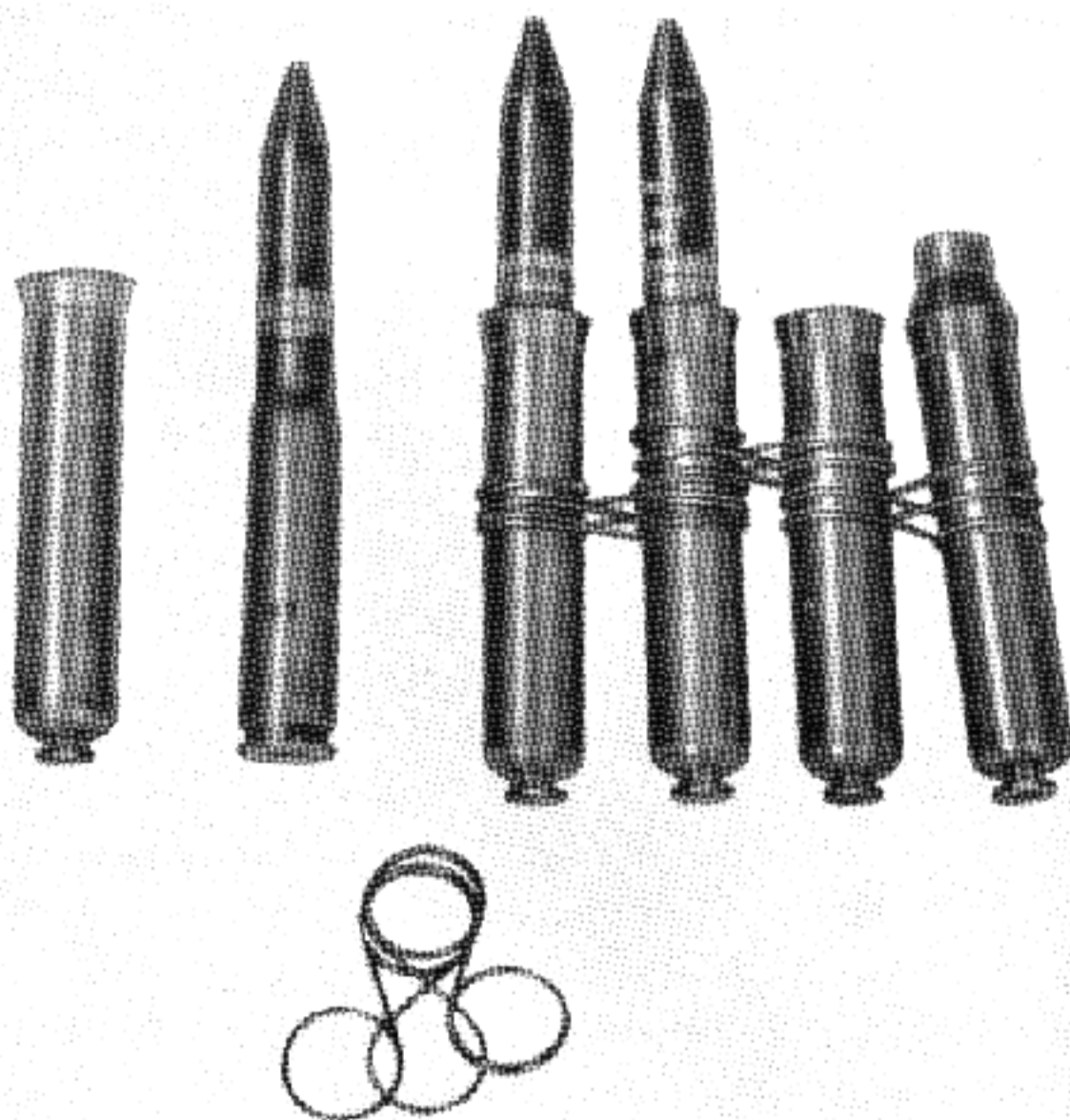


Figure 6-4. Ammunition and links for 20-mm Machine Gun Mk 11 Mod 0. Side view.

### Description of Components

*Barrels.* The gun barrels are quickly detached by raising a spring-loaded detent and rotating the barrel through one-sixth of a revolution. The rifling of the barrels is machined to engrave the rotating band with straight rifling and then progressively increase the twist so that a constant angular acceleration is applied to the projectile for the full length of the barrel.

*Pneumatic Tank.* The pneumatic tank acts primarily as a reservoir for the pneumatic ejection,

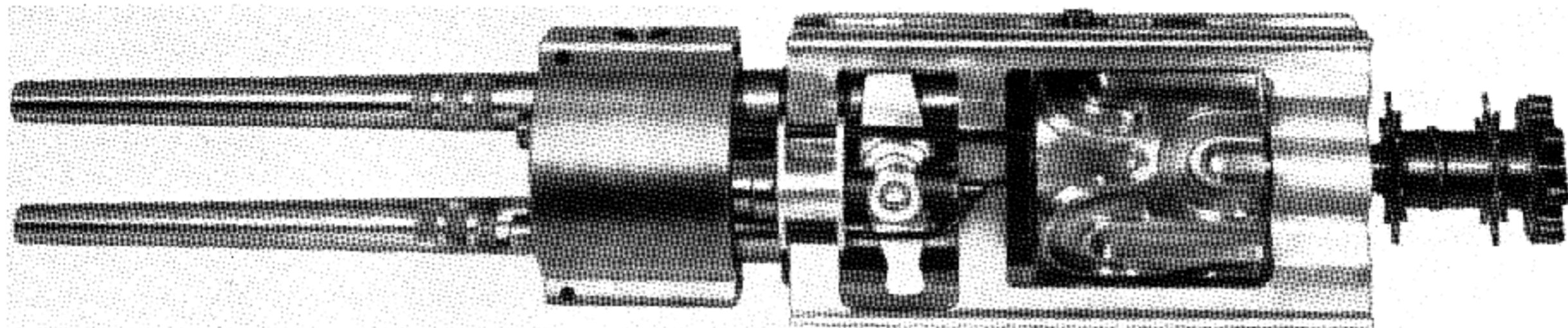


Figure 6-5. 20-mm Machine Gun Mk 11 Mod 0. Side view with receiver removed.

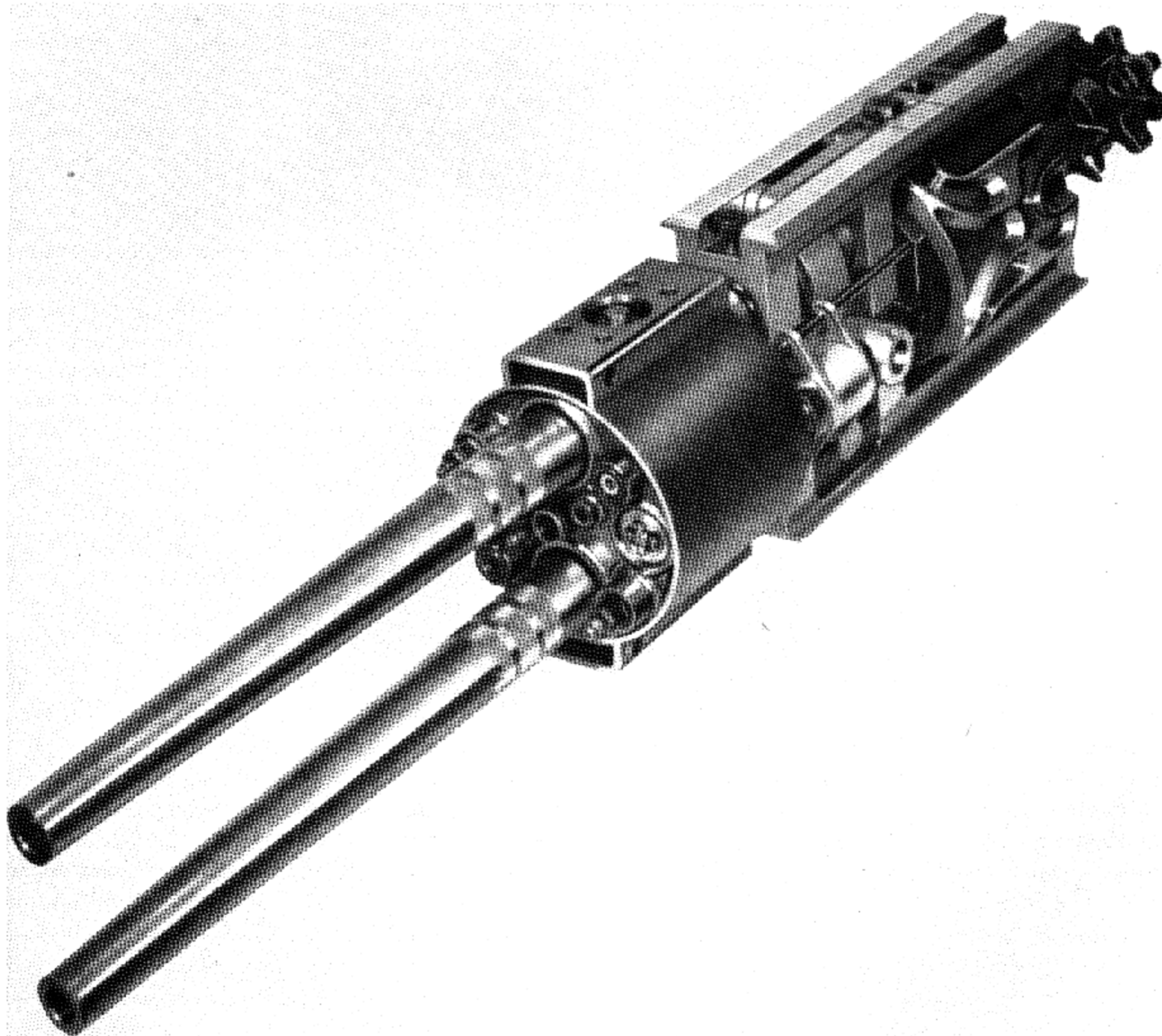


Figure 6-6. 20-mm Machine Gun Mk 11 Mod 0. Three-quarter front view with receiver removed.



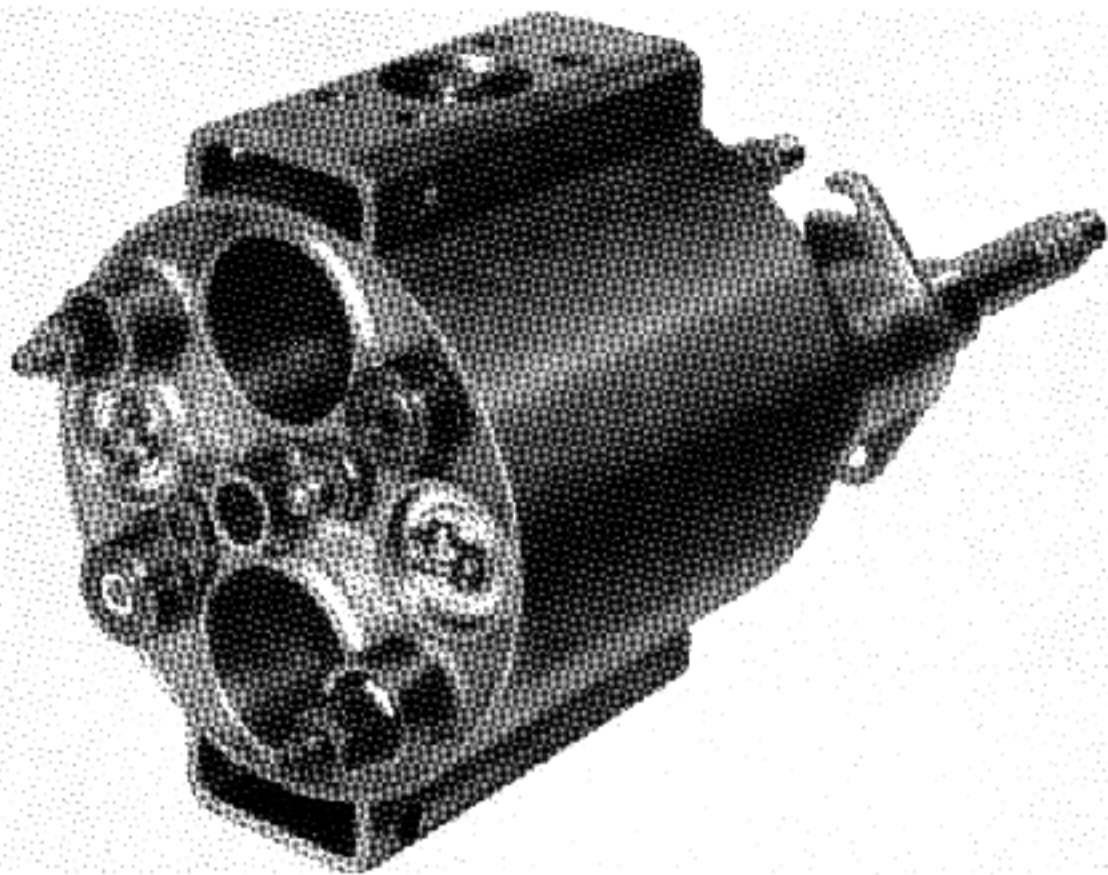


Figure 6-7. Pneumatic tank of 20-mm Machine Gun Mk 11 Mod 0.

charging, buffing, and hold forward. There are two arrangements for supplying pneumatic pressure to this tank. The front of the tank contains a connection for a pneumatic hose if an external supply of air is available. The tank also contains check valves so that gas pressure in the barrels, being of a higher pressure than the tank pressure, will flow into the tank, thus replenishing the pneumatic air used for charging and for ejecting empty cases and duds. When the barrel gas pressure is used to replenish the tank pressure, a relief valve must be connected to the pneumatic hose connection on the front of the tank to prevent too large a buildup of pressure in the tank.

*Hold Forward.* The gun is equipped with a pneumatic piston to keep the gun mechanism from moving aft of the in-battery position under a force equivalent to  $2\frac{1}{2}$  g's. The buffer pistons keep the gun from moving forward of the in-battery position under a force equivalent to 37 g's. Side g's do not affect the in-battery position.

*Return Mechanism.* The recoil distance of the gun is 1.0125 inches and is controlled mechanically by means of two levers that are pivoted about a shaft through the center of the gun. One end of the links is connected to the recoiling mass, and the other end is connected to a tie bar that drives the cam follower assembly. By pivoting the links at the center of the gun, the cam follower assembly is pulled forward as the recoiling mass moves aft, thus increasing the motion between the cam follower assembly and the chamber. The firing chamber has a

series of 8 elliptical cams cut on its exterior in such a manner that the 4 forward cams start in the same plane as that in which the 4 after cams end. At the end of each cam, there is a sloped surface that raises the driving roller out of its cam track at the end of a cycle. The cam follower assembly contains two rollers that are connected together by means of a lever so that as the driving roller is raised out of its cam track, it lowers the other roller into its cam track, thus changing the drive at the end of each cycle with the result that the chamber is always rotated in the same direction. The principle of operation is to transfer the recoil energy of the reciprocating mass into rotational energy of the firing chamber and then to transfer the rotational energy of the chamber into a counterrecoil energy of the reciprocating mass. When this is done, the chamber is indexed through  $45^\circ$  of rotation, while the recoiling mass is decelerated aft and then accelerated forward.

*Charger.* There are two chargers built into the gun. Their pneumatic power source is taken from the pneumatic tank that is also a part of the gun. The solenoid-operated valves are of a quick-opening type being manually operated. The solenoid raises an inner needle valve that creates a differential pressure with the result that the large plunger is raised off of the main seat by the high-pressure air in the pressure tank, thus obtaining quick opening with a small amount of electrical energy. The end of the charger shaft is equipped with a leakage valve that is open at low pressures and closed at high pressures. The purpose of the leakage valve is to prevent any air that may escape from the pressure tank from accumulating in the charger and moving the gun out of the in-battery position when not operating.

## Operation

*Loading.* The receiver is unlocked from the pneumatic tank as described in step 3 under Disassembly and moved rearward approximately 3 inches to disengage the sprocket assembly splines from the cylinder splines, thus permitting the sprocket assembly to be rotated independently of the gun mechanism. The ends of two belts of ammunition are now started into the mechanism and, with the first round of each belt resting in the sprockets, the sprocket assembly is rotated until the two rounds

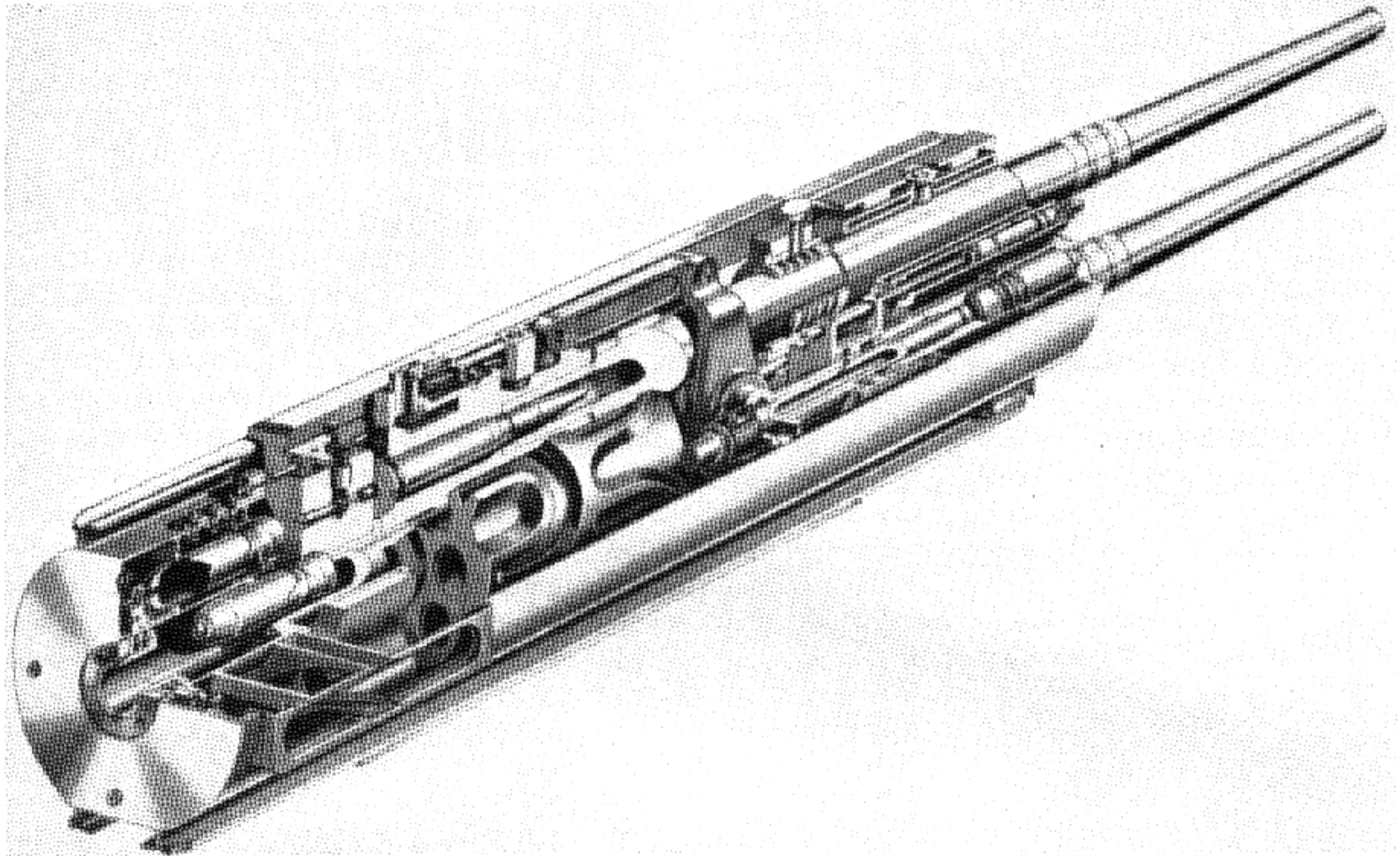


Figure 6-8. 20-mm Machine Gun Mk 11 Mod 0. Cutaway view.

are approximately  $45^\circ$  from alignment with the gun barrels. The receiver is now returned to its proper location and locked to the pneumatic tank. As the receiver is being returned, it may be necessary to turn the sprocket assembly slightly in alternate directions in order to engage the splines of the sprocket assembly shaft with those of the cylinder.

*Feeding.* The sprocket assembly is driven by means of a spline located in the center of the cylinder. The sprockets rotate with, but do not reciprocate with, the cylinder, being held from reciprocation by means of a double acting radial-thrust bearing fastened to the after end of the receiver. The linked projectors serve a dual purpose in that they are used to carry the fixed cartridge cases and duds away from the gun as well as to carry the ammunition to the gun.

*Projection.* The complete round of ammunition is contained in the projector, a thin walled tube with a closed end containing an electric primer. As the ammunition enters the gun, the primer comes in contact with a firing pin contained in the rear of the sprocket assembly. Approximately  $10^\circ$  be-

fore the sprocket reaches the at-rest position, the firing pin contacts the live wiper thus igniting the primer in the end of the projector. The pressure created by the ignition of the primer reacts on the base of the cartridge, forcing it out of the projector and into one of the eight chambered holes in the cylinder at a velocity of approximately 80 to 90 feet per second. The rotating band of the projectile has a flange on the forward end; as the cartridge enters the chamber this flange, being slightly larger than the tapered hole it enters, causes a drag force on the round, thus decelerating the round and coming to rest with the flange in contact with the obturating sleeve in the chamber. If the round stops before contacting the obturating sleeve, it is cammed into position mechanically by the breech face plate when the cylinder rotates into the firing position. This flange controls the headspace of the gun as well as assuring a tight seal when the projectile is fired through the smooth bore of the obturating sleeve.

*Ejection.* The fired cartridge case is blown from the firing chamber by means of a 1,500-pound-per-square-inch air supply contained in the pneumatic

tank located at the front of the receiver. Since the cartridge case is enlarged during firing, the increased diameter will cause a force fit in the projector. The friction caused by this force fit will dissipate the energy imparted to the ejected case and will also act to retain the case in the projector. A dud will be ejected in the same manner. The different weight of a fired case and a dud is compensated for by the different volumes the 1,500-p. s. i. air expands into. When a dud is to be ejected, only a small volume remains around the dud, thus higher pressures are created for ejection. When a fired cartridge case is to be ejected, the 1,500-p. s. i. air has a large volume to expand into, thus lower pressures are created for ejection. The pneumatic tank contains an automatic valving mechanism that is operated from the reciprocation of the recoiling parts. The recoil caused by the firing of the first round pulls the shutoff sleeve aft against the force of a return spring, thus exposing the 1,500-p. s. i. air supply to the slide valve cylinder. Since the slide valve piston is aft of the in-battery position when the shutoff valve is opened, no air will flow into the slide valve ejector tube until the gun returns in a counterrecoiling direction and uncovers the opening in the slide valve. At this time, the fired cartridge case is alined with the ejector tube opening and the flow of air from the pneumatic tank will blow the fired case out of the chamber and into the projector. The gun returns to battery faster than the spring can return the shutoff valve, so that the shutoff valve remains open, being carried back each cycle until the gun ceases firing in the in-battery position, at which time the shutoff valve creeps forward and shuts off the flow of air from the pneumatic tank. The adapter at the front of the cylinder has a sealing piston to reduce leakage of the ejecting air at this position.

*Firing.* When the gun is loaded by the method explained under Loading, closing the ready switch will energize the generator which, in turn, will energize the projector condensers and fire the first two projector primers, thus loading two rounds into the firing chambers. Closing of the ready switch will also energize the charger solenoid relay which will open the charger electric circuit. The gun switch is open when the gun is in battery. Closing the firing switch will energize the top barrel relay, thus closing the electrical circuit to the top barrel and

breaking the charger relay circuit. The charger relay has a delayed pullout of approximately 15 milliseconds, after which time the charger circuit is closed and the charger solenoids are energized. Energizing the charger solenoids opens the charger valves allowing the 1,500-p. s. i. air in the pneumatic tank to enter the pneumatic chargers which, in turn, pushes the recoiling parts aft. As the gun moves aft the gun switch is closed with the result that the bottom barrel relay is energized, thus closing the bottom barrel firing circuit and the circuit to the charger solenoid relay. When the charger solenoid relay is energized, it breaks the electrical circuit to the charger solenoids, thus allowing the charger solenoid valves to close and cutting off the supply of air to the charger pistons. At the end of the charger stroke, the air in the charger is exhausted to atmosphere. At this time, the energy imparted to the recoiling mass is converted into rotational energy of the cylinder which, in turn, drives the recoiling mass back into battery. The cylinder will have rotated through  $45^\circ$ , bringing the 2 formerly chambered rounds into alinement with the 2 barrels. As the gun enters the in-battery position, the two firing pin wiping contacts on the receiver will allow the condensers to discharge through the electric primers in the cartridge cases alined with the barrels. As the 2 rounds fire, the forward motion of the recoiling mass will be stopped and the recoiling mass sent aft with approximately the impulse of 1 round, since the chargers impart approximately the same energy to the recoiling mass as the firing of 1 round of ammunition. Each  $45^\circ$  of rotation of the cylinder causes 2 projectors to be fired with the result that 2 rounds are loaded into the firing chambers. The gun continues to fire two rounds each time the recoiling parts enter the in-battery position until the firing switch is opened. At this time the top barrel relay is released, breaking the firing circuit to the top barrel. The bottom barrel relay has a delay pull-out so that the bottom barrel firing circuit remains closed long enough for the gun to complete the cycle and fire the bottom barrel round, thus ending the burst with a live round in alinement with the top barrel, a fired cartridge case in alinement with the bottom barrel, and two live rounds loaded in the chamber holes adjacent to the top and bottom barrels. When the firing switch is closed again to fire the next burst, the top barrel relay closes the top

barrel firing circuit and the top barrel condenser discharges through the electric primer in the base of the round alined with the top barrel, thus firing the top barrel and starting the second burst. The shortest burst that can be fired is 2 rounds, 1 to start the burst and 1 to stop the burst. It is possible to fire these two-round bursts at any rate desired so that the overall rate of the gun can be controlled and the spacing between pairs of projectiles in flight can be controlled to obtain the most effective arrangement for hit probability. The control can be such that a low cyclic rate can be used to conserve ammunition until it is determined that the projectiles are hitting the target and then the control can be immediately switched over to maximum cyclic rate to destroy the target.

*One Dud.* When one round fails to fire during a burst, the round that did fire as the gun came into battery will stop the gun in the same manner a normal burst is stopped, by firing only the bottom barrel. The only difference is that the firing switch is still closed when the gun comes to rest. When the gun remains at rest with the gun switch closed, the bottom barrel relay will pull out, thus breaking the circuit to the charger solenoid relay, which will then close the electrical circuit to the charger solenoids and the gun will go through a charging cycle the same as described under Firing. As the gun returns to battery after this charging cycle, the two new rounds will be fired, and the dud and empty cartridge case, having rotated through  $45^\circ$ , will be ejected. The gun will then continue on a normal firing cycle. If the dud happened to occur in the bottom barrel after the firing switch was released to stop a burst, the forward motion of the gun would not be stopped by the firing of the bottom barrel and the live round in the top barrel would not be fired to stop the forward motion because its firing circuit is broken when the firing switch is released. In order to stop the forward motion of the gun under this condition, the 1,500-p. s. i. pneumatic tank is equipped with two pneumatic pistons that act as buffers for the counterrecoiling mass when it passes the in-battery position. The energy remaining in the counterrecoiling mass is stored in the pneumatic tank through these pistons, which return the energy to the mass by accelerating it in a recoiling direction.

As the gun returns to the in-battery position with the energy now in the recoiling direction, the drive linkage, through the rollers in the cam follower assembly and the cams cut on the outside of the cylinder, transfers the recoil energy into rotational energy of the cylinder. The cylinder, in turn, transfers the rotational energy into translation of the mass in a counterrecoiling direction. During this transfer of energy, the chamber is rotated through  $45^\circ$ , bringing two new rounds into alinement with the barrels and, as the gun enters the in-battery position again, the round alined with the lower barrel will be fired, thus stopping the gun.

### Malfunctions

*Two Duds.* When duds are encountered simultaneously in the top and bottom barrels, the same condition prevails as when a dud occurred in the bottom barrel after the firing switch was released. (See One Dud, under Operation.) The only difference is that the firing switch is closed, so that when the gun returns to the in-battery position after being buffed in the forward direction and indexed through the cams, the gun will continue to fire the burst. In this case, the two duds will be ejected and carried away from the gun by the linked projectors. If the firing switch is released when two duds occur, only the bottom barrel will fire when the gun returns to the in-battery position, thus stopping the gun with a live round in alinement with the top barrel and a fired cartridge case in alinement with the bottom barrel. The chargers only operate when one dud occurs during a burst and the firing switch remains closed.

*Projector Misfire.* The projectors contain an electric primer that is tested for shorts and resistance during manufacture to assure no greater probability of a misfire than one in a million. The only other factor that might cause a misfire would be a failure of the projector electrical firing circuit. If the firing circuit fails, the gun, as presently designed to minimize the overall length, will become inoperative. The gun can be made to continue firing one barrel in bursts of two rounds with a charging cycle in between bursts by lengthening the receiver so that a complete round of ammunition will pass in back of the breech. In order to obtain this feature, the overall length of the gun would have to be increased

approximately 3 inches. This would also increase the distance the rounds have to be projected and ejected, which is undesirable.

*Hangfires.* The cartridge case is ignited by means of an electric primer that is void of all the factors that cause a hangfire with percussion ignition. If, for some unknown reason, a hangfire should occur with the electric primer, the result would be that the round that did fire would stop the gun in battery, and as soon as the hangfire went off,

the gun would continue to fire the burst. At no time would the gun be unsafe because the breech would be locked and at rest in battery. If two hangfires occur simultaneously, they would fire while the gun is against the pneumatic buffers since the gun is against the buffers for a period of approximately 16 milliseconds while a hangfire only exists for a period of a few milliseconds. The gun would not be unsafe since the breech is locked while the gun is against the buffers.

#### SECTION 4. DISASSEMBLY

Prior to proceeding with the disassembly of the gun, it is necessary that the gun be located in the recoil position with the aft roller of the cam follower assembly in the down position engaging 1 of the 4 aft came grooves of the cylinder. The gun may be

moved manually from the battery to the recoil position by inserting a bar between the pneumatic tank and the breech. Using the bar as a lever, the breech is then moved away from the pneumatic tank until the roller of the cam follower assembly reaches

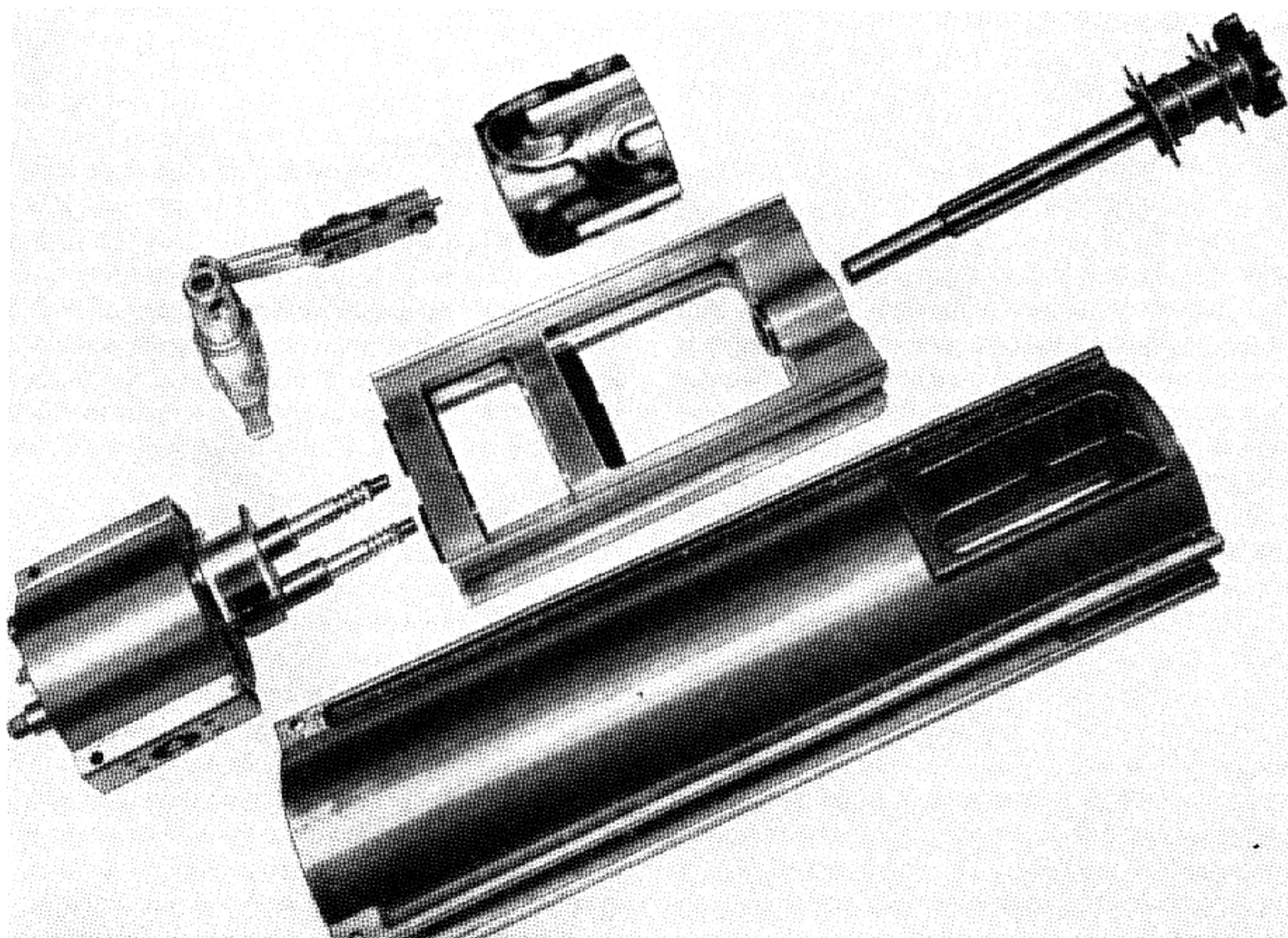


Figure 6-9. 20-mm Machine Gun Mk 11 Mod 0. Exploded view. (Barrels not shown.)

the center position on the cam groove curve. Moving the breech may become difficult when the roller moves in the curved portion of the groove, and it may be necessary to assist the rearward movement of the breech by tapping lightly on the rear face of the raised roller. If the forward roller is in the down position, the same procedure is followed with the exception that as the breech starts to move away from the pneumatic tank, the raised aft roller is tapped down into one of the aft cam grooves. It will be noted that as the breech is continued to be moved after the transfer of the rollers, the cylinder will rotate in the reverse direction to that of firing. This is due to the aft roller being lowered into the exit end of the cam groove.

The gun is now ready for disassembly as follows:

1. Remove the two barrels by pulling out on the barrel lock with one hand and removing the barrel with the other. After unlocking the barrel, it must be rotated slowly until it is disengaged from the barrel bushing.

2. Disconnect the electrical wiring between the receiver and pneumatic tank at the chargers and terminal joints.

3. Disconnect the receiver from the pneumatic tank by pulling out on the knobs of the two lockpins and rotating the lockpins 180°. With the re-



Figure 6-10. Revolving cylinder of 20-mm Machine Gun Mk 11 Mod 0.

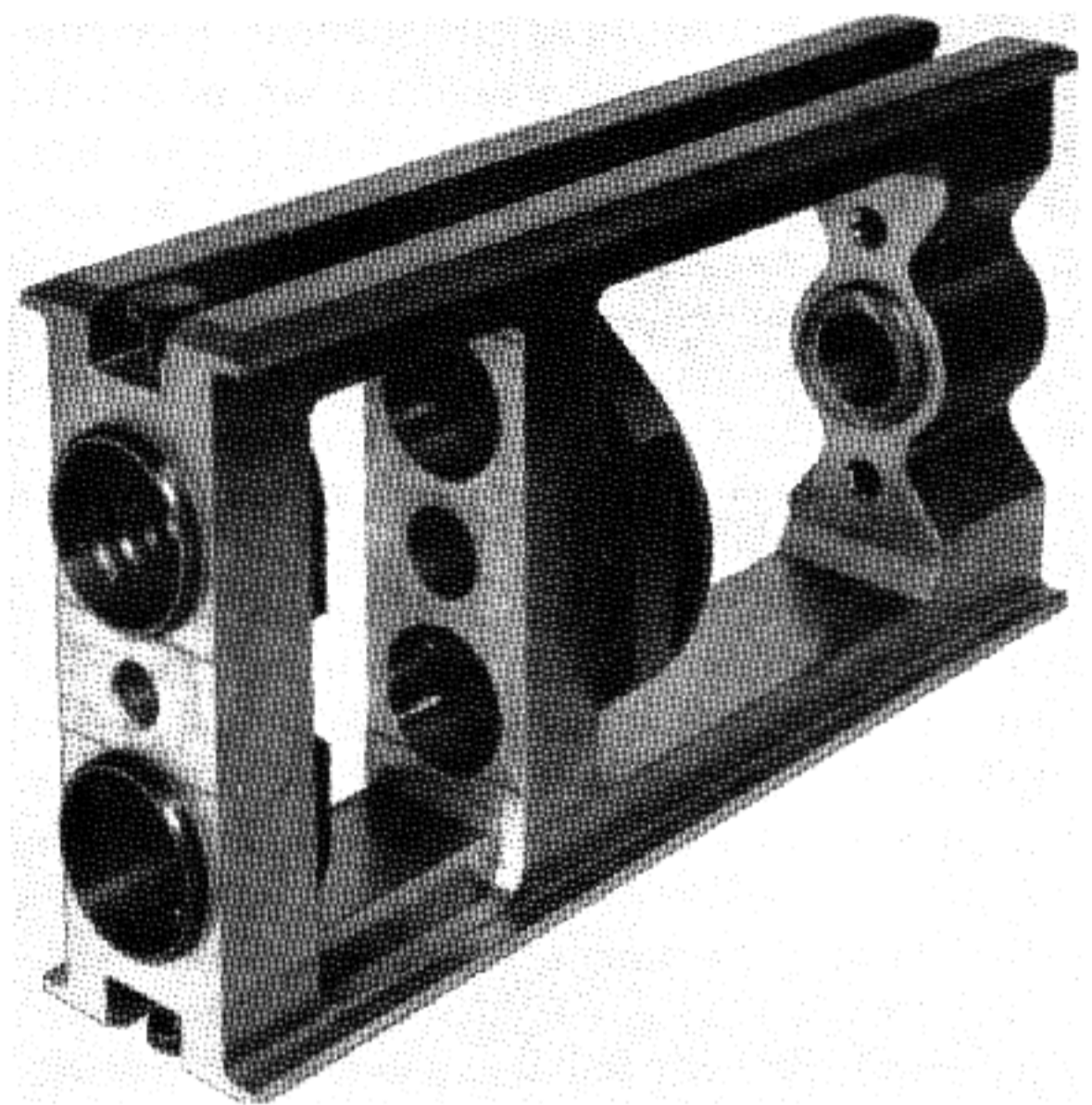


Figure 6-11. Breech of 20-mm Machine Gun Mk 11 Mod 0.

ceiver thus disconnected, it is moved rearward and removed from the mechanism together with the sprocket assembly and ammunition tracks. Removal of the sprocket assembly will leave the cylinder unsupported and it will therefore drop approximately 0.010 inch to the adjacent surface of the breech.

4. Lower the forward roller of the cam follower assembly into a space between two cam grooves. This space was brought directly under the roller when the gun was positioned prior to disassembly as outlined above. Place both hands on the cylinder, and remove the cylinder from the breech by rotating it with the upper hand while pushing the bottom of the cylinder out with the lower hand. This may be accomplished from either side. Exercise caution during this operation to prevent injury to the hand at the bottom of the cylinder as the cylinder leaves the support of the breech.

5. Move the breech toward the pneumatic tank (maintaining the cam follower assembly in the forward position) enough to permit removal of the spring clips and locking segment from the ends of the chargers, and remove the chargers by pushing them forward and out through the pneumatic tank.

6. Remove the yoke shaft and push the large end of the 2 sleeves into the 2 charging chambers.

With the sleeves and charging chambers thus positioned, move the breech away from the pneumatic tank until the sleeves and the charging chambers clear the two pneumatic tank extensions. Remove the sleeves and charging chambers from the breech by grasping the charging chambers and pulling outwards. The charging chambers also serve as retainers for the ejection and coolant tubes, therefore, the removal of the chambers permits the separation of the breech from the pneumatic tank.

7. After separating the breech and pneumatic tank, remove the yoke shoes and position the yokes. Remove the connecting link pin, yokes, and spacer block resting in the breech between the yokes where it dropped upon removal of the yoke shaft described in 6 above.

8. Remove the upper firing pin contact and spring clip.

9. Move the cam follower assembly to the rear of the breech with the aft roller raised until the for-

ward roller stops against the rear section of the breech. Push the aft roller down against the surface below it and slide the cam follower assembly out of the breech.

10. Remove the coolant and ejection valve assemblies from the pneumatic tank by removing the securing clips. Caution must be exercised when removing the ejection valve securing clips to prevent injury from the ejection valve spring which is released by the removal of the securing clip. The ends of the two ejection valves differ from the two coolant valves in that the coolant valves are provided with tube fittings.

The foregoing instructions are intended as guides for the disassembly of the gun mechanism by major components. Disassembly of the components and the removal and disassembly of minor assemblies can be accomplished by referring to the applicable BuOrd drawings.

## SECTION 5. ASSEMBLY

1. Install the coolant valve assemblies, the ejection valve assemblies and the gun switch in the pneumatic tank locking the coolant and ejection valve assemblies with the securing clips and the gun switch with the spring pin. Since the pneumatic tank bores are similar for both the ejection and coolant valves, care must be taken to locate the four valve assemblies properly.

2. With the hold forward valve, barrel bushings, barrel locks, firing-pin assemblies, firing-pin spring assemblies and lower firing-pin contact and spring clip assembled in the breech, place the spacer block in the breech and install the yokes, connecting link, and cam follower assembly. Follow the procedure outlined in step 6 under "Disassembly" for pinning the yokes and connecting link together.

3. Install the upper firing-pin contact and securing clip.

4. Raise the spacer block and assemble the yoke shaft through the yokes and spacer block.

5. If the adapter plate was removed, assemble the adapter plate with its valves relocated.

6. Assemble the yoke shoes.

7. Bring the pneumatic tank and breech assembly together, taking care that the gun switch rod protruding from front of the breech is properly aligned

with the center hole in the pneumatic tank. Failure to take this precaution may result in damage to the rod. Continue bringing the two items together until they are approximately 20 inches apart and maintain this position by inserting any suitable spacer between them.

8. With the breech located 2 inches from the pneumatic tank as described in step 7 above, move the two coolant valve assembly tubes rearward from the pneumatic tank and insert the ends in proper holes in the adapter plate. Assemble the 2 sleeves into the 2 charging chambers so that the large end of the sleeve extends approximately one-fourth inch out of the chamber. The sleeves and charging chambers are now ready to be mounted on the breech. However, prior to mounting these items, the ejection valve assembly tubes must be moved rearward from the pneumatic tank and their ends inserted in proper holes in the adapter plate. In moving the ejection valve assembly tubes, the spring pressure in the ejection valve assembly must be overcome and, therefore, once the ends of tubes are positioned in the adapter plate, they must be held in position against spring pressure while the charging chambers and sleeves are mounted. In mounting the charging chambers and sleeves, slight re-

positioning of the tubes may be necessary in order that the large diameter of the tubes may properly be located between the charging chamber extensions.

9. Move the cam follower assembly forward in the breech with the forward roller down. Install the obturating sleeves in the cylinder and install the cylinder in the breech. In bringing the cylinder into the breech, position the cylinder in such a manner that the lowered forward roller will be positioned in one of the spaces between two forward cam grooves of the cylinder. Once the cylinder is positioned in the breech, lower the aft roller of the cam follower assembly in the aft cam groove of the cylinder.

10. Move the cam follower assembly to the extreme aft position with the lowered rear roller engaging the cam groove at its open end. To ac-

complish this, it is necessary that the cylinder be rotated as the cam follower assembly is moved rearward.

11. Remove the temporary spacers between the pneumatic tank and the breech and move the tank toward the breech as far as the assembly will permit. Install the two charger assemblies and assemble the locking segments and spring clips.

12. Install the receiver together with the sprocket assembly and ammunition guides, and lock the receiver to the tank by means of the two lock-pins.

13. Connect the wiring from the receiver to the pneumatic tank.

14. Install the two gun barrels.

This will complete the assembly of the gun mechanism.



## Chapter 7

# BUREAU OF ORDNANCE GAS-OPERATED AIRCRAFT CANNON (SHIRGUN)

## SECTION 1. HISTORY AND BACKGROUND

NOTE. The present chapter on the Shirgun contains results of development and testing in much greater detail than the other chapters of this volume. The reason for this lies in its present status with the Bureau of Ordnance of being neither accepted nor rejected. In the event that consideration of the weapon is resumed, the information assembled in this chapter would provide valuable background material for development engineers.

### History of the Program

The United States Navy in 1942 became interested in an automatic firing mechanism that was under development by the Shirgun Corp. of New York City. The principal personality in the company was Henri Schirokauer, a well-known European engineer, who has since changed his name to Henry Allen Sherwood. He was educated in Germany and studied engineering at the University of Charlottenburg and Mittweida, from which college he obtained his mechanical and industrial engineering degree in 1933. His experience before coming to America in 1940 included research and development engineering on industrial products and automatic weapons for Swedish industry and government. The chief engineer at Shirgun was Ernest S. Rosmarin, a graduate of Stevens Institute of Technology, who has had engineering and designing experience with ordnance, electronic and industrial equipment.

The company submitted a caliber .30 light machine gun in the Army competition of 1941. The weapon had been made in small machine shops around New York City. Army records indicate that it was not fired during that competition. All entrants to the test were rejected, and the Army used its Browning gun throughout World War II.

The light machine gun submitted by the Shirgun Corp. resembles another gun with which Sherwood had earlier been associated. From 1937 to 1940 he had been an engineer with the Industrie Aktiebolaget Svensk Automat Vapen, of Stockholm, Sweden. This firm is best known for its production of the L. H. 33, or Knorr-Bremse, gun. It is interesting to note that Sherwood attended the University of Charlottenburg (Germany), and Char-



Figure 7-1. The designer of the Shirgun, Henry Allen Sherwood.

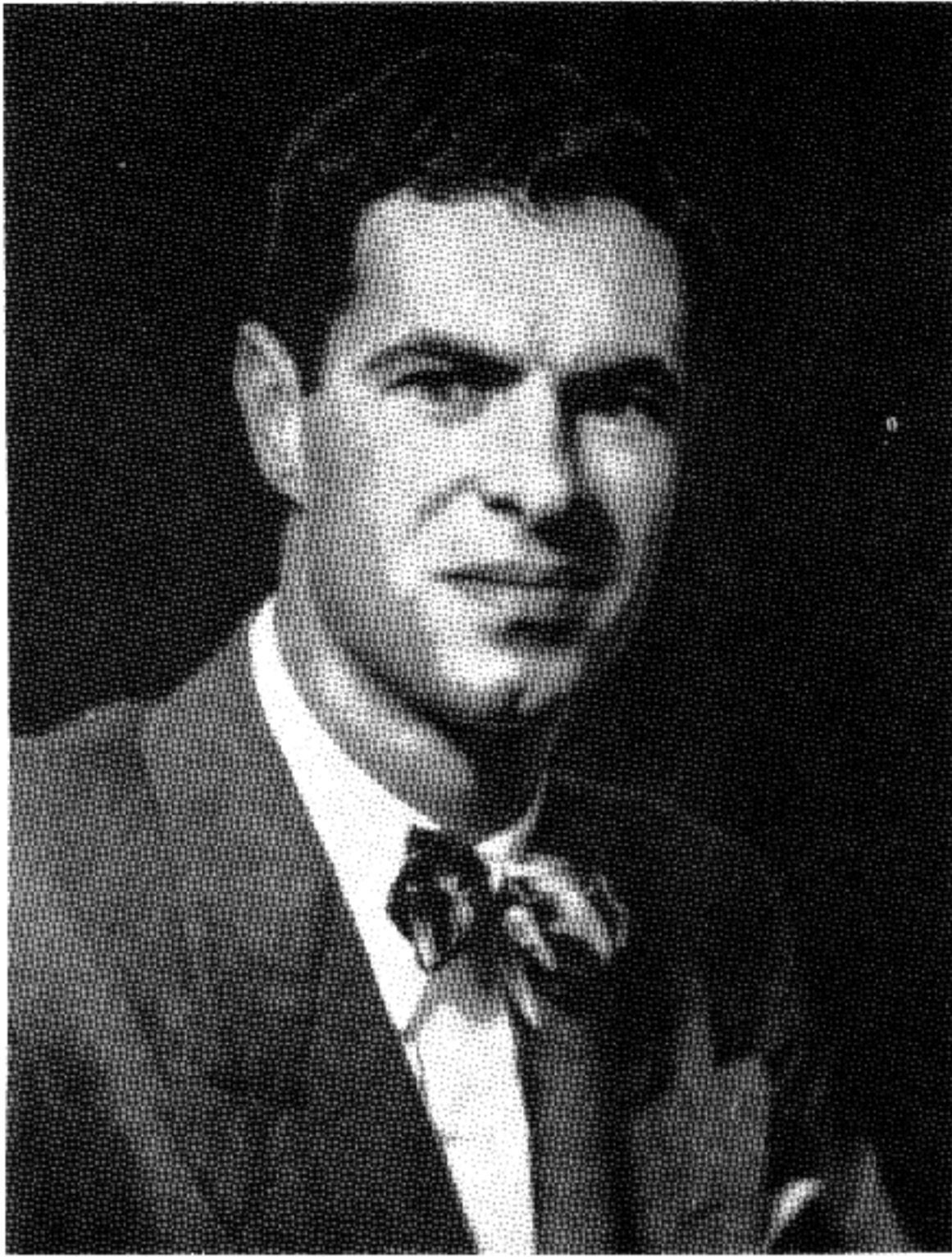


Figure 7-2. The codesigner of the Shirgun, Ernest Rosmarin.

lottenburg was the residence of Hans Lauf, designer of the L. H. 33 gun. (See vol. 1, p. 469.)

In July 1942, the Bureau of Ordnance initiated a project to develop a 20-mm aircraft gun to have a low silhouette for use in thin wing aircraft then being planned. Weight was not considered an important characteristic. The original design characteristics were based on utilization of Oerlikon ammunition.

In 1943 the Navy Department contracted with the Shirgun Corp. for the development of such a gun. During that year the company worked on the preliminary designs, and certain changes were incorporated as suggested by the Bureau. It was decided early in the discussions to change the chamber to use Hispano ammunition instead of Oerlikon, and to make allowance for longer projectiles.

The earliest correspondence between the Navy and the Shirgun Corp. indicates that the company's name was spelled "Schirgun." However, the name was changed to the "Shirgun Corp." and this spelling is used throughout this chapter in connection with the company and the mechanism itself.

By 28 February 1944, the work had progressed to a point where the Bureau of Ordnance forwarded

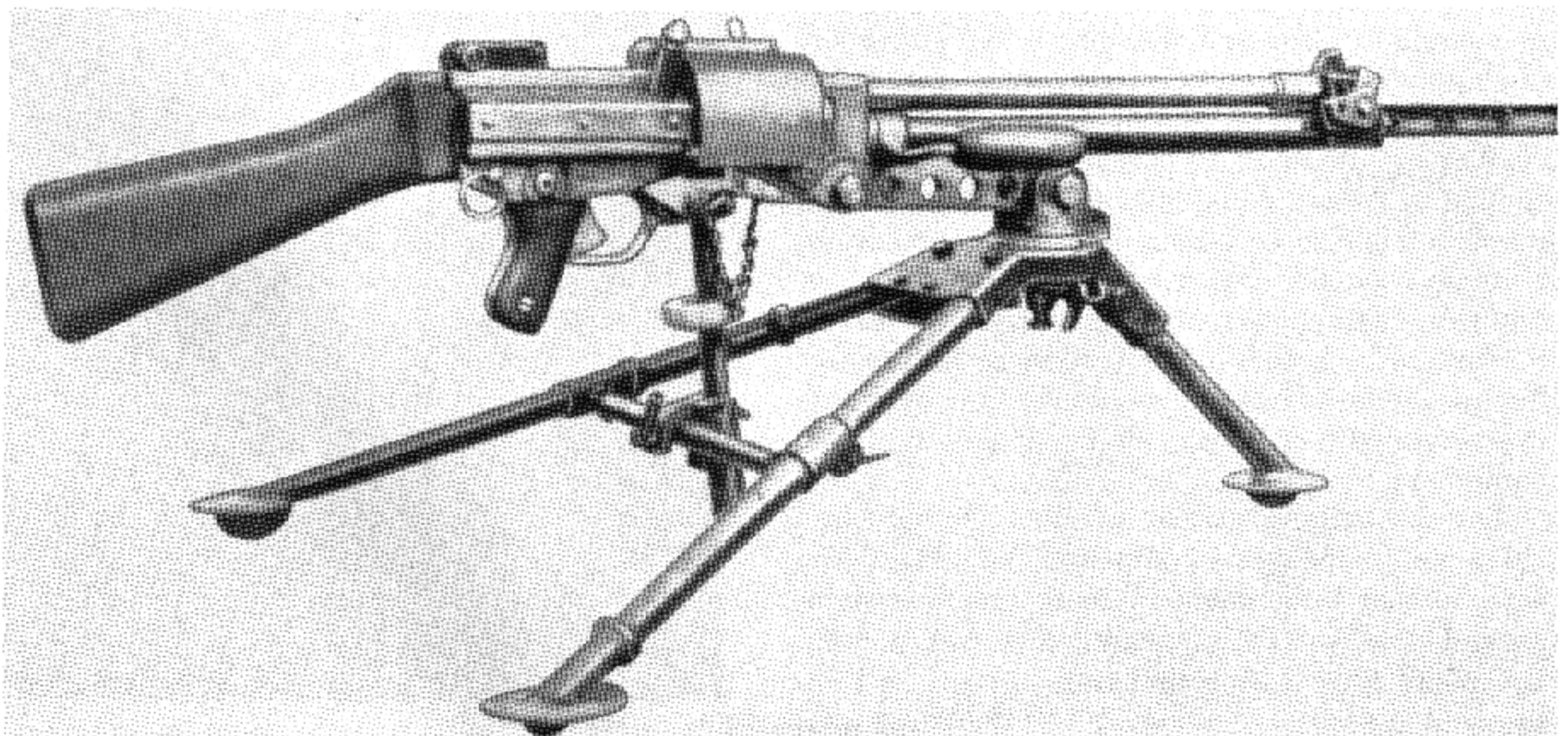


Figure 7-3. The Caliber .30 Machine Gun entered by Sherwood in the Army tests of 1941.

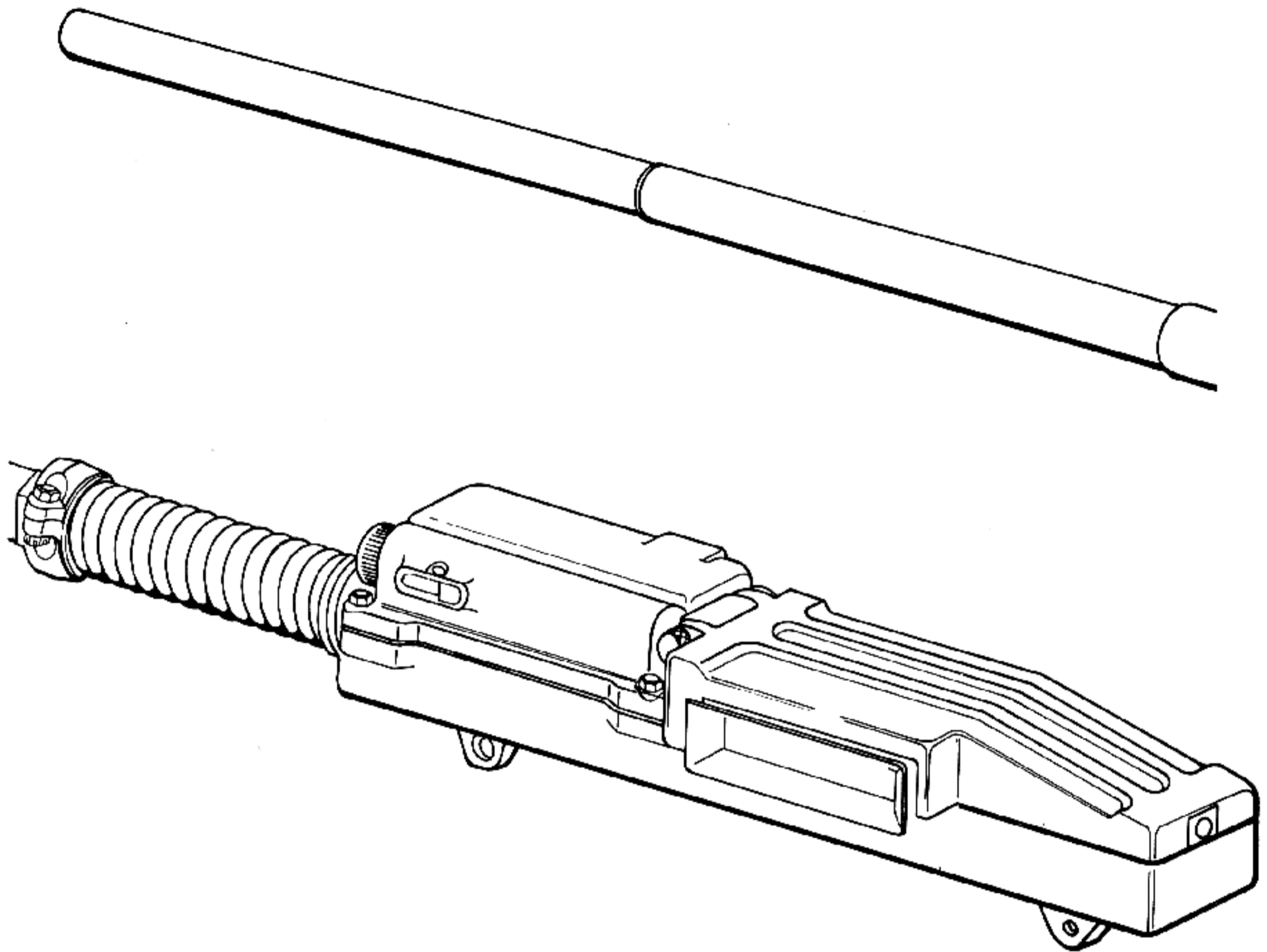


Figure 7-4. Drawing prepared by the Shirgun Corp. to show the prototype of the proposed EX 1 Type O.

drawings to the Naval Gun Factory and requested the manufacture of two gun mechanisms, to be designated EX 1. The letter requesting this manufacture was very broad in the technical sense in that no specifications were outlined.

On 15 March 1944, the Superintendent of the Naval Gun Factory returned the request and pointed out that although the Gun Factory could do the development, it would not be possible to continue the work if mass production was desired at a later date. Since any facility engaged in producing such a new weapon would need the technical knowledge acquired in the development stage, it was suggested that the job be given to a contractor who had capacity to mass produce the gun in case it was adopted later. The suggestion was accepted, and an official withdrawal of the request was made.

Shortly thereafter, 2 companies were approached as possible contractors in the making of 2 prototype guns, the Oldsmobile division and the Pontiac division, both of the General Motors Corp. Pontiac was overloaded with work, and Oldsmobile agreed to take the job on a net cost basis. It was decided to make one gun plus spare parts. The price quoted was \$32,389.15. This was accepted by the Bureau, and manufacture got under way.

About this time, the Shirgun Corp. asked payment of \$30,000 as a true cost under its contract, claiming that this represented the cost of developing the caliber .30 gun, "unique features" of which had been carried over to the 20-mm gun. In reply, the Bureau noted that the patent application for the caliber .30 gun design was dated 12 February 1942, while the contract with the Navy was dated 6 March

COMPARISON CHART

NAME	HISPANO	SCHIRGUN SINGLE	SCHIRGUN DOUBLE	BROWNING		
	20 MM AIRCRAFT	20 MM AIRCRAFT	20 MM AIRCRAFT	37 MM A A	37 MM A A	37 MM AIRCRAFT
MUZZLE VELOCITY $\frac{FT.}{SEC.}$	2850	2800	2800	2600	2050	2000
WEIGHT OF PROJECTILE LBS.	.300	.300	.300	1.340	1.900	1.340
FIRING RATE ROUNDS MIN.	650	950	1900	120	120	150
RATE OF MUZZLE ENERGY HP.	745	1040	2080	514	453	377
WEIGHT OF FIRE LBS/MIN.	195	285	570	161	228	200
KINETIC ENERGY/ FT-LBS./ROUND	37800	36,100	36,100	141,000	25,000	83,200
STRIKES PER SECOND	10.8	15.8	31.6	2.0	2.0	2.5
TRUNNION REACTION LBS.	3500	2300	3800			
RECOIL STROKE IN.	1.18	2.00	2.00	10.75	10.75	9.75
WEIGHT OF POWDER LOADING LBS.	.07	.07	.07			
WEIGHT OF COMPLETE ROUND LBS.	.56	.56	.56	262	312	193
WEIGHT OF DISINTE- GRATING LINK LBS.	14	14	14	.32	.32	.32
BELT RESISTING FORCE LBS.	40	450	640			
LENGTH OF COMPLETE ROUND IN.	723	723	723	13.01	13.01	9.75
LENGTH OF BARREL IN.	67.5	67.5	67.5	78.0	78.0	65.0
WEIGHT OF BARREL LBS.	47.5	47.5	47.5	119.0	119.0	55.0
WEIGHT OF GUN EST. LBS.	136	130	190	365	365	213
OVERALL LENGTH OF GUN IN.	94	85	87	104	104	89
WEIGHT OF RECOILING PARTS EST. LBS.	118	70	120			
CARTRIDGE TRAVEL+LOCKING STROKE+BUFFING STROKE+ BUFFING CLEARANCE IN.	$90+0.6+0.5+0.7=10.80$	$92.18+0.688+1.000+0.469=11.375$	$10.00+0.65+1.00+0.00=11.65$			
WEIGHT OF RAMMING PARTS LBS.		6	9			
TYPE OF OPERATION	GAS	GAS	GAS OR RECOIL	RECOIL	RECOIL	RECOIL
TYPE OF RECHARGING	HYDRAULIC	FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC			
TYPE OF LOCKING	LOCKING LEVER	SINGLE RISING WEDGE	DOUBLE RISING WEDGE	VERTICAL SLIDING	VERTICAL SLIDING	VERTICAL SLIDING
SILHOUETTE INCLUDING FEED	8x13	6.75x7.25	7.00x7.50			
MUZZLE BRAKE	35%					
			GAS: 2800 lbs - 1900 RPM RECOIL: 2800 lbs. - 1400 RPM 5400 lbs - 1700 RPM			
RANGE						

JUNE - 1944

Figure 7-5. Chart prepared by Shirgun Corp. to show estimated

AUTOMATIC GUNS

SCHIRGUN SINGLE			SCHIRGUN DOUBLE			SCHIRGUN BOFORS		
37 MM A.A.	37 MM A.A.	37 MM AIRCRAFT	37 MM A.A.	37 MM A.A.	37 MM AIRCRAFT	40 MM A.A.		
2600	2050	2000	2600	2050	2000	2850		
1.340	1.900	1.340	1.340	1.900	1.340	2.000		
600	600	600	1200	1200	1200	180		
2570	2265	1520	5140	4530	3040	1370		
804	1140	804	1610	2280	1610	360		
141,000	125,000	83,200	141,000	125,000	83,200	250,000		
100	100	100	200	200	200	30		
4700	6330	4280				4150		
5.00	5.00	5.00	5.00	5.00	5.00	7.25		
						.65		
2.62	3.12	1.93	2.62	3.12	1.93	4.67		
.32	.32	.32	.32	.32	.32			
13.01	13.01	9.75	13.01	13.01	9.75	17.62		
78.0	78.0	65.0	78.0	78.0	65.0	88.58		
119.0	119.0	55.0	238.0	238.0	110.0	295.0		
						1100		
105	105	90				144		
200	200	130				500		
18.00+1.00 +1.25+0.75 =21.00	18.00+1.00 +1.25+0.75 =21.00	15.00+1.00 +1.25+0.75 =18.00				CARTRIDGE TRAVEL =27.00		
15	15	15						
RECOIL	RECOIL	RECOIL	RECOIL	RECOIL	RECOIL	RECOIL		
FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC	FULL-AUTO. ELECTRIC	MANUAL		
DOUBLE RISING WEDGE	DOUBLE RISING WEDGE	DOUBLE RISING WEDGE	DOUBLE RISING WEDGE	DOUBLE RISING WEDGE	DOUBLE RISING WEDGE	VERTICAL SLIDING		

SCHIRGUN CORP. NEW YORK, N.Y. *H. M.*

performance of its proposed designs as compared with standard weapons.

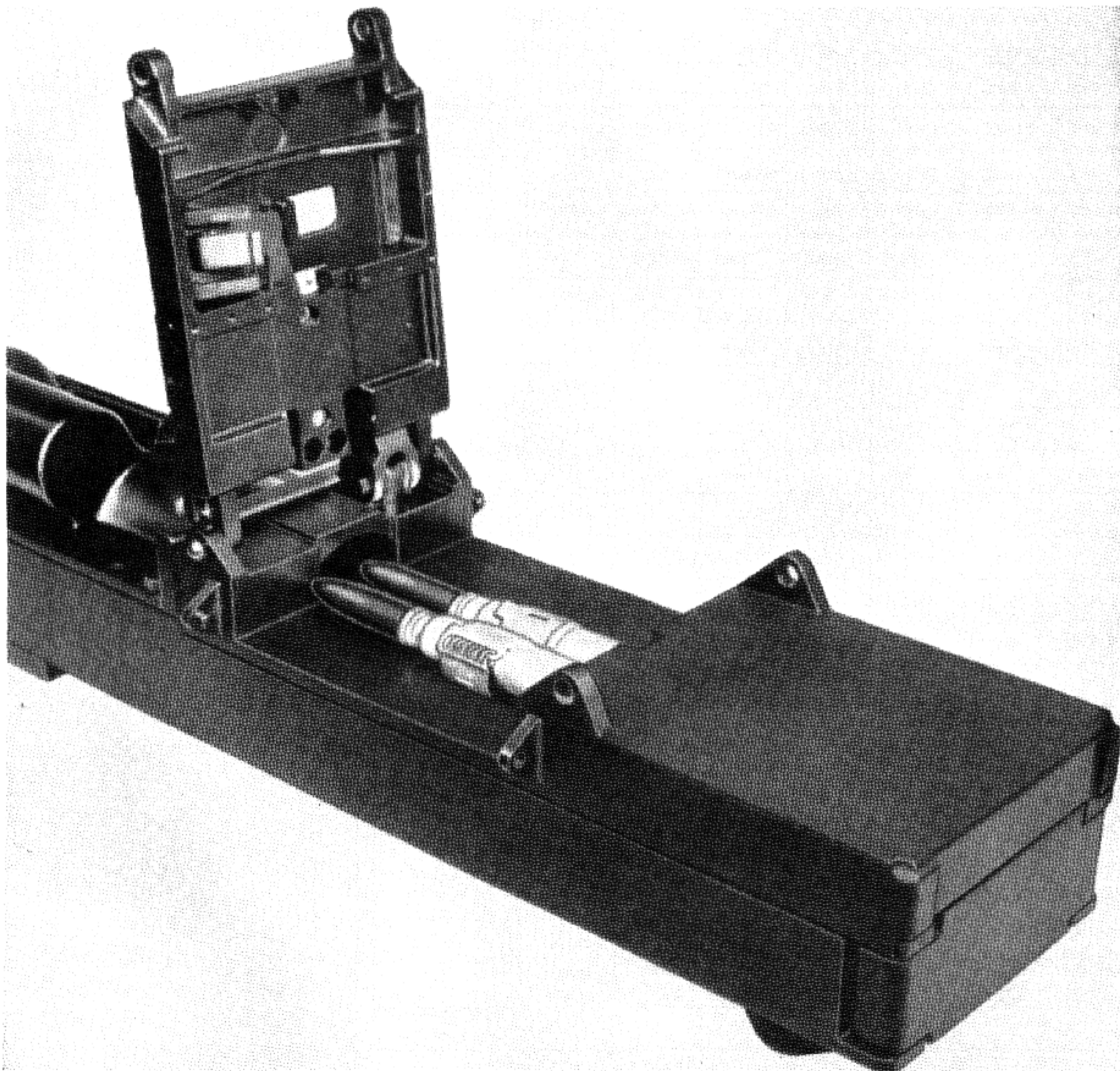


Figure 7-6. Breech of the original Shirkun. Cover open to show feedway.

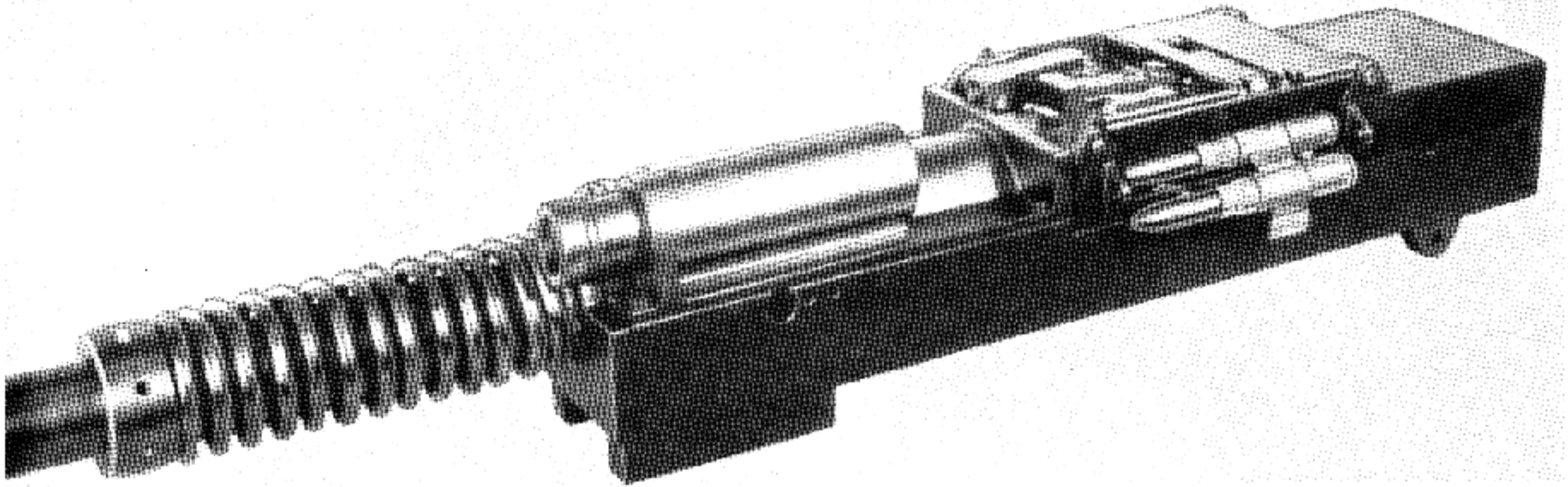


Figure 7-7. Left side of original Shirgun. Closeup view.

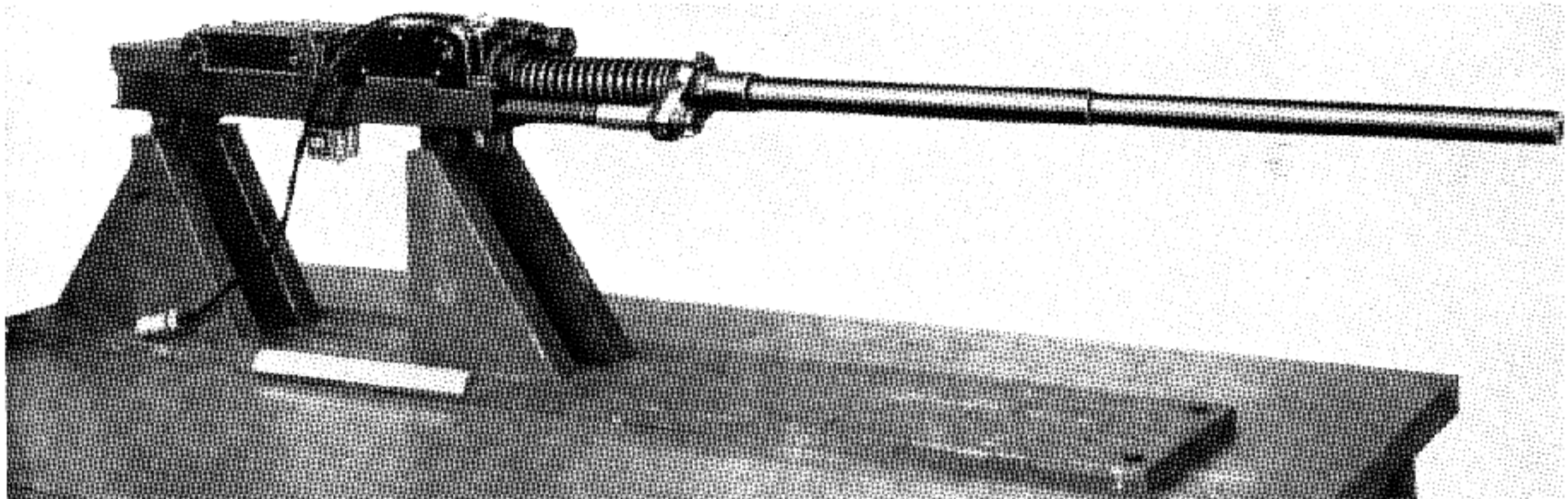


Figure 7-8. The original 20-mm Shirgun mounted on a test stand. Right side view.

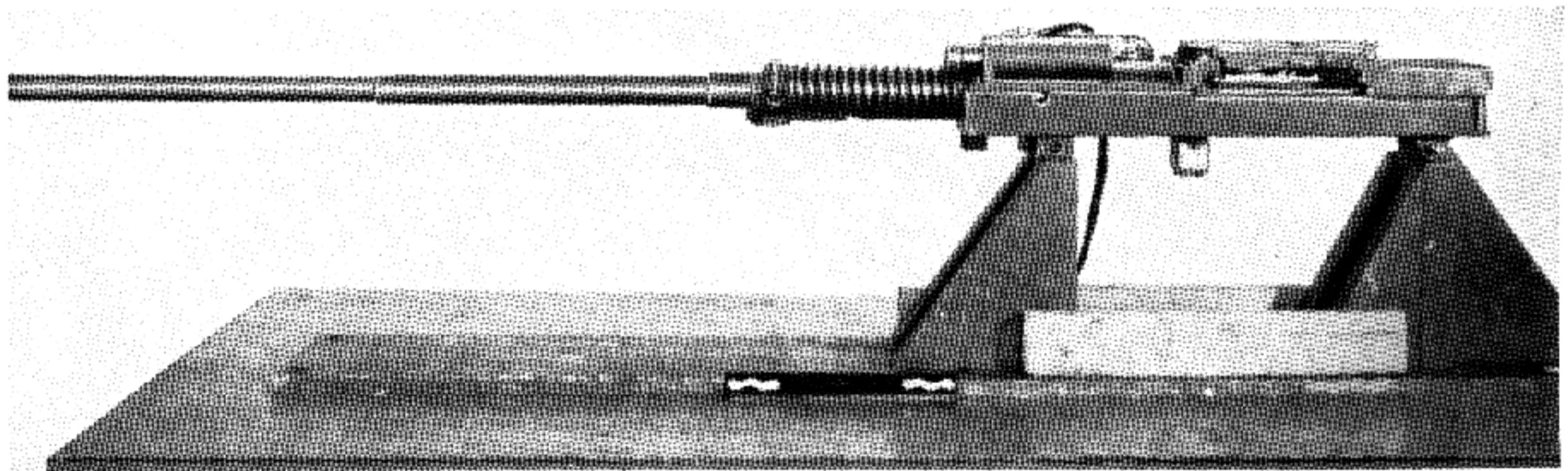


Figure 7-9. The original 20-mm Shirgun mounted on a test stand. Left side view.

1942 and further that there was no relationship between the caliber .30 gun and the proposed 20-mm design. Since the contract granted to the Government the rights to all inventions made during the term of the contract, the claim was disallowed.

On 26 August 1944, the gun built by Oldsmobile was test fired at its plant at Lansing, Mich. Eight rounds were fired when a breechblock failure stopped the test. A new contract between the Navy and Oldsmobile provided for the manufacture of more parts. This added \$10,000 to the manufacturing cost, exclusive of development costs. The gun was shipped to the Shirgun Corp. on 26 September 1944. Shortly thereafter, Oldsmobile, at the request of the Bureau of Ordnance, shipped all remaining castings,

forgings, and unfinished parts to the Shirgun Corp.

In 1944 a separate task was initiated with the Shirgun Corp. for the development of the double barrel gun to meet the same characteristics as the original project. Preliminary drawings were submitted of the mechanism design to feed 20-mm ammunition to the two barrels.

On 24 February 1947, the Shirgun Corp. requested permission to change the company's name from the Shirgun Corp. to Industro-Matic Corp. of America. This request was granted, and a short time later the Navy bought from this concern all manufacturing rights to produce this weapon, with the result that all following development was done at the Naval Gun Factory. Considerable difficulty

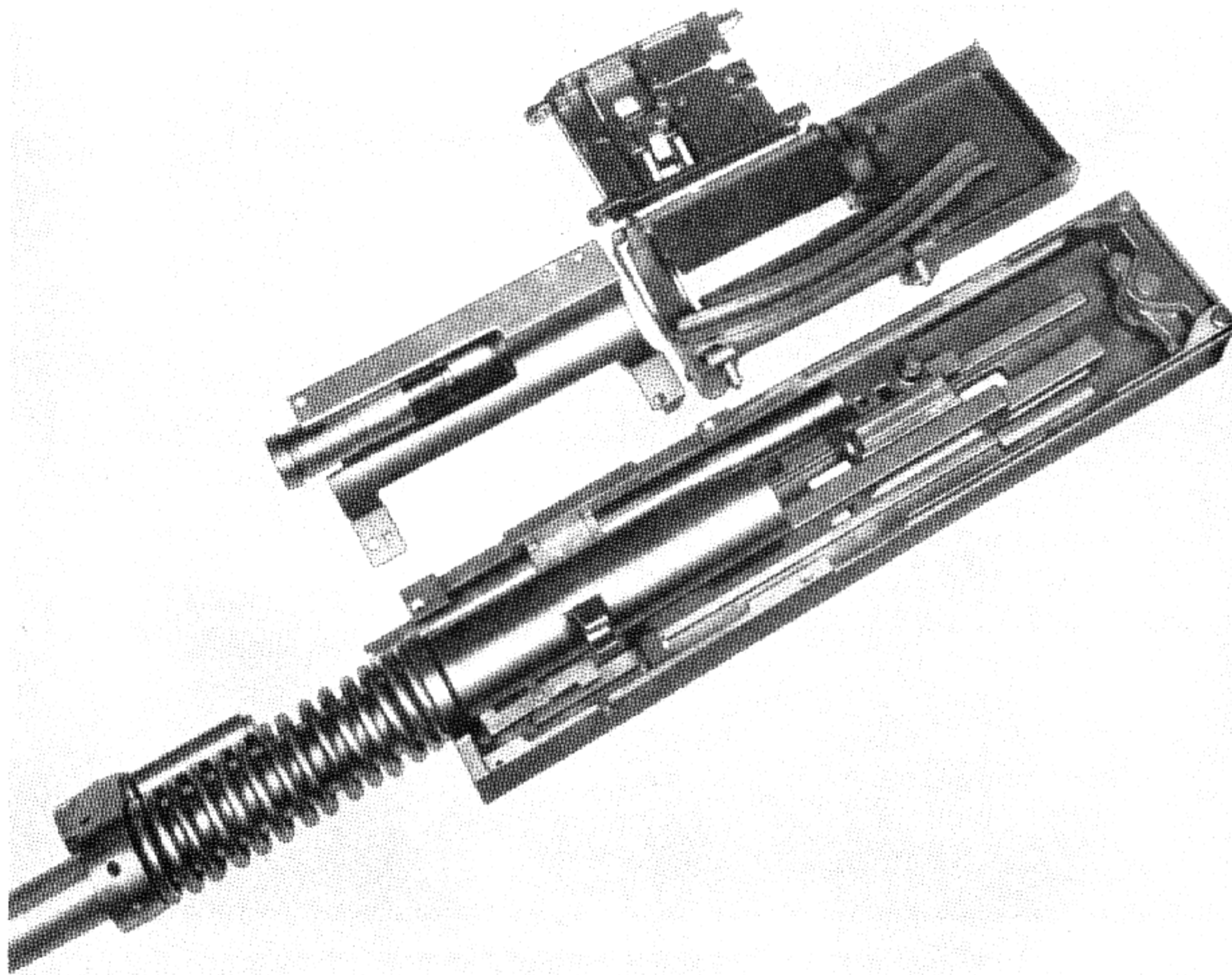


Figure 7-10. Original 20-mm Shirgun. Top of receiver removed.



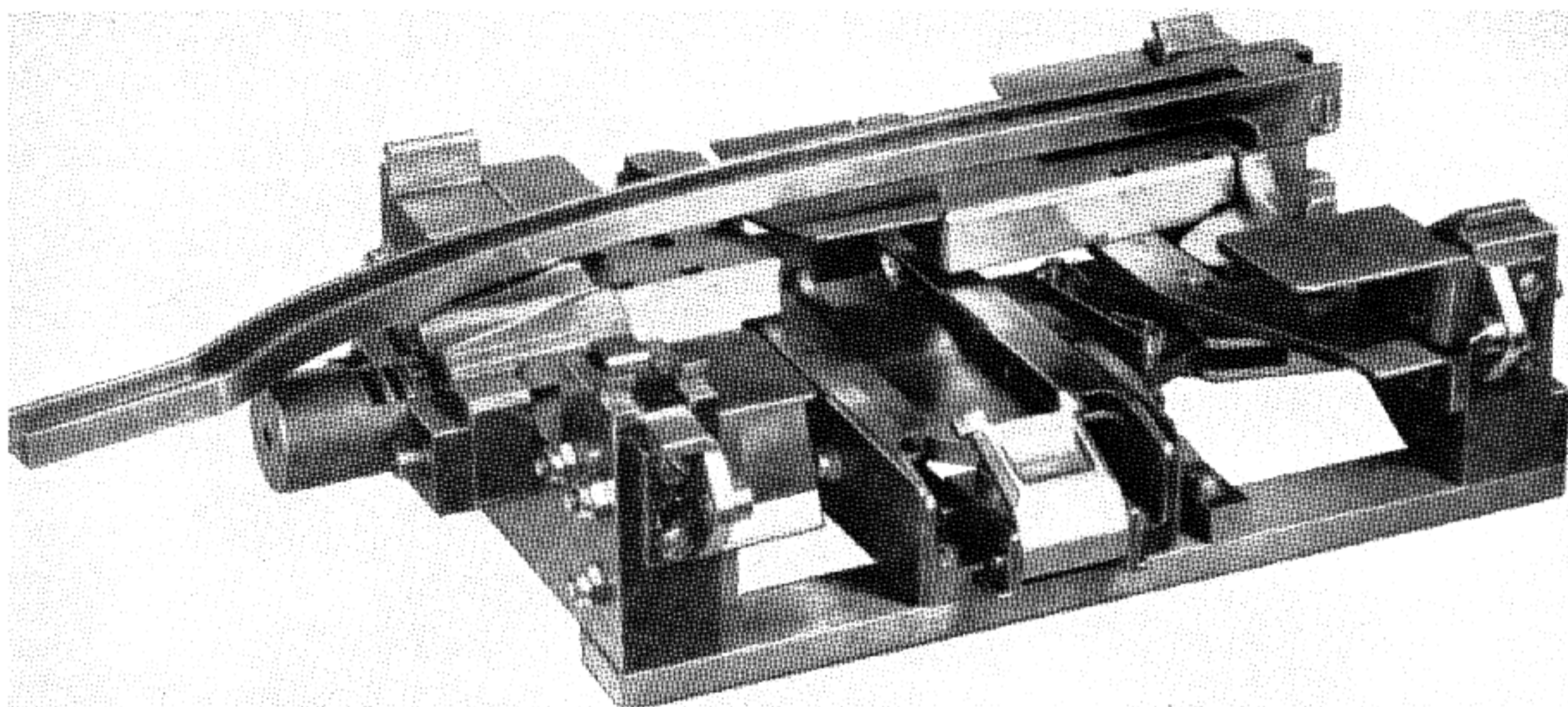


Figure 7-11. The feed of the original 20-mm Shirgun.

was experienced in function firing the first versions of the low profile type, the main difficulty being the breakage of breech locks in a comparatively few rounds.

The Shirgun program was discontinued in 1949. However, the project was revived as the 20-mm machine gun mechanism EX 5, and in the fall of 1953 it was in the blueprint stage. Along with the EX 5, a program of converting the Mk 13 Mod 0 to 30-mm was initiated and given the official designation Mk 3 Mod 0.

**Various Models Based on the "Shirgun"**

The Shirgun, as it was known in 1941, represented the Navy Department's first attempt to develop an aircraft machine gun mechanism. Because of the experimental nature of the project, it was decided that the use of the conventional "Mark and Mod" system of marking might be misleading in the early stages of the work. Accordingly, a new method of designation was applied, with "EX" and "Type" roughly corresponding to "Mark" and "Mod." "Mark" and "Mod" designations were assigned to models which advanced in design sufficiently to warrant it. The accompanying table shows Navy and Army designations of the models. It is interesting to note that the Ordnance Corps identified several models as simply T55, thus violating the precedent of adding E numbers to the basic

number to indicate variations of the basic design. The following paragraphs summarize the development work on the various models.

Caliber	Designations		
	Army	Navy	Navy
20-mm.....		EX 1,.....	
20-mm....	T55...	EX 1, type 0.....	
20-mm....	T55....	EX 1, type 1.....	
20-mm....	T55....	EX 1, type 2.....	
20-mm....	T55....	EX 1, type 3.....	Mk 9 Mod 0
20-mm....		EX 1, recoil operated.	
20-mm....	T128...	.....	Mk 9 Mod 1
20-mm....	T129...	.....	Mk 13 Mod 0
20-mm....	T54....	EX 3.....	Mk 10 Mod 0 (Double barrel version)
20 mm.....		EX 5.....	
30-mm....		.....	Mk 3 Mod 0

*20-mm Machine Gun Mechanism EX 1.* In the earliest stage of design, two versions were proposed, both of which were to use Oerlikon ammunition from a closed, disintegrating link. They were to be gas operated and to employ a rising wedge lock. One was to be rear seared and was designed to fire

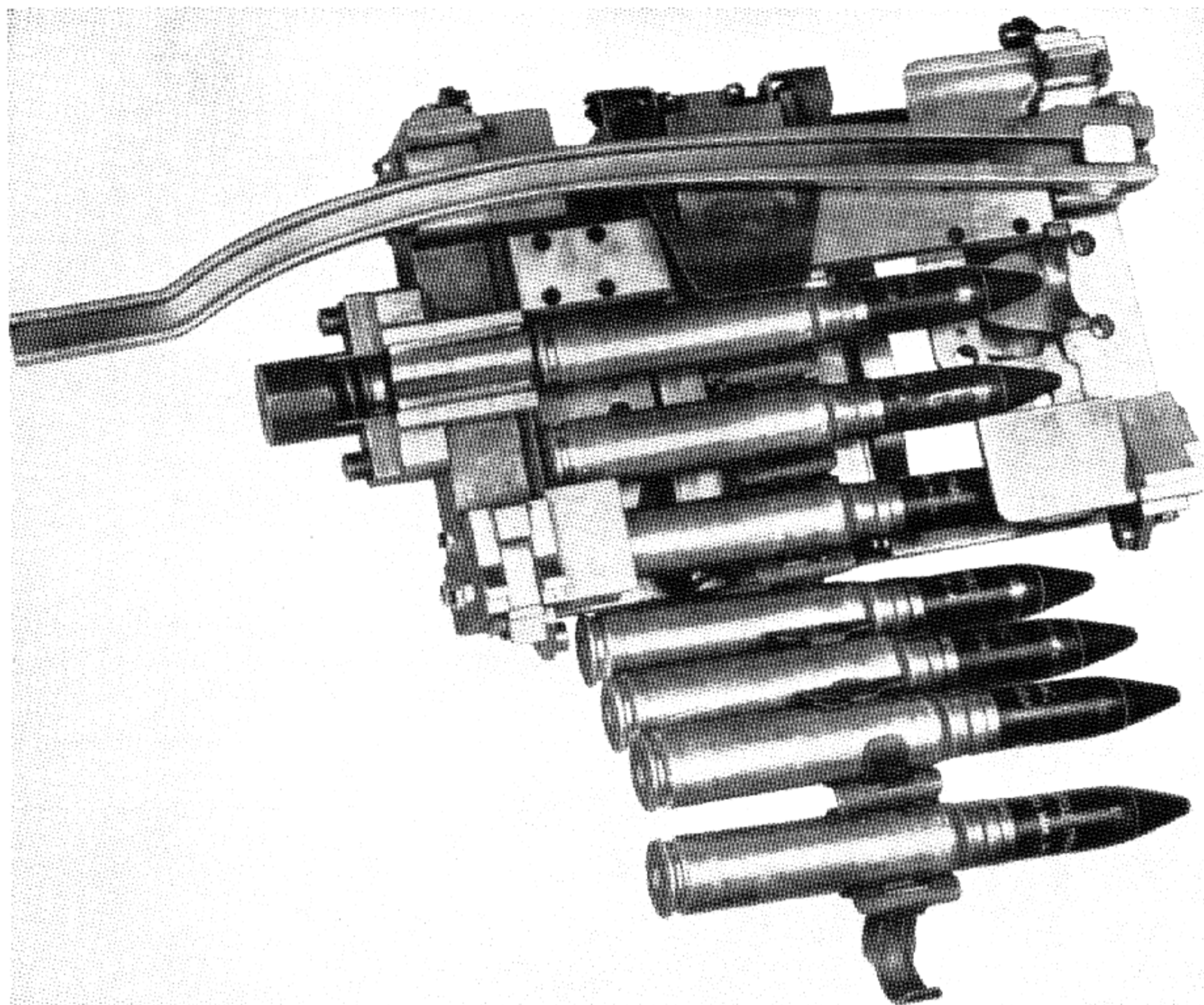


Figure 7-12. The feed of the original 20-mm Shirgun. Bottom view, showing belt of ammunition in position.

at an estimated rate of 715 rounds per minute. The other, the forward seared version, had a calculated rate of 950 rounds per minute. However, no guns were made to these specifications, this design never getting beyond the mock-up stage.

*20-mm Machine Gun Mechanism EX 1, Type 0.* This is a single-barrel, automatic, gas-operated, belt-fed, air-cooled weapon firing standard 20-mm ammunition.

This was the prototype gun. It was actually constructed at the Oldsmobile factory by subcontract. The existing Hispano-Suiza ammunition was to be used in this gun and the rate of fire was given at 800 rounds per minute. The complete unit weighed

175 pounds and had an overall length of 86 inches. An electric charger was in the original plans, and the weapon was forward seared. Open disintegrating links were used in an integral, reversible feed having a maximum pull of 450 pounds. Only one gun was made to this design.

*20-mm Machine Gun Mechanism EX 1, Type 1.* In this experimental version, the feed was redesigned to employ the standard M8 link then in service with the Hispano-Suiza ammunition. The charger was hand operated, and a pneumatically controlled device was used for actuating the sear. The weight was the same as that of EX 1 Type 0. Five of these guns were fabricated at the Naval Gun Factory and

one, somewhat different, was built by the Shirgun Corporation. The differences in the latter model grew out of results of firing tests of the guns made at the Naval Gun Factory. The tests were conducted at the Naval Proving Ground at Dahlgren, Va.

*20-mm Machine Gun Mechanism EX 1, Type 2.* This developmental type had redesigned operating parts. The silhouette was accordingly flattened out, and the weight was reduced to 160 pounds. The charger was of the double-acting pneumatic type, and an inertia type firing pin was fitted. The work was done at the Naval Gun Factory. Five guns of this type were made. This model was commonly known by the testing personnel as the T55.

*20-mm Machine Gun Mechanism EX 1, Type 3.* It was proposed to assign this designation to the EX 1 until a model suitable for mass production was developed. No gun of this type was ever made.

*20-mm Machine Gun Mechanism EX 1, Recoil Operated.* In 1948, an experiment was conducted at the Naval Aviation Ordnance Test Station at Chincoteague, Va., to test the feasibility of converting the EX 1 Type 0 gun to recoil operation. The gun was modified with components manufac-

tured at the test station, but firing was done by single shots only to prove the principle. Only one gun was produced by modification of the prototype, EX 1 Type 0.

*20-mm Machine Gun Mechanism Mk 9 Mod 0.* This model was developed from the EX 1 Type 2; the weight was reduced to 113 pounds, and the profile was smaller. There were improvements in the pneumatic system, and the firing pin was seared. With the 52½-inch barrel, a muzzle velocity of 2,680 feet per second was obtained and a rate of fire of 1,247 rounds per minute was reached (the highest ever recorded for this type of automatic cannon). There were two guns of this type built at the Naval Gun Factory. Both guns were successfully fired at the Naval Proving Ground at Dahlgren, Va.

*20-mm Machine Gun Mechanism Mk 9 Mod 1.* This model was modified from the Mk 9 Mod 0. It uses Hispano-Suiza type of electric primed ammunition and has been fired at a rate of 1,100 rounds per minute. The feed is operated by a camway on the bolt extension. The pneumatic sear was removed. Two guns of this type were produced by

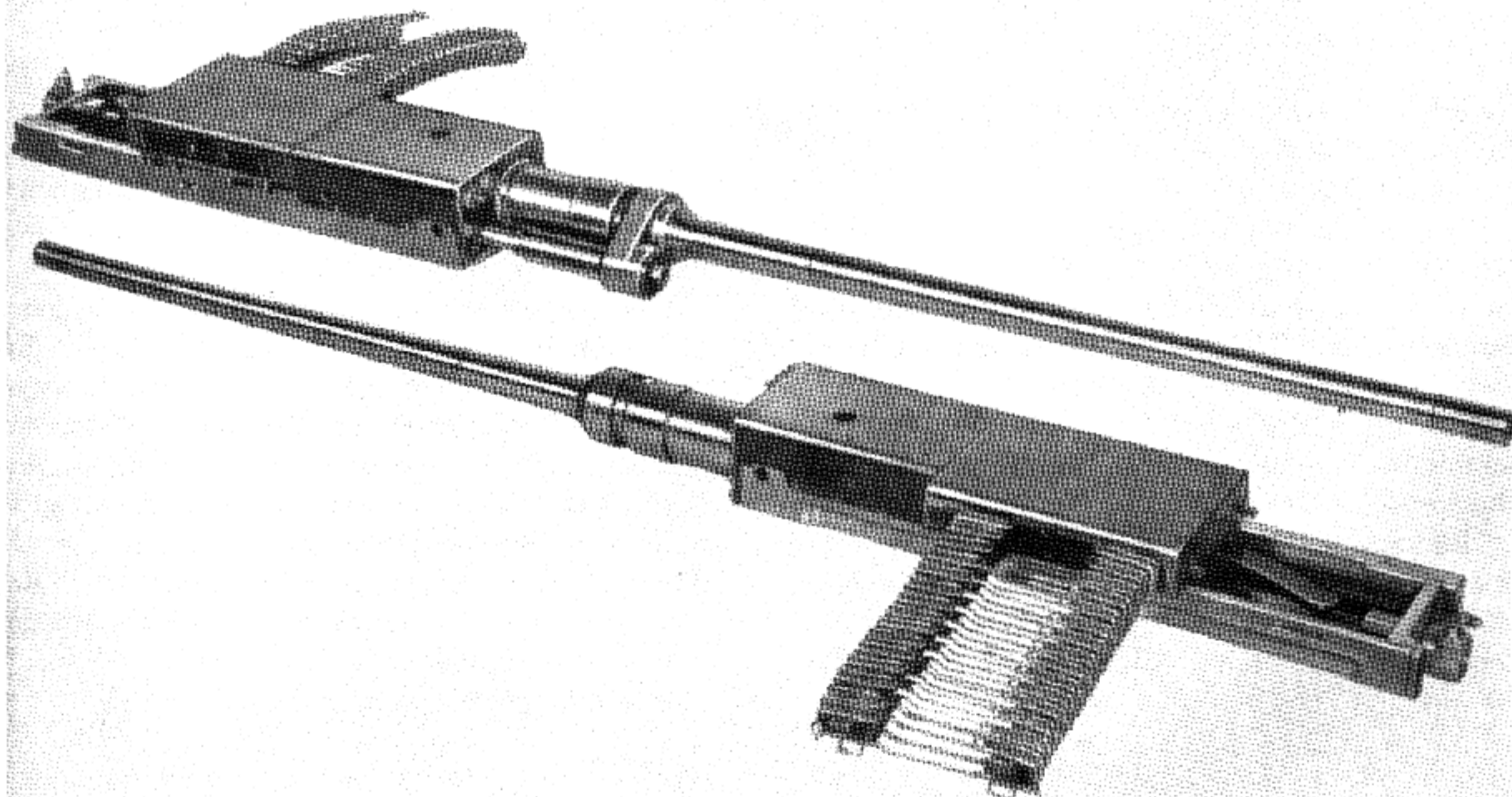


Figure 7-13. 20-mm Shirgun Mk 9 Mod 0. This model represents an intermediate stage in the development of the 20-mm Shirgun.

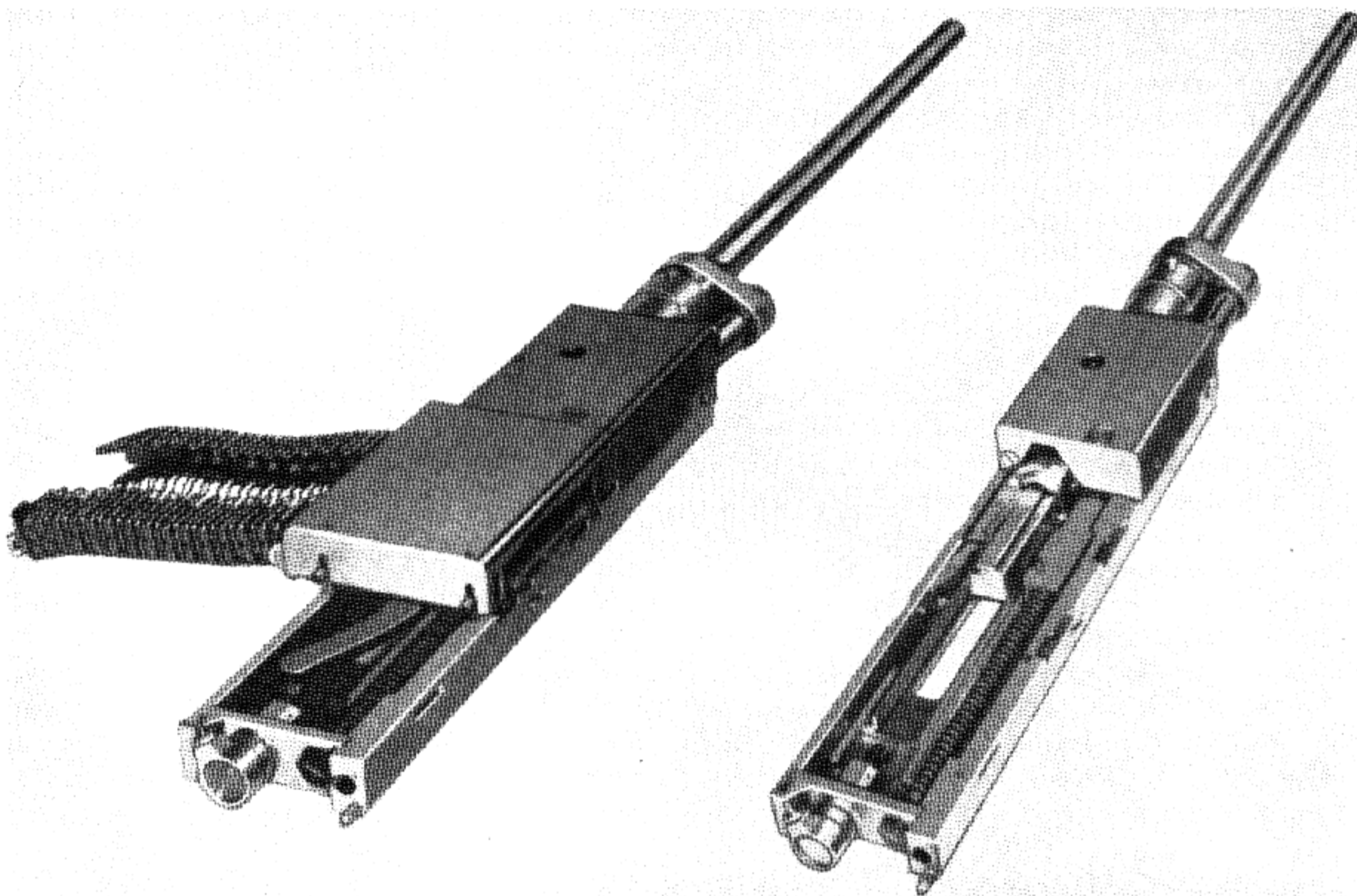


Figure 7-14. 20-mm Shirgun Mk 9 Mod 0. Two rear views showing the weapon with and without feeder.

modifying Mod 0 units. These weapons were fired at the Naval Proving Ground at Dahlgren, Va., but no conclusive test has been completed.

*20-mm Machine Gun Mechanism Mk 13 Mod 0.* This gun resembles the Mk 9 Mod 1 but is chambered for the short 60/20 round of the Army Ordnance Corps. The 60-inch barrel gives a muzzle velocity of 3,300 feet per second. There is no driving spring, and the ignition is electric. Only two of this model have been built, both at the Naval Gun Factory.

Function firing tests had been conducted in which the average rate of fire has been 1,000 rounds per minute, with over 1,200 rounds per minute having been obtained. Kinematic studies have also been made.

The Army designation for this model is T129.

*20-mm Machine Gun Mechanism EX 3.* This was a proposed twin barrel gun to feed from a single belt. Early design work by the Shirgun Corp. was based on the Hispano-Suiza round.

The Naval Gun Factory later made gun design and layout studies based on various rounds. Experimental design drawings were prepared based on a caliber 60/20 electric primed round of ammunition, and plans were made for fabrication of a prototype gun. The Navy indicated funds would be made available for development of the link for the T54 gun and contract action was initiated with Roy S. Sanford and Co. for this work. Only a wooden model has been made.

The Army designation for this model is T54.

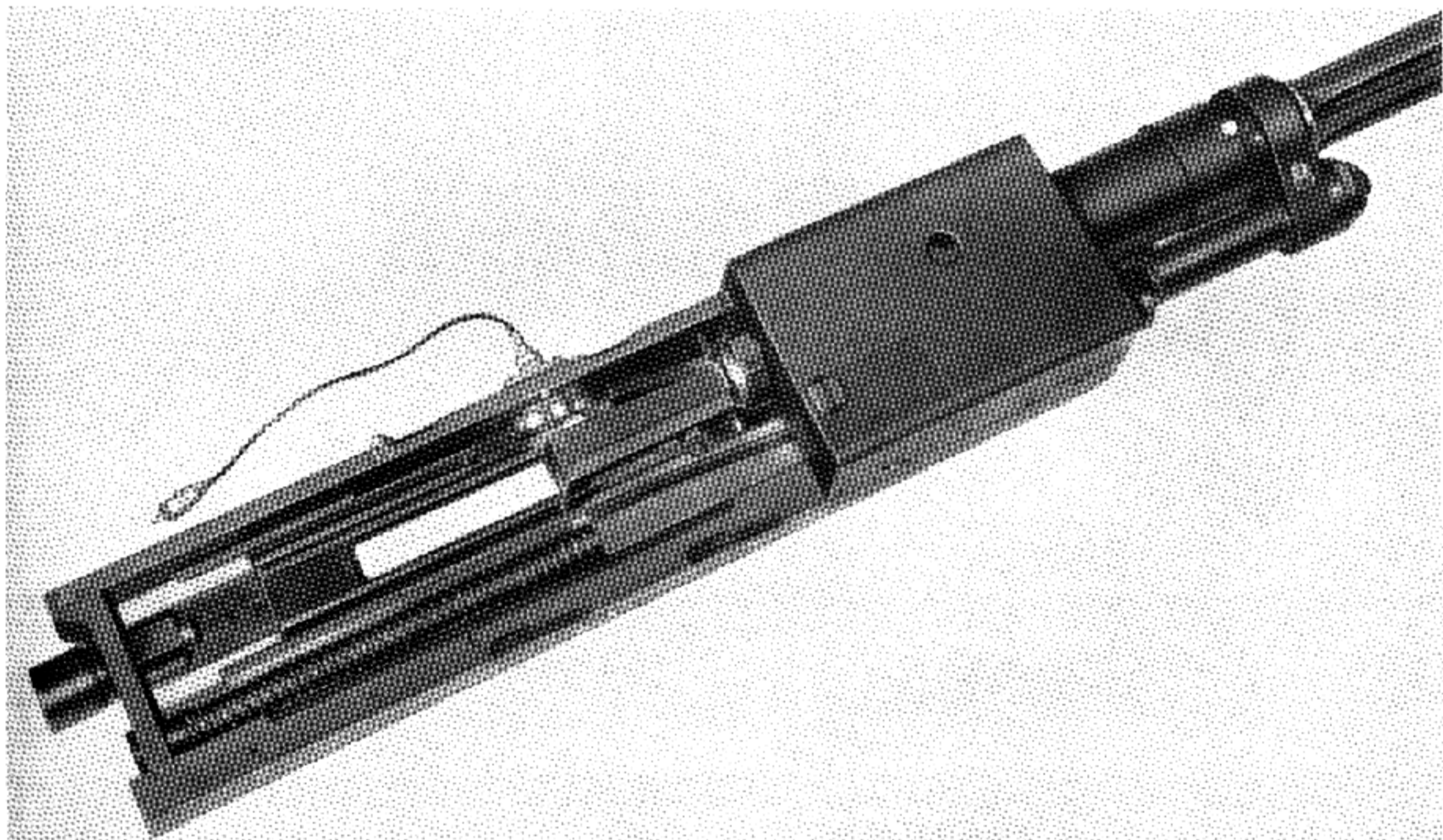


Figure 7-15. 20-mm Shirkun Mk 9 Mod 1, also known as the T128. This weapon is a conversion of the Mk 9 Mod 0 to electric ignition.

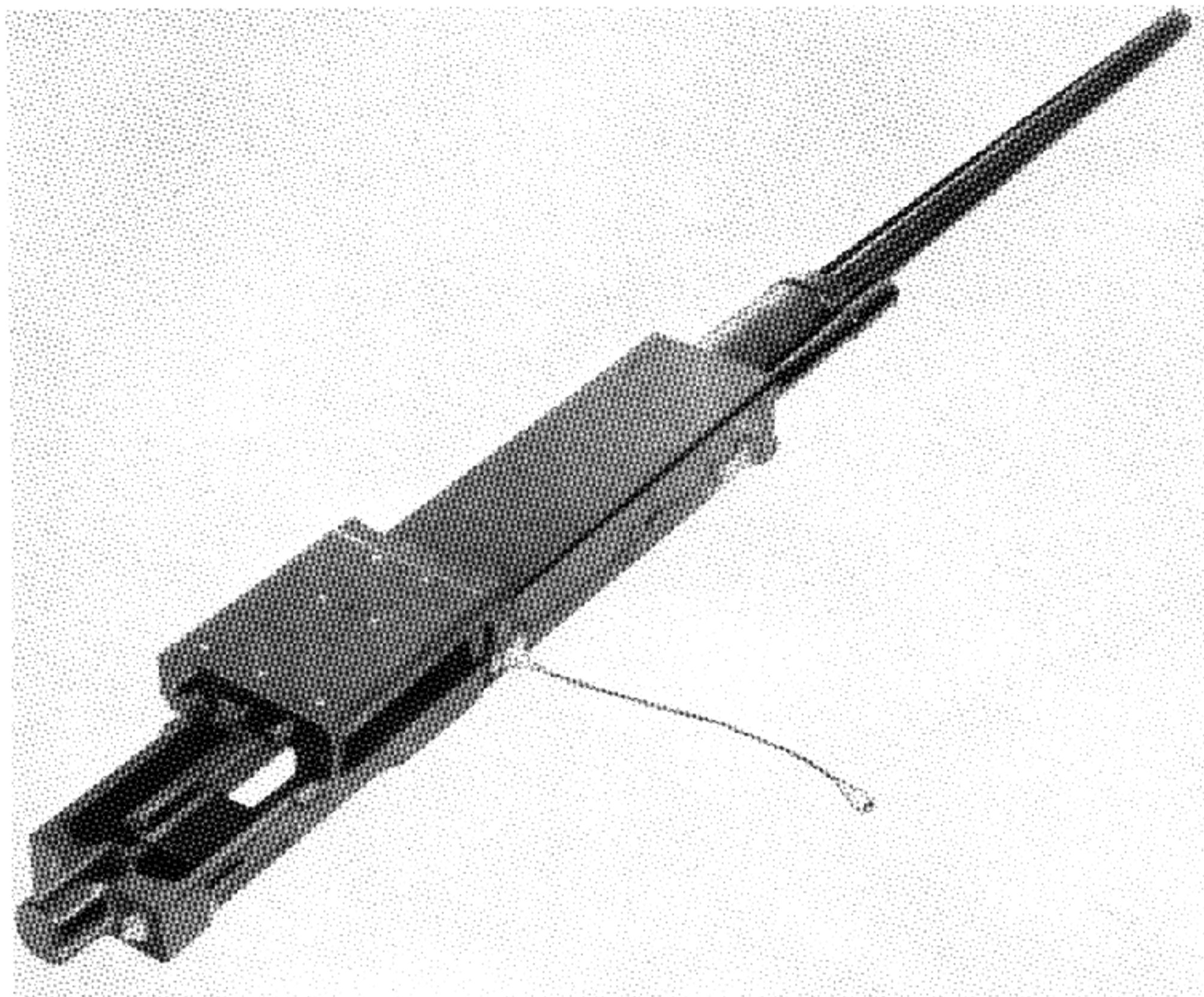


Figure 7-16. The 20-mm Shirgun as fully developed for electric ignition and high-velocity ammunition. This version is called the Mk 13 Mod 0.

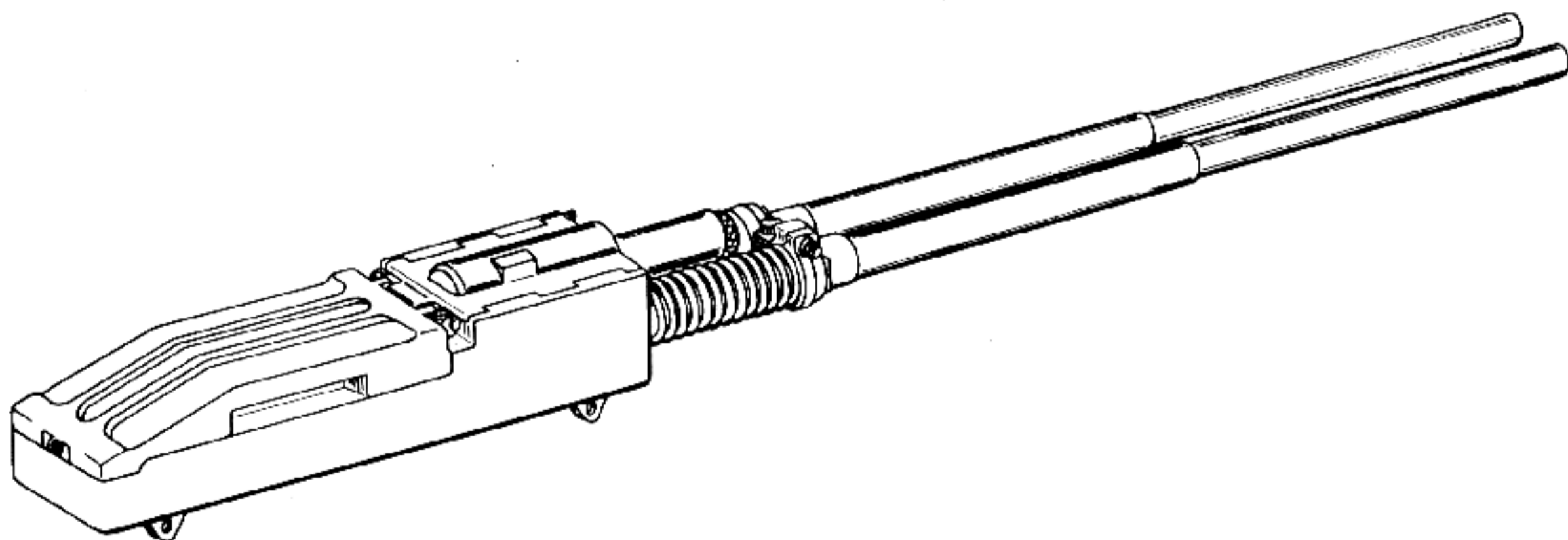


Figure 7-17. Drawing prepared by the Shirgun Corp. to show the prototype of the proposed EX 3 or Mk 10 Mod 0, double-barrel version.

## SECTION 2. TESTS AND DEVELOPMENT OF 20-MM MACHINE GUN MECHANISM EX 1 TYPE 1, GUN NO. 1

### Tests at Naval Proving Ground, 30 October 1946 to 15 April 1947

This gun, made at the Naval Gun Factory, was delivered to the Naval Proving Ground on 30 October 1946. More than 4 weeks were used by the firing officers in studying the weapon's construction and many peculiarities. The discussion of tests as given here is substantially as given in official reports. No editorial comment has been added.

During the month's time interval just mentioned the longest burst was 16 rounds before a malfunction or serious breakage brought the tests to a halt. The most prevalent malfunction was a "faint strike", and, accordingly, solving this problem was given the highest priority. The "faint strike" was caused by an error in design. The cocking lug on the bolt extension could get directly in the way of the firing pin on its forward travel and had to be advanced enough by the time the sear mechanism released to avoid colliding with the firing pin lug.

All things that could cause this retarded movement forward of the bolt extension, on which the above mentioned lug was located, had to be eventually traced down one at a time and corrected before automatic fire could be accomplished. The various things found that aided in bringing about the "faint-strike" were then listed with the method used in preventing their recurrence:

1. It was observed that, while the bolt extension had more than ample speed and power on its recoil stroke, even with the strongest driving spring obtainable, it was returning to battery so slowly that many types of malfunction resulted. The ever-present "faint-strike" still headed the list. High-speed photography revealed that the barrel return spring, while returning to its normal position after recoil compression, could shift so that the coils rubbed the bolt extension. After a 15° cut was filed 1/4-inch deep along the entire length of the forward upper left-hand part of the bolt extension,



Figure 7-18. Complete disassembly of the original 20-mm Shirgun.

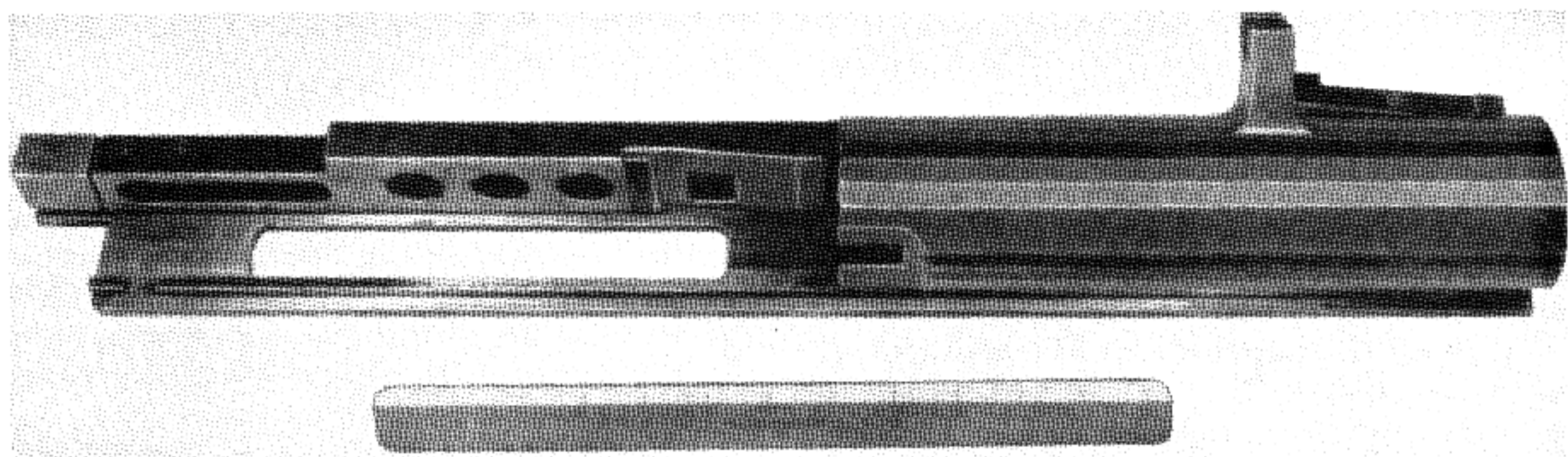


Figure 7-19. The barrel extension of the original 20-mm Shirgun.

this friction was eliminated and the number of light-struck primers was cut down noticeably.

In an effort to reduce this prevalent malfunction further, a heavy single spring (taken from another gun) with a weighted insert was used in lieu of the three-spring firing pin assembly that was originally issued. The three-spring assembly having repeatedly failed to fire the first round, this weighted position in the firing pin and single spring fired every round when there was no obstruction of the cocking lug in the firing pin's path. It was used during the test until a similar single spring was designed by the Naval Gun Factory. The experiment proved conclusively that the remaining "faint-strikes" were happening in the last  $\frac{8}{10}$  inch of travel of the bolt extension, in other words, from the point of the release of the firing pin to its farthest travel forward.

The weapon was delivered with a set timing of .501 from battery, and the bolt extension required a speed of no less than 8 feet per second during this interval in order to carry the cocking lug out of the path of the faster traveling firing pin lug. Because of this arrangement, it was believed that by changing the timing, allowing the bolt extension to go farther forward before searing off the firing mechanism, continuous automatic fire could be accomplished and the remaining malfunctions could be picked up by close observation. Through the process of gradual refinement, high rates of fire and longer bursts would result.

Five sear plungers were taken to the machine shop to be altered and numbered in the following manner. In lieu of the original  $45^\circ$  angle plunger that made the sear disengage the firing pin when

the bolt extension was 0.501 inch from battery, sear plunger No. 1 was made with a  $27^\circ 15'$  angle. By placing gages inside the bolt recess and in front of the bolt extension, holding back on the sear release, and shoving the entire assembly smartly forward, it was found that plunger No. 1 released at 0.307 inch out of battery. Sear plunger No. 2 was given a  $20^\circ 15'$  angle, and released at 0.272 inch out of battery. Sear plunger No. 3 was cut at  $17^\circ$  and released at 0.190 inch; sear plunger No. 4 was cut at  $13^\circ$  and released at 0.140 inch; sear plunger No. 5 was cut at  $7^\circ$  and released at 0.087 inch.

2. Removing the original sear plunger with the  $45^\circ$  angle as delivered to the Naval Proving Ground by the Shirgun Corp., sear plunger No. 1 was used in an attempt to fire. After a short burst, a "faint-strike" resulted. Sear plunger No. 2 was next used, and a longer burst was accomplished. A "faint-strike" also stopped this attempt. However, when the "faint-strike" of sear plunger No. 2 was compared with No. 1, it was found that while still most definitely a "faint-strike", the indentation in primer from plunger No. 2 was noticeably deeper. No. 3 sear plunger was then tried with the result that 42 rounds were fired, although the rate of fire was very slow and was likewise stopped by a "faint-strike". However, the indentation in the primer was much deeper than the one from sear No. 2. No. 4 gave a 51-round burst and was stopped only by a broken extractor. All primer indents were perfect. Modified sear plunger No. 5 gave a "faint-strike" by firing too close to battery, making the bolt extension rebound which caused the cocking lug to collide with the bottom of the firing pin.



3. Firing was continued using the heavy firing spring and weight, combined with the modified sears, until it was certain that the many malfunctions and consistent breakage that still plagued the weapon were from sources other than "timing" and weak firing pin springs. It was hoped by the firing officers that by close observation they could detect the remaining faulty components.

The worst performance at this point was coming from the gas cylinder group; whether by accident or intent, the weapon was deriving roughly 90 percent of its operating power from the impact of the gas piston on the face of the bolt extension. This terrific blow broke pistons and set every type of return spring in the designated space in as little as five rounds of automatic fire. The length of the "throw" of the original piston was  $2\frac{1}{2}$  inches when the shoulder bottomed at the rear of the gas cylinder. It was decided at this point to try an experiment in order to take some of the shock from the gas piston.

4. A piston was cut back from the shoulder to the lower end of the head. This increased the "throw" to  $4\frac{1}{4}$  inches after five Belleville washers for final cushioning effect were placed under it. Splines were cut in the gas cylinder guide to break the vacuum under the piston, and an adjustable device was then made to govern the forward clearance in order to lessen the travel between the end of the piston and the face of the bolt extension. The purpose of cutting the piston back was to allow it to continue to push on the bolt extension, after the breechlock was raised. This let the piston dissipate its energy on the face of the bolt extension by a long thrust movement in lieu of a short impact stroke. This not only ended for all time the gas cylinder troubles, but brought to light one of the most needed changes in the gun's design.

5. Apparently the weapon was purposely designed so that the breechlock was held down until the firing pin was carried rearward far enough to engage the sear or, in other words, completely cock before the breechlock was raised into the bolt to unlock. However, it was found that if the breechlock was allowed to remain down that long there was a retarded unlocking with the result that most of the operating power was lost. This hesitation also contributed to a great extent in the breaking of gas cylinders, pistons, cocking lugs, bolt extensions, and other parts.

6. The bolt extension lug was modified by removing metal from the rounded part which cams the breechlock down. This change resulted in earlier and smoother unlocking and an appreciable reduction in parts breakage.

The firing pin is cocked by the bolt striking the rear buffer. This method has proved highly successful, since it eliminates some of the initial shock by a smooth thrust movement rearward. After continued automatic firing was accomplished, the cocking lug proved to be inadequate. The cocking lug recess in the bolt extension was enlarged from three-sixteenth-inch to three-eighth-inch in diameter. A cocking lug of that dimension with one-fourth-inch face and an overall length of three-eighth-inch was installed. In order to prevent the bottom of the firing pin lug from camming the cocking lug down and out of engagement, it was brazed on the bottom. This modification held up successfully throughout the remainder of the test.

After a suitable cocking lug was installed, the base of the firing pin was being torn through in comparatively few rounds. Mr. Middlebrook of the Bomb-sight Shop at the Naval Proving Ground, Dahlgren, designed a gage to check the firing pin tunnel. It was found that there was a bulge in the wall directly in front of, and caused by, the upper cam on the rear of the breechlock, the unlocking impact bending the thin (0.073 inch) wall at this point. The impact of the lock being coincidental with the retracting movement of the firing pin created a resistance that allowed the cocking lug to tear through the base of the pin.

To correct this weakness, the breechlock cam was ground down until the breechlock in the unlocked position did not contact the thin wall portion. This odd malfunction was detected and remedied early and never made a reappearance in over 5,000 rounds. However, since all locks still were made with the cam of like dimensions, it was suggested that Middlebrook's gage be used frequently during future tests as a preventive measure against this malfunction.

In this series of tests, it came early to everyone's attention that the driving spring was inadequate in that it took a permanent set sometimes beginning with 1 round and no later than 5, the last 4 coils being telescoped and distorted beyond repair.

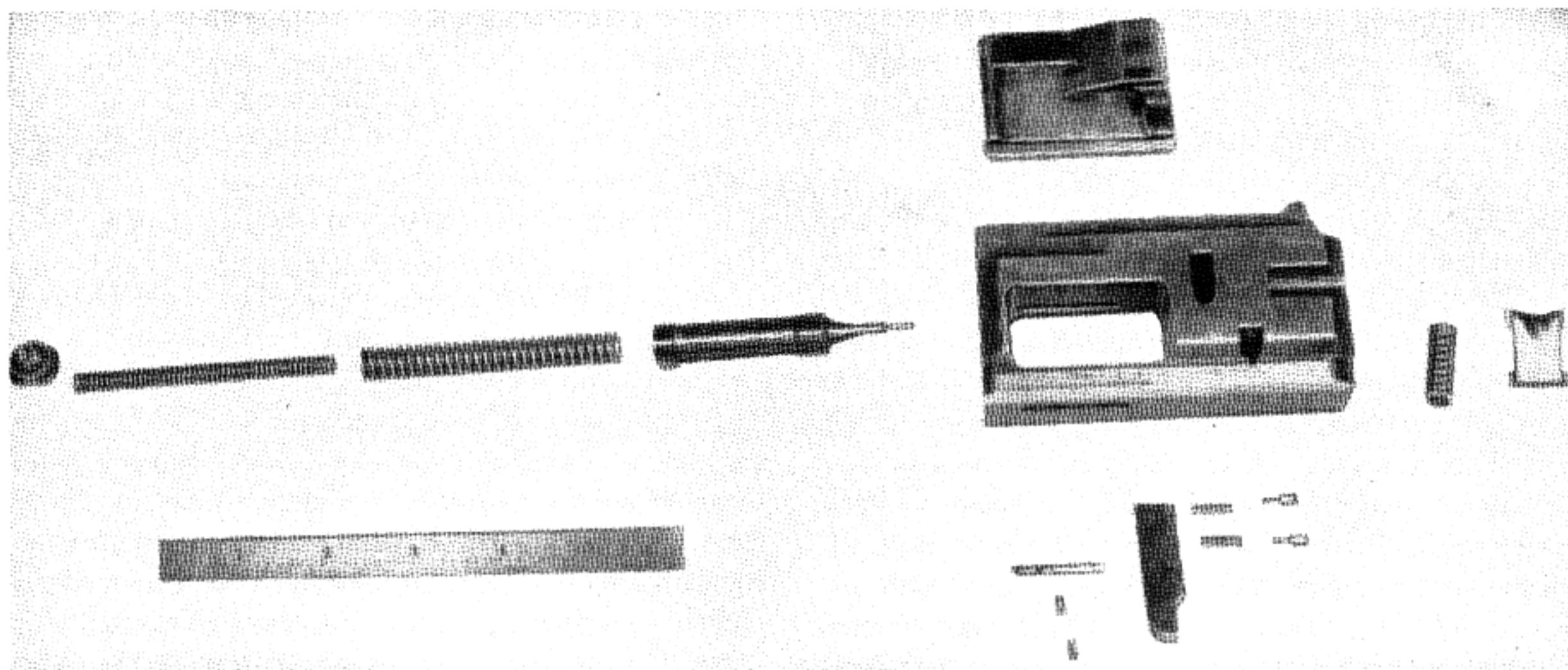


Figure 7-20. Components of the bolt of the original 20-mm Shirgun.

While it was still possible to fire the weapon, this disfiguration cut its operating power by an unknown amount. Many unsuccessful attempts were made to overcome this. Without going further into failures, Mr. J. C. Weaver, of the Naval Proving Ground, Dahlgren, Bombsight Shop, found the solution in modifying the original spring by inserting a brass bushing at the rear and under the exposed coils, thus preventing distortion. Following this modification, the gun fired more than 1,500 rounds. No setting was evident, and the modified spring was used satisfactorily throughout the remainder of the test.

It is obvious that the perfect operation of any self-loading weapon is dependent to a great extent on the limitations of its feed system, the feeder of any automatic weapon being in many respects analogous to the carburetor of a motor. It must allow the "fuel" to flow evenly and be proportioned perfectly, regardless of the variable speeds.

The initial check of its performance during automatic fire is first to be able to work it manually, for in this simple manner all points of undue friction can be located and removed. It was found with the Shirgun, on the first attempt to charge a round through, that in the last three inches of rearward travel the belt feed lever operating post located on the bolt extension exerted so much strain on the belt feed lever it would result in various types of malfunctions, the most serious of which are listed here.

1. Belt feed lever after a few rounds would loosen and fall off, it being secured by an Allen screw one sixty-fourth of an inch in diameter.

2. Bottom plates on floor would bulge down, striking operating arm and causing everything from a jammed feeder to a "faint-strike".

3. The incoming round would practically lurch into position and sometimes hit the spent case being ejected. This would prevent the bolt from going all the way rearward; and, upon returning to battery, the rammers on top of bolt would strike the sides of the incoming round, gouging out long slivers of brass and jamming it in such a manner as to make it very difficult to remove without doing permanent injury to the feeder.

4. The few rounds attempted while this situation existed showed that there was a snatching movement on the belt that under ordinary conditions would separate the average 20-mm links.

The blueprint of the bolt extension was consulted to determine whether a mistake had been made in the fabrication. It was found that the bolt extension conformed in every detail with the manufacturing drawing. It was decided to remove enough material from the bolt feed lever operating post to accomplish smooth feeding manually. Beginning at the centerline of the feed belt lever post, a hack-saw cut was made 0.087 inch to the right and angled in  $15^\circ$  as it came aft. This allowed only one point of contact with the belt feed lever slot, thereby re-

ducing friction to a minimum and permitting the weapon to be charged manually. Other feeder adjustments and minor changes also found necessary are listed here:

1. First assemble the gun with all parts in battery, remove driving spring, then pull the retracting assembly rearward until the incoming round enters the feeder mouth. Since there is no driving spring to drive the belt and bolt extension back to battery upon release of the charger handle, measurements can be made with the round properly positioned in the feeder mouth.

(a) The travel of the feed pawl carrier assembly was 1.809 inches.

(b) In order for the belt feed lever arm to clear a step on the bottom of the floor plate, there should be, when assembled, a minimum clearance of 0.071 inch.

(c) When the incoming round is properly aligned, using the projections on the belt feed lever pawl as a reference point, the distance should be 2.70 inches to a straight line across the rear of the feeder.

(d) In order that the ejector will be brought to bear on the rim of the spent cartridge case so that it is knocked down in time to clear the feeder mouth for the incoming round, the forward face of the ejector should be a minimum of 0.263 inch to the rear of the feed frame floors.

(e) The feed stop can be cut back or spacers put in front of it to bring it forward after the proper throw has been established. In order to get the desired position, the feed stop was cut back 0.080 inch.

(f) When pushing through rounds by hand or manually charging, the belt holding pawls would consistently bind on the ears of the link. It was decided that no amount of alteration could make this arrangement reliable. A substitute arrangement was made, and the original pawls were not used in the entire test.

(g) High-speed movies of the first firing showed that the two small studs that held the feeder latch in place were bending on the recoil stroke. These bolts were giving to the extent of causing friction between the floor plate and the feeder lever. Two supporting posts were made and put under the feeder at this point.

(h) The studs that held the ejector housing were undercut, making the outside diameter only one-

quarter inch. When the threads stripped during firing, the holes were reamed to three-eighths of an inch and tapped for a heavier stud.

(i) If, in the belt feed lever slot, the last eight-tenth inch of travel of the actuating post on the bolt extension rubbed the sides upon entering battery, the forward movement of the bolt extension was retarded and a "faint-strike" was partly accounted for. A relief cut was made to insure freedom of movement at this critical point.

2. After these modifications were made, the gun was considered ready for tests and subsequently was fired over 5,000 rounds without one failure which was traceable to the feeder. There was no parts replacement during the entire test; in fact, the gun was not disassembled from the time of its modification in November 1946. After each day's firing it was washed thoroughly with boiling soapy water to remove the residue of the primer salts, and oiled lightly. No other maintenance was necessary to keep it in perfect order. One reporting officer stated, "It is by far the most outstanding single piece of ordnance equipment I have ever tested."

It is impossible to overemphasize the importance of correct timing in automatic weapons; especially, the relationship of high rates of fire and longevity of component parts. There is first a timing range that merely permits the operation of the weapon. As the rate of fire increases, a more definite point of release of the searing mechanism must be established.

As the rate of fire increases, this factor becomes more and more critical. In modern design demanding light weight and very high rates of fire, we find the trend toward the system whereby the firing pin, powered by a spring, is released by a sear. This arrangement has largely replaced the antiquated method of inertia firing, whereby the firing pin is ridden home by a forward motion of the firing pin assembly after the breech lock has dropped. The latter system, while more reliable than anything known and from which equally high rates of fire can be obtained, is without a means of timing. Every round fired causes metal to metal contact, as the weapon's functioning is dependent on the whole mechanism being ridden forward after the bolt has come to a complete stop.

Any weapon designed to fire anywhere near the approximate speed of 1,000 rounds per minute

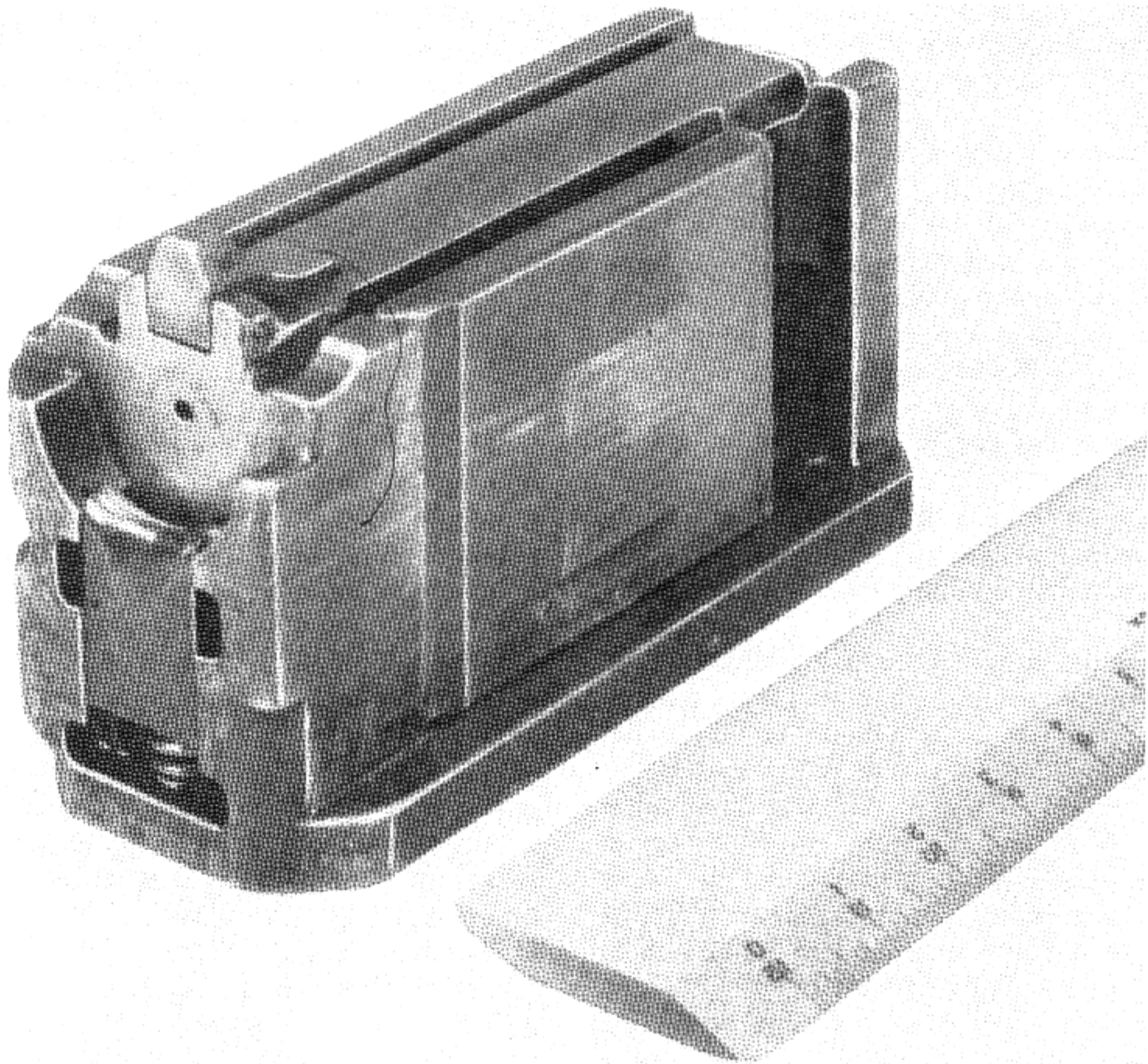


Figure 7-21. The bolt of the original 20-mm Shirgun.

using the inertia firing system must have an abnormally large firing pin, firing pin key or post, and searing device. A shuttling mass cannot be stopped with delicate components.

Shirgun No. 1, as designed, apparently attempted to incorporate both features in its firing system. It utilized the spring loaded firing pin and sear, and, as if to undo this very excellent system, it also had a sear release located on the bolt extension operating in the manner of inertia firing systems.

To further complicate matters, on the same bolt extension that housed the sear release was located the cocking lug whose position had to be taken into consideration in order that the sear be tripped when the cocking lug was out of the path of the firing pin. This latter fact gave Shirgun No. 1 the dubious honor of being the only weapon known that re-

quired the timing of an appendage of the bolt (the bolt extension) and not the bolt itself in order to make it fire. A major contributing force that drove the bolt extension home after the breech lock dropped was the driving spring. Even the condition and surges of the driving spring were a factor.

It was suggested that this abortive method of cocking and searing be removed from Shirgun No. 1 as soon as possible. The sear release could be synchronized so that the breech lock's dropping into locked position removed an obstruction from the firing pin's path. This held the firing pin "safe" until the weapon was securely locked.

In the original cocking system, the firing pin spring set after a few rounds of high rates of fire from the terrific impact of the cocking lug. The slow camming method of firing pin compression, a

design which employs over 7 inches of recoil movement in compressing the firing pin springs the small amount necessary to allow the sear to engage, was proposed. It was pointed out that there are many other machine guns that cock by slow retraction and their firing pin springs have a life expectancy of thousands of rounds and function at rates of fire higher than that demanded of the Shirgun.

There was listed in the original nomenclature of Shirgun No. 1 a part called the "throttle." This device metered the amount of gas from the barrel port through the gas cylinder bracket and finally onto the face of the gas piston. The speed of the weapon was regulated by merely turning the "throttle" the necessary number of turns in the desired direction. However, it was found that the "throttle" had only two settings, "too little" or "too much." As it was imperative that this critical feature be definitely under control before any great amount of firing be attempted, it was locally modified to workable condition.

After sustained bursts were accomplished, however, this modification was dropped altogether in favor of graduated orifices, resulting in a stepped adjustment for rate of fire depending on the size of orifice used. Shirgun No. 1 had the port in the barrel one-half inch out of position, and, to compensate for this mistake, a recess was cut from the abnormally large barrel opening leading to the port in the gas cylinder bracket. This made the gas come through the orifice in the barrel, turn right 90° for one-half inch, then make a 90° left turn upon reaching the port in the gas cylinder bracket. In other words, the gas made two turns before acting on the piston.

It was pointed out that it was inconceivable to think that the location of the 0.250-inch barrel orifice not be changed to align with the gas cylinder bracket port and reduced in diameter to 0.125 inch as the existing size was beyond all reason for the amount of work expected.

With a simple device on the side of the frame and the rear of the buffer to measure barrel extension and buffer recoil, a series of experiments was run to determine the point at which to unlock to get maximum buffer compression with a minimum amount of gas pressure working on the piston. It was found, with a five-eighths turn on the modified gas port working in conjunction with all the

other modifications (such as cutback piston, 0.035-inch clearance between breechlock and bolt extension, etc.), that the breechlock rose into unlocked position after the barrel and barrel extension had recoiled six-tenths inch and that the bolt and bolt extension continued rearward with such force as to compress the buffer springs until the back of the bolt was striking the buffer housing. Even with this full compression, the rate of fire was only 700 to 750 rounds per minute.

The continued mutilation of the bolt and the inability to raise the rate of fire made it necessary to discard the original springs. The work required for the changeover and the various springs employed were as follows.

1. The barrel return spring of the 20-mm T31 cannon was used for the outer spring. It fitted the buffer housing without alteration.

2. A recoil spring from the Edgewater adapter of the British Mark II 20-mm cannon was cut to proper length and turned down to nest in the outer spring.

3. To strengthen the assembly further, a rear buffer spring of a 20-mm M2 was placed inside the second spring. Two horn fiber inserts were put fore and aft of the spring assembly to prevent metal to metal contact.

The addition of the third spring gave the strength required. For a makeshift arrangement, it gave satisfaction beyond all expectations. Bursts of up to 200 rounds and at various rates of fire, up to 900 rounds per minute, or only 45 rounds slower than Shirgun's oil buffer, were fired without buffer failure. Shirgun's liquid spring arrangement was considered an outstanding buffer, but the three spring buffer was considered a reliable alternate.

In helping stop the barrel and barrel extension on the recoil movement, there was, besides the barrel return spring, an oil filled tube also called the "oil buffer." If the gas was cut completely off from the piston so that the weapon made no attempt to unlock, then the barrel and barrel extension recoiled as much as 1 7/8 inches. However, when the gas was bled into the gas cylinder in sufficient quantities to cause unlocking and automatic fire, the recoil of the barrel and barrel extension was interrupted by the act of unlocking, the travel rearward of the barrel and barrel extension being in direct relationship to the speed employed in unlocking. For example,

with a 0.161-inch orifice and a speed well above 850 rounds per minute, the barrel and barrel extension recoiled only six-tenths inch rearward before being returned home by the barrel return spring.

Shirgun No. 1 was fired well over a thousand rounds with the oil buffer less than 1/4 full, with noticeably smoother performance. It was suggested that a similar test be carried on by Shirgun, and further suggested that a flat barrel return spring be designed (in lieu of the round type) that would compress relatively easily the first one-half inch and then build up load rapidly. This would allow the gun to unlock while the barrel and barrel extension were still traveling rearward at high speed, materially increasing the rate of fire.

The designers of this machine gun overlooked the fact that when the earlier 20-mm "blowback" action speeds of 600 to 650 rounds per minute were left behind and 1,000 rounds per minute and above were attempted, there should be some provision made for initial extraction whereby the empty cartridge case still under high gas pressure would be "jacked" back gradually a few thousandths of an inch, breaking the gas seal and freeing the empty brass before the main snatching movement of extraction took place. Unless this very important feature is incorporated in high-speed weapons it is impossible to get long bursts without a very noticeable "stuttering" effect.

As a future "yard stick" for experiments that would be run on other Shirguns and their component parts, the following information was offered on longevity of parts, rates of fire, and length of bursts:

Highest rate of fire with modified (coiled spring) buffer: 900 rounds/minute.

Highest rate with Shirgun "liquid spring" buffer: 906 rounds/minute.

Of a total of 6,721 rounds, it was possible to fire the following length bursts:

1 burst of 200 rounds . . . . .	200
9 bursts of 100 rounds . . . . .	900
5 bursts of 75 rounds . . . . .	375
35 bursts of 50 rounds . . . . .	1,750
55 bursts of 25 rounds . . . . .	1,375
<hr/>	
Total . . . . .	4,600

Barrel assembly over 6,000 rounds: Original part.  
Gas cylinder over 6,000 rounds: Original part.

Gas piston over 6,000 rounds: After being modified 13 November 1946.

Breechblock over 6,000 rounds: Original part.

Oil buffer over 6,000 rounds: Original part.

Feeder over 6,000 rounds (Has not been disassembled in over 6,000 rounds): One broken part (ejector housing) occurred at 5,753 rounds.

Bolt 4,753 rounds longest life.

Firing pin 1,053 rounds longest life. (Shortest life 50 rounds.)

Firing pin spring 1,053 longest life. (Shortest life 25 rounds.)

Modified buffer over 5,000 rounds.

Bolt extension 2,016 longest life.

Sear 3,565 rounds. (Removed and modified by mistake.)

Driving spring with Weaver modification 1,605 rounds longest life. (Shortest life 10 rounds without modification.)

Cocking lug: Average above 1,500 rounds.

*Conclusions.* Since the type 1 gun was to be followed by the type 2 gun which more nearly resembled the final design, no conclusions were submitted on the type 1. The latter appeared to have sound operating characteristics but it was felt that many more tests and much more firing was required. Work continued, and subsequent reports both formal and informal were submitted as progress was made. Recommendations that were eventually made for improvement of the type 1 gun follow.

*Recommendations.* As a result of the test firing done at the Naval Proving Ground before 15 April 1947, it was recommended that the following steps be taken to improve the operation and functioning of the gun:

1. That the Naval Proving Ground be supplied with the latest type twisted coiled wire driving springs and firing pin springs as used at that time by the Shirgun Corp. Considerable investigation work should be done in the functioning of these springs and the recoil spring, as the test firing to date indicated that surging or bottoming due to surging, of all of the springs had a detrimental effect on the gun operation and the life of the springs.

2. That the Naval Proving Ground be supplied with oil spring type rear buffers to replace the coil spring rear buffers.

3. That the Naval Gun Factory continue its very effective and productive studies and design changes, particularly in the improvement of the metallurgy of gun parts, and the manufacture of spare parts.

4. That a production-type feeder and receiver be supplied in place of the mockup-type feeder and extra-wide receiver installed on the gun at that time. It was suggested that in case the production type feeder was not available, the feeder in use at the Naval Proving Ground should be supplied with properly hardened link guides, floors, and stop pawls, as then in use at the Shirgun Corp.

5. It was stated that the following gun assemblies and parts required redesign as a result of the test firing, and the Naval Proving Ground would forward sketches of suggested improvements, which are described below.

(a) Firing Pin. Tip made as a straight sided cone with round end.

(b) Ejector. Face angle of prongs made closer to perpendicular (approximately  $10^\circ$ ) instead of  $45^\circ$  to reduce the upward thrust of the spent case on the feeder and the breakage of the extractor stop.

(c) Sear. Angle of contact with front face of firing pin lug changed to give a positive full release of the firing pin and not an angular release.

(d) Sear Plunger. Change to a pivoted type in place of sliding type in order to reduce breakage and to cut down resistance to the bolt extension on its forward travel.

(e) Gas cylinder. Enlarge front section so that threads cut both inside and out do not weaken the side wall thickness.

(f) Feed operating lug on bolt extension. Change to roller bearing type to reduce wear.

### Tests and Development Work at NAOTS, Chincoteague, Va.

On 26 November 1947 an aviation ordnance conference was held at the Naval Gun Factory for the purpose of setting up the development program of the low profile aircraft machine gun. (The low profile gun is another name for the EX 1 type 2.) One outcome of the recommendations of this conference was the initiation of a project at Naval Aviation Ordnance Test Station, at Chincoteague, Va. The purpose of this project was to perform developmental and functional firing of the 20-mm single

barrel gun EX 1 type 1, to improve the operating principles, reliability, and parts life.

*Summary of Earlier Development at Dahlgren.* During functional firing of the weapon at the Naval Proving Ground, Dahlgren, described earlier in this section, it was observed that the method of cocking then employed resulted in such an impact force as to permanently set and deform the firing pin spring to the point of uselessness in as few as 2 or 3 rounds. It was decided then that the gun could not be given a fair test until the cocking action was improved. One method of accomplishing this is to use a slow camming action in the process of cocking the weapon.

A "quick-fix" was attempted at the Naval Proving Ground by cutting the bolt extension away so that it allowed the breechlock to rise before the weapon was cocked, and the bolt to go rearward to the buffer before the bolt extension compressed the firing pin beyond the sear. In addition, long belts of ammunition were used so that the greater pull could help slow down the action and reduce the impact on the firing pin spring. This crude method not only raised the life of the firing pin spring but definitely singled out the cocking system as being the "bottle neck" in future testing of the weapon.

#### *Chronological Record.*

8 DECEMBER 1947. Date of project directive.

11 DECEMBER 1947 TO 8 JANUARY 1948. Five guns were received at Chincoteague.

5 JANUARY 1948. Modification of cocking system and breechlock was commenced.

20 JANUARY 1948. Commenced proof firing of modified cocking system and breechlock in gun No. 4.

2 FEBRUARY 1948. Commenced firing gun No. 1 with modified cocking system and breechlock.

18 MARCH 1948. Demonstration firing of modified gun for the Bureau of Ordnance.

9 APRIL 1948. Demonstration firing of modified gun for the Bureau of Ordnance and the Ordnance Corps.

*Conduct of the Test.* To attain the objective it was planned to conduct the test in the following manner:

1. Determine the cause of malfunctions occurring in previous test firing at the Naval Proving Ground, Dahlgren, Va. Specifically these malfunctions were:

(a) The firing pin spring was being permanently set and deformed.

(b) The breechlock was also deforming to such an extent that it had to be replaced after firing a few rounds.

2. Make modifications as required to overcome these malfunctions.

3. Conduct test firing to prove the above modifications and to determine if any further improvements could be made to the gun.

*Physical Equipment.* The 20-mm single barrel gun EX 1 type 1 is a low-profile, automatic, gas-operated, belt-fed, air-cooled weapon firing standard 20-mm ammunition and utilizing a caliber .50 type feeder.

*Operation of the Gun.* The gun was set up for firing on a rigid ground mount on an outdoor range. The belted ammunition was fed to the gun through a flexible ammunition chute attached to the feeder. The gun was initially charged and fired manually since no automatic charging and firing mechanisms were furnished with the gun for this test.

*Tests Conducted and Discussion.* It was determined from visual inspection that the firing pin

spring malfunction was being caused by the nearly instantaneous cocking action of the firing mechanism. The cocking system was such that the firing pin spring was compressed and cocking accomplished in the first 0.483 inch of bolt extension rearward travel during recoil. The recoil motion of the bolt extension, derived from the high pressure propellant gas acting on a piston, resulted in an impact force on the firing pin lug and a nearly instantaneous compression of the firing pin spring.

To correct this situation, it was deemed desirable to modify the cocking system so that the cocking action would be a gradual motion. This was accomplished by utilizing an elbow linkage joining the bolt and firing pin, cammed by a surface of the barrel extension. As installed, the linkage and cam surface required  $7\frac{5}{16}$  inches of bolt recoil to retract the firing pin lug one-sixteenth inch beyond the rear face of the sear, thus allowing a comparatively gradual compression of the firing pin spring. In order to install the linkage and cam arrangement, the following alterations to components were necessary:

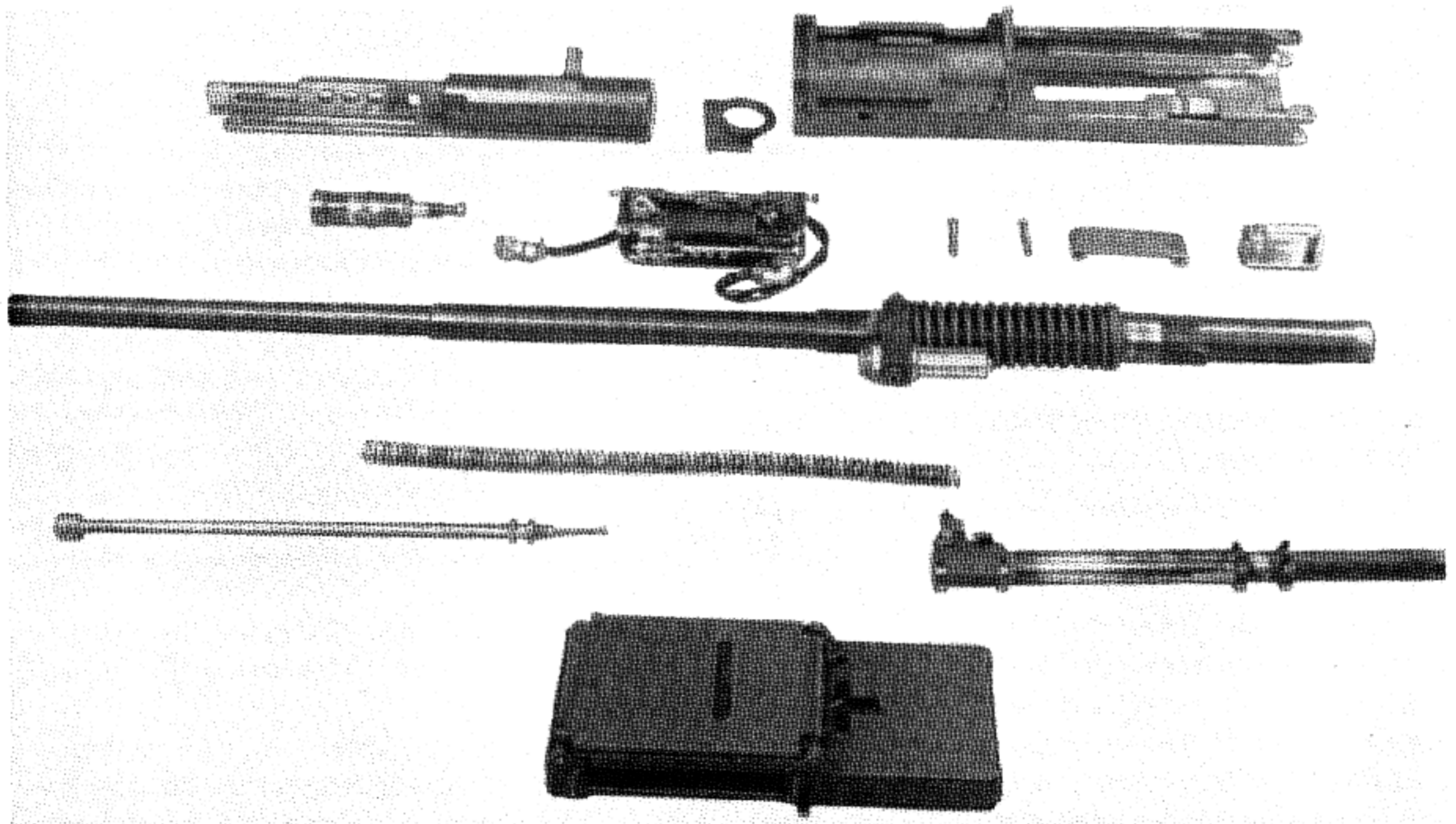


Figure 7-22. Partial disassembly of the original 20-mm Shirgun.



1. A portion of the upper left side of the barrel extension was cut away to permit mounting of the camming surface.

2. The breechlock was reduced in width to allow clearance for the linkage system.

3. A lug was silver soldered to the left side of the firing pin in order to connect it with the linkage.

Mutilation of the breechlock in previous firing tests of this gun was determined to be caused by the bolt extension failing to clear the breechlock before unlocking took place. This fault was corrected by removing metal from the after face of the breechlock until there was 0.035-inch clearance between this face and the bolt extension. This clearance is measured in the following manner:

1. Remove firing pin and spring from bolt.

2. Place bolt and breechlock on bolt extension and slide forward into receiver until breechlock is half covered by friction plate.

3. Hold bolt and pull bolt extension rearward until it strikes rear of bolt housing.

4. With the assembly positioned as above, check for 0.035-inch clearance between after face of breechlock and bolt extension.

No further modifications to this gun were found to be necessary, in order to fulfill the task objective, during the test conducted.

A total of 2,900 rounds was fired through the experimental weapon for test and demonstration purposes. Firings ranged from single shots to several bursts of 75 rounds.

*Summary of Results.* After the above modifications were incorporated in the subject weapon,

approximately 2,600 rounds were fired to the completion of the test without stoppage or parts failure. Inspection of the gun after this firing revealed no undue wear on any part.

*Conclusion.* The operating principles, reliability and parts life of the gun have been improved in that:

1. The life of the firing pin and firing pin spring has been increased indefinitely through the incorporation of a locally designed cocking system, which for the period of this test (about 2,600 rounds) functioned satisfactorily.

2. The breechlock, as modified locally, performed satisfactorily during the period of this test without showing evidence of wear.

3. The weapon, as a whole, after modifications above had been made, satisfactorily fired about 2,600 rounds including several bursts of 75 rounds.

*Opinions Formed.* None.

*Recommendations.* That the modifications made on the gun during this test be studied and refined by a competent engineering agency for possible incorporation into future guns of similar design.

### Conversion to Recoil Operation

Subsequent to the tests and development work on EX 1 type 1 gun No. 1, which were held at NAOTS, Chincoteague, Va., between January and April 1948, an experiment was commenced to replace the gas operating principles of the Shirgun with a recoil system. This experiment is described in section 7 of this chapter.

## SECTION 3. TESTS AND DEVELOPMENT OF 20-MM MACHINE GUN MECHANISM EX 1 TYPE 1, GUN NO. 3

In October 1946, the Bureau of Ordnance directed that the Naval Proving Ground conduct proof firing tests of five 20-mm machine gun mechanisms EX 1 type 1. In addition, the Bureau directed that experimental ground firing tests be conducted on 3 of the 5 guns; the other 2 guns were to be shipped to the Shirgun Corp. upon completion of proof firing.

The experimental ground firing was for the purpose of obtaining functional firing data on all components of the guns, life of parts, etc. Specific data were requested on the belt pull, rate of fire, trunnion

reactions and muzzle velocities with a 67.5-inch and a 52.5-inch barrel length.

The Naval Proving Ground was also requested to conduct whatever tests seemed necessary in connection with the above work and was to keep the Bureau of Ordnance, the Naval Gun Factory, and the Shirgun Corp. informed of the firing data obtained. In addition, regular conferences were to be held as the work progressed.

The tests were conducted at Dahlgren between 15 October 1946 and 15 April 1947. The following material was used:

1. 20-mm service aircraft ammunition AP-T, M95, of various lot numbers.
2. 20-mm calibrated standard ammunition, M97, inert loaded, Lot PA 47-1.
3. 20-mm proof ammunition (120 percent normal powder pressure). Lot 22349-3.
4. Audio-Velograph equipment for obtaining rates of fire.
5. Electronic resistance type strain gages, recording oscillograph, and drum-type camera for obtaining time-force displacement curves.
6. Hydraulic equipment for testing springs and rear buffer.

During the test work various officers and civilian personnel of section Re8 of the Bureau of Ordnance, the Aviation Ordnance section of the Naval Gun Factory, and the Shirgun Corp. witnessed the firing. The conduct and results of the tests appear here in substantially the same form as in official reports prepared in connection with the projects. No editorial comment has been added. The body of the report pertains to gun No. 3.

### Description of Material Tested

The 20-mm Shirgun EX 1 type 1 (prototype) is an automatic, gas-operated aircraft weapon, with a semiintegral feed mechanism. The overall length, with the 67.5-inch barrel, is 89.5 inches; the maximum height, with the feeder installed, is 7.25 inches; and the maximum width of the receiver is 7 inches. The addition of a pneumatic or hand operated firing mechanism which was supplied with the guns, on the side of the receiver, increases the maximum width to 8 inches.

The barrel is the same as is used in the 20-mm AN-M2 aircraft gun with the addition of interrupted threads on the chamber end of the barrel to make it quickly detachable, and an enlarged gas port ( $\frac{1}{4}$  inch diameter). The Shirgun bolt is positively locked in battery at the time of firing by a side-mounted lock which is cammed into the locked position against a lock plate mounted in the barrel extension by action of the forward movement of a bolt extension. The bolt carries an internal spring-loaded firing pin which is seared to fire, by a sear plunger mounted in the bolt extension, when the bolt extension is 0.501 inch out of battery.

The initial recoil force of the gun is absorbed by a heavy recoil spring mounted on the barrel. The

final recoil force is absorbed by an oil-filled orifice type recoil buffer mounted on the upper left side of the gun, in addition to the spring. All the counter-recoil force is absorbed by the above oil buffer. The bolt recoil is absorbed by a coil spring near the buffer.

The gas system has a screw-type adjustable vent between the barrel gas port and gas cylinder. Belted ammunition is fed into the feedway above the path of the bolt on the recoil stroke by action of the bolt extension on the feeder, the bolt extension being driven to the rear by the gas piston. The bolt extension, in addition, unlocks the bolt on its rearward travel stroke.

The ammunition used was service issue 20-mm aircraft ammunition for the AN-M2 or M3 (T31) guns, belted with M7E3 links (Army Ordnance drawing No. D-7230014). These links are required by the Shirgun feed mechanism.

### Description of Tests

Upon receipt of the first four guns, a measurement check was made of all the parts against a complete set of Shirgun drawings that were furnished by the Naval Gun Factory. All springs were calibrated at the lengths specified by the drawings and recorded. Barrel rifling and chamber measurements were also made. A set of drawings was maintained throughout the test for each one of the guns and any substitution or change in the parts of the gun was recorded on the set of drawings for the gun or on a new drawing inserted in the set.

The four guns were proof-fired as directed by the Bureau of Ordnance, by using 5 single shots. The proof ammunition used was obtained from Aberdeen, lot 22349-3, calibrated to produce 120 percent of normal chamber pressure at 70° F. During the proof firing, the guns were completely assembled and the barrel gas valve was closed. The guns were disassembled and inspected after each proof round. The requirement for the firing of two 10-round bursts of standard ammunition as part of the proof firing was attempted on all guns. This could not be accomplished on any of the guns during the proof firing and was waived in the case of the gun that was earmarked for shipment to the Shirgun Corp. by direction of the Bureau of Ordnance. This gun was shipped to the Shirgun Corp. on 29 October 1946.

The 3 guns that remained at the Naval Proving Ground were test fired to obtain functional firing data of parts and components, life of parts, both of the original design and of new or modified design developed during the test as a result of studies made of the firing results. All firing was done with service issue 20-mm M95 APT ammunition, except when a particular test, such as obtaining rates of fire, velocities, etc., warranted the use of calibrated standard ammunition.

Both oiled and waxed cases were used during the test. Although the use of ceresin wax is standard for use on this ammunition at the Naval Proving Ground, oiled cases were used in order to duplicate closely the test being conducted by the Shirgun Corp., in New York. All firing was conducted at ambient temperatures from rigid mounts. Although all the test firing conducted up to 15 April 1947 is included in this report, the complete life of many parts had not been determined. Parts that broke or otherwise failed during the firing have been replaced with spare parts on hand of original design or with modified or newly designed parts. The modified or newly designed parts were manufactured almost entirely by the Naval Gun Factory and were designed by that activity, the Naval Proving Ground, or the Shirgun Corp., as provided by Bureau of Ordnance directives. As specifically directed by the Bureau, the following functional data was obtained: maximum belt pull, rates of fire at various belt loads, and muzzle velocities with the 67.5-inch barrel. The short, or 52.5-inch, barrel had not been received when this report was written. Trunnion reactions had not been obtained. In addition to the data specifically requested by the Bureau, time-travel studies of the recoiling parts and force-displacement studies of the hydraulic recoil buffer were made. Generally, one gun was allocated to firing with parts and assemblies of the original design, one gun was allocated to the testing of modified or newly designed parts, and the third gun was used for functional studies. Time-travel data were obtained by using a drum type recording camera with light reflectors mounted on the recoiling gun parts, the movements of which were recorded. Force-time data were obtained by using electronic resistance type strain gage equipment and a recording oscillograph.

The fifth Shirgun was received from the Naval Gun Factory on 30 January 1947. The gun, although originally destined for shipment to the Shirgun Corp., was retained at the Naval Proving Ground with the approval of the Bureau of Ordnance, and the second gun received was delivered to a representative of the Shirgun Corp., on 5 February 1947.

Commencing on 1 November 1946, the Naval Proving Ground issued weekly test firing notes covering all phases of the firing each week, which were forwarded to the Bureau of Ordnance, the Naval Gun Factory, and the Shirgun Corp. These notes were not issued after 6 February 1947. At this time there was a reduction in the amount of test firing conducted as a result of the completion of the first phase of the firing on 1 February 1947.

Up to this time, four conferences had been held as follows: 29 October 1946 and 21 November 1946 at the Bureau of Ordnance, 10 December 1946 at the Naval Proving Ground, and 3 February 1947 at the Naval Gun Factory. These conferences were for the purpose of reporting progress by all of the agencies involved in the test, the Naval Proving Ground, the Naval Gun Factory, and the Shirgun Corp. The conferences proved very beneficial.

### Discussion

Considerable difficulty was experienced during the early stages of the test and also to a lesser degree throughout the test, in regard to maintaining a complete set of approved gun drawings. As a result of discrepancies in and changes made to the original drawings a standard sketch list of drawings was established as of 1 November 1946. Due to the many changes made in gun part design by all agencies engaged in the test work it was not possible to maintain an accurate approved list of sketch numbers and drawings. As a result, it was difficult to determine exactly what was and what was not approved or proven.

The guns as received from the Naval Gun Factory were prototypes. Some of the parts did not adhere strictly to the drawings in regard to finish, tolerances, and heat treatment. As a result, prior to firing, each gun had to be carefully checked and all rough spots or finish of moving parts removed. A limited amount of stoning was required in order

to get the moving parts, particularly in the feeder, to operate freely.

An accurate analysis of the life and function of each standard part and replacement parts of changed design was not included in the report.

Changes in manufacture and redesign work was done during the test by the Naval Gun Factory on the following assemblies and parts. The life of these parts and the reasons for redesign were covered in the weekly firing notes submitted by the Naval Proving Ground:

1. Gas cylinder piston: Change in heat treatment.
2. Breechblock extension: Redesign for greater strength.
3. Cocking lug: Redesign for greater strength.
4. Driving spring: Redesign for increased life.
5. Firing pin spring: Redesign for increased life.
6. Firing pin: New material and different heat treating to increase life.
7. Extractor: Redesigned for better operation.

#### *Successful Part Changes Made.*

**GAS CYLINDER GROUP.** Due to failure of the gas cylinder piston early in the test, steps were taken as follows to improve a Rockwell hardness of C52 to C54 throughout (Sk 194332). This effectively reduced the peening of the piston rod on contact with the forward face of the bolt extension. In addition, the manufacture was improved by replacing undercuts, at the juncture of the rod and shoulder and the shoulder and the piston proper, with fillets (Sk 194332). Records showed early in the test that the gas cylinder piston spring was inadequate to withstand the high impact forces of the piston and return it to the forward position. The springs set rapidly and high-speed pictures showed that the piston was not being returned. As a substitute for the spring, a nest of five Belleville type washers was tried (Sk 194357). These worked satisfactorily but transmitted the shock loading to the gas cylinder which broke at its thinnest section, the threads on the forward end. Two steps were taken in an attempt to absorb or dissipate the impact energy of the gas piston. These were not proven, but apparently were satisfactory. First, an adjustable plug (NPG Sk 235017) was made for insertion in the forward end of the cylinder in order that the free travel of the piston prior to its contact with the bolt extension could be reduced and controlled, thus reducing the contact impact. The best or correct clearance to

be used between the piston rod and the bolt extension was not determined exactly but was between 0.000 inch and 0.006 inch. Secondly, the shoulder on the gas piston rod was removed to accommodate a heavier gas cylinder spring. It was found that without this spring the longer stroke of the piston apparently was beneficial as it allowed the piston to follow the bolt extension on its rearward travel, dissipating the energy over a longer travel. High-speed motion pictures were planned for this last action. It was reported that the Shirgun Corp. confirmed this improved action. Further investigations were planned at the Naval Proving Ground on this and the subject of return of the piston to its forward position by use either of a bypass gas type cylinder (NPG Sk 235010) or back pressure developed by leakage past the piston. Both made a gas cylinder piston spring unnecessary. One gas cylinder tested was drilled to allow gas that leaked to the rear of the piston to escape. High-speed motion pictures showed that this piston, when no spring was used, stayed extended and was returned to its forward position by contact with the bolt extension. This did not appear advisable due to the fact that the bolt extension should be allowed to return to battery as smoothly as possible. The screw type gas vent control on the guns was not proven adequate for close adjustment, and a small amount of preliminary work was done on the use of small orifice plug type vent controls to meter the gas from the barrel to the gas piston.

**DRIVING SPRING GROUP.** It was apparent from the first of the test that the coiled wire driving springs (two nested) were inadequate to withstand the impact forces of the heavy recoiling bolt and bolt extension assemblies. The coils at the rear of the spring were damaged by a few rounds of firing. This was assessed as due to surging of the spring under heavy loads. High-speed motion pictures taken by the Shirgun Corp. showed that the rear of the spring left its seat due to surging. A driving spring assembly with a felt washer at the rear (Sk 194287) was tried; this produced an improvement in the life of the spring but was still unsatisfactory. In an effort to guide the rear unsupported coils of the spring when the bolt extension was in the forward part of its travel, a 15° chamfer was cut on the rear of the bolt extension inner circumference in order to prevent any enlarged coils from being

caught as they entered the bolt extension. Also 32 coils of the inner spring were removed in order to install a 3-inch guide sleeve in the rear of the spring assembly to keep the rear coils of the outer spring from distorting (NPG Sk 235019). This met with success as far as it was tested but was considered a secondary improvement in view of the success reported by the Shirgun Corp. with the use of twisted wire driving springs (Sk-347-20). None of these latter springs had been received at the naval proving ground.

*Rear Buffer Group.* The first time-travel data obtained at the Naval Proving Ground and reports received from the Shirgun Corp. indicated that the coil spring rear buffer supplied with the guns was of low efficiency in storing and returning the energy of the bolt assembly. A rear buffer employing Belleville type washers was received from the Naval Gun Factory, and this gave an increase of approximately 10 percent in the rate of fire. A rear buffer was assembled at the Naval Proving Ground using ring springs taken from other 20-mm guns, and this also gave an increase in the rate of fire. Further improvements in these two types of rear buffers, although possible, was not undertaken as a new hydraulic oil spring type of rear buffer was received from the Shirgun Corp. which was of high efficiency and gave higher rates of fire than any of the other types. Steps were taken to obtain two more of this type of rear buffer so that all Shirguns at the Naval Proving Ground could be equipped with them.

**BOLT EXTENSION ASSEMBLY.** Malfunctions of the bolt extension occurred as follows: Transverse fracture across the rear tube section, fracture of the bolt extension at the cocking lug hole, fracture of the cocking lug, fracture of the web section at the sear plunger slot, and breakage of the sear plunger. This assembly was the source of the most trouble in the gun. Bolt extensions were very difficult to manufacture; as a result, replacements were hard to obtain. Changes and modifications were made in attempt to prevent these breakages, some successful or partially successful. The cross section of the tubular section of the bolt extension was increased and the form changed by the Naval Gun Factory. Cracking at the cocking lug hole was reduced in frequency by brazing the cocking lug at the bottom to hold it in place rather than using a tight press fit, which apparently was the cause of the fracture at

this point. Breakage of the cocking lug mounted in the bolt extension was very frequent, having occurred in some instances during manual charging of the gun. Some improvement in the performance of the lugs resulted from enlarging and strengthening them (Sk 194354) and by improving the quality of the metal and heat treatment. The cause of the breakage was found to be due to contact of the cocking lug with the right side of the bolt cocking lug slot at the instant of unlocking. Contributory causes were believed to be excessive clearance between the bolt extension and the receiver side wall, which is accentuated by an elastic deformation of the receiver wall under the stress produced by the lock thrust on the bolt extension.

**BOLT ASSEMBLY.** The three nested coiled wire type firing pin springs supplied originally with the gun were repeatedly proven inadequate. This was another indication that unusually high resistance or impact forces were present in the firing pin-cocking lug assembly. A single coil wire spring of higher strength was used with moderate success, but one twisted wire spring supplied by the Shirgun Corp. proved more successful and apparently was adequate. In conjunction with the spring changes, the firing pin spring bayonet plug supporting the rear of the spring was strengthened by adding more metal through the center section, and breakage ceased. Improvement in the type of metal used and increasing the hardness of the firing pin apparently effectively reduced malfunctions of this piece, which occurred frequently early in the test. The malfunctions were broken firing pin tips and wear on the rear bottom lug on its front face which contacted the cocking lug. The extractor claw was modified during the test by cutting metal off the claw tips and modifying the contour of the claw face. It was found that lubricated ammunition cases were blown out of the chamber and ejected from the gun in automatic fire without an extractor installed on the bolt, which indicated that this gun operated partly by blowback of the residual chamber gases and that the extractor, while still required, did not need the positive grip on the case originally designed in it. The modifications just described aided the ejection by allowing the ejector to roll rather than lift the case out over the extractor claw.

**PRELIMINARY INVESTIGATION AND FIRING DONE ON ADJUSTING THE TIMING OF THE GUN.** This

work was closely tied in with the investigation of the proper gas vent size and the rate of fire. The original timing of the guns, as delivered to the Naval Proving Ground, was set for firing 0.501 inch out of battery. The highest rate of fire obtained on any of the three guns indicated that this was the correct timing for the gun when it was firing at approximately 1,000 rounds per minute.

**General Data**

*Comparative Dimensions.* The dimensions of the EX 1 Type 1 as compared with the AN-M3 20-mm gun are as follows:

Dimension	EX 1 Type 1	AN-M3
Maximum overall length (inches)	89½	77½
Length of barrel (inches)	67½	52½
Maximum height with feeder (inches)	7¼	<sup>1</sup> 11½
Maximum width (inches)	6⅞	5⅞
Maximum width with firing mechanism (inches)	8	.....

<sup>1</sup> M2 feed.

*Comparative Weights.* A comparison of weights of the EX 1 type 1, the AN-M3, and the T34 20-mm gun is as follows:

Total weight EX 1 type 1 with feeder: 194.0 pounds.

Total weight AN-M3 (T31) with M2 feeder: 118.5 pounds.

Total weight T34 with M2 feeder: 119.5 pounds.

Weight of EX 1 type 1 bolt assembly, bolt extension, lock, etc., minus driving spring assembly (bolt recoiling parts): 9.18 pounds.

Weight of AN-M3 bolt assembly complete with slides and lock (bolt recoiling parts): 6.74 pounds.

Weight of T34 bolt assembly complete with slides and lock (bolt recoiling parts): 5.36 pounds.

*Functional Characteristics of the Shirgun EX 1 Type 1.*

**VELOCITY.** Measured as 2,767 feet per second with the 67.5-inch barrel using ammunition lot PA-

47-1, which is assessed at 2,780 feet per second for the 20-mm AN-M2 barrel.

**RATE OF FIRE.** The average of the three highest rates of fire obtained with the standard nested coil spring rear buffer was 739 rounds per minute. The average of the three highest rates of fire obtained with the Naval Gun Factory type Belleville washer rear buffer was 797 rounds per minute. The average of the three highest rates of fire obtained with the Shirgun Corp. type solid oil rear buffer was 922 rounds per minute.

*Belt Pull.* The belt pull was determined to be 45 pounds. The limiting factor in this was not the ability of the feeder to pull, but the strength of the belt links (M7E3). The measurement was taken using a direct weight attached to the ammunition belt by a cable suspended by one pulley.

*Time-Displacement of Recoiling Parts.* Findings were obtained on EX 1 type 1, gun No. 3 under the following operating conditions: Gas system open two complete turns, oil spring rear buffer, single firing pin spring. Standard calibrated waxed ammunition at 70° F. was fired. A three-round burst was fired with the first round in the chamber. The data were obtained by mounting reflectors on two recoiling parts of the gun, that is, bolt and barrel extension. Light directed on the reflectors recorded their travel on sensitized paper in a drum-type camera. The average bolt recoil velocity was very high, whereas the bolt counterrecoil velocity was comparatively low. Even when using the oil spring type rear buffer the return of energy to the counterrecoil of bolt group was very low—approximately 47 percent. This loss of energy at the rear buffer was a critical point. It was believed that the lost energy from the recoiling gun should be used to preload the rear buffer prior to being struck by the recoiling bolt. If this were done, bolt counterrecoil velocity could be greatly increased with resulting higher gun cyclic rates. If the time required for bolt group counterrecoil equalled time required for bolt group recoil, the gun cyclic rate would be approximately 980 rounds per minute.

*Data Representing Average of Three Round Burst.*

Bolt travel to unlocking: 0.4976 inch.

Time required: 0.004366 second.

Average velocity: 9.28 feet/second.

Bolt travel from unlocking to striking rear buffer:  
9.6283 inches.

Time required: 0.011274 second.

Average velocity: 71 feet/second.

Bolt travel from rear buffer to battery position:  
10.125 inches.

Time required: 0.02518 second.

Average velocity: 33.5 feet/second.

Gun recoil: 0.759 inch.

Time required: 0.01175 second.

Average velocity: 5.38 feet/second.

Gun counterrecoil: 0.759 inch.

Time required: 0.01946 second.

Average velocity: 3.25 feet/second.

Time between rounds: 0.00375 feet/second.

Total time required for 3-round burst: 0.225  
second.

Cycle rate: 799.99 rounds/minute.

*Force Displacement of Recoil Buffer.* These data were obtained on EX 1 type 1, gun No. 3, at the same time as the data on time displacement of recoiling parts, under the same operating conditions. Two resistance type strain gages were mounted on the barrel extension yoke. These strain gages were calibrated statically in a hydraulic testing machine.

### Total Rounds Fired

As of 15 April 1947, the following total rounds were fired on the guns:

Gun No. 1: 6,721 rounds.

Gun No. 2: 998 rounds (shipped to the Shirgun Corp.).

Gun No. 3: 255 rounds.

Gun No. 4: 5 rounds.

Gun No. 5: 1 proof round.

Total: 7,980 rounds.

### Conclusions

Since the type 1 gun was to be followed by the type 2 gun which more nearly resembles the final design, no conclusions were submitted on the type 1. The latter appeared to have sound operating characteristics but many more tests and much more firing were required.

### Recommendations

As a result of the test firing done at the Naval Proving Ground on the 20-mm Shirgun EX 1 type 1, it was recommended that the following steps be taken to improve the operation and functioning of the gun.

1. Firing pin. Tip made as a straight sided cone with round end.

2. Ejector. Face angle of prongs made closer to perpendicular (approximately  $10^\circ$ ) instead of  $45^\circ$  to reduce the upward thrust of the spent case on the feeder and the breakage of the extractor stop.

3. Sear. Angle of contact with front face of firing-pin lug changed to give a positive full release of the firing pin and not an angular release.

4. Sear plunger. Change to a pivoted type in place of sliding type in order to reduce breakage and to cut down resistance to the bolt extension on its forward travel.

5. Gas cylinder. Enlarge front section so that threads cut both inside and out do not weaken the side-wall thickness.

6. Feed operating lug on bolt extension. Change to roller-bearing type to reduce wear.

## SECTION 4. DEVELOPMENT OF 20-MM MACHINE GUN MECHANISM EX 1 TYPE 2

### Gun Failures Due to Lock Breakage

At the outset of the testing program for EX 1 type 2, there was lock breakage with every round fired. Accordingly, in June 1948, the Chief of the Bureau of Ordnance authorized the Naval Aviation Ordnance Test Station at Chincoteague, Va., to conduct functional and developmental tests of this gun for the purpose of correcting troubles being experienced in attempted firing of the low-profile weapon.

### Modification and Test at NAOTS, Chincoteague, Va.

A report dated 29 July 1948 from the commanding officer of NAOTS, Chincoteague, Va., indicates cause and cure for the many malfunctions that plagued the first attempts to fire the weapon.

If the gun had been fired as it was delivered without modification, it would have been completely wrecked in from 1 to 3 rounds.

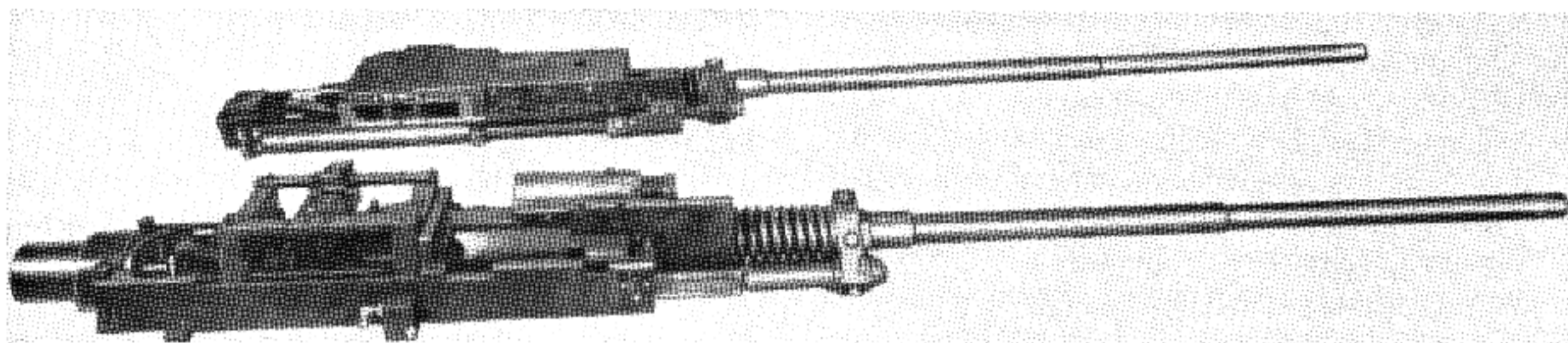


Figure 7-23. Early versions of the 20-mm Shirgun. In the foreground: EX 1 Type 1. In the rear: EX 1 Type 2, which is also known as the T55.

This weapon's bad reputation of wrecking itself preceded its arrival at Chincoteague by months. Since the part breakage had been so high at each attempt to make it function, it was decided to give the weapon a very thorough visual check and make modifications before any attempt was made to fire.

The following things were noted and correction made:

1. Gas cylinder piston lacked three-eighths inch of meeting face of bolt extension. The gas cylinder piston was machined back until there was 0.005-inch clearance between the face of the bolt extension and the end of the piston.

2. With cartridge in chamber positioned for firing, the face of the bolt was 0.028 inch short. This amount was added to the redesigned firing pin so that it could make contact with the primer and ride home with the crush of the cartridge.

3. That the firing system was inadequate. When the bolt extension thrust rearward to unlock the piece, it withdrew the firing pin  $1\frac{1}{8}$  inches. This removal of the firing pin from the hole in the face of the bolt allowed small particles of brass and carbon to blow into the firing-pin tunnel. The original pin had to have close bearing surface due to both its small dimensions and length of stroke.

Any foreign matter getting into the firing-pin tunnel, regardless of how small, would cause bending of pins, "faint strike" primers, etc. A floating-type firing pin was designed that did not retract beyond flush with face of bolt; and, while it was spring loaded, it was also cammed rearward by the raising of the breechlock in the act of unlocking.

The hole leading from the barrel to the gas cylinder was checked and found to be 0.131 inch. A series of plugs with gradual orifices from 0.048 to 0.159 inch were made at test facilities machine

shop, and the gas cylinder sleeve was tapped at a point where the gas could be metered to the face of the piston. The intention was to allow the weapon to have just enough power to barely operate and then gradually increase it until the part or parts giving trouble could be located. The first orifice used was 0.048 inch, with single-shot firing that unlocked the weapon but did not allow the bolt to strike the buffer. The orifice was then increased until  $\frac{1}{2}$ -inch buffer compression was obtained with the feeder on the gun and a 50-round belt in position. The orifice that gave most satisfactory results was 0.085 inch.

*Feeder.* The feeder sent to this activity had bronze floor plates and locking lugs, which represents a new low in feeder design. This soft metal bent with each round fired, causing bind on bolt, feeder arm, etc. The lugs broke as soon as burst firing was accomplished.

The link guide rails had an opening that after the ear of the link entered, there remained only 0.010 inch clearance on either side. Unless the ammunition was calibrated absolutely correct, the ear of the links would strike the sides causing all kinds of trouble, such as friction bind, erratic speed, faint strikes, ear of link under rail, etc. This part was modified at test facilities machine shop, expanding the opening by  $1\frac{1}{2}$  inches inside, link guide rail and one-fourth inch both horizontal and vertical on right and left sides. This allows the ammunition to be belted out of calibration one-fourth inch either right or left of what was heretofore demanded. The angles in the feeder mouth will cam the ears into exact calibration upon being pulled into position. This self-calibrating feature is considered very important in successful feeding.



The link guide rails were placed in this feeder in such a manner that by unsnapping a metal top cover, they could be removed by hand and reversed, for changing feeding from right to left or vice versa. This is a very desirable feature on paper, but when the weapon started to fire full automatic, the loose rails lurched from the heavy rounds being pulled at high speed and allowed the ears of ejected links to hit the solid frame of the feeder, causing erratic fire. Had it not been detected and corrected by bolting down securely to floor of feeder it would, in time, have wrecked all inner working parts.

*Buffer.* The oil buffer as sent out with this weapon violated a basic law of gun design by using weld to hold any part subjected to high operating pressure. After firing a total of 106 rounds the weld failed and oil reservoir cap blew off, going 200 feet in the air.

In order to continue test of the weapon, a makeshift air buffer was improvised that proved satisfactory as far as allowing the continuation of the test.

Extra precaution was taken, due to the fact that no spare parts were sent with this weapon and if a part breakage was experienced, the test was over until the piece could be manufactured locally. Outside of the weld failure of the oil buffer cap, the only actual part breakage was the stud on the breechlock stop and the feed actuating post on top of the bolt extension. The latter was caused by an experimental camming shoe, the use of which was discontinued after repair of the stud and no further trouble was experienced.

*Rebounding Brass.* Six stoppages were experienced in this test by rebounding brass that was thought at first to be caused by empty cartridge cases failing to clear the opening in the firing stand and bouncing back into the mechanism. However, when the stand was modified so that this was impossible, this malfunction still continued. Further investigation showed that the trouble was coming from the weapon itself. The opening in the floor was of such close dimensions that unless the empty case was cammed down in perfect alignment, brass could hit the side and fail to clear the opening. By watching the condition of the ejector and the extractor closely, this could probably be remedied for stand testing. However, it is quite a different thing

when tried in air firing, as a sudden maneuver of the plane could bring about this malfunction. This could be corrected by opening up the ejection slot. However, this would weaken the barrel extension bearing at this point, where the part might fail.

### Investigation and Development at Naval Proving Ground, Dahlgren, Va.

The first partial report on the functional investigation and development of this gun at Naval Proving Ground was dated 22 March 1949. In this report EX 1 type 2 is identified by the Army designation which had been assigned to the gun, T55 (type 2).

Although the directive stated that 5 guns would be made available for the investigation, only 2 were received by this activity, the first in July 1947 and the second in March 1948. The progress of the investigation was seriously delayed by lack of sufficient guns and by modifications made to the guns in order to overcome functional failures encountered. Considerable progress was made in overcoming certain of these failures but little or no progress was possible in overcoming others.

*Background.* The 20-mm aircraft gun T55 (type 2) is a modified 20-mm aircraft gun EX 1 (type 1) formerly referred to as the "Shirgun." The T55 (type 2) gun differs from the EX 1 (type 1) gun in the following major changes.

1. Addition of double acting pneumatic charger with pneumatic searing.
2. A seared bolt extension in place of a seared firing pin.
3. Lower profile height.

*Description of the Gun.* The 20-mm aircraft gun T55 (type 2) is an experimental single barrel gas operated percussion inertia fired gun. It has a profile height of 4 inches and a width of 8.6 inches. The gun weighs 159 pounds.

The basic components of the gun are: (1) Receiver consisting of upper housing and lower housing; (2) barrel with chamber and bore the same as the 20-mm automatic gun AN-M2; (3) barrel extension; (4) barrel recoil spring; (5) barrel recoil buffer (hydraulic); (6) gas bracket assembly with cylinder and piston; (7) bolt assembly with lock and firing pin; (8) bolt extension; (9) rear buffer, hydraulic or pneumatic; (10) drive spring assembly and drive spring guide; (11) pneumatic

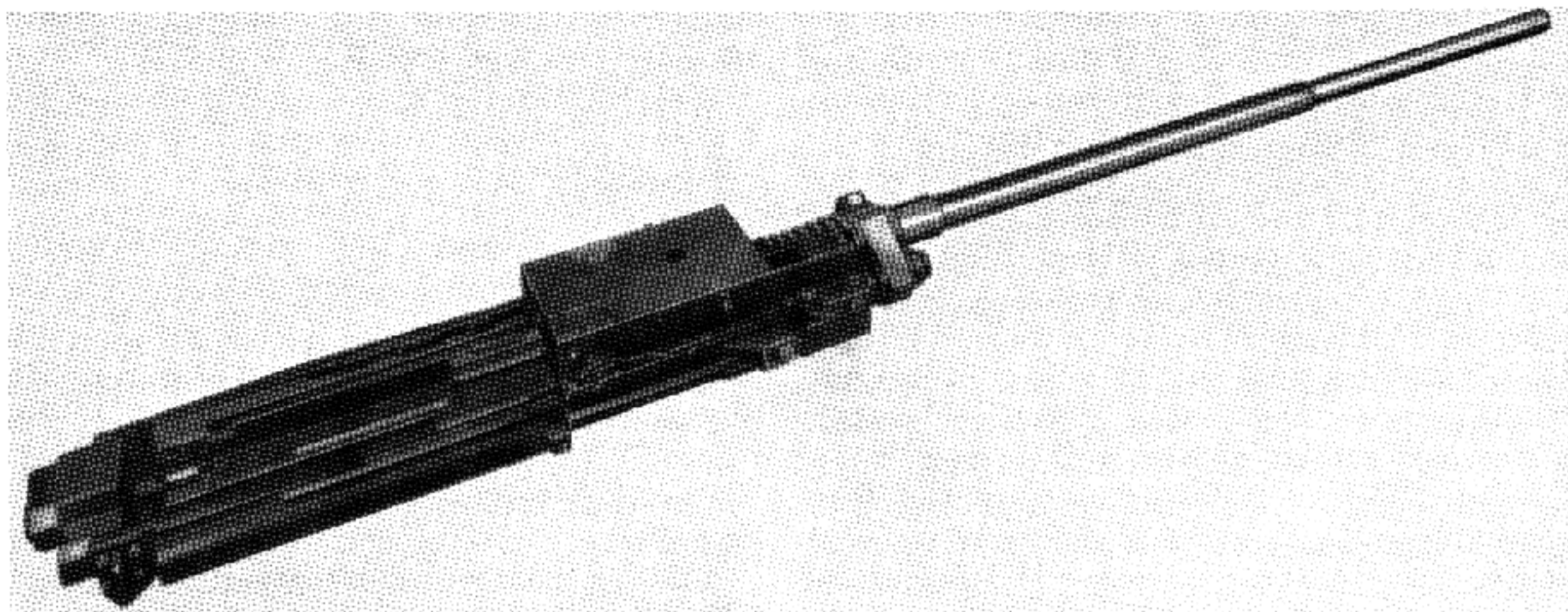


Figure 7-24. Closeup view of the T55 (EX 1 Type 2) Gun with its feed mechanism removed.

charger, double acting; (12) pneumatic safety sear and ready sear; (13) feed mechanism assembly.

The following accessories are required for gun operation: (1) Compressed air or other suitable gas at 1,500-pounds-per-square-inch pressure; (2) three electropneumatic valves with control switches and relays; (3) pneumatic tubing.

*Operation of the Gun.* When the gun is fired, the propelled projectile passes a gas port located in the barrel 16.562 inches forward of the rear face of the barrel, and propelling gases metered through a vent plug orifice enter a gas cylinder mounted on the right side of the gun. This gas pressure drives a gas piston in the cylinder to the rear. The rear of the piston shaft, in turn, drives the bolt extension to the rear. A projection on the bolt extension extends through the bolt body; when the gun is in battery, this projection holds the bolt lock in the locked position. The rearward motion of the bolt extension resulting from firing moves the projection to the rear clear of the lock. The firing pin in the bolt body is connected to the same projection and is drawn to the rear inside the bolt also as the projection moves rearward. The movement rearward of the projection relative to the bolt body is stopped by contact of the rear of this projection and the inside rear wall of the bolt body. After this contact is made, the bolt body and bolt extension move rearward together. With rearward movement of the bolt body, the lock is retracted into the left side of the bolt body by the camming action of the angles

on the rear locking surface of the lock and the forward surface of the lock plate mounted in the left side of the barrel extension.

The empty cartridge case is extracted from the barrel chamber by the spring-loaded extractor mounted in the bottom lower face of the bolt body. The case is carried rearward with the bolt until its top rear contacts the spring ejector mounted on the rear frame of the feed mechanism above the bolt body. The case is rolled over the extractor claw by the continued rearward movement of the bolt and ejected out of the bottom of the gun receiver through the ejection slot.

As the bolt extension moves rearward from the battery position, it also actuates a feed operating lever by means of a lug and roller mounted on the top of the extension. The feed-operating lever has a cam slot in its underside in which the roller and lug of the extension move. This cam slot and the position of the lever are such that the straight rearward motion of the bolt extension moves the feed-operating lever across the gun to the right, moving the pawl carrier and pawls in the feed mechanism across the feedway and carrying the ammunition to the feeding position over the feed mouth. Two cam blocks then force the next round downward out of its belt link and into position to be picked up and chambered by the bolt body moving forward. The empty belt link is forced out of the feeder by the movement of the round moving into the feeding position.

The gun barrel is mounted in a recoiling barrel extension which moves rearward in the fixed receiver. This movement is independent of the bolt and breechblock extension movement. The recoil of the barrel and the barrel extension compresses a coiled recoil spring. They are then brought to rest by a hydraulic recoil buffer mounted in the left upper housing of the receiver. The recoil spring returns these components to battery during the counterrecoil stroke. The rearward movement or recoil stroke of the bolt and bolt extension is stopped by a stationary buffer mounted on the rear of the receiver. The rear face of the bolt body contacts a buffer plunger. The rear buffer furnished with the gun is either hydraulic or pneumatic. The hydraulic buffer has a replenishment chamber to maintain a constant volume of fluid in the main buffer chamber. The pneumatic buffer has an air hose fitting for connection to the gun's pneumatic supply of 1,500-pounds-per-square-inch pressure. A stop valve at the rear of the buffer seals the air at full pressure within the buffer.

During the forward, or counterrecoil, movement of the bolt and bolt extension, the feed operating lever is moved in the opposite direction to the feeding stroke and in turn moves the feed pawl carrier over the ammunition into position to pick up the next round. The ammunition in the feedway is held stationary by two pawls. During this counterrecoil stroke, the bolt which contacted the rear buffer carries the bolt extension forward keeping the firing pin retracted. The live round of ammunition is chambered and the bolt body stopped against the barrel extension below the barrel rear face. The bolt extension continues forward under inertia and the projection of it through the bolt body cams the lock into the locked position and holds it there. The final forward movement of the extension carries the firing pin forward and fires the round. A driving spring inside the bolt extension is provided to fire the first round.

The operation of the pneumatic charger and pneumatically operated safety and firing sears is as follows: The safety sear in its normal position drops down in front of the bolt extension, holding the extension  $9\frac{3}{4}$  inches from battery. The bolt and firing pin are also held out of battery. When the

safety sear is raised pneumatically, air pressure is applied at the same time to the rear side of the charger piston. This together with the driving spring drives the bolt extension forward until it is again stopped by the firing or "ready" sear, if it is down in front of the extension. A round of ammunition is fed into the chamber on this stroke.

The firing sear stops the bolt extension five-eighth-inch from battery in the "ready" position. In this position the bolt body is home against the barrel extension and the bolt lock is cammed into the locked position. The firing pin with the extension is five-eighth-inch from firing the round. When the firing sear is lifted pneumatically from in front of the extension, air pressure is applied to the rear side of the charger which together with the driving spring forces the bolt extension into battery, and the firing pin strikes the primer, firing the round. During the last one-eighth inch of this firing stroke the charger lug, which has been in contact with the bolt extension, is cammed out of the way. This lug does not engage the bolt extension again until air is applied to the forward face of the charger piston, moving it to the rear. The complete charging cycle stopping the gun on safety and ready prior to firing requires 9 cubic inches of air, minimum.

The pneumatic retraction of both sears results in automatic firing. The sears are prevented from dropping and dragging on the bolt extension by a "telltale" rocker assembly located in the upper housing of the receiver.

*Ammunition.* The 20-mm aircraft gun T55 (type 2) is designed to fire service issue 20-mm aircraft ammunition belted with either M7 or M8 metallic belt links.

*Conclusions.*

1. The 20-mm aircraft gun T55 (type 2) did not meet the Bureau of Ordnance specifications for a 20-mm aircraft machine gun.

2. The following changes are necessary to improve the functioning of the T55 (type 2) gun.

(a) Increase firing pin energy to prevent "light struck" primers.

(b) Use steel feed mechanism floors to prevent bending of bronze floors.

(c) Change contact angles of breechblock lock and lock stop plate to insure reliable unlocking and to increase the rounds life of the lock.

(d) Use rotating and nonrotating bolt extension feed lug shoes to insure against breakage of rollers and feed lugs.

(e) Strengthen and taper the extractor projection and increase the chamfers on the forward and rear edges of the extractor claw to prevent sheared extractor flanges and excessive crush up of cartridge cases.

(f) Increase the life of the driving spring and driving spring guide.

(g) Use the pneumatic rear buffer in place of the hydraulic rear buffer which was too weak in construction.

(h) Use dumping valves on the pneumatic safety sear, and ready sear lines to insure positive action of the sear.

(i) Chamfer the feed mechanism link ear guides to permit easier entry of the link into the feeder and improve the action of the link retaining and feed pawls.

(j) Design and manufacturing tolerances should be carefully controlled to prevent such accumulations of tolerances as occurred in this gun.

(k) Modify the breechblock to prevent seating of the breechblock lock adjacent to the firing pin tunnel.

(l) Modify the gun in order to increase the cyclic rate of fire to 1,000 rounds per minute.

It was recommended that:

1. No further investigation be conducted on the 20-mm aircraft gun T55 (type 2).

## SECTION 5. DEVELOPMENT OF 20-MM MACHINE GUN MECHANISM MARK 9 MOD 0 FIRING PERCUSSION AMMUNITION

### Functional Investigation

*Synopsis.* On 26 September 1949, the Naval Proving Ground issued a partial report on the functional investigation and development of the 20-mm aircraft gun T55 (Mark 9). As directed, the procedure followed in this investigation was in accordance with that established by the Aircraft Guns Test and Evaluation Procedures Manual.

During the period covered by this partial report, 1,820 rounds of percussion ammunition were fired.

In the investigation and development of the T55 (Mark 9) gun, 243 malfunctions and stoppages occurred. The longest length burst fired was 20 rounds.

It was concluded that:

1. The 20-mm aircraft gun T55 (Mark 9) in the state of development existing at that time was not satisfactory, due to the large number of malfunctions and excessive dispersion patterns.

2. The cyclic rate of fire of the gun was satisfactory.

### General Data: 20-mm Machine Gun Mechanism Mk 9 Mod 0

Gun length: 116 inches.  
 Gun weight: 113 pounds.  
 Rate of fire: 1,247 rounds/minute. (This is the highest rate of fire officially recorded during test.)  
 Muzzle velocity: 2,680 feet/second.  
 System of operation: Gas unlock, blowback.  
 System of locking: Swinging lock.  
 System of feeding: Lever actuated by recoil of bolt.  
 Method of headspace: Governed by tolerances of operating components.  
 Location of feed opening: Top of receiver, either right or left side.  
 Location ejection opening: Bottom of receiver.  
 Method of charging: Air and hydraulic.  
 Method of cooling: Air.

Barrel length: 52½ inches.  
 Barrel weight: 26 pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect (by means of French threads).  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 inch.  
 Groove width: 0.205 inch.  
 Pitch: 7 degrees (equals 1 turn to 25.587 calibers and 1 turn to 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Uniform.  
 NOTE: This represents the most improved version that was actually put under test.

3. Even though the reliability of many parts was improved during the investigation, the following gun components were unsatisfactory: extractor spring, ejector springs, firing pin spring, feed mechanism, gas cylinder, "stop fire" pawl, firing pin, and firing pin automatic sear.

4. The methods of cocking and searing the firing pin were unsatisfactory and resulted in light struck primers similar to those which occurred in the two guns investigated earlier.

It was recommended that no further investigation be conducted on the 20-mm aircraft gun T55 (Mark 9) percussion gun in view of conversion of this gun to an electric fired T55 (Mark 9) gun, which was then being investigated.

*Background.* The 20-mm aircraft gun T55 (Mark 9) is an experimental weapon developed from two previous experimental guns, the T55 (type 1) and the T55 (type 2) 20-mm aircraft guns. In this chapter, these two guns are also designated 20-mm machine gun mechanism EX 1 type 1 and 20-mm machine gun mechanism EX 1 type 2, respectively.

The design of the T55 (Mark 9) gun incorporates improvements or changes in an attempt to remedy the deficiencies of and to improve the earlier weapons. The basic design features of all these guns have been directed at obtaining an aircraft gun with the following features:

1. Lowest possible profile height, and not in excess of 4 inches.
2. Highest possible cyclic rate of fire, and not below 1,000 rounds per minute.
3. An integral feed mechanism easily changed from right- to left-hand feeding.
4. Capable of using present service issue 20-mm aircraft ammunition of the M90 series.
5. A nonrecoiling receiver and quickly detachable barrel.

*Description of Items Under Test.* The 20-mm aircraft gun T55 (Mark 9) is an experimental, single barrel, gas operated, percussion fired gun with the following dimensions: height, 4 inches; width, 6.3 inches; length, 72 inches. The gun weighs 111 pounds.

The description of the components and the operation of the T55 (type 2) gun contained in section 4 are applicable to a large extent to the Mark 9 gun. The T55 (Mark 9) gun, however, contains the fol-

lowing important changes from the T55 (type 2) gun.

1. Reduction in the profile width from 8.5 inches to 6.3 inches.
2. Reduction in weight from 159 pounds to 111 pounds.
3. Reduction in length from 88 inches to 72 inches.
4. Replacement of the barrel recoil spring and barrel hydraulic buffer by a recoil ring-spring assembly, similar to that used in the caliber .60 T17E3 machine gun.
5. Pneumatic charger assembly made integral with the receiver housing.
6. Seared, spring-loaded firing pin replacing the inertia type firing pin.
7. Replacement of the firing sear, which acted on the bolt extension, with two sears; an automatic sear and a "stop-fire" sear, both acting on the firing pin. The automatic sear is operated by a cam on the bolt extension, while the "stop-fire" sear is operated by a pneumatic piston in the upper housing.
8. A redesign of the boltlock to change the locking angle from 10° to 13° and to shift the point of contact between the lock and bolt, after unlocking, from the firing pin tunnel area to an area below the firing pin tunnel.
9. Separation of the barrel and gas cylinder group so that the barrel may be removed independently.

10. Reduction in bolt assembly recoil travel distance from 10<sup>1</sup>/<sub>8</sub> to 9<sup>1</sup>/<sub>16</sub> inches.

The T55 (Mark 9) gun requires a source of air pressure at 1,500 pounds per square inch to operate the pneumatic charger, rear buffer, and the sears.

It was determined on the first T55 type gun (type 1) that the "impact" or rapid method of firing-pin cocking was not practicable because it either compressed the spring to solid directly or created surges which allowed the coils to go solid.

Eleven firing pins and six automatic sears were used during the firing. As with the first type T55 gun tested (type 1), wear developed at the points of contact between the firing pin and the automatic sear to the extent that premature firing-pin releases would occur. Variation of sear and firing pin metals and hardnesses, as well as amount of engagement, had little effect on this wear. It was not possible to perform any modification during firing, to prevent

this wear without a complete redesign of the firing pin searing actions.

Poor dispersion patterns in general were believed due to:

(a) Looseness between the upper and lower receiver housings, and between the barrel ring spring assembly and the upper housing. The barrel was designed to derive most of its stability through the ring spring assembly and the upper housing. Rivets between the upper and lower housings had to be continually reset, while nothing could be done about the increasing looseness which developed in the ring spring assembly upper housing threads.

(b) Rapid accelerations and decelerations of relatively large offcenter masses in the gun.

Motion (barrel whip) of a point on the forward end of a standard original barrel was photographed by high-speed cameras. Cameras were mounted at right angles to each other, on opposite sides of the barrel and 45° above a horizontal plane through the axis of the barrel. Unfortunately, ring-spring assembly and receiver motions could not be recorded by this means.

Five dispersion patterns were fired during investigation of an externally ribbed, uniform bore barrel. Three patterns were fired with the original barrel (No. 433) with an 0.082-inch vent plug, and two were fired with the ribbed barrel under the same conditions. Patterns obtained with the ribbed barrel were superior to those with the standard.

Because of the loose upper housing and ring spring assembly, and because sufficient bursts were not fired, it was impossible to determine if the improvement was due to the added barrel rigidity produced by the ribbing or by the increase in mass of the barrel (29.5 pounds for the ribbed barrel and 26.7 pounds for the standard).

Of the 223 rounds fired with barrel No. 433, for which patterns were obtained, 35 percent of the rounds showed evidence of yawing up to a maximum of 0.88 inch across the major diameter of the target punching. With the ribbed barrel, only 6 percent of the rounds fired showed evidence of yawing. The following must be considered in regard to the rough yaw determination:

(a) The standard barrel had a bore that was oversize.

(b) Service ammunition was used.

(c) Yaw may have been affected by barrel whip and cyclic rates.

First rounds of bursts fired were consistently high and to the right of the bore-sight point (approximately 6 inches high and 2 inches to the right).

10. Cyclic rates of fire at the designed rate and above were possible with this gun. Highest rate of fire recorded was 1,247 rounds per minute for 13 rounds of a 20-round burst. A correlation table of vent plug sizes and rates obtained is shown in an accompanying tabulation.

Vent plug size (inches)	Rate of fire variation (rounds/minute)	Average rate (rounds/minute)
0.052	464- 474	469
0.070	590- 715	664
0.082	661- 923	801
0.098	787-1,043	947
0.110	931-1,125	997
0.127	873-1,247	1,115
0.157	.....	.....

As vent plug size was increased, a trend toward increased parts breakage was observed.

Six cartridge case ejections during a burst are tabulated below:

Case No.	Ejection angle (degrees)	Tumble distance (inches)	Average velocity (feet/second)
1.....	21	11	24
2.....	12	28	30
3.....	21	15	28
4.....	21	10	30
5.....	30	11	28
6.....	0	.....	.....

Ejection angle equals angle between an imaginary chord through the first 30 inches of the centerline of case motion and a vertical plane through the transverse axis of the ejection slot. Angles of all

cases considered (except case No. 6) were in a quadrant forward of the vertical plane.

Tumble distance equals distance along the path centerline for the case to complete one rotation. All cases tumbled with the neck of the case dropping first and the flange moving forward over the neck.

Average velocities were determined by considering the portion of the path centerline for each case, from 15 to 30 inches.

Rate of fire for the burst was 793 rounds per minute with an 0.098-inch vent plug.

All ejected links followed the same general path and had a fairly consistent velocity. The average velocity of one ejected link during the first 9½ inches of travel was approximately 4½ feet per second. All links came out of the feeder in an uncanted position and in a horizontal plane.

A program was initiated to determine the practicability of shortening the overall length of the gun to 52 inches by shortening the barrel. The program was begun with a barrel having fired less than 100 rounds and when the receiver had approximately 1,600 rounds fired. Cyclic rates, velocities, and dispersions were to be obtained for each 5-inch increment of shortening. Because of the high malfunction rate of the gun, the program was discontinued.

Excessive gas system leakage was observed early in the firing. Leakages occurred around the gas ring on the barrel and back into the recoil ring-spring housing. This developed temperatures within the housing high enough to melt the ring-spring packing grease. Leakage was also present around the gas piston, depositing carbon on the face of the receiver, but was not serious.

## Cycle of Operation

To load this weapon, the bolt has to be all the way forward when the operator places the first round in the feedway ahead of the belt holding pawl. He then pushes in the air charger button. The pneumatic piston-actuated charger starts to the rear after placing great force on the bolt extension. When the bolt extension moves to the rear, it compresses the firing pin spring and at the same time causes the lug on the extension to be removed as an obstruction to the breechblock lock. It raises as soon as it is uncovered, allowing the breechblock to swing into the bolt body and go to the rear as a unit.

By the time the bolt and its extension have reached the buffer, the feed post (located in the bolt extension) by riding in a curved slot in the feed arm has cammed the feed pawls over the space of one round, putting the incoming cartridge in position to be picked up and shoved forward by the bolt returning to battery. When the charger has completed its cycle, the operating parts start into counterrecoil. As the bolt face starts under the rear of the positioning slot in the feedway, two projections on the top of the bolt engage the rim of the cartridge pushing it ahead into the chamber.

The bolt body comes to rest first, while the bolt extension continues on for approximately three-quarter inch. The swinging lock, which is now over its recess in the receiver, is cammed by the locking lug on the bolt extension until it rests in front of its abutment.

To fire the weapon, the operator pushes the compressed air trigger actuating device which raises and engages the spring-loaded lever arrangement that pivots out of the way of the firing pin, allowing it to fly forward and ignite the powder charge.

The barrel, barrel extension, and bolt all remain locked together until the projectile has passed the port in the barrel; at this time, gas is metered to the face of the piston. By the time the projectile has cleared the muzzle and a safe operating pressure exists, the backward thrust on the bolt extension has compressed the firing-pin spring and the raising of the breechlock begins. The first movement rearward of the bolt after being unlocked starts extraction of the empty cartridge case where it is held to the bolt face by the extractor claw. Further movement rearward of the recoiling bolt causes the rim to collide with the ejector, knocking it down through the ejection opening in the bottom of the receiver.

By the time the bolt reaches the buffer, the belt feed lever has been moved over, positioning the next round and the air buffer has been struck, putting the bolt assembly into counterrecoil. The bolt on the way home picks up the indexed round and chambers it; at the same time, the lip of the extractor snaps over the rim into the cannellure of the cartridge. If the firing switch remains depressed, the advancement of the bolt extension after camming the lock into its recess causes the sear to pivot automatically, releasing the spring-loaded firing pin to repeat the cycle.

## Disassembly

To disassemble the Mk 9 Mod 0 gun, remove the feeder by pushing in on two latches and lift off; then push in on the driving spring guide and turn one-quarter turn counterclockwise. Pull guide and

spring to rear. Lift buffer assembly up; with a finger, push rearward on feed post of the bolt extension until the whole assembly comes out of the aft end of the receiver, then separate lock from bolt and bolt from extension.

To assemble, reverse the procedure.

## SECTION 6. FUNCTIONAL INVESTIGATION OF 20-MM MACHINE GUN MECHANISM MARK 9 MOD 0 FIRING ELECTRIC PRIMED AMMUNITION

### Tests of This Weapon

The Naval Proving Ground at Dahlgren, Va., conducted tests of two Mk 9 Mod 0 guns which had been converted to fire electric primed ammunition.

### Synopsis of the Functional Investigation and Development

The final report on the functional investigation and development of the 20-mm aircraft gun T55 (Mk 9) was dated 31 October 1949.

During the period covered by this report, 1,103 rounds of electric primed ammunition were fired from two electric fired T55 (Mk 9) guns which had been converted from percussion fired guns.

It was the opinion of the Naval Proving Ground that, even though the T55 (Mk 9) gun had not been developed to the reliability of a service issue weapon, valuable technical knowledge was gained, which was applicable to future aircraft gun design.

It was concluded that the 20-mm aircraft gun T55 (Mk 9) electric fired was not suitable for service use in its existing stage of development.

### Background

The 20-mm aircraft gun T55 (Mk 9) is an experimental gas operated blowback, belt-fed, pneumatically charged weapon developed from previous experimental guns, the T55 (type 1) and the T55 (type 2). This report covered the investigation of two T55 (Mk 9) guns which had been converted to fire electric primed ammunition.

### Description of Item Under Test

The 20-mm aircraft gun T55 (Mk 9) was an experimental single barrel gas operated blowback gun, which was modified to fire electrically primed ammunition. The profile dimensions of the gun were as follows: Height, 4.1 inches; width, 6.3

inches; length, 72 inches. The weight was 112 pounds.

The main design features of the gun were:

1. Low profile height (4.1 inches).
2. Cyclic rate of fire of 1,000 rounds per minute.
3. Integral feed mechanism capable of being changed rapidly from left- to right-hand feed.
4. Employment of present service issue M90 series 20-mm aircraft ammunition and service issue belt links.
5. A nonrecoiling receiver.
6. A quick detachable barrel.

The detailed description of the operation of the T55 (type 2) gun contained in section 4 of this chapter is applicable to the T55 (Mk 9) gun. The changes in the components between the type 2 gun and the Mk 9 percussion fired gun are enumerated in section 5.

The Mk 9 electric fired gun contains the following modifications to the percussion fired gun.

1. Replacement of the spring-loaded firing pin with a two-piece spring loaded electric pin in wire spring, pin core, locknut, rear-housing, tip insulator, core insulator, contractor squid and squid setscrew. The spring, positioned between the housing and the tip, keeps the tip in the forward position during all parts of the firing cycle. The rear portion of the pin is keyed to the bolt extension projection; thus the spring tension on the tip varies as the bolt extension moves relative to the bolt assembly. This enables the round being picked up from the feeder mouth to clear the pin tip by camming it rearward when the tension is least. Electrical contact between the squid and the barrel extension contactor is completed or interrupted as the bolt extension moves relative to the barrel extension.

2. Addition of a contractor on the barrel extension and a connector on the receiver to complete the firing circuit to the firing pin.



3. Removal of the stop-fire sear from the barrel extension and the stop-fire piston from the upper housing.

The Mk 9 electric fired gun requires the following external sources of power.

1. Air at 1,500 pounds per square inch for the pneumatic double acting charger and pneumatic rear buffer.

2. Source of 250 volt e. m. f. to fire the ammunition.

## Results and Discussion

Two guns were modified from percussion to electric and were used for the evaluation. The first gun (gun No. 1), had been fired 1,820 rounds prior to the conversion; the second (gun No. 2) had been fired 62 rounds.

As electric guns, the following number of rounds were fired and attempted:

Gun No. 1. 1,223 rounds attempted, 644 rounds fired.

Gun No. 2. 726 rounds attempted, 459 rounds fired.

At the time of conversion, a new barrel (No. 436) with uniform twist rifling, standard chamber and ribbed exterior was installed in gun No. 2. Other barrels used during later firing with this gun were:

No. 433. Uniform twist, standard chamber and standard exterior.

No. 434. Gain twist, standard chamber and standard exterior.

No. 435. Uniform twist, standard chamber and ribbed exterior.

No. 434(a). Gain twist, fluted chamber and standard exterior.

The following barrels were used during the firing with gun No. 1:

Barrel No. 436. Uniform twist, standard chamber, ribbed exterior.

Barrel No. 434. Gain twist, fluted standard dimension chamber and standard exterior (same as Barrel No. 434 above with chamber modified by fluting).

Firing with both guns revealed, among other things, that the firing pin hole in the recoil plate, as originally received, was too large (0.160 inch diameter). This opening did not offer sufficient support for the primer; consequently, the primer of the first proof round fired ruptured. Gas pres-

ures damaged the metal portions of the pin and completely shattered the fiber insulators. A new firing pin was installed with a redesigned tip which permitted reduction of the recoil plate opening to 0.125 inch. No further primer blowbacks were experienced with the reduced opening in either gun.

The firing pin, as designed and fabricated, had many weak points. The pin was designed to convert from percussion to electric without major bolt assembly modification. Weak points could best be eliminated by a bolt assembly and firing pin redesign. Among the weaknesses were:

1. Difficulty in securing the firing-pin squid. The setscrew that secured the squid would work loose, allowing the squid to back out. This was remedied by silver soldering a threaded section onto the squid so that it would screw into the core.

2. Fatigue rate of the firing-pin spring was high. After 300 to 400 rounds on each spring used, no force would be exerted on the tip with the housing in the rear position, even though force was maintained in the forward position.

3. The rear core and tip, as originally received, had an undercut to provide a seat for the spring ends. Fractures of both components at the undercuts occurred. Elimination of these undercuts, which were found to be unnecessary, eliminated the fractures.

4. Frequent shattering of the original type fiber insulating sleeves (between the core and the housing) occurred.

5. The firing pin housing was provided with a lug that mated with a groove in the bolt extension projection. Frequent shearing of this lug occurred. A reduction of the mass of the housing had no effect on the tendency to shear. At the time testing was concluded, sketches had been drawn up for a pin housing whose lug thickness was increased.

More difficulties during electric firing were due to the feeder than to any other gun component. Difficulties included: Failures to feed, failures to strip, incomplete ejections, structural failures, difficulties in securing and removing the feeder and feeder cover.

The cause of failures to feed, failures to strip, and incomplete ejections were traced to an incorrectly designed feeder arm or feeder arm cam on the bolt extension.

An attempt to ensure stripping by shortening the feeder connecting link failed since doing so added to the incomplete ejection tendencies.

Failures to feed, in which the bolt assembly would return to battery without a round and without a round being in the feed mouth, was also caused by insufficient feeder arm travel. The rounds were not being moved inboard far enough for the link ears to be retained by the holding pawls. When this happened, the belt would back out with the pawl carrier assembly.

Two barrel modifications were tried during electric firing; namely, a gain twist rifled barrel and a fluted chamber barrel.

Velocities with the gain twist barrel were about 16 feet per second (average), which was lower than for two uniform twist barrels. Dispersions were not compared.

The fluted chamber corrected numerous failures to extract encountered during percussion and electric firing. Extractor marks on the case flanges were barely visible; whereas before, many flanges were stripped or partially stripped. However, the flutes

allowed excessive gases to pass back around the case into the receiver. Secondary explosions of these gases occurred frequently when using the fluted chamber with the larger vent plugs. One explosion was severe enough to spread the feeder guide rails. Although some fluting appeared necessary to aid extraction, a reduction in the number of flutes, length of flutes, or depth of flutes may be possible to reduce danger of secondary explosions while still permitting proper extraction.

Sufficient rounds were not fired with either the fluted chamber or the gain twist rifling to determine effects on erosion, barrel life, etc.

### Conclusions

It was concluded that the 20-mm aircraft gun T55 (Mk 9) electric fired was not suitable for service use in the existing phase of development.

### Recommendations

In order to improve the functioning of the 20-mm aircraft gun T55 (Mk 9), modifications in several components were recommended.

## SECTION 7. CONVERSION OF 20-MM MACHINE GUN MECHANISM EX 1 TYPE 1 TO RECOIL OPERATION

### Background

In July 1948, an experiment was commenced at NAOTS, Chincoteague, Va., on the 20-mm EX 1 type 1 to replace the gas operating principles of the Shirgun with a recoil system which has proved reliable in previous machine-gun designing, so that the weapon will perform functions of unlocking, cocking, extracting, loading, and locking from recoil force in lieu of gas pressure.

### Conclusions

The conclusions reached were stated as follows:

1. That operation of the 20-mm Shirgun by the short recoil principle is feasible.
2. That a "mockup" gun so modified at NAOTS has successfully performed the function of unlocking, extracting, cocking, loading, and locking by recoil and counterrecoil force.
3. Principles involved in changing this weapon to a short recoil system in lieu of gas operation are basically sound.

4. The method employed in pinning down the breech lock on a cam insures positive zero headspace at all times.

### General Discussion

The 20-mm experimental type 1 aircraft machine gun (Shirgun) was the prototype of a low-profile, gas-operated machine gun. The object of this experiment was to change this weapon from gas operation to recoil operation.

The gas operating system used on all 20-mm machine guns had such an excessive gas discharge rearward from the blowback features which had to be incorporated in guns of this design that it was extremely hazardous to install them in any type of jet-propelled plane. Because of the tremendous speed of the "jets," a constant negative pressure is built up in the gun bays during flight. With each shot fired, a considerable amount of inflammable gases are pocketed in the bay until a high enough concentration is reached to produce an explosion.

Because to the date of this work it had been necessary for all known 20-mm cannon to use externally lubricated ammunition, hot oily cases further created an explosive hazard, since all empty brass must be retained in the fuselage of jet planes.

As gas operation is impractical under these conditions and since the short recoil principle has proved successful in guns of smaller caliber, it was decided to adapt it, if possible, to the 20-mm. Short-recoil operation utilizes the energy of the recoiling parts to perform the cycle of unlocking, loading, and locking at high speed. Unlocking is usually accomplished in less than an inch from battery. The caliber .50 machine gun was the largest gun as of July 1948 to employ successfully this operating principle. Many times during World War II, the question was asked, "If the caliber .50 machine gun is so successful, why not build a 20-mm mechanism like it?" Only one thing prevented this. The caliber .50 when charged retracted the barrel, bolt, and the barrel extension three-fourth inch before unlocking. Upon unlocking the rearward movement of the barrel extension compressed the oil buffer spring. It remained compressed during the major part of the recoil and counterrecoil of the bolt. When the accelerator holding the oil buffer to the rear was released by the forward movement of the bolt into battery, the oil buffer spring (released from compression) assisted the forward movement of the parts into battery. In the 20-mm, a spring taking the place of the oil buffer spring would have to be so much heavier because of the heavier barrel and barrel extension that charging the gun manually would be almost impossible, while a mechanical charger would have to be so large as to be impracticable.

Another drawback to the present 20-mm gun is the terrific blast and flash. The 20-mm high-speed machine gun is ideal for night fighters since it can carry a high-explosive projectile. However, the flash of the guns, according to pilots who used them in combat, was so bad that some method of flash control had to be worked out. The blast also has been such a problem that in planes where the in-

stallation places the muzzle close to the body of the ship, considerable damage has been experienced.

For the recoil-operated 20-mm, it was decided to make an adapter which would screw into the barrel housing and fit over the last three inches of the barrel. In the adapter, a chamber was designed in front of which was an orifice slightly larger than the bore. The purpose of this device is to allow the chamber to catch the explosion and hold the gases long enough to allow the piece to unlock while a high pressure is on hand to blow empty brass and bolt rearward. This not only gives a reserve of energy for operation, but in trapping the blast after the projectile clears the bore and by literally working the gases over again, flash is practically eliminated as is the danger of gun bay explosion.

The Naval Proving Ground at Dahlgren, Va., has proved that if a 20-mm can be held to a headspace of 0.001 to 0.006 inch, externally lubricated ammunition is not necessary. To accomplish this, a new form of lock which would allow the gun to go fully into battery was designed. The most advantageous method would be to have a pin encased in the bolt extension which would slide home on a cam. This would not only allow the gun to be charged manually but would give zero headspacing with each shot. The importance of this latter feature should not be overlooked. The mechanism of the new locking device on this weapon utilizes the momentum of the bolt extension forward, to pin the breech lock down. An added 0.005 inch has been added to the measurements computed for the cam to compensate for wear and to insure zero headspace at all times.

An accelerator had to be designed that would give the bolt extension a considerable thrust rearward ahead of the other recoiling parts (bolt, barrel, barrel extension). In designing the accelerator, considerable attention was given the control over the unlocking and timing so that it could be synchronized with a high residual pressure in the barrel adapter. Also, an added impetus given the bolt extension would add materially to the rate of fire. An accelerator was produced which accomplished controlled unlocking.

## Chapter 8

# ARMOUR AIRCRAFT AUTOMATIC CANNON AND RELATED MODELS

## SECTION 1. BACKGROUND AND EVOLUTION OF THE T33

Design of the 20-mm automatic gun T33 was initiated by the Oldsmobile division of General Motors Corp. in 1944 under a contract with the Ordnance Corps to produce a high cyclic rate 20-mm aircraft weapon. The first line of endeavor was to modify the 20-mm automatic gun T19 that was being devised by the Draper Corp. of Milford, Mass.

The Draper weapon featured a compact cross-feed mechanism with a star wheel which straddled the bolt and held the link while a round was stripped, fired, and returned to the link for ejection.

The rate of fire as specified by the Army for the original T33 was 750 rounds per minute, but Oldsmobile found it theoretically impossible to synchronize the feeder star wheel and bolt at rates in excess of 500 rounds per minute.

The reason was that the Draper scheme of having the star wheel straddle the bolt did not allow enough time for the feeder to operate while the bolt traveled between the feeder and buffer and back again

to pick up the next round. Accordingly, Oldsmobile stopped work on the original version in April 1945 and initiated a project on an improved design to eliminate the objections to the earlier weapon.

The later gun incorporated a feeder driven by springs wound by gun recoil and counterrecoil. The feeder star wheel was located off center to clear the bolt. Cases were ejected out of the bottom and links out of the side. The bolt had a lock on each side and was patterned after the German 30-mm automatic gun MK 103. No bolt drive springs were used in either model.

The T33 was a combination blowback and gas-operated weapon designed to fire electrically primed ammunition. It was also made for mounting as a fixed gun in the wing or fuselage of aircraft.

At the end of World War II, the Oldsmobile development of the 20-mm automatic gun T33 was terminated before the design of the improved model had been completed. In the spring of 1946, the Ordnance Corps revived its interest in this develop-

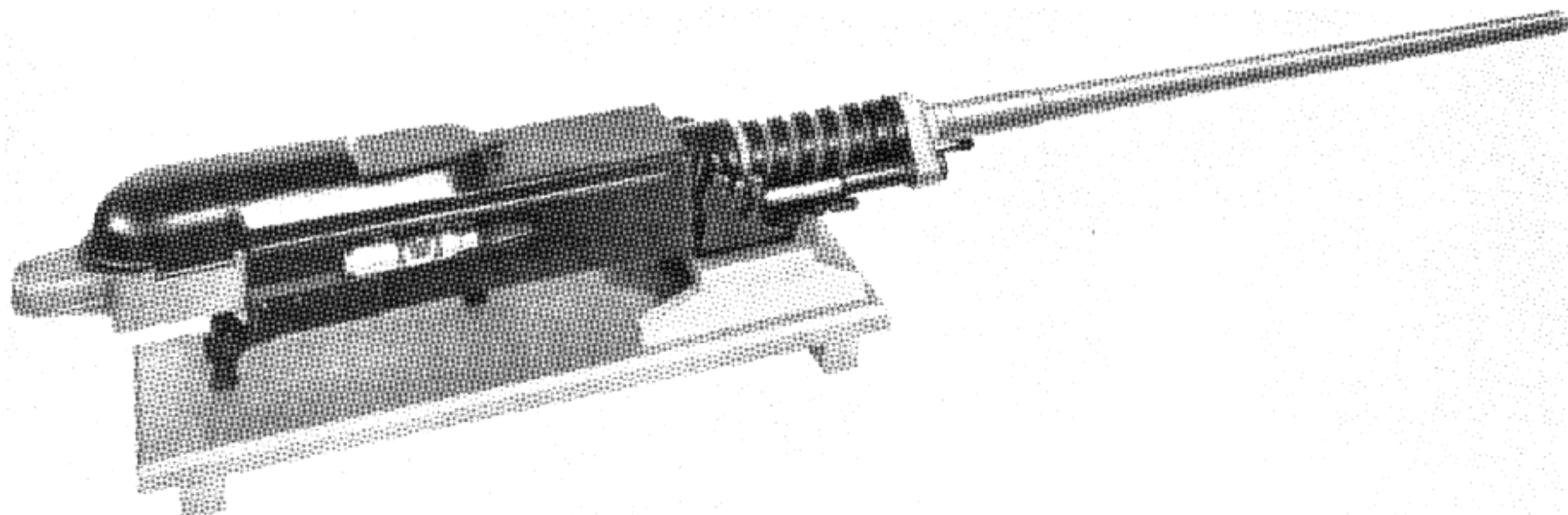


Figure 8-1. 20-mm Automatic Gun T33. Wooden mockup.

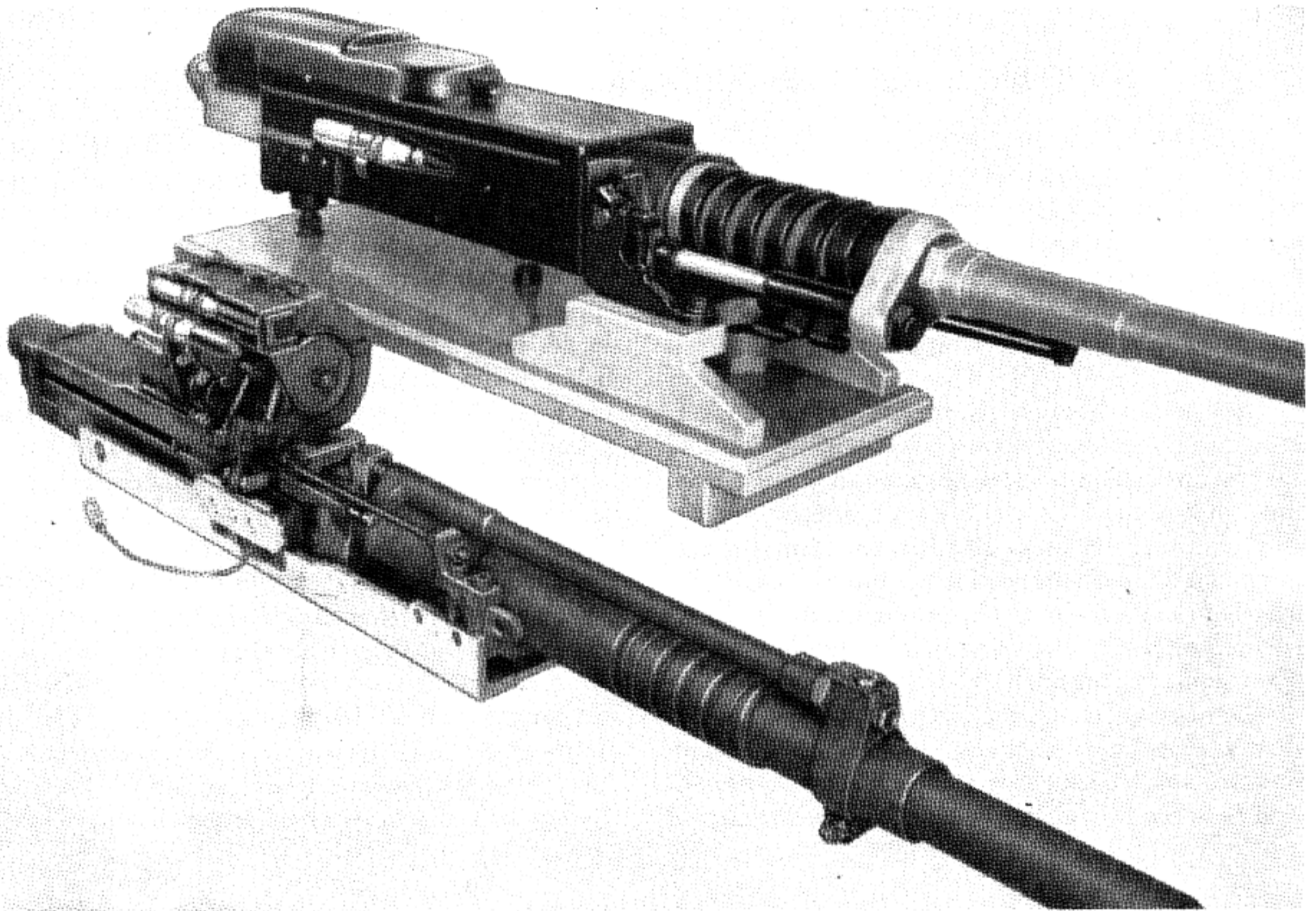


Figure 8-2. Comparison of 20-mm guns. On left, T31; on right, mockup of T33.

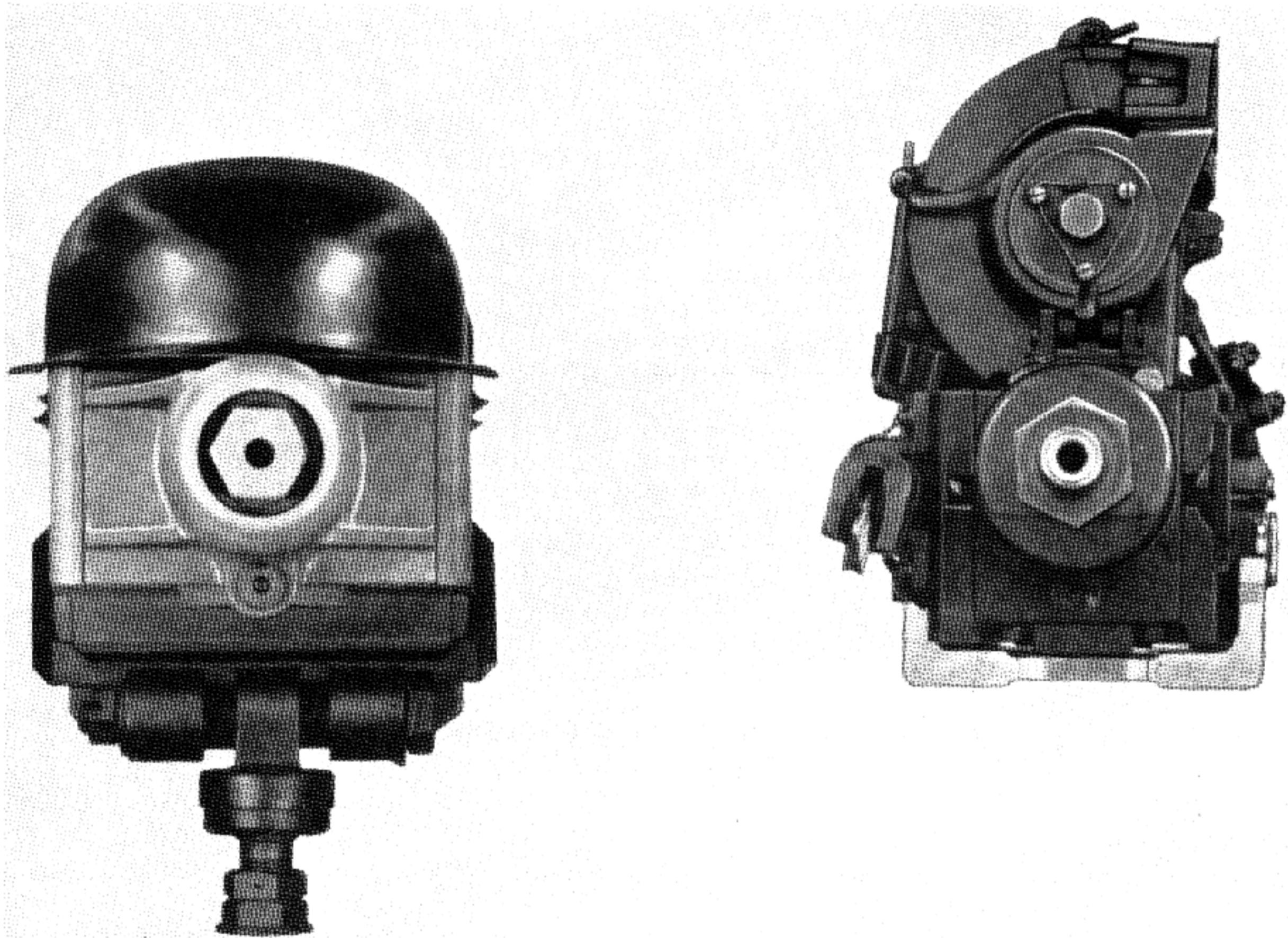


Figure 8-3. Comparison of 20-mm guns from the rear. On left, T33; on right, T31.

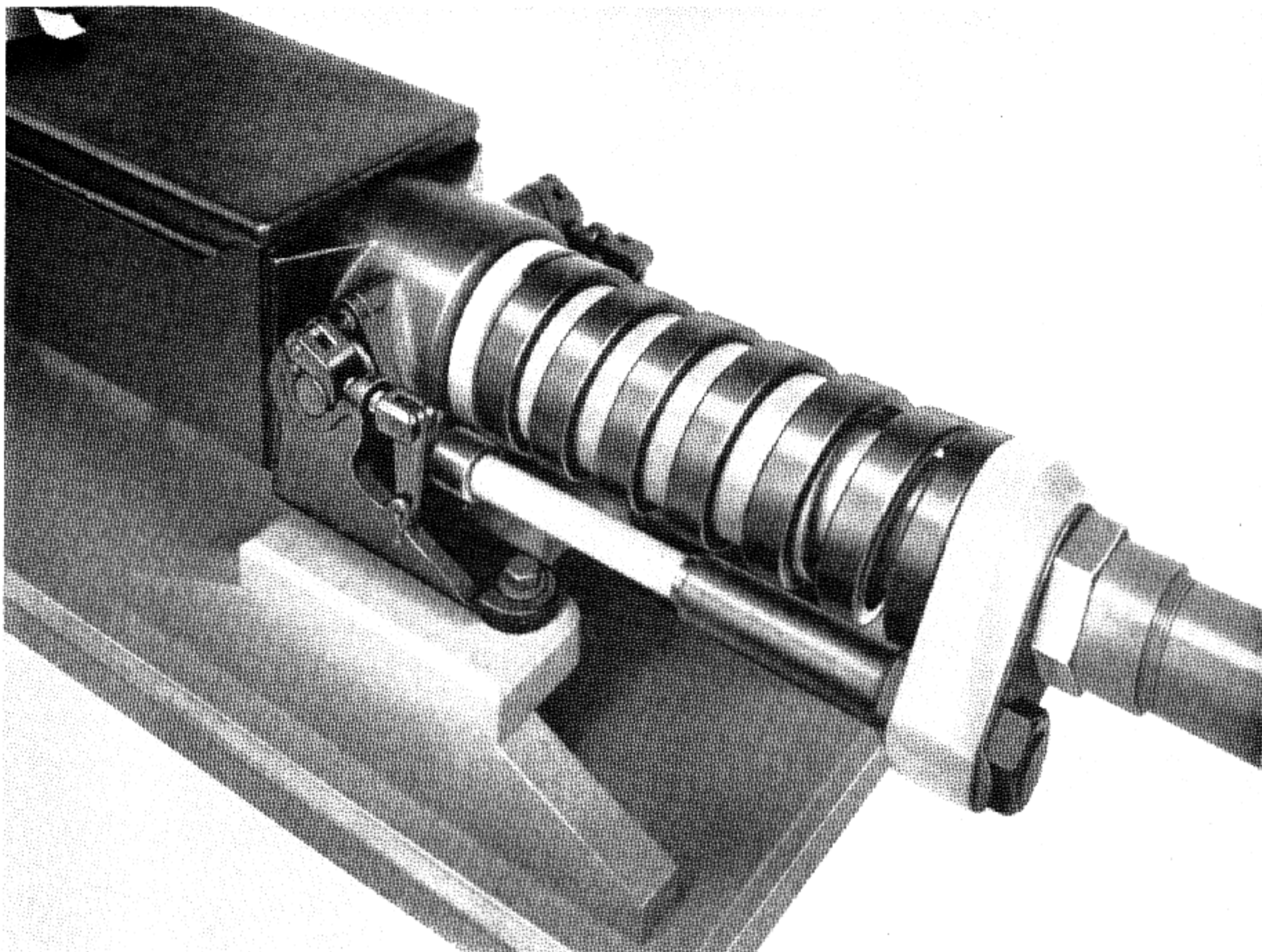


Figure 8-4. 20-mm Gun T33. Closeup view of front mounting.

ment and negotiated Contract No. W-11-022-ORD-11053 with Armour Research Foundation (ARF) for its continuation. All Oldsmobile drawings, layouts, and design data were turned over to the ARF for this task.

This development program was conducted in several phases and resulted in the design, construction, and test firing of a prototype weapon designated Gun, Automatic, 20-mm, T33E3, Model A, and the design and construction of a succeeding weapon designated Gun, Automatic, 20-mm, T33E3, Model B. The contract with ARF was terminated December 31, 1949, and progress of the work performed in this contract period was summarized in a final report and submitted to the Ordnance Corps in July of 1950.

Development was continued with ARF, however, in January of 1950, under Contract DA11-022-ORD-14. This contract was canceled in March 1952, prior to its termination date of 30 September 1952. Progress of the work performed during this contract period was reported in detail in 26 monthly progress reports.

Section 3 of this chapter is excerpted from the ARF final report for the period of the contract, 1 January 1950 to 26 March 1952.

This report describes the various design details of the model B and modified model B weapons, summarizes the results of kinematic analysis, and reviews the results of limited firing tests.

The accompanying table serves as a means of identifying the Armour aircraft automatic cannon and related models.

Armour Aircraft Automatic Cannon and Related Models

Model	Built by	Tested by	Date	Remarks
T33.....	Oldsmobile.....		1944	20-mm. Action based on MK 103. Used large cartridge.
T33E1 .....	Oldsmobile.....		1945	20-mm. Same as T33 except for 0.006 chrome-plated bore and chamber.
T33E2.....	Oldsmobile.....		1945	20-mm. Same as T33 except for 0.010 chrome-plated bore and chamber.
T33E3 Model A.....	Armour.....		1946-49	20-mm. Pivot locks in barrel extension. Change in cartridge.
T33E3 Model B.....	Naval Gun Factory..	Armour	1950	20-mm. Two versions { rotary lock drop - type lock.
T109.....			1948	20-mm. Barrel shortened from 63 inches to 40 inches.
Mk 5 Mod 0 (also called the T120).	Naval Gun Factory...		1950	30-mm. version for British cartridge.

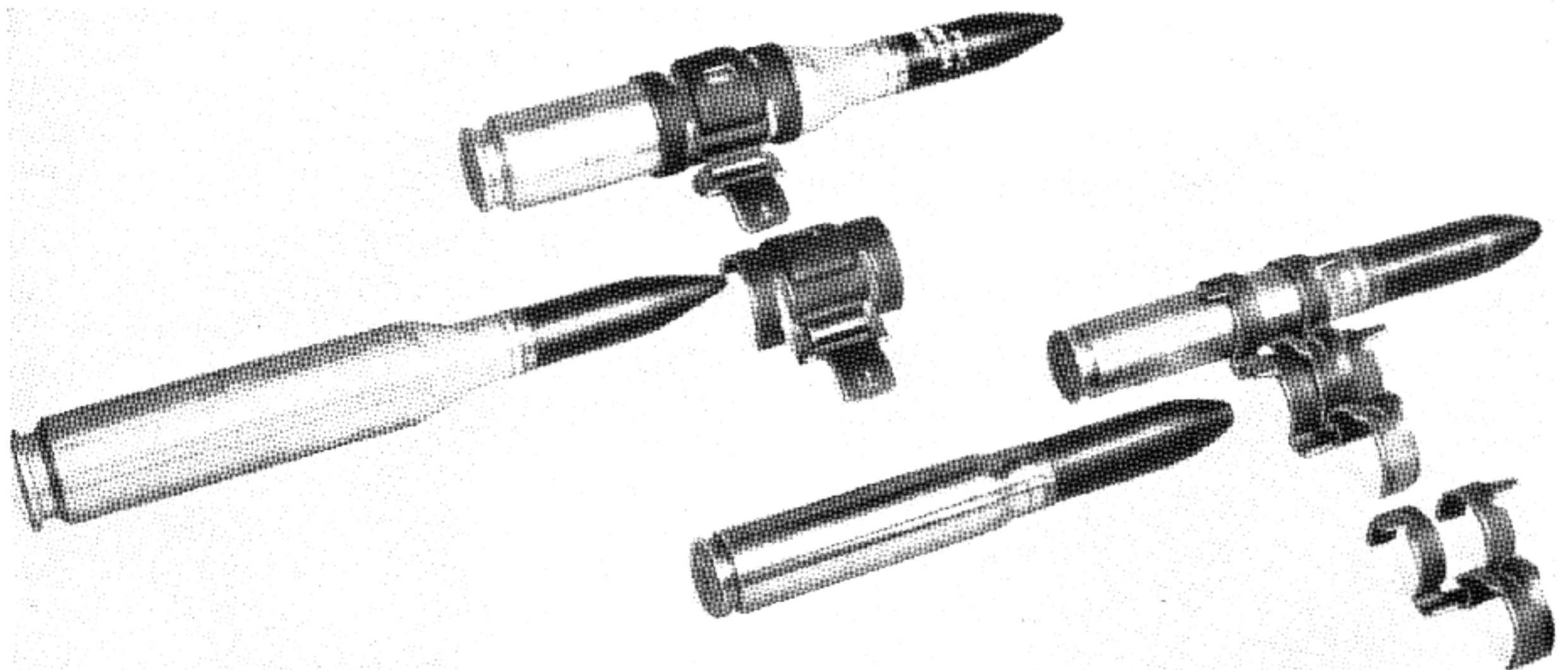


Figure 8-5. Large ammunition and links for 20-mm Gun T33 compared with normal-sized Hispano-Suiza ammunition.



## SECTION 2. RESEARCH AND DEVELOPMENT WORK OF ARF, 1946-49

## Phases of the ARF Project

The ARF development was conducted in five phases which overlapped with respect to time.

Phase I consisted of a study and survey of previous development work. The Oldsmobile design was studied, and Oldsmobile engineers were consulted concerning design details and plans they had for completing the design. Various weapons of similar construction were studied and a preliminary dynamic analysis was made.

Under phase II, the Oldsmobile design was used for a basis, and a weapon was designed for use with the 20-mm case T5 and a 2,000-grain projectile. An entirely new feeder which utilized energy from propellant gases was incorporated in the latter design. In March 1948, the Ordnance Corps decided that this weapon should use the same ammunition as that which was being developed for the 20-mm automatic gun T74.

Under phase III, the weapon was redesigned for use with the 20-mm case T7 and projectile T61E1. The redesigned weapon was designated T33E3 model A. One model was built and tested.

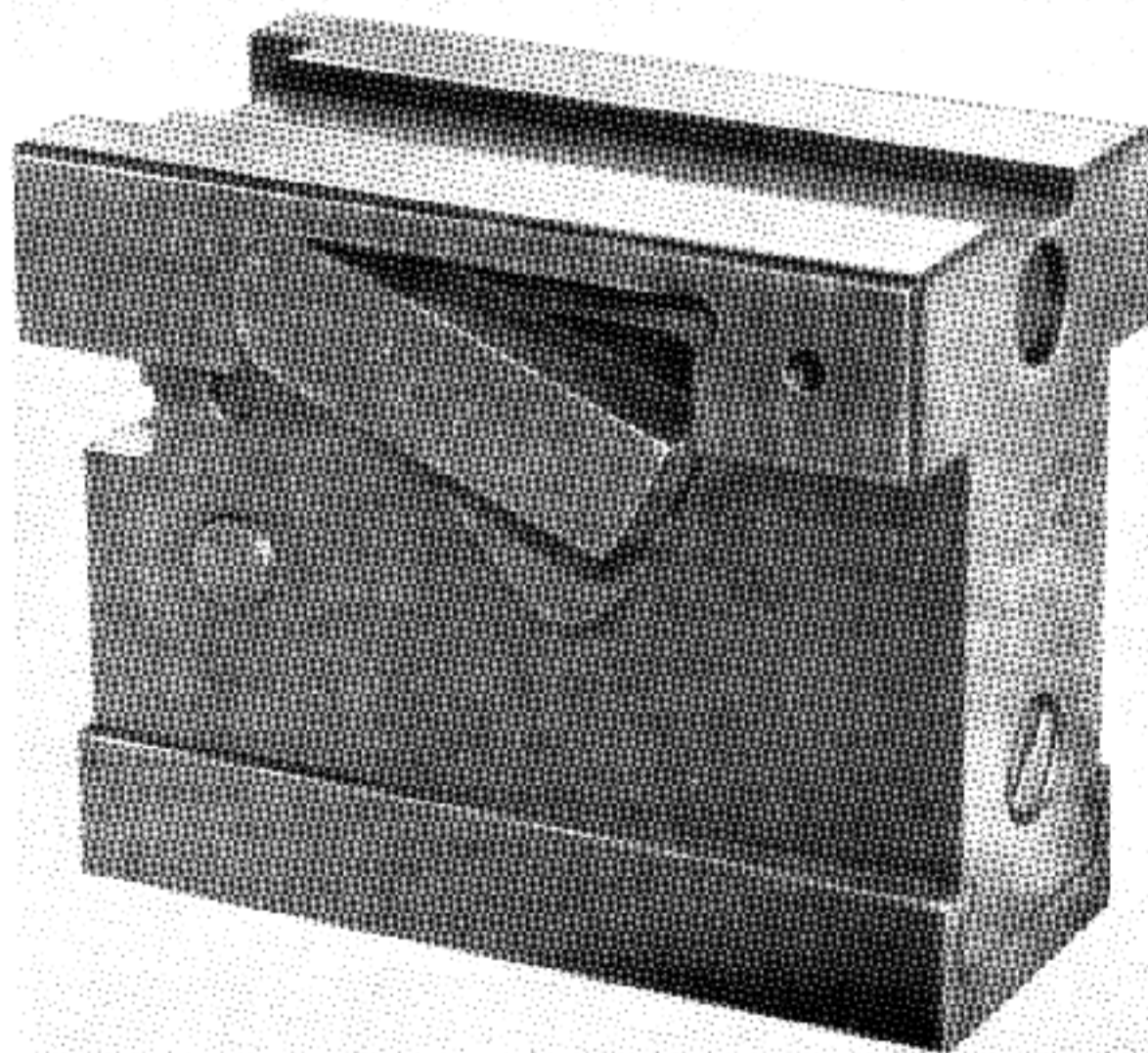


Figure 8-6. Bolt of the 20-mm Gun T33E3, showing parts in the locked position. This bolt is the pivot-locking type.

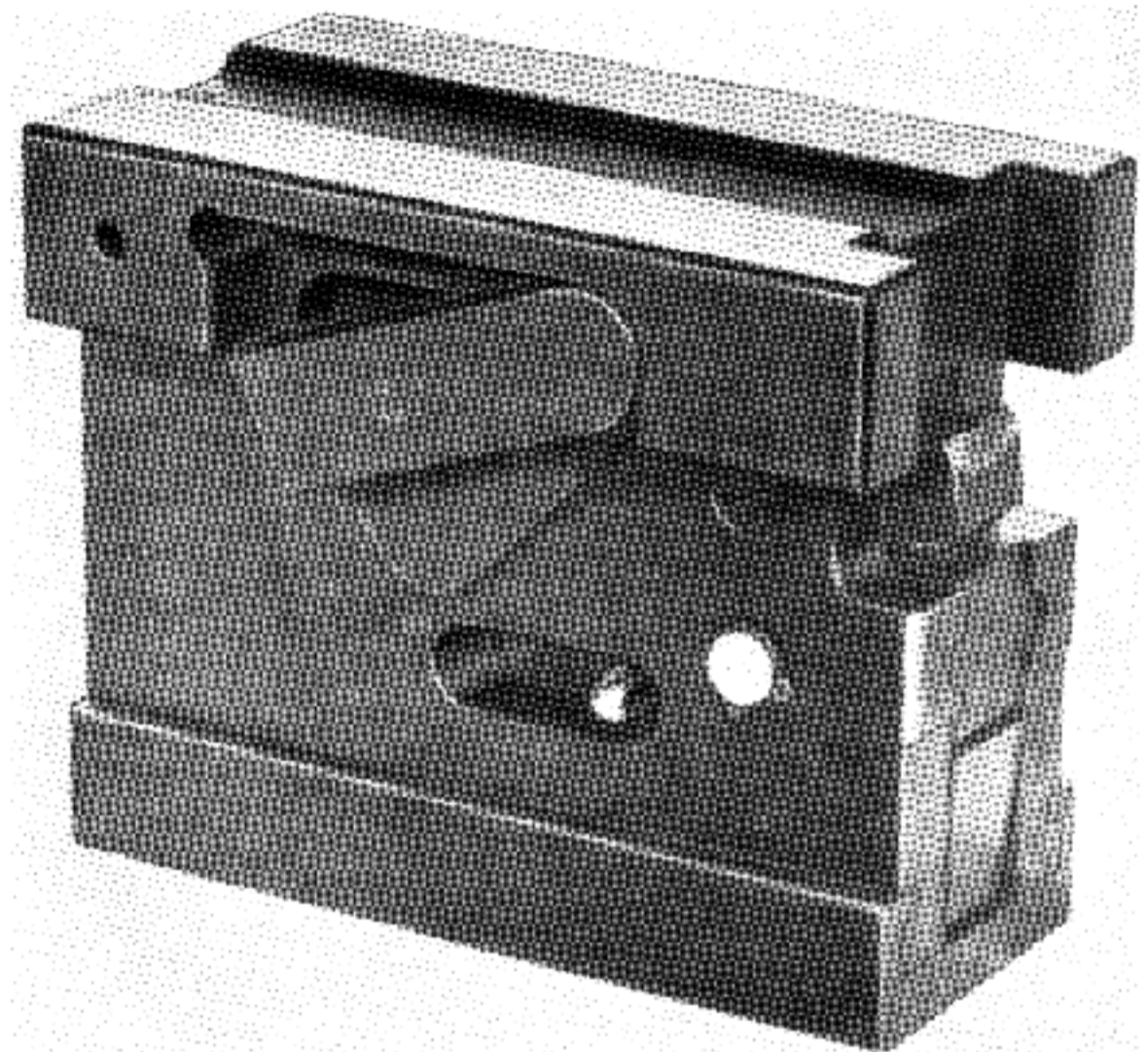


Figure 8-7. Bolt of 20-mm Gun T33E3, showing extractor.

Under phase IV, an entirely new model was designed which incorporated the new bolt and rotary locks, a rammer actuated by bolt recoil, a gas-operated feeder utilizing feed pawls instead of sprocket, and design features which greatly simplified manufacture, assembly, and servicing. One model was made by the Naval Gun Factory but was not delivered for testing during the period of this contract. This model was designated Gun, Automatic, 20-mm, T33E3, Model B.

Under phase V, design of alternate components for the model B was initiated. These alternate designs included a bolt having a different method of locking, a pneumatic buffer, a hydraulic rammer, and a spring-loaded ejector. However, designs were not completed during the period of the contract.

In December 1949, the Ordnance Corps decided to terminate the contract and to continue the development of the 20-mm automatic gun T33E3 under a new contract with ARF. Progress during the period of the contract, from 15 May 1946 to 31 December 1949, was reported to the Army in detail in 48 progress reports.

The time schedule set up for the Armour Research Foundation project is given in the accompanying table.

Research and Development Time Schedule of the ARF Project

Work Schedule	T33		T33E3 model A		T33E3 model B	
	Start	Finish	Start	Finish	Start	Finish
Study and Survey.....	May 1946..	Aug. 1946..	Aug. 1946..	Feb. 1947...	Feb. 1946...	Apr. 1947.
Design.....	Aug. 1946..	Mar. 1948..	Apr. 1948..	July 1948...	June 1948..	Apr. 1949.
Manufacture.....			June 1948..	Mar. 1949..	June 1949..	
Test and Modification....			Mar. 1949..	Dec. 1949..		

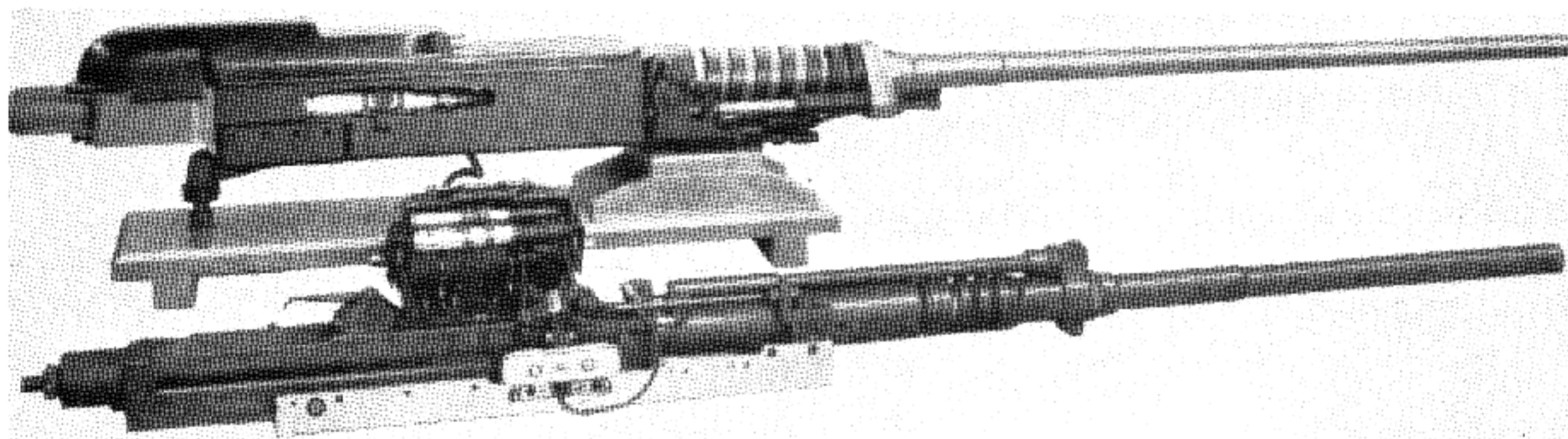


Figure 8-8. 20-mm Automatic Guns, T33 (above) and T31 (below). Right side views.

**Phase 1. Study and Survey of Previous Work by Oldsmobile**

At the time the Oldsmobile development of the 20-mm automatic gun T33 was terminated, a number of design details of the weapon had not been worked out. ARF engineers, after studying the drawing prepared by Oldsmobile, discussed the design with Oldsmobile engineers and obtained their ideas on how they had intended to solve some of the remaining problems. As a part of the preliminary survey work, ARF personnel assigned to the project studied 20-mm automatic guns M1, M2, and the T31, in addition to the German 30-mm automatic gun MK 103. Firing of a 20-mm automatic gun T31 was observed at the Oldsmobile range. Various weapon installations in aircraft were examined and discussed at Wright Field. A study of the Oldsmobile drawing as submitted to ARF indicated the following major design problems.

1. Redesign of the tube support to support the tube for one-quarter to one-third of its length.

2. Redesign of the feeder to provide greater reliability and ease of manufacture.

3. Provide means of charging the weapon.

The feeder design was subjected to an extensive study and was found to contain a number of functional faults which could result in jams or interferences of the rounds in the feeder and of the links with the bolt. Its design was such that accumulated tolerances could cause difficulty in chute and feeder sprocket alignment and in accurate axial location of the linked round in the feeder throat and on the feeding ramp. The design also required the bolt to strip the round from its link at the expense of bolt energy and cyclic rate.

After a survey of various feeders and links was made, a feeder was devised which utilized two sets of pawls instead of a sprocket for feeding the belt. Coil springs, which could be loaded by recoil energy or by pneumatic or gas pistons, were used for operating the pawls. In this feeder design, the belt is advanced by the retraction of a set of pawls when the cocked springs are tripped by the bolt on its forward travel after removing a round from the feeder throat. When the gun fires, the other set of pawls are retracted, and their actuating springs are cocked

by gun recoil or gas pressure. A feeder incorporating these features appeared to have the following advantages over existing feeders:

1. It could be designed to handle greater belt pulls.
2. The number of parts could be reduced.
3. The gun silhouette could be reduced.

During the survey period, an analysis of slide and bolt motion and of gun recoil and counterrecoil was made for the 20-mm automatic gun T31. Since the T31 and T33 weapons were similar, it was believed that such an analysis would be of value in the calculation of forces and motions in the T33 when design data became available. In this analysis, the equations of motion were derived, and velocities and

travel times of bolt, slide, and recoiling parts were computed. These values were compared with measured values from a time displacement record.

**Phase 2. Design of Gun, Automatic, 20-mm, T33**

*Design and Description.* In a steering committee meeting held 27 November 1946, it was decided to incorporate in the T33 design the gas-operated duplex pawl feeder briefly described earlier. At the same meeting, the desire for an overall height limitation of 4.75 inches was expressed. In designing such a feeder to meet this reduced overall height limitation, difficulty in devising a reasonably simple control mechanism was not overcome. Therefore,

Comparative Data: 20-mm T33 and T33E3 Automatic Guns

Gun Characteristic	20-mm T33	20-mm T33E3			Estimated potential characteristics
		Model A	Model B	Modified model B	
Gun length . . . . . inches . . . . .	81 <sup>17</sup> / <sub>32</sub> . . . . .	81 <sup>17</sup> / <sub>32</sub> . . . . .	80 <sup>1</sup> / <sub>2</sub> . . . . .	93 <sup>1</sup> / <sub>8</sub> <sup>1</sup> . . . . .	83 <sup>1</sup> / <sub>2</sub> . . . . .
Gun weight . . . . . pounds . . . . .	177 . . . . .	177 . . . . .	130 . . . . .	158 <sup>1</sup> . . . . .	140 . . . . .
Rate of fire rounds/minute . . . . .	900-1,200 (computed).	900 (approximate).	1,200 (computed).	780 (approximate).	1,000 (approximate).
Muzzle velocity feet/second . . . . .	3,500-3,775 (computed).	3,775 (approximate).	3,775 (approximate).	3,775 (approximate).	3,800 (approximate).
System of operation . . . . .	Gas unlocking, blowback.	Gas unlocking, blowback.	Gas unlocking, blowback.		
System of locking . . . . .	Rotary locks . . . . .	Pivot locks . . . . .	Drop locks . . . . .		
System of feeding . . . . .	Buffer actuated . . . . .	Buffer actuated . . . . .	Buffer actuated . . . . .		
Method of headspace . . . . .	Factory established; could not be adjusted.	Factory established; could not be adjusted.	Factory established; could not be adjusted.		
Location of feed opening . . . . .	Top of receiver . . . . .	Top of receiver . . . . .	Top of receiver . . . . .		
Location of ejection opening . . . . .	Bottom of receiver . . . . .	Bottom of receiver . . . . .	Bottom of receiver . . . . .		
Method of charging . . . . .	None ever designed.	None ever designed.	None ever designed.		
Method of cooling . . . . .	Air . . . . .	Air . . . . .	Air . . . . .		
Barrel length . . . . . inches . . . . .	63 . . . . .	63 . . . . .	63 . . . . .	63 . . . . .	63 . . . . .
Barrel weight . . . . . pounds . . . . .	58 . . . . .		56 (approximate).		
Rate control . . . . .	None . . . . .	None . . . . .	None . . . . .		
Barrel removal . . . . .	Quick disconnect type.	Quick disconnect type.	Quick disconnect type.		
Chamber pressure p. s. i. . . . .			49,000 . . . . .		

<sup>1</sup> Figures are higher because of experimental arrangement of weapon.

Comparative Data: 20-mm T33 and T33E3 Automatic Guns—Continued

Gun Characteristics	20-mm T33	20-mm T33E3			Estimated potential characteristics
		Model A	Model B	Modified model B	
<b>Bore:</b>					
Number of grooves...	9.....	9.....	9.....	9.....	
Groove depth (inch)...	0.015 ± 0.002.....	0.015 ± .002.....	0.015 ± 0.002.....	0.015.....	
Groove width (inch)...	0.205 ± 0.010.....	0.205 ± .010.....	0.205 ± 0.010.....	0.205.....	
Pitch.....	7° slope = 1 turn in 25.587 calibers and 1 turn in 20.137 inches.	7° slope = 1 turn in 25.587 calibers and 1 turn in 20.137 inches.	7° slope = 1 turn in 25.587 calibers and 1 turn in 20.137 inches.	7° slope = 1 turn in 25.587 calibers and 1 turn in 20.137 inches.	7° slope = 1 turn in 25.587 calibers and 1 turn in 20.137 inches.
Direction of twist....	Right hand.....	Right hand.....	Right hand.....	Right hand.....	Right hand.
Form of twist.....	Constant.....	Constant.....	Constant.....	Constant.....	Constant.
Diameter across grooves (inch).....		0.817.....	0.817.....	0.817.....	
Width of lands (inch).....		0.068.....	0.068.....	0.068.....	
Diameter across lands (inch).....		0.787.....	0.787.....	0.787.....	
Gun width, overall (inches).....		14 <sup>5</sup> / <sub>16</sub> .....	14 <sup>7</sup> / <sub>16</sub> .....	14 <sup>7</sup> / <sub>16</sub> .....	14 <sup>7</sup> / <sub>16</sub> .
Gun height, overall (inches).....		4 <sup>3</sup> / <sub>4</sub> .....	4 <sup>7</sup> / <sub>16</sub> .....	4 <sup>7</sup> / <sub>16</sub> .....	4 <sup>7</sup> / <sub>16</sub> .
Distance from muzzle to face of chamber (inches).....		63.....	63.....	63.....	63.
Distance of gas orifice from breech (inches).....		11 <sup>3</sup> / <sub>32</sub> .....	19 <sup>1</sup> / <sub>2</sub> .....	19 <sup>1</sup> / <sub>2</sub> .....	

Complete round characteristics	Projectile model		
	T61E1	T61E1	T61E1
Projectile weight (grains).....	1,600.....	1,600.....	1,600.....
Cartridge case model.....	T7E2.....	T7E2.....	T7E2.....
Cartridge case weight (pounds).....	0.45.....	0.45.....	0.45.....
Primer, electric.....	M52A2.....	M52A2.....	M52A2.....
Propellant type.....	2, IMR 6052.....	2, IMR 6052.....	2, IMR 6052.....
Propellant weight (grain).....	900.....	900.....	900.....
Complete round weight (pound).....	0.8.....	0.8.....	0.8.....
Complete round length (inches).....	7 <sup>29</sup> / <sub>32</sub> .....	7 <sup>29</sup> / <sub>32</sub> .....	7 <sup>29</sup> / <sub>32</sub> .....
Weight of belt link, T46 (pound).....	0.08.....	0.08.....	0.08.....

this feeder design was abandoned in favor of a second feeder design utilizing a gas-operated sprocket in conjunction with a pawl for stripping the round from the link.

Detail drawings of the design had been completed and manufacture of parts was about to be started

when the Ordnance Corps decided, in April 1948, that this weapon should be redesigned for use with the same ammunition being developed for the 20-mm automatic gun T74. The T33 weapon was designed for use with the 20-mm case T5 and a 2,000-grain projectile, whereas the T74 weapon was

designed for use with the smaller 20-mm case T7 and the 1,600-grain projectile T61E1. Therefore, development of the T33 model was discontinued.

*Analytical Studies.* During the period the T33 design was being produced, the following design calculations and analytical studies were reported:

1. Design calculations of gun tube.
2. Design calculations of buffer springs.
3. Procedure for calculating recoil characteristics of a gun application of the procedure to the T33 weapon.

The presentation gives the derivations of equations used and a method of constructing a bore pressure-time curve. Results of calculations for the T33 weapon with a 6,000-pounds-per-inch recoil spring were:

Recoil travel: 0.899 inch.

Recoil time: 0.013 second.

Total trunnion reaction: 5,890 pounds.

4. Method for determining characteristics of motion of gas piston, bolt unlocking slide, and bolt, and application of the method to the T33 weapon. As a result of the calculations just mentioned, a cyclic rate of 820 rounds per minute was computed.

### Phase 3. Design and Development of Gun, Automatic, T33E3 Model A

*Design and Description.* The T33E3 model A weapon consists of a redesign of the T33 weapon for use with ammunition using case T7 and projectile T61E1. Most of the drawings of the T33 model were used by making revisions as required by the new ammunition. Assembly and subassembly drawings of this weapon and photographs of the engineering model which was built for testing were presented to the engineers in charge for further study.

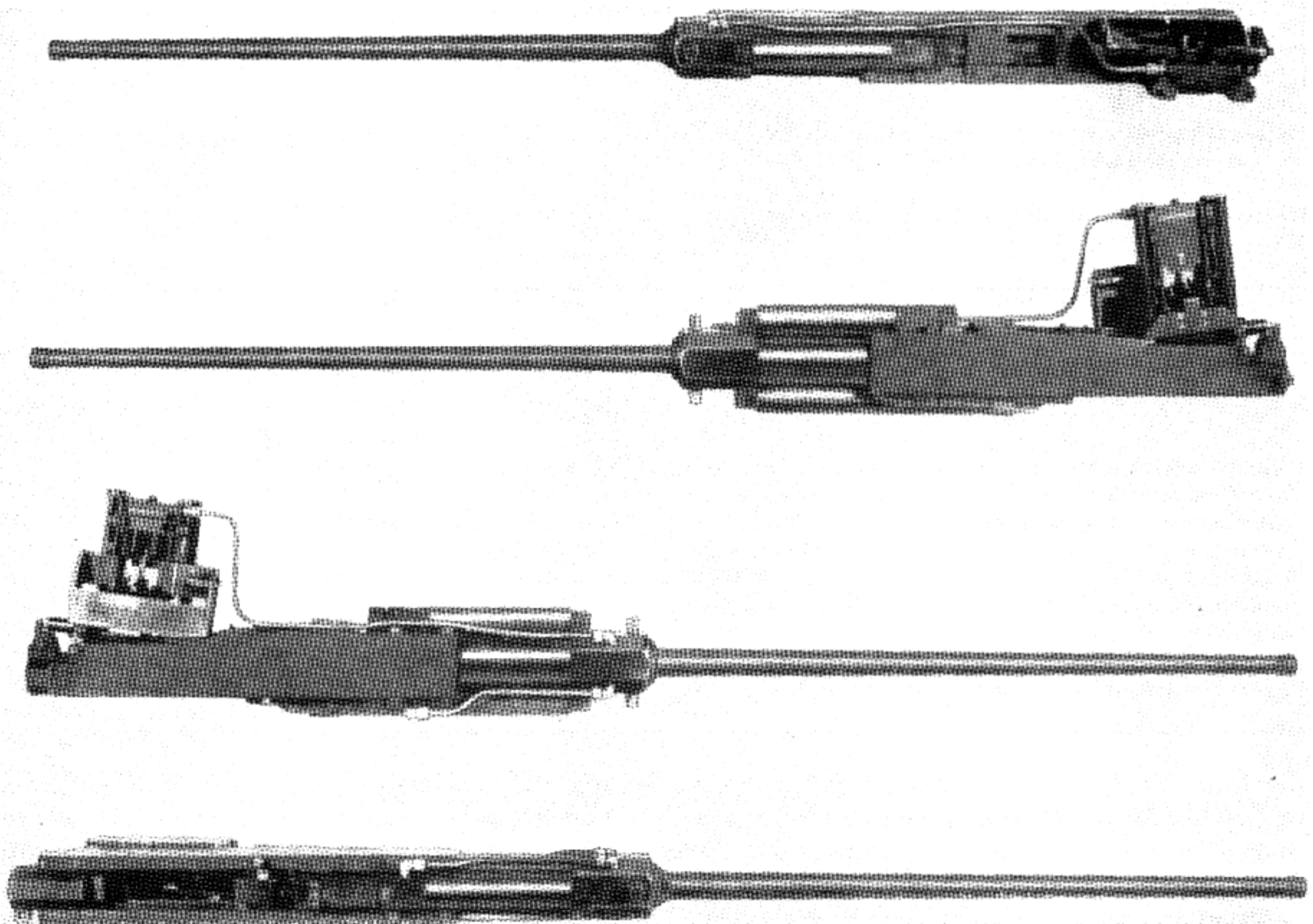


Figure 8-9. 20-mm Automatic Gun T33E3. Four views showing left side, bottom, top, and right side.

The T33E3 model A weapon was designed for mounting flat on its side to keep the height within  $4\frac{3}{4}$  inches. Therefore, the feeder extends from the left or right, depending upon whether the weapon is mounted for feeding from the left or right side. Feeding from either side is permissible by reversing certain parts in the feeder.

Gun recoil and counterrecoil are absorbed by double-acting ring springs mounted concentrically with the barrel.

The bolt is an inversion of the bolt in the German 30-mm automatic gun MK 103. The bolt locks, instead of being parts of the bolt, are located in the tube extension and engage abutments in the bolt when the bolt is in its locked position. An inertia slide in the bottom of the bolt contains cam slots which engage extensions on the locks and cam the locks into engagement when the bolt is stopped in battery position. The gas piston, operated by gas piped from an orifice in the barrel, forces the slide rearward after firing and unlocks the bolt. Drive springs are not provided, and the bolt is returned to battery by the bolt buffer.

The double-spring buffer is mounted on top of the receiver and receives the energy of the bolt through a pivoting arm, the lower end of which is struck by the bolt.

The gas operated feeder positions the incoming round at the same time it indexes the round to be picked up. The next round to be fired is then put under engagement with the feed pawls. The bolt is in battery position. When firing occurs, gas from the bore enters the gas cylinder and forces the main slide toward the feeder throat where it is latched in place against the compression drive spring. The main slide, acting through a spring, carries the feed pawl slide with it. The feed pawls strip the next round from its link and position it against the stops in the feeder throat just above the path of the bolt. As the bolt passes under the feeder throat on its rearward travel, it trips the stops and allows the feed pawls, under pressure of the compressed feed pawl springs, to continue advancing a round into the feeding ramp. After the round passes through the stops, the stops spring out of their latched position again and prevent the round from reentering the feeder when the bolt contacts the base of the round and carries it forward into the chamber. When the stops in the feeder throat open up and allow the

feed pawls to push the round onto the ramp, the feed pawl slide trips the main slide latch. The main slide then moves back under pressure of its drive spring, carrying the feed pawl slide with it, and, by means of an overrunning clutch between the slide and sprocket, causes the sprocket to rotate and position the next round in front of the feed pawls.

*Analytical Studies.* The following design and analytical studies were made in connection with development of the T33E3 model A weapon.

1. Calculation of the rifling twist for the barrel.

Assuming forward fire at a muzzle velocity of 3,900 feet per second from a plane traveling at 650 miles per hour, the calculations determined that a rifling twist of one turn in 34.8 calibers was necessary to provide stability.

2. Analysis of powder gas operated feeder.

The analysis was made to determine the necessary characteristics of the two feeder springs, the peak gas pressure required to compress the springs, and the effect of heat transfer on pressure loss in the gasline between the barrel and the feeder. The results of this analysis indicated that each feeder spring should have a spring rate of 1,000 pounds per inch of deflection, and an operating range of  $1\frac{3}{4}$  inches minimum deflection to  $3\frac{7}{16}$  inches maximum deflection. The peak force requirement was determined to be 1,440 pounds corresponding to a peak gas pressure of 3,300 p. s. i. in a gas cylinder of  $\frac{3}{4}$ -inch diameter. The analysis indicated that heat transfer from the gas through the gasline walls may produce a pressure drop of several thousand p. s. i. under favorable conditions which may exceed considerably the pressure drop due to pipe friction.

3. Calculation of pressure-travel and velocity-travel curves for purposes of gun design.

This analysis was made to determine the type of powder, the weight of powder charge, and the web thickness of the powder grain to produce a muzzle velocity for a 1,600-grain projectile of 3,800 to 4,000 feet per second at a maximum chamber pressure of 55,000 p. s. i.

A solution of the problem was obtained by considering the powder charge and the web thickness as the only unknown quantities in the ballistic equations for the pressure-travel and velocity-travel relations. A method derived in the analysis makes it possible to solve these equations for the powder

charge and web thickness. This procedure was carried out for various available powders. It was found that an 840-grain charge of IMR powder with a 0.020-inch web thickness would produce a muzzle velocity of 3,900 feet per second at a maximum pressure of 54,500 p. s. i. Pressure-travel and velocity-travel curves for IMR powder with 0.020-inch web thickness are found to be satisfactory.

*Difficulties Encountered During Tests.* The initial firing tests were conducted to determine the minimum sizes of orifices for the feeder and for the bolt unlocking cylinder. Orifices of  $\frac{1}{16}$ -inch and  $\frac{1}{8}$ -inch diameter were tested in the feeder gas system. Gas delivery with the  $\frac{1}{8}$ -inch diameter orifice was sufficient to operate the feeder when the gas cylinder was not vented. Orifices of  $\frac{3}{64}$ -inch and  $\frac{5}{64}$ -inch diameter were tested in the bolt unlocking gas system. The bolt failed to cycle with the  $\frac{3}{64}$ -inch orifice but cycled satisfactorily with the  $\frac{5}{64}$ -inch orifice. Orifices larger than five sixty-fourths of an inch caused the bolt to cycle too fast to permit the feeder to feed the next round in position for ramming. During the firing tests, following difficulties were encountered.

**BOLT BUFFER.** The buffer lever, of brazed two-piece construction, failed at the brazed joint, and the lever pivot pin bent. After a one-piece lever and stronger pivot pin were made and installed, no further failures occurred. However, study of the offset buffer revealed the following disadvantages.

1. An excessive amount of bolt energy is lost because of the mass of the lever which must be moved in compressing the buffer springs.

2. When the bolt strikes the lever, the force of impact, which is transmitted to the trunnions, is greater than the recoil force.

In order to minimize these effects, a pneumatic in-line buffer, similar to the buffer of the 20-mm automatic gun Mk 9, was designed. This buffer is connected to an air supply which maintains the pressure in the buffer through a check valve in the buffer. During the firing tests of the buffer, good performance was obtained at an initial pressure of 1,500 p. s. i. Because of a defective check valve, there was insufficient buffer force during one test, which permitted the bolt to strike the buffer housing and resulted in damage to the bolt.

**FEEDER.** During the initial firing tests, bursts of several rounds could not be fired because the feeder

failed to deliver the next round into the feeding ramp in time for the bolt to engage it on its forward travel. The following changes were made to overcome this difficulty.

1. The combined rate of the feed pawl slide springs was increased from 30 pounds per inch to 50 pounds per inch.

2. The cam faces on the feed pawl slide, which trip the toggle for latching the main slide in its extended position, were moved back one-fourth inch. This allowed the main slide to remain locked a longer period of time, which in turn allowed the feed pawl slide a longer time for pushing the rounds into the feeder throat.

3. The main slide-drive springs were shortened one-half inch. This caused the main slide to be retracted from its forward latched position at a slower rate and thus allowed the feed pawl slide still more time for pushing the round into the feeder throat.

4. The end of the buffer lever which is struck by the bolt was machined back three-sixteenths inch to increase the time of bolt travel before the bolt picks up the next round.

5. The orifice in the feeder gasline was increased from one-eighth inch to three-sixteenths inch. With this orifice, the feeder operated with the cylinder either vented or unvented.

During subsequent tests, the feeder failed to index because of gas leakage at the joints in the gasline. The gasline was redesigned to eliminate this difficulty.

During further tests in which attempts were made to fire bursts, more than two rounds in a single burst could not be fired because of failures to feed. A study of the problem indicated the following reasons for failure to feed during bursts.

1. Insufficient gas pressure at the feeder.

2. Binding of the feeder mechanism due to flexing of the feeder frame.

3. Interference between the feeder throat locks and the round because the feeder throat locks were not tapered to exactly match the taper of the case and thus caused the rear of the round to be held back in the locks out of the path of the bolt.

*Modifications Resulting From These Tests.* The following modifications were made to overcome these difficulties.

1. The three gas ports in the tube were increased in diameter from one-eighth inch to fifteen sixty-fourths inch.

2. A new feeder frame, designed for greater rigidity, was made.

3. The throat locks were tapered to match the taper of the case.

During tests conducted after these modifications were made, no further major difficulties were experienced with the feeder. However, the feed pawls failed once, requiring replacement, and the gun jammed occasionally because the nose of the round being rammed struck the face of the tube.

**BOLT.** The bolt frequently failed to lock upon returning to battery, because the inertia slide in the bolt moved forward past the retaining detents into its locking position before the bolt reached battery position. The bolt was modified as follows.

1. The detents for holding the slide rearward until the bolt returns to battery were replaced with a positive spring-loaded latch.

2. A trip was installed in the receiver to trip the latch and allow the slide to move forward just as the bolt reaches battery position.

3. The slide was spring loaded into its forward direction to assist the force of inertia moving the slide forward.

High-speed motion pictures taken during firing tests of the modified bolt showed that this latch also failed to positively hold the slide rearward.

A new type of slide lock was then devised, consisting of two disks which engaged cam slots in the sides of the receiver. After the slide is forced rearward by the gas piston, the disks are cammed inward between the end of the slide and the shoulder of the bolt and hold the slide rearward. When the bolt returns to battery, the disks are opposite their cam slots in the receiver and are cammed into these slots as the slide moves forward to actuate the bolt locks.

A new bolt, incorporating the disk-type slide locks, was made and tested in the weapon. No failure of the bolt to lock occurred during the firing tests. However, a crack occurred across a thin section at the front end when the pneumatic bolt buffer bottomed because of insufficient air pressure. The crack was repaired by welding but failed repeatedly during subsequent tests.

One failure to extract occurred, and the next round was picked up by the bolt and rammed into the unextracted case. The cause of this malfunction was not determined.

**EJECTOR.** During the firing tests, some bursts were interrupted because the next round to be rammed was barely engaged by the bolt, resulting in a jam. High-speed motion pictures indicated that the expended case being ejected might be striking the round to be fed and preventing it from seating fully into the feed throat under the locks. In an attempt to get faster ejection, the springs were removed from behind the ejector and replaced with a solid block. This appeared to eliminate the difficulty during subsequent firing tests.

#### *Performance Data.*

**MUZZLE VELOCITY.** Instrumental muzzle velocities for five rounds of lot PA-E2293 were recorded as follows: 3,700, 3,782, 3,765, 3,782, and 3,782 feet per second.

**CYCLIC RATE.** Cyclic rates were determined from high-speed motion pictures, taken during two 6-round bursts with a 25-round belt load, to be approximately 900 rounds per minute.

**BOLT VELOCITIES.** Bolt velocities were determined from high-speed motion pictures, taken during a single round, as follows:

Rear velocity, approximately 40 feet per second.

Forward velocity, approximately 22 feet per second.

*Summary.* The study and test of this weapon indicated the following major design faults, which, though serious, could be overcome in a redesign.

1. The weapon design does not lend itself to easy manufacture.

2. The bolt is inherently weak because excessive stock must be removed to provide space for moving parts.

3. Control of the round in the feed throat is inadequate, as the round being rammed occasionally strikes the face of the chamber.

On the other hand, this weapon, with the novel features of its bolt, gas-operated feeder, pneumatic buffer, low silhouette, and absence of drive springs, demonstrated considerable potentiality of being developed into a high velocity, high cyclic rate weapon.



#### Phase 4. Design of Gun, Automatic, T33E3 Model B

*Design and Description.* While the model A weapon was being manufactured, an alternate design, the model B, was initiated. This model, like the model A, was designed for mounting flat on its side to keep the height within  $4\frac{3}{4}$  inches, and for feeding from left or right by reversing certain parts in the feeder. However, the model B design is much simpler and easier to manufacture. It features an entirely different bolt with rotary locks instead of gate-type locks, a gas-operated feeder of much simpler construction than that of the model A, a rammer actuated by bolt recoil, double acting recoil springs arranged in two sets at each side of the receiver instead of concentrically with the barrel, and a receiver made of a number of parts for ease of manufacture.

The bolt is locked in firing position by rotary locks mounted in the receiver on each side of the bolt. Lugs on the inertia slide extend out through each side of the bolt and under the locks, and hold the locks in engagement with lugs on each side of the bolt.

Unlocking is accomplished by a gas piston which forces the inertia slide rearward and from under the locks. The locks are then free to rotate and are cammed downward out of engagement with the bolt lugs as the bolt moves rearward.

No drive springs were provided, and the bolt is returned to battery by the bolt buffer. When the bolt returns to battery, it strikes projections on the locks and rotates the locks into engagement with the bolt locking lugs. The bolt is fully forward and the locks are up, the inertia slide, assisted by a spring, moves forward under the locks and wedges them into position. The inertia slide is held rearward by a latch until the bolt is in battery position. The front projection of the latch then strikes the tube extension and causes the latch to rotate out of engagement with the slide and thus allows the inertia slide to move forward to engage the bolt locks. The electric firing circuit is completed by contacts when the slide is forward.

The gas-operated feeder consists of a single slide, two slide return springs, two gas pistons which fit in cylinders machined in the slide, two feed pawls

which are attached to the slide and strip the round from the link, and a feed sprocket which is connected to the slide through a ratchet and lever arrangement. As the gun fires, gas tapped from the barrel to the feeder's gas cylinders moves the slide against its return springs to a position forward, and the feeder pawls push the round ahead of it from its link into the feeder throat. On its return stroke, the slide, acting through the ratchet, causes the feed sprocket to rotate and place the next round in feeding position ahead of the feed pawls.

The round deposited in the feed throat in front of the rammer is held in place by retaining fingers which engage the rim extractor groove. When the bolt moves rearward, it strikes the spring buffer and rammer slide and actuates the rammer through a lever. The round, upon being struck by the rammer, slides forward through the feed throat which, being inclined at an angle toward the chamber, guides the round into the chamber. The bolt then picks up the round on its forward travel and chambers it.

With this feeder, acceleration of the ammunition belt is low, since most of the cycle time is available for feeding of the belt, and since the belt is fed by the energy of compressed springs on the return stroke of the feed slide instead of by the energy of propellant gases on the forward stroke of the slide. Therefore, belt links can be constructed of light material.

*Analytical Studies.* The following analytical work was performed in connection with the design of the T33E3 model B weapon.

**KINEMATIC ANALYSIS.** A cyclic rate of 1,230 rounds per minute was calculated for the T33E3 model B weapon.

**ANALYSIS OF BOLT LOCK.** This analysis was made to determine the most suitable wedging angle on the top face of the bolt inertia slide, which slides under the lock lugs and wedges the lock in locked position. A steep angle could allow premature unlocking under the setback force of the chamber pressure. A flat angle could offer excessive resistance to unlocking. On the basis of this analysis, a  $3^\circ$  angle was selected.

**STRESS ANALYSIS OF TUBE SUPPORT.** In this analysis of the action of the bolt locks on the tube extension, the interrelation between the bolt locks, inertia slide, bolt, and tube extension was consid-

ered. The maximum chamber pressure of 55,000 p. s. i. produces a setback force of 62,200 pounds on the bolt. The static analysis indicated that this force produces bending stresses in the tube extension of 2,230 p. s. i. tension in the outer fiber above the bolt lock trunnion and 4,150 p. s. i. compression in the outer fiber below the bolt lock trunnion. These computed stresses were low enough so that the section was considered structurally safe, notwithstanding the recognized inaccuracies involved in the analysis.

*Manufacture and Test.* The model B weapon was manufactured by the Naval Gun Factory, but was delivered to ARF for testing.

### Phase 5. Alternate Designs of Components

While the model B was being made, alternate designs of the following components were conceived.

*Bolt.* A bolt with a different type of lock was designed. The locks form parts of the bolt and engage abutments in the tube extension when the bolt is locked in battery position. When the inertia slide in the bolt is moved rearward by the gas piston, the locks are cammed up into alignment with the bolt guide grooves by cam tracks in the slide which engage trunnions on the locks. The bolt is then free to move rearward. When the bolt returns to battery position, the bolt slide moves forward under the force of inertia and of the coil spring and cams the lock down into engagement with the abutments in the tube extension.

This bolt appears to have the following advantages over the rotary lock bolt.

1. The locks, traveling in the bolt guide grooves, hold the inertia slide rearward and, therefore, require no auxiliary latching device.

2. The locks are cammed into position by the inertia slide. This action is much gentler than the action that occurs with the rotary locks, which are rotated into position after receiving a sharp blow from the bolt.

3. The inertia slide has some free travel after closing the locks, which will permit the slide to bounce rearward a certain distance without starting to actuate the locks.

*Rammer and Buffer.* In anticipation of wear and possible breakage of parts in the mechanical linkage rammer, development of a hydraulic rammer was initiated in conjunction with the development of a pneumatic buffer. A test device incorporating a pneumatic buffer and a hydraulic rammer was designed and built for determining the practicability of such an arrangement.

The buffer consists of a piston and a cylinder which is charged with air through a check valve. The rammer consists of a bolt-actuated hydraulic piston and a hydraulic rammer piston. When the bolt strikes the hydraulic piston, oil is displaced into the rammer cylinder and causes the rammer piston to strike the base of the cartridge to be rammed. A coil spring in the rammer cylinder restores the system to its initial position.

Laboratory tests prove this development to be quite promising.

*Spring-Loaded Ejector.* On the basis of the results of tests of the model A weapon, it was considered desirable to incorporate a spring-loaded ejector in the model B weapon. It was found that such an ejector readily could be a part of the feeder throat, and an initial layout was prepared. A finished design was not made, however, because the design is dependent upon the method of ramming to be employed.

## SECTION 3. RESEARCH AND DEVELOPMENT WORK OF ARF, 1 JANUARY 1950 TO 26 MARCH 1952

### Phases of the Development Program

The development program in this period was conducted in five phases, as shown in the accompanying table. Phase 1 was initiated with the receipt of the 20-mm automatic gun, T33E3, model B, from the Naval Gun Factory on 20 February 1950. The

gun was assembled and test fired using a rotary-lock type bolt of two-piece body construction.

In phase 2, part of which was conducted in parallel with phase 1, the design and manufacture of replacement and alternate component parts for the model B were completed.

Design and Development Time Schedule for Project

Phase	Development program	T33E3 model B					
		Design		Manufacture		Test fire	
		Start	Finish	Start	Finish	Start	Finish
1	Test firing of the T33E3 model B with 2-piece rotary-lock-type bolt.	.....	.....	(1)	(1)	Feb. 1950....	Nov. 1950.
2	Design and manufacture of replacement and alternate component parts for T33E3 model B.	Mar. 1950... Nov. 1950...	June 1950... Dec. 1950....	May 1950... Dec. 1950....	June 1951... Feb. 1951....	.....	.....
3	Test firing of T33E3, model B with 1-piece rotary-lock-type bolt.	.....	.....	.....	.....	July 1951....	Oct. 1951.

Phase	Development program	Modified T33E3 model B					
		Design		Manufacture		Test fire	
		Start	Finish	Start	Finish	Start	Finish
4	Modification and redesign of various components of model B.	Oct. 1951....	Jan. 1952....	Nov. 1951... .....	Feb. 1952.... .....	.....	.....
5	Initial test firing of the modified T33E3, model B.	.....	.....	.....	.....	Feb. 1952....	Mar. 1952.

<sup>1</sup> Weapon received from Naval Gun Factory.

Development in phases 1 and 2 progressed at low efficiency. This was due to the necessary meetings between ARF engineers, the Army Ordnance Corps, and the Navy Bureau of Ordnance regarding the manufacture of gun components and the time required for the manufacture and delivery of replacement and alternate component parts by the Naval Gun Factory. In June 1951, a contract supplement for additional funds and extension of the contract termination date was negotiated which permitted fabrication of weapon components by ARF on a less limited basis, thereby accelerating the development activity in the succeeding phases of the program.

Under phase 3, test firing of the T33E3 model B was conducted to study the performance of the major working units both individually and in con-

junction with each other in the overall gun cycle. The effects of subsequent modifications incorporated in various components of the weapon were observed and evaluated, and the nature of additional redesign and modification requirements was determined.

In phase 4, a modification and redesign program was launched involving modifications to the feeder, feeder throat, and receiver, and redesign of the ejector, rammer, buffer, and both rotary-lock and drop-lock type bolts. Provisions were made to permit axial adjustment of the buffer for experimental determination of the optimum buffer location, and for the incorporation of bolt drive springs in the succeeding series of firing tests.

In phase 5, test firing of the modified T33E3 model B was initiated and progressed to the stage of successful burst firing. The effects of modifica-

tion and redesign of various major working units was observed and evaluated, and the nature of additional minor modification requirements in various component parts was determined.

The target requirements and specifications at the

inception of the program as compared with the actual performance characteristics achieved with the modified model B and potential characteristics believed possible of the T33E3 weapon are shown in the accompanying table.

Comparative Table of Desired, Attained, and Potential Characteristics of Weapon

Characteristic	Desired requirements of weapon	Attained in ARF development program of modified T33E3 model B	Estimated potential of weapon
Weight.....pounds..	Minimum.....	158	140
Length.....inches..	do.....	93 $\frac{3}{8}$	84
Height.....do.....	4 $\frac{3}{4}$ .....	4 $\frac{7}{16}$	4 $\frac{7}{16}$
Width.....do.....	Minimum.....	14 $\frac{7}{16}$	14 $\frac{7}{16}$
Approximate muzzle velocity....feet/second..	3,775.....		3,800
Approximate rate of fire.....rounds/minute..	1,200.....	780	1,000

**Phase 1. Test Firing of the T33E3 Model B With Two-Piece Rotary-Lock Bolt**

Development of the T33E3 model B gun was initiated upon the receipt of components from the Naval Gun Factory on 20 February 1950.

A general description of the overall design, kinematic and stress analysis, and characteristics of this model was recorded in the final report on contract No. W-11-022-ORD-11053 dated July 1950, after the termination of the contract. To maintain continuity, however, in describing the succeeding phases of the development, a description of the overall design and its major working units is presented here.

*Design and Description.* The model B weapon, like the model A, was designed to be mounted flat on its side to keep the height within 4 $\frac{3}{4}$  inches, and for feeding from left to right by reversing and replacing certain parts in the feeder. However, the model B design is simpler in arrangement and in many respects easier to manufacture. It featured a rotary-lock type bolt of two-piece body construction, a gas-operated feeder, a fixed ejector, a rammer actuated by bolt motion, a dual recoil spring arrangement, and a two-piece receiver.

**BOLT.** The bolt is locked in firing position by the rotary locks mounted in the tube extension on each side of the bolt. Lugs on the inertia slide ex-

tend out through each side of the bolt and engage the locks to prevent their rotation when firing occurs. Unlocking is accomplished by a gas piston which forces the inertia slide rearward and out of engagement with the locks. When the inertia slide reaches its rear position in the bolt and the bolt begins to move rearward, the inertia slide latch is actuated by a spring to sear the inertia slide. The locks are then free to rotate and are cammed out of engagement with the bolt lugs as the bolt moves rearward toward the buffer. No drive springs are provided, and the bolt is returned to battery by the bolt buffer. When the bolt returns to battery, it strikes projections on the locks and rotates the locks into engagement with the bolt locking lugs. When the bolt is fully forward, the front projection of the inertia slide latch strikes the tube extension and releases the inertia slide. The inertia slide, assisted by a spring, then moves forward under the locks and wedges them in position. The electric firing circuit is completed when the slide is fully forward.

**EJECTOR.** The ejector consists of an abutment machined in the feeder throat. It is struck by the extracted case, which pivots about the extractor and is ejected through the side of the gun.

**FEEDER BUFFER AND RAMMER.** The gas-operated feeder consists of a single-slide, two-slide return springs, 2 gas pistons which fit in cylinders

machined in the slide, 2 feed pawls which are attached to the slide and which strip the round from the link, and a feed sprocket which is connected to the slide through a ratchet and lever arrangement. As the gun fires, gas bled from the barrel to the feeder gas cylinders moves the slide against its return springs and the feeder pawls push the round ahead of it from its link into the feeder throat. On its return stroke, the slide, acting through the ratchet, causes the feed sprocket to rotate and place the next round in feeding position ahead of the feed pawls.

The round deposited in the feed throat in front of the rammer is held in place by retaining fingers, which engage the rim extractor groove. When the bolt moves rearward, it strikes the spring buffer and rammer slide, which actuates the rammer through a lever. The round, upon being struck by the rammer, slides forward through the feed throat which, being inclined at an angle toward the chamber, guides the round into the chamber. The bolt then picks up the round on its forward travel and chambers it.

Acceleration of the ammunition belt is low with this feeder, since the belt is fed by the energy of compressed springs shortly after firing, leaving most of the cycle time available for indexing the belt. Therefore, belt links can be light.

#### *Tests and Modifications.*

**TWO-PIECE ROTARY-LOCK-TYPE BOLT.** Testing was initiated to determine the strength of the bolt and locks, using ammunition which contained a reduced charge of 840 grains of IMR 6052 propellant in a T7E4 case.

The bolt fractured at the locking lugs upon firing the first round.

Investigation showed that the components had not been heat treated as specified, and therefore did not contain the proper strength characteristics. The stress conditions in the bolt and locks were reevaluated and the components were modified as follows:

1. The radii at the base of the bolt lugs were increased.
2. The size of the screws that held the two halves of the bolt together was increased.
3. The bolt and locks were properly heat treated.

A new two-piece bolt and a set of rotary locks incorporating the above modifications were manufactured by the Naval Gun Factory and tested in

the weapon. Complete failure of the bolt and both rotary locks occurred at the firing of the second round.

Examination of high-speed motion pictures indicated that disintegration of the components was initiated by a sequence of failures in the bolt and was followed by failure of the rotary locks as full setback load was applied first on one lock and then the other.

It was concluded that a bolt of two-piece body construction was inherently weak, and a design study of a one-piece bolt body was initiated.

**MECHANICAL BUFFER.** With the rammer and feeder removed, tests were conducted to determine buffer performance by using the fractured bolt and a vented pressure bomb as a source of energy to operate the gas piston. The results of these separate cycling tests are tabulated in an accompanying table.

**RAMMER.** The damage to the bolt which was incurred in the buffer tests was repaired, and testing was conducted to determine rammer performance.

With the feeder installed and one round in the feeder throat, the bolt was actuated by the pressure bomb at a velocity of 34 feet per second. The round in the throat was rammed and tightly chambered. The contacting surfaces of the rammer slide and bell crank were badly upset and the bell crank was cracked about its pivot hole and external radii.

**PNEUMATIC BUFFER.** With an initial pressure of 1,500 p. s. i. in the buffer and the pressure bomb adjusted to produce a rearward bolt velocity of 34 feet per second, two separate cycling tests showed the pneumatic buffer to be approximately 60 percent efficient.

**GAS PISTON.** The gas piston as originally designed tended to bind in the gas cylinder. This was due to the eccentric location of the axis of the gas piston extension with respect to the gas piston body. In subsequent tests the extension failed completely at its junction with the gas piston body. A new piston was made in which the extension was changed from a round to a rectangular section. A  $\frac{5}{8}$ -inch diameter extension was also added to the front end of the piston body to reduce the initial impact force on the bolt after unlocking. In further tests, the performance of the gas piston was satisfactory.

## Results of Mechanical Buffer Tests Using Vented Pressure Bomb

Test number	Peak gas pressure (p. s. i.)	Rearward bolt velocity (f. p. s.)	Buffer efficiency (percent)	Remarks
1	3, 219	18	.....	Bolt returned to within 1 1/2 inches of breech face.
2	5, 885	20	.....	Bolt returned to within 1/4 inch of breech face, gas piston tight in cylinder.
3	21, 000	34	64	Bolt returned to within 1/4 inch of breech face, gas piston tight in cylinder, inspection of bolt showed cracks in back section contacted by slide.

## Phase 2. Design of Alternate and Modified Replacement Components

A major part of the design work in this period was performed in parallel with the testing activities conducted in phase 1. Alternate designs of the rammer, buffer, bolt and tube extension assembly were completed, and the new rammer and buffer assembly was manufactured. The design of replacement parts, containing modifications in accordance with the evaluated results in the initial testing phase of the model B, was also completed.

*Drop-Lock Bolt and Tube Extension Assembly.* The new design of the drop-lock bolt employed a different method of locking. The bolt consists of a one-piece bolt body, locks, inertia slide, inertia slide spring, extractor, and firing-pin assembly.

The locks, which are contained in the bolt, engage abutments in the tube extension when the bolt is locked in battery position. When the inertia slide in the bolt is moved rearward by the gas piston, the locks are cammed upward into alignment with the bolt guideways in the tube extension by camways in the slide which engage cam followers in the lock. The bolt is then free to move rearward. The inertia slide is held rearward in the bolt by the bolt locks as the bolt travels to the buffer and forward again to battery. As the bolt stops in battery, the inertia slide continues its forward motion aided by the inertia slide spring camming the bolt locks down into their locked position in the tube extension abutments. Further forward motion of the inertia slide

closes the firing circuit to the firing pin, and the action is repeated.

This bolt possesses the following advantages over the rotary-lock bolt:

1. The locks hold the inertia slide rearward in the bolt and require no auxiliary latching device.
2. The locks are cammed into position by the inertia slide. This action is smoother than the action of the rotary locks, which are rotated into position after receiving a sharp blow from the bolt.
3. The inertia slide has some free travel after closing the locks, which permits the slide to bounce rearward a small distance thereby providing greater insurance against premature unlocking.

*Hydraulic Rammer and Pneumatic Buffer.* In anticipation of wear and possible breakage of parts in the mechanical linkage rammer, the design of a hydraulic rammer in conjunction with a pneumatic buffer was completed and manufactured.

The buffer consists of a piston and cylinder which is charged with air through a check valve. The rammer consists of a bolt actuated hydraulic piston and a hydraulic rammer piston. When the bolt strikes the hydraulic piston, oil is displaced into the rammer cylinder, causing the rammer piston to ram the cartridge. A coil spring restores the system to its initial position.

Preliminary tests of the pneumatic buffer were conducted in phase 1 with satisfactory results.

*One-Piece Rotary-Lock Bolt.* Following the second failure of the two-piece rotary-lock bolt, a new bolt was designed to provide greater cross-sectional

area in the highly stressed zones. The bolt body in this design was of one piece. Although modifications were also incorporated in the design of the inertia slide, extractor and firing pin, the overall arrangement was essentially like that of the preceding two-piece bolt design.

*Gas Piston.* Along with the redesign of the inertia slide in the new one-piece bolt, a modification was made in the design of the gas piston and gas piston plug. The gas piston extension was made shorter and its cross-sectional shape was reportioned. The result was a more compact design having increased strength.

### Phase 3. Tests and Modifications of the Model B Using One-Piece Rotary-Lock Bolt

Test firing of the model B was resumed upon the receipt of the new one-piece bolt and rotary locks manufactured by ARF. Tests in this period were conducted to study the performance of the bolt, feeder, ejector, rammer, and spring buffer, in the overall gun cycle. The ammunition used contained a reduced charge of 735 grains of IMR 6052 propellant in a T7E4 case, producing a maximum chamber pressure of approximately 30,000 p. s. i.

In this phase of development, modifications were made to various components of the bolt, feeder, and rammer. Their effects were observed and evaluated, and the nature of additional modification and design requirements were determined.

*Orifice Size Investigation.* Firing tests to determine feeder line and gas cylinder line orifice sizes were conducted with all gun components in operation. A variety of orifice combinations was used in a series of 17 tests. A  $\frac{1}{8}$ -inch diameter feeder orifice and a  $\frac{1}{8}$ -inch diameter gas cylinder orifice were found to be adequate to cycle the feeder with an accompanying bolt velocity of approximately 44 feet per second.

*Spring Buffer Investigation.* The helical spring buffer was used for a good number of cycles and its performance was satisfactory.

Data computed from time displacement records showed that the overall buffer efficiency, obtained by squaring the ratio of the bolt velocity leaving the buffer to the bolt velocity approaching the buffer, varied from 29 to 39 percent, depending upon the

amount of energy lost when the moving bolt struck the buffer.

It was noted, however, from the study of high-speed motion pictures and time-displacement records that the buffer was compressed almost completely solid in tests where the bolt velocity approached 45 feet per second.

*Feeder Investigation.* Excessive gas leakage occurred between the gas manifold and the piston retainer plate, which spread apart under gas pressure. These parts were replaced with wider ones and were more adequately supported by an additional lug welded on the feeder frame.

In further tests, the feeder gas pistons seized in the slide cylinders after the firing of a few rounds. This condition was caused by the accumulation of carbon deposits on the cylinder walls. An annular groove was machined at the end of each cylinder, and a series of annular grooves were machined in the gas pistons. Seizing did not occur after these changes were made.

In attempts to ram the round in the feeder throat, it was found that the timing between ramming and feeder indexing was such that a round was indexed into stripping position before the round being rammed had moved far enough forward to be out of its path. This condition was corrected by spacing the feeder sprocket away from the feeder throat.

At the end of 37 single-shot feeder cycling tests, the two Fabreeka impact pads which stop the feeder slide were badly frayed. Larger pads were designed and installed.

In further attempts to ram, it was found that the positioning of the round and the link prior to stripping was inadequate. Guides were attached to both ends of the radial link guide in the feeder, providing the axial control necessary for proper stripping.

It was found also that the spring guides, located on each side of the feeder throat, were not strong enough to prevent the stripped round from bouncing back out of the throat nor to control the round in the throat during ramming. Steps were taken to correct these conditions by increasing the strength of the guides.

*Mechanical Rammer Performance.* The mechanical rammer, as first designed, was proved too weak in prior tests using a vented bomb as a source of energy.

Calculations based on time-displacement records of the bolt motion indicated that a ramming velocity of 50 feet per second would be necessary in order to place the round in front of the bolt in the existing gun. Since the original design provided for a higher ramming velocity, the rammer linkage was modified by relocating the rammer pivot pin and by adjusting the rammer slide length to provide the required ramming velocity. It was realized that a ramming velocity of 50 feet per second would probably result in debulleting; however, a series of tests was conducted in order to obtain data on all the individual components under complete cycling conditions in the shortest possible time.

In none of 17 tests conducted using this modified rammer was the round rammed with sufficient velocity to place it ahead of the bolt returning to battery. The cause of the insufficient ramming velocity was not determined; however, it was felt that a ramming mechanism free of impact phenomena would be desirable. Therefore, the study of the design of an accelerator-type rammer was initiated.

*Ejector Performance.* Examination of ejected cases showed very severe extractor marks beginning to appear at bolt velocities of 40 feet per second. It was felt that the high ejection load could be reduced considerably by the use of a spring-loaded ejector; consequently, a study to incorporate such a design in the gun was also initiated.

#### *One-Piece Rotary-Lock Bolt.*

**INERTIA SLIDE.** After 18 rounds were fired, radial cracks appeared at the threaded hole in the forward part of the inertia slide body. The part was salvaged by grinding out the threads and cracks and welding the hole closed. After six additional rounds, the slide failed completely at the fillet between the inertia slide extension and the slide body.

A new slide was made identical with the original part, but the threaded hole was omitted. After two rounds, cracks appeared at the fillet where complete failure had occurred in the original slide. These cracks were ground away, giving a larger fillet at this section, and the part was inspected by magnaflux. Four more rounds were fired, and a new crack appeared in the same region.

Examination revealed that the bolt body was sprung open at the forward section by a wedging action of the cylindrical section of the slide in the bolt body. To improve the support of the slide in

the bolt, guideways were cut in the bolt body for engagement with two lugs incorporated into the modified inertia slide.

**INERTIA SLIDE SEAR.** Examination of inertia slide sear action in high-speed motion pictures showed that the sear did not always act to lock the inertia slide to the rear position of the bolt during bolt unlocking but that this action was accomplished when the bolt contacted the buffer. The cause of the erratic sear action was not determined.

**EXTRACTOR.** On round No. 50, the extractor failed at the pivot hole. A stronger extractor was made, and its performance in the remaining tests was satisfactory.

**FIRING PIN.** In all the rounds fired, the primers were upset because the firing-pin hole in the face of the bolt was not small enough to provide adequate support for the primer. Otherwise, the firing pin performed satisfactorily.

**BOLT BODY.** Failure of the bolt body at the left locking lug occurred after the firing of 84 rounds. Steps were promptly taken to increase the strength of the bolt body in a new design for a rotary-lock bolt.

#### *Modified Components.*

**DROP-LOCK BOLT AND TUBE EXTENSION ASSEMBLY.** The drop-lock bolt and tube extension components were received from the Naval Gun Factory in June 1951. Inspection of the components, however, showed the parts to be unusable because of distortion caused by heat treatment and welding repairs. It was also learned that a similar lock used in the Navy 30-mm version of this weapon had a tendency to unlock under setback load. It was felt that any attempts at salvage by annealing, straightening, and heat treating would probably lead to further difficulties and would be impractical from a time and cost point of view. Therefore, it was decided to make the necessary modifications in the locks, and manufacture new components of this assembly.

**PNEUMATIC BUFFER AND HYDRAULIC RAMMER.** Calculations involving the pneumatic buffer showed that its energy absorption capacity was limited to a bolt velocity of approximately 35 feet per second. Since testing in this period was conducted with bolt velocities upward of 40 feet per second, the air buffer was not used.



In hand actuation tests of the hydraulic rammer, it was found that the rammer piston returned too slowly to its original position after being actuated. Modification in the cylinder body would have been required in order to incorporate a stronger return spring.

Since the hydraulic rammer and pneumatic buffer were incorporated into one integral design, it would have been necessary to separate the rammer and adapt it for use with a spring buffer if further tests were to be made. This did not seem practical, and the hydraulic rammer was abandoned in favor of an improved mechanical rammer.

*Conclusions.* The bolt travel in the original T33E3 model B gun, excluding buffer action, was 8 inches. With bolt velocities of 44 feet per second rearward and 25 feet per second forward, a ramming velocity of 50 feet per second would be required in order to position the rammed round forward of the bolt returning to battery. Experience had shown that ramming velocities in excess of 35 feet per second could result in debulleting.

It was decided, therefore, to modify the gun and incorporate an accelerator type rammer which would ram at 30 feet per second with an accompanying bolt velocity of 50 feet per second. A bolt velocity in the 50-feet-per-second velocity range was selected because of the increased probability of parts breakage associated with higher impact velocities. To compensate for the slower ramming velocity, it would be necessary to move the buffer rearward so that the bolt would not return soon enough to jam the round being rammed. Preliminary calculations indicated that moving the buffer about 3 inches rearward would accomplish this purpose. The cyclic time would not be appreciably increased by moving the buffer rearward, since the bolt would move at a higher average velocity.

#### Phase 4. Modification and Redesign of Various Components of Model B

Tests conducted in phase 3 yielded considerable information. Evaluation of these data resulted in the initiation of an overall modification and redesign program involving modifications to the feeder throat, tube extension, and receiver, and redesign of the ejector, rammer, buffer, and both rotary-lock and drop-lock type bolts.

An analysis of the cyclic function of the modified weapon was made and debulleting tests were conducted to verify assumptions made in the analysis regarding allowable chambering velocities.

The program was directed toward bringing the development of the weapon to a stage where the evaluation of its potential, in terms of cyclic rate, estimated weight, and performance, could be determined in reasonably early firing tests.

Specific modification, analytical, redesign, and test activities conducted in this period were as follows:

*Rotary-Lock Bolt.* The rotary-lock-type bolt was redesigned. Modifications incorporated in this new design were as follows:

1. The locking lugs were made heavier to provide greater strength.
2. The contour and method of machining the locking lug bearing faces were changed to insure identical machining of the two lugs and therefore equal loading of the 2 lugs.
3. The radius of the fillet at the junction of the locking lug with the bolt body was increased.
4. The inertia slide sear was redesigned for operation by the rotary locks. This change resulted in the elimination of the opening in the bottom of the bolt.
5. Greater support was provided for the inertia slide.
6. The firing-pin hole in the bolt face was reduced to 0.124 inch in diameter, and the firing pin design was patterned after one which had performed successfully in the caliber .60 T130 gun.
7. Provisions were made on the bolt body for the use of bolt drive springs.

#### *Drop-Lock Assembly.*

**DROP-LOCK TYPE BOLT.** In view of the failure of the rotary-lock-type bolt, modifications toward strengthening the drop-lock bolt were considered desirable. Consequently, the drop-lock bolt was redesigned, and a new bolt was made. The following modifications were included in the redesign.

1. The separate buffer contact plate at the rear of the bolt was eliminated by the use of a one-piece bolt body construction.
2. The axially elongated, machining-clearance hole at the top forward portion of the bolt was removed.
3. The drop-lock pivot holes at right angles with the axis of the bolt were removed.

4. A 7° locking angle was incorporated in the locks to prevent premature unlocking.

5. Modifications to the inertia slide were made to facilitate machining.

6. A firing pin similar to that used on the caliber .60 T130 gun was provided, and the hole in the bolt face was reduced to 0.124 inch in diameter.

**TUBE EXTENSION FOR USE WITH DROP-LOCK BOLT.** Modifications necessary to make the tube extension manufactured by the Naval Gun Factory usable were found to be impractical from a time and cost point of view. A design change aimed at increasing the strength of the load-carrying insert section was made, and the gas piston and gas piston plug were redesigned to be interchangeable for use with the rotary-lock tube extension.

**ANALYSIS OF CYCLIC FUNCTION OF WEAPON.** Together with the redesign of the rotary-lock bolt, drop-lock bolt, and tube extension assembly, a study layout of the overall gun action was initiated. This study incorporated new designs of the rammer, ejector, and buffer, and provided for the adjustment of the buffer location in the receiver and the optional use of bolt drive springs.

A companion analysis was made in which the effects of the redesigned components in the overall kinematic action of the weapon were determined.

**SPRING-LOADED EJECTOR.** The spring ejector consists of an ejector, anvil, guide rods, and springs, and is mounted to the feeder throat.

When the spent case contacts the ejector, the anvil and guide rods are moved rearward, compressing the springs. The rearward motion is stopped when the anvil contacts the abutment, and the assembly is then returned to its original position by the springs.

**ACCELERATOR RAMMER.** The accelerator-type rammer, which employs a different method of ramming and is mounted on the feeder throat, consists of a reset spring, lever, links, and accelerator.

After ejection of the spent case has been initiated, the actuating cam on the bolt contacts a lever, and through links rotates the accelerator, ramming the round. The linkage is returned to its original position by the reset spring.

The timing of ejection and the initiation of ramming was so related that with a ram velocity of 30 feet per second, ejection of the spent case would

be completed in time to prevent interference with the round being rammed.

Three accelerators were made, to ram rounds at calculated velocities of 30, 35, and 40 feet per second, respectively. This was done to guard against kinematic inadequacies which might occur in the system through inefficient operation of the linkage, and to observe the effects of higher ramming velocities with respect to ejection.

**RECEIVER.** Computations in the analysis showed that it would be necessary to move the buffer rearward 3 inches in order to compensate for lower ramming velocities. The receiver was extended, therefore, to provide for the new buffer location. Further modifications were incorporated to make the buffer location adjustable in the receiver, in the forward direction, in five increments of one-half inch each. This was done in order to adjust the ramming and bolt velocities for experimental determination of optimum ramming conditions and maximum cyclic rate.

**BUFFER.** A two-stage spring action, providing for the compression of a coil spring and a ring spring in successive steps, was incorporated into the design of a new buffer. The buffer was also designed to satisfy the following requirements:

1. To provide rear housings for the bolt drive springs.
2. To adapt the buffer for adjustable location in the receiver.
3. To provide a greater capacity for the absorption of energy in the buffer springs.

**FEEDER THROAT.** Gate-type guides were designed as an alternate means for controlling the round in the feeder throat during ramming. The new design was also intended to check the tendency for the round to be raised back out of the feeder throat by the action of the rammer.

**DEBULLETING TESTS.** The allowable round-chambering velocity, which is limited by the danger of debulleting, was not known. Consequently, a series of tests was conducted to determine the chambering velocity at which debulleting would occur.

Tests were conducted using a bolt testing device which was modified to chamber rounds at 30, 35, and 40 feet per second. Tests were made at velocities of 30, 36, and 39 feet per second, at which time the test bolt broke. Since none of the rounds tested debulleted more than one thirty-second inch, it ap-

peared that chambering velocities in the order of 40 feet per second were permissible.

### Phase 5. Tests of Modified T33E3 Model B

*Details of Tests.* In this phase, 106 rounds were fired with the modified 20-mm T33E3 model B gun in a series of 59 separate firing tests, bringing the total number of rounds fired to 190. Test firing was conducted in two phases in which the new rotary-lock bolt assembly and the new drop-lock bolt and barrel extension assembly were used consecutively with the new spring-loaded ejector, accelerator rammer, and modified feeder throat and receiver.

Testing was initiated with the use of ammunition containing a reduced charge of 735 grains of IMR 6052 propellant in a T7E4 case, which produced a maximum chamber pressure of approximately 30,000 p. s. i. The ammunition used in the last 14 tests contained a reduced charge of 840 grains which produced a maximum chamber pressure of approximately 42,000 p. s. i. The normal charge of 900 grains produces a pressure of about 49,000 p. s. i. (copper crusher gage). Tests were conducted to study the performance of the bolt, feeder, ejector, rammer, and buffer in the overall gun cycle. The effects of modifications and redesign incorporated in the feeder throat, ejector, rammer, buffer, and both rotary-lock and drop-lock bolts were observed and evaluated, and the nature of additional modification requirements was determined. All activities were brought to a halt on 26 March 1952 at the request of the Ordnance Corps.

Test results in this phase were as follows:

#### *Rotary-Lock Type Bolt Performance.*

**BOLT BODY.** Failure of the bolt body at the left locking lug occurred at the firing of the third round. High-speed motion pictures of this test showed that the bolt failed before unlocking.

**INERTIA SLIDE, INERTIA SLIDE SEAR, EXTRACTOR, FIRING PIN, AND ROTARY LOCKS.** Examination of these component parts after firing tests showed no evidence of damage. Their performance in the bolt cycle as seen through high-speed motion pictures was satisfactory, and all difficulties experienced in the old rotary-bolt cycle appeared to have been corrected.

**CONCLUSIONS.** The fracture of the locking lug on the bolt body in this series of tests was the second consecutive failure of this section on the rotary-lock bolt of one-piece body construction. It was then apparent that this structural weakness was inherent in the design and could be overcome only by increasing the proportions of the load sustaining sections. Although the testing of the rotary-lock type bolt was short-lived, there was sufficient evidence in its satisfactory performance in the gun cycle to indicate that the overall design was generally sound. However, in view of the modifications necessary to bring the bolt up to strength and the related extensive changes which would be required in the overall gun design, it was decided to abandon the rotary-lock-type bolt in favor of the drop-lock bolt at that time.

*Drop-Lock Bolt Performance.* With the use of the new drop-lock bolt, test firing of the modified T33E3 model B gun progressed to the stage of successful burst firing. One hundred and three rounds were fired with this bolt in this phase in a series of 56 separate firing tests. Average rearward bolt velocities were in the 50-feet-per-second velocity range. Both locks of this bolt failed at the firing of the twenty-fifth round and a resultant rearward bolt velocity of 115 feet per second was recorded. A new and slightly modified set of locks was installed and their performance in subsequent tests was satisfactory.

The performance of the drop-lock bolt components in the bolt cycle was as follows.

**BOLT BODY.** The performance of the bolt body in this series of tests indicated that the design was within strength requirements with respect to buffer impact loads. Magnafluxing of the bolt body after the lock failure showed no signs of fracture and there were no indications of undue strain or deformation resulting from the lock breakage or from the bolt striking the buffer housing on the ensuing 115-feet-per-second bolt cycle.

**BOLT LOCKS.** Failure of both locks occurred at the firing of the twenty-fifth round. The exact cause of the failure was not determined. However, it was felt that the initial fracture of both locks occurred at the section above the cam followers and was followed by the fracture in the left lock across the principal load-sustaining section. There was reason to believe that the initial failure was due to inter-

ference and impacting of the lock cam followers against the inertia slide camways during the bolt unlocking action. Steps taken to correct this condition and to improve the locks were as follows.

1. Material in the inertia slide camways was removed to eliminate interference and allow a smoother unlocking action.

2. The direction of the grain in the locks was changed and made perpendicular to the plane of the initial fracture.

3. The hardness of the locks was decreased from Rc 55 to Rc 43-48.

A new set of locks incorporating above modifications (2) and (3) was installed, and no further breakage occurred. The endurance of the modified locks through the last 14 tests was significant in that the ammunition used in these tests contained an 840-grain powder charge. However, upon inspection of the locks after the termination of tests, the presence of impact marks on the cam followers and at the radii at the base of the locking faces was noted.

**INERTIA SLIDE.** Together with the slight changes made in the design of the locks, modifications were incorporated in the inertia slide, which seemed to have corrected the conditions causing lock failure. The presence of impact marks on the locks at the end of cycling tests indicated that further modifications in the inertia slide camways were in order. Otherwise, the performance of the inertia slide was satisfactory.

**INERTIA SLIDE SPRINGS.** Damage was incurred to the inertia slide springs when the bolt locks failed. The damaged springs were replaced and after being used in 78 cycles, examination showed that both springs had taken a slight set. It was felt, however, that this condition could be corrected by redesigning the springs without effecting any significant changes in the bolt body or inertia slide.

**EXTRACTOR.** The performance of the extractor as seen through high-speed motion pictures was satisfactory. Deformation of the extractor occurred in the cycle of the bolt lock failure when the case was extracted and ejected with a bolt velocity of 115 feet per second. The extractor was replaced and there was no further occurrence of deformation in the subsequent tests.

**FIRING PIN.** Upsetting of the primers, which had occurred in earlier tests, was greatly improved at this time. The hole provided in the face of the bolt

for the firing pin had been changed from 0.156-inch diameter to 0.124-inch diameter, thereby providing greater support for the primer at the time of firing.

*Spring-Loaded Ejector Performance.* The performance of the new spring-loaded ejector was satisfactory in every way. Although a slight set was taken by the ejector springs on the 115-feet-per-second bolt velocity cycle, they were not replaced.

Inspection of the ejector action in high-speed motion pictures showed that the spent case was rotated out of the path of the approaching rammed round in time to provide an unobstructed path to the chamber. Examination of the ejector and extractor marks on all of the ejected cases in this series of tests indicated that the combined action of the new ejector and extractor, associated with bolt velocities of 50 feet per second, was not severe.

Both guide rods of the ejector assembly failed on the last test when 8 rounds were successfully fired in an attempted 8-round burst. It was felt, however, that this failure was initiated in the 115-feet-per-second bolt velocity cycle and that the design was well within strength requirements.

*Accelerator Rammer and Feeder Throat.* Tests involving the new accelerator rammer and modified feeder throat were initiated in order to ram the round in the feeder throat ahead of the bolt returning to battery. With the buffer adjusted in its rearmost position, providing an 1 1/8-inch battery to buffer bolt travel, and the orifice to the gas cylinder adjusted to produce a rearward bolt velocity of 50 feet per second, a series of tests was conducted using the 30-, 35-, and 40-feet-per-second rammers consecutively. In no instance was the round in the throat given a velocity sufficient to place it ahead of the bolt returning to battery.

Markings on the rounds indicated that the rammed round was being cocked by the action of the rammer, causing the shoulder of the case to strike the forward part of the feed throat.

The spring-type round guides in the throat were replaced with the new gate-type guides, but the condition still existed to some degree.

The gate guides were moved forward and lead angles were provided in the throat at the points of interference. A new actuating cam with a 1 7/8-inch radius of curvature was also installed in the bolt, and successive 2- and 3-round bursts were fired.

Timing of the round motion with a calibrated synchronous motor in view of the Fastax camera showed the rammed round to be moving at an average velocity of  $29\frac{1}{2}$  feet per second. This average velocity was the same for each round rammed in the two bursts. It was also seen that the bolt did not overtake the rammed round until the round was fully chambered.

Failure of the drop-lock bolt locks on the next test resulted in damage to the buffer support block, making it necessary to move the buffer forward in the receiver one-half inch to an undamaged mounting point.

In further tests, with a battery to buffer bolt travel of  $10\frac{5}{8}$  inches, burst firing was erratic. Inspection of the feeder and ramming actions in high-speed motion pictures showed that the stripped round was not always placed in the proper axial position in the feeder throat prior to ramming. Additional spring guides, which engaged the extractor groove in the round, and a rear round guide plate were installed to provide the necessary control of the round during stripping.

In further tests, bursts were frequently halted because the gate guides would not close over the stripped round. This resulted in the rammed round jamming against the forward part of the feed throat. Additional torsion springs were installed in the gate guides to make them faster acting. A new actuating cam with a  $1\frac{1}{2}$ -inch radius of curvature was placed in the bolt; and with the use of 840-grain ammunition, bursts of various lengths up to and including 8 rounds were fired.

High-speed films and time-displacement records were not taken in the latter part of these burst tests, but calculations from the films available showed that rounds were being rammed at average velocities of 40 feet per second. These higher ramming velocities resulted from the use of the new actuating cam and from the higher bolt velocities obtained with the use of 840 grains of propellant.

*Feeder Performance.* The performance of the feeder in this phase of testing was satisfactory.

With the initiation of burst firing, it was possible for the first time to test all aspects of the overall feeder action in the complete gun cycle. Inspection of high-speed films showed that the relative timing of indexing and stripping with respect to the initiation of ramming was satisfactory.

General inspection of the feeder after termination of firing tests showed the following miscellaneous parts damage.

1. The two Fabrecca pads which stop the feeder slide were badly frayed.

2. Both Fabrecca stripper pads in the front of the slide had come off.

3. The pawl and spring which prevent the feeder sprocket from overriding on the stripping stroke were damaged.

*Buffer Performance.* Data computed from time-displacement records showed that the overall buffer efficiency, obtained by squaring the ratio of the bolt velocity leaving the buffer to the bolt velocity approaching the buffer, varied from 33 to 44 percent. The overall buffer efficiency of the original coil-spring buffer as computed from time-displacement records varied from 29 to 39 percent. The two-stage spring action, providing for the compression of a coil spring and a ring spring in successive steps, incorporated in the new buffer resulted in an increase in buffer efficiency of approximately 12 percent.

*Summary of Gun Performance.* Test firing of the modified model B gun in phase 5 was conducted in two stages under varying conditions of bolt travel, bolt velocities, ramming velocities, and ammunition charge. From a study of high-speed films and time-displacement records and from the results of test firing, the following observations and conclusions were made regarding the overall gun cycle.

**DROP-LOCK BOLT.** The performance of this bolt in the gun cycle was satisfactory. The locking and unlocking action appeared to be smooth, but the presence of impact marks on the locks at the end of firing tests indicated that further modifications were required in the inertia slide camways.

**EJECTION.** The action of the ejector was smooth; the timing was satisfactory. If the failure of the guide rods, which occurred on the last burst-firing test, had not initiated in the prior lock failure cycle, it was felt that modifications toward improving the method of securing the guide rods would bring the assembly up to strength requirements.

**FEEDER OPERATION.** The overall feeder performance was good. Eleven rounds had been pulled into the feeder with the existing springs, but the maximum belt pull capacity was not known.

Modifications were required in the feeder slide to improve the method of supporting the Fabreeka impact pads and to improve the means of fastening the Fabreeka stripper pads to the slide. Modifications toward increasing the strength of the sprocket pawl and spring were also required.

**FEEDER THROAT.** The principal causes of interrupted burst firing in overall cycling tests were found in the feeder throat. It was not known whether the final modifications made prior to the firing of the eight-round burst were sufficient to correct all the difficulties encountered in earlier tests. However, lengthening of the spring-loaded gate guides and refinement of the methods used in controlling the transfer of the round during stripping were considered desirable.

**ACCELERATOR RAMMER.** Shortly after the initiation of ejection, the actuation cam at the rear of the bolt contacts the rammer and the round in the feeder throat is driven toward the chamber. With the buffer position adjusted to provide an  $11\frac{1}{8}$ -inch bolt travel and with a ramming velocity of  $29\frac{1}{2}$  feet per second, the bolt did not overtake the rammed round until the round was fully chambered. With the buffer adjusted for a  $10\frac{5}{8}$ -inch bolt travel and with a ramming velocity of 40 feet per second, the bolt did not contact the rammed round until the round had been chambered for about 6 milliseconds. It was noted that the rammer did not produce ramming velocities as expected and that it was necessary to use a much higher accelerating curve in the actuator cam along with bolt velocities in the vicinity of 60 feet per second in order to produce ramming velocities of 40 feet per second. This weakness was traced to one or a combination of the following causes.

1. The design of the accelerator rammer was kinematically weak.

2. Control of the round in the feeder throat prior to ramming was insufficient to keep the round in the proper ramming position under actual firing conditions.

3. The round was retarded in free flight after leaving the rammer.

Test activities were terminated before it was possible to determine which of these conditions was responsible for the reduced ramming velocities.

**BUFFER.** The design of the buffer was kinetically adequate and its performance in firing tests was

good. It had an energy capacity sufficient for bolt velocities of 50 feet per second, and its efficiency was approximately 34 percent.

**CYCLIC RATE.** Although the test firing program of the modified model B gun was terminated while still in the initial stage, sufficient data were obtained to indicate that cyclic rates in the order of 1,000 rounds per minute were possible.

Test firing was conducted in two stages under the following conditions:

**STAGE 1:**

Weight of propellant: 735 grains.

Battery to buffer bolt travel:  $11\frac{1}{8}$  inches.

Approximate ramming velocity:  $29\frac{1}{2}$  feet per second.

**STAGE 2:**

Weight of propellant: 840 grains.

Battery to buffer bolt travel:  $10\frac{5}{8}$  inches.

Approximate ramming velocity: 40 feet per second.

From a 3-round burst fired under the conditions existing in stage 1, the average cyclic rate as calculated from the time-displacement record was 696 rounds per minute. The average rearward bolt velocity was 48 feet per second, and the average overall buffer efficiency was 38 percent. The time required for the inertia slide to accomplish locking and effect ignition was 0.020 second.

From a 3-round burst fired under conditions existing in the stage 2, an average cyclic rate of 780 rounds per minute was calculated. The average rearward bolt velocity was  $58\frac{1}{2}$  feet per second, and the average overall buffer efficiency was 34 percent. The time required to accomplish locking and ignition was 0.018 second.

Locking and ignition time was much higher than was expected. The basic cause for this condition was not determined. It can readily be seen that if this time were reduced to 7 milliseconds which seems ample, the cyclic rate of this typical 3-round burst would be increased to 920 rounds per minute. Steps toward decreasing locking and ignition time by spring loading the locks downward and installing stronger inertia slide drive springs in the bolt were suggested.

With initial bolt velocities of 60 feet per second, ramming velocities of 40 feet per second, and the use of bolt drive springs, cyclic time could be re-

duced further by adjusting the buffer position forward in the receiver until an optimum condition was reached with respect to the bolt pickup of the rammed round.

*Summary of Conclusions.* The test study and modification activities on this weapon were halted in the intermediate phase of development; therefore, conclusions regarding the merits of individual components or overall performance characteristics were limited in scope.

From the tests and studies conducted in this development period, the following difficulties were encountered, which were considered to be minor in nature and rectifiable through modification or redesign.

1. Control of the round during stripping was inadequate, resulting in improper positioning of the

round in the feed throat prior to ramming. This condition was the principal cause of burst interruptions.

2. During ramming, the action of the rammer accelerator on the round being rammed tended to cock the round causing the shoulder of the case to strike the forward part of the feed throat.

3. The time required for the bolt inertia slide to accomplish locking and effect ignition was excessive, amounting to approximately 23 percent of the cycle time.

The weapon lent itself to easy manufacture and with the novel features of its bolt, gas-operated feeder, accelerator rammer, and low silhouette, demonstrated considerable potentiality of being developed into a reliable, high-velocity weapon with a cyclic rate in the order of 1,000 rounds per minute.

#### SECTION 4. T109 AIRCRAFT AUTOMATIC CANNON

In 1948, there was a trend to cut down the overall lengths of automatic cannon for turret installation. A requirement was set up for a gun having a maximum length of 52 inches, and it was proposed that the T33 be redesigned to fill this need. The muzzle

velocity anticipated was 3,700–3,800 feet per second. Accordingly, the Army's Ordnance Corps assigned the project the number T109. This weapon progressed only to the blue print stage.

#### SECTION 5. 30-MM AIRCRAFT GUN MARK 5 MOD 0

##### Background and Development

The Navy became interested in the possibilities of a larger bore automatic cannon of the type of the T33, and in 1950 a project was initiated. The prototype was made at the Naval Gun Factory under

the official designation, 30-mm aircraft gun Mk 5 Mod 0. The Army designation for the same design is T120.

In the same year, the prototype was delivered to the Naval Proving Ground, Dahlgren, Va., for test-

##### General Data: 30-mm Gun Mechanism Mk 5 Mod 0

Gun length: 85 inches.  
 Gun weight: 135 pounds.  
 Rate of fire: 750–800 rounds/minute (estimated).  
 Muzzle velocity: 1900 feet/second.  
 System of operation: Gas unlocking, blowback.  
 System of locking: Swinging locks.  
 System of feeding: Buffer actuated.  
 Method of headspace: Factory established.  
 Location of feed opening: Right- or left-hand side of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: None.  
 Method of cooling: Air.

Barrel length: 63 inches.  
 Barrel weight: 58 pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect.  
 Bore:  
 Number of grooves: 16.  
 Groove depth: 0.020 inch.  
 Groove width: 0.250 inch.  
 Pitch: 9° 30'.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: Same type as German MK 108.

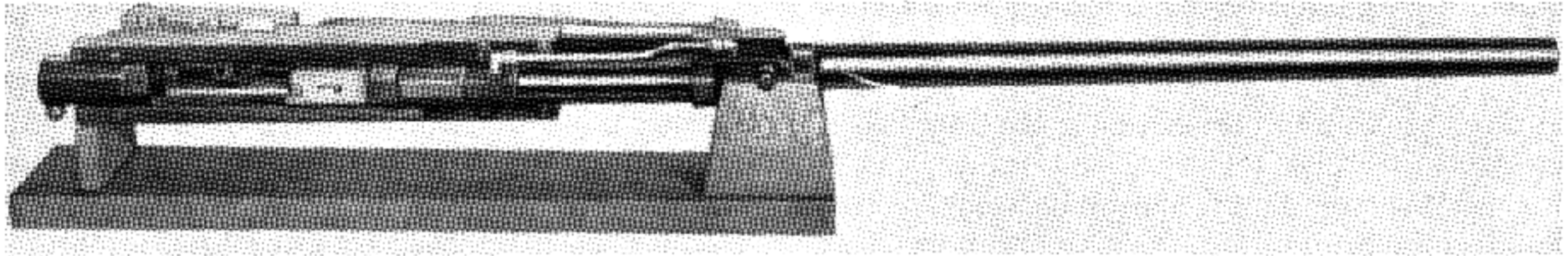


Figure 8-10. 30-mm Gun Mk 5 Mod 0. Right side view.

ing. Single shots were fired. Damage to bolt and locks resulted; when these parts were checked, they were found to be improperly heat treated.

This defect resulted in a redesign for greater strength and in the construction of new parts with proper heat treatment. Construction was also started on a new type bolt with a drop lock that was considered to be less marginal than the previous types.

A test device was set up in the Naval Gun Factory which bench tested certain components while the parts were undergoing stresses that would be found only in actual firing.

With this device, a test of a new mechanical buffer indicated high efficiency. The test of the auxiliary rammer indicated, however, that the design was not only inefficient, but also inadequate and, that it would not withstand the impact forces. Accordingly, a new type of hydraulic rammer was conceived, and a combination pneumatic buffer and hydraulic rammer was designed and built.

A second rotary lock bolt was received at the Naval Proving Ground; it also failed after a few rounds.

Although the failure of this bolt was attributable to improper heat treatment, the factor causing the earlier failure, a decision was reached to drop this bolt design in favor of the drop-lock type that was then being manufactured.

A new one-piece rotary lock bolt was made and placed in the testing device together with redesigned rotary locks. Upon receipt of new bolts and parts, the Naval Proving Ground again resumed tests to determine the best combination of components and to evaluate the improvements in heat treatment and metallurgy under severe firing strain.

### Description of Assemblies of Redesigned Prototype

*Main Assembly.* The main assembly of the 30-mm aircraft gun Mk 5 Mod 0 includes the breech-block, feed mechanism, buffer and rammer, and barrel extension assemblies.

The nonrecoiling components are receiver, barrel support, feeder, rammer and buffer assembly, and the gas tubes that are necessary for the operation of the feeder and unlocking of the breech. Trunnions and lugs for supporting the forward end of the recoil springs (two springs, 180° opposed on center-line of gun) are integral. Recoil springs are of the ring-spring type; length of recoil of guns is about 0.375 inch.

The gun barrel is the quick disconnect type, having bayonet threads at the breech end. Removal of barrel is accomplished by depressing the barrel catch on the barrel extension and rotating the barrel 90° counterclockwise, then pulling the barrel forward. Receiver slides are bolted to the barrel sup-

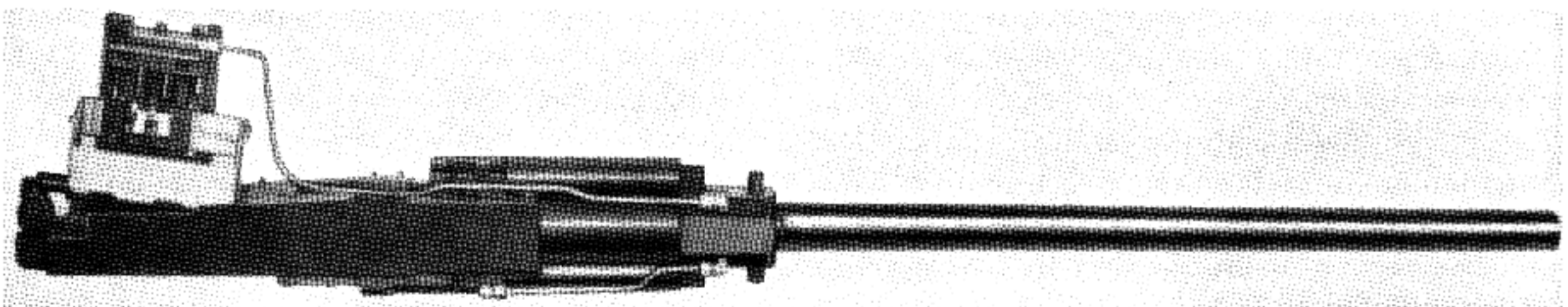


Figure 8-11. 30-mm Gun Mk 5 Mod 0. Top view.



port at their forward end and are enjoined by two support plates on the left side of the receiver. The buffer and rammer assembly is supported by guides in the receiver and are secured thereto by 0.375-inch diameter pins. The feeder is secured to the rammer assembly by special screws. The electric terminal for firing the gun is located on the upper right-hand side of the receiver. The gas tubes are "18-8" alloy steel of 0.187-inch inside diameter. They are secured by commercial compression fittings.

The orifice in the forward end of the breech unlocking and feeder gas tubes is adjustable by selection of washer type molybdenum inserts.

*Barrel Extension Assembly.* The barrel extension has bayonet threads that mate with the threads on the barrel and recoil with the barrel. The barrel latch is a spring-loaded device that keeps the barrel from rotating in the barrel extension. The latch must be depressed to facilitate removal of the barrel. The gas piston that unlocks the breech is contained in a cylinder that is an integral part of the barrel extension.

Two guide rails (right and left) are secured by cap screws to the aft end of the barrel extension. The rails support and guide the breechblock during recoil and counterrecoil, and they are extensions of guide grooves in the barrel extension. Within each side of the rearward section of the barrel extension is a key insert. The keys (right and left) receive the breechblock locks when the breechblock is locked in battery position. The keys become a permanent part of the barrel extension when installed; however, they may be replaced if necessary.

*Breechblock Assembly.* The breechblock assembly is the nonsecured type. Its normal position in the gun mechanism is in the battery position, both before and after firing. Therefore, all electrical contacts with the breechblock assembly and the gun mechanism are closed, and firing takes place upon closing the main switch, located away from the gun.

The parts within the breechblock are: slide, which carries the electrical components that make and break contact with the receiver, contact, and firing pin group; slide spring, which returns to forward position after firing. The external sides of the slide have cam shaped slots that receive lugs on the breechblock locks. Fore-and-aft motion of the slide raises and lowers the locks. During firing,

the slide is pushed rearward by the gas piston in the barrel extension. Forward motion of the slide is restrained by the stop that also retains the extractor spring. The extractor is operated by a short coil spring. Removal of the slide is accomplished by sliding the breechblock cover forward.

The firing pin group consists of the firing pin, spring, contact, insulators, and retaining plugs. The entire group may be taken out of the breechblock by removing the roll pin in the breechblock. A pin that is used to manually unlock the breechblock in the gun is secured to the slide and projects through a slot in the cover of the breechblock. Retracting the pin moves the slide rearward; thus the locks are raised. The wide groove in the top of the breechblock is clearance to allow the ejecting surface on the feed throat of the buffer and rammer mechanism to contact the rim of the cartridge case during ejection. Thick flange-like surfaces support the breechblock in the guide grooves and rails of the barrel extension assembly.

*Buffer and Rammer Assembly.* The primary function of the buffer and rammer assembly is to retard, stop, and return the breechblock to the battery position, since there is no driving spring in the gun mechanism, and to project a round of ammunition from the feed throat into the chamber of the gun barrel.

The mechanical buffer consists of: housing, anvil, two coil springs (one inside the other), and retaining plug. Integral side supports assist in securing the buffer to the receiver of the gun. Lugs for supporting the hammer and feed throat and a lug for securing the rear of the gun in an aircraft installation or test mount are also integral with the buffer housing.

On one side of the buffer is the hammer slide, which, when struck by the breechblock, partially rotates the lever-type hammer. The slide travels 0.375 inch before the breechblock contacts the anvil of the buffer. The rammer subassembly is at the rear end of the feed throat, which is secured to the buffer housing. When the rammer is struck by the hammer, the rammer pushes a round of ammunition out of the feed throat. The rammer is returned by a coil spring to a position of rest. Two spring-loaded detents in the feed throat grip the extracting groove of the cartridge case to prevent forward motion of the round until ramming takes place. Two

spring-loaded latches (right and left) in the feed throat keep the round from falling out of the feed throat. The latches have camming surfaces that cause them to open when a round is fed into the feed throat. The forward lugs of the feed throat are keyed into the receiver of the gun in the main assembly. The feed throat is positioned at an angle of  $7^{\circ} 30'$  to the centerline of the gun. It is along this path that the round of ammunition is projected into the chamber of the gun barrel.

*Feeder Assembly.* The feeder is actuated by gas pressure resulting from firing the gun. Gas enters at the manifold and is directed into two positions, through the pistons and acts with force upon the end of the cylinder walls, thereby moving the feed slide. However, the rotation of the star wheels that carry the belted ammunition takes place on the return stroke, by action of the feeder springs after the gas has dissipated. There are ratchets between the feed slide links and the star wheel shaft. During compression of the feeder springs and movement of the feed slide toward the star wheels, these ratchets slip until the return stroke of the slide and springs takes place. The ratchets then become engaged with and rotate the star wheels. A spring-loaded pawl prevents reverse rotation of the star wheel.

During the feeding operation, the round is pushed out of its link, the round goes into the feed throat, and the link continues around with the star wheel and emerges on the side opposite from whence it was fed. The feed frame is stationary and supports the feed springs, guides, and feed cover which guides the ammunition. The feed frame and feed throat are secured together by special screws.

### Cycle of Operation

In this description of the cycle of operation, it is assumed that a belt of ammunition is in the feeder with one round about to be stripped from its link, a stripped round in the feed throat, and a round in the chamber of the gun barrel. The breechblock assembly is locked in battery position, and all operating components are at a position of rest. The firing circuit is closed except at the main firing switch located away from the gun.

Upon closing the main firing switch, an electrical current travels to the terminal on the receiver, through the breechblock contact, through the slide and firing-pin contacts, through the firing pin, and

to the primer of the cartridge case. As the explosion sends the projectile down the gun barrel and past the gas ports, a portion of the gases go into the feeder tube and a portion into the breech unlocking gas tube. Since these gas actions occur simultaneously, the operation of the breechblock buffer and rammer assemblies is described first.

Gas from the breech unlocking gas tube is directed into the gas cylinder in the barrel extension and forces the piston rearward, thereupon pushing, with considerable force, the breechblock slide, which raises the locks out of the barrel extension keys and permits the breechblock assembly to travel in recoil. This operation also opens electrical contact between the receiver terminal, breechblock slide, and firing-pin contacts. As the breechblock travels rearward and under the feed throat, the extractor pulls the empty cartridge case from the chamber of the gun barrel. Ejection occurs when the rim of the cartridge case opposite the extractor strikes the ejecting surface on the lower forward edge of the feed throat. The case is ejected from the side of the gun opposite to the side from which the round was fed.

The breechblock assembly is driven in recoil by combination of the force of the gas piston and blow-back from the breech. As it continues its travel rearward, the block strikes, first, the rammer slide which partially rotates the hammer, thereupon striking the rammer which projects the waiting round in the feed throat into the chamber of the barrel. Secondly, the block continues rearward 0.375 inch to strike the buffer anvil, which compresses the buffer springs, which then return the breechblock assembly in counterrecoil.

At the end of the counterrecoil stroke, a round is in the chamber of the barrel and the breechblock assembly has been returned to battery due to energy from the buffer springs, since there is no driving spring. The breechblock slide has been driven forward, the locks have dropped into the locking position in the barrel extension keys, and electrical contacts within the breechblock assembly have been closed simultaneously with the receiver contact.

The operation of the feeder begins with the explosion of the round in the chamber of the barrel. When the projectile goes down the barrel and past the gas ports, gas is directed into the feeder gas tube and travels to the feeder manifold where it is directed into two pistons, through the pistons, and

acts on the end of the cylinder walls, thereby pushing the feed slide on the feed frame toward the gun.

While this is taking place, the feeder springs are compressed and the feed slide links move toward the star wheels, partially rotating the ratchets preparatory to indexing a round of ammunition on the star wheels. The round on the star wheels is indexed when the gas pressure in the feeder subsides, allowing the compressed feeder springs to return to their initial length in the mechanism. Therefore, on the return stroke of the feed slide, the star wheel ratchets become engaged and rotate the star wheels. At the same time, the round on the star wheels is indexed, the round preceding it is stripped by being pushed out of its link by lugs on the end of the feed slide. Such a push is sufficient to place the round in the feed throat, which has been vacated by ramming action on the previous round during recoil of the breechblock assembly.

Stripping in this manner is possible, as each round is supported by its link on the star wheel. When stripping has been completed, the links remain with the star wheels until the links emerge from an opening at the bottom of the feeder. The links are in contact with the star wheels for 180° of rotation.

Since the feeder and breech unlocking mechanism are actuated by gas pressure from the gun barrel, the cycle of operation of the gun is continuous as long as a belt of ammunition is in the feeder and the main firing switch is closed.

## Firing Tests

The following statements are taken from a report of firing tests conducted at Naval Aviation Ordnance Test Station, Chincoteague, Va.

*6 November 1951.* The gun was partially disassembled for a general visual inspection. The cam slots in slide in the breechblock assembly were deformed slightly as a result of previous firing. The slide was then ground to remove burrs and sharp edges to insure proper functioning. In the rammer and buffer assembly, a tightness was discovered between the buffer anvil pin and the oblong slot on the forward underside of the rammer slide. Width of the slot was increased 0.031 inch to allow free operation between the two parts.

*7 November 1951.* During previous firing tests, the feeder assembly was inoperative due primarily

to a leakage of gas at the feeder manifold subassembly, comprising manifold, piston, manifold plate, and screw.

A soft copper gasket was made and placed in the subassembly between the manifold and manifold plate. A single round of ammunition was placed in the chamber of the gun and fired. Gas immediately escaped around the copper gasket at the feeder manifold. The feeder remained inoperative.

To investigate functioning of the rammer assembly, 2 rounds of ammunition were placed in the gun, 1 round in the chamber and 1 round in the feed throat. Upon firing the first round, the breechblock assembly recoiled, struck the buffer assembly and rammer slide, and returned toward the battery position, but was stopped by the second round which had been projected only part way out of the feed throat. The rammer did not push the round out of the feed throat due to a malfunction caused by the True-Arc retaining ring on the rear end of the rammer being knocked off, thereby diminishing the force of the ramming blow.

*8 November 1951.* Inspection of the breechblock slide revealed a further deformation of the cam slots and an actual "breaking down" of the metal. The slide was again ground in preparation for firing.

Firing contact of subassembly in the breechblock assembly was broken and was replaced by a new contact subassembly.

The feeder manifold subassembly was removed from the feeder. Bushings were made and were placed around the pistons in the manifold. These parts were then brazed together, thereby eliminating the possibility of gas leakage. During assembly of the gun, the rammer subassembly was fastened with a Spirolox retainer.

Two rounds of ammunition were placed in the gun, 1 round in the chamber and 1 round in the feed throat. Upon firing the first round, the breechblock assembly recoiled, struck the buffer assembly and rammer slide, and returned to within 2 inches of battery position. The reason for this stoppage was a too-strong breechblock slide spring (40 pounds) which caused too much friction between the breechblock locks and the guide rails (two).

The rammer subassembly operated properly, projecting the second round from the feed throat into the chamber of the gun barrel.

Gas leakage at the feeder manifold was not in evidence. However, the feeder did not operate, which indicated insufficient gas pressure at the feeder.

The second round was not fired because the breechblock assembly did not return to the battery position, as just mentioned.

*9 November 1951.* During a total of eight rounds fired, four misfires occurred. An increase

in the length of the firing pin should remedy this situation. However, investigation of clearances between the breechblock, locks, slide, gun barrel, and ammunition, relative to headspace, was planned.

Ammunition used in this gun was British-type 30-mm using special links of a peculiar design. A cradle also had been fabricated at the activity in which the weapon was being tested since it was intended that the gun be supported by structures in the aircraft. Standardization of a cradle had not been accomplished at this time.

## Chapter 9

## 20-MM COLT AIRCRAFT CANNON BASED ON GERMAN MAUSER MG-151/20

### SECTION 1. 20-MM AUTOMATIC AIRCRAFT CANNON T22

#### Development of the T22

In December 1943, Colt's Patent Fire Arms Co. began development of an experimental gun designated the 20-mm automatic gun T22. The design was to be based on principles of operation found in the recently captured German Mauser MG-151/20 but to utilize the movement of the bolt to operate the feed mechanism.

The requirements were set up as follows: That existing ammunition for the 20-mm M2 gun should be used for initiating the project; that the feed mechanism be of the disintegrating link-belt type without involving a separate transfer, as in case of a magazine throat; that the link be capable of taking different lengths of shell; that the gun be of the self-locking blowback type with a cyclic rate of fire of 575 to 650 rounds per minute; that the round must be controlled at all times in the gun and be fed from either right or left side without the addition of extra parts; that the belt pull should be at least 75 pounds, the limit permitted; and, if possible, that the existing link be used.

The 20-mm automatic gun T22 as developed has the following items in common with the German Mauser gun: Mechanical unlocking, location and type of adapter, quickly removable barrel with interrupted concentric rings, and the reciprocating bolt on the axis of the weapon. The T22 does not use a rotating bolthead for unlocking, as does the Mauser weapon. The T22 has much simpler lines than the MG-151/20 or the American AN-M2.

Several major components lend themselves to easy, rapid manufacture because of their prismatic slope.

In November 1944, a new development was initiated to produce a weapon capable of fulfilling these requirements and having a higher muzzle velocity than the guns under production or development. Increased muzzle velocity would result in decrease in time of flight and would increase armor penetration. To expedite designs, three approaches by private facilities were originated. One of these was the Colt T24, which was designed and operated on the same principles as the T22.

On 9 August 1945, the T22 program was canceled by OCM 28678, and future experimental work was concentrated on the T24.

Preliminary firing indicated that a muzzle velocity of 3,500 feet per second could be obtained using M-1 powder and a barrel length of 78 inches.

The firing also demonstrated that armor penetration of the M-95 projectile was not satisfactory. As the maximum penetration was only 1 1/8 inches, the Army Air Force requested that the projectile be able to penetrate 1 1/2 inches of face-hardened armor plate at 200 yards normal impact with matching ballistic characteristics on all rounds of ammunition.

#### Description of the Weapon

The T22 is of the short recoil operated type, with the mechanical unlocking of the breech delayed until the residual pressure in the bore has dropped to a safe degree for unlocking. While the AN-M2 and T31 guns are a combination blowback and gas operated type of aircraft weapon, the T22 can be seared on the right in the rear, or open bolt, position and on the left or right in the forward, or closed bolt, position. It is provided with a set of trunnions

on the adapter housing for connecting the gun to its mounting, and two additional trunnions are carried on the receiver body for firing from fixed trunnions if desired.

It fires standard Hispano-Suiza-type ammunition loaded to give a muzzle velocity of 2,850 feet per second. When a round is fired, blowback action causes the tube, tube extension, and bolt unit to move backward a distance of three-fourths inch. Before reaching this point, angular surfaces on the bolt lock make contact with angular surfaces on the lock cams, causing the bolt lock to turn on its axis pin and move out of the locking cut at the rear of the tube extension. Further movement rearward of approximately one-fourth inch moves the bolt lock entirely out of the locking cut, permitting the bolt unit to recoil sharply in the bore. The motion is speeded up by the accelerator.

In this movement rearward, the bolt unit performs the function of extracting the empty cartridge case; and because of its connection to the feed mechanism, it also moves the next round along the feedway into position for chambering. At the end of its stroke, the bolt extension strikes the buffer at the rear, giving a quick rebound action to the bolt unit which is further activated by two driving spring units.

As the bolt moves forward in counterrecoil, the gap between the bolthead and the front of the bolt extension closes to about one-fourth inch. The

curved end of the cocking lever is forced forward, and the pointed end moved backward when it enters the slot in the cocking actuating plate. In this way, the obstruction is removed from its position in front of the firing pin extension so that the firing pin is free to fly forward when the sear is released.

When the bolt is nearing its forward position, the pressure of the bolt extension on the rear bolt lock causes the latter to descend and engage the locking nut. Pressure on the bolt extension on the angular surfaces at the rear of the bolt lock holds it down so that the bolt remains in the locking position.

The feedway located in the forward end of the receiver forms a channel through which the rounds loaded in metallic links pass into the gun. The ears of the link are carried on guides formed along the stripper cams. The cartridge holding pawl positions the rounds, which are chambered by action of the bolt. A cartridge case ejector is located at the rear of the feedway, which is held securely in position by the action of closing the cover.

The T22 gun is convertible to feed from right-to left-hand side without the addition of any parts. The preliminary test carried on by the private contractor indicated that the use of an accelerator would be necessary to increase the cyclic rate of the weapon and provide sufficient power for feeding under high belt pulls.

## SECTION 2. 20-MM AUTOMATIC AIRCRAFT CANNON T24

### Description

This weapon was designed to use the new 20-mm, 3,500-feet-per-second T5E1 round. Since this round has a much larger case than the standard one, the T24 chamber is larger and the receiver  $2\frac{1}{2}$  inches greater in diameter than the T22 gun; otherwise, the two guns are identical in construction.

It is short-recoil operated, has right- or left-hand feed without extra parts, forward sear, bolt holding back sear, mechanical feed for link belt, and quickly detachable barrel. The weapon can be operated by electric trigger or solenoid from the right- or left-hand side, as may be required, and is capable of synchronized fire.

Since the 20-mm T24 gun is of the short-recoil operated type, the unlocking of the breech is delayed

until the residual pressure in the bore has dropped to a degree where it is safe for unlocking.

The basic structure of the gun consists of a receiver, built up by riveting, which is composed of the following main parts: receiver body, two side plates and back plate. On top of the receiver body, a cover support is secured by a screw. The cover is hinged to the support by a joint pin and is provided at the rear with a latch for locking the cover to the receiver in the closed position.

Located in the cover near its forward end is the feed slide, which is controlled in its lateral movement in guides formed in the cover. Located longitudinally and able to slide in the cover in guides is the actuating bar which receives its movement through a stud located in the upper rear portion of

the bolt extension and operating in a gap or slot in the actuating bar.

The feed lever, pivoted on a stud located in the cover, receives its movement through a stud in the actuating bar sliding in a gap or slot in the feed lever. The feed lever in turn causes the feed slide to move due to its being in contact with a circularly formed end of the feed lever which works in a gap in the feed slide. The slide carries the feed pawl, which is actuated by a spring and pivots on an axis pin.

The forward end of the receiver is threaded to receive the tube housing. The tube housing and

#### General Data: 20-mm Automatic Gun T22

Data for this gun are the same as that for the 20-mm automatic gun T24 except the following:

Rate of fire: 575-650 rounds/minute (computed).

Muzzle velocity: 2,850 feet/second.

Gun length: 78 inches.

Gun weight: 112 pounds.

receiver body in addition to receiving the tube and tube extension contain a tube return spring and an inner Edgewater ring dampening unit.

A retainer secures the tube return spring to the tube extension at the front end. A spring seat stops the tube return spring at the rear.

Located outside the tube housing is an adapter containing Edgewater ring springs for the purpose of taking up excess recoil and for dampening counter-recoil.

The adapter housing carries, in addition to the Edgewater ring assembly, two trunnions for connecting the gun to its mounting.

In addition to the trunnions carried on the adapter housing, there are two trunnions carried on the receiver body for use if it should be desired to fire the gun from fixed trunnions.

There are also two brackets at the rear underneath and integral with the backplate of the receiver providing means for securing the gun to the mount at the rear.

#### General Data: 20-mm Automatic Gun T24

Gun length: 100 inches overall.

Gun weight: 141 pounds 6 ounces with tube but without adaptor.

Rate of fire: 700-750 rounds/minute (computed).

Muzzle velocity: 3,500 feet/second (approximately).

System of operation: Short recoil.

System of locking: Pivoting lock.

System of feeding: Recoil actuated.

Method of headspace: Could not be adjusted after leaving factory.

Location of feed opening: Right or left hand without additional parts.

Location of ejection opening: Bottom of receiver.

Method of charging: Hydraulic.

Method of cooling: Air.

Gun height without accessories: 6 inches.

Gun width without accessories: 8 inches.

Weight of adapter unit: 8 pounds.

Weight of manual charging slide: 1 1/4 pounds.

Bolt travel (nominal) to buffer: 15.75 inches.

Firing pin spring:

Load cocked (approximate): 68.25 pounds.

Load at fired position (approximate): 60 pounds.

Firing pin protrusion: 0.095 inch.

Diameter of firing pin: 0.123 inch.

Driving spring load (bolt in rear position) approximate: 130 pounds.

Tube length: 63 inches.

Tube weight: 38 pounds 4 ounces.

Rate control: None.

Barrel removal: Quick disconnect.

Bore:

Number of grooves: 9.

Groove depth: 0.015 inch.

Groove width: 0.205 inch.

Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).

Direction of twist: Right hand.

Form of twist: Constant.

Driving spring load (bolt in forward position) approximate: 40 pounds.

Edgewater tube spring unit, preload: 4,500 pounds.

Load compressed 0.25 inch beyond preload: 6,100 pounds.

Edgewater adapter spring unit, preload: 1,500 pounds.

Load compressed 0.25 inch beyond preload: 3,100 pounds.

Tube return spring, assembled load: 300 pounds.

Load at 1 1/8 inches of tube travel: 100 pounds.

Sear release: 35 to 40 pounds.

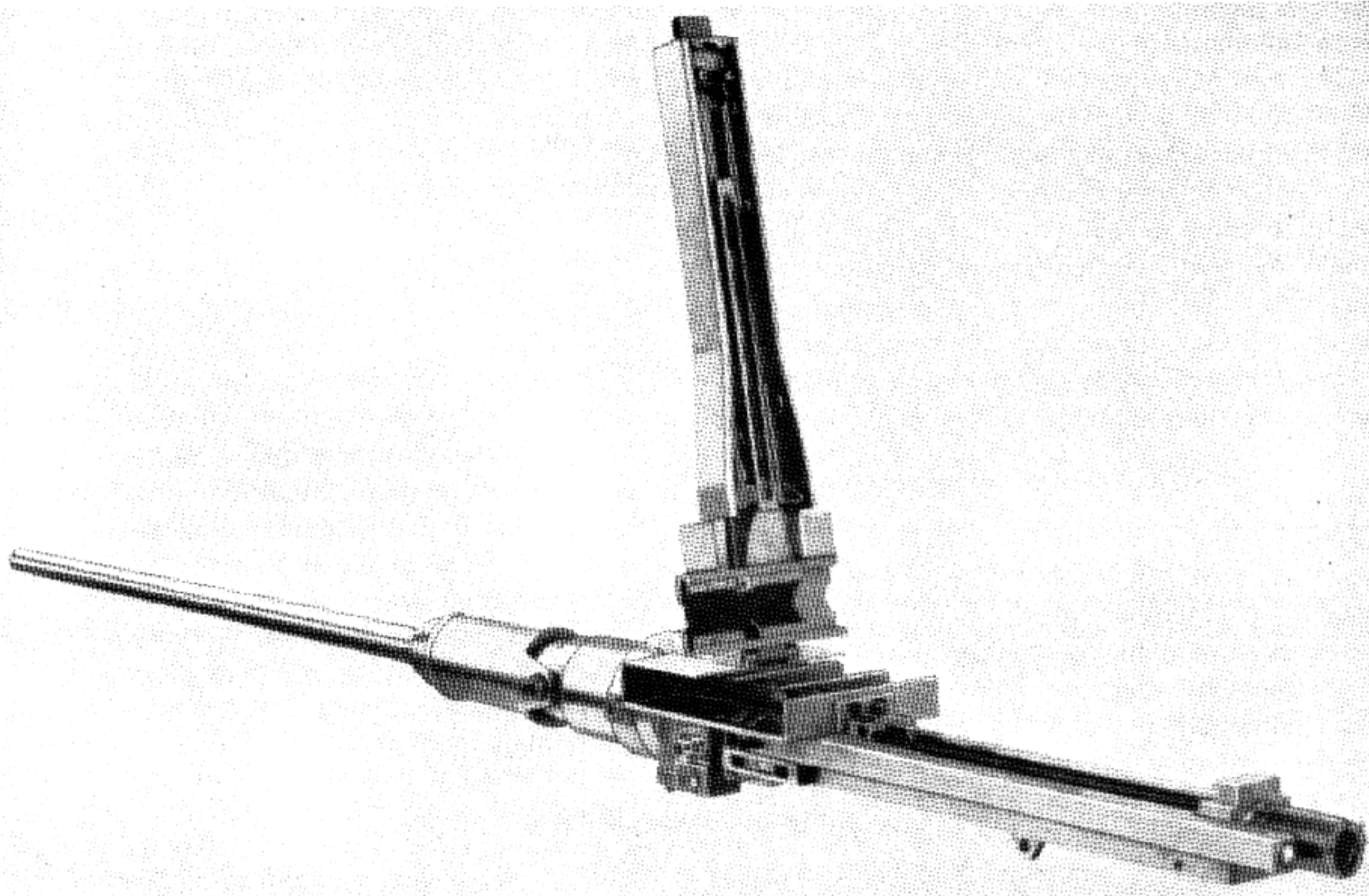


Figure 9-1. 20-mm Gun T24. Left side view with cover open.

When the cartridge is fired, blowback action causes the tube, tube extension, and bolt unit to move backwards a distance of about three-fourths inch; but before this amount of travel is completed, angular surfaces on the bolt lock contact angular surfaces of lock cams mounted inside each of the side plates, causing the bolt lock to turn on its axis pin and move out of a locking cut at the rear of the tube extension.

In a further movement rearward of approximately one-fourth inch, the bolt lock moves entirely out of the locking cut in the tube extension, thus permitting the bolt unit to recoil sharply under the action of the residual pressure in the bore. A separator, located at the rear of the tube extension and actuated by the latter when the tube and tube extension recoil, relieves the pressure of the bolt lock from against the bolt lock cam at the instant of unlocking.

In its movement rearward, the bolt unit performs the function of extracting the empty cartridge case and, due to its being in connection with the feed mechanism, of moving the next cartridge along the feedway into position for chambering. At the end of its stroke, the bolt extension strikes the buffer at the rear, thus giving a quick rebound action to the bolt unit which is further activated by two driving spring units (one located at each side of the receiver in channels formed in the side plates), which connect with the bolt extension by means of a cross-member in the latter.

The bolt consists of three main parts, namely, bolt extension, bolt head, and bolt lock. This unit can slide backward and forward upon ribs or guides formed inside the side plates of the receiver.

The bolt extension is in the form of a long block having a hole drilled along its full length through its center to receive the firing pin unit. It also houses the cocking lever and the sear.



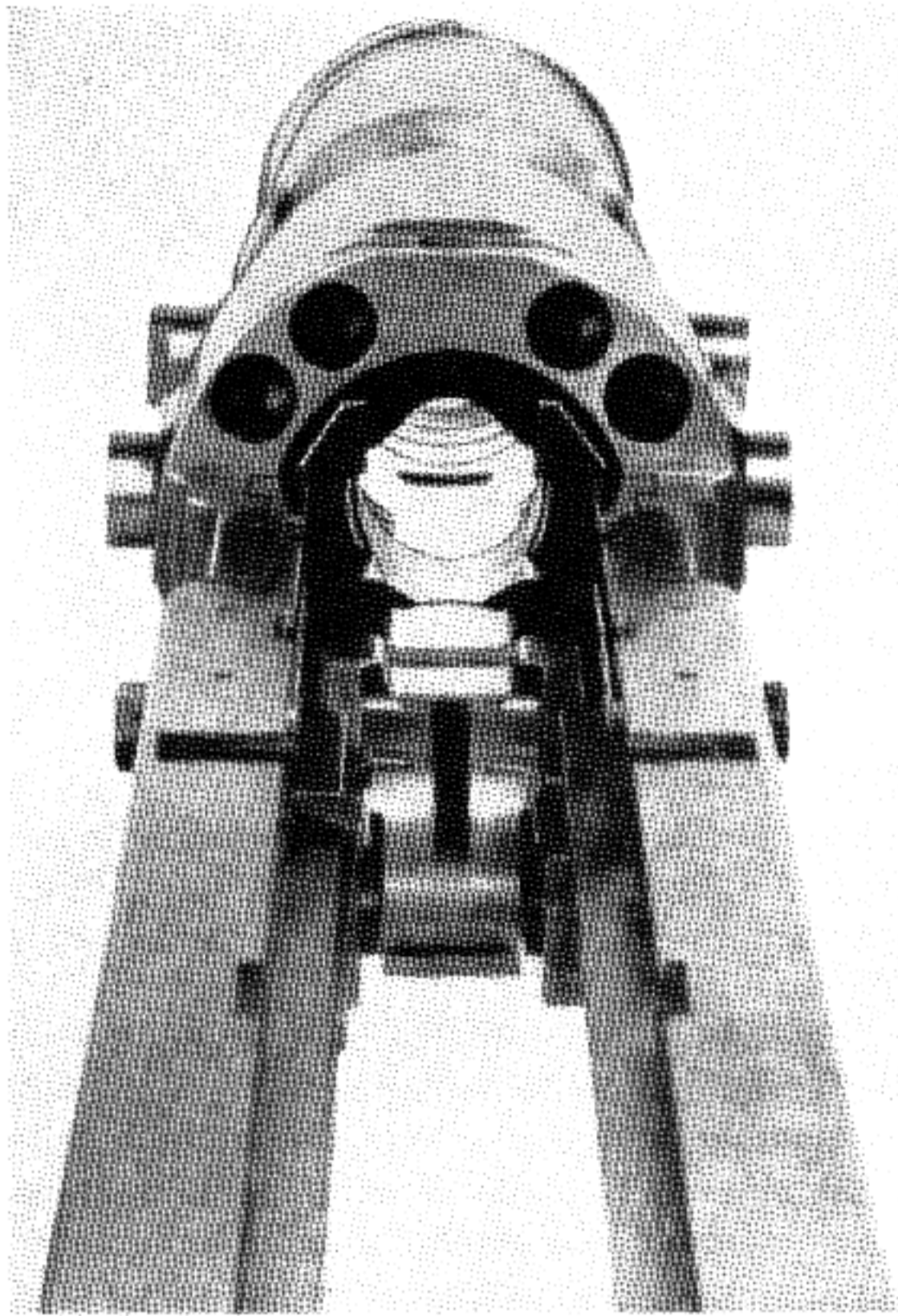


Figure 9-2. 20-mm Gun T24. Rear view with feed, cover, and tube removed.

Approximately at the center of the bolt extension, a crosspiece is formed, the projections of which have holes drilled at each side in order to receive the driving spring rods. In addition, these holes have re-

cesses at the rear forming seats for the driving springs. In the center of the crosspiece is a rectangular opening to receive the sear. The sear makes contact with the firing-pin extension which passes through a hole in the center of the sear and has a shoulder formed on it which engages a shoulder formed on the firing-pin extension. By this means the firing pin is retained in the cocked position.

When the pressure is applied to the sear, the shoulder on the sear disengages from the shoulder on the firing-pin extension, permitting the latter, together with the firing pin, to fly forward under the action of the firing-pin spring housed in the firing-pin extension and to explode the primer. At the forward end of the firing-pin extension, the firing pin is seated in a U-shaped cut and held in position by the firing-pin spring pressure.

The cocking lever is pivoted on an axis pin, which is located vertically in the bolt extension.

The bolthead is a block of cylindrical form at the front end. At the rear it has a shank extending for about an inch, which enters a hole at the front of the bolt extension and holds the assembly in alignment.

The bolthead carries the extractor, the extractor spring, and the extractor axis pin. About midway along the bolthead are two side projections, or blocks, which serve to steady the bolthead in the guides or runway inside the receiver and which also have two radial or cupped surfaces at the rear against which the corresponding radial surfaces of the bolt lock take bearing in the locked position.

A bolt-lock pin passing through a hole drilled transversely through the bolthead connects the bolt-

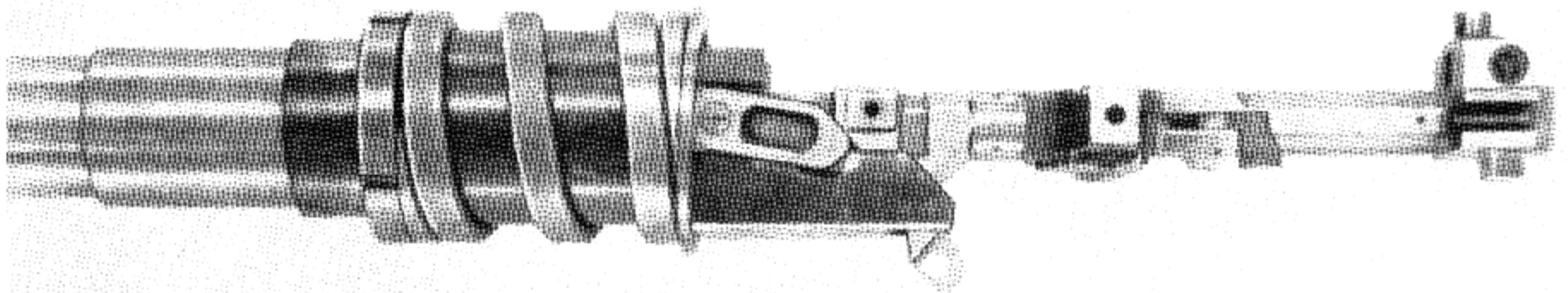


Figure 9-3. 20-mm Gun T24. View showing bolt engaging lock cut in tube extension.

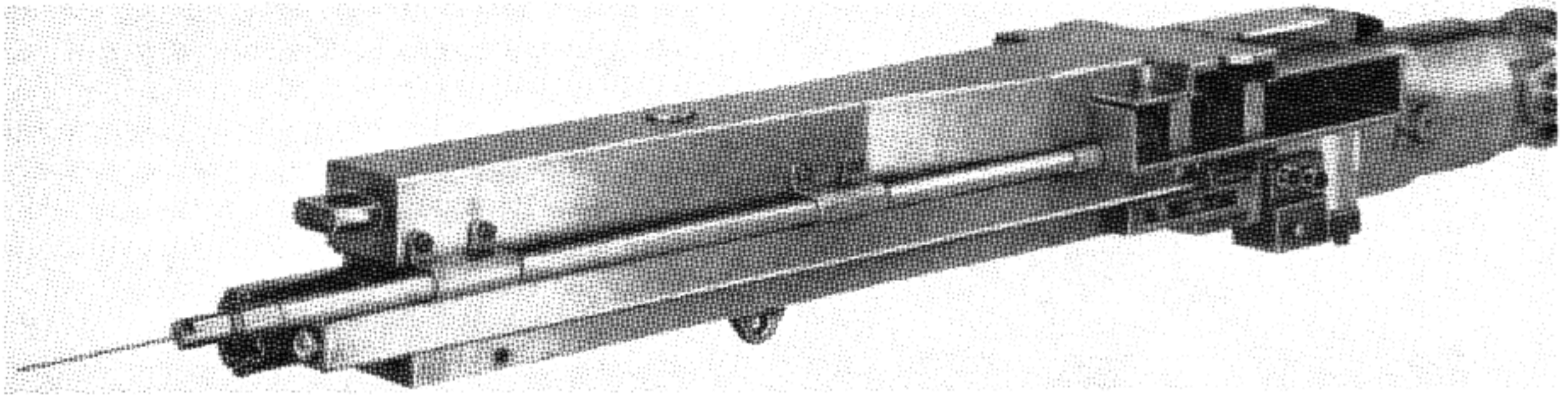


Figure 9-4. 20-mm Gun T24. View showing manual charger.

head and the bolt lock, serving to hold the assembly together. The bolt-lock pin is only for that purpose, the actual rearward thrust at the instant of firing being taken by the radial surfaces formed on the front of the bolt lock, engaging in the corresponding radial or cupped surfaces in the bolthead. The bolt lock is of U-form and locks the bolt securely at the instant of firing and remains locked until the residual pressure in the bore has dropped to a degree safe for unlocking.

As the bolt moves backward, the bolt extension pulls apart from the bolthead, showing a space of about seven-sixteenths inch. At the same time the tip of the cocking lever, which is held in a slot in the actuating plate located in the left side plate of the gun receiver, is forced forward by the latter bringing the curved portion of the cocking lever to the rear.

When the curved portion moves to the rear, it moves with it the firing-pin extension which carries the firing pin, thus withdrawing the firing pin from the face of the bolt and compressing the firing-pin spring against the firing-pin spring stop pin. The

shoulder of the firing-pin extension engages with the shoulder in the sear under pressure of the sear spring.

As the bolt moves forward in counterrecoil, the gap between the bolthead and the front of the bolt extension closes to within about one-fourth inch, due to the pressure of the angularly formed surfaces at the front of the bolt extension on the rear of the bolt lock.

The curved end of the cocking lever is forced forward, and the pointed end moves backward when it enters the slot in the cocking lever actuating plate before referred to. In this way, the obstruction is removed from in front of the firing-pin extension so that the firing pin is free to fly forward when the sear is released.

When the bolt is nearing its forward, or closed, position, the pressure of the bolt extension on the rear of the bolt lock causes the latter to descend and engage in the locking out in the rear of the tube extension. Pressure of the bolt extension on angular surfaces at the rear of the bolt lock holds it down so that the bolt remains in the locked position and only becomes unlocked when the cam action described elsewhere goes into play.

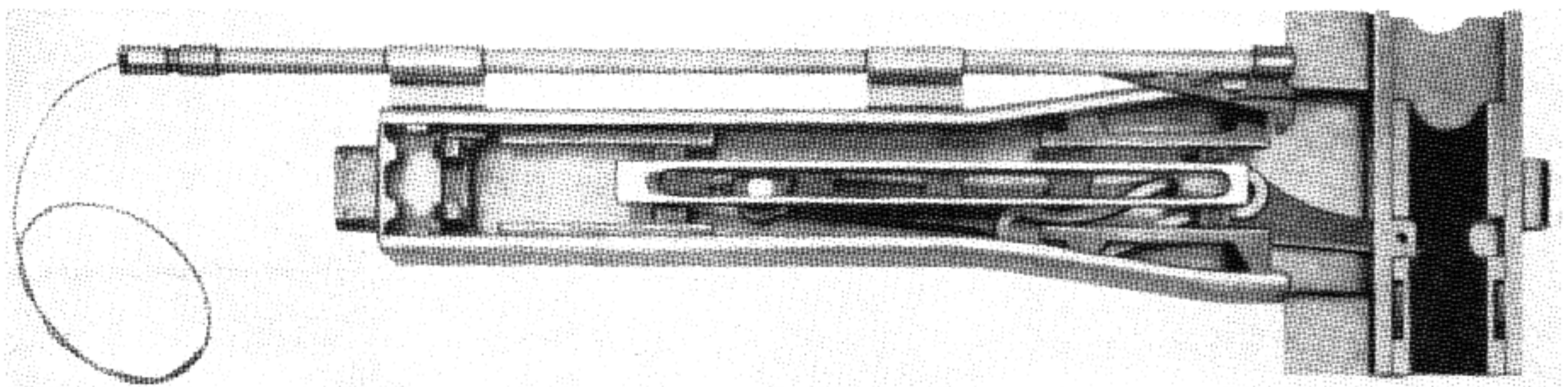


Figure 9-5. 20-mm Gun T24. View of cover from below showing mounting of charger.

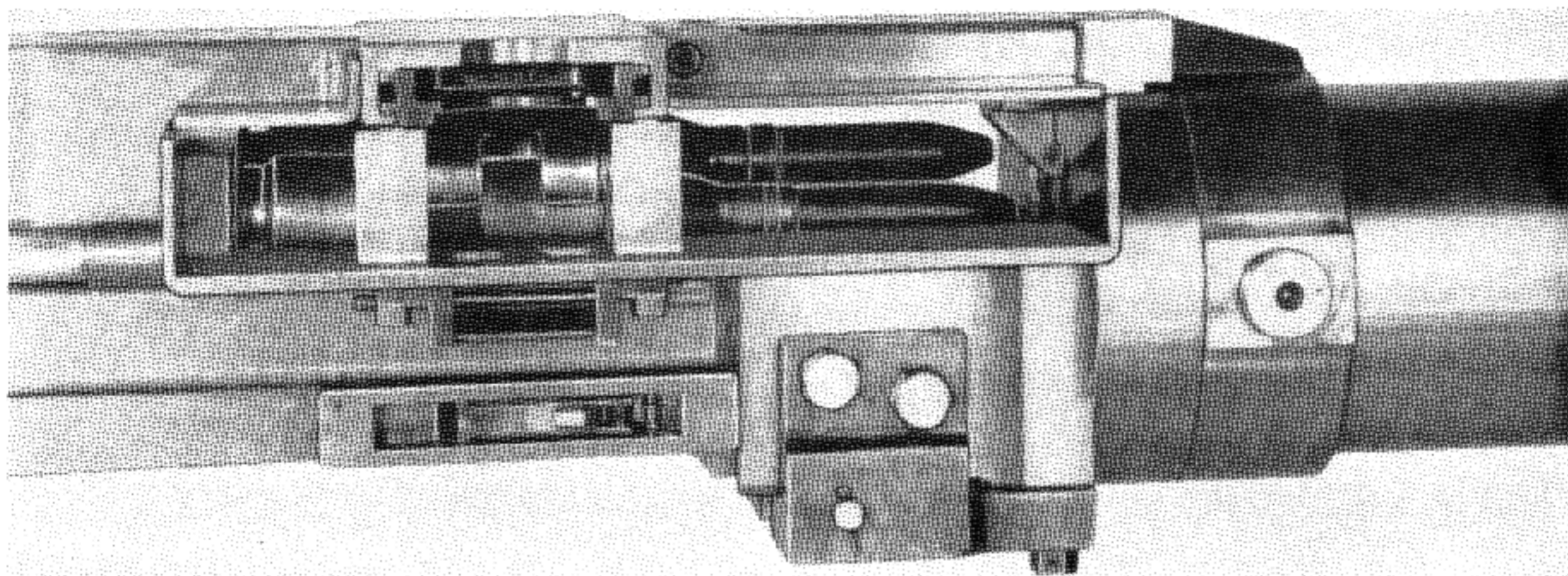


Figure 9-6. 20-mm Gun T24. Closeup view of cartridges in feedway.

A feedway located in the forward end of the receiver and resting on the side plates immediately under the feed slide unit forms a channel through which the cartridges loaded in metallic links pass into the gun. A deflector plate, located over the feedway, acts as a guide, giving the necessary downward pressure to the cartridge and insuring that it enters the chamber correctly. Two stripper cams are positioned in the feedway, the cars of the cartridge metallic links being carried on guides formed along the stripper cams on top and inside. At the side of the feedway and underneath is a cartridge holding pawl actuated by spring and held in position by the cartridge holding pawl pin. At the rear of the feedway is the ejector bracket which carries

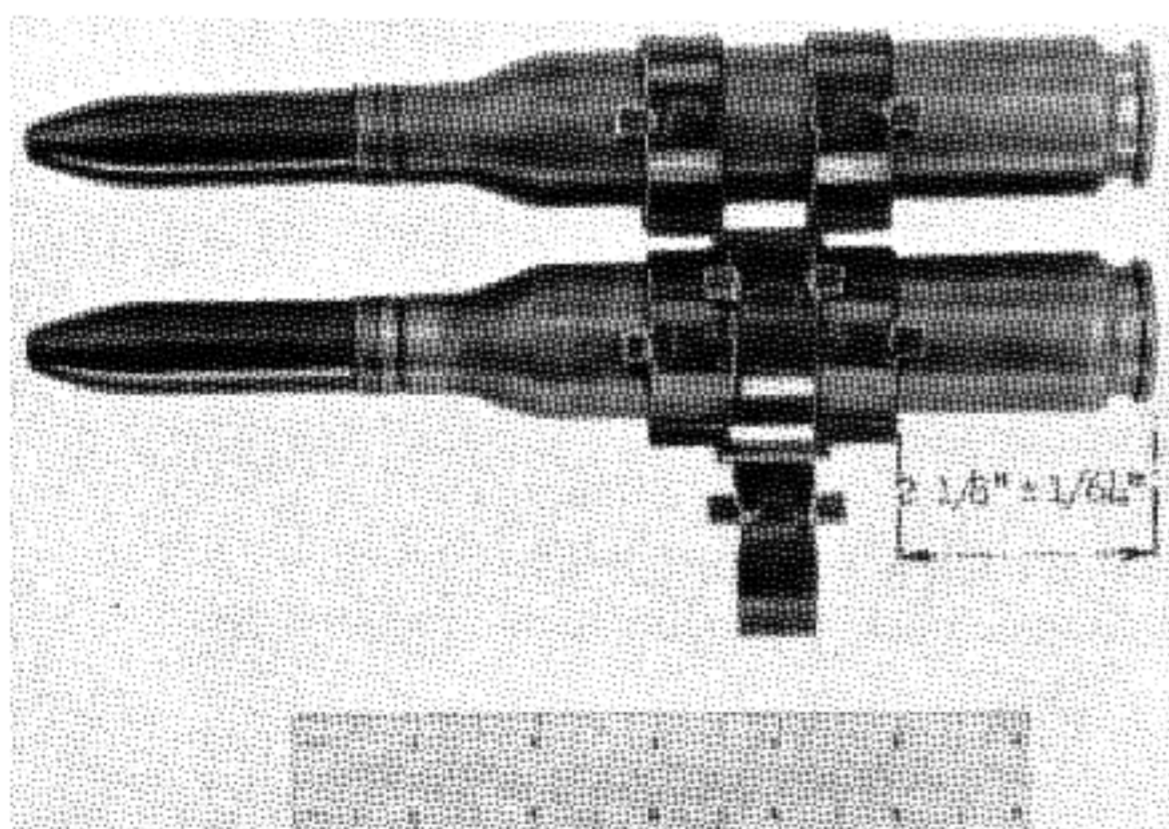


Figure 9-7. 20-mm Gun T24. Cartridges and links.

the cartridge case ejector. The action of closing the cover holds the feedway securely in position.

The gun is convertible to feed from the right-hand side or the left-hand side as may be required. Change of feeding direction is accomplished without the addition of any parts.

### Disassembly

The procedures given in this section apply to both the T22 and the T24.

To disassemble the gun into subassemblies, proceed as follows:

1. Open the cover. Press in on the cover latch release. The gun will then be ready for disassembly.

2. Remove the cover. With the cover down and using a screwdriver blade, turn the cover joint pin so that its locking catch disengages from the slot in the deflector plate. Push in on the cover latch release to relieve pressure on the joint pin, then remove the joint pin and cover.

3. Remove the feedway and deflector plate. To remove the feedway and deflector plate, grasp the feedway, raise it vertically a small amount, then pull straight to the rear until clear of the cover support. The feedway can now be taken out of the receiver.

4. Remove the bolt. To remove the bolt, push in on the end of the 2 driving springs rods (1 on each side of the gun) enabling the 2 thrust pins to be pushed out.

NOTE. When thrust pins are being removed, take care that the two rods do not fly out.

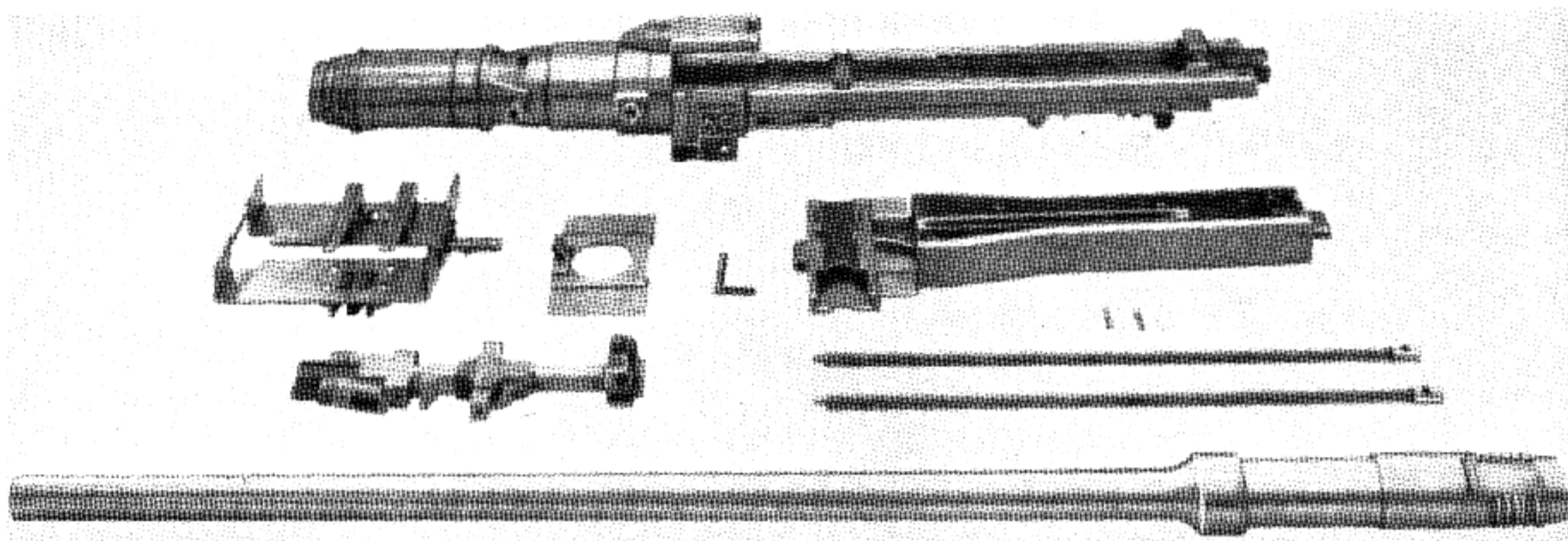


Figure 9-8. 20-mm Gun T24. Subassemblies.

The two driving springs with rods can now be removed from the rear of the gun. Grasp the rear of the bolt extension and pull the complete bolt unit back in its guides in the receiver until the crosspiece of the bolt extension is in line with the gaps in the side plates. The bolt assembly unit can now be removed from the receiver by pulling vertically upward.

5. Remove the tube. To remove the tube, press down on the latch. Grasping the tube, turn it counterclockwise one-sixth turn so as to disengage it from the locking segment in the tube extension. Now pull the tube straight out toward the front.

NOTE. Do not remove the cover support from the receiver.

### Assembly

To assemble the gun from subassemblies, follow this procedure:

1. Replace the tube. Enter the breech end of the tube into the tube housing, taking care that the indicating arrow on the tube is to the top; then give one-sixth turn in the clockwise direction, noting that the tube latch clicks in place.

2. Replace the bolt assembly. With the bolt unit in position and the cocking lever in the position for camming the action back, enter the unit into the receiver so that the crosspiece of the bolt extension enters the gaps in the side plates. Now push the bolt fully home.

3. Replace the driving spring units. Enter the driving spring rod assemblies into the rear of the

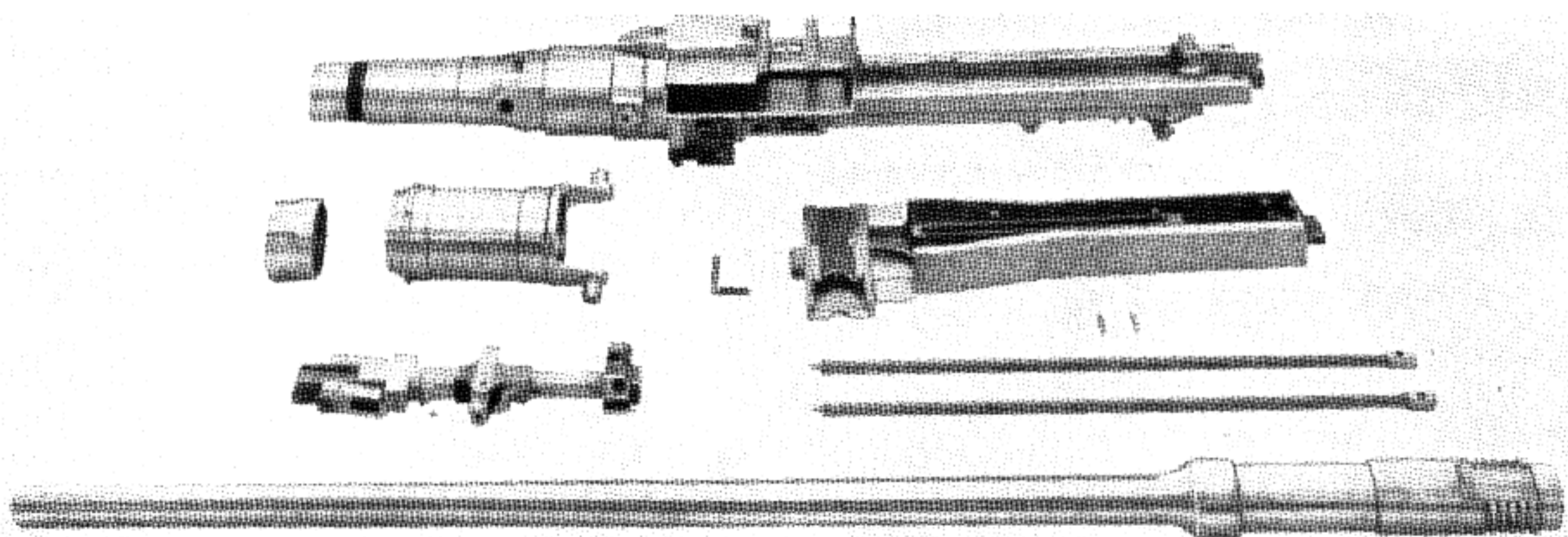


Figure 9-9. 20-mm Gun T24. Subassemblies showing adaptor removed.

receiver through the holes provided. Push in on the assemblies until the rods enter the holes in the crosspiece of the bolt extension and the springs seat in recesses at each side in the rear of the crosspiece. Push the enlarged ends of the driving spring rods in far enough so that the two thrust pins can be put in place.

4. Replace the feed way and deflector plate. Place the deflector plate in position over the front of the feedway, then slide the feedway with the deflector plate into place in the receiver.

5. Replace the cover. With the cover right side up, enter the joint pin bearing end into the gap in the cover support. Holding the cover at an angle of about  $45^\circ$ , enter the cover joint pin so that it passes through the cover support and cover. When fully home, turn the spring end of the cover joint pin down, noting that it engages a slot in the deflector plate of the feedway.

## Detailed Disassembly and Assembly

### *To Strip the Bolt.*

1. To remove the bolthead, push down on the end of the bolt lock. Slide the bolthead forward until it becomes detached from the bolt extension.

### *To Strip the Bolthead.*

1. With a special drift, push the extractor axis pin, allowing the extractor and extractor spring to be removed.

2. Push out the bolt lock axis pin, thus separating the bolt lock from the bolthead.

### *To Strip the Bolt Extension.*

1. With a special drift, push out the firing-pin extension buffer pin. Remove the buffer.

2. Push out the cocking lever axis pin lockpin, then remove the cocking lever axis pin and cocking lever.

3. Push out the firing pin spring stop pin lockpin, then push out the firing pin spring stop pin.

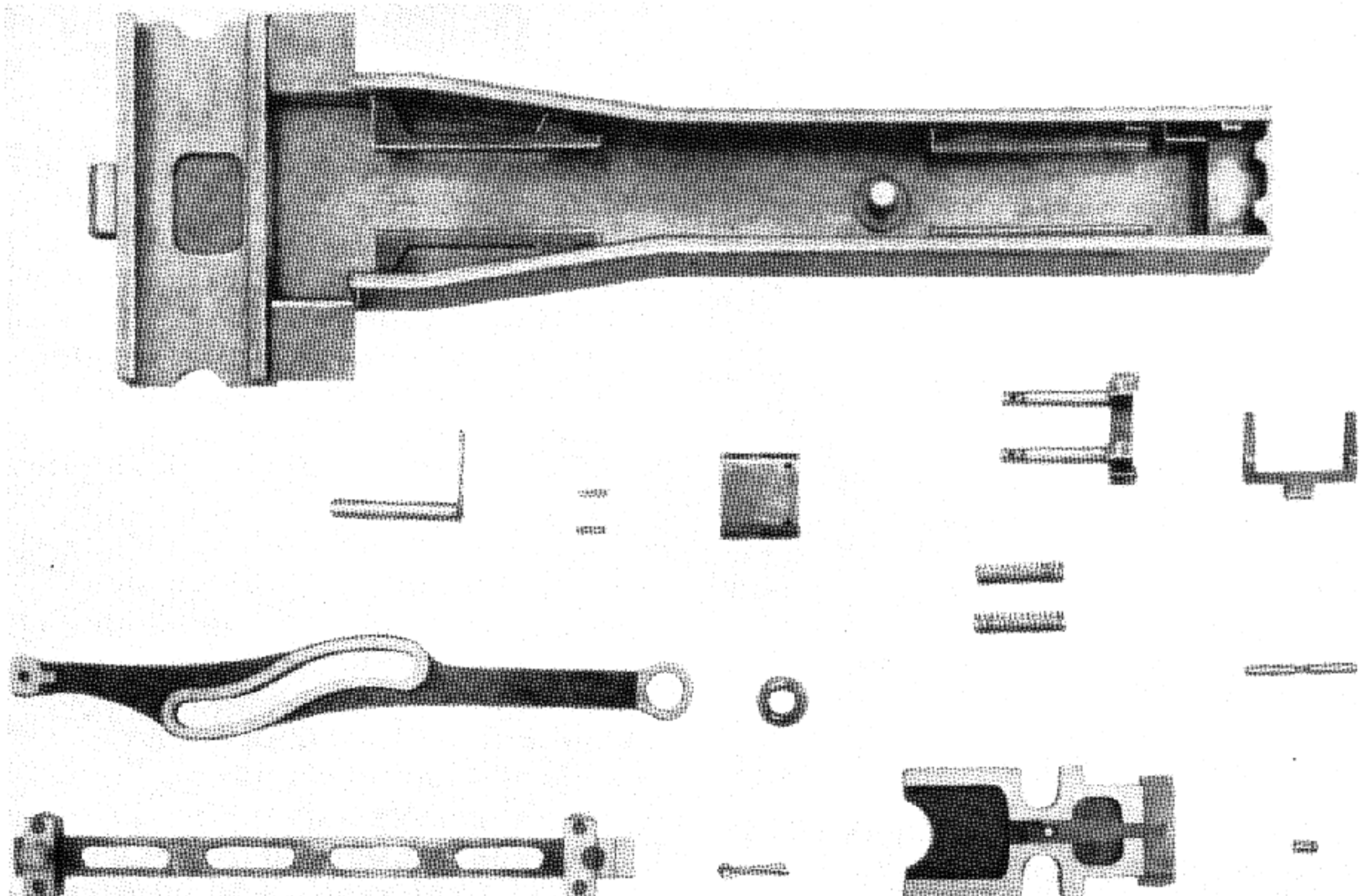


Figure 9-10. 20-mm Gun T24. Components of cover group.

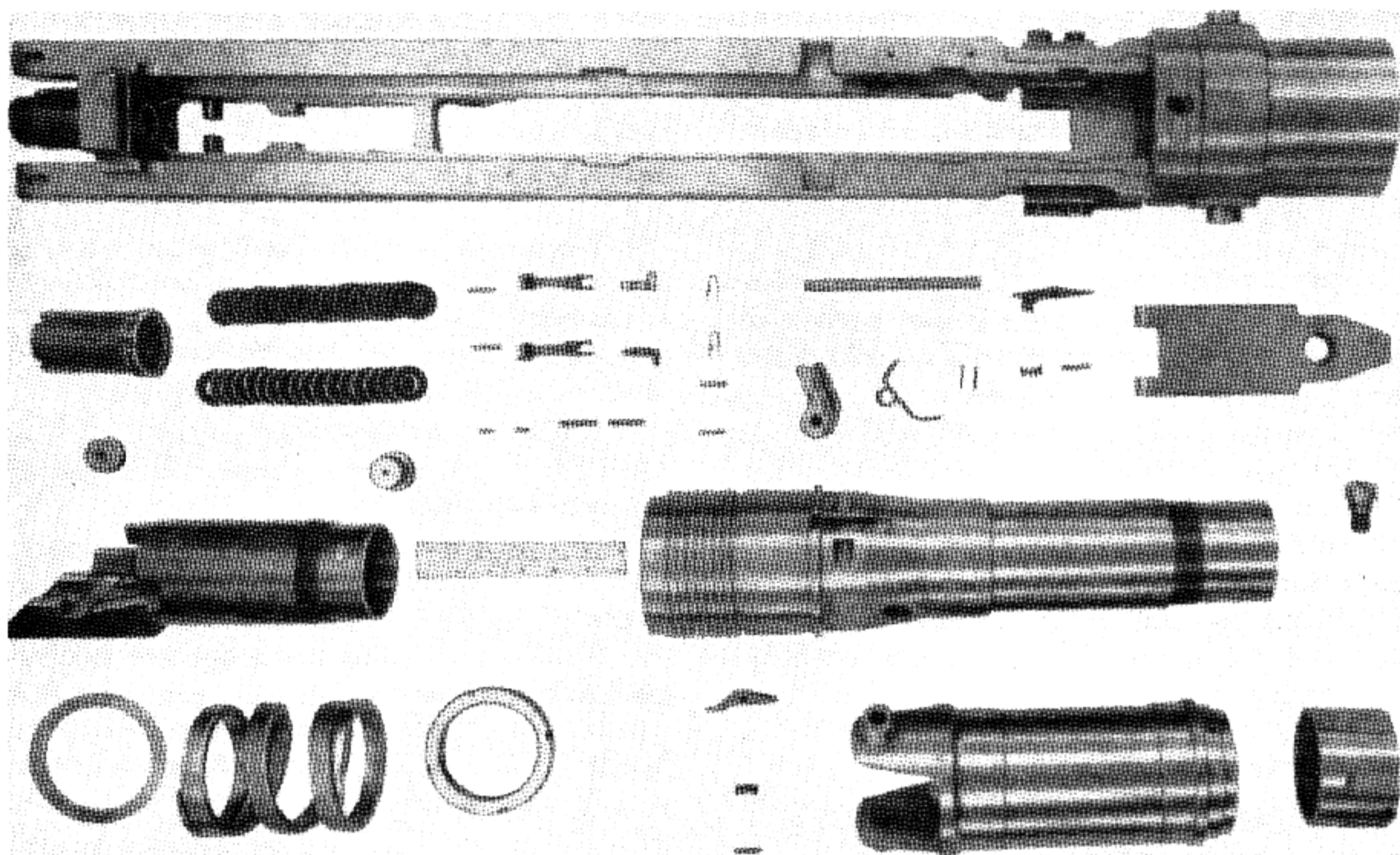


Figure 9-11. 20-mm Gun T24. Components of receiver group.

Up-end the bolt extension so that the firing pin assembly can drop out of the rear end.

4. Push out the sear plunger seat stop pin, then remove the sear spring seat and sear spring, taking care that these do not fly out when the stop pin is removed.

5. Push out the sear cover plate lockpin; slide out the sear cover plate top and the sear cover plate bottom; then remove the sear.

*To Strip the Firing Pin Unit.* Clamp the special tool provided in the vise with the U-cut uppermost; allow the knife edge at the top of the U to pass between the rear of the firing pin large flange and the front of the firing-pin sleeve. Push on the rear of the firing pin extension, compressing the firing-pin spring until the firing pin can be slid out of the U-cut in the firing-pin extension. Take care that the firing-pin spring and sleeve do not fly out in so doing.

*To Assemble the Firing Pin Unit.* Slip the firing-pin spring onto the firing-pin extension, and place the sleeve in position on the firing-pin extension flange toward front.

With the special tool provided clamped in a vise (U gap uppermost), push in on the sleeve so that the firing-pin spring is compressed sufficiently to allow the firing-pin button end to enter the U-cut in the end of the firing-pin extension.

Remove the unit carefully from the special tool in the vise. The assembly is now completed.

*To Assemble the Bolt Extension.*

1. Slide the sear cover plate bottom into position in the bolt extension.

2. Place the sear in position in the slot in the center of the crosspiece of the bolt extension.

NOTE. It can be entered to operate either right hand or left hand as may be required.

Replace the sear cover plate top by sliding it into the guides in the bolt extension. Insert the sear cover plate lockpin and push home.

3. Insert the sear spring with the sear spring seat.

NOTE. The sear spring seat will be adjacent to the lockpin in the assembly. With a drift, push in on the sear spring seat so that the lockpin can be

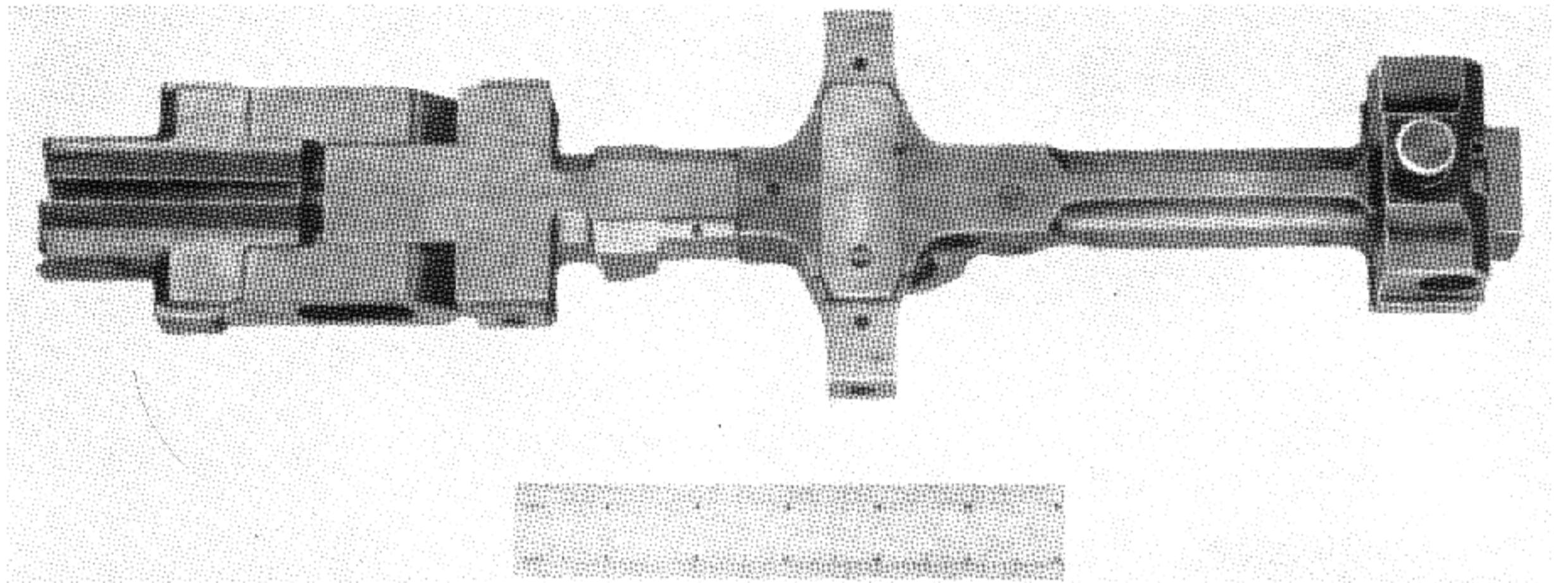


Figure 9-12. 20-mm Gun T24. Top view of bolt.

entered in its hole in the bolt extension. Push the lockpin home.

4. Replace the firing-pin assembly in its hole in the bolt extension. Up-end the bolt so that the rear is to the top and the firing-pin assembly will drop until stopped by the shoulders of the sear. Push in on the sear to allow the firing-pin assembly to go fully forward. Insert the firing-pin spring stop pin and insert the lockpin, pushing it home.

5. Place the cocking lever in its slot in the bolt extension and firing-pin extension, flat surface toward top. Then insert cocking lever axis pin and cocking lever axis pin locking pin, pushing same home.

6. Replace the firing-pin extension buffer in the hole in the bolt and replace its lockpin.

*To Assemble the Bolthead.*

1. Place the extractor with the extractor spring in position in the lower part of the bolthead and insert the extractor axis pin, pushing it home.

2. Place the bolt lock in position on the bolthead. NOTE. The connecting web is to the bottom.

3. Replace the bolt lock axis pin.

NOTE. The hole in the bolt lock axis pin is centralized so that the firing pin can pass through.

4. Slide the bolthead assembly on to the bolt extension, after first entering the bolthead shank in the hole in front of the bolt extension.

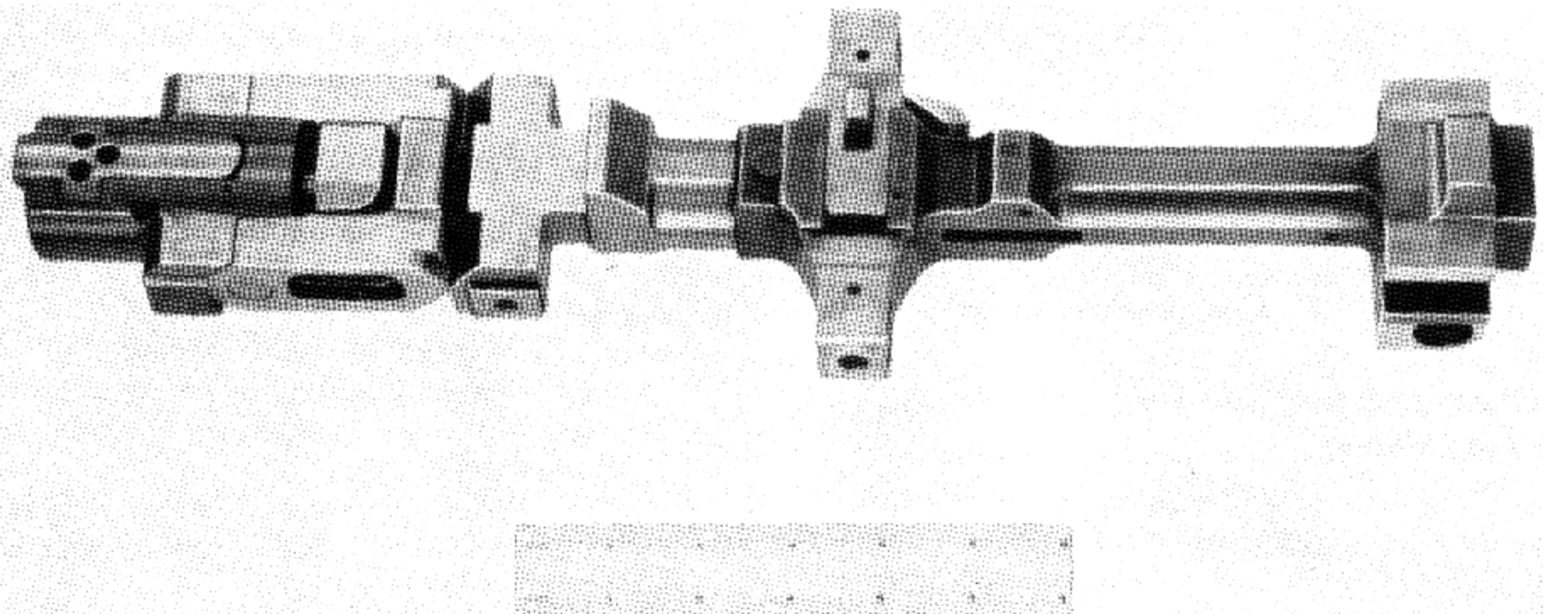


Figure 9-13. 20-mm Gun T24. Bottom view of bolt.

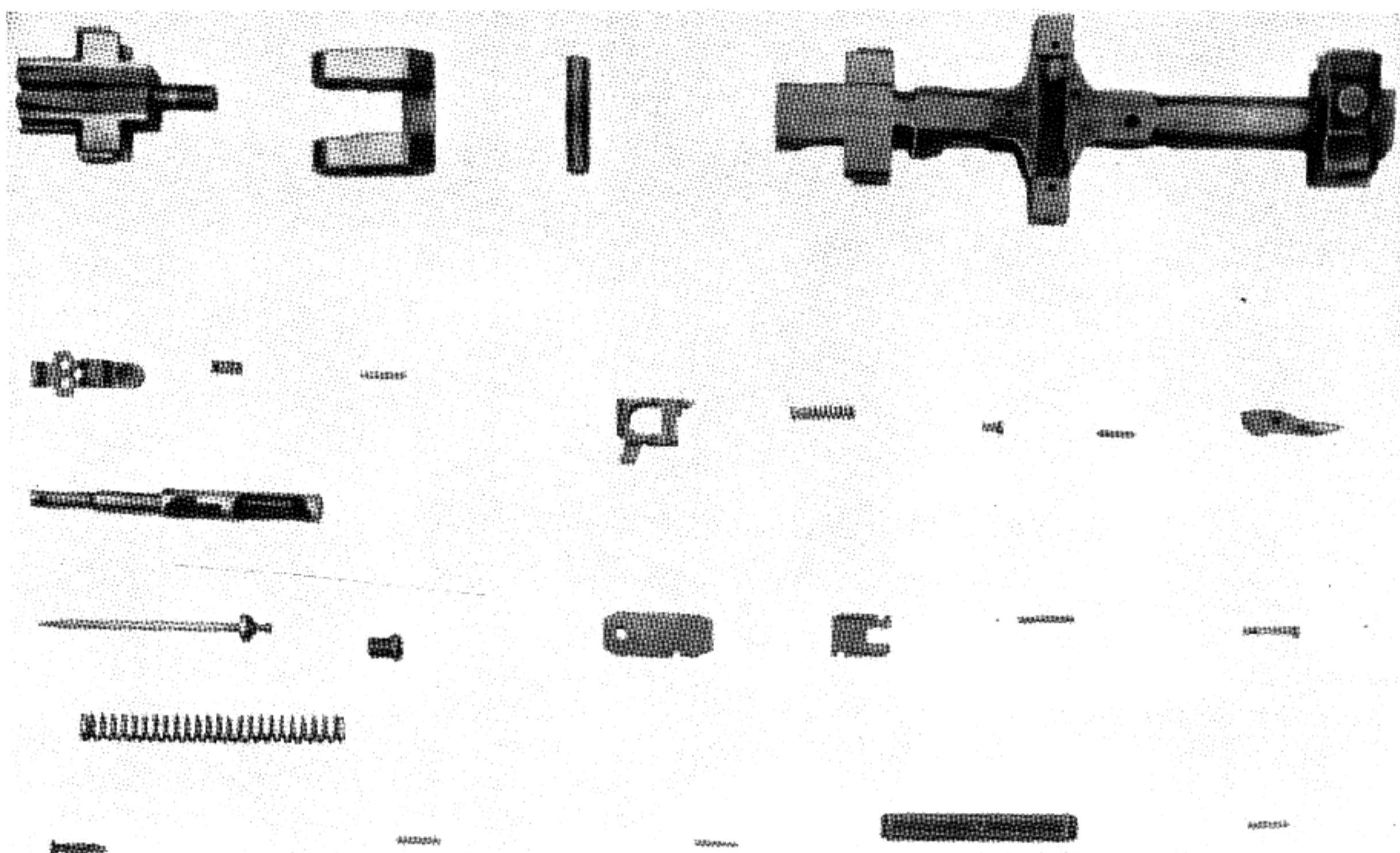


Figure 9-14. 20-mm Gun T24. Components of bolt.

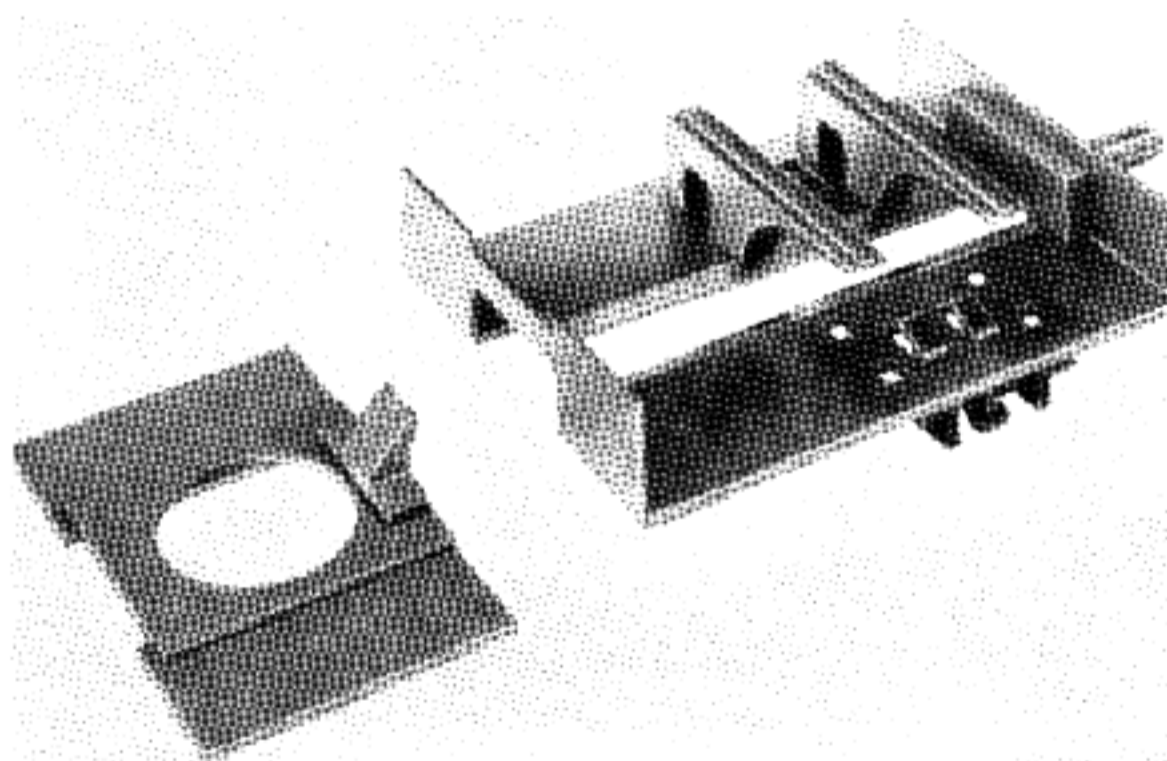


Figure 9-15. 20-mm Gun T24. Feedway.

### Changing the Gun from One Hand Feed to the Other

The gun as shipped from the factory has its components positioned for left-hand feeding. To change from left- to right-hand feeding, the following procedure is used. This applies to both the T22 and the T24.

#### *Changes to be Made in the Feed Mechanism Components in the Cover.*

1. Open cover. Remove the actuating bar.
2. Take out cotter. Take off the feed lever.
3. Noting how the feed lever appears when in position to feed left hand, remove it from the cover. Push out the feed pawl pin and enter same from the other side. The head of the pin must be toward the rear when the cover is closed. Enter the feed slide in the guides in the cover so that it feeds right hand.

4. Replace the feed lever on the stud in the correct position to feed right hand. Replace cotter. Replace actuating bar.

#### *Changes to be Made in the Feedway.*

1. Remove stripper cam pin and change the two stripper cams to the other side of the feedway.
2. Replace stripper cam pin.
3. Remove holding pawl pin. Remove cartridge holding pawl and spring, and assemble same in bracket at other side of feedway.
4. To change from right-hand to left-hand feeding, reverse the procedure just given.



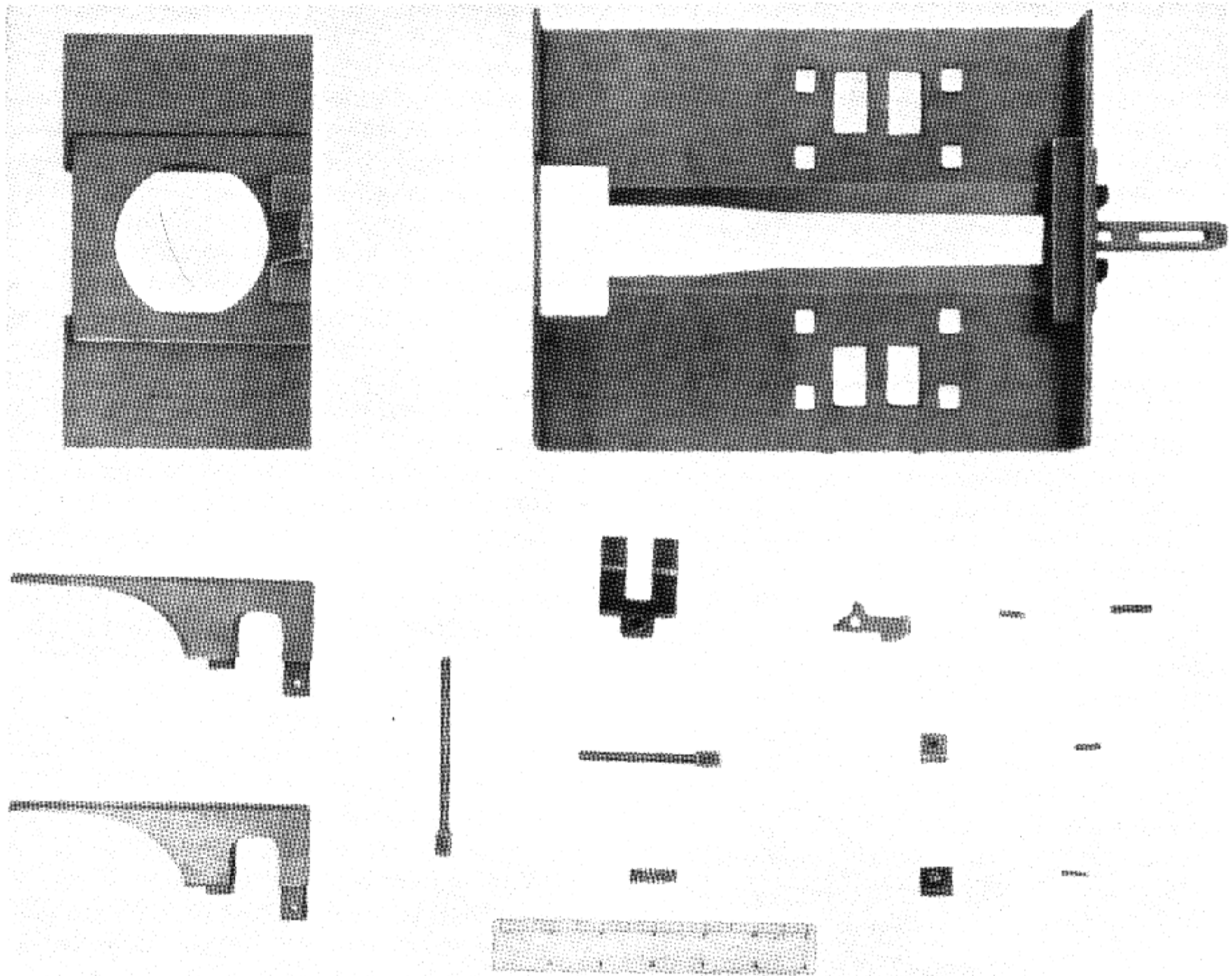


Figure 9-16. 20-mm Gun T24. Components of feedway.

### Tests of the T24

Between 14 February 1945 and 24 August 1945, 40 test rounds were fired from the T24. These rounds are described in detail in paragraphs which follow. Tests were conducted at the Colt plant except as otherwise noted.

#### Firing on 14 February 1945

The 20-mm T24 gun is chambered to take the 20-mm cartridge of 3,500-feet-per-second velocity, and the first firing of this gun took place on 14 February 1945.

Ammunition used was part of a lot of 25 rounds received from Picatinny Arsenal on 6 February

1945, having these characteristics as noted from data card accompanying the ammunition:

Expected pressure: 51,400 p. s. i.

Muzzle velocity: 3,500 feet/second.

Weight of charge: 863 grains 4,879 I. M. R.

All of the rounds showed a poor condition as regards seating in the chamber, and faults (such as large neck diameter of cartridge case, eccentricity of projectile in the cartridge case, and radius interference at rear of neck) contributed to inability of cartridge to seat correctly in the chamber. These faults were noted; nevertheless, firing of these 25 rounds was undertaken after careful measurements had been made of certain body dimensions. The "B" dimen-

sion ran from maximum 5.197 inches to minimum 5.170 inches on these cartridges, whereas the applicable drawing calls for maximum 5.200 inches and minimum 5.185 inches. With this condition there would be no crushup on some of these cartridges.

The gun was set up on a Colt test mount, adapter unit was set provisionally at 200 pounds preload, and inner spring unit at 4,500 pounds preload. The T22 adapter was used in this test on the T24 gun owing to the adapter for the T24 gun not having been completed.

The gun was fired by lanyard attached to trigger bar. A solid ejector was located in the ejector bracket. Driving springs had combined preload, with bolt at rearmost position, of approximately 152 pounds. The back plate cap was screwed tightly down on the 23 fiber disks, and firing-pin protrusion measured .095 inch. Length of gun tube, 75 inches.

*Test 1.* Extractor removed from bolthead.

With tube dismounted from the gun, round marked 11 was placed in the chamber and rotated until it seated, the bolt meantime being held on the holdback sear. The tube with round seated in the chamber was replaced in the gun. The following measurements were taken:

Cartridge head protrusion: 0.175 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.186 inches.

The holdback sear was depressed, allowing the bolt to slam forward onto the round. The round fired correctly on pulling the lanyard, the empty case remaining in the chamber. The following particulars were noted from the firing:

Recoil time: 0.066 second.

Counterrecoil time: 0.085 second.

Total cycle time: 0.151 second.

Tube cycle time: 0.042 second.

Tube travel: 0.705 inch.

Receiver travel: 0.750 inch.

Receiver cycle time: 0.032 second.

Rate of fire based on single round cycle was approximately 400 rounds per minute.

*Test 2.* The adapter preload was changed from 200 pounds to 2,200 pounds, the inner spring setting remaining at 4,500 pounds preloaded.

The driving springs, being considered too heavy at 152 pounds preload, were changed to a lighter

combination showing approximately 130 pounds preload.

No extractor in bolthead.

Round marked 13 was placed in the chamber in the same way as before with tube out of the gun so that the cartridge could be rotated until it seated.

These measurements were taken:

Cartridge head protrusion: 0.189 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.180 inches.

The bolt was allowed to slam forward from off the holdback sear and was noted to travel  $15\frac{5}{16}$  inches from rear position to closed position in 0.084 second, which is a velocity of approximately 15.25 feet per second.

The round fired correctly, and the empty case remained in the chamber.

The following particulars were noted from firing of this round:

Recoil time: 0.023 second.

Counterrecoil time: 0.061 second.

Total time cycle: 0.084 second.

Tube cycle time: 0.024 second.

Tube travel: 0.750 inch.

Receiver travel: 0.350 inch.

Receiver cycle time: 0.027 second.

The rate of fire based on this single-round cycle was approximately 714 rounds per minute.

*Test 3.* No extractor in bolthead.

Adapter setting as before, namely, 2,200 pounds; and inner spring setting 4,500 pounds as before. Round marked 1 was placed in the chamber and rotated until it seated. The following dimensions were taken:

Cartridge head protrusion: 0.197 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.186 inches.

Before firing this round, the backplate cap was given one-fourth turn to tighten down on the fiber disks.

Fired round marked 1, the empty case being caught in ejecting.

The following particulars were noted for this firing:

Recoil time: 0.028 second.

Counterrecoil time (estimated): 0.056 second.

Total time for cycle (estimated): 0.084 second.

Tube cycle time: 0.024 second.

Tube travel: 0.800 inch.

Receiver travel: 0.350 inch.

Receiver cycle time: 0.023 second.

Rate of fire based on this single-round cycle was approximately 714 rounds per minute.

Before proceeding with the next test, the adapter setting was changed from 2,200 pounds to 1,500 pounds preload, the inner spring setting remaining at 4,500 pounds preload.

*Test 4.* Round marked 2 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.187 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.180 inches.

Round fired correctly and ejected. ( $\frac{1}{8}$ -inch buffer compression noted.)

The following particulars were noted from this firing:

Recoil time: 0.028 second.

Counterrecoil time: 0.062 second.

Total time for cycle: 0.090 second.

Tube cycle time: 0.030 second.

Tube travel: 0.730 inch.

Receiver travel: 0.450 inch.

Receiver cycle: 0.027 second.

Rate of fire based on single round cycle was approximately 654 rounds per minute.

The adapter setting was now changed from 1,500 pounds to 900 pounds preload.

*Test 5.* Round marked 3 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.186 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.180 inches.

Round fired correctly and ejected, and the following particulars were noted from this firing:

Recoil time: 0.030 second.

Counterrecoil time: 0.060 second.

Total time for cycle: 0.090 second.

Tube cycle time: 0.032 second.

Tube travel: 0.700 inch.

Receiver travel: 0.550 inch.

Receiver cycle time: 0.030 second.

Rate of fire based on single round cycle was approximately 654 rounds per minute.

The ejector was removed from the ejector bracket after this firing as the impact of same against rim of the cartridge case on recoil at so great a velocity sheared sections out of each rim.

Different ring springs were assembled into the T24 housing. Due to  $\frac{1}{4}$ -inch accidental additional length in the inner spring adjusting collar, a preload setting of 6,500 pounds was obtained instead of the expected 4,500 pounds preload. Two rounds were fired with this condition.

*Test 6.* Extractor placed in position in bolthead. Round marked 4 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.193 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.180 inches.

This round fired correctly but the case did not eject, having been caught between the rear of tube extension and front of bolt and damaging the extractor. The following particulars were noted from this firing:

Recoil time: 0.028 second.

Counterrecoil time (estimated): 0.055 second.

Total time for cycle (estimated): 0.083 second.

Tube cycle time: 0.030 second.

Tube travel: 0.950 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.038 second.

Rate of fire based on single-round cycle was approximately 714 rounds per minute.

*Test 7.* Continued firing using the preload of 6,500 pounds on inner spring unit. Adapter as before was set at 900 pounds preload. No extractor in bolt. Round marked 5 was placed in chamber, and the following measurements were taken:

Cartridge head protrusion: 0.190 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.176 inches.

The round fired correctly and ejected and the following particulars were noted from this firing:

Recoil time: 0.065 second.

Counterrecoil time: 0.087 second.

Total time for cycle: 0.152 second.

Tube cycle time: 0.038 second.

Tube travel: 0.900 inch.

Receiver travel: 0.600 inch.

Receiver cycle time: 0.034 second.

Rate of fire based on single round cycle was approximately 394 rounds per minute.

*Test 8.* The preload of inner ring springs was changed from 6,500 pounds to 4,500 pounds preload. Adapter setting remained as before, 900 pounds preload. Round marked 6 was placed in

chamber, and the following measurements were taken:

Cartridge head protrusion: 0.177 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.170 inches.  
 Round fired correctly but case caught in ejecting.  
 The following particulars were noted from this firing:

Recoil time: 0.032 second.  
 Counterrecoil time (estimated): 0.051 second.  
 Total time for cycle (estimated): 0.083 second.  
 Tube cycle time: 0.032 second.  
 Tube travel: 0.700 inch.  
 Receiver travel: 0.600 inch.  
 Receiver cycle time: 0.034 second.  
 Rate of fire based on single round cycle was approximately 730 rounds per minute.

*Test 9.* Round marked 7 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.203 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.197 inches.  
 Round fired correctly and empty case went back into chamber. The following particulars were recorded from this firing:

Recoil time: 0.072 second.  
 Counterrecoil time: 0.080 second.  
 Total time for cycle: 0.152 second.  
 Tube cycle time: 0.038 second.  
 Tube travel: 0.700 inch.  
 Receiver travel: 0.600 inch.  
 Receiver cycle time: 0.034 second.  
 Rate of fire based on single-round cycle was approximately 394 rounds per minute.

*Test 10.* Round marked 8 was placed in the chamber and the following measurements were taken:

Cartridge head protrusion: 0.193 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.187 inches.  
 Round fired correctly and empty case went back into chamber. The following particulars were recorded from this firing:

Recoil time: 0.060 second.  
 Counterrecoil time: 0.084 second.  
 Total time for cycle: 0.144 second.  
 Tube cycle time: 0.038 second.  
 Tube travel: 0.800 inch.

Receiver travel: 0.600 inch.

Receiver cycle time: 0.030 second.

Rate of fire based on single-round cycle was approximately 414 rounds per minute.

*Test 11.* The adapter preload was changed from 900 pounds to 1,500. Inner spring preload remained unchanged at 4,500 pounds. Round marked 9 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.191 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.187 inches.  
 Round fired correctly, but the primer blew out of the cartridge case and was found lodged transversely between the cartridge case and front of bolt; closing of breech was thus prevented. The following particulars were recorded from this firing:

Recoil time: 0.046 second.  
 Counterrecoil time (estimated): 0.091 second.  
 Total time for cycle (estimated): 0.137 second.  
 Tube cycle time: 0.034 second.  
 Tube travel: 0.800 inch.  
 Receiver travel: 0.500 inch.  
 Receiver cycle time: 0.030 second.

Rate of fire based on single round cycle was approximately 430 rounds per minute.

It was observed at the first firings of this gun on February 14 and 15 that the rate of firing was not consistent in cases of repetition firings where no changes in spring settings had been carried out; accordingly, the gun was carefully gone over in order to remove excessive friction which might have caused a drag in firing rate.

Exterior of the tube recoil spring was reduced slightly on outside diameter, and hard rubbing spots on bolt extension were given attention. An amount of about 0.005 inch was removed from cocking lever where it had been rubbing hard on guide in recoil.

### Firing on 23 February 1945

*Test 12.* Round marked 10 was placed in the chamber, and the round was rotated until it seated correctly. The following dimensions were taken:

Cartridge head protrusion: 0.197 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.189 inches.  
 Cartridge fired correctly and ejected. The following particulars were recorded from this firing:  
 Recoil time: 0.027 second.

Counterrecoil time: 0.043 second.

Total cycle time: 0.070 second.

Tube cycle time: 0.027 second.

Tube travel: 0.780 inch.

Receiver travel: 0.420 inch.

Receiver cycle time: 0.024 second.

Rate of fire based on single round cycle approximately 857 rounds per minute.

### Firing on 24 February 1945

Owing to difficulties experienced due to faults in the ammunition composing the first lot of 25 rounds received, a further lot of 25 rounds for tests was sent from Picatinny Arsenal. These cartridges had the following characteristics according to the data card accompanying the consignment:

Expected pressure: 51,400 p. s. i.

Muzzle velocity: 3,500 feet/second.

Weight of charge: 863 grains.

Powder: 4,879 I. M. R.

The cartridges were measured on the "B" dimension and the results tabulated. The "B" dimension on these cartridges ran from maximum 5.201 inches to minimum 5.168 inches. Drawings called for maximum 5.200 inches and minimum 5.185 inches. With this condition, there would be no crushup on some of these cartridges.

These rounds showed the same fault as before, namely, that they could only be made to seat in the chamber by rotating the cartridge until seated.

Gun adjustments were made as at the last firing: inner spring, preload, 4,500 pounds; adapter preload, 1,500 pounds.

Standard driving springs in gun had 130 pounds preload. Twenty-three fiber disks in back plate screwed down tightly. Firing pin protrusion, as before, 0.095 inch.

*Test 13.* No extractor. No ejector.

Round marked 26 was placed in the chamber, and the following dimensions were taken.

Cartridge head protrusion: 0.194 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.186 inches.

Round fired correctly but did not eject. The following particulars were recorded from this firing:

Recoil time: 0.042 second.

Counterrecoil time (estimated): 0.057 second.

Total time for cycle (estimated): 0.099 second.

Tube cycle time: 0.030 second.

Tube travel: 0.750 inch.

Receiver travel: 0.500 inch.

Receiver cycle time: 0.027 second.

Rate of fire based on single round cycle was approximately 604 per minute.

NOTE. After being fired, the cartridge case went back into the chamber and had to be removed by pushing it out with a rod. In firing, the primer blew out of the case and lodged against the rear of the case so that the bolt could not complete its stroke at counterrecoil. Also, due to loss of pressure through the gas escaping through primer hole in cartridge case, the recoil of bolt was weak, the recoil stroke taking 0.042 second to complete.

*Test 14.* No extractor. No ejector.

Round marked 27 was placed in the chamber, and the following dimensions were taken.

Cartridge head protrusion: 0.195 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.183 inches.

Round fired correctly but did not eject. The following particulars were recorded from this firing:

Recoil time: 0.042 second.

Counterrecoil time (estimated): 0.061 second.

Total time for cycle (estimated): 0:103 second.

Tube cycle time: 0.032 second.

Tube travel: 0.800 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.027 second.

Rate of fire based on single round cycle was approximately 581 rounds per minute.

NOTE. After firing this round, cartridge case went back into chamber and had to be pushed out with a rod. In firing, the primer blew out and lodged below the bolt in the extractor cut.

Recoil stroke of the bolt was weak due to gas leak through the primer hole in the cartridge case.

On conclusion of firing these two rounds, Nos. 26 and 27, orders were given to discontinue using this batch of ammunition and preparation of another lot of ammunition was ordered for further testing at as early a date as possible.

While awaiting a new batch of ammunition, firing was continued using rounds from the first batch of 25 in order to determine a suitable type of ejector.

**Firing on 2 March 1945**

*Test 15.* Ejection was tested using wire type ejector (wire diameter 0.062 inch). Round marked 12 was placed in the chamber, and the following dimensions were taken:

Cartridge head protrusion: 0.175 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.171 inches.  
 Round fired correctly but did not eject.

The following particulars were noted from this firing:

Recoil time: 0.028 second.  
 Counterrecoil time: Not obtained.  
 Total time for cycle (estimated): 0.076 second.  
 Tube cycle time: 0.030 second.  
 Tube travel: 0.750 inch.  
 Receiver travel: 0.450 inch.  
 Receiver cycle time: 0.027 second.

The wire ejector was found to be deformed after this test.

Rate of fire (estimated) based on single round cycle was approximately 785 rounds per minute.

*Test 16.* Testing ejection, using wire ejector (diameter 0.062 inch).

Round marked 14 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.203 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.188 inches.

Round fired correctly but did not eject. The following particulars were recorded from this firing:

Recoil time: 0.038 second.  
 Counterrecoil time: Not recorded.  
 Tube cycle time: 0.030 second.  
 Tube travel: 0.687 inch.  
 Receiver travel: 0.450 inch.  
 Receiver cycle time: 0.027 second.

Ejector showed deformation after this test.

**Firing on 9 March 1945**

*Test 17.* Testing ejection, using wire ejector (0.067-inch wire). Round marked 15 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.195 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.188 inches.

Cartridge fired correctly but did not eject. Primer blew out. The following particulars were noted from this firing:

Recoil time: 0.038 second.  
 Counterrecoil time: 0.059 second.  
 Total time for cycle: 0.097 second.  
 Tube cycle time: 0.032 second.  
 Tube travel: 0.750 inch.  
 Receiver travel: 0.500 inch.  
 Receiver cycle time: 0.027 second.

Bolt closed on empty cartridge case in chamber, which did not eject and had to be pushed out with a rod. Rate of fire based on single round cycle was approximately 614 rounds per minute.

*Test 18.* Continuing test of wire ejector (0.067-inch diameter wire). Round marked 19 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.186 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.184 inches.

Cartridge fired correctly but did not eject. Primer had pierced, causing gas leakage. The following particulars were recorded from this firing:

Recoil time: 0.051 second.  
 Counterrecoil time: 0.076 second.  
 Total time for cycle: 0.127 second.  
 Tube cycle time: 0.032 second.  
 Tube travel: 0.750 inch.  
 Receiver travel: 0.500 inch.  
 Receiver cycle time: 0.028 second.

Cartridge case did not eject and had to be pushed out with a rod. Rate of fire based on single round cycle was approximately 460 rounds per minute.

*Test 19.* Testing wire ejector (0.067-inch diameter wire). Round marked 21 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.189 inch.  
 Dimension "A" (chamber): 5.188 inches.  
 Dimension "B" (cartridge): 5.185 inches.  
 Cartridge fired and ejected correctly.

The following particulars were recorded after this firing:

Recoil time: 0.027 second.  
 Counterrecoil time: 0.020 second.  
 Total time for cycle: 0.077 second.  
 Tube cycle time: 0.030 second.  
 Tube travel: 0.775 inch.  
 Receiver travel: 0.350 inch.  
 Receiver cycle time: 0.032 second.

NOTE. Ejector was found to be badly deformed after this test. Rate of fire based on single round cycle was approximately 785 rounds per minute.

**Firing on 10 March 1945**

Gun in same condition as at last firing.

Test 20. Round marked 33 was placed in the chamber, and the following measurements were taken:

- Cartridge head protrusion: 0.187 inch.
- Dimension "A" (chamber): 5.188 inches.

Cartridge fired correctly but did not eject. The primer blew out of the cartridge case; the case itself remained in the chamber and had to be pushed out with a rod inserted from the front.

Rate of fire not recorded.

**Firing on 13 March 1945**

Test 21. Testing flat type spring ejector 0.065-inch thick. Round marked 23 was placed in the chamber, and the following measurements were taken:

- Cartridge head protrusion: 0.197 inch.
- Dimension "A" (chamber): 5.188 inches.
- Dimension "B" (cartridge): 5.195 inches.

Cartridge fired correctly but did not eject. Ejector was found to be badly deformed after this test. Recoil time as shown by graph was 0.028 second. Rate of fire not recorded.

**Firing on 14 March 1945**

Tests 22, 23, and 24. The tests were only for the purpose of noting action of bolt locking, the bolt being allowed to fly forward off the holdback sear.

Test 25. Testing flat type spring ejector 0.065-inch thick.

Since last firing, ejector bracket has had a slot cut to hold flat type ejector spring. Round marked 22 was placed in the chamber, and the following measurements were taken:

- Cartridge head protrusion: 0.184 inch.
- Dimension "A" (chamber): 5.188 inches.
- Dimension "B" (cartridge): 5.183 inches.

Cartridge fired correctly but did not eject. The following particulars were recorded from this firing:

- Recoil time: 0.027 second.
- Counterrecoil time: Not recorded.
- Tube cycle time: 0.028 second.
- Tube travel: 0.750 inch.

- Receiver travel: 0.400 inch.
- Receiver cycle time: 0.027 second.

NOTE. The flat type ejector in use for this test was found to be deformed.

**Firing on 30 March 1945**

Test 26. Testing ejector provided with a depressor. Round 20 was placed in the chamber. The following measurements were taken:

- Cartridge head protrusion: 0.189 inch.
- Dimension "A" (chamber): 5.188 inches.
- Dimension "B" (cartridge): 5.185 inches.

Cartridge fired correctly but did not eject. The following measurements were recorded from this firing:

- Recoil time: 0.027 second.
- Counterrecoil time (estimated): 0.050 second.
- Total time for cycle (estimated): 0.077 second.
- Tube cycle time: 0.028 second.
- Tube travel: 0.750 inch.
- Receiver travel: 0.450 inch.
- Receiver cycle time: 0.027 second.

NOTE. Bolt, on examination after test, was found to show a crack. Rate of fire (estimated) based on single round cycle was 785 per minute.

**Star Gauge Inspection Report**

20-mm Tube T24, 12 April 1945 (Tube had Fired 23 Rounds)

Inches from muzzle	Lands (inches)	Grooves (inches)
0.....	0.7880	0.8160
5.....	.7880	.8160
10.....	.7875	.8160
15.....	.7875	.8170
20.....	.7875	.8170
25.....	.7875	.8170
30.....	.7875	.8180
35.....	.7875	.8180
40.....	.7875	.8180
45.....	.7870	.8180
50.....	.7870	.8180
55.....	.7870	.8180
60.....	.7870	.8175
65.....	.7865	.8160
68.50.....	.7870	.8170

**Firing on 11 May 1945**

*Test 27.* Testing with a new bolthead cut away at the top for cartridge entry. Using Type 2 ejector (medium length). Round marked 24 was placed in the chamber. The following measurements were taken:

Cartridge head protrusion: 0.176 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.172 inches.

Cartridge fired correctly but did not eject. The following particulars were recorded from this firing:

Recoil time: 0.028 second.

Tube cycle time: 0.750 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.027 second.

Rate of fire was not recorded. New bolthead appeared satisfactory.

*Test 28.* Test with cartridge case head reduced to diameter of 1.183 inches to determine if a tight head diameter influences ejection. Using type 1 ejector (medium length). Round marked 18 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.192 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.185 inches.

Cartridge fired correctly but did not eject. The following particulars were recorded from this firing:

Recoil time: 0.028 second.

Counterrecoil time not recorded owing to ejection jam.

Tube cycle time: 0.028 second.

Tube travel: 0.750 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.028 second.

Reduced diameter of cartridge case head had no influence on firing.

**Firing on 15 May 1945**

*Test 29.* Testing type 1 ejector (long). Round marked 16 was placed in the chamber and the following measurements were taken:

Cartridge head protrusion: 0.194 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.192 inches.

Cartridge fired and ejected correctly. The following particulars were recorded from this firing:

Recoil time: 0.028 second.

Counterrecoil time: 0.047 second.

Total time for cycle: 0.075 second.

Tube cycle time: 0.028 second.

Tube travel: 0.750 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.028 second.

Examination of fired cartridge case showed that it was slightly bulged on the front cone. Ejector bracket was found to be badly bent. It was decided not to continue with long type ejector. Rate of fire based on single-round cycle was approximately 785 rounds per minute.

**Firing on 18 May 1945**

*Test 30.* Test using ejector type 1 (medium length) modified by having pivot point advanced  $1\frac{3}{8}$  inches in the ejector bracket. Round marked 17 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.185 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.184 inches.

Cartridge fired and ejected correctly. The following particulars were recorded from this firing:

Recoil time: 0.028 second.

Counterrecoil time: 0.046 second.

Total time for cycle: 0.074 second.

Tube cycle time: 0.028 second.

Tube travel: 0.750 inch.

Receiver travel: 0.450 inch.

Receiver cycle time: 0.028 second.

Rate of fire based on single-round cycle was approximately 800 rounds per minute.

**Firing on 14 and 15 June 1945**

Acting upon instructions received from the Ordnance Department, the T24 gun was shipped to Aberdeen Proving Ground on 13 June 1945, where it underwent tests at the ballistic research laboratory on 14 and 15 June 1945. These tests consisted of taking time spark photographs, recording velocity of recoil, trunnion reaction, etc. Also acting upon instructions from the same source in a letter dated 2 June 1945, the tube had been reduced in length from 75 inches to 63 inches, this work was carried out at the Colt plant before shipping the gun to Aberdeen.

Before shipping the gun to Aberdeen Proving Ground, an addition was made of a cartridge guide inside the feedway at the rear, this guide also form-



ing a backplate to which the ejector bracket was attached. The gun was fitted with a new ejector (type 3) having a fiber insert to afford resilience.

At the tests carried out on 14 and 15 June 1945, some difficulty was experienced due to the exposed head of the cartridge case expanding considerably in firing. In the firing at the Colt plant of about 30 rounds, no difficulty of this kind was experienced.

Instructions were given to modify the T24 tube in such a way as to increase support of the cartridge case at the point where the deformation took place. This was carried out by making a large counterbore in the tube breech face and by inserting a threaded bushing which was afterward ground out to obtain the extended chamber.

On the return of the gun from Aberdeen Proving Ground, a separator was added to the gun to release the pressure of the bolt extension from the bolt-head and also to assist the bolt unlocking action, it having been observed that there was a slight Brinelling occurring at the top of the lock recess.

### Ammunition Received by Colt on 10 July 1945

A third lot of 200 rounds of ammunition reached the Colt plant on 10 July 1945. Particulars of this ammunition as shown on the data card are as follows:

Pressure: 51,200 p. s. i.

Muzzle velocity: 3,500 feet/second.

Weight of charge: 903 grains.

Powder: 5,010 I. M. R.

The "B" dimension on the first 25 of these cartridges ran from maximum 5.182 inches to minimum 5.165 inches. With this condition there would be no crushup on some of these cartridges.

### Firing on 10 August 1945

The modifications having been carried out, this third lot of ammunition was test fired at the Colt plant.

*Test 34.* Gun had a solid ejector (type 3) with fiber insert. Tube had chamber modified to afford increased support to the cartridge case. Separator was in gun. Round marked 52 was placed in the chamber, and the following dimensions were taken:

Cartridge head protrusion: 0.191 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.180 inches.

Round fired correctly and ejected. Cartridge case showed bulge and splits on cone. The splits, in nearly all cases, followed longitudinal die marks along the case. These bulges and splits did not show up at Aberdeen Proving Ground testing.

Circumferential mark noted on cartridge case where joint of bushing with chamber takes place.

*Test 35.* Round marked 53 was placed in the chamber, and the following dimensions were taken:

Cartridge head protrusion: 0.178 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.182 inches.

Round fired correctly and ejected. Cartridge case bulged and split on cone. Circumferential mark noted on the cartridge case where joint of bushing with tube chamber takes place.

*Test 36.* Round marked 54 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.184 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.178 inches.

Round misfired and removed from gun.

*Test 37.* The 23 fiber disks were taken out of the buffer tube and changed to 16 Belleville washers. These washers had been supplied by the Edgewater Steel Co. Round marked 55 was placed in the chamber, and the following measurements were taken:

Cartridge head protrusion: 0.185 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.176 inches.

The round fired correctly and ejected. The case showed bulge and splits on cone. Circumferential mark noted on the cartridge case where joint of bushing with tube chamber takes place.

*Test 38.* Still using Belleville washers in buffer tube round marked 56 was placed in the chamber and the following measurements taken:

Cartridge head protrusion: 0.186 inch.

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.177 inches.

The round fired correctly and ejected. Cartridge case showed bulge and splits on cone. Circumferential mark noted on the cartridge case where joint of bushing with tube chamber takes place.

*Test 39.* The separator was removed from the gun for the purpose of observing whether this had any effect on the bulged cone condition. Belleville

washers in buffer tube. Round marked 57 was placed in the chamber, and the following measurements were taken:

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.178 inches.

The round fired correctly and ejected case showed bulge and splits on cone. Circumferential mark noted on cartridge case where joint of bushing with tube chamber takes place.

Removal of separator from gun did not change bulged-cone condition.

*Test 40.* Without separator and with Belleville washers in buffer tube. Round marked 58 was placed in the chamber, and the following dimensions were taken:

Dimension "A" (chamber): 5.188 inches.

Dimension "B" (cartridge): 5.179 inches.

The round fired correctly and ejected. The case showed bulge and splits on conc. Circumferential mark noted on the cartridge case where joint of bushing with tube chamber takes place.

## Chapter 10

## 20-MM JOHNSON AIRCRAFT CANNON

## SECTION 1. HISTORY AND BACKGROUND

NOTE. The 20-mm Johnson aircraft cannon has been neither accepted nor rejected by the Navy. Therefore, available information on the design, proofing and testing of the weapon has been included in greater detail than in other chapters of this volume, since the data would be of great convenience to future project officers in the event consideration of the Johnson cannon should be resumed.

## Johnson's Early Interest in Guns

Melvin M. Johnson, Jr., was born in August 1909 in Boston, Mass., and attended Noble Greenough Preparatory School in Boston and Dedham.

At an early age he began to do big-game hunting in the Maine woods, and when he was 14 years old, *Hunting and Fishing* magazine printed an article by Johnson on sporting arms with some reference to military weapons. This latter is one instance of his early aptitude for the study of weapons.

After finishing his preparatory schooling, Johnson entered Harvard University in 1927, enrolling in the Field Artillery R. O. T. C. In his freshman year, he organized the Harvard caliber .30 rifle team, of which he was elected captain. He was also captain of the Harvard gun team. He graduated from Harvard with a B. S. degree in 1931 and entered Harvard Law School, receiving an LL. B. degree in 1934.

Soon after completing the R. O. T. C. course at Harvard, Johnson became active in the Army Reserve. In 1933 the Marine Corps, taking note of his reputation as an ordnance expert, offered him a commission of second lieutenant, which he accepted. He had several tours of duty at Quantico, Va., where he attended the weapon school.

In August 1934, the Marine Corps ordered Johnson to visit Springfield Armory to see the Garand and Pedersen rifles, which were then in experimen-

tal stages. Johnson later said that he was struck with certain limitations which he anticipated would be present in production models of these rifles.

## Johnson's Early Gun Designs

In 1935, Johnson became involved in his first design project, an attempt to complete the development of a retarded blowback mechanism in competition with the Garand and Pedersen rifles. At this time, he wrote a number of articles for the *Marine Corps Gazette* and for *Ordnance* magazine.

After abandoning his project involving the blowback mechanism, he turned his attention to other possibilities. In 1936, he made some rough parts in a machine shop on Atlantic Avenue in Boston, where he assembled them and fired the prototype of the weapon later to become the Johnson automatic rifle.

This weapon had an unprepossessing appearance. The hammer was taken from a Browning automatic shotgun, and a steel knitting needle was used for a firing pin. To this device was attached a Springfield barrel which recoiled in the sleeve and caused a multilug arrangement to turn the bolt so as to rotate 18° to the unlocked position. The parts were arranged in a vise and fired by a string. The first time this somewhat crude mechanism was fired, however, it successfully extracted and ejected the empty shell.

Spurred on by his initial success, Johnson devised a shoulder rifle model on this action; and on 1 September 1936 he fired it at the Marine range at Wakefield. It was a very clumsy and somewhat heavy model, but it exemplified the action. In 1937 Johnson built a crude experimental light machine gun model using the same basic action.

By the fall of 1937 he had prepared drawings for the making of several models of what was to be called the Johnson semiautomatic rifle. He had



Figure 10-1. Melvin M. Johnson, Jr., inventor of the Johnson system of automatic weapons, with his light machine gun.

these models made, using the facilities of the Marlin Fire Arms Co., during 1937 and early 1938.

During 1938, two of these rifles were tested extensively at Fort Benning on an informal demonstration basis. One of the guns was fired some 3,000 rounds in one and a half hours by a team of infantry personnel, each man shooting 200 rounds while an assistant loaded the magazine. This rifle gave a rather remarkable performance for a model in that status.

At that time, a Garand M1 rifle was fired in competition against Johnson's gun and was withdrawn after 198 rounds because of overheating and extraction difficulties. Later, at Aberdeen Proving Ground, some 1,200 rounds were fired through Johnson's gun. One magazine gave feed failures and a

number of these were charged to the weapon, resulting in some confusion among the authorities present as to the actual performance of the operating system.

In December 1939, Melvin Johnson submitted rifle number 17 with rotary magazine, made by Taft-Pierce, to the Ordnance Department.

This weapon was tested at Aberdeen Proving Ground, where it fired some 6,000 rounds. The actual stoppage record was something less than 12, mostly minor failures, there being no major breakage. The magazine spring had to be rehooked once, and this cost the weapon several failures until it was corrected.

Notwithstanding the creditable showing made by the weapon, the War Department decided after con-

siderable deliberation that nothing further would be done with the Johnson rifle, generally on the grounds that this rifle did not represent material advantages over the 1936-adopted M1 rifle which would warrant replacing the M1 rifle in its advanced stage of manufacture. The Chief of Staff was opposed to having two standard rifles for supply and training reasons.

Certain defects, such as the inability to use the standard M-1905 16-inch bayonet and the lack of wooden hand guards around the barrel, were also cited against the Johnson rifle. Some criticism of the magazine was made, involving the possibility of denting it. The mechanical performance and accuracy were, however, always noted as being satisfactory.

This attitude of the Army is sometimes misunderstood, it being interpreted as lack of interest in pro-

gress. As a matter of fact, the Army was committed to the M1 rifle, had already adopted it in 1936, and had manufactured some 50,000 of the rifles. While having experienced certain difficulties, the Ordnance Corps by 1940 had made rather radical improvements in the original rifle. In these circumstances and with the war in Europe, it was the policy of the Chief of Staff to consider the rifle already in production as standard and not to consider a co-standard or a second rifle. However, plausible as these facts are, they in no way detract from the high regard held in the service for the working principles of the Johnson rifle and light machine gun.

### Development Work for the Armed Services

Early in 1942 the Bureau of Ordnance initiated a 20-mm aircraft machine gun program for the pur-



Figure 10-2. Senate Military Affairs Committee meeting of 2 July 1940. Left to right: Senator Morris Sheppard, Chairman of Committee; Maj. Gen. George A. Lynch, Chief of Infantry; (standing, left) Brig. Gen. R. C. Moore, Assistant Chief of Staff, United States Army; Melvin M. Johnson, Jr.; Senator A. B. Chandler (seated far right). The Johnson semiautomatic rifle was discussed at this meeting.

pose of either replacing or having a companion arm to the Hispano-Suiza which was then the adopted weapon in the naval service.

In July, Dr. Henry B. Allen, director of the Franklin Institute, Philadelphia, and Vice Chairman of Division 1, National Defense Research Committee, discussed the problem of the belt-feed system with Melvin Johnson, who by this time had design and manufacturing facilities available. At this time, Johnson was president of Johnson Automatics, Inc.

On 7 August 1942, Johnson attended a conference at the Bureau of Ordnance, Navy Department, at the request of Dr. L. H. Adams, Chairman of Division 1, National Defense Research Committee, and Dr. Allen. Present were Lt. Comdr. E. A. Junghans, USN, Lt. Hildenbrand, USNR, Dr. Allen, and Melvin Johnson. It was requested that Johnson submit a letter on the subject of aircraft cannon and the Navy's feed system after inspecting weapons at Dahlgren, Va.

On 8 August 1942, Melvin Johnson and C. B. Gardiner, of Johnson Automatics, visited Dahlgren. The Hispano-Suiza gun was fired for them. Then Johnson wrote a letter to the National Defense Research Committee (NDRC) and the Bureau of Ordnance recommending the development of a complete aircraft cannon designed for belt feed.

The contact with the Bureau of Ordnance resulted in a long series of development contracts and efforts which continued throughout World War II. While this program did not result in a finished weapon, it is an accepted fact that many advanced features and basically new ideas were incorporated in the prototypes Johnson originated.

As a prototype in this cannon development field, his first attempt resulted in the self-unlocked, gas-timed, semiblowback, 20-mm machine gun. There were actually three models attempted on this project, but the second model was never made because the third model was sufficiently advanced for preparation of its parts, eliminating the necessity of the second model.

A major difficulty encountered in this project was the fact that initially the Navy required the use of 20-mm Oerlikon ammunition and set this forth as a specification. This ammunition, Johnson felt, was radically unsuited for the type of performance desired and eventually this was changed over to the

20-mm Hispano-Suiza ammunition which he felt would give better performance.

The action was so fast and powerful that in early prototype firing the projectiles loosened occasionally in the mouth of the cases of the Hispano-Suiza ammunition. In one of Johnson's early reports, he asked that it be recognized that this ammunition was never originally made for use in a gas-operated, belt-fed system, especially one in which a cartridge was to be pulled to the rear out of a closed loop belt. It was pointed out that it would have been better had the development been along lines where the cartridge is shoved out of the feed mouth into the chamber instead of the retracted movement. It was further pointed out that the closed loop belt imposed basic disadvantages upon the mechanism.

In less than 18 months, a firing model was demonstrated. Johnson not only fired the 20-mm Hispano-Suiza ammunition, but by shifting the barrel was able to shoot a 20-mm Hispano-Suiza case necked down to a caliber .50 and employing a pre-engraved projectile. This necking down gave an official reading of 4,400-feet-per-second velocity. It was found that the mechanism would pull a very heavy belt load somewhat in the range of 140 pounds while only losing 10 percent of its cyclic rate.

Before Johnson's weapon was ready to fire, the Bureau of Ordnance asked him to consider the charging device and electric mechanism for retraction of the bolt, a barrel removing feature and a right- and left-hand belt interchange, and to submit advanced reports on what he expected to achieve as to high cyclic rates and the force that would be exerted in pulling the belt and feeding the cartridges.

The war's end stopped further development of the Johnson 20-mm high cyclic rate aircraft machine gun.

### Summary of Development Work for the Armed Services

This project was undertaken with definite service requirements in mind. A major requirement, intended to overcome a drawback of the Hispano-Suiza system, was a self-feeding gun mechanism which did not require external forces to actuate the belt. In order to pull its own belt, this gun was constructed with a reciprocating breechblock which would have as early opening and as much available

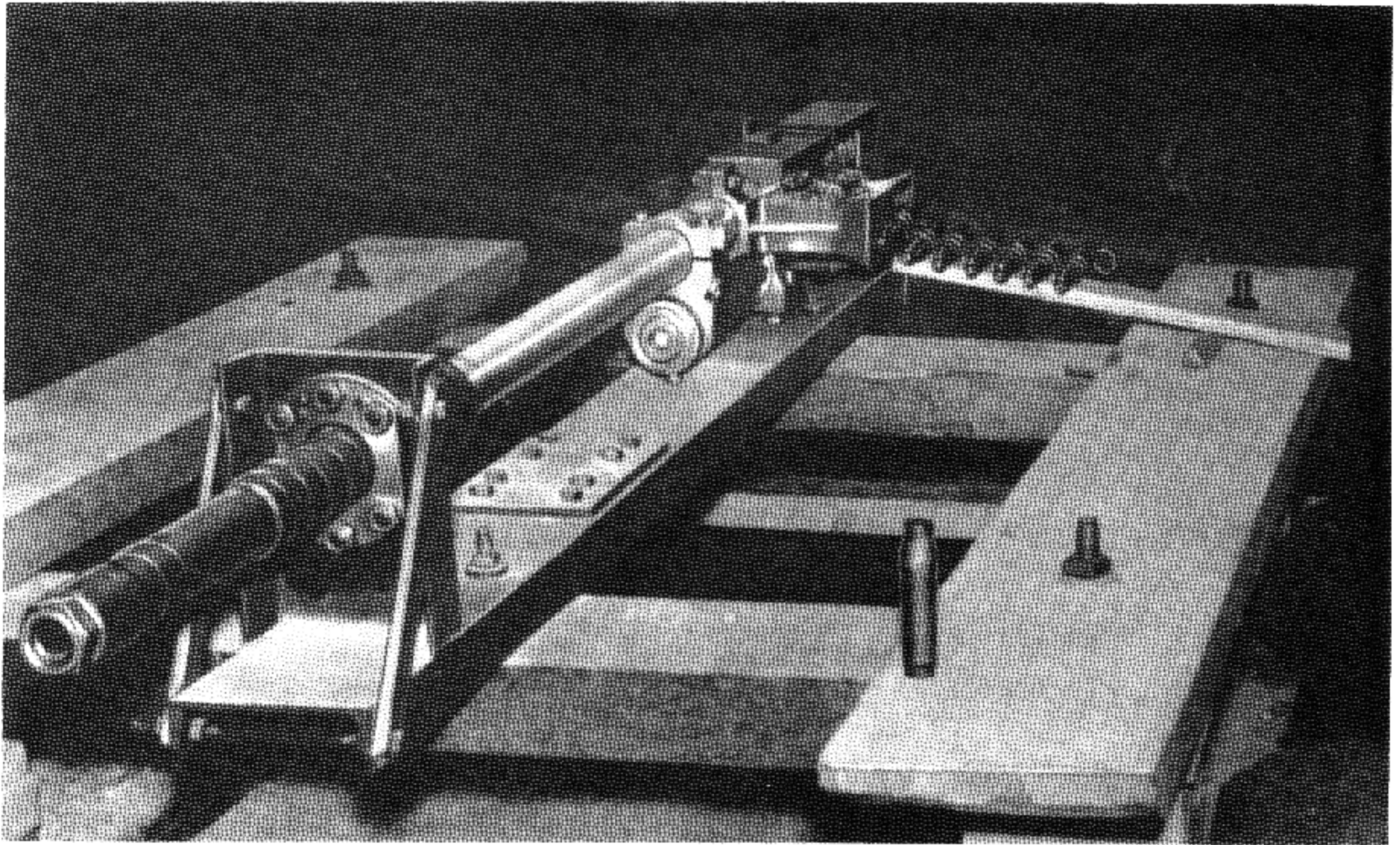


Figure 10-3. The 20-mm Johnson Automatic Cannon mounted on a test stand firing Oerlikon ammunition.

power to do all the work as possible. Hence the gas-timed, self-unlocked, retarded blowback plus gas actuation system. In other words, there were two forces available to do the total work required of this gun, the gas piston force and the residual pressure force. This gun, especially the 3rd model, took some of its feed features from the Browning machine gun.

During the summer and fall of 1942, the service requirements for cyclic rate were not especially high. As month after month passed, requirements grew for higher cyclic rates. These combined with the

requirement for a self-feeding gun mechanism put quite a strain upon Johnson's ingenuity, especially with what proved to be obsolescent requirements for accessories. There was no question about the desirability of a removable barrel nor fundamentally any question of the requirement for right- and left-hand feed. As later events proved, Johnson's prophecy, that the original arrangement of his gun would permit right- and left-hand feed by changing the mounting arrangements, proved correct.

Another requirement was ultimately for bottom ejection of the empty cases. Later aircraft devel-

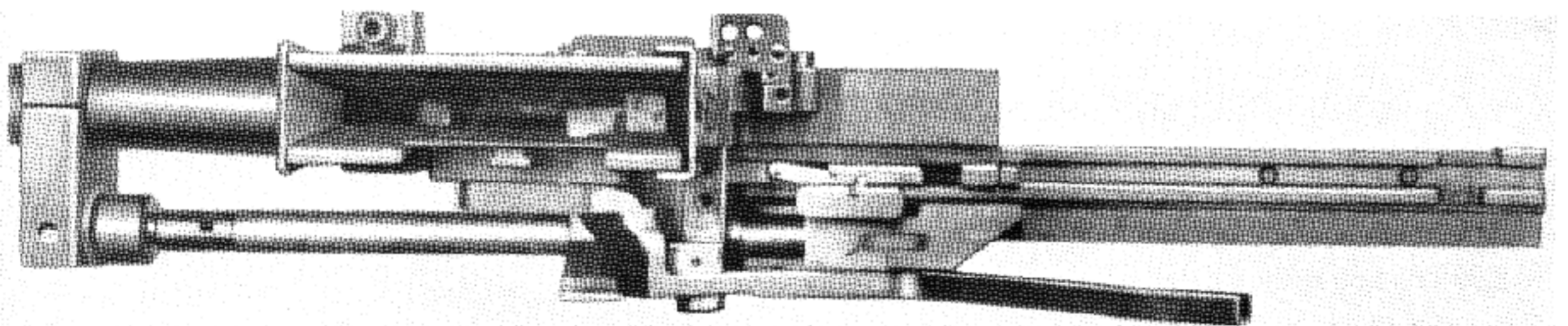


Figure 10-4. Mechanism of the 20-mm Johnson gun in its developmental stage. Left side view.

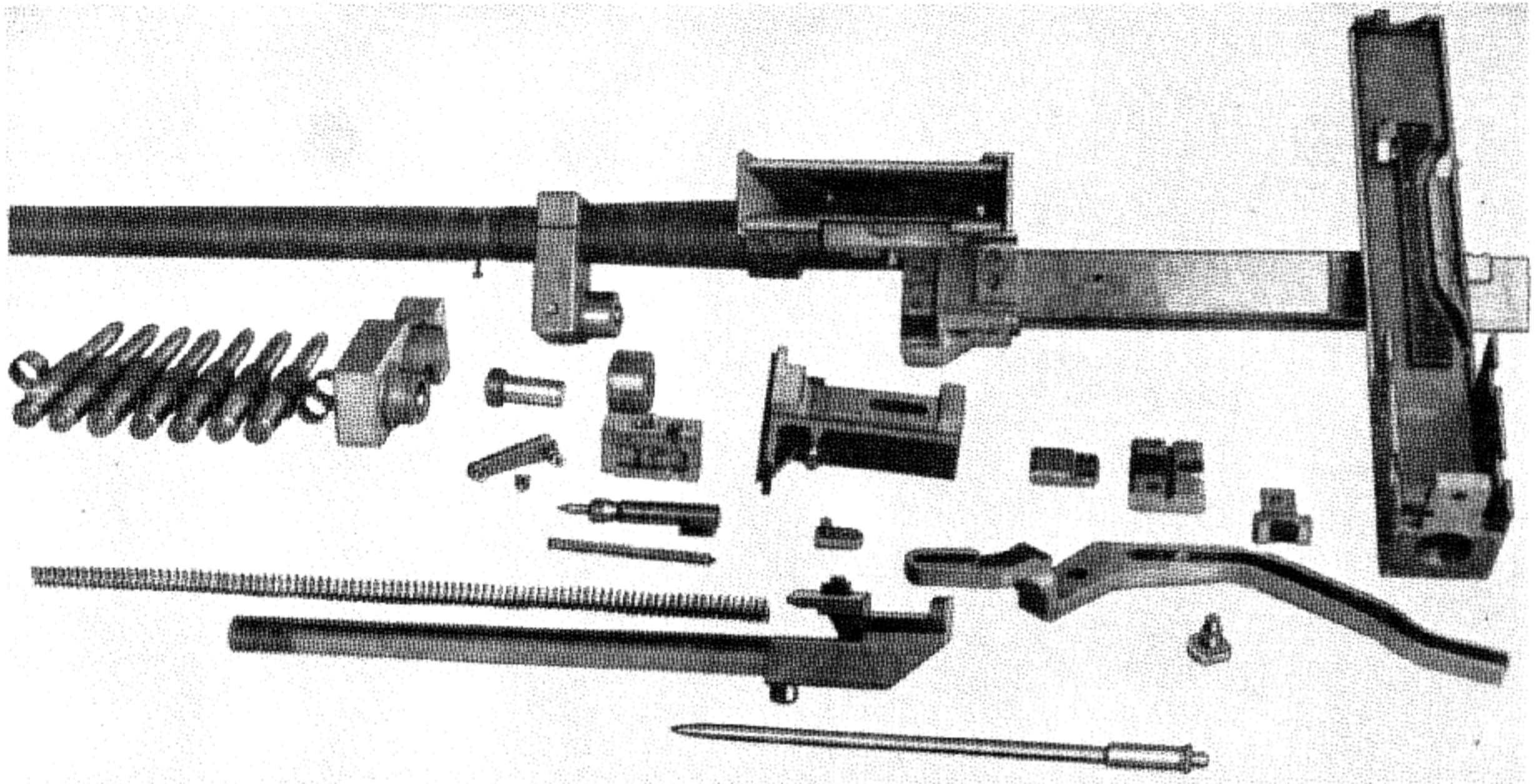


Figure 10-5. An early version of the 20-mm Johnson gun, disassembled.

opments indicated that this requirement was not as real as it was supposed to be when imposed.

Johnson has always advocated development of a basic gun mechanism along "blacksmith" lines without regard to details and accessories. This philosophy is based upon the proposition that if the basic blacksmith gun doesn't work very well, no useful purpose would be served to put all the gadgets on it. If the basic gun, on the other hand, does prove to be sound, it is always possible to modify it in such a way as to keep its basic virtues while at the same time arranging for accessories such as charging devices, right- and left-hand feed, and firing devices. It cannot be questioned that much progress can and has been made by this method with a relatively low outlay of funds. There are some interesting similarities between this Johnson

20-mm gun system and that of the Russian VYa aircraft gun.

A designation indicating experimental models was assigned to the Johnson guns developed in this program. This designation was EX 2; four models were developed under this designation, which may be identified by the following descriptive notes.

*First Model.* Originally made for Oerlikon ammunition; later for Hispano-Suiza ammunition. Gun is now at Winchester Repeating Arms Co.

*Second and Third Model.* Designed as belt-fed automatic, gas-operated weapon cooled by air. Second model replaced by third model before the former was built.

*Fourth Model.* This model was commenced during the summer of 1945. It had progressed to the drawing board stage by V-J Day, when work on it was terminated.

## SECTION 2. DEVELOPMENT OF THE EX 2, FIRST MODEL

### Description

This 20-mm belt-fed machine cannon was designed for mounting in the wing, fuselage, or gun turret of standard service aircraft. The cyclic rate is estimated from 600 to 900 rounds per minute.

Belts were of the disintegrating metallic link closed-loop type, fed in from the right- or left-hand side of the cannon by optional assembly of the parts.

The recoiling portion of the cannon consists of the tube, gas cylinder, receiver, breechblock, piston, feed tray, belt lever, and buffer assemblies.



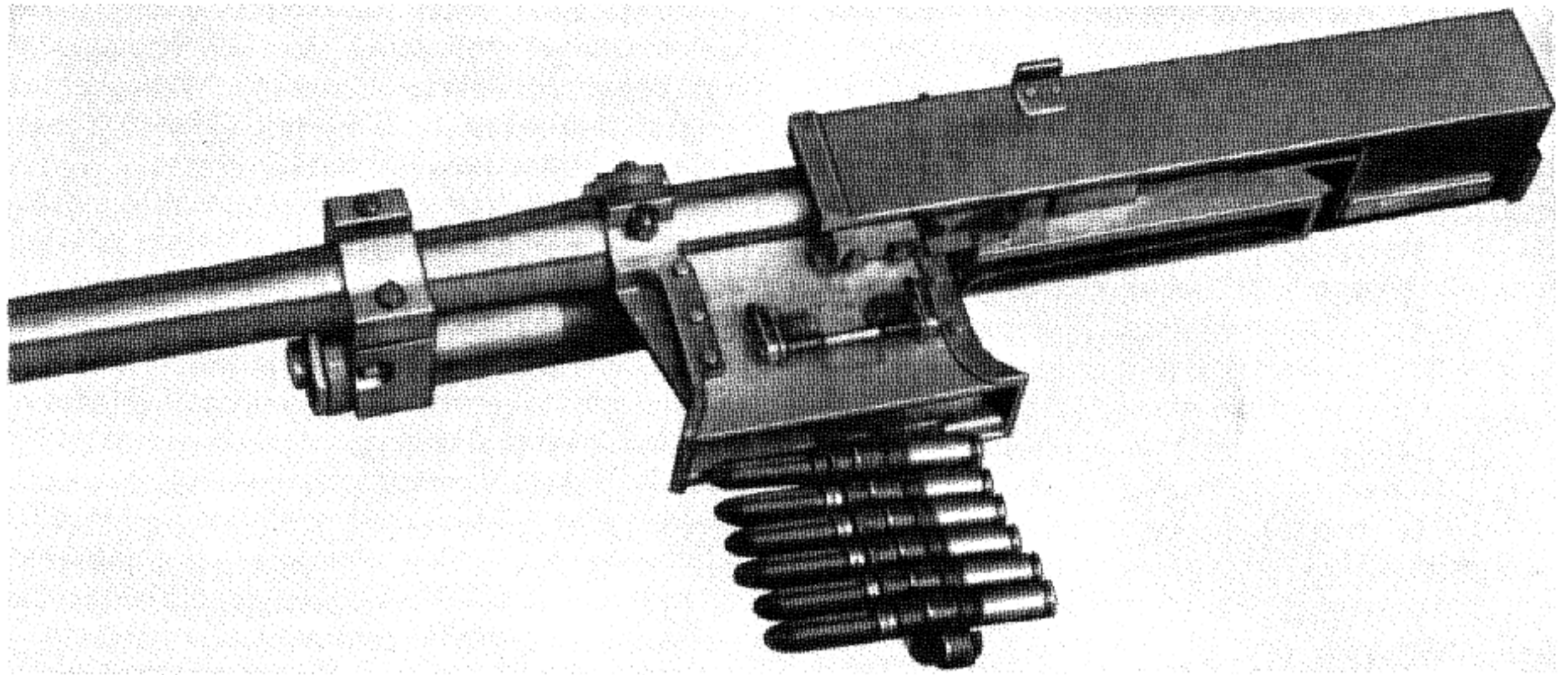


Figure 10-6. Later version of the Johnson gun EX 2. Left view from above.

The tube is similar to the 20-mm M1 and M2, which are based on Hispano-Suiza principles. In the trial model, the front of the barrel is supported in the standard-type dash pot. The tube is engaged to the receiver by interrupted threads, locking at 60 degrees, and is locked into position by a clamp. It may be removed readily. The gas port is located about 18.5 inches from the breech. The gas cylinder and piston assembly are normally attached to each barrel and are removed with it. The operating shaft is not a part of nor is it connected with the gas cylinder and piston assembly of the barrel. The rear end of the piston is in contact with the forward end of the operating shaft at the time of firing. The total stroke of the piston is approximately 1.5 inches. This stroke carries the action through the unlocking and primary extraction stage.

The gas cylinder assembly is locked to the barrel in the following manner: the cylinder is set into the annular groove on the barrel and clamped by two bolts. The gas cylinder assembly consists of the one-piece cylinder bracket assembly, bored to receive the piston and threaded on the outer rear side for the retaining cap. The piston stem protrudes through the cap, a plate on the stem contacting the forward end of the operating shaft. This plate has two return springs attached inside tubes, operating against screws bolted to the plate. The forward portion of the receiver accepts the barrel and serves

to guide the piston shaft. The receiver and barrel provide support for the belt tray and feed lever. The receiver, consisting of two side rails and a top housing, holds the breechblock, which runs in the two longitudinal slots or tracks in the receiver rails.

The breechblock has in its front section the breech slide, which reciprocates laterally during the breechblock travel. The breech slide carries the rounds from the moment of extraction from the belt until they are ejected after firing. The breech slide is actuated by the breech slide arm. The breech slide arm stud runs in a track in the inside of the breech housing, or cover.

The breechblock retains the firing pin assembly, the breech lock, the automatic sear and the trigger sear. The breech lock is a rectangular wedge-shaped block with an angular lock abutment, engaging a corresponding angular abutment in the receiver assembly.

The other end of the lock, which is rounded on its bearing, engages a corresponding recess in the bottom of the breechblock. The lock operates through a slight arc on this axis. The rear end or locking face of the lock is in the downward position when engaged, and moves up upon unlocking to ride through the channels in the receiver rails. The position and locking action of the breech lock are regulated by the operating shaft locking platform.

The breech slide, which is engaged to the breech-block assembly through a lateral dovetailed slot in the front face of the breechblock, aligns the striker hole through which the striker passes when the breech slide is in position for firing and the piece is locked, and also provides extracting means either on the right- or left-hand side of the cannon as the gun may be assembled for feeding. Spring extractors of the conventional type are mounted on the top and bottom of the breech slide, and on the outer end, engaging the rim of the round at three points.

On the inner edge of the breech slide is provided a cam-actuated plunger which projects from the face of the breech slide at an angle of  $45^\circ$  inward against the rim of the round at that point. This plunger serves in part as an extractor and in part as a positioning plunger. It is cammed out of the way when the breech slide moves across the block at the moment of breech loading. The plunger also prevents the round which is being fed from jumping across the breech slide out of position when the breech slide moves across during the first part of the closing stroke of the breechblock at which time the round is transferred from the side of the receiver to the centerline or chamber path.

No detent is provided on the opposite side of the slide to control the empty shells. Thus, the empty shell is withdrawn from the chamber simultaneously with the extraction of the fed round from the belt; and as the breech slide moves across on the commencement of the closing stroke to introduce the fed round to the chamber, this lateral motion is sufficient to loosen the empty shell from the breech slide in such manner as to cause the empty shell to be ejected horizontally at an angle of  $45^\circ$  toward the front. This presupposes an empty shell chute to deflect the round out through the wing, or into a receptacle in the case of turret-mounted guns.

The operating shaft assembly consists of the operating shaft, the feed lever cam stud lock and stud, and the locking platform which is engaged in the receiver rail channels. The mainspring is carried inside the piston shaft and extends rearward around the mainspring guide shaft which is assembled into the rear of the receiver assembly. This shaft serves also to position the buffer assembly.

The operating shaft locking platform has a section with angular slope for locking and releasing the breech lock. Actuated by the piston stroke, the

operating shaft reciprocates approximately 10.5 inches relative to the breech lock. The locking platform causes the striker to be cocked during the rearward movement of the platform. This movement is limited by the recess in the breechblock. As the platform moves rearward and compresses the striker spring, it moves away from the breech lock and permits the lock to slide out of engagement with the receiver locking abutment.

The feed tray, fastened on the left or right side of the cannon opposite the chamber of the barrel, has a bell-mouthed opening to introduce the metallic link closed-loop disintegrating belt. The laterally reciprocating belt lock carries the belt fingers which pull the belt across the tray during the closing stroke of the breechblock. The tray carries the belt latches which hold the belt in position, the feed lever moving the belt lock across preparatory to picking up the next round while the breechblock is on the opening stroke.

The bolt lock is actuated by the feed lever, the curved lever with cam path operated by the operating shaft stud. The feed lever is located underneath the cannon. One end of the feed lever is attached to the feed block through a driving slot. The lever turns on a fixed stud in the bottom of the receiver, and the long end is actuated by the operating shaft stud through the full stroke of the shaft in operation.

The buffer assembly consists of the buffer plate, spring tube cap, plunger, buffer spring, and cover plate. The buffer spring is similar to the Hispano-Suiza but has greater tension. This is assembled into vertical slots in the rear of the receiver and is engaged by the mainspring guide shaft.

The trigger is arranged for release by means of a standard solenoid. The trigger lever is in the receiver.

The belt is similar in design to the caliber .50 Browning type for aircraft. Each link has two loops on one side, spaced apart, and one central loop on the other side. The rounds join the links, acting as link pins. Extraction of each round disintegrates the link in which it was secured from the belt to which it was joined.

### Log of Development in 1942

On 9 August 1942 Johnson sketched a basic system for an aircraft cannon in which the barrel

moved forward under gas-cylinder pressure. Closed-loop links were used. It is significant that only two days had elapsed since Johnson's first conference with the Bureau of Ordnance with regard to this design.

In August, Johnson developed a tentative design, and a crude caliber .30 model was fired to try the principle.

Early in September Johnson became generally dissatisfied with this "blow-forward" design and changed to the design since known as "Project No. 10," a breech-ported, gas-operated weapon having certain unique unlocking features. In this gun, the belt is moved during the initial 1-inch travel of the piston prior to unlocking.

The design was initiated on 10-11 September 1942, and a preliminary drawing was completed by 14 September. A brief description was prepared at this time.

On 8 October, a contract between the NDRC and Johnson Automatics, Inc., became effective. All previous development and engineering expense was borne by Johnson Automatics, Inc. The NDRC contract resulted from an understanding with the Navy Department that the NDRC would procure for the Navy the design and development of an aircraft cannon, the Ordnance Department, United States Army, to be advised on all progress.

Because of the pressure of time, Johnson chose to make two sets of parts, one set to be finished first, leaving the other set available for minor alterations of finished dimensions.

On 22 December, the parts were tentatively weighed together with the 44-pound Hispano-Suiza barrel. The approximate complete weight was found to be 120 pounds. It was expected that excess weight would be eliminated from some parts, aside from the barrel. It was anticipated the final weight should be closer to 110 pounds with standard barrel.

*Summary.* The log of the Johnson aircraft belt-fed machine cannon indicates that the weapon was conceived within 1 month, reaching basic form 5 weeks after the original Bureau of Ordnance conference of 7 August 1942.

The first cannon model, therefore, was conceived, designed, developed, and built, substantially ready for assembly, within 5 months, or within 3 months after the contract was entered upon.

## Log of Development in 1943

The feed tray assembly was put together at the end of December 1942. It was found correct as far as ascertainable.

The breechblock was assembled and found generally correct except that the firing sear required slight modification to insure correct function. A study of the redesign of this sear was initiated.

The ignition was tested by placing primed shells in the T-slot of the breech slide. Proving that support of the shell in the barrel chamber is not requisite to obtain ignition, it was found that ignition and primer indent were excellent using the lightest of several experimental striker springs.

The receiver rails were welded on. However, the rails went out of shape. An attempt was made to straighten them. The other assembly was put together with bolts. It was then found that due to a minor error in the drawings, one rail did not meet the dimension sought. Over the weekend 9-10 January 1943, Johnson Automatics Manufacturing Co. made a new rail. This was assembled and sent for heat treating on 11 January. A new pair of rails were started and it was planned to redesign the other receiver so as to use bolts instead of welding to hold the rails.

Some 400 belt links were sent for heat treatment after inspection.

The problem of headspacing was studied on 7-8 January. No difficulty was anticipated after consulting the Bureau of Ordnance. Actual adjustment was delayed pending completion of correct receiver assembly.

During this period, the chief delay encountered was centered around the receiver due to welding and rail difficulties. The date of the final assembly was thus postponed by approximately a week.

*Period 12-17 January 1943.* The receiver rails were reassembled with one new rail. This assembly was checked, heat treated, and rechecked. The breechblock assembly appeared to function manually as required.

The receiver assembly was then fitted to the barrel, the headspace adjusted, and the gas-cylinder components assembled.

The feed tray was attached, the breech-housing group attached, and single rounds appeared to go through the action manually without difficulty.

There remained final adjustment and heat treatment of the breech-housing cams. The cannon was substantially put together by 17 January.

The cannon was assembled for preliminary study of basic operation and mounted in the cradle.

Five dummy rounds were loaded into the belt links and inserted with the feed tray. These rounds were run through the action. Apart from a slight stiffness in the working parts in manual operation, the only difficulty noted was due to lack of sufficient overtravel of the feed lever and feed finger block, actuated by the piston shaft, to permit full and satisfactory engagement of the rounds by the belt fingers, especially the rear finger.

It was decided to make a correction of this condition. Otherwise the action appeared normal. The empty rounds ejected as did the empty links.

**FIRST ROUND.** One preliminary round was then discharged to determine the action of the lock and piston. As a result of this trial round the following points were noted:

1. The locking platform must be more adequately supported. The design is erroneous in this respect.
2. The platform has virtually no appreciable support directly beneath the lock.
3. The 45° angle of the lock causes nearly 50 percent of the thrust of the explosion to be directed downward upon the platform at the extreme end of an unsupported point.
4. About one-half of the platform ahead of the lock contact cross bar takes the thrust. It is almost analogous to a springboard, with the downward thrust on the free end.
5. This condition causes fracture of the platform support slot in the breechblock at the point of the full forward locked position.
6. This fracture occurred at the instant of discharge. The piston had not moved rearward whatsoever at the time of the fracture.
7. It was observed that the empty case ruptured about one inch from the extracting groove, the severed rear section appearing bell-mouthed. This indicates great pressure, in turn showing that the rupture was caused entirely by platform slot fracture, not by gas piston action.
8. The above action resulted in sending the breechblock rearward with great force. The piston shaft was buckled, due chiefly to the giving way of the platform. The breech housing was bent slightly.

The breech-lock guide shafts were broken, and the locking lug surfaces were slightly scored due to premature opening.

9. Aside from damage to the breechblock-platform grooves, the lock-guide shafts, the piston-shaft extension, and bending of breech cover, no other damage was noted.

10. The ignition, as shown by the indent in the primer, was excellent.

After study of the parts in question, ample space was found to extend the platform bearing, so as to provide better support to relieve the downward thrust of the lock, and it appeared desirable to steepen the lock angle from 45° to 65°.

Ultimate production changes in the affected parts were studied. Ample space for increased metal in the platform support lugs, breechblock platform grooves, and lock-guide shafts appeared available.

In particular, it was noted that there were excellent opportunities for possible locking platform support using parallel receiver guide channels instead of the support of the breechblock channels.

*19 January 1943.* Conference on the next operation resulted in the following plan:

1. To make new receiver rails with double channels, the upper guiding the breechblock, the lower guiding and supporting a new locking platform.
2. To make new locking platform with long, thick lugs supported in new rails.
3. To make new breech lock with angle of 55°.
4. To straighten breech housing.
5. To reassemble piston shaft.
6. To clean up breechblock and clear path for platform.

This program was primarily intended to permit further firing and testing within 10 days, or by about 1 February.

In addition, an improvement in the belt fingers was studied. Examination disclosed the possibility of putting solid cams on the tray which would positively cam the fingers into the rounds at the end of the lateral feeding stroke of the feed lever.

In other respects the model appeared satisfactory so far as could be determined at this time.

The feed lever was found not quite correct to specification as stated in the manufacturing drawing. Detent plunger was found too stiff for proper functioning. As the spring was excessive, it was decided to reduce it.

Binding of breechblock was noted in the cradle. Supports were pinching rails. This indicated the support should be moved to the rear of the receiver. Also that a yoke or support might be desirable to support the rails.

*20-25 January 1943.* Drawings of new receiver rails, a new locking platform, and new lock were prepared by Briggs Young. Steel was available for all new parts except the locking platform. Johnson Automatics commenced making the new rails on 22 January. These were substantially finished on 25 January. The new, reinforced, heavier breech lock was ready for heat treatment by 25 January. Steel for the locking platform was not obtained till 25 January. The receiver housing was straightened and the breechblock cleaned.

Provision was made to give a slight overtravel in camming the feed arm, so as to insure full engagement of the round to be fed.

Under the proposed modified design, disassembly was improved. On removing the housing and withdrawing the breechblock and piston shaft assembly, the locking platform dropped instantly out of engagement with the block, in turn allowing the breech lock to be removed.

*26-30 January 1943.* The new parts were completed, sent for hardening on 28 January, and were returned on 29 January.

On 29 January, Dr. Allen of the NDRC visited Johnson Automatics informally and inspected the model.

For manual demonstration, the cannon was assembled with original parts. Several belts of 12 rounds each were manually fed.

It was noted, as already known, that more overtravel of the feed lever was necessary to insure full engagement of the round before the feeding stroke. This had already been corrected in the new assembly. Provided the feed fingers fully engage the round before commencing the stroke, the feed seemed correct. However, the detent which positioned the round in the breech slide appeared inadequate, as some rounds moved over it causing incorrect positioning.

It was decided to have a new plunger made with more abrupt shoulder. Also a study was authorized to develop a new type detent means, one cammed out of the T-slot pathway upon the closure of the breechblock. It was believed that such a

means could readily be developed to insure positive positioning of the round at this point.

It was noted that the empty link was positively ejected, that the empty round was thrown forward to the right at 45° to the barrel.

Where the round was not fully engaged by the feed fingers, it did not fully enter the breech slide, and was, therefore, not engaged by the retainer plunger in the slide. Thus, if it could be fed, it failed to reach correct positioning when the slide moved over. However, it was believed that overtravel would clearly overcome this difficulty.

Allowance had to be made for compound slack in the feed parts (shaft, cams, feed lever, feed finger block, fingers, etc.). This required some adjustment and study with the new assembly.

*6 February 1943.* All new parts were finished, heat treated, reassembled after polishing.

There was a new plunger in the breech slide, and a new feed lever with more overtravel.

In re-assembling, a tendency of the parts to pinch with gun set in cradle was noted. Receiver shafts were springy and seemed to need extra yokes to prevent pinching breechblock assembly.

The detent plunger spring was too strong and therefore reduced.

One round was fired. A misfire resulted due to friction in rails; and, perhaps, retarding of auto sear.

Feed by hand was found to be normal. Trip was OK.

**SECOND ROUND.** Platform held. Lock cracked on cross bar, indicating necessity for direct support under the lugs. Downward thrust appeared very great even with 55° lugs. Everything else was found normal.

Platform should be under the lugs on each side to give direct support during critical pressure interval.

*7-15 February 1943.* During this period the locking lugs were changed to a 70° angle. A sliding "lock support" was developed and made to operate with the locking platform. The locking platform guide became a third piece which engaged the piston shaft.

The "lock support" is under the locking lugs at the moment of high pressure.

The trigger sear was installed with trigger.

The mounting was corrected and the assembly was again fired on 15 February about 4 p. m.

**THIRD ROUND.** Extracted OK. All correct except interference of belt fingers with piston shaft due to disengage spring on latches. Breech was found open. The lock and cartridge case was perfect. The ignition was excellent. There was a very slight bite of T-slot in brass rim.

**FOURTH ROUND.** Extracted and ejected. Breech stayed open due to belt fingers interference because of spring slipping. The case was excellent. Extraction was good. The trigger spring broke.

Feed tested by hand and found normal except for shell detent plunger which permits overtravel of round being fed. This, as was seen earlier, must be replaced with a positive positioning guide lug to be canned out of the T-slot only upon closure of the breech.

*16 February 1943.* The trigger spring was corrected.

**FIFTH ROUND.** The feed lever stud bit into the operating shaft cam face, breaking off a piece of the cam and bruising the stud. The breech was not opened.

**SIXTH ROUND.** As a study of a better feed lever was started some weeks ago, it was decided to remove the lever temporarily, and fire the round for function. This was normal, with fast breech closure indicating very high speed action. Breech slide cam path plate loosened. This was welded up for further single-round tests.

The gun was then prepared for another round.

**SEVENTH ROUND.** The gun was fired. It extracted and ejected. A very slight extraction print was noted on the rim, similar to previous rounds. The action indicated considerable power.

However, the buffer, through error, had not been adjusted correctly and the breechblock stopped on the piston, in turn putting a severe thrust on the temporary locking platform guide at the end of the stroke. As a result, this temporary piece broke.

A new guide was prepared on paper for tool-room fabrication.

It was decided to restudy the camming and lever condition of the feed lever and piston shaft cam.

*Summary to 16 February 1943.* There is reason to believe that the timing, lock, and basic actuation of this cannon is sound and generally in accordance with expectations. The action appears smooth, fast,

and powerful. Judging from the empty shells, the timing is not too early even without any load in the belt. The condition of the broken feed lever cam stud showed considerable power. Through oversight, the buffer was not fully operative on the last two rounds, contributing to the minor breakages noted.

The successful function of the basic actuating mechanism was thought encouraging.

*16-26 February 1943.* A new piece for the lock platform assembly was prepared. For temporary use, a slightly stronger detent spring was prepared for the breech slide.

An improved bearing on the feed lever and corrected cam on the piston shaft was prepared.

A modified lever with stud on the piston locking platform guide and cam slot in a solid arm on the feed lever was designed.

A new-type detent with cam to prevent positively any positioning difficulty with the rounds in the breech slide was designed.

It was found that the initial piston stroke could be increased to two inches if desired by taking advantage of the slack in the lock support. The possibility of developing a double buffer to contact both the breechblock and the piston platform was noted.

*26 February 1943.* The gun was again tried on hand operation, and the feed was found excellent. The belt was pulled hard and rapidly without difficulty. It was noted that the rounds should be loaded uniformly in the links.

One trial round was fired. This extracted perfectly. The breechblock remained open. This was due to breaking of the cocking lug on the firing pin. Lack of a fillet may have contributed to this. The retaining plate was found to have a marked indication of very great momentum affecting the firing pin.

A new pin was selected from spare parts. A fillet was welded in.

*27 February 1943.* Visit of Dr. L. H. Adams, Chairman, Division One, NDRC.

**EIGHTH ROUND.** One round was fired singly. It was normal. The vertical guide shaft on the lock (left side) was broken.

**NINTH ROUND.** Fired with dummy in tray. This round failed to feed; otherwise it was normal. The other guide shaft on lock broke. No harm was noted; lock appeared to function without requiring

guides. The feed lever was not throwing over all the way.

**TENTH ROUND.** Fired normally. It failed to feed over dummy due to detent and overswing of feed lever. Dummy was positioned in T-slot.

**ELEVENTH ROUND.** Normal. It ejected excellently as before. The dummy failed, probably due to detent.

Loaded a belt of dummies to put load on action to determine potential operating power of action subjected to weight. Selected 32-pound weight for belt test, using 20° slope on leadin tray. The belt finger spring was adjusted.

It was found that a wider area for bearing of belt fingers on shells was needed. Finger dents in the shells were noted.

**TWELFTH ROUND.** One round was fired. It ejected powerfully. The belt of 13 rounds and 32-pound weight was moved three-fourths of an inch.

Weights were added to give 57 pounds, plus 13 rounds, or a total of 64 pounds.

**THIRTEENTH ROUND.** Round ejected with force pulling 64-pound load.

The rounds were moved one space as shown by markings. The 57-pound weight was moved three-fourths of an inch.

Ejection was powerful. Action looked fast. One link was slightly distorted from taking full thrust of 57 pounds.

**FOURTEENTH ROUND.** Belt of 13 rounds plus 110-pound steel bar, total weight of 117 pounds, was used at a slope of 20°. The round was fired normally. One link slightly opened. The whole belt moved three-fourths of an inch. There was a loss of nine-sixteenths of an inch due to link stretch. The round ejected excellently. The action looked fast.

Loaded one round and one dummy. Lever was removed.

**FIFTEENTH ROUND.** Round was fired and it extracted. The firing pin lug broke, preventing full ejection.

**SUMMARY.** From the tests of 27 February, it appeared that the action of this cannon is extremely powerful. The stretch of one link with heavy weight attached does not necessarily indicate any weakness of the links. Normally, there will be one link per each 0.6-pound weight (one round). Thus the thrust will be distributed.

The breakage of the firing-pin lug also indicates considerable power. The fact that excellent extraction and ejection is obtained with or without any load on the action indicates a flexible, positive mechanism.

*1 March 1943.* A close examination of the mechanism disclosed that the feed difficulty experienced was due to the longitudinal displacement of the round being fed into the T-slot, due to shock of firing. This displacement caused the rim of the shell to be forced into the narrow section of the T-slot, breaking down the upper and lower edges of the rim as it was forced into the narrow section. In turn, this caused the feed fingers to dent the body of the shell due to resistance of the rim in the slot.

In the tests of 27 February, several dummy rounds were positioned in the T-slot before firing. These failed to feed across, due to disengagement from the positioning latch in the breech slide.

Accordingly, it was decided to improve the latch temporarily, while at the same time designing an improved, cam-actuated latch and considering a shell-positioning lever. Temporarily an undercut on the hook and stronger spring were prepared; this later proved satisfactory.

Steps were taken to prevent the forward movement shock of recoil of the round to be fed so as to insure its entrance into the T-slot. An improved design of this point providing more positive positioning was also undertaken. Relief of the firing-pin lug was also studied.

For the next tests, the above temporary improvements were initiated.

The possibility of obtaining high-speed moving pictures of the action was considered, and Dr. Adams authorized employment of Prof. Harold Edgerton in this matter.

Still pictures taken and developed by C. T. Haven, of Johnson Automatics, Inc., were prepared, and one set for approval was mailed to Dr. Adams on 1 March. Additional sets for the Navy were requested.

*6 March 1943.* Assembled with new feed lever, new breech slide detent with cam, undercut latch hook on slide, double buffer to include platform contact. Used muzzle brake.

**SIXTEENTH ROUND.** Assembled belt with dummies, placed live round in chamber with dummy in line to feed. Took high-speed movies of this round.

The round fired correctly and fed and chambered the dummy. The next link was stretched, however.

The feed lever was not moving over quite enough. Some slack may have developed. Some rounds were fed by hand. Action was stiff. Cam on detent caused friction. Feed lever gave way due to weld crack on temporary joint.

This was corrected and gun re-assembled. The action was quite stiff due to some bind on cover and cam of detent.

Two live rounds were loaded with belt of 10 rounds.

SEVENTEENTH ROUND. Round fired correctly, ejected powerfully and reloaded.

Temporary trigger lever obstructed sear, preventing firing of second round. This was a minor annoyance, as the gun would otherwise unquestionably have fired the burst of two rounds.

Again a link was stretched. This indicated that the open joint of the link was inadequate. It was decided to weld a piece on the open link joint for trial the following week.

Firing-pin lug was again broken.

Very slight burr found on one corner of lock probably due to rocking movement during cycle. Feed finger support was broken.

A new firing pin was installed.

The gas chamber was opened one-fourth of an inch to give longer gas chamber; no change in port.

Possibility of buffer spring piston considered.

EIGHTEENTH ROUND. Two rounds were loaded. The link was inadvertently forgotten on the second. Feed fingers ripped the neck.

The cannon fired and ejected excellently but pulled case of bullet, loading empty round with primer into chamber, spilling powder.

NINETEENTH ROUND. Two rounds were loaded. Everything was normal, but the trigger lever got in the way, preventing second round from firing. This fed round showed loose bullet. The feed fingers needed alteration.

TWENTIETH ROUND. Platform broke, permitting shaft to go back without breechblock. This caused failure to unlock. Temporary platform appeared inadequate.

Broke buffer plate on lower buffer.

SUMMARY. The tests of 6 March indicated the following:

1. The new breech slide detent with cam was an improvement, but the cam caused some stiffness of operation which could be overcome readily.

2. The undercut hook of the breech slide latch prevented the fed round jumping off when the slide moved over.

3. The new feed lever was an effective improvement. The gun was basically capable of feeding positively.

4. The open expander-type link joint needed to be reinforced to prevent spreading.

5. The gas port, and probably the cylinder, was unnecessarily large. A 1-inch piston and smaller gas port might prove quite adequate.

6. The thrust on the firing pin lug was too harsh. The lug needed to be redesigned.

7. The belt fingers no longer bruised the case, but the front finger loosened the bullet in the case.

#### General Data: 20-mm Johnson Aircraft Cannon, First Model

Gun length: 97 inches.  
 Gun weight: 115 pounds, without feeder.  
 Rate of fire: 750-800 rounds/minute.  
 Muzzle velocity: 2,750 feet/second.  
 System of operation: Gas unlocking, blowback assist.  
 System of locking: Sliding wedge.  
 System of feeding: Gas actuated.  
 Method of headspace: Governed by component tolerances.  
 Location of feed opening: right or left hand.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Hydraulic, manual or air.  
 Method of cooling: Air.

Barrel length: 67.52 inches.  
 Barrel weight: 47.8 pounds.  
 Rate control: None.  
 Barrel removal: Cannot be removed in field.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 ± .002 inch.  
 Groove width: 0.205 ± .010 inch.  
 Pitch: 7 degrees (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: Hispano-Suiza type, M90 series.



It might be necessary to shift the thrust of the fingers from the bullet to the link shoulder and to widen the rear finger bearing.

8. The locking guide platform required reinforcement to absorb the thrust of the piston.

9. Securing the rounds against displacement due to recoil tended to produce a basically sound feed, especially correct engagement of the rim in the T-slot.

10. The naturally sudden movement of the parts indicated the possibility of using a buffer spring between the piston and piston shaft, possibly with an airtight tube to soften the blow of gas on parts, or a buffer head on the end of the cylinder.

11. The fed round entered the barrel chamber readily, judged on the day's feeding of four rounds out of four tries.

8 March 1943. Proceeded with new guide platform of improved reinforced type.

The design of new belt fingers was commenced, as was the reinforced firing-pin-lug design.

Reinforcement of links was studied and work begun.

Firing on 6 April 1943: 671 through 674 Rounds. The gun was assembled with new parts including

new type piston, 1 inch in diameter; gas porthole moved forward from old position approximately 4 inches; new parts assembled in breech mechanism, including new sear assembly, breech slide, anti-rebound components, fixed buffer in cradle, modified locking platform, new breechblock. Fired four single rounds, which indicated gas porthole too small, insufficient power. Opened gas porthole.

Firing on 7 April 1943: 675 through 679 Rounds. Fired 5 rounds. Empty cases ejected, but not sufficient power or speed for desired results. Therefore, opened gas porthole to maximum of approximately 0.200 inch.

Firing on 8 April 1943: 680 through 704 Rounds. Visit by NDRC, Navy, and Oldsmobile representatives including Dr. L. H. Adams, Mr. Rose, Mr. Cummings, Mr. Ten Brook, of NDRC; Lt. Mitchell of the Navy; Mr. Youngran, Mr. Watters, Mr. Metzell, of Oldsmobile. Although the gun was not actually ready for demonstration due to insufficient time for adjustment of new assembly, approximately 25 rounds were fired covering bursts of 3 and 4 rounds.

Initially, two rounds failed to feed because of improper pickup adjustment. With this corrected,

General Data: 20-mm Johnson Aircraft Cannon, Second Model (Estimated)

<p>Gun length, less muzzle brake: 90 inches.                  Gun weight, empty: 120 pounds.                  Rate of automatic fire: 600-900 rounds/minute.                  Muzzle velocity: 2,800+feet/second.                  System of operation: Gas unlocking, blowback assist.                  System of locking: Sliding wedge.                  System of feeding: Gas actuated.                  Direction of feeding: May be assembled for either right- or left-hand feed.                  Method of headspace: Factory established.                  Location of feed opening: Bottom right or left side on upper part of receiver.                  Location of ejection opening: Bottom of receiver.                  Method of charging: Manual and hydraulic.                  Method of cooling: Air.                  Gun width, maximum, including feed tray: 8 inches.                  Gun height, maximum: 7 inches.                  Type of belt: Standard closed loop disintegrating link (modified from Standard .50 caliber Browning type).                  Position of breechblock when gun is cocked: Closed (same as aircraft Browning, caliber .50).                  This weapon was front seared.</p>	<p>Tube length: 67.52 inches.                  Tube weight: 44 pounds.                  Rate control: None.                  Barrel removal: Detachable type.                  Bore:                  Number of grooves: 9.                  Groove depth: 0.015 inch.                  Groove width: 0.205 inch.                  Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).                  Direction of twist: Right hand.                  Form of twist: Constant.                  Maximum powder pressure: 50,000 p. s. i.                  Ammunition adapted to 20-mm Hispano-Suiza type.                  Cartridge: Hispano-Suiza (M90 series).</p>
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the only stoppage noted was misfire due to locking platform tripping sear too early, thus slowing down forward speed of striker. Accordingly, following the visit, adjustments in the automatic sear timing were made.

*Firing on 10 April 1943: 705 through 728 Rounds; 729 through 788 Rounds.* Firing was resumed as follows: A belt of 24 rounds was loaded and a burst of 6 rounds fired, the seventh misfiring, but with a very deep indent. After the stoppage was cleared, all the remainder of the belt gave a full burst of 17 rounds during which all phases of the function including primer indents appeared excellent. Due to the position of the gas port, the cyclic rate was slower than previously noted. The cyclic rate was about 350 rounds per minute.

A belt of 60 rounds was then loaded; with the exception of 4 misfires having deep indents, this belt was fired with excellent performance at a uniform rate of 350 rounds per minute. This rate was arrived at by taking the count with a stop watch. Bursts were as follows: 17; 5; 13; 15; 16.

Miscellaneous rounds were then made up covering several five-shot bursts, with misfires occurring

only when using the previously misfired rounds from the above described belt.

It was decided that the misfiring was probably affected by the following:

1. Striker protrusion at 0.060 had best be increased to 0.080.

2. The Oerlikon ammunition had no shoulder sufficient to prevent the round moving forward somewhat in the chamber when struck.

3. Closure of the platform may be sufficiently slow compared to the striker to necessitate further delaying of tripping of the automatic sear.

4. A rebound condition which had been experienced considerably with the Johnson light machine guns M1941 and M1944, caliber .30, was eliminated entirely by use of a rebound of the equivalent locking platform or locking cam. It was thought that it might be desirable, if further misfire was noted to adopt the same device to this 20-mm gun.

It was decided to adjust the timing as above, modify the striker protrusion, relocate the gas port-hole 3 inches rearward, repair the tailpiece of the housing cover, and strengthen the assembly slot of the new two-piece locking platform.

### SECTION 3. DEVELOPMENT OF THE SECOND MODEL

By 1 December 1943 the second model showed considerable promise on paper, and, accordingly a tentative technical manual was issued by the National Defense Research Committee, Division 1, for the Navy's Bureau of Ordnance. The following description and the general data for the second model are quoted from this manual.

#### Functioning of the Second Model

*General.* The second model aircraft belt-fed machine cannon by Johnson Automatics, Inc., is a belt-fed automatic gas-operated type weapon, cooled by air. The primary source of operating power is derived from the impingement of the gases against the gas piston, taken through the gas port located as near as practicable to the breech. The position of the gas port is governed by the pressure curve and timing of extraction, since premature extraction would necessitate lubricated ammunition, or otherwise cause case rupture. The exact final location

is purely theoretical on the earliest prototype weapons.

The secondary source of operating power is derived from the delayed blowback, a force which, for example, is the primary source of operating power in the Hispano-Suiza gun. This blowback force is regulated by the moment of release of the breech lock following the initial opening stroke of the piston assembly.

The breech lock is so arranged, due to the angle of abutment, that it tends to slide out of engagement when pressure is applied to the breechblock. However, the operation shaft locking platform prevents this motion initially. As the platform travels rearward under the direct thrust of the piston stem, the lock becomes free to slide out of engagement. At this time the heavy striker spring is being compressed, thus building up an additional opening thrust on the breech lock. Finally, the platform is arrested against the rear inside shoulder of the

breechblock slot, the striker spring acting as a buffer. This action, added to the blowback pressure, causes the breech lock to complete the unlocking movement.

During the time of the disengagement of the breech lock, primary, or "slow," extraction takes place. This action eliminates a relatively sudden thrust on the empty case when it is loosened in the chamber.

It should be noted that while the locking platform cams the breech lock into the locked position, the breech lock is self-unlocking and is not cammed out of engagement by the piston action. In this respect, the system differs materially from other gas-operated systems.

The piston stroke of 1.5 inches accomplishes the unlocking and cocking operations. When the breechblock is well underway on the opening stroke, the piston is arrested and returned to battery by the two piston return springs. Thus there are no exhaust gases, the piston acting as a self-closing valve, only its stem being in contact externally with the head of the operating shaft. This design also facilitates barrel removal, the piston and cylinder assembly being integral with the barrel and not attached otherwise to the receiver.

The reciprocation of the operating shaft provides belt feeding power, the belt being fed through the energy of the buffer and mainspring during the closing stroke. Also during the last part of the opening and the first part of the closing stroke, the fed round is aligned with the chamber.

The locking platform nose releases the automatic sear as the platform completes engagement of the breech lock.

*Initial Ignition.* When the trigger sear is released, the cannon being loaded and locked, an automatic sear is already released by the closure of the locking platform. Actuated by the heavy striker spring, the striker, which somewhat resembles that of the U. S. M1903 Springfield rifle, moves forward, passing through the breech slide aperture and penetrating the primer up to 0.050 to 0.075 inch.

The primer is thus exploded and ignition takes place.

*Unlocking Phase.* The projectile passes the gas port, which is about 18 inches from the rear of the barrel. At this point the projectile has traveled a distance of 14 inches.

The pressure is approximately 20,000 pounds per square inch.

The piston moves rearward, its stem in contact with the operating shaft. This contact is maintained for 1.5 inches of travel. The initial action of this piston is similar in some respects to that of the U. S. carbine M1. However, the stroke of the carbine is only sufficient to start up the operating slide, not following through to unlocking as in this cannon.

As the pressure of firing forces the breechblock back against the lock abutment, the angle of the breech lock and abutment causes the lock to tend to slide upward out of engagement. However, the locking platform in its channels in the receiver rails prevents the lock from rising. Thus the thrust of the pressure is controlled and distributed partially through the platform.

As the platform, shaft, and piston continue rearward 1.5 inches, the striker is being cocked through the platform cocking lug in contact with the striker

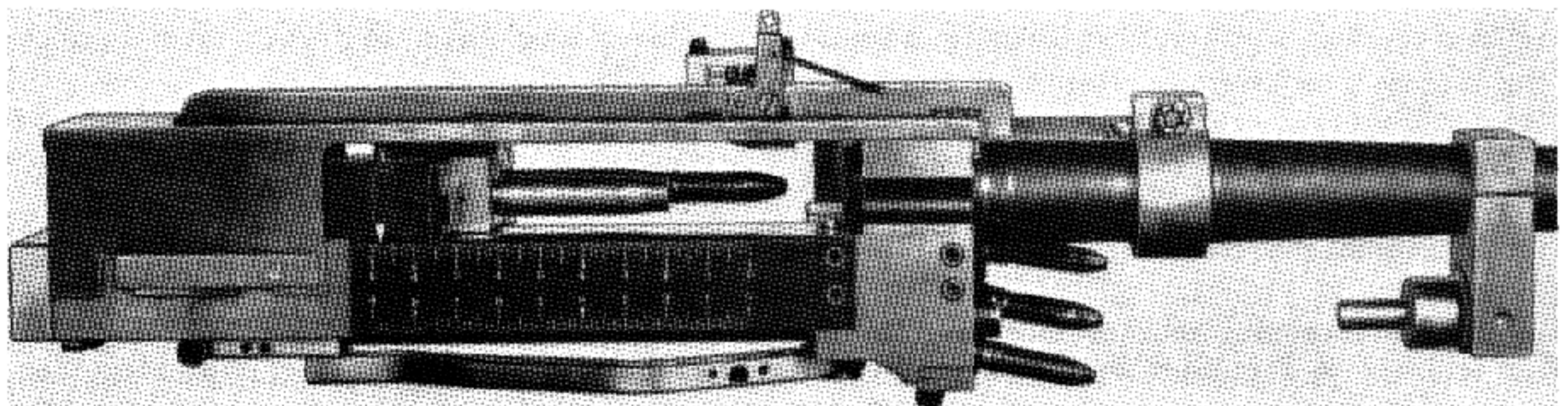


Figure 10-7. Development of the Johnson gun. Bolt recoil measured.

nose. This action builds up an increasing thrust on the breech lock.

As the sloping end of the platform moves rearward past the breech lock, the lock is now free to commence disengagement, which results from blowback pressure and striker spring thrust.

*Primary Extraction.* During the actual unlocking interval, the angle of the lock,  $30^\circ$ , requires a rearward movement of 0.06 inch of the breech lock. This insures a gradual primary, or "slow," extraction.

As the platform reaches the rear of its stroke within the breechblock, a final primary extraction force is achieved, virtually "tapping" the breechblock and empty case rearward and thus insuring efficient extraction.

*Opening Stroke.* The breechblock being disengaged from the locking abutment, the platform is now in the fully rearward position. The striker has passed to the rear of the automatic sear and will rebound slightly so as to take up on the automatic sear, thus holding the striker in the cocked position until the action has closed again.

As the locking platform reaches the rear of its stroke relative to the breechblock, the locking platform positioning the latch is cammed upward through the channels in the receiver rails, causing the locking cam positioning latch to hold the platform in the rear position relative to the breechblock. This prevents any friction in the action during the opening and closing stroke which might otherwise be caused by the pressure of the locking platform through the mainspring coming against the breech lock and forcing the lock downward against the shoulders of the receiver rails. Elimination of this friction is especially appropriate for the closing stroke when the mainspring is forcing the locking platform relatively forward. The locking platform positioning latch maintains this position until the action has returned to the forward position, ready for locking.

The breechblock and operating shaft assembly are carried rearward by the momentum derived from the piston coupled with blowback through the breechblock.

During the opening stroke, the feed lever actuating stud on the bottom of the locking platform causes the feed lever to move laterally, thereby reciprocating the belt feed block across, causing it to

engage, through the belt fingers, the round of ammunition next to be fed. The belt at this time is held in stationary position by the belt latches in the feed tray. Thus, during the opening stroke, the feed lever is prepared to feed the belt across one space of the closing stroke.

The breech slide actuating lever stud passes through the cam channels and cams the breech slide cam lug in the cam path, this lug being actuated by a spring which causes it to snap back as the stud passes it, thereby presenting its shoulder to the breech slide stud during the closing stroke which will cause the breech slide to reciprocate laterally, feeding the round.

During the opening stroke, the round to be fed is extracted from the belt in the feed tray, and, as the round clears the feed tray, the link ejecting fingers press downward and snap the empty link out through the bottom of the feed tray. Also during the opening stroke, the empty case is extracted from the chamber, being held in the solid section of the breech slide T-slot. The fed round is engaged by the belt extractors, of which there are three, together with the cam plunger positioning retainer.

At the end of the opening stroke, the breech slide is partially cammed across. This causes the total movement and speed of feeding across the round to be chambered.

*Action of Buffer.* As the moving parts come to the rear of the stroke, the breechblock is arrested by contact with the buffer plunger, the force of recoil being absorbed in the compression of the heavy buffer spring, quite similar to that of the Hispano-Suiza M1 and M2.

The recoil momentum in the operating shaft and locking platform assembly is generally absorbed by thrust against the compressed striker spring. Thus the moving parts are arrested with the full compression of the mainspring.

Energy of the buffer and mainspring now commence forcing the moving parts forward at high speed.

*Action of Breech Slide, Feeding Round.* The breechblock moves forward, actuated by the mainspring. The cam stud in the breech slide lever contacts the face of the actuating cam lug on the inside of the receiver housing, causing the breech slide to be reciprocated laterally and carrying with it the

round being fed. This movement completes traversing the fed round into line with the axis of the bore. As the breechblock continues moving forward, the nose of the round enters the mouth of the chamber. The thrust which is exerted on the base of the round resulting from this motion is taken up by the grip of the three extractors and the positioning plunger which bears against the inside center of the cartridge rim.

*Action of Breech Slide, Ejecting.* The above motion of the breech slide also carries the empty cartridge case across the outside edge of the receiver housing. There being no detent in the breech slide at that point, the lateral motion of the breech slide tends to throw the empty shell outward and, due to the forward motion of the breechblock at that time, tends also to throw the case forward at an angle of about  $45^\circ$  from the barrel. In the event that the empty cartridge case did not clear the breech slide at this time, it is knocked off positively near the finish of the closing stroke, as the breech slide is cammed across to the opposite side of the receiver. The empty case is knocked off on the edge of the barrel collar.

*Action of Feed Lever, Belt Feeding.* As the moving parts close under the action of the mainspring, the feed lever cam stud on the bottom of the locking platform, directly impelled forward by thrust of the mainspring through the operating shaft, causes the long end of the feed lever to be actuated laterally. This action causes the belt feed block to move across toward the gun, carrying with it the belt and moving the next round to be fed into position into the feed tray for engagement with the extractors of the

breech slide when the action has locked. This movement of the belt is accomplished through a total stroke of approximately 8 inches.

*Closing Stroke.* In addition to the operation of feeding the belt, during the closing stroke the round to be fired is carried forward into the chamber and engaged in the solid T-slot section of the breech slide as it is returned across by the breech slide lever.

As the belt feeds across during this closing stroke, the next round to be fed compresses the belt link ejector springs. The springs thereafter operate to eject the link as described. The round is withdrawn from the feed tray on the next opening stroke.

As the breechblock nears the closed position, the cam shoulder in the receiver housing, being contacted by the stud on the breech slide lever, causes the breech slide to be returned to its original, or closed, position. Since the slide moves across the base of the chambered round, this action brings the lips of the T-slot into engagement with the rim. At the same time, the plunger positioning retainer is cammed inward to clear the round.

As the breech slide feeds across, the spring extractors come over the base of the round in the feed tray, and the extractors engage the rim of the cartridge on three sides. At the same time, the positioning plunger bears against the rim from the fourth side.

*Locking Phase.* The breechblock having been arrested by contact on its lower side with the shoulder of the receiver at the closed position, the remainder of the closing stroke is taken up by the final forward motion of the operating shaft and locking platform.

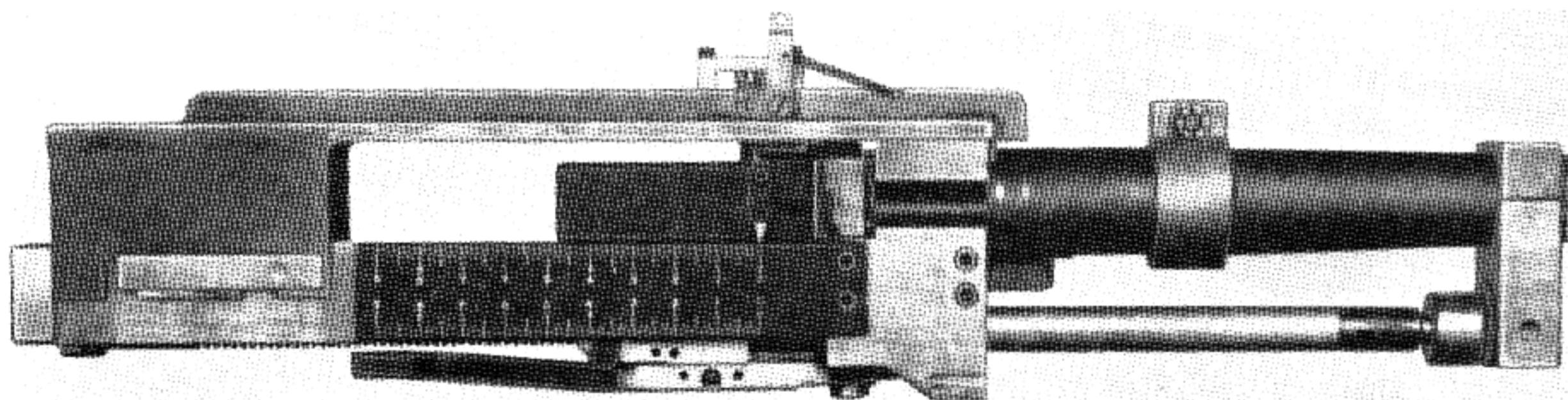


Figure 10-8. Test set to measure bolt recoil. The 20-mm Johnson gun is under test.

In this phase, the latch which holds the locking platform in its relative rearward position with respect to the breechblock is cammed out of engagement by the channels in the receiver rails through which it operates. This action permits the locking platform, acted upon by the mainspring, to thrust directly against the breechblock, forcing the breech lock downward. Thus, with the breechblock in the fully forward position, the locking platform as it moves forward in its final stroke thrusts the breech lock downward into engagement with the abutment in the receiver.

During its final motion, the nose of the locking platform trips the automatic sear. In its final forward position the platform acts as an abutment, in one aspect, preventing the breech lock from sliding upward under pressure.

*Ignition, Automatic Fire.* Just before the locking platform stops its final forward motion, the nose of the locking platform contacts the automatic sear, releasing the sear.

The automatic sear being released and the trigger being held down for a burst, the striker spring causes the striker to move forward with considerable force, the striker passing through its path in the breechblock, protruding through the striker hole provided in the breech slide. It will be noted that until the breech slide has been moved over to the normally

closed position, no aperture is available for the striker to pass through and hence the piece cannot possibly be fired until the breech slide is moved over into its proper position. This is a safety feature which prevents any possible ignition during the closing stroke prior to locking.

*To Unload Cannon After Firing.* Unloading consists of two phases: First, the removal of the belt; second, clearing the chamber and feed tray.

Rotate the belt feed block retaining lever, and disengage the feed fingers from the belt, thus preventing feeding of the belt.

Pull the cocking handle or operate the solenoid twice. The first operation removes the round from the chamber, ejects it, and chambers the round from the feed tray which has already been engaged by the belt extractors in the breech slide. The second operation removes the round from the chamber. There being no round in the feed tray due to the previous disengagement of the belt feed fingers, the chamber and feed tray are now empty.

Raise the belt retaining latch in the feed tray and pull the belt out of the feed tray. The same operations are required in unloading the Browning aircraft gun caliber .50.

*To Load the Belt.* Ammunition is loaded into the metal disintegrating links by the same method as employed in the caliber .50 Browning aircraft machine gun.

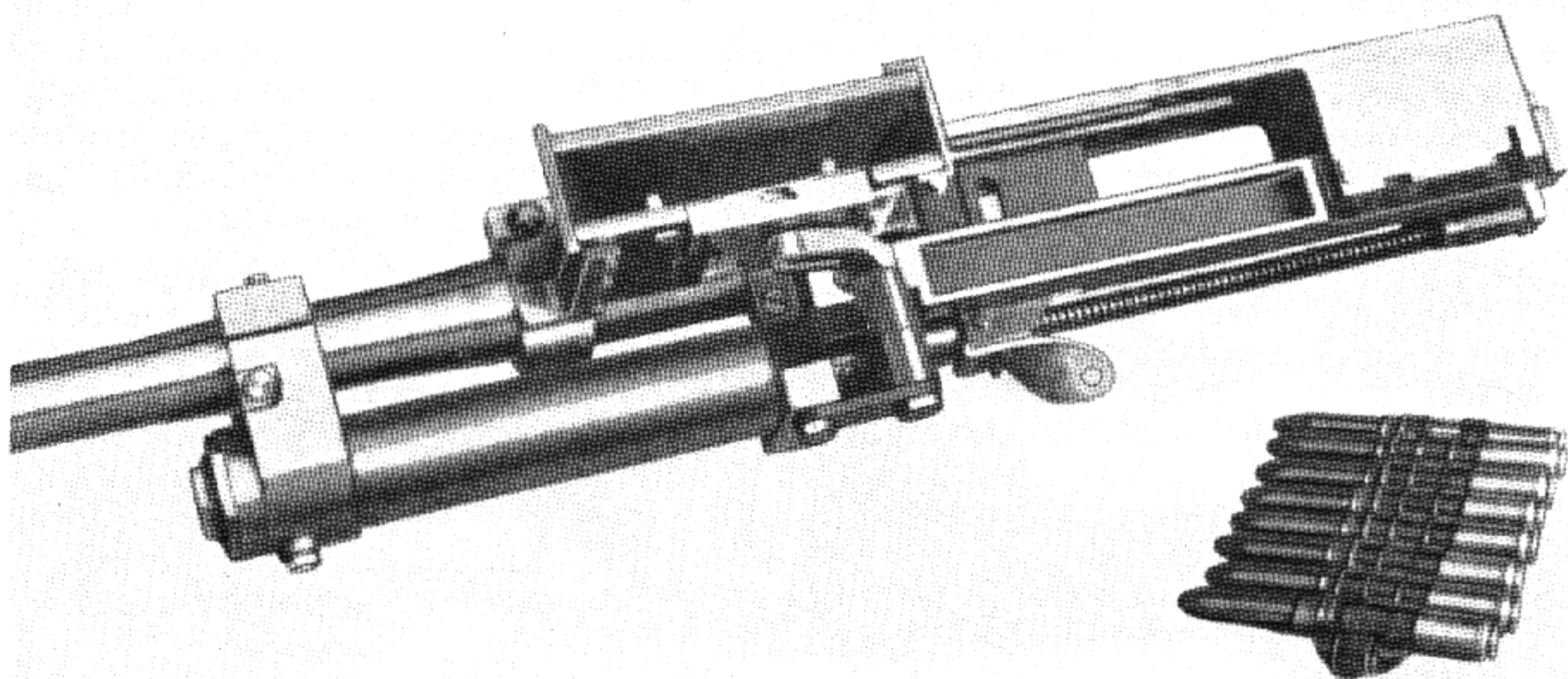


Figure 10-9. Johnson gun EX 2. Left view from below.

Belts should be checked to insure that all rounds are correctly seated in links and that rounds are in line. Links should be carefully checked for defects, deformation, etc.

*To Load the Cannon from the Belt.*

1. Grasp the first three rounds in the belt and insert these into the mouth of the feed tray.

2. Push the rounds into the side of the feed tray until the first round is engaged by the belt latches. This engagement takes place when the fourth round is just entering the feed tray mouth and also effects the engagement of the first round by the belt fingers in the belt block.

3. To chamber the first round, pull the cocking handle or operate the cocking solenoid twice. One stroke feeds the belt across and causes the belt extractors of the breech slide to engage the round in the tray. This is known as half-load. The second stroke extracts the first round and chambers it, also engaging round two in the belt and ejecting the first link.

NOTE. This cannon is designed to be cocked with the breechblock closed in order to obtain instantaneous firing in action. It may, however, be modified readily to be cocked open or half closed to avoid a cook-off. The firing pin is controlled by the automatic sear. It is therefore necessary only to install a breechblock catch if cocking open is desired.

### Disassembly of the Model

The parts are so arranged that the barrel with the gas cylinder assembly may be removed without affecting the body of the cannon.

When the barrel is removed for cleaning, the gas cylinder and piston may be serviced. Normally each barrel includes its own cylinder and piston assembly complete.

Removal of the buffer assembly permits withdrawal of the complete operating mechanism, including mainspring, operating shaft, and breechblock assembly. The striker and sear assemblies are in the breechblock. The belt feed lever is removed at any stage by removing bolts.

### Field Stripping of the Second Model

Field stripping should require no longer than 1 to 2 minutes.

*To Change the Barrel.*

1. Raise the barrel clamp lever.
2. Rotate the barrel clockwise 60° and withdraw toward the front.

*To Remove the Buffer.*

1. Press in the mainspring guide shaft and rotate 90° in either direction.
2. Withdraw the guide and spring.
3. Withdraw the locking plunger from the buffer plate and lift up and remove the buffer assembly.

*To Remove the Breechblock and Operating Shaft Assembly.*

1. If it is not already cocked, grasp the cocking handle, hold the breechblock cock striker, and unlock the action.

2. Withdraw the entire unit rearward.

3. The lock, platform and shaft assembly, and breechblock may now be separated.

4. Lift off the breech slide lever, slide the breech slide off to the side from block.

*To Disassemble the Striker.*

1. Release both sears on the breechblock, allowing the striker to move forward.

2. With a drift punch or spare striker, press in the striker spring plunger through the hole in the retaining plate.

3. Lift up the plate, allowing the spring assembly to move rearward.

NOTE. Use care not to lose this assembly.

4. Withdraw the striker.

*To Disassemble Gas Cylinder and Piston Unit.*

1. Remove two cap screws, and separate cylinder and cap.

2. Remove two spring screws. Withdraw the springs from their tubes.

3. Unscrew the cylinder cover from the cylinder. Withdraw the piston. Unscrew the plate from the piston, disengaging it from the cylinder cover.

*To Disassemble the Receiver.*

1. Remove 16 cap screws which retain the rails and housing.

2. Remove the retaining screw in the cover key.

3. Lift out the cover key, using the screw in the tapped hole. The cover can now be withdrawn from the rear.

NOTE. This operation is not included in normal service stripping.

## SECTION 4. DEVELOPMENT OF THE THIRD MODEL

## Chronology of Development

During the early part of 1944, the Johnson organization prepared the third model, which was somewhat more complicated due to the imposition of certain service requirements such as bottom ejection, right- and left-hand feed, provision for charging devices, removable barrel, etc. There was no objection to ultimate provision for these essentials; but it was felt that more progress might have been made by carrying out the building of the second model, which probably would have functioned more reliably than the third model proved to do.

On an occasion during February 1944 when a demonstration was held for persons concerned, both the 20-mm rounds necked down to take a caliber .50 bullet and the regular 20-mm rounds were fired from the same gun, the first model. The Johnson crew changed calibers in approximately half an hour. The barrel was not removable in that model, although provision was made for barrel removal in later barrels.

On that occasion, several bursts in the order of 100 rounds without cessation were fired. During a final burst of 20-mm, the gun ran some 80 rounds of a 100-round belt when there was a misfire due to a bad primer. This stoppage proved to be most fortunate as personnel in the factory area came running to the test pit in great alarm, shouting that the gun had drilled through a 24-foot sand bunker and had released some 15 blind-loaded 20-mm projectiles into the area. Some of these projectiles passed across a rifle range, went through a toolroom, passed beyond that across a public highway.

As a result of this episode, Johnson took over facilities originally built by the Navy at Cumberland, R. I., on Diamond Hill.

The project report for the month of June 1944 contained the following information concerning the 20-mm aircraft machine gun mechanism.

A four-shot burst was obtained which evidenced a much higher cyclic rate than previously obtained on this gun, but it was not recorded as the camera was not working at the time. The fifth shot was thrown out of the breech slide because of failure to be properly retained. A correction was made and

several more short bursts fired when a misfortune occurred—a break in the locking platform stud which engages the fixed striker and also contacts the back of the breechblock. This breakage very definitely indicated that there was a great increase in operating power from the increased diameter piston, and it was decided that the breakage was the result of the additional velocity of the operating shaft and locking platform assembly resulting from the action of the piston. This caused the platform assembly to strike the back end of the breechblock with much greater force than had obtained in the past with the 1-inch piston. It happened that this part in the redesign of the second model had already been substantially reinforced. However, on this older model the platform had not been reinforced because of other limitations.

Accordingly, a tentative study was made of the existing breechblock of the basic model with a view to modifying the platform especially for this gun so that firing could be continued with the larger piston. In the meantime, a spare platform was prepared in the hope of getting the gun firing again at least for a few shots by 10 July 1944.

In July 1944, arrangements were made to take the weapon to the Naval Air Station at Charlestown, R. I., for the purpose of seeing if it could be adapted for installation on naval aircraft. The inventor was particularly desirous of locating the position that the ejection slot would have to be mounted in relation to the wing so that the expended brass would not strike any of the parts of the plane. The location of the feed was another item that was to be taken into consideration.

In July 1944, the inventor reported that he was satisfied that from the few shots fired with the larger diameter piston, that it would result ultimately in a very marked increase in the cyclic rate, and it was quite probable that the weapon would fire at a cyclic rate of well over 600 rounds per minute. He reported further that progress had been made toward more completely overcoming the problem of acceleration of the round as it feeds across the breechblock during the action of the breech slide in chambering the round, and that at that time the



record stood at 41 rounds consecutively in 1 burst.

By early 1945, the third model had been fabricated and subjected to test firing. The chief trouble with that model lay in its somewhat excessive weight (there had been no attempt to keep the weight down) and in the inherent difficulty previously noted of debulleting rounds as they were extracted from the close-loop belt and fed down to the barrel chamber (through the same path as the M3 Browning machine gun, for example).

The third model also developed some trouble with the side plates due to the downward thrust through the breech locking system. The essential principles of this gun were the same as the first model and the second model. The gun was of the gas-timed self-unlocking type with retarded blow-back.

In spite of the difficulty with cracking of the side-plates, this gun succeeded in firing a rather notable series of extended bursts without malfunction. By double-crimping the 20-mm Hispano-Suiza rounds, the Johnson organization was able to get bursts in a number of series which went to about 100 rounds each. There were several thousand or more rounds fired from this gun. During these bursts, the only major stoppages were attributable to the debulleting of 20-mm Hispano-Suiza rounds. The trouble encountered from the loosened projectile divided into three categories:

1. The projectile would be left in the feedway as the case was withdrawn from it in extracting the round from the belt.

2. The loosened projectile would break off from the case as the round of ammunition was moved from the feed tray level down to the bore axis for introduction to the chamber.

3. Because the projectile had been loosened, the round would fail to chamber and lock due to its deformation, causing apparent misfire.

No such difficulty was noted when the gun was fired with the 20-mm caliber cartridge necked down for the caliber .50 bullet. Here the projectile was double crimped, and, as a result, much better functioning was established with that modified round. However, extended testing of this round was considerably limited by the unavailability of substantial numbers of these rounds.

## Cycle of Operation

This gun is fed by a closed-loop type disintegrating metallic-link belt holding any number of rounds desired. As with the Browning M2 caliber .50 aircraft machine gun, the cover can be raised, the belt inserted from either side (depending upon right- or left-hand feed adjustment), and the first round of the belt is engaged in the breech slide extractors. Operation of the automatic or manual charger withdraws the round from the belt on the opening stroke, chambers the round, and locks the breech on the closing stroke. The gun is normally cocked with the round of ammunition in the chamber and the breech locked. (Arrangement can be made to cock the gun open if desired, but at the time of the report quoted, the requirements specified that the gun be cocked closed.) For the purposes of describing the cycle for one round, it is assumed that the gun is arranged to feed the belt from the left side of the gun. (The gun may be arranged for right-hand or left-hand feed by making minor adjustments of the parts affecting feed of the belt but without any difference or replaced parts.)

A round being chambered, and the gun being cocked, locked, and ready to fire, the brief cycle of operation is generally as follows:

*Ignition.* The manual sear is displaced by the trigger solenoid, allowing the firing pin to move forward under the impulse of the firing-pin spring. At the time of ignition, the breechblock is fully forward and the breech slide is in the relatively upper position with respect to the breechblock. Thus, with the breech slide in the closed and locked position, the firing pin will continue forward until the point reaches out through the face of the breech slide contacting the primer. Experiments indicate that the time for the firing pin to move forward and hit the primer will be in the order of 6 milliseconds. This action causes the cartridge to be fired. (Cartridge is used synonymously with round in this description.)

*Initial Gas Action.* As the bullet, or projectile, passes down the bore, the expanding gases are tapped off through the gas porthole. Gas enters the gas cylinder and strikes the gas piston. This causes the gas piston to move with great force rearward in its seat in the gas cylinder, the stem of the

gas piston being in contact with the gas rod or operating shaft. The gas rod, or operating shaft, runs back and splits into a fork section running on either side of the ejection port and continuing back to a point just in front of the lock. Integral with the gas rod is the cocking nose.

*Cocking Action.* As the gas rod moves rearward, its first function is to cock the firing pin. This is done by contact of the cocking lug with the cocking slide. The cocking slide is in contact with the cocking lever. The cocking lever engages the firing-pin body in a recess in the firing-pin body. This gives a powerful leverage through the action of the gas piston and cocks a powerful firing-pin spring. The firing pin is cocked by engagement with the automatic sear just before the lock is disengaged. Thus, cocking of the striker takes place before the gun is unlocked.

*Locking and Unlocking.* When locked, the breechblock is forward, and the lock rotates on its hinge so as to bear against the rear face of the breechblock. The lock has an angular face which bears on an angular face of the breechblock, and the lock is prevented from rotating due to the angle of its bearing by the platform which supports the lock. The lock also bears upon the lock thrust key. Therefore, until the platform has moved rearward so as to release the lock, the lock is held securely in place.

As the gas rod moves back, its rear end is in contact with the platform extension. Therefore, movement of the gas rod causes the platform to go rearward, compressing the platform spring.

As the projectile is leaving the barrel, the platform has moved back sufficiently to permit the lock to slide out of engagement through the angle of its bearing surface coupled with a slight primary extraction motion obtained from the gas rod contacting the lock segment. Slow, or primary, extraction is also secured by means of the angle of the platform against which the lock must slide in order to completely release the breechblock. This insures reliable and positive extraction without tearing the case. Otherwise, however, the lock is self-unlocking through the release action of the platform which supported it.

The lock being unlocked, the platform spring urges the platform slightly forward so that a detent

means in the platform keeps the lock in the unlocked position.

The gun is now unlocked and primary extraction or initial loosening of the empty case has been effected.

*Extraction.* Extraction consists of two phases, extraction of the empty cartridge case and extraction of the fresh round of ammunition from the feed tray.

The empty case is held in the T-slot section of the breech slide which provides an extraction pull on each side of the head of the cartridge case or rim. This T-slot retains the empty case as it is pulled out of the chamber.

The fresh round of ammunition is gripped by the belt extractors on the top of the breech slide as well as by the angular round control pin. Thus the round is gripped on 4 sides by 3 extractors and by the control pin. As the fresh round is pulled out of the feed tray, the empty link which retained it is disengaged from the rest of the belt and is free to be ejected from the side of the gun.

The breechblock moves to the rear, compressing the driving spring and finally contacting the buffer. This completes the opening stroke.

*Action of the Feed Lever on the Opening Stroke.* When the breechblock opens, the feed lever, swinging on the feed lever pivot pin, is actuated by the breechblock cam tracks in the breechblock. (These tracks are similar in principle to the Browning M2 caliber .50 aircraft machine gun.) Consequently, the forward end of the feed lever is moved laterally so as to prepare to pick up the next succeeding round of ammunition contained in the belt. At this time, the belt latches in the feed tray prevent the belt from dropping out of the tray in a conventional manner. Thus the gun is prepared by this motion of the feed lever to feed the belt across, bringing the next round of ammunition into line during the forward stroke.

*Action of the Gas Rod After Unlocking.* As the breechblock is moving backward to extract, the gas rod having performed its function of cocking the gun, performs the further function of imparting its full energy to the breechblock just as the lock is disengaged. Thus, this mechanism derives its basic power of actuation from two forces: (1) action of the gas rod in turn actuated by the gas piston, and (2) by delayed or retarded blowback action derived

from the early opening of the breech. These two forces are combined in full to provide a maximum operating power for opening the breech.

The gas rod through its shoulder and cocking lugs imparts its energy for a short distance after unlocking to the breechblock, so that its full effect is imparted to the breechblock in order to speed up the opening of the breech. The gas piston stops after a 2-inch travel.

After the gas rod has performed this function, the gas rod spring returns the gas rod and piston as well to the forward closed position. This independent motion, among other factors, is desirable in order to avoid any possible interference with the firing pin due to rebounding when the mechanism closes for the next shot.

*Ejecting.* At the commencement of the closing stroke, the breech slide is cammed downward, thereby causing the empty shell to be thrown out of the bottom of the gun through the recess provided by the forked section of the gas rod extension. The same motion of the breech slide is also used to place the fresh round of ammunition in line with the chamber, described below.

*Feeding a Fresh Round into the Chamber.* The breech slide, being cammed downward by the breech slide, cams in the receiver plates and carries with it the fresh round of ammunition still engaged by the extractors and control pin. When the breech slide moves downward, the breechblock is moving forward under the impulse of the buffer and of the mainspring.

*Feeding of Belt.* The feeding of the belt, one of the most important functions of this mechanism which is of the self-fed type and requires no external assist, takes place during the forward stroke of the breechblock. During this motion, the forward end of the feed lever is caused to swing laterally toward the right, the belt-holding pawls on the feed slide gripping the round in the belt and causing the entire belt to be moved laterally one space so as to bring the next round into line with the breech slide when the action closes and locks, ready for extraction and chambering on the next succeeding shot. (This function of the breechblock and feed lever is similar in general principle to that of the Browning aircraft machine gun M2 caliber .50.)

*Closing of the Breech Slide.* When the breech slide and action are in the closing position, a round has just entered the chamber. The breech slide is relatively below the breechblock. As the action continues forward and just before it is fully closed, the breech slide is cammed upward by the cam paths in the receiver plates. At this time, the angular control pin is cammed out of engagement with the round, permitting the breech slide to slide upward relative to the base of the round of ammunition in the chamber. This action returns the breech slide to the upper closed position, and now for the first time permits the firing pin to move forward when released through the aperture in the breech slide provided for it.

As the breechblock closes up all the way, and just as locking takes place, the breech slide contacts the base of the fresh round of ammunition which has been fed across by the above described action of the feed lever, and the extractor fingers and angular control pin grasp the base of the next round of ammunition. At the same time, the rising of the breech slide causes the T-slot to slide over the base of the round in the chamber, ready to extract the empty case when that round has been fired after locking and release of the automatic sear.

*Locking.* As the breechblock closes, a spur on the breechblock contacts the forward end of the lock, disengaging the lock from the detent in the platform and thus releasing the platform so that it can move forward under the impulse of the platform spring, thereby exerting a strong locking or lifting pressure on the back end of the breech lock. Thus, the breech lock is cammed into the locked position by this independent action of the platform spring, thereby providing a powerful and rapid locking means.

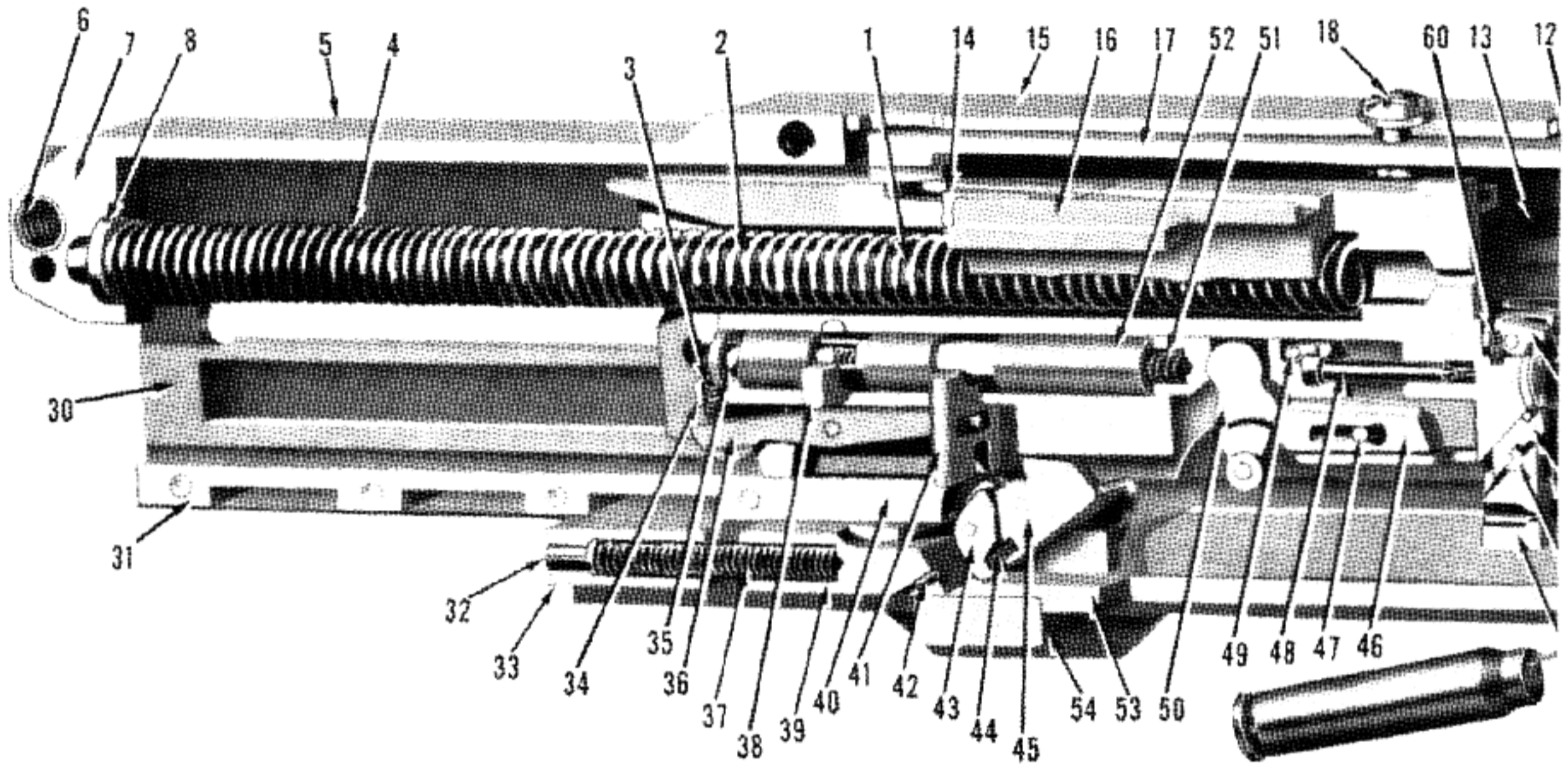
*Automatic Ignition.* It is assumed that the manual sear is still being compressed, in order to fire a burst. If not compressed, it will hold the firing pin body in the cocked position. For the succeeding shot, the release lever and the lock are cammed by the platform after the lock is locked, contacting the automatic sear lever. This releases the firing pin automatically and causes the succeeding round to be fired.

SECTION 5. DEVELOPMENT OF THE FOURTH MODEL

Summary

During the summer of 1945 the Johnson organization commenced to design the fourth model, in which the weights of the parts were radically re-

duced. The fourth model was designed with the same fundamental mechanism as previous models, but full advantage was taken from all the lessons learned in the previous two firing models. It was

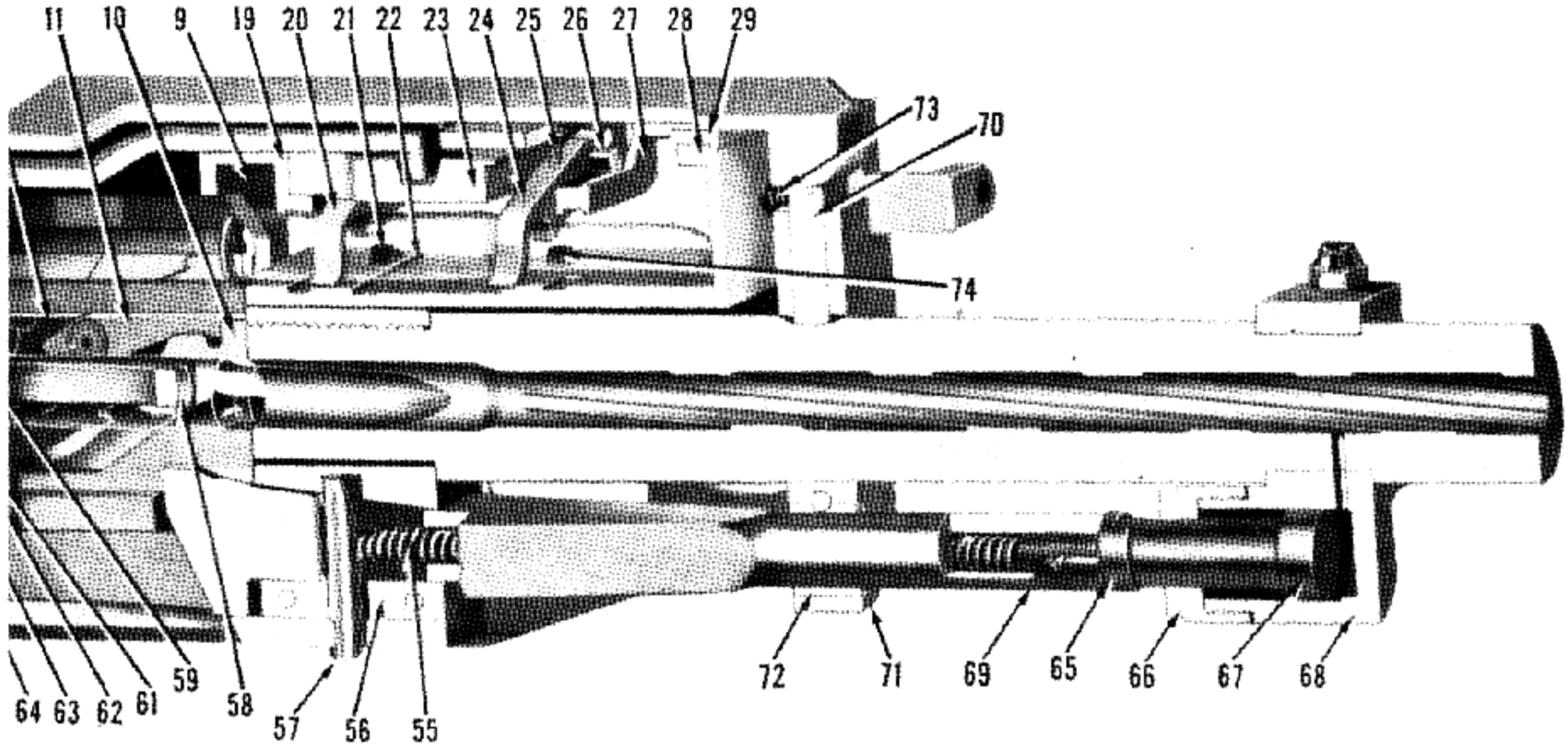


- |                                |                                 |
|--------------------------------|---------------------------------|
| 1 MAIN SPRING PILOT NOSE       | 20 REAR PAWL                    |
| 2 MAIN DRIVE SPRING PILOT      | 21 BACK STOP, KEFT REAR         |
| 3 AUTOMATIC SEAR LEVER SPRING  | 22 BOTTOM PLATE                 |
| 4 MAIN DRIVE SPRING            | 23 SLIDE                        |
| 5 TOP COVER PLATE              | 24 FRONT PAWL                   |
| 6 REAR RETAINER PLATE SPRING   | 25 PAWL SPRING                  |
| 7 REAR RETAINER PLATE          | 26 PAWL SHAFT                   |
| 8 PILOT GUIDE PLUG             | 27 FRONT GIB                    |
| 9 BACK PLATE                   | 28 FRONT PLATE                  |
| 10 CAM TRACK, LOWER            | 29 TOP PLATE                    |
| 11 CAM FOLLOWER, SWITCH, FRONT | 30 RECEIVER PLATE, L.H.         |
| 12 CAM TRACK, MIDDLE           | 31 REAR BOTTOM PLATE            |
| 13 CAM TRACK, UPPER            | 32 PLATFORM SPRING GUIDE        |
| 14 FEED CAM SWITCH BLOCK       | 33 PLATFORM STOP BLOCK          |
| 15 COVER                       | 34 FIRING PIN SPRING LOCK PLATE |
| 16 BREECH BLOCK                | 35 FIRING PIN SPRING GUIDE      |
| 17 FEED LEVER                  | 36 AUTOMATIC SEAR LEVER         |
| 18 FEED LEVER PIVOT PIN        | 37 PLATFORM SPRING              |
| 19 REAR GIB                    | 38 MANUAL SEAR                  |
|                                | 49                              |
|                                | 48                              |
|                                | 47                              |
|                                | 46                              |
|                                | 54                              |
|                                | 53                              |
|                                | 50                              |
|                                | 52                              |
|                                | 51                              |
|                                | 60                              |
|                                | 13                              |
|                                | 12                              |

Figure 10-10. Drawing of Johnson's

estimated that the fourth model would considerably exceed a cyclic rate of 1,000 shots per minute using 20-mm ammunition. This model was planned either for the close-loop belt or, ultimately, for an open-loop belt of the push-through type similar to the German MG-151. (Also similar to the Ger-

man MG-34 and MG-42 ground guns.) In a belt-fed version of Johnson's light machine gun which was under process of development for the Ordnance Corps in 1945, the German open-loop links were being used.



- |                         |                              |
|-------------------------|------------------------------|
| 39 PLATFORM             | 58 GRIPPER ARM, L.H.         |
| 40 LOCK THRUST KEY      | 59 EXTRACTOR                 |
| 41 AUTOMATIC SEAR       | 60 EXTRACTOR SPRING          |
| 42 LOCK STOP PIN        | 61 ANGULAR ROUND CONTROL PIN |
| 43 RELEASE LEVER        | 62 EJECTOR                   |
| 44 RELEASE LEVER SPRING | 63 VERTICAL CONTROL PIN      |
| 45 LOCK                 | 64 BREECH SLIDE              |
| 46 COCKING SLIDE        | 65 GAS ROD PLUG              |
| 47 COCKING SLIDE SPRING | 66 GAS CYLINDER CAP          |
| 48 FIRING PIN           | 67 GAS PISTON                |
| 49 FIRING PIN LATCH     | 68 GAS CYLINDER              |
| 50 COCKING LEVER        | 69 GAS ROD                   |
| 51 FIRING PIN SPRING    | 70 BARREL LOCK               |
| 52 FIRING PIN BODY      | 71 FRONT SUPPORT             |
| 53 FRONT BOTTOM PLATE   | 72 BUSHING                   |
| 54 LOCK SUPPORT KEY     | 73 TRAY POSITIONING SPRING   |
| 55 GAS ROD SPRING       | 74 BACK STOP, LEFT FRONT     |
| 56 BARREL BLOCK         |                              |
| 57 GAS ROD SPRING PIN   |                              |

proposed fourth version of his 20-mm gun.

## Chapter 11

## BROWNING CALIBER .50 MACHINE GUNS

## SECTION 1. HISTORY AND BACKGROUND

## Early History of Browning Weapons

The early years of John M. Browning's work in the field of automatic machine gun design and the company's contributions to aircraft machine gun development are discussed in volume 1 of this series. (See vol. 1, pp. 156-186 and pp. 327-344.)

## Development Programs for the T22, T27, and T25

The earliest two guns of the caliber .50 Browning design, which were constructed in the year 1918, fired at a cyclic rate of 500 rounds per minute. Improvements of these weapons resulted in the M1921 aircraft gun, actually standardized in 1923, and the M1921 water-cooled gun which was officially adopted in 1925. Only a small number of each were procured. These weapons had a nominal rate of fire of 500 to 600 rounds per minute but were handicapped by their being able to feed only from the left side.

In 1933, a new series of guns were standardized and given the designations: Caliber .50 M2, water-cooled; caliber .50 M2, aircraft; and caliber .50 M2, heavy-barrel. These three guns used the same basic receiver and included features originated by Dr. Samuel G. Green of the Ordnance Corps and others developed by the Colt Co. for their commercial guns. Production was still slow, though somewhat better than 1928, when not a single machine gun was produced for our Army. In this unfortunate era, the financial support of the Navy was instrumental in continuing development.

During a conference held at the Aberdeen Proving Ground, 18 June 1937, a group of Air Force personnel, headed by Gen. H. H. Arnold, requested that the Ordnance Corps undertake to increase the rate of fire of the caliber .50 aircraft machine gun, which was then recorded as 600 rounds per minute for a 750-grain projectile fired at a velocity of 2,500

feet per second. Subsequent improvement in caliber .50 ammunition resulted in the adoption in 1937 of an improved propellant which increased the velocity to 2,700 feet per second. In 1940, a 710-grain projectile was adopted, which further increased the velocity to 2,810 feet per second when fired in the 36-inch barrel.

Late in September 1939, formal statement of the military characteristics desired in an improved caliber .50 machine gun was made by the Chief of Air Corps, as follows:

1. Cyclic rate: Maximum consistent with other design requirements, not less than 1,000 rounds per minute. (Major consideration in the development of this machine gun to be given to this feature.)
2. Time of flight: 0.7 second to 600 yards.
3. Effectiveness: Penetration of  $\frac{3}{4}$ -inch armor-plate at 600 yards with armor-piercing bullets.
4. Overall length of gun: 68 inches maximum.
5. Weight: Minimum possible consistent with performance.
6. Type of fire: Full automatic.
7. Feed: Right and left hand.
8. Cooling: Air cooled, maximum efficiency possible with aerodynamic barrel jacket for distance of at least 20 inches aft of muzzle.
9. Control: Hand trigger and trigger motor.
10. Sight: No provision.
11. Trunnion reactions: Lowest possible consistent with performance.
12. Mounting: Suitable for fixed or flexible use.

Following the Aberdeen conference mentioned, Springfield Armory and the Colt plant undertook the development of higher cyclic rate caliber .50 machine guns. Work continued during 1937, 1938, and 1939, but it was not until January 1940 that a high cyclic rate gun was submitted for test at Aberdeen. This weapon produced by Colt's in cooperation with Springfield Armory, fired at a rate

of 997 rounds per minute but was unsatisfactory because of excessive breakages and malfunctions.

Up to 1940, Springfield Armory had not produced a specific high-speed gun, but data were accumulated which led to the adoption during 1940 of lighter barrels (9.5 pounds approximately) and double driving springs, which increased the rate of the standard M2 aircraft gun to approximately 750 rounds per minute. The second high-speed gun to appear at Aberdeen was a Colt-and-Springfield-Armory collaborative effort, tested in May 1940 with unsatisfactory results; namely, excessive breakages and malfunctions. After further development a third test, at Aberdeen in November 1940, revealed the same defects. After still further development the Colt gun, then designated T21, was given a fourth test at Aberdeen in September 1942 with continued unfavorable results. No Colt high-speed gun has been presented since that time.

As a guide to future development, the standard of performance of an acceptable high-speed gun was placed at 1 breakage and 5 malfunctions in 5,000 rounds of firing at 1,200 rounds per minute.

During the early part of 1942, the High Standard Manufacturing Co. designed a high cyclic rate caliber .50 machine gun and made two models. These guns, designated T22, were submitted to the Aberdeen Proving Ground for test 10 August 1942. One gun was fired on that date, 554 rounds at a cyclic rate of 1,066 rounds per minute, during which 5 stubbed rounds and 2 failures to feed occurred. Both guns were returned to High Standard for modification.

While the performance of the T22 gun was not acceptable, it was felt that sufficient promise was demonstrated to warrant further development. Accordingly, a research and development contract was placed with High Standard on 16 September 1942, to cover the delivery of two additional T22 guns.

These 2 guns, together with the original 2 guns tested, were returned to Aberdeen, given limited firing tests, and were shipped elsewhere for further tests, 1 to Wright Field, and 2 to Eglin Field for informative tests during October 1942. As a result of these tests, several structural weaknesses in the gun were discovered, the most serious of which was insufficient strength of the Armasteel bottom plate. Further development of the gun was recommended.

In November 1942, a research and development contract for 6 additional T22 guns was initiated, making a total of 10 such guns procured. The first of these guns, T22 gun No. 5, was fired on 21 November 1942, at Aberdeen Proving Ground. Total rounds fired was 250, and nine stubbings occurred.

The gun was returned to High Standard for modifications. The remaining five T22 guns on order were delivered to Aberdeen and tested 11 December 1942 with the following results:

T22 Gun	Rounds Fired	Average Rate	Malfunctions
6.....	1,000	1,172	1
7.....	1,000	1,156	5
8.....	882	1,136	3
			(Test stopped by broken back-plate.)
9.....	1,000	1,180	7
10.....	1,000	1,169	4

T22 gun No. 7 was subsequently fired 3,150 rounds during this firing with 16 malfunctions and seven breakages occurring. Gun No. 10 was fired 2,308 rounds with 3 malfunctions and 5 breakages.

During the first 10 months of 1943, various modifications of the T22 gun were tested at Aberdeen as follows:

Date of test	Gun model	Rounds fired	Cyclic rate	Malfunctions	Breakages
Feb. 26, 1943.....	T22E1	111	.....	( <sup>1</sup> )	.....
Mar. 18, 1943.....	T22E2	3,700	1,219	43	7
Aug. 3, 1943.....	T22E4	5,000	1,108	36	2
Oct. 11, 1943.....	T22E5	.....	( <sup>2</sup> )	.....	.....

<sup>1</sup> Broken sear ruined bolt.

<sup>2</sup> 2 guns fired—cyclic rate below 1,000 rounds per minute.

A turning point in the development of the high-speed gun was the advent of the T22E6, although the initial tests of this model were discouraging. On 13 December 1943, two T22E6 guns were fired 400 rounds and 1,000 rounds, respectively. Cracks developed in the new lighter bolts supplied with the guns. New bolts were made, and the guns refired on 29 December 1943 with the following results:

Gun A: 5,000 rounds fired; average cyclic rate, 1,160; 7 breakages causing 6 malfunctions.

Gun B: 5,000 rounds fired; cyclic rate not recorded; 11 breakages causing 8 malfunctions.

While the performance of these two guns was not acceptable, it was greatly improved over that of previous models.

Ten T22E6 guns were ordered from High Standard on 25 January 1944. The order was increased later to 30 guns in order to supply 10 guns requested by the Navy Bureau of Ordnance and five guns to the Army Air Force.

The first 10 T22E6 guns were received at Aberdeen 17 March 1944. Seven of these guns were given check tests of 200 rounds each and subsequently sent elsewhere for evaluation, five to Wright Field and two to the Naval Proving Ground at Dahlgren.

Tests of the T22E6 guns were continued at Aberdeen. Guns were fired under the various conditions to be expected in service, and the results were as follows:

Date of test	T22E6 gun No.	Rounds fired	Cyclic rate	Malfunctions	Breakages
Mar. 20, 1944....	10	5,000	1,136	2	1
Do.....	11	5,000	1,183	2	4
Apr. 4, 1944.....	12	5,000	1,202	2	2

Gun No. 12 was fired at 80° depression and 60° elevation and upside down. The belt-load capacity was determined to be 38 pounds maximum. The Wright Field report of test of T22E6 guns recommended further development of the gun to accomplish the following changes, which were stated to be essential before the gun could be used in aircraft installations.

1. A decrease in the effort required to charge the gun; during charging, gun should drive itself back into battery position without being forced.

2. Elimination of stoppages due to firing before full battery position is reached by correctly timing the weapon.

3. Dispelling of blowback gases so that carbonization and fouling of gun parts do not occur.

4. Change in firing pin design to eliminate frequent breakages.

The Naval Proving Ground report of test of T22E6 guns dated 26 August 1944 recommended further development and nonacceptance of the T22E6 gun for service use in its existing form.

Many of the defects noted in the foregoing tests were inherent in the mechanism of the T22E6 gun, and it was decided that further development could not be expected to produce a completely acceptable weapon. Accordingly, further development of the T22E6 gun, as such, was not undertaken by the Ordnance Corps although certain features of the weapon were incorporated in the T36 (M2A1) and T25E3 (M3) guns.

In the development of the T22E6 gun, an effort was made to hold to a minimum the changes in the standard M2 gun. A brief description of the special components of the T22E6 gun follows:

1. Recoil booster with 1/16-inch gas orifice, to increase cyclic rate.

2. Special top cover, to increase belt lift capacity by improving feeding conditions.

3. Split holding pawls, to improve feeding of ammunition.

4. Modified cover extractor cam. Curved camming surface and increased throw to prevent extractor from riding over top of side plate switch in counterrecoil.

5. Auxiliary spring on side plate switch, to speed action of switch and prevent overriding by extractor.

6. Belleville washer backplate buffer, to increase return of energy to bolt to speed counterrecoil.

7. Lightened bolt, approximately 1 1/2 pounds lighter than standard, to increase cyclic rate and decrease reaction forces.

8. Larger ejector pin, to eliminate breakage.

9. Modified oil buffer. Oil removed from oil buffer and auxiliary barrel return spring used to increase cyclic rate.



10. Special sear and sear slide, to eliminate breakage.

11. Heavier driving spring, to increase load and aid in returning gun to battery.

In addition to the foregoing major changes, many other components were modified in design and metallurgy.

Concurrently with the development of the T22E6 gun, an attempt was made by the High Standard Manufacturing Co. to provide a kit of parts which could be used to convert the standard M2 gun to a high-speed weapon. The first two models of this gun, designated T27, were submitted to Aberdeen for test 1 January 1944. The tests of both guns were discontinued before the completion of the regular 5,000-round test. During the next 14 months, 18 guns of the T27 series were tested at Aberdeen. The results of these tests showed excessive numbers of malfunctions and breakages, and actual danger to personnel and equipment. The kit of parts to convert the M2 gun to the T27E7 gun included:

1. Bolt stabilizer, to stabilize bolt and depress extractor at end of recoil.
2. Muzzle booster, to increase cyclic rate.
3. Side plate switch, strong spring and changed contour.
4. Special extractor, no ejector to be used.
5. Special bolt with spring clips to position round in T-slot, replacing ejector.
6. Split holding pawls, to improve feeding conditions.
7. Rubber plug for backplate buffer, to replace fiber disks.

In addition the oil was removed from the oil buffer.

In the development of the T22 and T27 series high-speed guns, an effort was made to hold to a minimum changes over the then standard M2 caliber .50 machine gun. So that no practicable approach to the development of an acceptable high-speed gun might be overlooked, a contract was placed 4 August 1943 with the Frigidaire division, General Motors Corp., to cover the development of the T25 series of guns. The basic mechanism of the M2 gun was to be used in this development, but no restrictions were placed on the number of changes over the M2 gun and no requirement for interchangeability of the components of the two guns was imposed. The development was to begin by correcting certain known mechanical weaknesses of the M2 gun, and to proceed by making all changes necessary to provide reliable functioning at a rate of fire of 1,200 rounds per minute. For example, the backplate buffer, barrel buffer, and receiver were redesigned.

It was not until 10 March 1944 that the first T25 gun was submitted to Aberdeen Proving Ground for test. The gun gave a fair performance for 2,000 rounds; but from that point on, excessive breakage and malfunctions occurred, and at 3,100 rounds the test was discontinued because of the breakage of the backplate buffer.

Work was immediately started on a second gun, the T25E1, which was tested at Aberdeen 10 May 1944. This gun was completely unsatisfactory.

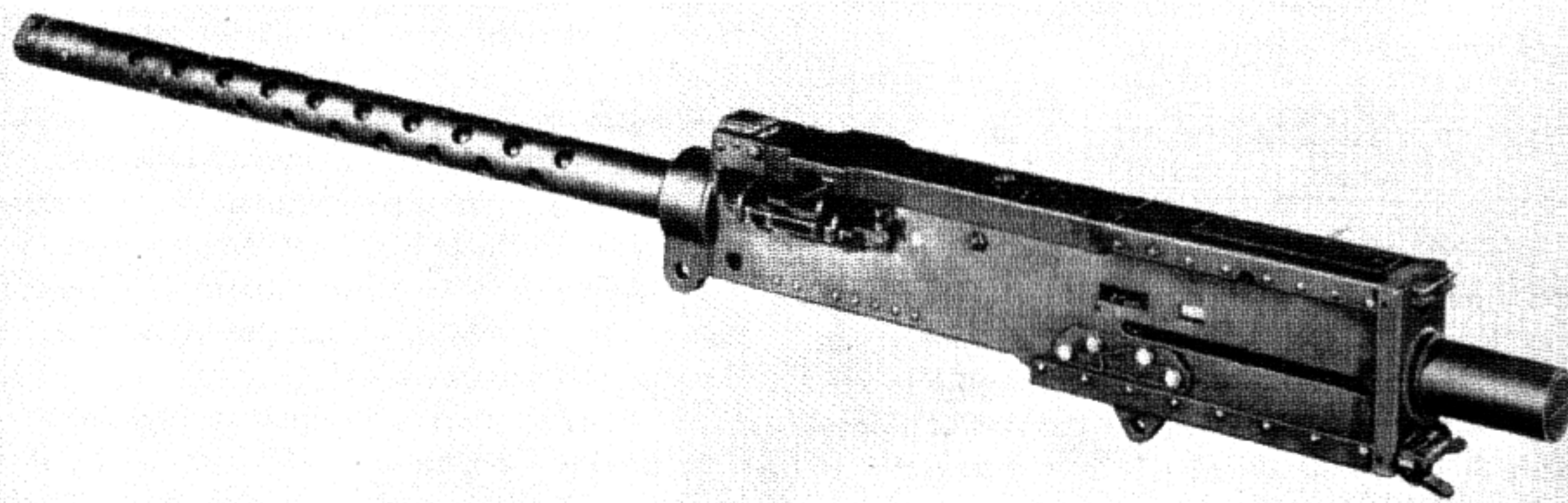


Figure 11-1. Browning Machine Gun, Caliber .50, T25. Left side view.

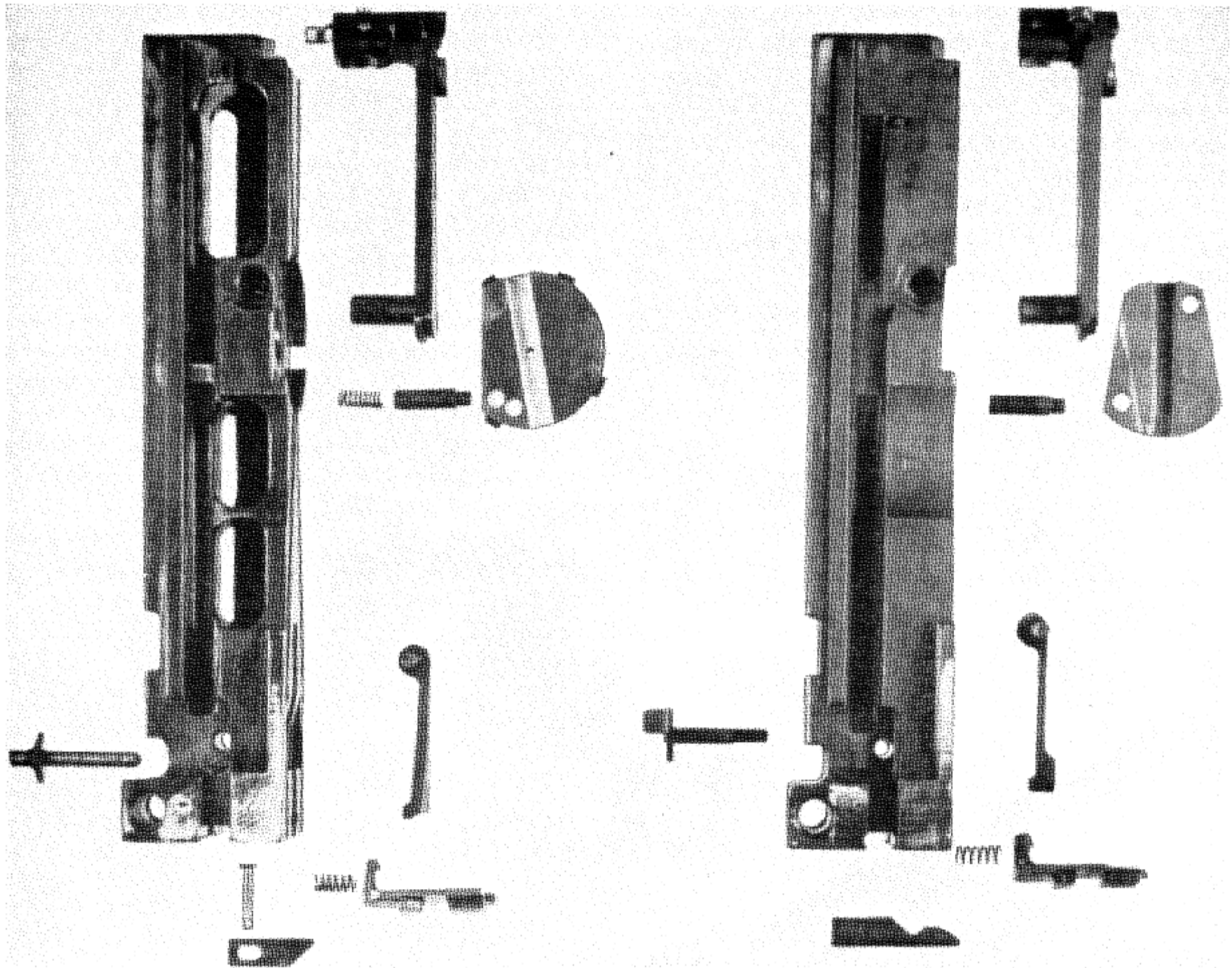


Figure 11-2. Comparison of bolt components for Browning Caliber .50 machine guns. Parts for the M2 bolt assembly are shown at right, and corresponding parts for T25E1, at left.

Nine breakages and three malfunctions occurred in 770 rounds, and the test was stopped.

Satisfactory functioning had not been obtained with the T25 series guns, but certain features of these guns were considered very desirable. To permit further study of the causes of this unsatisfactory functioning, the T25E2 gun was made up by substituting the bolt, top cover, and recoil booster of the T22E6 gun for corresponding components of the T25E1 gun. This gun was fired at Aberdeen 1 June 1944. Functioning was unsatisfactory, and the test was stopped at 1,800 rounds. A careful examination indicated that the nested helical springs in the backplate buffer were breaking and causing extreme impact forces on the gun components. The use of

this type of spring was discontinued in favor of Belleville spring washers for the T25E3 gun.

The first T25E3 gun was tested at Aberdeen 19 July 1944. The functioning of this gun was greatly improved over that of the T25E1, and the cyclic rate averaged 1,250 rounds per minute. Eight malfunctions occurred, but for the first time in the development, it was possible to determine the specific cause of each malfunction. A projecting corner on the bolt was responsible for "shorting" rounds in the feedway and causing failures to feed; the remainder of the malfunctions were caused by fatigue of the sear spring.

To permit more extensive tests of the T25E3 gun, 12 additional guns were ordered immediately.

These were completed in October 1944; two were left at Frigidaire to be used in further development, and the remainder shipped to Aberdeen. To permit a positive check on the performance of the initial gun, no changes were made in these guns from the T25E3 gun already tested.

During October 1944, three T25E3 guns were given the regular 5,000-round endurance test at Aberdeen, with the following results:

Gun	Rounds fired	Cyclic rate (r. p. m.)	Malfunctions	Break-ages
T25E3.....	5,000	1,250	2	2
T25E3.....	5,000	1,285	8	0
T25E3.....	5,000	<sup>1</sup> 1,195	5	1

<sup>1</sup> No booster.

Thirteen out of the fifteen malfunctions occurring in the above tests were failures to feed or lightly struck primers. Both were attributable to the premature release of the firing pin by the sear. New sears, having the angle of engagement with the firing-pin extension increased from 3° 30' to 4° 30', were installed in the 2 guns at Frigidaire, and these guns were fired 5,000 rounds each. An extractor was broken in the first gun at 3,500 rounds, and the second gun had one failure to extract from the bolt at 3,300 rounds; no other malfunctions or breakages occurred during the tests. Two T25E3 guns were furnished to the Navy Bureau of Ordnance and two to the Army Air Forces, for informational tests.

In view of the promising results obtained in the above tests, Ordnance Committee action was taken to procure 1,100 T25E3 guns as follows:

1. One hundred guns to be procured by Research and Development Service to establish final engineering design and to provide guns for service test.

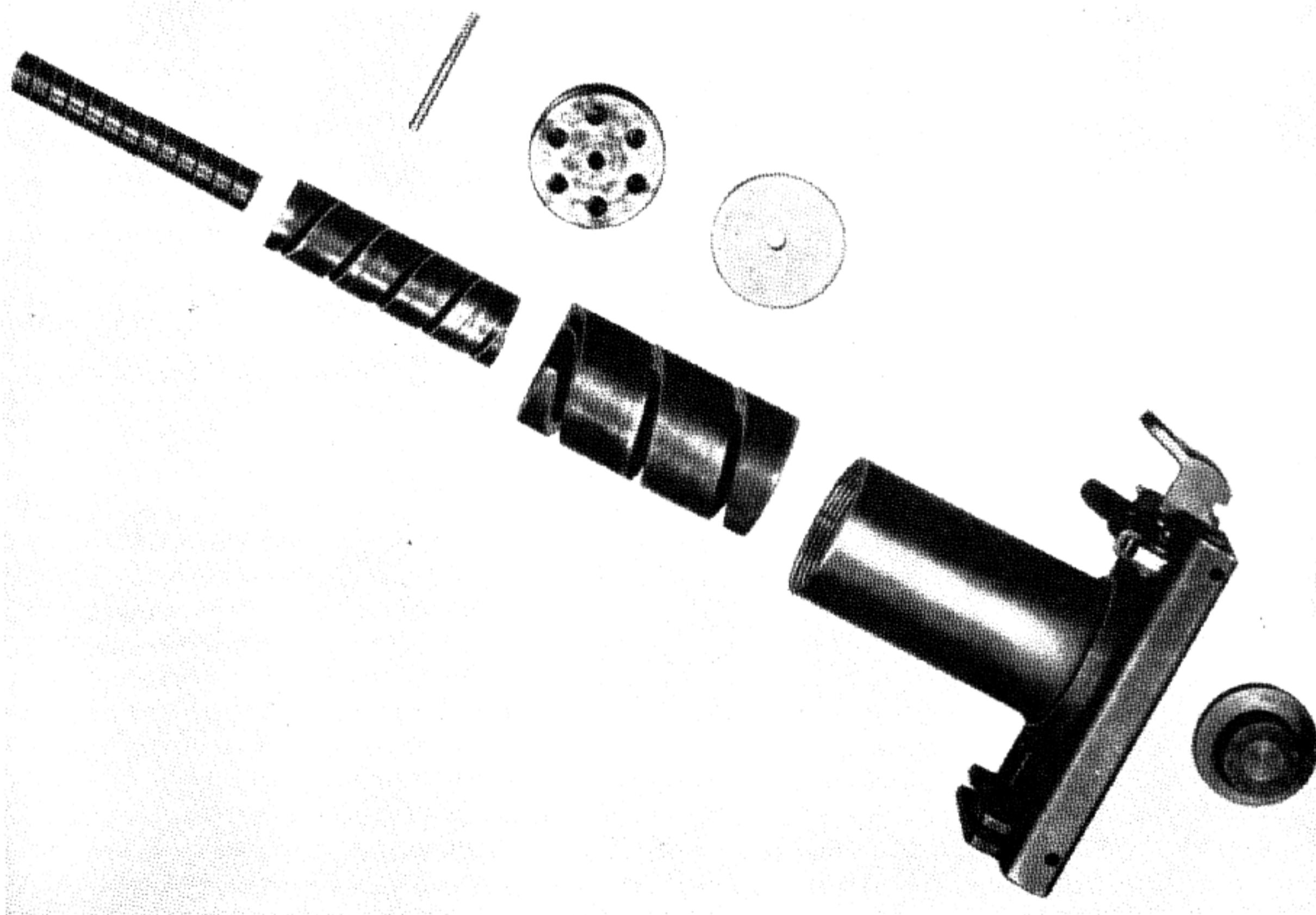


Figure 11-3. Backplate of T25 high-speed machine gun. View showing three nesting buffer springs.

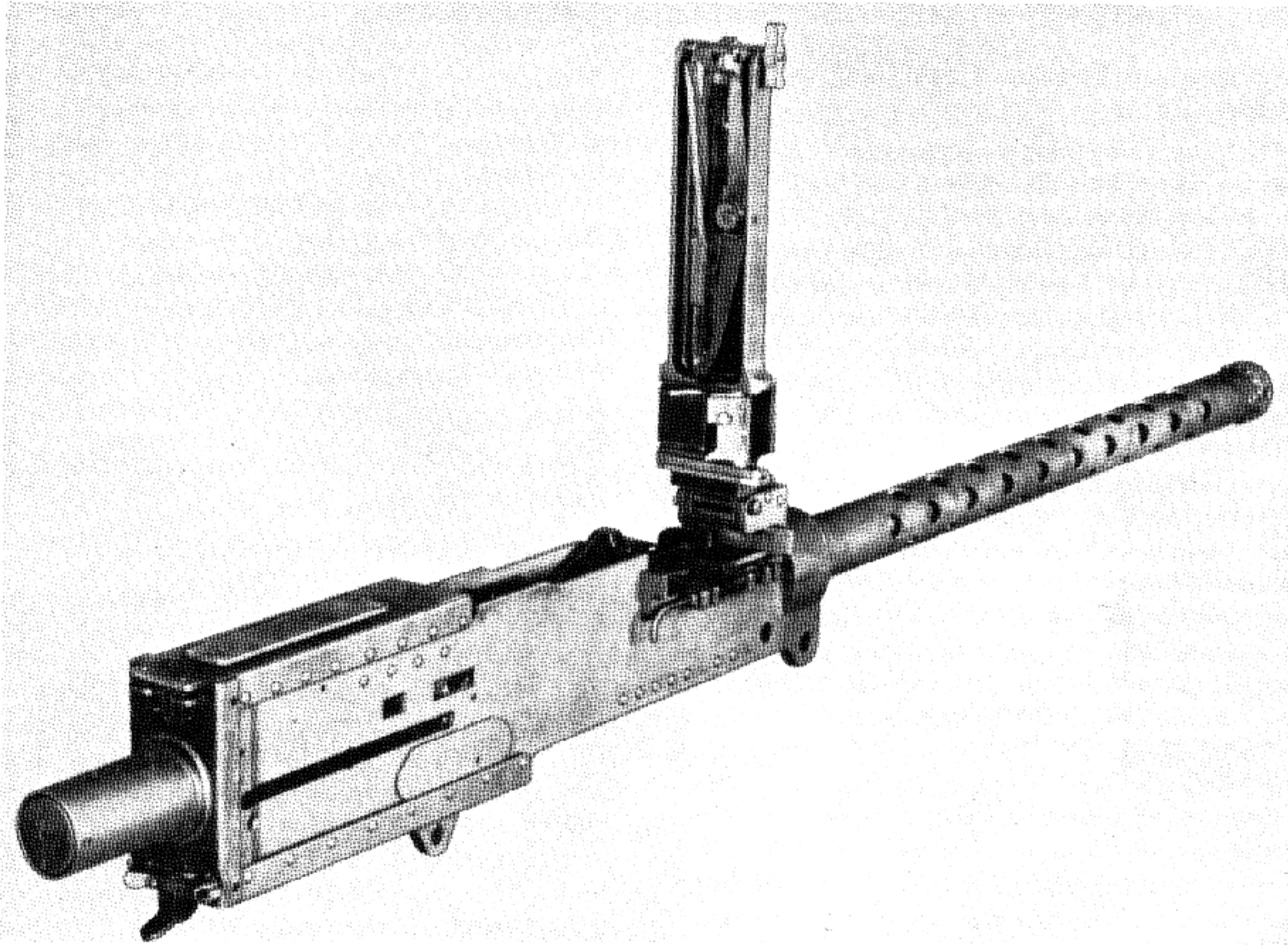


Figure 11-4. Browning Machine Gun, Caliber .50 T25E3. Right rear view.

2. One thousand guns to be procured by Industrial Service to enable the development of production facilities and to provide guns for extended service tests.

Supplemental action was taken by the Ordnance Committee on 14 December 1944 to provide for the procurement of an additional 1,000 T25E3 guns to be used for evaluation by the Navy.

Following the above authorization, a Research and Development contract was placed with Frigidaire 6 December 1944 for 100 T25E3 guns. The first gun was delivered 6 January 1945 and the hundredth gun was delivered 12 February 1945. These guns were distributed as follows:

- 7, Fired for acceptance at Frigidaire.
- 20, Army Air Force.
- 15, Navy Bureau of Ordnance.
- 2, Frankford Arsenal.
- 1, Springfield Armory.
- 1, Frigidaire (for development work).
- 1, A. I. O. (Army inspector of ordnance) Savage Arms Co.
- 1, A. I. O. (Army inspector of ordnance) International Business Machines Co.
- 47, Aberdeen Proving Ground.
- 5, Army Ordnance Experiment Station, Purdue University.

The acceptance tests for these guns are described in the following section.

## SECTION 2. CALIBER .50 T25E3 GUN

## Acceptance Test for First 100 Frigidaire-Made Guns

The initial procurement program for the T25E3 gun is described in the preceding section. An acceptance test was established for the 100 T25E3 guns delivered by Frigidaire during January and February 1945. Test specifications were as follows:

1. Fire one high-pressure test round in each gun.
2. Fire each gun 200 rounds in burst fire, 100 with right-hand and 100 with left-hand feed. If stoppages or breakages occur, rework guns and refire.

3. Select 1 gun from each lot of 20 and fire 5,000 rounds in 50-round bursts, one-half with right-hand and one-half with left-hand feed. Guns are to be cleaned and oiled at the end of each 1,000 rounds. Guns are acceptable if not more than 1 breakage and 5 malfunctions occur during the test. Should any gun prove unacceptable, an additional gun from the same lot will be fired an identical test.

In the 200-round functioning test given each of the 100 T25E3 guns, stoppages occurred in 7 guns. These guns were reworked and all gave perfect functioning when refired.

Seven guns were fired from a factory test stand for the 5,000-round acceptance test. This firing was conducted under the direction of the Army inspector of ordnance at the Frigidaire division plant and the results have been summarized as follows: As a result of sear breakage during the tests, they were stopped, and forged sears were substituted for the machined ones previously used. The sears of all T25E3 guns already manufactured were replaced with the forged type, and the 5,000-round acceptance tests continued without further breakage of sears.

In the 35,000 rounds fired from 7 guns during this part of the test there were 18 stoppages, of which only 12 were definitely attributable to the gun.

A report received from the Naval Proving Ground, Dahlgren, Va., stated that two T25E3 guns were fired approximately 7,000 rounds each. In the first 5,000 rounds of firing on each gun, only 1 stoppage occurred in each gun. In the remainder of the firing, a total of three breakages occurred. This firing was conducted at temperatures ranging

from  $-70^{\circ}$  F. to  $+140^{\circ}$  F., and functioning was satisfactory at all temperatures. Among the conclusions of the Naval Proving Ground were the following:

1. All parts of the T25E3 gun are reliable for 5,000 rounds of firing.
2. The guns will maintain a high cyclic rate (1,150 to 1,200 r. p. m.) for at least 5,000 rounds.
3. Subject gun will feed satisfactorily under adverse feeding conditions.

## Flight Tests

Flight tests of the T25E3 guns in aircraft were carried on at Wright Field.

## Standardization of the T25E3 Gun

After the satisfactory tests of the T25E3 guns, and to expedite procurement of this weapon, the Army Air Force requested its standardization in April 1945. Ordnance Committee action was immediately taken to standardize the T25E3 gun as Gun, Machine, Caliber .50, M3 Aircraft, Basic. This same action reclassified the Caliber .50 Aircraft Machine Gun M2 as Limited Standard.

Large-scale procurement of M3 guns was started, and by the end of September 1945, approximately 2,400 guns had been made.

The standardized basic machine gun fired at the rate of 1,200 rounds per minute. Satisfactory performance was obtained from the service test guns; however, when guns were fired in the various new aircraft installations, unsatisfactory functioning was reported and a remedial development and test firing program was immediately undertaken.

Improved gun components were designed, test fired, and standardized for incorporation in production guns. These included improved firing pin, firing-pin extension, and feedway components. Reversion to the T23E type sear eliminated breakages which had become recurrent under 5,000 rounds. The Air Force reported cracked bolts under 5,000 rounds; and although no accounts were received of gun malfunctions caused thereby, action was taken to standardize both right- and left-hand single-track bolts at the request of the Air Force. Development continued on double track bolts and the "insert type bolt" was standardized.

Light-struck primers have caused more gun stoppages when guns are mounted in aircraft than any other single factor. Changes made in the sear spring and the adoption of bolt hold-down bracket reduced stoppages due to this cause. New design bolts incorporating a positive sear holding device were studied to eliminate this type of malfunction.

The M3 gun was standardized to allow for 5,000 rounds with no parts replacements. The Air Force was advised that if guns are fired 10,000 rounds certain parts must be replaced in accordance with the list supplied by the Ordnance Corps.

Development was initiated for increasing the life of gun parts failing between 5,000 and 10,000 rounds. Tests were conducted at increased rates of fire to provide accelerated test conditions. Observations at the 1950 USAF gunner meet, at Las Vegas, Nev., confirmed the assumption that proper maintenance would assure satisfactory gun functioning.

Following formal standardization of the basic components of the M3 gun, other changes were authorized, including:

1. Reduction in length of backplate buffer.
2. Provision of method of locking feed pawl pin in place.
3. Redesign sear permitting use of a much larger sear spring.

### General Description

The caliber .50 basic aircraft machine gun AN-M3 is an automatic, recoil-operated, link-belt-fed, air-cooled machine gun having a rate of fire over 1,000 rounds per minute. A metallic link disintegrating belt is used to hold the ammunition while it is being fed into the gun. By means of changes of position for some of the components, the gun may be set up so that the ammunition can be fed from either the left- or right-hand side.

When issued with an alternate feed (double-track) bolt, the gun is referred to as Caliber .50 Basic Aircraft Machine Gun AN-M3, alternate feed bolt. If the gun is issued with a single-track bolt, marked L it is referred to as LH Feed Basic Aircraft Machine Gun AN-M3; and when issued with a single-track bolt marked R, it is referred to as RH Feed Basic Aircraft Machine Gun AN-M3.

The gun can be mounted in the wing or fuselage of a fighter plane. It may also be mounted in a turret of a bomber.

The gun fires percussion type primed ammunition. A solenoid, which can be mounted on the top plate or on either side of the gun, depending upon what side the sear slide is assembled, is used to fire the gun.

Basic aircraft machine gun caliber .50 T25E3 is similar in general appearance to caliber .50 basic aircraft Browning machine gun M2.

The recoil booster, cover group, belt holding pawls, breech lock, barrel, and short round stop are used in both the T25E3 and the M2. The T25E3 differs from the M2 in the following respects:

1. The bolt has been redesigned. In order to decrease its weight, it has several holes drilled completely through the sides, and other lightening cuts.
2. The accelerator has been redesigned by changing the curvature of the claw end.
3. The outer driving spring has been redesigned by removing two of the solid-wound coils from each end.
4. The inner driving spring has been redesigned by removing three coils from each end.
5. The backplate has been redesigned to clamp around the side plates. Washer springs (Belleville type) are used in the buffer tube in place of fiber disks used in the gun M2.
6. A cocking lever stop assembly which is housed in the cocking lever slot in the top of the bolt has been added.
7. The cocking lever has been redesigned to provide thicker cross sections and to eliminate sharp corners. In addition, a shoulder has been added to the lever to facilitate assembly.
8. The sear has been redesigned to make the top left side thicker and the tip stiffened with a rib. In addition, a larger fillet has been provided where the hook joins the main body of the sear.
9. The sear slide has been redesigned to eliminate the V-shaped cut on the end and by adding an elongated slot on the other end for retention in the bolt.
10. A sear slide stop pin has been added to retain the sear slide in the bolt.
11. The bolt switch has been redesigned to provide an interlocking tongue on the underside.
12. The side plate switch has been redesigned.
13. The side plate switch spring has been made slightly heavier.

14. The extractor cam has been modified by slightly changing its shape and making it much wider.

15. The cover extractor cam has been redesigned by forming a steeper cam having a concave camming surface.

16. The barrel extension has been changed by providing additional clearance cuts for the ejector and the depressor slots and milled across the entire side.

17. The extractor assembly has been redesigned so that the position of the ejector may be shifted to facilitate feeding from the left side of the gun.

18. A new air and washer spring type barrel buffer is used in place of an oil buffer assembly.

19. The breechlock depressors are securely fastened to the side plates. On the gun M2, the depressors are attached to the oil buffer body. The depressors have a curved camming surface formed on the front end.

20. The breech lock cam has been changed to add a radius at the top of the camming step.

### Description of Components

*Backplate Assembly.* The backplate assembly is assembled to the rear end of the receiver. In general, the backplate assembly is composed of the backplate, latch lock, and buffer components. The backplate slides downward into grooves inside and around the outside the receiver. The backplate is held in position, when assembled, by the backplate latch engaging the bottom plate of the receiver. The latch is prevented from disengaging by the backplate latch lock. Both latch and lock are spring operated.

The backplate houses a buffer plate and 10 cup-shaped washer springs (Belleville type) assembled in pairs and held in place by the backplate adjusting screw threaded in the backplate. The buffer plate bears upon the washer springs and projects through

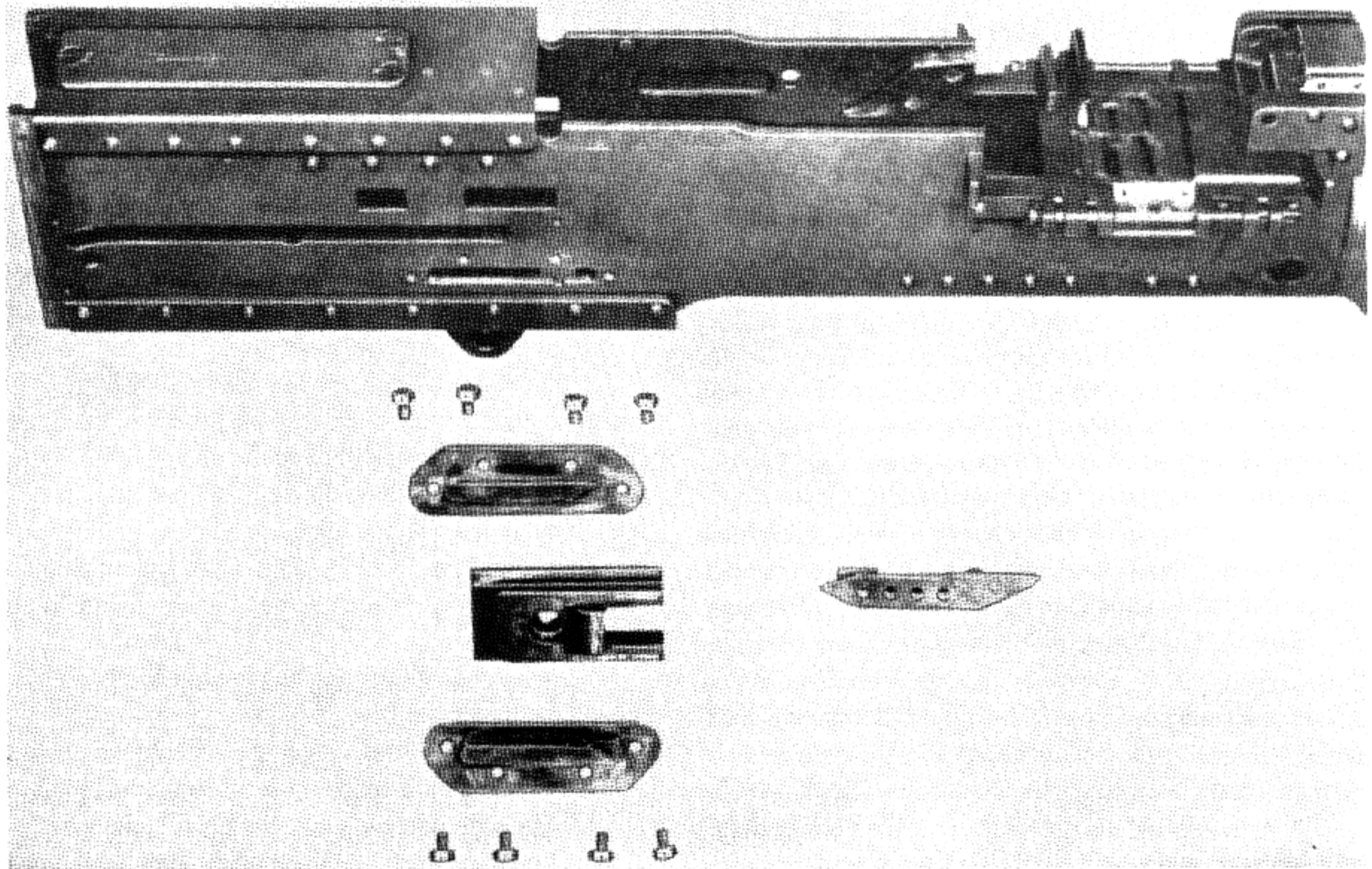


Figure 11-5. Modified parts of T25 gun. The rear of this receiver is fitted for a special backplate.

the front face of the backplate. A spring-loaded plunger seated in the adjusting screw and a slot in the backplate prevents the screw from loosening from vibration.

The main function of the backplate assembly is to stop and cushion the bolt on recoil. The bolt strikes the projecting buffer plate which bears upon the washer springs. These springs, which are slightly compressed at assembly, cushion the blow and store up part of the recoil energy to return it to the bolt to speed up the counterrecoil. The backplate assembly also acts as a stop for the barrel buffer group and the rear end of the driving-spring-rod-

with-springs assembly which bears in a groove in the backplate when assembled.

*Bolt Group.* The bolt group contains the firing and extracting mechanisms of the gun and actuates the belt feed mechanism of the cover. In general, it is composed of the bolt assembly, sear, sear slide, cocking lever, firing pin group, and extractor assembly. It also houses the driving-spring-rod-with-springs assembly when the gun is assembled. The bolt slides in ways cut in the barrel extension and is locked to it to hold the cartridge in the chamber of the barrel, when firing, by the breechlock in the barrel extension. The bolt withdraws the fired car-

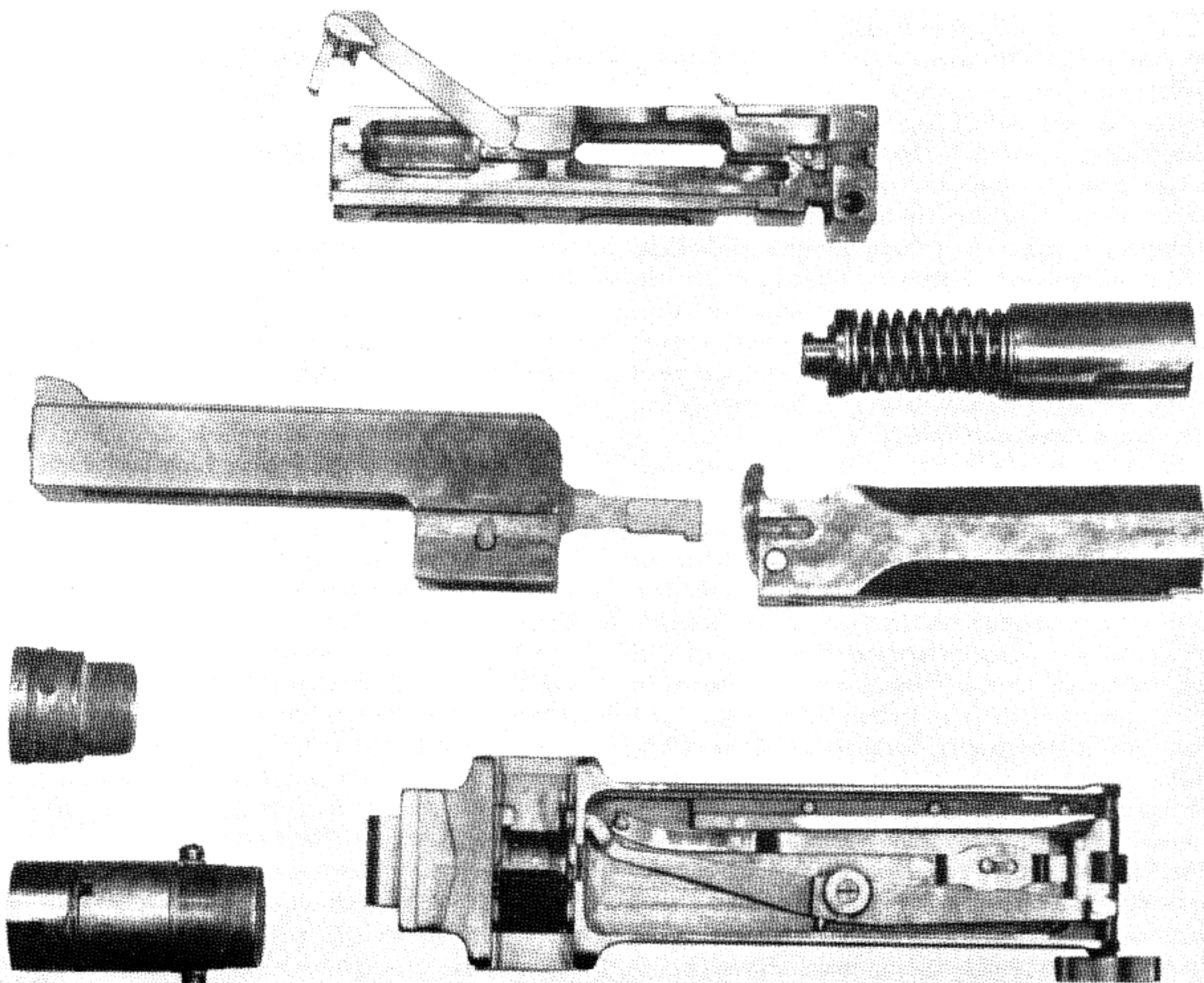


Figure 11-6. Modified parts of T25 gun. Lightened bolt at top. Air buffer immediately below. Barrel extension with wide depressor grooves. Buffer body. Booster and barrel bearing. Cover with heavier belt feed lever and curved cover extractor spring.



tridge from the chamber by means of the T-slot in the front end, in which the cartridge is seated when chambered.

The sear slides vertically in grooves in the rear end of the bolt; is actuated by a spring which seats on a lug on the sear and in a seat in the bolt; and is retained in the bolt by the sear slide. The sear slide is assembled in lateral grooves in the rear face of the bolt; is held in place by a retaining pin; and acts upon a lug on the sear. The purpose of the sear is to hold the firing pin group in the cocked position when cocked by the cocking lever.

The cocking lever is pivoted vertically in a slot in the rear part of the bolt on the cocking lever pin which is inserted in the bolt from the side. A curved extension of the firing pin spring stop cushions the lever on its forward movement. The upper end of the lever projects above the bolt, and the lower end engages in a slot in the firing-pin extension assembly. The cocking lever cocks the firing-pin group when its upper end is cammed forward by the top plate bracket or bolt holddown bracket (riveted type) on the top plate of the receiver, during recoil of the bolt.

The firing pin extension assembly, assembled to the firing pin, is housed in a longitudinal tunnel in the bolt and contains the firing pin spring, one end of which bears upon the firing pin spring stop whereas the other end is retained by a firing pin spring stop pin, when assembled.

The extractor assembly, which contains the extractor and ejector, is pivoted in the left side of the bolt and can be assembled for either left-hand or right-hand feed. A stop lug on the bolt limits the downward movement of the extractor assembly. The extractor assembly extracts a cartridge from the belt, aids in guiding it into the T-slot in the bolt, and thence into the chamber of the barrel on recoil.

In alternate feed (double-track) bolts, two diagonal grooves or ways are cut in the top of the bolt. At the rear end of the bolt stroke, the feed lever is in one of the grooves, depending on the direction of feed. In later type alternate feed bolts, either of the bolt grooves may be made continuous by positioning the bolt switches in their proper holes in the top of the bolt. The switches are retained in the bolt by bolt switch locking pins. In early type alternate feed bolts, the bolt switch seats in a circular recess in the top of the bolt and is furnished with a groove similar to the bolt grooves. The switch may

be positioned and retained in place by a spring-loaded stud to make either of the bolt grooves continuous. The switch is retained in the bolt by an undercut in its seating recess.

In single-track bolts, one diagonal groove is cut in the top of the bolt. This groove seats the rear end of the bolt feed lever.

One bolt, marked "L," has the diagonal groove machined in the proper direction for left-hand feed; the other bolt, marked "R," has the diagonal groove machined in the proper direction for the right-hand feed. Single-track bolts, therefore, do not require a bolt switch.

The bottom of the bolt is designed to prevent the accelerator claws from entering the breechlock recess in the bolt, thus preventing jamming of the bolt. A bolt stud is assembled in the side of the bolt as a means for retracting the bolt when the gun is assembled. One end of the stud projects through a slot in the side plate and is retained by a collar bearing upon the inside of the side plate.

The driving-spring rod with springs assembly is housed in a longitudinal tunnel in the bolt when the gun is assembled. A shoulder at the forward end of the tunnel acts as a bearing for the springs and to compress them against a shoulder on the rear end of the driving spring rod when the bolt recoils.

The general function of the bolt group is to load and fire the gun, extract and eject the fired cartridges, and actuate the belt feed mechanism of the gun through the medium of the belt feed lever in the cover group. The driving springs act to return the bolt to forward position at the end of recoil.

*Barrel and Barrel Extension Group.* The barrel is cylindrical and is threaded at the rear end to screw into the barrel extension loosely enough for easy adjustment. Just forward of this thread, serrations are cut around the periphery for engagement of the barrel locking spring which holds the barrel in adjustment. The front end of the barrel has an integral machined bearing surface for engagement in the bearing formed by the recoil booster in the barrel jacket of the receiver and barrel jacket group. The bore of the barrel is chromium plated to increase accuracy life and has a special liner assembled near the breech end to increase velocity life.

The barrel extension extends to the rear of the barrel when assembled to it. Its forward end is a formed lug, drilled and threaded, into which the

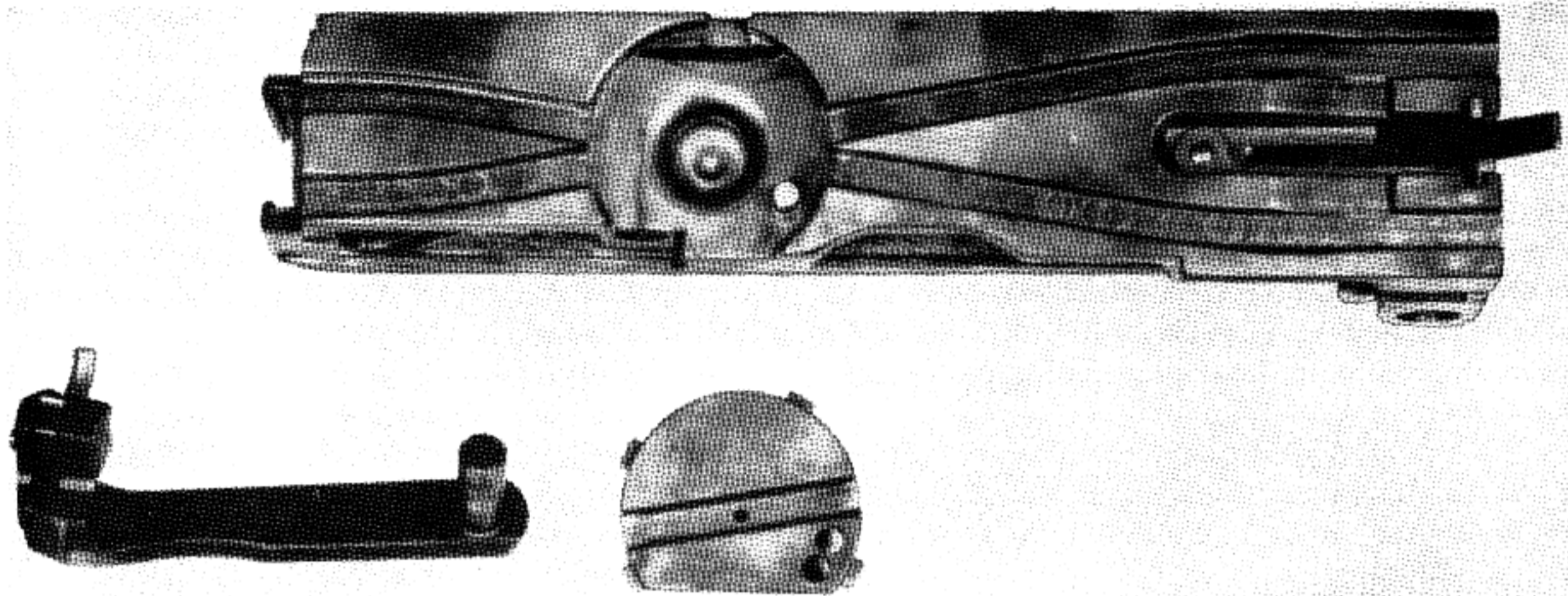


Figure 11-7. Modified parts of Browning Machine Gun, Caliber .50 T25. Lightened bolt and modified bolt switch and extractor.

barrel is screwed. Integral side members extend rearward, terminating in lugs pointing downward and carrying the breechlock. At the rear end is the barrel extension shank, pinned in position between the side members. The shank terminates in a hook and extends rearward to engage a similar hook on the piston rod of the barrel buffer assembly, when assembled. Grooves cut in the inside of the side members of the barrel extension support and form a slideway for the bolt, when assembled. Cuts in the upper inside edges of the side members, and the top of the forward portion into which the barrel is screwed, provide clearance for the extractor assembly of the bolt group when assembled for left- or right-hand feed.

The breechlock slides vertically in grooves in the rear part of the barrel extension and is retained by a pin passing laterally through the breechlock and through elongated holes in the side members of the barrel extension. The barrel-locking spring is staked in an undercut groove in the right side of the extension, at the forward end.

The function of the barrel extension group is to support the rear end of the barrel and maintain its adjustment, with regard to headspace, by means of the barrel locking spring. The extension, in turn, is supported by the breechlock cam in the receiver. The extension also supports the bolt group, forms a slideway for it during operation, and provides a means of locking the bolt to the barrel extension

during firing of the cartridge. The extension shank, engaging with the piston rod of the barrel buffer, operates the piston and compresses the buffer spring on the recoil movement. On counterrecoil movement, this shank is, in turn, forced forward by the expanding spring. The breechlock, acted upon by the breechlock cam on the forward movement of the extension and by the breechlock depressors on the rearward movement, locks and unlocks the bolt with respect to the barrel extension. The extension also acts upon the accelerator in the barrel buffer body group to accelerate the rearward movement of the bolt group.

*Cover Group.* The cover group carries the feeding mechanism of the gun and is operated by the bolt through the medium of the belt feed lever. The group, in general, is composed of the cover, belt feed slide group, cover extractor cam, cover extractor spring, and belt feed lever.

The cover hinges in the trunnion block, pivoting on the cover pin. It is held open by a spring-loaded cover detent seated in the trunnion block, and latched by the cover latch engaging under the top plate when the cover is closed. The cover extractor cam is fastened to the left inner side of the cover. The cover extractor spring is secured beside the cam by means of a headed stud engaging in a slot in the spring, and by an undercut in the cam. The cover latch spring assembled to the right of the extractor spring, by means of a headed stud and slot, holds

the cover extractor spring in position and places spring pressure on the cover latch.

The belt feed lever is pivoted at the middle on a stud in the cover. The forward end engages in a slot in the belt feed slide, and a lug on the rear end engages in one of the two camming grooves in the top of the bolt when the cover is closed. A spring-loaded plunger is housed in one of two wells in the side of the lever and bears on the side plate of the cover to position the lever properly for left- or right-hand feed.

The belt feed slide group contains the belt feed pawl and pawl arm pivoted in the slide, which moves laterally in the guideways in the forward section of the cover and is held in place by a retainer fastened by a pin. The pawl is spring operated by an inner and outer spring seating in the slide and pawl. The pawl arm is positioned on the pawl by a spring-loaded plunger in the pawl, and retains the pawl pin through the medium of a notch in the end of the arm seating in a groove in the pin, when assembled. The slide group and lever may be assembled for either right- or left-hand feed by positioning of parts.

The function of the cover group is to pull the ammunition belt into the gun, position a cartridge in the feed way and assist the extractor of the bolt group to withdraw a cartridge from the belt, position it in the T-slot of the bolt, and guide it into the chamber of the barrel. The belt feed slide is operated laterally by the belt feed lever, which is, in turn, operated by the bolt during recoil and counterrecoil. The rear end of the lever engaging in the diagonal camming groove in the bolt is moved from side to side as the bolt moves backward and forward. This causes the slide, which is engaged with the front end of the lever, to move laterally. The cover extractor cam forces the extractor downward against the extractor switch in the receiver, to guide the cartridge into the T-slot in the bolt when extracted from the belt during the recoil movement of the bolt. The belt feed pawl arm prevents the feed pawl from engaging the ammunition belt to pull it into the feedway should the cartridge awaiting extraction fail to be extracted. In this way jamming is prevented.

*Receiver and Barrel Jacket Group.* The receiver and barrel jacket group consists of the receiver as-

sembly, barrel jacket with recoil booster assembly, and other parts assembled to them. The receiver assembly consists of the trunnion block, two side plates, a bottom plate, top plate, and other parts assembled permanently to them. The trunnion block forms the basic part of the receiver assembly. The side plates are attached to the trunnion block and extend rearward. The top and bottom plates are attached to the side plates.

The barrel jacket with recoil booster assembly contains the breech bearing permanently fastened to the rear end and the recoil booster. The breech bearing screws into the trunnion block to support the jacket when assembled. A recoil booster is screwed into the front end of the jacket. The booster acts as a front barrel bearing and contributes to an increased rate of fire by momentarily confining gas pressure at the muzzle, which accelerates recoil of the barrel and barrel extension group. The breech bearing acts only as a guide for the barrel, which is supported at the rear by the barrel extension into which it threads. The barrel extension is, in turn, supported by the breech lock cam in the receiver. Holes in the barrel jacket provide ventilation to dissipate heat from the barrel when the gun is firing.

A lateral feedway for the ammunition belt is cut into the top of the trunnion block and the front-top of the side plates. At the lower edge of the feedway, right- and left-hand belt holding pawl brackets are riveted to the side plates to support the belt holding pawls and link chute adapter assembly which are secured in the brackets by belt holding pawl pins. The link chute adapter assembly contains the cartridge stops, link stripper, and guide. A hole bored through the side plates and trunnion block acts as a bearing for the front gun trunnion pin when mounting the gun in some installations. Two drilled lugs on the bottom plate act as bearings for the rear trunnion pin. A lateral hole bored through the trunnion block at the top-forward end acts as a bearing for the cover pin.

A trunnion adapter, with a lug drilled to form a bearing for the front trunnion pin in some installations, is threaded onto the front end of the trunnion block lock housed in the trunnion block. Thread qualification is obtained by use of shims of varying thickness. A recoil adapter, which may be used in place of the trunnion adapter in some installations,

is assembled to the trunnion block in a similar manner.

The breech lock cam is fastened to the inner face of the bottom plate by means of a lug on the cam passing through a hole in the plate and secured by a bolt and nut. The cam is grooved at the sides to form a slideway for the barrel extension which it supports. A ramp on the rear end of the cam acts to cam the breech lock upward to lock the bolt during counterrecoil of the barrel and barrel extension.

The top plate bracket is fastened to the underside of the top plate, and forms a bearing surface which engages the upper end of the cocking lever to operate it during recoil and counterrecoil movements of the bolt. (See note following.) A lateral hole through the bracket and left-hand side plate forms a bearing for the trigger bar pin, which acts as a pivot for the trigger bar when used. An adjustable trigger bar stop assembly is fastened to the underside of the top plate to the rear of the bracket, for the purpose of limiting the upward movement of the trigger bar when acted upon by a top plate solenoid. The adjustable stop is positioned on the rear trigger bar stop (pin) riveted into the top plate, and is retained by a screw extending through the top plate cover and top plate, and threaded into the body of the adjustable stop.

NOTE. An improved top plate (bolt-down) bracket has been developed, the lower portion of which is a bearing surface for limiting the upward movement of the bolt. When the bolt is in its rear-most position, it will jump as much as one-eighth of an inch. This bracket is held in place with the trigger bar pin and is easily installed. Clearance between the bolt and the bracket ranges from 0.002 inch to 0.026 inch.

Breech lock depressors are fastened to the inner faces of the side plates. The rear ends of these depressors anchor the front end of the barrel buffer group, when assembled, and the front ends are formed into cams which engage the breech lock pin in the barrel extension to cam down the breech lock and unlock the bolt during recoil.

The extractor switch is pivoted to the inside of the left-hand side plate and is positioned by a threaded stud, nut, and spring. The switch, in conjunction with the cover extractor cam in the cover group, assists the extractor to position the cartridge in the T-slot of the bolt. The extractor cam riveted

to the side plate, just ahead of the switch, raises the extractor near the end of the counterrecoil movement of the bolt, after the cartridge has been started into the chamber.

The purpose of the receiver and barrel jacket group is to house the working mechanism of the gun as well as to act as a support of the fixed parts which contribute to operation. It also acts, through the barrel jacket, to support and protect the barrel.

### Cyclic Functioning

*General.* Cyclic functioning of the caliber .50 basic aircraft machine gun AN-M3 is identical with that of the caliber .50 basic aircraft Browning machine gun AN-M2. The barrel buffer of the gun AN-M3 takes the place of, and functions in the same general manner as, the oil buffer of the gun AN-M2. In the barrel buffer of the gun AN-M3, the washer springs and air compression feature take the place of the oil and valve system of the oil buffer of the gun AN-M2.

The gun AN-M3 may be fired (1) by means of a top plate solenoid acting upon the sear through the medium of a trigger bar or (2) by side plate solenoid, trigger motor, or other device acting upon the sear through the medium of the sear slide. In any case, the functional operation of the gun is the same.

Each time a cartridge is fired, the mechanical action within the gun involves many parts moving simultaneously or in their proper order. The action of these parts and their relationship one to the other can be explained more clearly if each cycle of operation is divided into various phases. These phases, explained in following paragraphs, are: firing; recoiling; counterrecoiling; cocking; automatic firing; feeding; extracting and ejecting.

*Firing.* When the gun has been loaded and the firing pin has been cocked, the firing pin extension engages the sear. The firing mechanism of the gun is ready to be fired by disengaging the sear from the firing pin extension. In this case, the trigger bar will be rotated on its pin to depress the sear by the top plate solenoid when operated.

If the gun is fired by means of a top plate solenoid and trigger bar, the firing pin extension and firing pin are released by actuating the solenoid. When the plunger of the top plate solenoid acts on the trigger bar, which is assembled to the trigger bar

pin assembly, it forces the front end of the trigger bar down to depress the sear. The sear is forced downward until the notch in the sear is disengaged from the shoulder of the firing pin extension. The firing pin and firing pin extension are driven forward by the compressed firing pin spring to fire the cartridge.

If the gun is fired by means of a side plate solenoid, a trigger motor or other device, when actuated, is forced against the sear slide. The sear slide, moving laterally, cams down the sear, and the firing pin is released to fire the cartridge as just explained.

*Recoiling.* The complete cycle of the recoiling parts of the gun, which takes place as each cartridge is fired, consists of the recoil movement when certain parts move rearward and the counterrecoil movement when the same parts move forward. At the instant of firing of the first shot, the barrel, barrel extension, and the bolt (known as the recoiling parts) are in the fully forward or "battery" position in the gun.

At this time, the bolt is locked to the barrel extension and held securely against the rear of the cartridge in the chamber of the barrel by the breech lock, which extends up from the barrel extension into a notch in the underside of the bolt. The breech lock is held up by the breech lock cam upon which it rests.

After the cartridge explodes and as the bullet travels out of the barrel, the force of recoil drives the recoiling parts rearward. During the first five-eighths inch of rearward travel, the breech lock is moved off the breech lock cam step. This permits the breech lock to be forced down out of the notch in the bolt by the breech lock depressors engaging the breech lock pin. This unlocks the bolt from the barrel extension.

As the recoiling parts move toward the rear, the barrel extension bears against the accelerator and rotates it rearward. The tips of the accelerator strike the lower projection on the bolt and accelerate the bolt to the rear.

The barrel and barrel extension have a total rearward travel of  $1\frac{1}{8}$  inches, at which time they are completely stopped by the barrel buffer body.

During this recoil of  $1\frac{1}{8}$  inches, the buffer spring in the barrel buffer is compressed by the rearward movement of the barrel extension, transmitted through the barrel extension shank to the buffer

piston rod with which it is engaged. The spring is held in the compressed position by the barrel extension, locked by the claws of the accelerator which are moved against the shoulders of the barrel extension shank. The buffer spring assists the barrel buffer piston in bringing the barrel extension to rest during the recoil movement.

During recoil, the barrel buffer piston is forced from the forward end of the barrel tube to the rear, compressing the air confined in the tube to the rear of the piston. The piston starts rearward rapidly due to an air port or hole in the wall of the barrel buffer tube within which it moves. The port allows some air in the tube to escape quickly at the start of the rearward movement of the piston. As the piston moves beyond the port, the remaining air in the tube is gradually compressed, thus forming a cushion. As the compression increases, the compressed air escapes into the piston through a spring-operated relief valve in its rear end. The escaped air then passes through the enlarged rod hole in the tube cap. The valve regulates the flow of escaping air so that the rearward movement of the barrel extension and barrel is decelerated gradually. The opening of the relief valve is controlled by a coil spring seated in a retainer in the piston. The retainer is held in place by 10 cupped washer springs assembled in the piston, which bear upon the retainer and the rear face of the piston rod and act as a cushion for the rod at the end of the rearward movement. No terminal shock is transmitted to the buffer piston rod or piston pin due to the elongation of the pin hole in the rod.

The bolt travels rearward, compressing the buffer washer springs in the backplate. During this travel, the driving springs are compressed. The rearward movement of the bolt is finally stopped as the bolt strikes the buffer plate in the backplate. Thus, part of the recoil energy of the bolt is stored in the driving springs, and part is absorbed and stored by the cupped washer springs upon which the buffer plate bears, in the backplate tube. Any remaining recoil energy is transmitted to the recoil adapter of the gun or to the gun mountings.

*Counterrecoiling.* After completion of the recoil movement, the bolt is forced forward by the energy stored in the driving springs and the compressed backplate buffer washer springs. When the bolt has moved forward about  $5\frac{3}{4}$  inches, the projection

on the bottom of the bolt strikes the tips of the accelerator and rotates it forward. This rotation moves the claws of the accelerator away from the shoulders of the barrel extension shank. This releases the barrel buffer spring. The energy stored in the spring, supplemented by the counterrecoil energy of the bolt transmitted through the accelerator, forces the barrel and barrel extension forward.

No restriction to the forward motion of the barrel and barrel extension is desired; therefore, on the forward movement, the air ahead of the piston in the barrel buffer tube is allowed to escape through the enlarged hole in the tube cap through which the piston rod passes. As the piston nears its forward position, the air port in the tube is uncovered, allowing air to enter the rear end of the tube and relieve the vacuum created by the forward movement of the piston.

**NOTE.** Air is permitted to leave and enter the port in the barrel buffer tube through a longitudinal groove in the tube. This groove extends from the port to the rear end of the tube.

As the barrel extension moves forward, the breech lock engages the sloping ramp of the breech lock cam and is forced upward. The bolt, which has been continuing its forward motion since striking the accelerator, has at this instant reached a position where the notch in the underside of the bolt is directly above the breech lock, permitting the breech lock to enter the notch and engage the bolt. Thus, the bolt is locked to the barrel extension just before the recoiling parts reach the firing position.

**Cocking.** The act of cocking the gun begins as the bolt starts to recoil, immediately after firing. As the bolt moves rearward, the tip of the cocking lever, which is in the V slot in the top plate bracket, is forced forward. Since the cocking lever pivots on the cocking lever pin, the lower end, which engages in a slot in the firing pin extension, is forced rearward, thereby pulling the firing pin extension and firing pin rearward and compressing the firing pin spring against the pin of the firing pin spring stop. The shoulder on the rear end of the firing pin extension forces the sear downward, against its spring, and continues to travel rearward until slightly beyond the front face of the notch in the sear. The sear is then immediately forced upward by the sear spring to be in position to engage the shoulder

on the firing pin extension when it starts moving forward again.

During the forward movement of the bolt, in counterrecoil, the tip of the cocking lever again enters the V slot in the top plate bracket and is forced rearward. This action swings the lower end of the cocking lever forward out of engagement with the firing pin extension which moves forward and is engaged and held by the sear. The cocking lever acts as a safety device to prevent the firing pin extension and firing pin, if released prematurely, from moving fully forward to fire the cartridge before the bolt has gone forward sufficiently for the breech lock to be engaged, and thus lock the bolt to the barrel extension. When the recoiling parts are 0.116 inch or less from the fully forward "battery" position, depending on the "timing" of the gun, the gun is ready to fire. If, at this instant, the sear is not depressed, the recoiling parts will assume their fully forward "battery" position and the gun will cease to fire.

**Automatic Firing.** For automatic firing by means of a top plate solenoid, the solenoid must be actuated so that its lever moves and holds the front end of the trigger bar downward. The sear is depressed as it contacts the cam surface of the depressed trigger bar by the forward movement of the bolt near the end of the counterrecoil movement. The depression of the sear releases the firing pin, thus automatically firing the next cartridge. The gun fires automatically as long as the solenoid action is maintained and until the ammunition supply is exhausted.

Automatic firing by means of a side plate solenoid is accomplished in a similar manner. As the bolt nears the end of its counterrecoil movement, the end of the sear slide is contracted by the cam surface of the projecting solenoid plunger and is forced sideways. This lateral movement of the sear slide cams the sear downward, thus releasing the firing pin extension and firing pin to fire the gun.

**Feeding.** The belt feed mechanism is actuated by the bolt. When the bolt is in the forward position, the belt feed slide is entirely within the gun.

A lug on the rear end of the belt feed lever rides in a diagonal cam groove in the top of the bolt. The forward end of the belt feed lever engages in a slot in the belt feed slide to which the belt feed pawl and belt feed pawl arm are attached.

When the bolt is moved rearward, the belt feed lever is pivoted about the belt feed lever pivot stud, and the forward end of the lever moves the slide out of the side of the gun over the ammunition belt, which is held in the gun by the belt holding pawl.

When the bolt moves forward, the belt feed lever is again pivoted and moves the belt feed slide into the gun. By the time the bolt has reached its forward position, the belt feed pawl has pulled a cartridge into the feedway to a central point directly above the chamber of the barrel and against the cartridge stops of the link chute adapter. At this position, the hook of the extractor is in engagement with the rim of the cartridge case. The belt holding pawl has assumed a raised position behind a link of the ammunition belt to prevent the belt from falling out of the gun. Feeding during recoil and counterrecoil is as follows:

1. As the bolt recoils, the extractor withdraws the centered cartridge from the belt, the belt feed slide is moved out over the belt, and the belt feed pawl pivots to ride over the link holding the next cartridge in the belt.

2. At the end of the recoil movement, the travel of the belt feed slide is sufficient to permit the belt feed pawl to snap down behind the link holding the next cartridge in order to pull the belt into the gun. The chambered cartridge has been extracted from the belt.

3. As the bolt moves forward in counterrecoil, the belt is pulled into the gun by the belt feed pawl. The belt holding pawl is forced downward as the belt is pulled over it. As the cartridge is positioned in the feedway, the belt-holding pawl snaps up behind the link holding the next cartridge to keep the belt from falling out of the gun.

**NOTE.** If the cartridge in the feedway awaiting extraction from the belt fails to be extracted as the belt feed slide starts moving out to engage and pull the belt into the gun, the belt feed pawl arm attached to the pawl rides over this unextracted car-

tridge and lifts the pawl so that it cannot engage the belt. This prevents double feeding.

*Extracting and Ejecting.* As recoil starts, a cartridge is drawn from the ammunition belt by the extractor. The empty case is withdrawn from the chamber by the T-slot in the front face of the bolt.

**NOTE.** The empty case, having been expanded by the force of the explosion, fits the chamber very tightly, and the possibility exists of tearing the case if the withdrawal is too rapid. To prevent this and to insure slow initial withdrawal, the top front edge of the breechlock and the front side of the notch in the bolt are beveled. Thus, before the bolt is completely unlocked it has moved slightly away from the rear end of the barrel in a gradual manner.

As the bolt moves to the rear, the cover extractor cam forces the extractor down, causing the cartridge to enter the T-slot in the bolt.

As the extractor is forced down, a lug on the side of the extractor rides against the top of the extractor (side plate) switch on the side plate, causing the switch to pivot downward to the rear. Near the end of the rearward movement of the bolt, the lug on the extractor clears the end of the switch, and the switch snaps up to its normal position.

On the counterrecoil movement, the extractor is forced farther down by the extractor lug riding under the extractor (side plate) switch. This pushes the live cartridge into its correct position in the T-slot. At the same time, the live cartridge moving into place expels the empty cartridge case which has been withdrawn from the chamber. The extractor stop lug on the side of the bolt limits the downward travel of the extractor so that the cartridge, guided by the ejector, enters the chamber of the barrel. When the cartridge is partly chambered, the extractor rides up the extractor cam on the side plate, compresses the cover extractor spring, and is forced down into the extractor groove of the next cartridge in the belt.

**NOTE.** The empty case of the last cartridge fired is forced out of the T-slot by the ejector.

### SECTION 3. DIFFERENCES BETWEEN GUNS AN-M3 AND AN-M2

Although the caliber .50 basic aircraft machine gun AN-M3 is similar in general appearance and functioning to the caliber .50 basic aircraft machine gun AN M2, nearly all components of the AN-M3

gun differ in detail from those of the AN-M2, having been improved in design and metallurgy. Substituting any of the components of the machine gun AN-M3 listed below for similar components of the

machine gun AN-M2 may result in causing malfunctions, breakage of parts, or serious damage to gun or personnel and is therefore not permitted.

The gun AN-M3 differs from the gun AN-M2 as follows:

1. A recoil booster is used for the gun AN-M3 instead of the front barrel bearing.

2. The cover group for the gun AN-M3 differs not only in shape but also in design of parts.

3. The backplate assembly is larger and when assembled to the receiver extends around the side plates. Washer springs (Belleville type) are used in the buffer tube, whereas fiber disks are used in the gun AN-M2.

4. The driving spring rod with springs assembly differs in the outer and inner springs. The head of the driving spring rod with springs assembly for the gun AN-M2 has part of a countersink while the gun AN-M3 has a square shoulder.

5. The cocking lever for the gun AN-M3 has a shoulder to facilitate proper assembly. In addition, the contour of the surface that engages the firing pin extension is slightly different from that for the gun AN-M2.

6. The latest type cocking lever pin for the gun AN-M3 is quite different from the early type pin for the gun AN-M2. It is used only with the modified alternate feed bolt and has two notches for retaining it in the bolt with the cocking lever pin locking pin. The early type cocking lever pin is used with early manufacture alternate feed bolt and the single-track bolt.

7. The sear for the gun AN-M3 differs in shape from the sear for the gun AN-M2. The most noticeable difference is a lug on the bottom of the sear for the gun AN-M3, which is a guide for the sear spring.

8. The sear spring for the gun AN-M3 is larger in diameter than the spring for the gun AN-M2 and has  $4\frac{1}{2}$  coils, whereas the sear spring for the gun AN-M2 has 6 coils.

9. The sear slide for the gun AN-M3 differs from the sear slide for the gun AN-M2 in that it is shorter, does not have a V-shaped notch, and has an elongated hole near the straight end for the sear slide stop pin.

10. A sear slide stop pin is used in the bolt of the gun AN-M3. The gun AN-M2 does not have a sear slide stop pin.

11. A cocking lever pin locking pin and cocking lever pin locking pin spring are used in the modified bolt of the gun AN-M3. The gun AN-M2 does not have these two items.

12. The firing pin for the gun AN-M3 is slightly different in shape from the firing pin for the gun AN-M2. In addition, firing pins for the gun AN-M3 are drilled so that they may be secured to the firing pin extension by a pin.

13. The bolts for the gun AN-M3 are lighter than the bolts for the gun AN-M2.

14. The extractor assembly for the gun AN-M3 has a slightly different shape than that of the extractor assembly for the gun AN-M2. In addition, the ejector must be repositioned to facilitate feeding when the direction of feed is changed to the right-hand side of the gun.

15. A firing pin spring stop is used in the bolt of the gun AN-M3. In the bolt of the gun AN-M2, a sear stop or accelerator stop and accelerator stop lock performs a similar function.

16. The breech lock depressors for the gun AN-M3 are riveted to the inside of the side plates. On the gun AN-M2, the breech lock depressors are riveted to the oil buffer body.

17. The barrel extension for the gun AN-M3 differs from the barrel extension for the gun AN-M2 in that it has additional ejector clearance cuts and different breech lock depressor grooves.

18. The gun AN-M3 has a barrel buffer assembly which contains Belleville washer springs and utilizes air as a buffer, whereas the gun AN-M2 uses oil as a buffer.

19. The accelerator for the gun AN-M3 differs from the accelerator for the gun AN-M2 in that the slot for the barrel buffer tube lock and two cuts on the edges are eliminated.

20. The barrel buffer body assembly for the gun AN-M3 differs from that for the gun AN-M2 in that the slot for the barrel buffer tube lock is not milled out due to the elimination of the barrel buffer tube lock.

21. The extractor (side plate) switch for the gun AN-M3 is shorter than the switch for the gun AN-M2. In addition, the camming surfaces are different.

22. The extractor (side plate) switch spring for the gun AN-M3 is shorter than the switch spring for the gun AN-M2.



23. The breech lock cam for the gun AN-M3 has a rounded surface at the top of the camming stop, whereas this point on the breech lock cam for the gun AN-M2 is sharp.

24. A link chute adapter assembly is used on the gun AN-M3 in place of the front and rear cartridge stops and link stripper on the gun AN-M2 when ammunition belt is fed from the right-hand side;

and the front cartridge stop assembly when ammunition is fed from the left-hand side.

25. A bolt holddown bracket is installed in the gun AN-M3. No similar component is used in the gun AN-M2.

26. Charging devices are not furnished with the gun AN-M3. Either a retracting slide or operating slide is furnished with the gun AN-M2.

## SECTION 4. BROWNING MACHINE GUN CALIBER .50 M2

### Description of the Browning Machine Gun, Caliber .50 M2 Aircraft, Basic

This is a highly efficient automatic weapon built to precision standards. It is air-cooled and may be fed from either the right or left side. It may be mounted on either a rigid or flexible mount. Manual cocking and loading of the gun is necessary before it is ready to function automatically. Then it may be fired by a mechanical or electrical accessory or by a manual trigger and trigger bar. While firing, all mechanical action is automatically performed by the gun itself.

The receiver and barrel jacket form the main exterior portions of the gun, and in gun operations are stationary or nonrecoiling.

The backplate is assembled to the rear of the receiver, forming an end cover.

The driving spring runs lengthwise of the gun with one end resting against the backplate. The bolt group is housed in the upper forward portion of the receiver, and slides backward and forward during operation.

The oil buffer body and oil buffer group are contained in the lower rear portion of the receiver. The bolt slides over the top of the oil buffer body during the back portion of the stroke.

The barrel extension is screwed onto the breech end of the barrel to form a single unit, and the barrel slides inside of the barrel jacket. Thus the normal position of the barrel extension is in the lower forward portion of the receiver. The bolt slides in grooves of the barrel extension.

The cover and belt feed group is hinged at its forward end to the top front portion of the receiver.

Single cartridges or rounds are first assembled into a series of nested links. This forms a flexible ammunition belt with a single unused link trailing on

one end and a double used link on the other. The double link end is fed into the gun.

*Backplate Group.* The backplate, besides enclosing the back end of the receiver, also houses the final bolt recoil cushioning parts. It also acts as a stop for the oil buffer group. The plate slides downward into grooves in the receiver side plates and is latched in place with a latch and latch lock.

Assembled and compressed into the projecting cylindrical portion is a stack of lightly greased fiber disks which are headed on the forward end by the buffer plate. The final movement of the bolt is stopped by the fiber disks as the bolt strikes this buffer plate, and these disks assist in starting the forward movement.

Although the back end of the driving spring group is retained during assembly by inserting the driving spring rod retaining pin into a hole in the receiver, in actual operation the force of the spring is counteracted by the backplate.

The backplate furnished with the basic gun is intended for fixed mount, remote firing applications. If the gun is to be used in a flexible manner, the necessary handle and manual trigger parts are added. An auxiliary filler piece is supplied with the basic gun to close the opening provided for a manual trigger.

*Bolt Group (Alternate Feed).* The bolt group holds the cartridge firmly in the chamber when it is fired; it withdraws the empty case and ejects; it extracts a fresh cartridge from the belt and inserts it in the chamber; it actuates the belt feed mechanism. The sear mechanism, when actuated by a trigger, trips the cocked firing pin, causing the gun to fire.

The sear, which moves vertically in the back end of the bolt, may be depressed by pushing down on

the small protrusion which extends up beyond the top of the bolt. When a manual trigger is supplied, the sear is depressed in this manner by means of the trigger bar in the top of the receiver. The downward motion of the sear unhooks or releases the firing pin extension. This extension, along with the firing pin, snaps forward under the action of the cocked or compressed firing pin spring, and the tip

of the firing pin protrudes from the front end of the bolt, thus striking the cartridge primer.

The sear may also be actuated by side pressure on the end of the sear slide. This slide may be assembled either right or left hand, and suitable openings in both side plates of the receiver permit the gun to be fired from either the right or left side. The necessary pressure may be supplied by electrical (sole-

Comparative Data: Browning Caliber .50 M2 Gun

Characteristic	Browning caliber .50 M2 gun		
	Basic	Heavy barrel	Water cooled
Gun length (inches).....	56.125.....	65.125.....	65.93.
Gun weight (pounds).....	61.....	81.....	121.5 (with water). 100.5 (without water)
Rate of fire (rounds/minute).....	750-850.....	400-500.....	600-750.
Muzzle velocity:			
feet/second.....	2,845.....	2,935.....	2,935.
miles/hour.....	1,940.....	2,000.....	2,000.
System of operation.....	Short recoil.....	Short recoil.....	Short recoil.
System of locking.....	Rising block.....	Rising block.....	Rising block.
System of feeding.....	Bolt actuated.....	Bolt actuated.....	Bolt actuated.
Method of headspace.....	Rotation of band.....	Rotation of band.....	Rotation of band.
Location of feed opening.....	Right and left side (top).....	Right and left side (top).....	Right and left side (top).
Location of ejection opening.....	Bottom of receiver.....	Bottom of receiver.....	Bottom of receiver.
Method of charging.....	Manual, hydraulic, or air.....	Manual, hydraulic, or air.....	Manual, hydraulic, or air.
Method of cooling.....	Air.....	Air.....	Air.
Barrel length (inches).....	36.....	45.....	45.
Barrel weight (pounds).....	10.....	27.4.....	16.
Rate control.....	Muzzle booster can be installed.	Drain oil buffer.....	Drain oil buffer.
Barrel removal.....	Quick disconnect.....	Quick disconnect.....	Quick disconnect.
Bore:			
Number of grooves.....	8.....	8.....	8.
Groove depth.....	0.015.....	0.015.....	0.015.
Groove width.....	0.110.....	0.110.....	0.110.
Pitch.....	1 turn in 15 inches.....	1 turn in 15 inches.....	1 turn in 15 inches.
Direction of twist.....	Right hand.....	Right hand.....	Right hand.
Form of twist.....	Constant.....	Constant.....	Constant.
Number of lands.....	8.....	8.....	8.
Weight of bullet:			
Grains.....	712.....		
Ounces.....	1.62.....		
Weight of powder charge:			
Grains.....	250.....		
Ounces.....	0.57.....		
Weight of cartridge (ounces).....	4.20.....		
Weight of 100 cartridges in metallic links (pounds).....	30.25.....		
Maximum range:			
Yards.....	7,200.....	7,600.....	7,600.
Miles.....	4.1.....	4.3.....	4.3.

noid) means or by a cable attachment which fastens to the side plate.

Although the sear is constantly being forced upward by the sear spring, it is retained in its slot by the sear slide. The sear stop pin projects downward through the body of the bolt to act as a stop for the firing pin spring.

The cocking lever, which at its lower end engages with a slot in the firing pin extension, has its top end projecting above the bolt. This top end engages with a cam in the top plate bracket of the receiver to cock the firing pin.

The top surface of the bolt has two diagonal ways or grooves which act as cams to actuate the belt feed mechanism in the cover. The bolt switch fits into the circular depression on top of the bolt and may be assembled to make one or the other of these two ways continuous, the selection depending on whether ammunition will be fed from the right or left side.

The extractor which fits into a circular hole on the left-hand side of the bolt, withdraws a cartridge from the belt and places it in the T-slot at the front end of the bolt. The extractor stop pin stops the extractor in its downward swing on the counter-recoil stroke.

The ejector is fastened to the end of the extractor, and helps to position a new cartridge in the feedway when ammunition is being fed from the right-hand side. It also guides a new cartridge into the chamber, and pushes the last empty case out of the T-slot.

A driving spring assembly fits into a lengthwise hole in the bolt, and is compressed by the rearward motion of the bolt. After the bolt recoil has been stopped by the backplate, the spring drives the bolt forward. This assembly actually has two springs, one nested inside the other, and both are slipped over a rod with suitable end retaining parts.

*Barrel and Barrel Extension Group.* The function of the barrel is to direct the discharged projectile. The rifling, or grooving, causes the projectile to rotate and maintain direction and prevent tumbling.

The barrel is of one piece, threaded at the rear, or breech end, to screw into the barrel extension. Although the barrel tapers toward the front, or muzzle end, the last portion is ground straight so as to permit it to slide in the front bearing of the

barrel jacket. A chamber is formed in the barrel at the breech end which has the exact contour of the cartridge. A series of notches, or serrations, is formed in the rear cylindrical outer surface. When the barrel is screwed into the barrel extension, one end of the barrel locking spring fits into these serrations to prevent any change in the degree of engagement between the barrel and barrel extension during firing. Should adjustment be necessary, it can readily be made against the tension of the barrel locking spring.

The barrel extension has lengthwise grooves in which the bolt rides, and, further, it houses the breech lock. The breech lock serves to lock the bolt to the barrel extension during and after firing.

Fastened to the back end of the barrel extension is the barrel extension shank which engages the oil buffer. The shank is fastened very securely into the extension by a pin.

*Oil Buffer Body and Oil Buffer Group.* On the recoil, or rearward, stroke of the barrel extension, the breech lock pin is engaged by the breech lock depressors which are riveted to the oil buffer body. The depressors cause the breech lock to unlock the bolt from the barrel extension.

The accelerator is assembled into the forward portion of the oil buffer body. On the recoil stroke, it assists in driving the bolt to the rear. During the rearward or recoil stroke, the claws on the accelerator bear against the shoulders on the barrel extension shank, thus locking and preventing the barrel extension from moving forward on the counter-recoil stroke until the bolt strikes and moves the accelerator forward. Thus the locking movement of the breech lock is timed so as to bring the lock up exactly when the notch in the bolt is in position.

The tube lock assembly which fits in a groove in the bottom of the oil buffer body exerts pressure against the bottom of the accelerator to keep it in the locked position until released by the bolt. The tube lock latch fits into the circular opening in the tube lock slot to prevent the tube lock assembly from moving rearward on the oil buffer body. This insures that the tube lock assembly will hold the accelerator firmly in the locked position, thus permitting the bolt to pass over the accelerator without interference until the back lug on the bolt actually strikes the accelerator. The projection on the other end of the tube lock assembly fits into the serrations

on the oil buffer tube, thereby preventing a change in the rate of fire by locking the tube securely.

The oil buffer group absorbs and partially stores the recoil energy of the barrel and barrel extension during the recoil stroke. It acts as a shock absorber. Most of the energy is absorbed and dissipated by the piston moving through the oil in the tube and the rest is absorbed and stored in the spring, to be used later in driving the barrel and barrel extension forward. The degree of oil leakage across the piston—which can be adjusted manually—on the recoil stroke controls the rate of fire.

Because of the greater weight of the barrel of the heavy barrel gun, its rearward motion is not nearly so rapid; therefore, there is less energy to dissipate. Accordingly, the oil and some of the parts are omitted from the oil buffer assembly.

The piston rod head may slide but it is prevented from rotating by the guide key seating in the slot in the oil buffer body. The piston valve may be rotated to change the leakage aperture at the edge of the piston by turning the oil buffer tube against restraining action of the tube lock assembly in the tube serrations.

A relief valve in the oil buffer tube cap permits some oil to escape on the initial recoil stroke as the piston rod crowds into the oil-filled tube. It also allows for oil expansion due to temperature rise.

*Receiver and Barrel Jacket Group.* The receiver is probably the most important portion of the gun since it is the "backbone," or main strength member. As such, it includes the mountings by which the gun is supported. In addition, it forms a strong, accurate housing to protect and position the working parts of the gun. It also contains a part of, and supports the remainder of, the ammunition feeding mechanism. It is further utilized to support the various types of trigger mechanisms which are necessary for the different services to which the basic gun may be adapted (fixed mounting, remote firing as in airplane wing installations; or flexible mounting, manual trigger as in tanks). The barrel jacket is supported by the receiver.

The receiver is made of two steel side plates riveted at their forward portion to a trunnion block, with top and bottom plates riveted to the side plates toward the rear. On top at the extreme forward portion of the receiver a trunnion block cover pro-

TECTS the sight grooves until such time as a sight is installed.

Directly below the trunnion block cover is a detent pawl which meshes with the cover to retain same in one of three open, or raised, positions. The top front of the receiver is open to permit access to the bolt and belt feed mechanism.

Riveted to the underside of the top plate is the top plate bracket which supports the trigger bar pin on which the trigger bar pivots. The trigger bar is assembled in all caliber .50 basic guns even though some applications which demand firing from remote position do not use this piece. Front and rear trigger bar stops are also provided. The top plate bracket has suitable cams for engaging the cocking lever of the bolt. Riveted to the underside of the top plate is the bolt latch bracket which, although part of all basic guns, is used only on those applications which require single-shot guns.

The rear of the receiver is slotted to receive the backplate.

The bottom plate carries the breech lock cam which because of a machined shoulder "floats" slightly when bolted down. The breech lock cam forces the breech lock up into the bolt recess, acts as a forward stop for the oil buffer body, and has grooves, or ways, in which the barrel extension rides.

The bottom front portion of the receiver is open to permit empty cartridge cases to be ejected.

A switch is pivoted on the inside of the left side plate, with a hairpin spring recessed in the plate under the switch.

The front end of the receiver is formed by the trunnion block which is threaded to fit into the trunnion adapter. A suitable shim is inserted between the trunnion block and adapter so that the adapter when screwed on tightly will position to line up with the other mountings.

The side plates are notched at the top front portion so that a cartridge belt may be fed into the gun from either side. At these notches the belt holding pawl brackets are riveted to each side plate. These brackets support the belt holding pawl and the cartridge stops, and are so built that parts may be assembled on either right or left side to permit feeding ammunition from either the right or left side. The link stripper and rear cartridge stop are used for right-hand feed only. The rear right-hand cartridge stop assembly is used for left-hand feed only.

The cartridge alining pawl, which is part of this cartridge stop assembly, helps to position a cartridge in the feedway when ammunition is being fed from the left-hand side.

The barrel jacket is perforated to permit air to blow through onto the barrel for cooling purposes. The jacket is stationary and prevents any object from interfering or rubbing against the barrel, which must move during firing. It screws into the trunnion and is locked in place with a small setscrew. The front barrel bearing is screwed into the front end of the barrel jacket and is locked in place with two small screws.

*Cover and Belt Feed Group.* The cover permits access to the bolt and to the feeding mechanism, some parts of which are located in the feedway and some on the underside of the cover.

The front, or hinge, end of the cover is serrated so that it may be retained in one of several open positions. A latch is built into the cover so as to lock it securely to the receiver. This latch may be assembled right or left hand, depending on the type of slide used.

Operating in a crosswise groove on the underside of the cover is the belt-feed slide. This is actuated by the belt-feed lever, one end of which rides in the ways on top of the bolt. The belt-feed slide carries the belt-feed pawl which on each stroke snaps over a new cartridge and pulls it into position so that it may be extracted from the belt. The pawl, slide, and lever may be repositioned to change the direction of feed. In the event that the extractor fails to extract a cartridge from the belt, the belt-feed pawl arm prevents damage to parts by holding the belt-feed pawl up so that it cannot engage the next cartridge in the belt.

The cover extractor cam is riveted to the underside of the cover. This cam forces the extractor and new cartridge downward as the belt travels toward the rear. The cover extractor spring, which is also assembled to the underside of the cover, limits the upward movement of the extractor during the final forward motion of the bolt.

### Functioning of the Browning Machine Gun, Caliber .50, M2

Although this gun is an automatic weapon, it is necessary to cock it manually to start the operating sequence. Assume that the gun is cocked and that

the first cartridge is in its firing position in a chamber in the rear portion of the gun barrel. When any cartridge is fired, the burning powder violently generates gas which, since it is confined by the cartridge case and barrel, exerts a tremendous pressure. This pressure reaches 50,000 pounds per square inch, and since this pressure pushes against the back face of the bullet, which up to this moment is still within the cartridge case and which has a diameter of one-half inch, a driving force of 5 tons pushes the bullet out of the barrel. This same force tries to drive the cartridge case out of the chamber toward the rear. Such action is prevented by having the bolt positively locked against the rear of the cartridge at the instant of firing.

When the cartridge is fired, the force of recoil carries the barrel, barrel extension, and bolt (known as the recoiling portion) backward a short distance. This motion unlocks the bolt from the barrel and barrel extension, and the bolt throws back farther toward the rear against a spring. This spring serves to drive the bolt forward again. The empty case is withdrawn by the bolt from the barrel chamber, and the next cartridge is extracted from the supply belt.

The long rearward motion of the bolt is checked; and, as it surges forward, the empty case is ejected and the next cartridge is moved into the barrel chamber. The short rearward motion of the barrel and barrel extension is checked by the oil buffer and its spring; this buffer spring serves to drive them forward again. This motion locks the bolt to the barrel extension, thus again preventing the case from being driven toward the rear. The last forward motion of the bolt and barrel causes the firing pin to strike the cartridge, providing a means of releasing the sear is furnished. This cycle continues as long as trigger action is maintained and as long as ammunition is supplied.

In the description of the detailed functioning of the caliber .50 Browning machine gun which follows, it is assumed that, first, the ammunition belt has been properly started into the gun and the cover has been closed and latched, second, the gun has been manually cocked and a cartridge is in its proper position in the chamber and ready to be fired, and, third, a manual trigger and trigger bar are to be used to fire the gun.

Each time a cartridge is fired, the mechanical action within the gun involves many parts moving simultaneously or in their proper order. To gain a working knowledge of the operation of these parts and their relationship to each other, the action has been separated into various phases.

These are described in the following order: firing; recoiling; counterrecoiling; cocking; automatic firing; feeding; extracting and ejecting.

*Firing.* When the gun has been loaded and the firing pin spring has been cocked or compressed manually, the gun is ready to fire.

When the trigger is pressed, it raises the back end of the trigger bar. The trigger bar pivots on the trigger bar pin, causing the front end to press down on the top of the sear. The sear is forced down until the notch in the sear is disengaged from the shoulder of the firing-pin extension. The firing pin and firing-pin extension are driven forward by the firing-pin spring to fire the cartridge.

*Recoiling.* The complete cycle of the recoiling portion of the gun, which takes place as each cartridge is fired, consists of the recoil stroke (when certain parts of the gun move rearward) and the counterrecoil stroke (when these same parts move forward). At the instant of firing, the barrel, barrel extension, and bolt, known as the recoiling portion, are in the forward position in the gun.

At this time, the bolt is held securely against the base of the cartridge by the breech lock, which extends up from the barrel extension into a notch in the underside of the bolt.

After the cartridge explodes and as the bullet travels out of the barrel, the force of recoil drives the recoiling portion rearward. During the first three-fourths inch of travel, the breech lock is pushed back off the breech lock cam step. This permits the breech lock to be forced down out of the notch in the bolt by the breech lock depressors engaging the breech-lock pin. This unlocks the bolt.

As the recoiling portion moves toward the rear, the barrel extension rolls the accelerator rearward. The top of the accelerator strikes the lower projection on the bolt and hastens, or accelerates, the bolt to the rear.

The barrel and barrel extension have a total rearward travel of  $1\frac{1}{8}$  inches, at which time they are completely stopped by the oil buffer body assembly.

During this recoil of  $1\frac{1}{8}$  inches, the oil buffer spring is compressed in the oil buffer body by the barrel extension shank. The spring is locked in the compressed position by the claws of the accelerator which are moved against the shoulders of the barrel extension shank.

The oil buffer assembly and the spring bring the barrel and barrel extension to rest after a recoil stroke of  $1\frac{1}{8}$  inches. The piston-rod head is forced from the front end of the oil buffer tube to the rear end. The oil at the rear of the tube, under pressure of the piston, escapes to the front. Its only path is through the valve-restricted notches between the edge of the piston-rod head and the oil buffer tube.

The recoiling portion of the heavy barrel gun, being heavier, moves rearward with less speed so it is easier to bring it to rest. Consequently, the oil and some of the parts are omitted.

The bolt travels rearward for a total of  $7\frac{1}{8}$  inches. During this travel, the two nested driving springs are compressed. The rearward stroke of the bolt is finally stopped as the bolt strikes the buffer plate. Thus, part of the recoil energy of the bolt is stored in the driving springs and the remainder is absorbed by the buffer disks in the backplate.

*Counterrecoiling.* After completion of the recoil stroke, the bolt is forced forward by the energy stored in the driving spring and the compressed buffer disks.

When the bolt has moved forward about 5 inches, the top of the accelerator is struck by a projection on the bottom of the bolt. This rolls the accelerator forward.

As the accelerator rolls forward, the accelerator claws are moved away from the shoulders of the barrel extension shank. This releases the oil-buffer spring. The energy stored in the spring shoves the barrel extension and barrel forward.

No restriction to motion is desired on the counterrecoil stroke. The piston-rod head moves away from the valve, thereby uncovering six additional ports in the head. Not only does the oil escape through the 2 notches at the edge of the head but also through the 6 additional ports in the head. It then flows through the opening at the center of the valve and also through the 2 valve notches at the edge. The oil and valve are omitted in the heavy barrel gun.

As the barrel extension moves forward the breech lock engages the breech-lock cam and is forced up-

ward. The bolt, which has been continuing its forward motion since striking the accelerator, has at this instant reached a position where the notch on the underside is directly above the breech lock, thus permitting the breech lock to engage the bolt. The bolt is thereby locked to the barrel extension just before the recoiling portion reaches the firing position.

*Cocking.* The act of cocking the gun is begun as the bolt starts to recoil immediately after firing. Thus the tip of the cocking lever which is in the V-slot in the top plate bracket is forced forward.

The cocking lever is pivoted so that the lower end forces the firing-pin extension rearward. The firing-pin spring is thus compressed against the sear stop pin. The shoulder at the back end of the firing-pin extension is hooked over the notch at the bottom of the sear under pressure of the sear spring.

During the forward motion of the bolt, the top of the cocking lever enters the V-slot of the top plate bracket. This action swings the bottom of the cocking lever out of the path of the firing-pin extension, thus permitting the firing pin to snap forward to fire the cartridge.

When the recoiling portion is almost in the forward position, the gun is ready to fire. If no trigger action is given at this instant, the recoiling portion assumes its final forward position, and the gun ceases to fire.

*Automatic Firing.* For automatic firing, the trigger is pressed and held down. The sear is depressed as its tip is carried against the cam surface of the trigger bar by the forward movement of the bolt near the end of the counterrecoil stroke. The notch in the bottom of the sear releases the firing-pin extension and the firing pin, thus automatically firing the next cartridge at the completion of the forward stroke. The gun fires automatically as long as trigger action is maintained and until the ammunition supply is exhausted.

*Feeding.* The belt-feed mechanism is actuated by the bolt. When the bolt is in the forward position, the belt-feed slide is within the confines of the gun. A stud at the rear of the belt-feed lever is engaged in one of the diagonal grooves, or ways, in the top of the bolt.

As the bolt moves rearward during recoil, the belt-feed lever is pivoted. The forward end of the

belt-feed lever moves the belt-feed slide out of the side of the gun and over the ammunition belt.

The ammunition belt is pulled into the gun by the belt-feed pawl, which is attached to the belt-feed slide.

When the bolt is forward, the belt-feed pawl has positioned a cartridge directly above the chamber. The belt-holding pawl is in a raised position to prevent the ammunition belt from falling out of the gun.

As the bolt recoils, the belt-feed slide is moved out over the belt, and the belt-feed pawl pivots so as to ride over the next cartridge.

At the end of the recoil stroke, the travel of the belt-feed slide is sufficient to permit the belt-feed pawl to snap down behind the next cartridge in order to pull the belt into the gun.

As the bolt moves forward on the counterrecoil stroke, the belt is pulled into the gun by the belt-feed pawl. The belt-holding pawl is forced downward as the cartridge is pulled over it. When the forward stroke of the bolt is completed, the belt-holding pawl snaps up behind the cartridge.

*Extracting and Ejecting.* As recoil starts, a cartridge is drawn from the ammunition belt by the extractor. The empty case is withdrawn from the chamber by the T-slot in the front face of the bolt.

The empty case, having been expanded by the force of explosion, fits the chamber very snugly and the possibility exists of tearing the case if the withdrawal is too rapid. To prevent this and to insure slow initial withdrawal, the top, front edge of the breech lock and front side of the notch in the bolt are beveled. Thus, as the breech lock is disengaged, the bolt moves away from the barrel and barrel extension in a gradual manner.

As the bolt moves to the rear, the cover extractor cam forces the extractor down, causing the cartridge to enter the T-slot in the bolt.

As the extractor is forced down, a lug on the side of the extractor rides against the top of the switch causing the switch to pivot downward at the rear. Near the end of the rearward movement of the bolt, the lug on the extractor overrides the end of the switch, and the switch snaps up to its normal position.

On counterrecoil, the extractor and cartridge are forced farther downward by the extractor lug riding on the under side of the switch. The cartridge pushes the empty case out of the T-slot. The extrac-

tor stop pin in the bolt limits the downward travel of the extractor so that the cartridge, assisted by the curvature of the ejector, enters the chamber. (The ejector also ejects the last empty case.) When the cartridge is practically chambered the extractor rides up on the extractor cam, compresses the cover extractor spring, and snaps into the groove in the next cartridge in the belt.

### Heavy Barrel, M2 Gun

The Browning machine gun, caliber .50 HB, M2 is an air-cooled gun for ground use, having a much heavier barrel than has the aircraft gun.

The gun is normally fired in short bursts or in rapid single shots, and when used in this manner firing may be continued for an appreciable length of time because the heavy barrel retards overheating.

In place of the barrel jacket assembly on the aircraft gun, this gun uses a short, perforated barrel support. The trunnion adapter of the aircraft gun is not used. The heavy barrel is removed from the gun by unscrewing it from the barrel extension and withdrawing it toward the front. This permits removing a hot barrel and installing a cool one without disassembling the remaining mechanism of the gun. The handle assembly is used for carrying the gun or as a means of turning the barrel when assembling, disassembling, or adjusting the headspace. It is moved to one side or down when the gun is being fired.

**CAUTION.** Disengage handle before turning so that headspace adjustment will not be altered.

The firing mechanism is modified somewhat from that included with the aircraft gun. A bolt latch is provided to permit the gun to be fired semiautomatically. It also serves to hold the bolt to the rear in order to keep the cartridge out of the hot chamber when firing has been suspended.

The bolt latch is forced downward by the bolt latch plunger spring. As the bolt reaches its rearward position, the bolt latch engages a notch on the upper rear surface of the bolt and holds the bolt to the rear, thus causing the gun to cease firing. The counterrecoil stroke is completed by pressing down on the bolt latch release which is pivoted in the backplate. This raises the bolt latch from the bolt notch and allows counterrecoil to take place. Providing a cartridge is in the chamber, firing will be resumed

when trigger action is supplied. If the bolt latch release is held down manually or if it is locked down by the lock on the buffer tube sleeve, the gun will fire automatically. However, if the bolt latch release is pressed down but not retained in that position, the gun will fire only once when trigger action is given.

The backplate spade grip assembly is similar to that used on the aircraft gun except for the addition of the buffer tube sleeve assembly and the bolt latch release and spring.

Since the recoiling portion is much heavier than in the aircraft gun, its rearward motion is not quite so rapid; therefore, it is unnecessary to have as much restriction in the oil buffer on the recoil stroke. Accordingly, the oil buffer piston valve, the gland packing, gland washer, gland spring, relief valve plus screw and spring, and oil are omitted from the heavy barrel gun.

With these exceptions and a few changes in the accessories supplied, such as front and rear sights, the heavy barrel gun is identical with the aircraft gun.

### Water-Cooled, M2 Gun

The Browning machine gun, caliber .50, M2, water-cooled, has a water jacket surrounding the barrel for the purpose of preventing barrel overheating when firing for prolonged periods.

The water jacket contains 10 quarts of water and is kept filled by a hand pump for an auxiliary water chest which has a capacity of about 8 gallons. During firing, heat absorbed from the barrel changes some of the water to steam. This is removed from the jacket with the water, which is returned through the jacket outlet to the water chest.

As in the aircraft gun, the barrel recoils. The water jacket, however, is stationary since it is screwed onto the trunnion block.

Thus packing glands must be provided near the breech and muzzle ends of the barrel to prevent water from escaping from the jacket where the barrel slides in and out of the jacket.

With these exceptions and a few changes in the accessories supplied, such as front and rear sights, the water-cooled gun is identical with the aircraft gun.



## SECTION 5. CALIBER .50 T27 SERIES

## Development and Tests

Currently with the development of the T22E6 gun, an attempt was made by the High Standard Manufacturing Co., to provide a kit of parts which could be used to convert the standard M2 gun to a high-speed weapon. The designation given this gun was caliber .50 T27E7. Experiments for the purpose of producing this high-speed weapon were carried on under the series No. T27. The first two guns

of this series were submitted to Aberdeen Proving Ground for test 1 January 1944. The tests of both guns were discontinued before the completion of the usual 5,000 rounds.

Over the next 14 months, Aberdeen Proving Ground carried on a program of testing and improving the T27. Eighteen guns designated as indicated in the accompanying table were tested. The results are summarized in the table.

Gun	Date tested	Rounds fired	Cyclic rate	Malfunctions	Breakages
T27.....	1 Jan 44	4,000	1,150	11	8
T27.....	do.....	1,200	1,140	<sup>1</sup> 6	.....
T27E1.....	15 Feb 44	2,400	1,150	6	11
T27E1.....	do.....	1,200	.....	( <sup>2</sup> )	.....
T27E3.....	6 Mar 44	5,000	1,150	10	8
T27E3.....	do.....	5,000	.....	( <sup>3</sup> )	14
T27E4.....	5 Apr 44	3,600	1,330	9	10
T27E5.....	27 Jun 44	2,100	1,100	( <sup>4</sup> )	.....
T27E5.....	do.....	400	1,030	( <sup>4</sup> )	.....
T27E5.....	do.....	1,600	1,057	( <sup>2</sup> )	.....
T27E6.....	8 Feb 45	5,000	1,078	5	1
T27E6.....	do.....	5,000	1,170	11	1
T27E6.....	do.....	5,000	1,000	1	0
T27E6.....	do.....	5,000	1,050	1	1
T27E7.....	20 Mar 45	5,000	1,259	0	3
T27E7.....	do.....	5,000	1,204	0	6
T27E7.....	do.....	5,000	1,148	0	2
T27E7.....	do.....	4,000	1,107	0	7

<sup>1</sup> Test stopped.

<sup>2</sup> Gun blew up.

<sup>3</sup> Numerous.

<sup>4</sup> Excessive - test stopped.

This table indicates that only guns giving an acceptable performance were fired at cyclic rates approximating 1,000 rounds per minute and were not true high-speed guns. In addition, during the firing and during an informative test at Wright Field, a total of three barrel jackets ruptured and damaged their guns; and in one test at Aberdeen, a backplate was blown from the gun. The unsatisfactory performance obtained, coupled with the possible danger to personnel and equipment by breakage or fail-

ure of the gun components, was responsible for the decision reached in March 1945 that no further consideration be given to this weapon.

The kit of parts used to convert the standard M2 gun to the T27E7 gun consisted of the following:

1. Bolt stabilizer. To stabilize bolt and depress extractor at end of recoil.
2. Muzzle booster. To increase cyclic rate.
3. Side plate switch. Stronger spring and changed contour.

4. Special extractor. No ejector used.
5. Special bolt, with spring clips. To position round in T-slot to take the place of the ejector.
6. Split holding pawls. To improve feeding conditions.

7. Rubber plug for backplate buffer. To replace fiber discs.

In addition to the installation of the above components, the oil was removed from the oil buffer to increase further the cyclic rate.

## SECTION 6. CALIBER .50 T34

### Development

In April 1944, projects were placed at the Springfield Armory for the development of a 1,200 rounds-per-minute and a 1,500 rounds-per-minute caliber .50 aircraft machine gun. Some progress was made in the design of the 1,200 rounds-per-minute gun, designated T28, and two guns were made and tested. However, at the time of completion of these guns the early standardization of the M3 (T26E3) gun was anticipated, and it was decided to discontinue

this project and to concentrate available personnel on the development of the 1,500 rounds-per-minute gun, which was designated T34.

This was to be an entirely new mechanism, operating on a principle suitable for very high-speed operation. Preliminary drawings of this gun were received in August 1945, and after careful study, the Springfield Armory was requested to supply additional drawings and information to make possible an appraisal of the potentialities of the mechanism.

## SECTION 7. CALIBER .50 M2A1 (T36)

### Objectives of Caliber .50 Machine Gun M2A1 (T36) Program

During the development of a high-speed caliber .50 machine gun, certain valuable improvements were made which were applicable to the standard M2 caliber .50 aircraft gun. In September 1944, it was decided to incorporate immediately into the M2 gun these features which had been proven in tests of various experimental high-speed guns. This improved gun, designated T36, was designed to accomplish limited objectives, compared to the M2 gun, namely:

1. Reduction in recurrent malfunctions.
2. Increase in cyclic rate of approximately 100 rounds per minute.
3. Increase in belt lift capacity to 30 pounds minimum.

Changes in the M2 gun were held to the minimum consistent with the accomplishment of these objectives.

### Objectives of Caliber .50 Machine Gun T37 Program

The T37 gun was to conform in general to the M2 gun with the inclusion of the following new components and changes.

1. T22E6 top cover assembly.
2. T22E6 split belt holding pawl assembly.
3. T22E6 recoil booster.
4. Oil removed from oil buffer.
5. T22E6 extractor assembly.
6. Accelerator stop assembly.
7. Present cocking lever with improved metallurgy.
8. T25E3 cover extractor cam.
9. T25E3 side plate switch and spring.
10. Stellite lined barrel.

### Test and Evaluation of the T36

Four T36 machine guns were given endurance tests of 5,000 rounds each during September 1944 at the Aberdeen Proving Ground. These guns were

## Comparative Data: Caliber .50 Machine Guns T36 and T25E3

Characteristic	Caliber .50 machine guns	
	T36	T25E3
Gun length, overall.....inches	57.25	58.25.
Gun length, overall, operating slide extended.....do	66.5	66.5.
Weight of basic gun, including bolt handle and cartridge stop.....pounds	62	62.
Rate of fire.....rounds/minute	850-950	1,200.
Muzzle velocity.....feet/second		2,730-3,450.
System of operation.....	Short recoil.	Short recoil.
System of locking.....		Rising block.
System of feeding.....	Disintegrating link belt.	Disintegrating link belt.
Method of headspace.....	Rotation of barrel.....	Rotation of barrel.
Location of feed opening.....	Top (right or left) of receiver.....	Top (right or left) of receiver.
Location of ejection opening.....	Bottom of receiver.....	Bottom of receiver.
Method of charging.....	Hydraulic, air, or manual.....	Hydraulic, air, or manual.
Method of cooling.....	Air.....	Air.
Barrel length.....inches	36	36.
Barrel weight.....pounds	9.8	9.8.
Rate control.....		None.
Barrel removal.....	Quick disconnect by unscrewing.	Quick disconnect by unscrewing.
Bore:		
Number of grooves.....	8	8.
Groove depth.....inches		0.015.
Groove width.....do		0.110.
Direction of twist.....	Right hand.....	Right hand.
Pitch.....	1 turn in 15 inches.....	1 turn in 15 inches.
Form of twist.....		Constant.
Weight of accessories:		
Operating slide group assembly.....pounds	1.62	
Retracting slide group assembly.....do	3.13	3.13.
Backplate with spade grips.....do	3.88	
Fixed backplate, included in weight of basic gun pounds.....	2.56	5.68.
Capacity for feeding device.....	As desired.....	As desired.
Sights.....	Not furnished by Ordnance Department.	Not furnished by Ordnance Department.
Force applied to sear.....pounds	10-20	10-20.
Force applied to sear slide.....do	30-35	30-35.
Maximum number of rounds which can be fired consecutively without cook-off before cooling.....	150	150.
Average accuracy life.....rounds	5,000	5,000.
Maximum range.....yards		5,350-7,275.

fired from the P38 airplane nose under strictly controlled conditions representative of the actual air-

craft installation. The test results are summarized in the accompanying table.

	Gun No.			
	146914	1605231	1605233	1605234
Average cyclic rate.....rounds/minute..	901	913	921	920
Breakages.....	2	1	None	None
Belt lift, maximum.....pounds..	35+	35+	35+	35+
Number of rounds fired.....	5,000	5,000	5,000	5,000
Malfunctions.....	None	None	None	1 link jam

Additional T36 guns were submitted to the Army Air Force and the Navy Bureau of Ordnance for evaluation.

### Procurement and Standardization of the M2A1 (T36)

On 12 October 1944, Ordnance Committee action was taken to authorize the limited procurement of 31,336 of the T36 guns. This procurement was discontinued after approximately 8,000 guns had

been produced because of the unexpected progress made in the development of the T25E3 high-speed gun, which led to its standardization as the M3 earlier than had been thought possible. Following the standardization of the M3 gun, the T36 gun was reclassified as Limited Standard, and redesignated Gun, Machine, Browning, Caliber .50, M2A1, Aircraft, Basic. No further procurement of these guns is anticipated.

## SECTION 8. CALIBER .50 T38

### Development

In June 1945, Ordnance Committee action was taken to authorize the requirement for a 1,500 rounds-per-minute caliber .50 machine gun. Subsequent to this authorization in July 1945, a contract was placed with the Frigidaire division to

provide for a continuation of the development of the M3 (T25E3) gun in an effort to increase its cyclic rate to 1,500 rounds per minute. Limited firing has been conducted on this gun, designated T38, at cyclic rates of 1,450 to 1,500 rounds per minute, but the development has not progressed sufficiently to permit an evaluation of the weapon.

## SECTION 9. CALIBER .50 T42

The development of a caliber .50 heavy barrel machine gun having increased muzzle velocity and rate of fire was initiated to provide antiaircraft guns superior to the caliber .50 M2HB gun. The gun, designated the T42, was developed primarily for the T133 mount. Eight caliber .50 M3 aircraft guns were converted to T42 heavy barrel guns by adapting them for 20-pound barrels. Rate of fire on a rigid test stand was 750 rounds per minute, and functioning was generally satisfactory. Development work was conducted by Crane to provide a

barrel having the required life, and the Springfield Armory conducted gun development work.

The Office of Assistant Chief of Staff, G4, Department of the Army, advised that T42 gun development was not to be terminated with the T133 mount development.

Four T42 guns with spare barrels and flash hiders were requested for the Army Field Forces Board at Fort Knox, and these guns were readied for test firing.

The Ordnance Corps was also advised that improvements were desired for caliber .50 M2 heavy barrel guns to render them more satisfactory for use in tanks. Improvements desired were simplified headspace and backplate adjustment, improved charger, and improved functioning at high angles of elevation. Test firing had been conducted to determine permissible headspace variations. A contract was placed for charger development, and test firing was conducted at Aberdeen Proving Ground on the M46 tank post mount from 13° depression to 70° elevation at ambient temperatures. No stoppages were charged to the guns due to elevated firing, and the rate of fire increased from increasing gun elevations. Stoppages were charged to ammunition hanging up on the ammunition box holder and ORDTT was advised of the installation modification used by Aberdeen Proving Ground to eliminate this stoppage.

At the request of Army Field Forces, 4 caliber .50 M3 aircraft guns were furnished the board at Fort Knox. Flash hidiers were also sent along for test. The Ordnance Corps was advised of the requirement for a new tank machine gun. The characteristics included a short receiver, a high and low rate of fire selectivity, and feedway location to the rear of the receiver.

The T42 guns and barrels and flash hidiers were test fired at Springfield Armory and at Aberdeen Proving Ground. Guns were then made available to AFF Board No. 2 for evaluation purposes. Firing tests were conducted with the M2HB gun at various elevations on the M46 tank post mount during 1950 and 1951 trials. Prototype chargers were also supplied for tests, and an additional contract was placed for charger development. Headspace simplification work was continued and an investigation was carried on to determine whether the adjustment could be eliminated. Facilities were selected and work initiated for the new tank gun.

## SECTION 10. CALIBER .50 MACHINE GUN AS MODIFIED BY THE BOEING AIRCRAFT CORPORATION

### Research Preceding Work on the Modified Gun

The Boeing Aircraft Corp. engineers attempted a modification of the caliber .50 machine gun that was the most unusual of all modifications attempted during World War II. Subsequent to research and observation of field conditions, they came to the following conclusions:

1. It is considered feasible to produce a more compact caliber .50 gun utilizing certain standard M2 parts.

2. Improvements in the characteristics of the M2 gun have resulted in two experimental models designated as the T25 and T36 caliber .50 machine guns. These guns are experimental in nature and while they are better weapons in many respects, they do not offer the advantages of a gun designed for aircraft use.

3. Rather than continue with the M2 gun as a basis, it is believed desirable to produce a gun more suitable for aircraft installations. The objectives for the new design would be:

(a) Produce a more compact gun.

(b) Increase firing rate to minimum of 1,200 rounds per minute.

(c) Eliminate muzzle flash and reduce blast.

(d) Provide improved integral mounting.

(e) Eliminate danger of cooked-off rounds.

(f) Improve cooling so that sustained bursts may be fired.

(g) Provide integral heating where required.

(h) Provide integral gun charging.

(i) Provide integral electrical and mechanical firing.

(j) Eliminate stoppages from short rounds.

(k) Improve ammunition feeding system.

### Objectives in Modifying the M2 Gun Used in 1945-46

The primary objective was to produce a weapon more compact and satisfactory than the M2 used in 1945-46. A secondary consideration was to use as many standard parts as possible so as to effect economy should the results of the study prove worthwhile.

In a comparison of the standard M2 gun and the modified version discussed here, several features are of particular interest:

1. The holdback feature, designed to eliminate the danger of cook-offs. This device was to be used with a solenoid operated plunger or a double sear as in the British Vickers machine guns.

2. The absence of the recoil buffer from the backplate, an improvement long desired, since even with the M2 it would effect a reduction in overall length.

3. The backplate on the modified gun was designed to contain the mechanism for mechanical and electrical firing and adjustment of the firing time. This change was in contrast to the existing M2 gun, which had several different types of solenoids all of which accomplished electrical firing but greatly increased the overall clearances required for the gun from the service as well as installation standpoint.

4. The addition of a gun charger. The position decided on did not increase the overall width or depth of the gun. The disadvantage was an increase in drag for certain installations in aircraft; however, since the use of a gun charger is many times optional, a conventional charger could readily be installed in the conventional manner.

5. A comparison of the assemblies of the modified gun with the parts of the M2 reveals that the important items suitable for use were very few, namely:

- (a) Oil buffer assembly.
- (b) Barrel and barrel front bearing.
- (c) Barrel jacket.
- (d) Ammunition feed guides and certain parts of ammunition feed mechanism.

Those portions of the gun that would have to be redesigned were principally:

- (a) Bolt assembly (including holdback).
- (b) Recoil buffer(s).
- (c) Backplate including firing mechanism.
- (d) Bolt accelerator.
- (e) Cover plate and feed lever.
- (f) Receiver.
- (g) Barrel extension.

While it was realized that continued study of modifying the M2 gun would result in a number of improvements, the fact still remained that the product would not be entirely suitable for aircraft installations. Good examples of such an effort are

two experimental models of the M2 gun. Neither development reduces the size or incorporates other features considered desirable. With these guns, the T25 and T36, there remained still much to be desired. Basically they are the old infantry guns that require the addition of many parts as recoil adapters, firing solenoids, charges, etc., before they are suitable as aircraft weapons.

It was concluded, therefore, that additional effort should be directed toward the development of a caliber .50 gun specifically for aircraft work. The new development should include all the desirable features of the M2, T25 and T36, in addition to having certain mechanisms built into the gun as standard components. For the purpose of clarifying the desirability of investigating a new gun design, the following objectives were established:

1. Produce a more compact gun. In the case of either fixed guns or powered turrets, a considerable saving in space and/or decrease in drag would result if the guns were shorter in length. In certain installations where virtually muzzle mounting would be used, the space saving within the fuselage would be considerable.

2. Increase in rate of fire. The desirability and necessity for increasing the rate of fire becomes more important as the speed of enemy aircraft becomes greater, and as a consequence on target time becomes less.

3. Eliminate muzzle flash and reduce blast. These features are secondary but important for certain types of installations and personnel distribution.

4. Improve integral mounting. The stress problems involved in mounting the M2 gun with its galaxy of recoil adapters would be simplified and resultant reduction of reaction loads very worthwhile, also boresighting and harmonizing operations could be improved.

5. Eliminate danger from cook-off rounds. This feature becomes important as the necessity for longer bursts is increased. Remote control devices contribute to the firing of lengthy bursts, thus increasing the hazards from cooked-off rounds. The solution involves the use of holdback solenoid for the bolt or the development of a double sear for the firing mechanism.

6. Improved cooling. An increase in gun cooling, as differentiated from cooked-off rounds, will

maintain good ballistics after prolonged bursts and will permit shorter intervals between bursts.

7. Provide integral heating. The feature may not be necessary depending upon the final design. If a bolt and oil buffer combination similar to the M2 is used, some type of heating must be provided. Compact and efficient electrical heaters should be designed as an integral part of the gun. The M2 gun provides an interesting cooling-heating complex in that the area that should be cooled is exactly adjacent to the area that must be heated and to date no satisfactory solution has been found.

8. Gun charging. It is desirable to have an efficient gun charger built into the gun. The current practice of having available several chargers has led to considerable confusion. Each charger seems to be for a specific job, therefore a charger built into the gun should suffice for all installations.

9. Integral electrical and mechanical firing. These features should be a part of the gun, thus eliminating the addition of any one of a number of devices to accomplish firing. The inclusion of such

a mechanism as a part of the gun would also improve the setting of firing time.

10. Elimination of stoppages due to short rounds. The presence of short rounds will always be a possibility with the current ammunition design and use of metallic disintegrating links. In automatic firing guns using a remote ammunition supply, short rounds have caused a fair share of gun stoppages.

11. Ammunition feed improvements. Consideration should be given to a complete redesign of the ammunition feed system. The M2 gun because of basic design and lack of improvement handles the ammunition through a series of steps that are time consuming and critical from the possibility of contributing to jams. It is contemplated that the feed system should be direct and that the ammunition will be brought into the gun in nearly the same plane as the bore axis. Ammunition alignment, short rounds, extraction, and link ejection can be simplified to a considerable degree, thus effecting improved operation.

## SECTION 11. JAPANESE BROWNING GUNS

In the United States, during World War II, the development of the Browning short recoil action was limited to calibers up to .50, although the Browning long recoil type was manufactured in 37-mm bore. As a matter of interest, it should be noted that the

Japanese thought so highly of the short recoil action that they adapted it to large calibers. Their 20-mm Browning gun was in very extensive use in the Pacific war. The action was also made in 30-mm and 37-mm sizes.

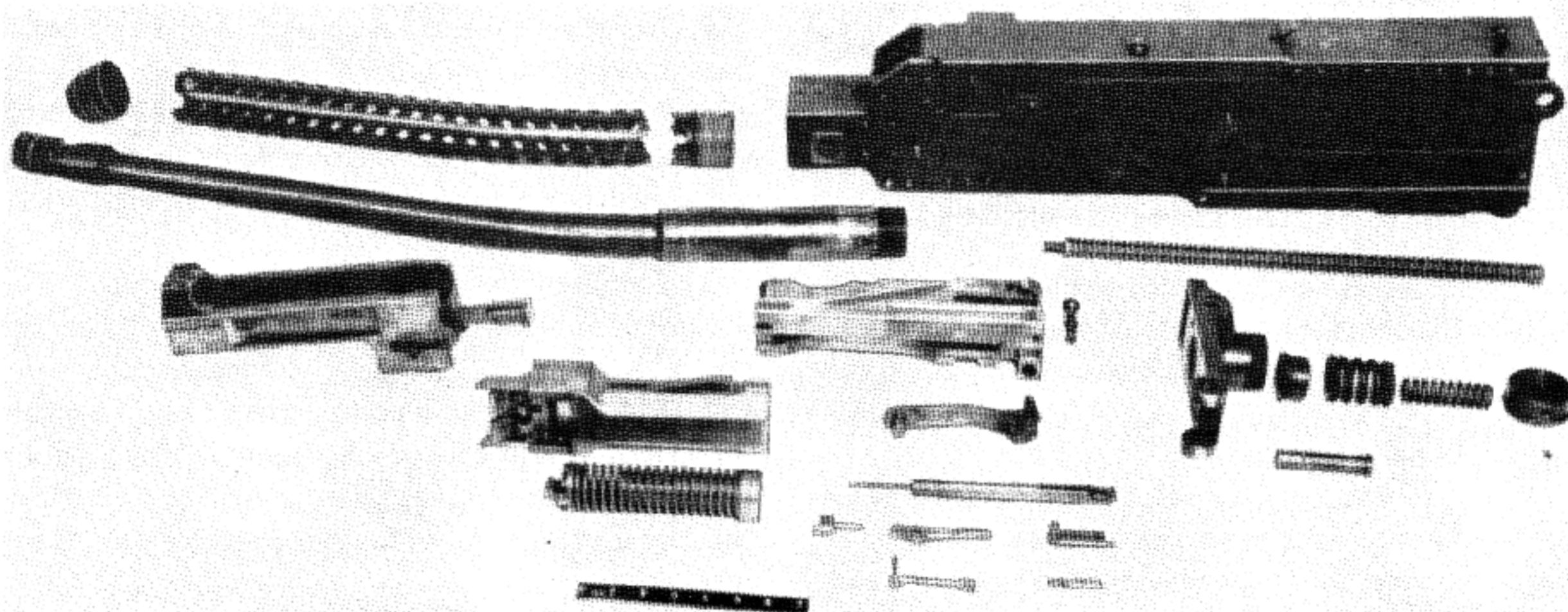


Figure 11-8. Japanese 20-mm Browning Aircraft Cannon HO-5B.

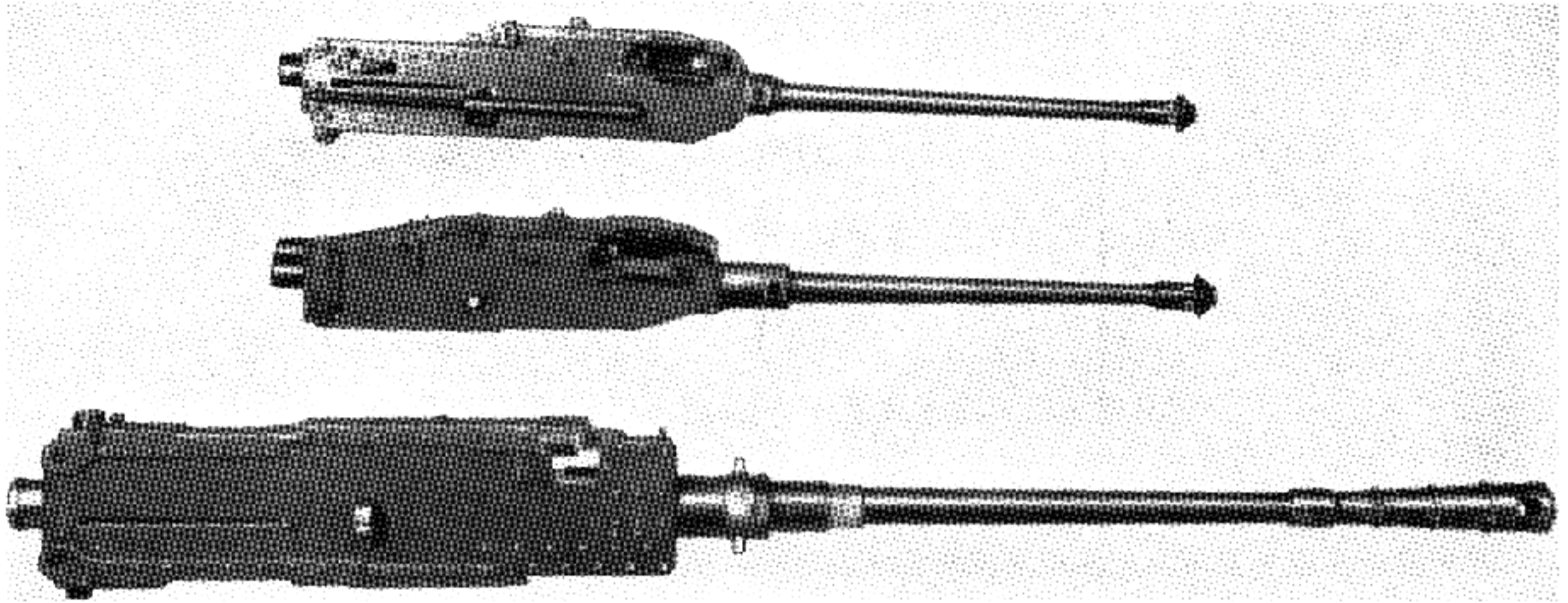


Figure 11-9. Japanese Browning Aircraft Cannon. Top, HO-155 Type 1, 30-mm; center, HO-155 Type 2, 30-mm; bottom, HO-204, 37-mm.



## Chapter 12

**BROWNING 37-MM AIRCRAFT  
AUTOMATIC CANNON****SECTION 1. HISTORY AND BACKGROUND**

The first Browning 37-mm aircraft cannon was designed in the 1920's by John M. Browning. Shortly after successful demonstrations of the prototype had been held, interest in all military weapons in the United States became apathetic; and interest in the 37-mm cannon did not revive until 1935, when the Air Force needed an automatic gun of large caliber for aircraft. The history of this gun, known as the M4, and of the full-automatic, high-velocity 37-mm automatic cannon M9, is discussed in volume 1 of *The Machine Gun* (pp. 531-536).

The M9 was basically the same as the M1A2 in general overall appearance, and the functioning of

its parts was very similar. The M9 was used primarily to attack mechanized ground forces, a purpose for which characteristics of ammunition for the M4 were inadequate.

The M9 had a muzzle velocity of 3,000 feet per second with approximately the same cyclic rate (140 rounds per minute) as the 37-mm gun M4, which had a muzzle velocity of 2,000 feet per second. It could be fed from either the right or left side by disintegrating belt links.

The standard 37-mm M4 gun was fed by an endless belt magazine from the left side only, but to satisfy the requirements of the Army Air Force it was



Figure 12-1. 37-mm Browning Gun M4 mounted in a P39F aircraft to fire through the propeller hub.

necessary to provide for its feeding also from the right. Five additional endless belt magazines were developed because of variations in the installation requirements of different airplanes. This constituted an additional disadvantage to the already existing disadvantages of size, weight, and magazine capacity, making it evident, early in 1942, that as long as an endless belt type was used with 37-mm automatic gun M4, it would be necessary to have a different magazine for each new type of airplane in which the gun was to be mounted. Accordingly, since a requirement still existed for a gun with the characteristics of the M4, the Ordnance Corps initiated a development program to modify this weapon so that it would be fed by a disintegrating link belt from either the right or the left side.

The result of this development was standardized as 37-mm automatic gun M10. This gun fired at a rate of 25 to 30 shots faster than the M4 (165 as against 140 rounds per minute), and, because of the disintegrating link belt used, it was possible to carry

in the P-63 airplane 28 additional rounds for each gun, a total of 56 additional rounds of 37-mm ammunition.

To increase aerial firepower further, a new development was initiated to step up the cyclic rate of 37-mm guns to at least 400 rounds per minute, while maintaining a muzzle velocity of 3,000 feet per second and firing a family of matched projectiles of improved ballistic characteristics. Four facilities made preliminary studies, from which the belt design was to be selected for further development.

These 37-mm guns were full automatic weapons of the long recoil type, especially designed for aircraft and for use of belted ammunition. They could be mounted to fire through the hub of the propeller shaft, or they could be mounted at some point outside the plane of propeller rotation, but they could not be used as synchronized weapons. They were fired by means of a remotely controlled electric solenoid mounted at the rear of each gun.

SECTION 2. COMPARATIVE DATA

Component	Component differences		
	M4	M9	M10
Loading handle.....	Cam and base assembly on feedbox.	On feedbox cover.....	Assembly replaced by loading slide with cable connection for manual loading.
Recuperator.....	None.....	Positioned rearward of the socket extends upward at 21° angle.	None.
Side plates.....	Without longitudinal rib.	Heavy longitudinal rib...	Four tapped holes to attach manual charger.
Backplate.....	Cylindrical portion inside gun between side plates.	Cylindrical portion outside gun.	Top of adjustment screw recessed. Longer plunger.
Trunnion block.....	Notches on outer flange.	No notches on the flange. Held by two screws to trunnion block.	Pressed in from front end of trunnion block body.
Tube splines and flats....	Neither.....	Splines on muzzle end of tube.	Splines on muzzle end of tube.
Feedbox and feed mechanism.		For disintegrating link belt. Boxes and mechanisms changeable for right or left feeding.	For disintegrating link belt. Boxes and mechanisms changeable for right or left feeding.

Comparative Data: 37-mm Automatic Guns, M4, M9, and M10

Characteristic	M4	M9	M10
Gun length, overall . . . . . inches . . . . .	89.5 . . . . .	104 . . . . .	89.57.
Gun weight, without mount and accessories pounds . . . . .	213 . . . . .	405 . . . . .	231.
Rate of fire (average) . . . . . rounds/minute . . . . .	140 to 150 . . . . .	140 . . . . .	150 to 165.
Muzzle velocity (HE shell) . . . . . feet/second . . . . .	2,000 . . . . .	2,600 . . . . .	2,000.
Muzzle velocity (AP shell) . . . . . do . . . . .	1,825 . . . . .	2,800 to 3,050 . . . . .	1,825.
Weight of projectile (HE) . . . . . pounds . . . . .	1.34 . . . . .	1.34 . . . . .	1.34.
Weight of projectile (AP) . . . . . do . . . . .	1.66 . . . . .	1.92 or 1.66 . . . . .	1.66.
System of operation . . . . .	Long recoil . . . . .	Long recoil . . . . .	Long recoil.
Type of recoil operation . . . . .	Automatic . . . . .	Automatic . . . . .	Automatic.
Length of recoil . . . . . inches . . . . .	9 $\frac{3}{8}$ . . . . .	10 $\frac{3}{4}$ . . . . .	9 $\frac{3}{4}$ .
Recuperator oil capacity . . . . . ounces . . . . .	42 . . . . .	72 . . . . .	42.
System of locking . . . . .	Vertical rising wedge . . . . .	Vertical sliding wedge . . . . .	Vertical rising wedge.
System of feeding . . . . .	Recoil actuated . . . . .	Recoil actuated . . . . .	Recoil actuated.
Method of headspace . . . . .	Not adjustable . . . . .	Factory set . . . . .	Not adjustable.
Location of feed opening . . . . .	Top of receiver either right or left hand.	Top of receiver either right or left hand.	Top of receiver either right or left hand.
Location of ejection opening . . . . .	Bottom of receiver . . . . .	Bottom of receiver . . . . .	Bottom of receiver.
Method of charging . . . . .	Hydraulic, air or manual . . . . .	Hydraulic, air or manual . . . . .	Hydraulic.
Method of cooling . . . . .	Air . . . . .	Air . . . . .	Air.
Barrel length . . . . . inches . . . . .	65 . . . . .	78 . . . . .	65.
Barrel weight . . . . . pounds . . . . .	55 . . . . .	120 . . . . .	57.5.
Rate control . . . . .	None . . . . .	None . . . . .	None.
Barrel removal . . . . .	Can be removed readily . . . . .	Can be removed readily but not designed for field replacement.	Can be removed easily.
Bore:			
Number of grooves . . . . .	12 . . . . .	12 . . . . .	12.
Groove depth . . . . . inches . . . . .	0.020 . . . . .	0.020 . . . . .	0.020.
Groove width . . . . . do . . . . .	0.2314 . . . . .	0.2314 . . . . .	0.2314.
Pitch . . . . .	1.48 turns in 65 inches . . . . .	1.56 turns in 78 inches . . . . .	1.48 turns in 65 inches.
Direction of twist . . . . .	Right hand . . . . .	Right hand . . . . .	Right hand.
Form of twist . . . . .	Constant . . . . .	Constant . . . . .	Constant.
Width of lands . . . . . inches . . . . .	0.150 . . . . .	0.150 . . . . .	0.150.
Number of turns rifling in tube, approxi- mately . . . . .	1.48 . . . . .	1.56 . . . . .	1.48.

## SECTION 3. 37-MM AUTOMATIC GUN M4

Functioning of 37-mm Automatic Guns  
M4 and M10

The 37-mm automatic guns M4 and M10, designed for use in aircraft, were equipped to use belted ammunition. The M4 gun was fed from the left side, employing the M6 magazine. The M10 gun was fed by a disintegrating metallic empty belt. Empty links were ejected through an opening in the opposite side of the feedbox. Empty cartridge cases were ejected through a longitudinal opening in the bottom of the feedbox, between the trunnion block side plates.

This type of gun depends upon a long movement of the recoiling portions for its operation. The series of operations and motions of the various parts of the gun occur in a definite and interrelated sequence. Each part receives its motion from some other part, and each functions in a definite and specific moment of the entire cycle. There are as many as 165 cycles a minute.

The trunnion block assembly houses the gun. In addition to providing for mounting the gun, it supports the operating mechanism, which consists of the tube and tube extension, recuperator group,

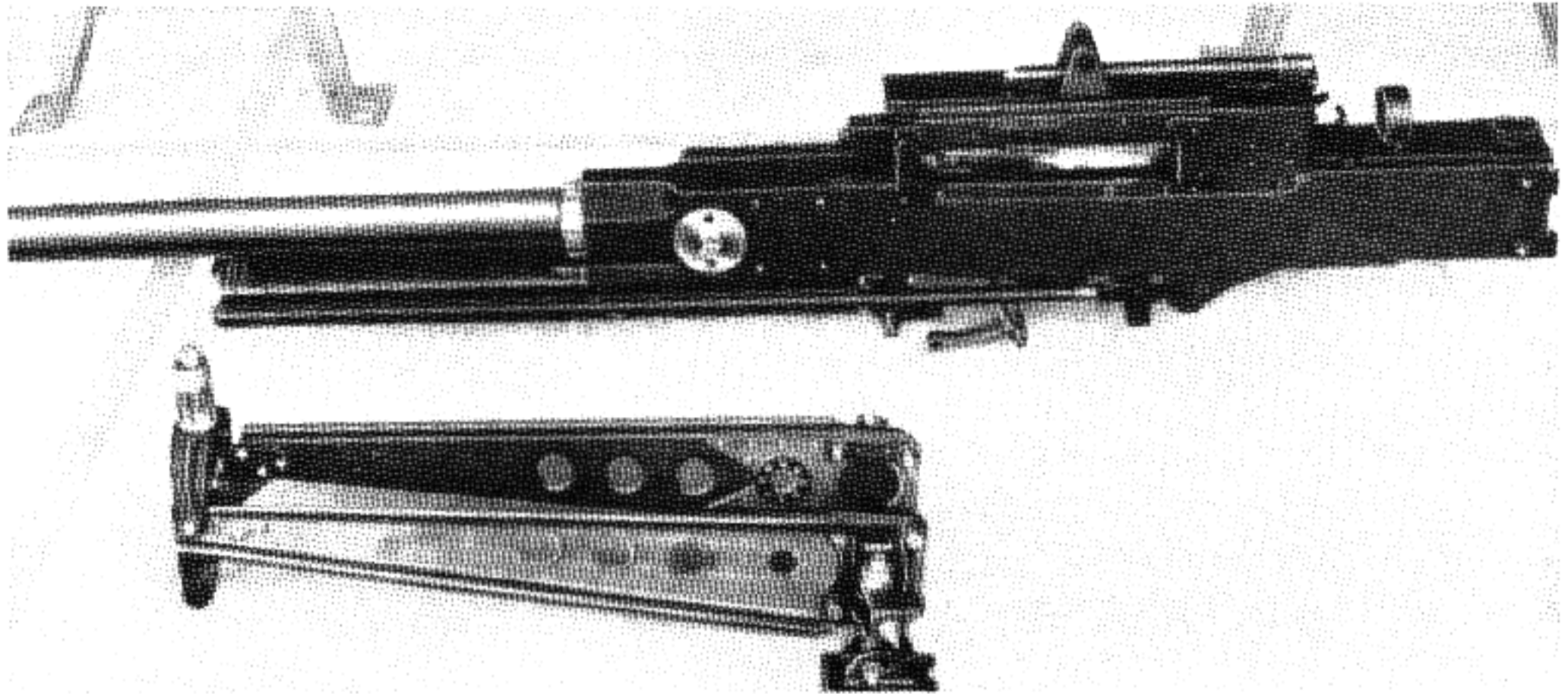


Figure 12-2. 37-mm Browning Gun M4. Left side view.

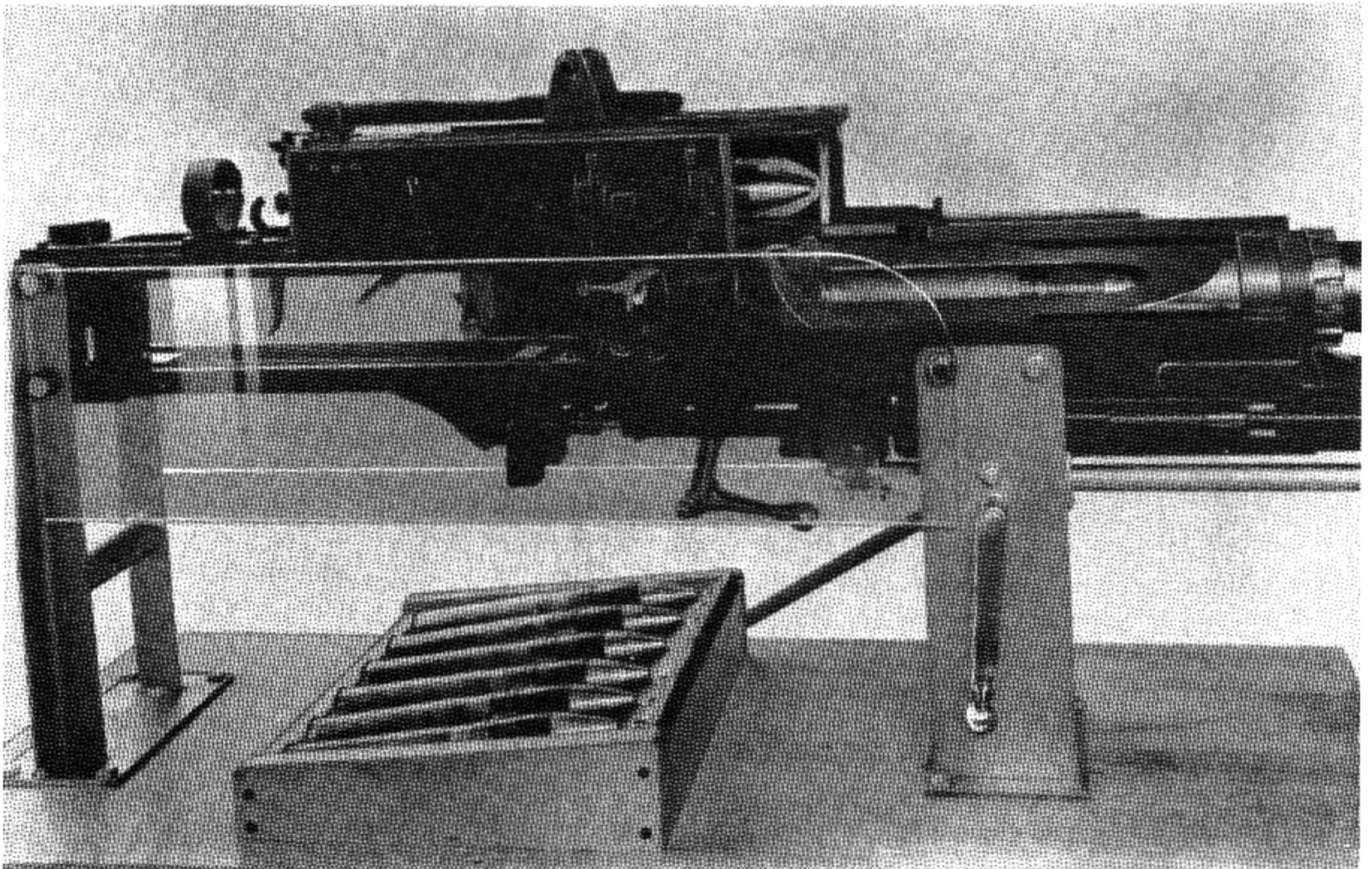


Figure 12-3. Cutaway demonstration model of 37-mm Browning Gun M4.

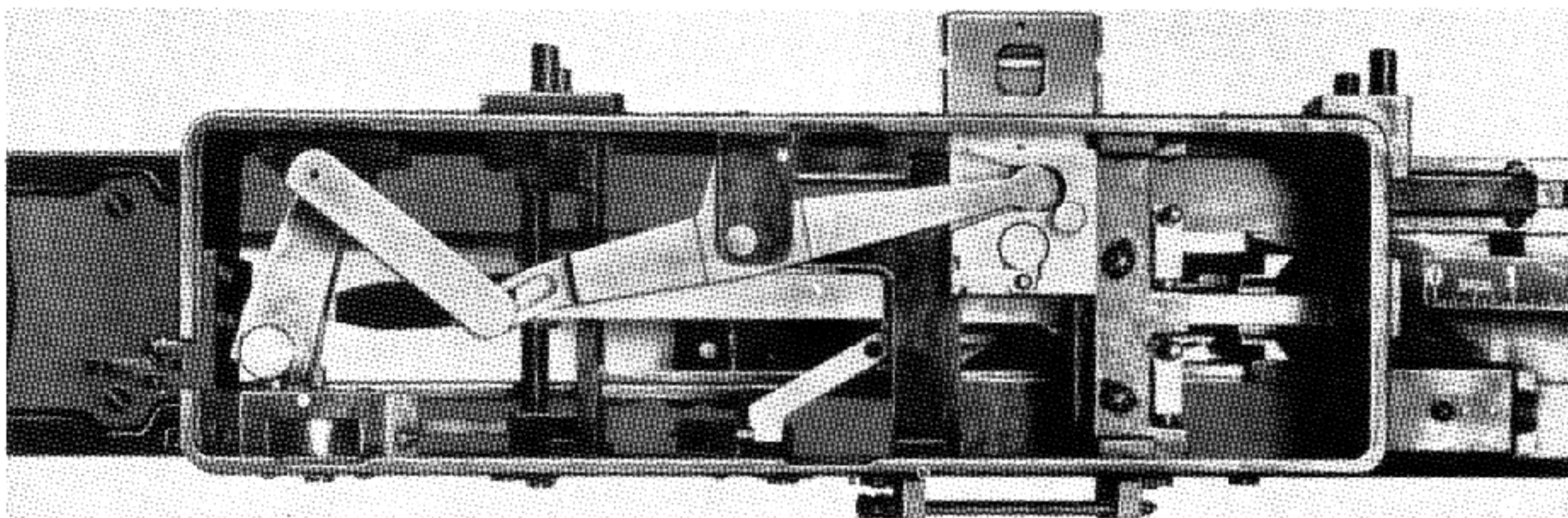


Figure 12-4. 37-mm Browning Gun M4 with cover removed. Top view.

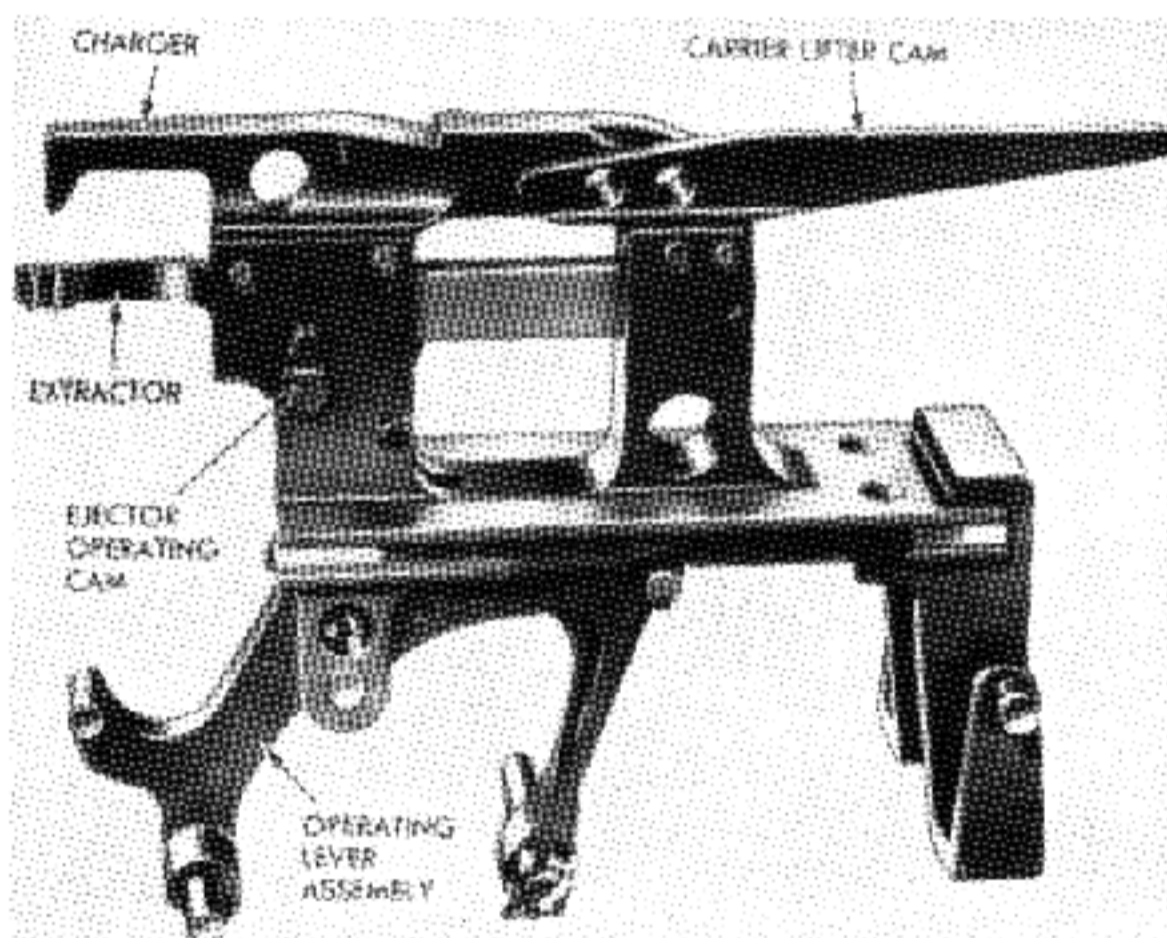


Figure 12-5. The lock frame assembly of the 37-mm Browning gun. The operating lever is retracted.

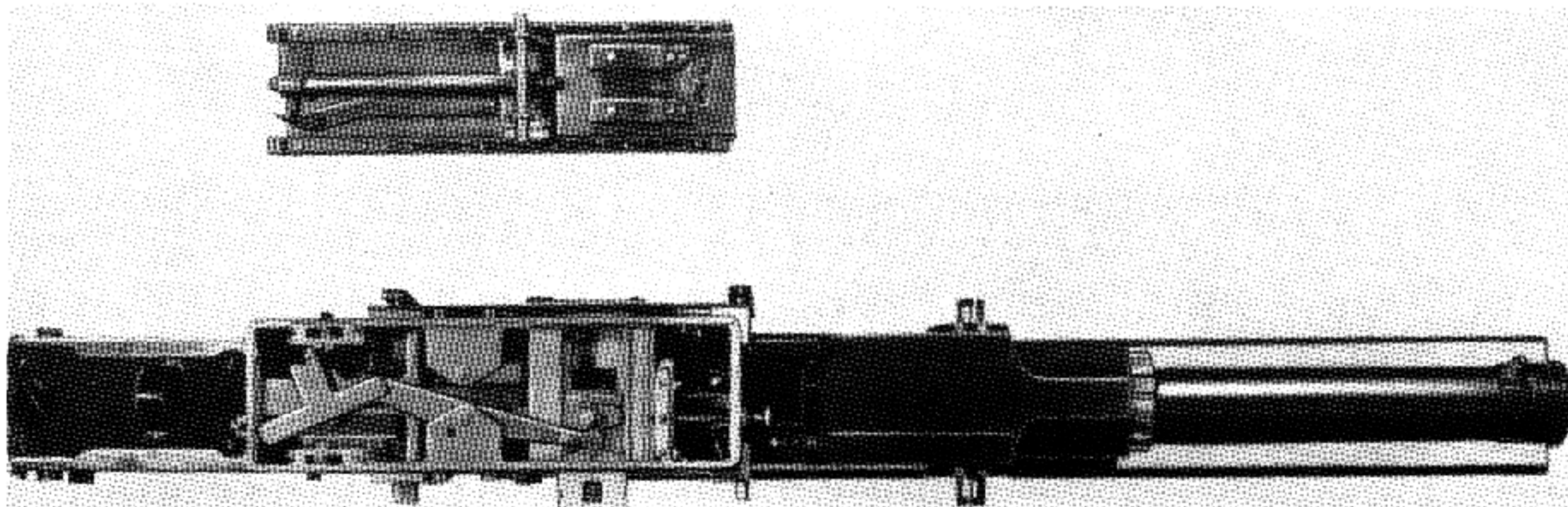


Figure 12-6. 37-mm Browning Gun M4E2 with right-hand feed box assembly. Top view.

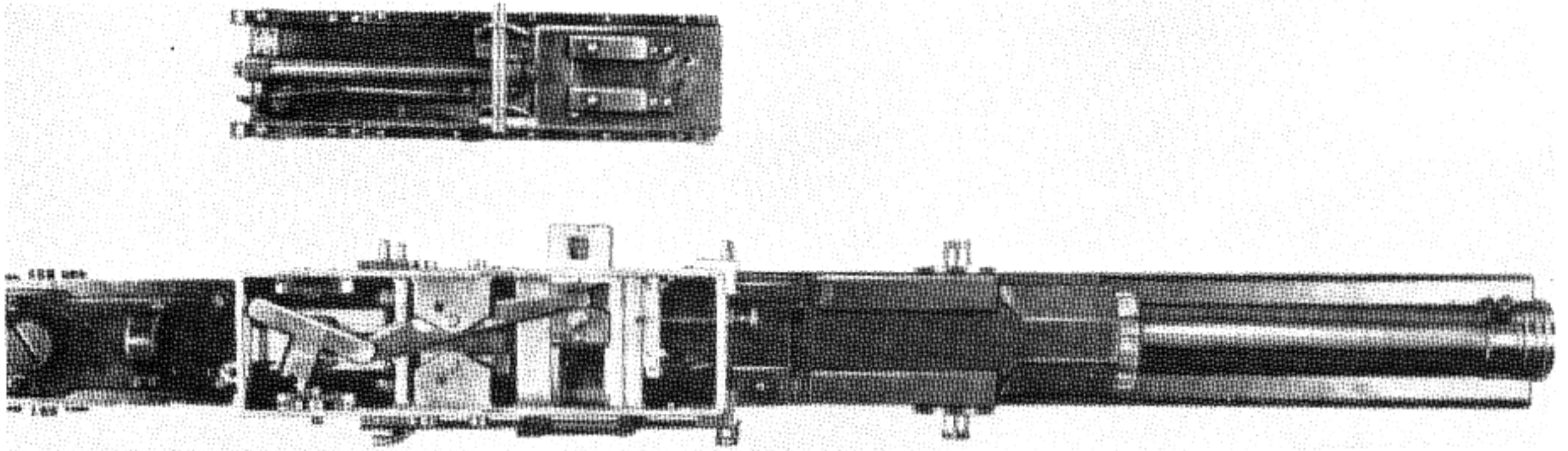


Figure 12-7. 37-mm Browning Gun M4E2 with left-hand feed box assembly. Top view.

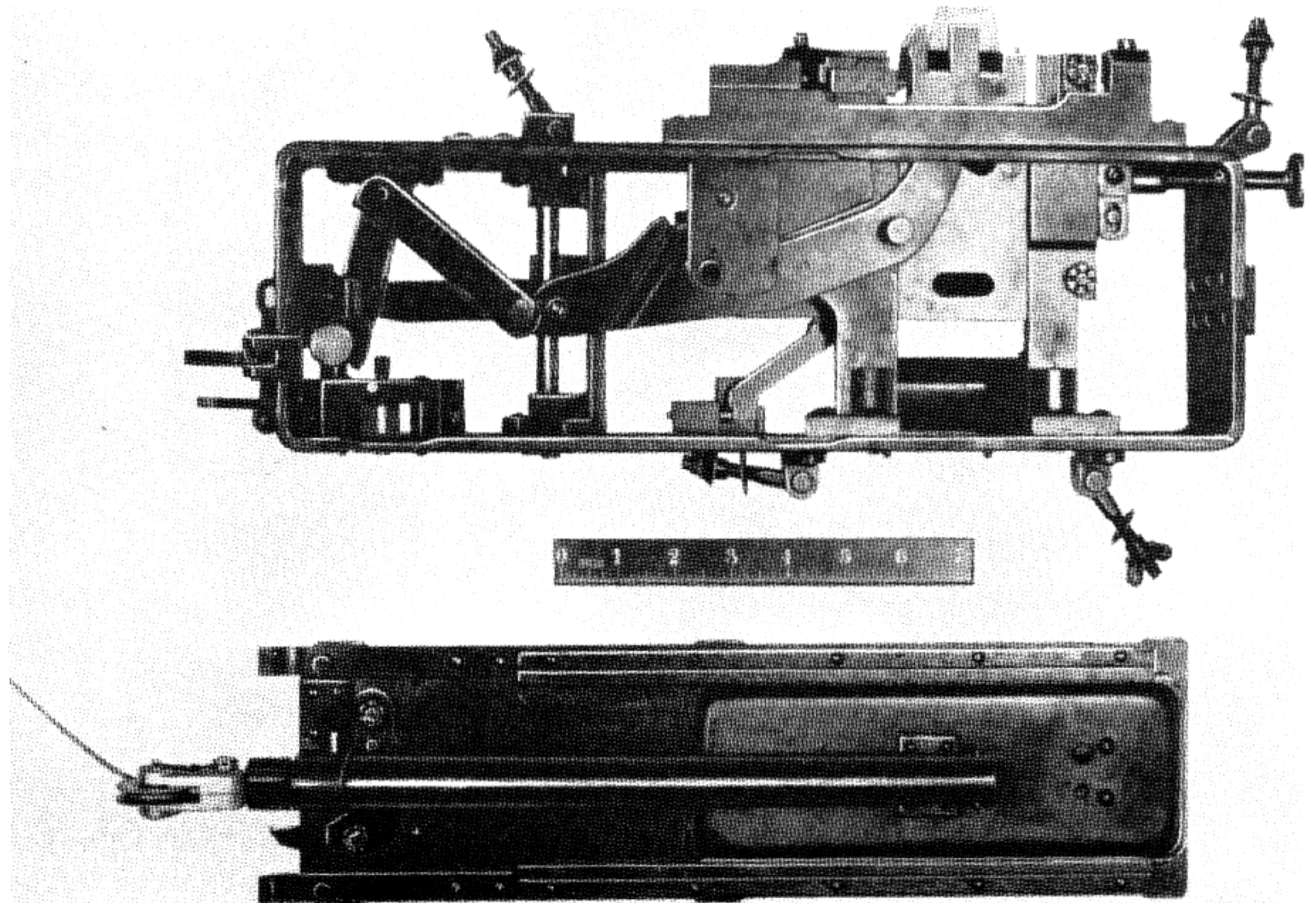


Figure 12-8. 37-mm Browning Gun M4E3 with left-hand feed box assembly.

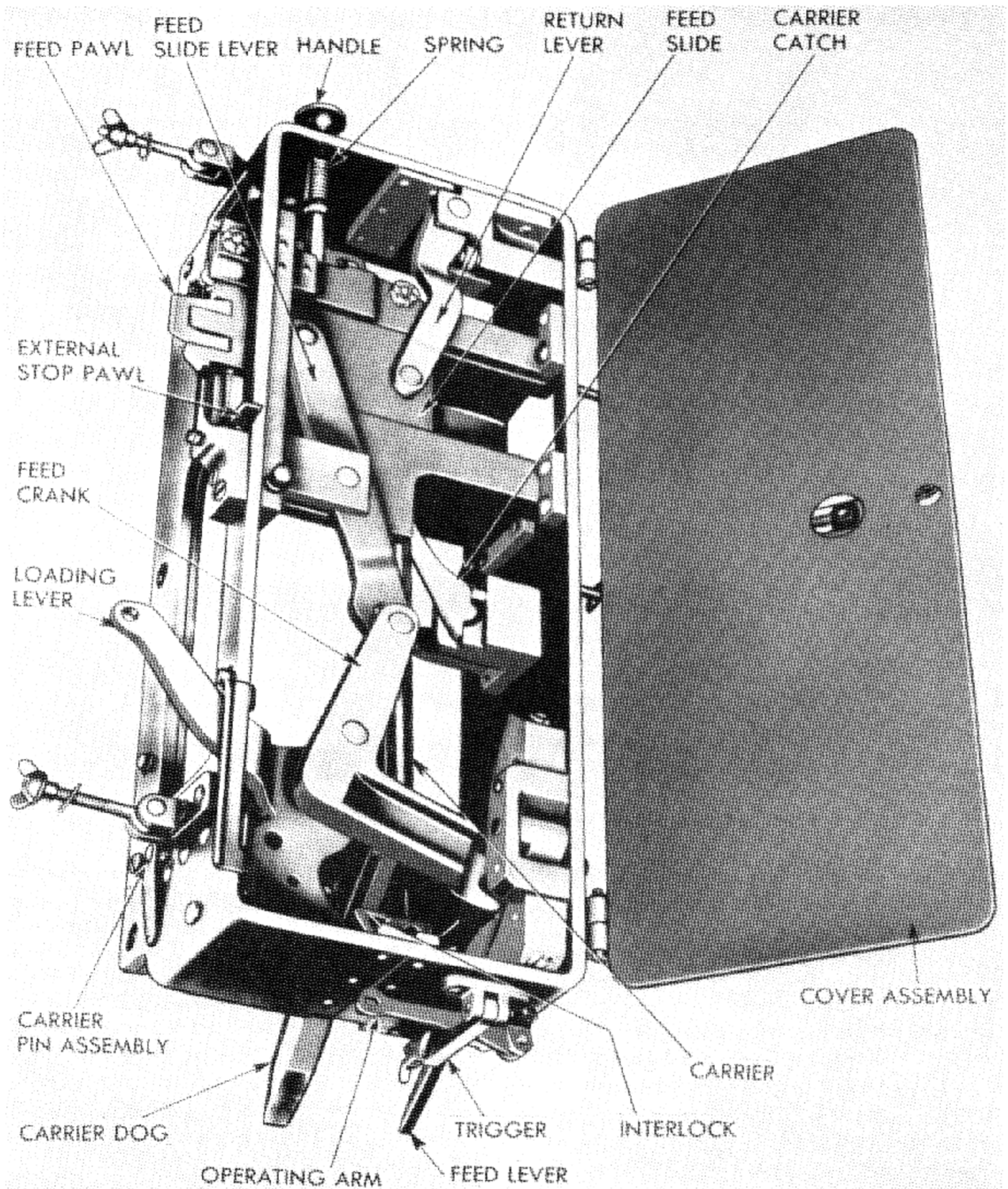


Figure 12-9. Feed box for 37-mm Automatic Gun M4E4.

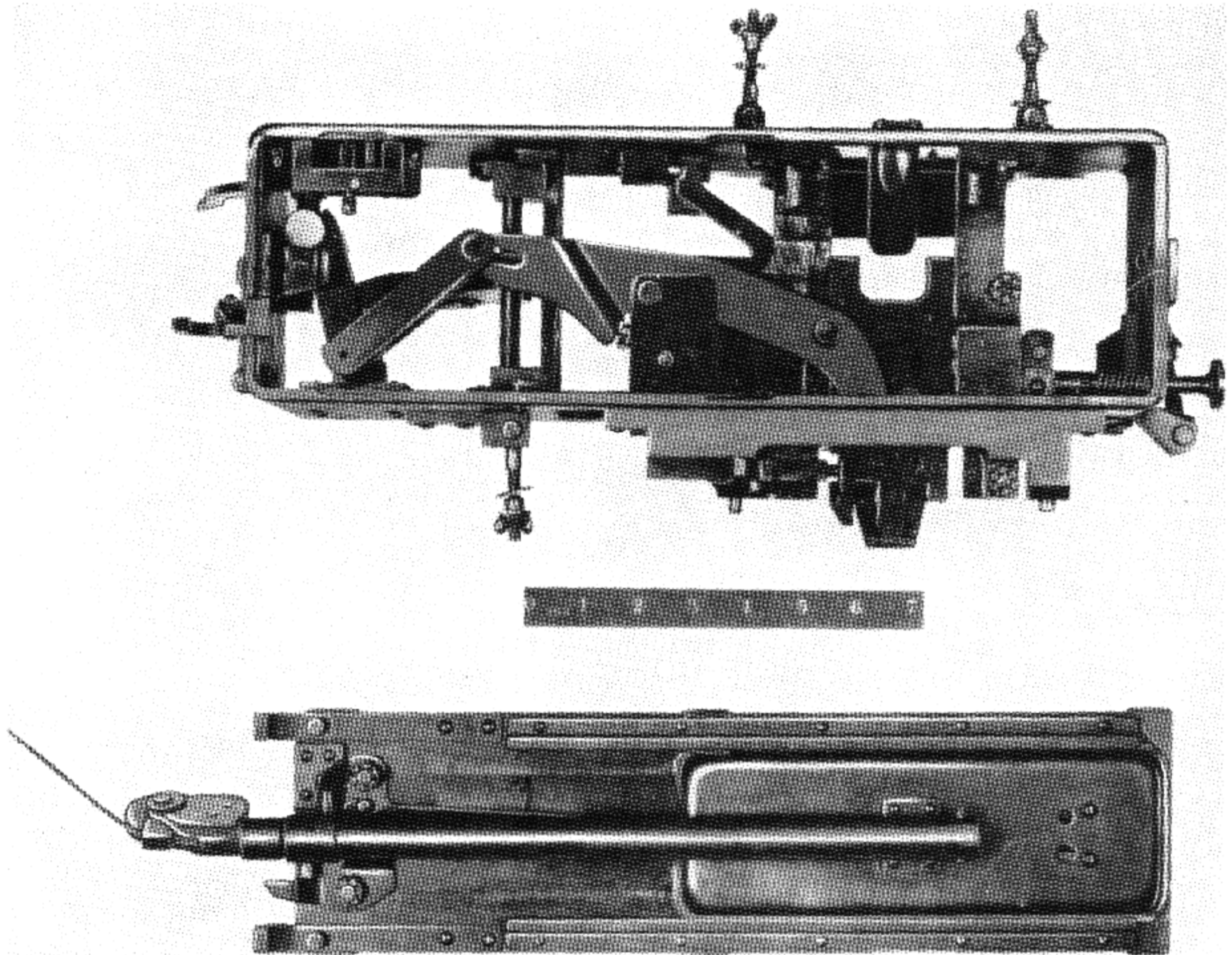


Figure 12-10. Right-hand feed box assembly for 37-mm Automatic Gun M4E4.

lock frame assembly, breechblock assembly backplate assembly, driving spring assemblies, and the feedbox group.

The principal function of the tube is to direct the discharged projectile and house the propellant charge. The rifling rotates the projectile, maintains direction, and prevents tumbling. The tube extension guides the rear end of the tube and provides a means of connecting the tube to the recuperator. The recuperator hydraulically controls the recoil and counterrecoil of the tube and tube extension, and serves to return these parts to battery position.

The major function of the lock frame assembly is to force the cartridge into the chamber, to actuate

the breechblock, to fire the round by means of the hammer striking the firing pin, to perform initial extraction, and to aid ejection. The breechblock assists in the final chambering of the round, closing the breech and actuating the trigger trip. It also provides a mounting for the firing pin.

The backplate absorbs the inertia of the lock frame during recoil and reduces its tendency to rebound against the carrier pin. Driving spring assemblies hold the lock frame against the carrier dog until the carrier is released by the incoming round and then drive the lock frame forward.

During the feeding operation of the M10 gun, in which the lock frame travels forward, the carrier lifter cam on the lock frame engages a surface on



the carrier and raises it above the carrier catch, which holds the carrier in the upper position. The feed lever operating stud on the side of the tube extension makes contact with the lower end of the feed lever, pivoting it rearward. The stud passes under the end of the lever which then snaps back into position, in front of the stud, by the force of the feed lever rear spring and plunger. During counter-recoil, the operating stud pushes the lower end of the feed lever forward.

The feed lever swivel actuates the feed crank, which in turn moves the feed slide lever, forcing the feed slide toward the inside of the feedbox. The spring-loaded feed pawl on the under side of the slide engages the inner ears of the link holding the first round. Therefore, as the slide moves inward, the belt is moved with it, bringing this round farther into the feedbox.

Near the end of this motion of the feed slide, the stop pawl on the front feed slide guide drops off the tongue of the slide and engages the outer ear of the link, positioning the round.

The external stop pawl engages the outer ear on the opposite side of the belt, one round back. This stop pawl differs in action from the first pawl, as it does not disengage from the link ear when the feed slide returns and thus prevents overfeeding when there is a heavy load tending to push the rounds inward. The holding pawl, on the front feed slide

guide, slides behind the outer link ear of the following round, preventing the belt from moving backward as the feed slide returns to engage the next link to feed in another round.

The stop pawls are operated by beveled surfaces on the feed slide, while the holding pawl is operated by the outer ears of the belt links. When the tube extension is near the battery position, the feed lever operating stud passes under the lower end of the feed lever. The feed slide lever, plunger, and spring then force the feed slide toward the inlet side of the feedbox to pick up the next round. This movement carries the feed crank and feed lever back to the initial feeding position. As the cartridge is fed into the feedbox, it is stripped from the belt.

The feeding operation of the M4 gun is similar to that of the M10 gun except that the M4 gun is provided with 2 feed pawls instead of the 1 feed pawl in the M10 gun. These feed pawls engage openings in the endless belt link plates. A stop and holding pawl engages notches which are cut in the side of the belt link plates.

Because the M4 gun does not incorporate an external stop pawl in its design, the chance of double feeding is reduced by incorporating a loading index into the endless belt magazine. This loading index, which is actuated by the upper left end surface of the feed slide, is spring loaded and engages the openings in the belt link plates.

## SECTION 4. 37-MM AUTOMATIC GUN M9

### General Description

The 37-mm automatic gun M9 is a fully automatic, high-velocity weapon of the long recoil type. It is designed for use in aircraft and may be mounted to fire through the propeller shaft or at some point outside the plane of propeller rotation. It is not used as a synchronized weapon. The gun is fired by means of a remotely controlled electric solenoid mounted at the rear of the gun.

The cannon is built with either a left-hand or a right-hand feedbox. With the exception of the feedbox and feeding mechanism, the right-hand feed and left-hand feed guns are identical. By changing the feedbox and feeding mechanism, the cannon can be made to feed from left to right or from right to left. The cartridges are fed into the side of the feedbox and the empty cartridge links ejected

through an opening in the opposite side of the feedbox. The empty cases are ejected through a longitudinal opening between the bottom of the trunnion block side plates.

The gun depends upon the movement of the recoiling portions for its operation. Recoil and counter-recoil are controlled by means of a hydro spring recoil mechanism.

### Components

*General.* The following mechanisms are described in the paragraphs which follow: manual charger assembly; backplate assembly; accelerator cam assembly; lock frame assembly; driving spring assemblies; tube; top plate assembly; carrier bearing brace; tube lock depressor; breechblock assembly; tube extension; trigger and trigger bar; backplate

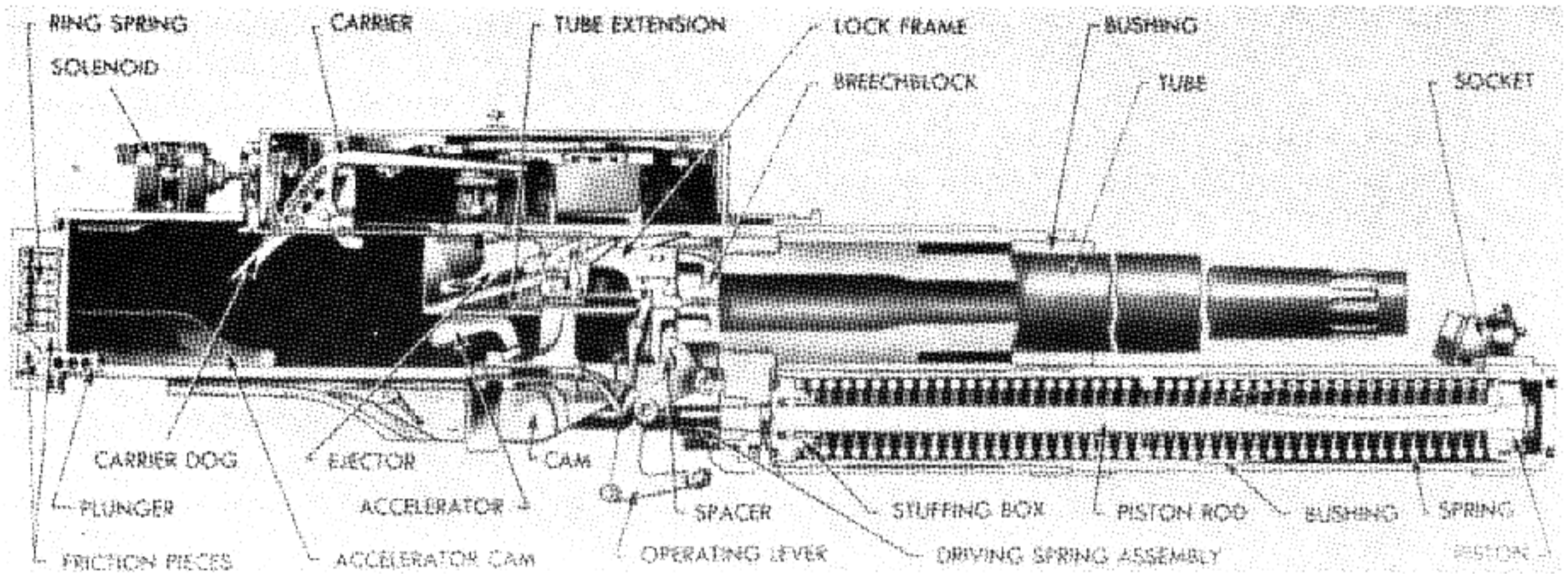


Figure 12-11. 37-mm Gun M9. Sectional view.

latch assembly; feedbox and feeding mechanism; driving spring tube guards; recuperator group; trunnion block group.

**Manual Charger Assembly.** A manual charger assembly known as the 37-mm charger M3 is attached to either side of the gun by four  $\frac{3}{16}$ -inch cap screws.

This assembly consists principally of a longitudinally slotted tube fitted with two mounting brackets and enclosing a coil spring and plunger. The plunger is fitted with a projecting shoe which contacts a pin attached to the operating lever. A flexible charging cable engages a plunger plug which contacts the plunger and moves it rearward within the tube when the cable is pulled, thus charging the gun manually. The plunger is returned to its forward position by the coil spring when the charging cable is released.

In certain installations it may be necessary to mount the charger on the left side. This may be done by installing the right-hand mounting brackets with a left-hand charger shoe. The manual charger shoe contact pin must be installed from the left side of the operating lever to complete this installation.

#### REMOVAL.

1. Remove the figure-eight locking wires from the bracket attaching screws.

2. Using a hexagonal wrench, remove the four cap screws attaching charger front and rear brackets to trunnion block side plate.

**INSTALLATION.** Reverse the above removal procedure.

#### DISASSEMBLY.

1. Remove screws and lockwashers securing front and rear brackets to tube, and remove brackets.

2. Pull out on cable slightly compressing the spring and remove safety wire, nuts, and shoe from plunger assembly and spring from tube.

3. Cut safety wire and remove pin, spacer, guard, and pulley from bracket on forward end of tube.

4. Loosen clamping screw, remove setscrew (staked), and remove bracket from tube.

#### ASSEMBLY.

1. Place bracket on forward end of tube. Replace and stake setscrew. Tighten clamping screw.

2. Replace guard, spacer, pulley, and pin in bracket and safety wire pin and clamping nut.

3. Place spring in tube. Thread cable through tube and pulley, and pull plunger into tube slightly compressing spring. Align holes in plunger with slot in tube and replace shoe and screws.

4. Replace brackets and bracket screws.

**Backplate Assembly.** The backplate body assembly contains the buffer mechanism of the gun consisting of a plunger, plunger stop screw, two bronze V-shaped friction pieces, a ring spring (consisting of 13 rings), an adjusting screw, and a lock screw.

During recoil, the lock frame contacts the buffer plunger forcing it rearward. The bronze friction pieces are so designed that they move upward against spring pressure and press outward against the walls of the housing as well, when acted upon by the tapered rear end of the buffer plunger. With this type of buffer, most of the energy of the

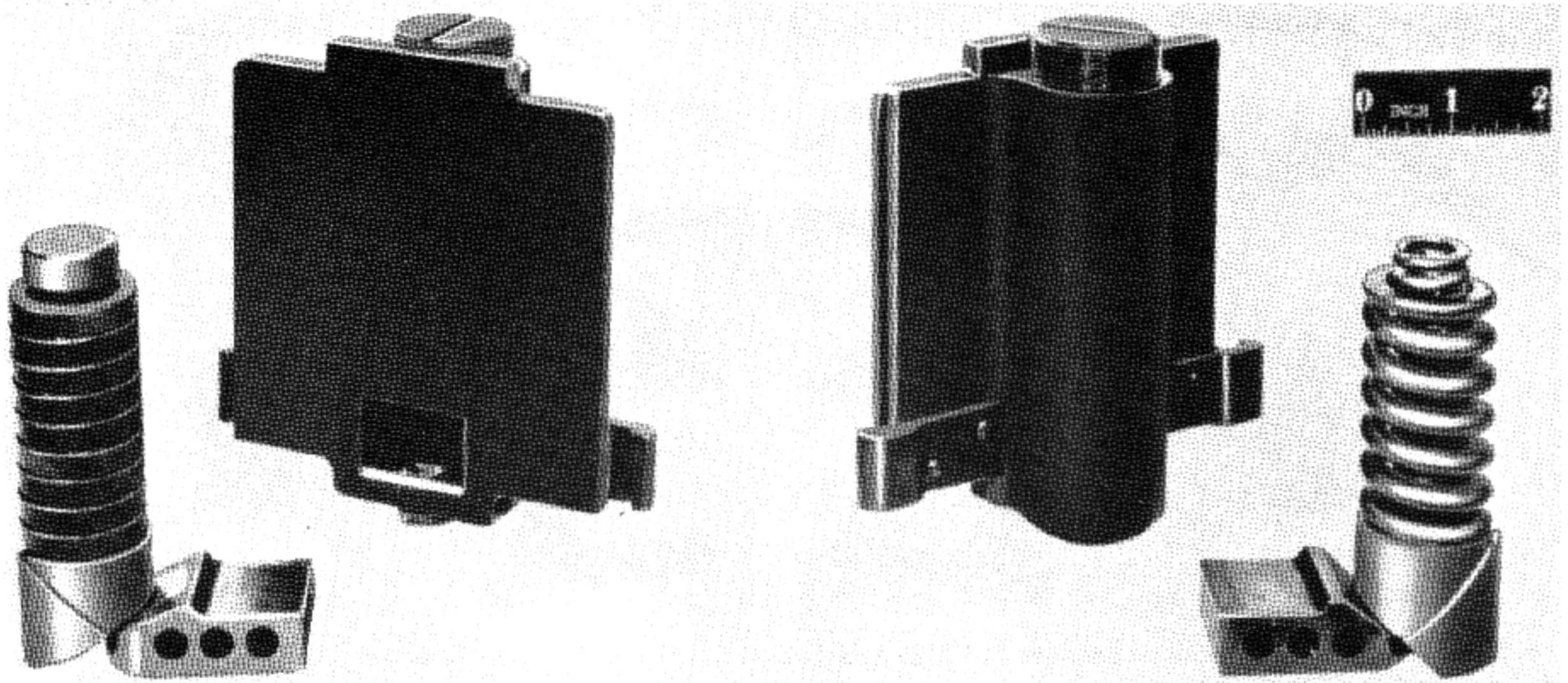


Figure 12-12. Comparison of buffers for different 37-mm Browning guns (left, T20; and right, M1A2).

lock frame is absorbed within the unit so as to reduce the tendency of the lock frame to rebound.

The backplate assembly, by absorbing the energy of the lock frame, reduces the shock against the carrier pin as the lock frame is latched to the rear.

**REMOVAL.** Push forward on backplate latch slide and slide backplate assembly downward.

**INSTALLATION.** Push forward on backplate latch slide and slide the backplate up into the slide-ways. Release backplate latch slide which must go under bottom edge of backplate housing.

**DISASSEMBLY AND ASSEMBLY.** The backplate assembly will not be disassembled. The unit will be replaced if not working properly.

**Accelerator Cam Assembly.** The accelerator cam is a flat plate with a stud projecting from one side and has an inclined surface at the forward end. The cam is held in position by the stud passing through a keyhole slot in the rear end of the left side plate.

As the tube extension moves rearward in recoil, the accelerator roll is brought in contact with the inclined surface of the accelerator cam, forcing the accelerator roll upward while the other end of the accelerator contacts the lock frame and accelerates it rearward.

**REMOVAL.**

1. Remove backplate assembly.

2. Slide accelerator cam rearward and remove the cam by pushing the cam stud out of the keyhole slot in the left side plate.

**INSTALLATION.** Installation is in the reverse order of removal.

**Lock Frame Assembly.** The lock-frame assembly is a separate recoiling unit that fits between the side plates of the tube extension. It consists principally of the slide assembly, hammer, sear, extractor, operating lever, and cocking lever, together with several springs.

The slide assembly is made up of the lock-frame body, driving spring rear bracket, charger, carrier lifter cam, and rivets. The carrier lifter cam raises the carrier to its uppermost position while the purpose of the charger is to help chamber the round as the lock frame moves into battery position. The driving spring rear bracket provides a means of attaching the driving spring rod hooks to the lock frame. Grooves at each side of the lock-frame body engage the side plate lower flanges. A square lug projects upward from the left rear surface of the lock-frame body in such a way that it will be contacted by the accelerator. The slide assembly supports all other parts of the lock-frame assembly.

The operating lever is pivoted at the lower side of the lock-frame body. The front end of the lever engages the breechblock, and both ends are fitted with guide pins which operate against cams on the

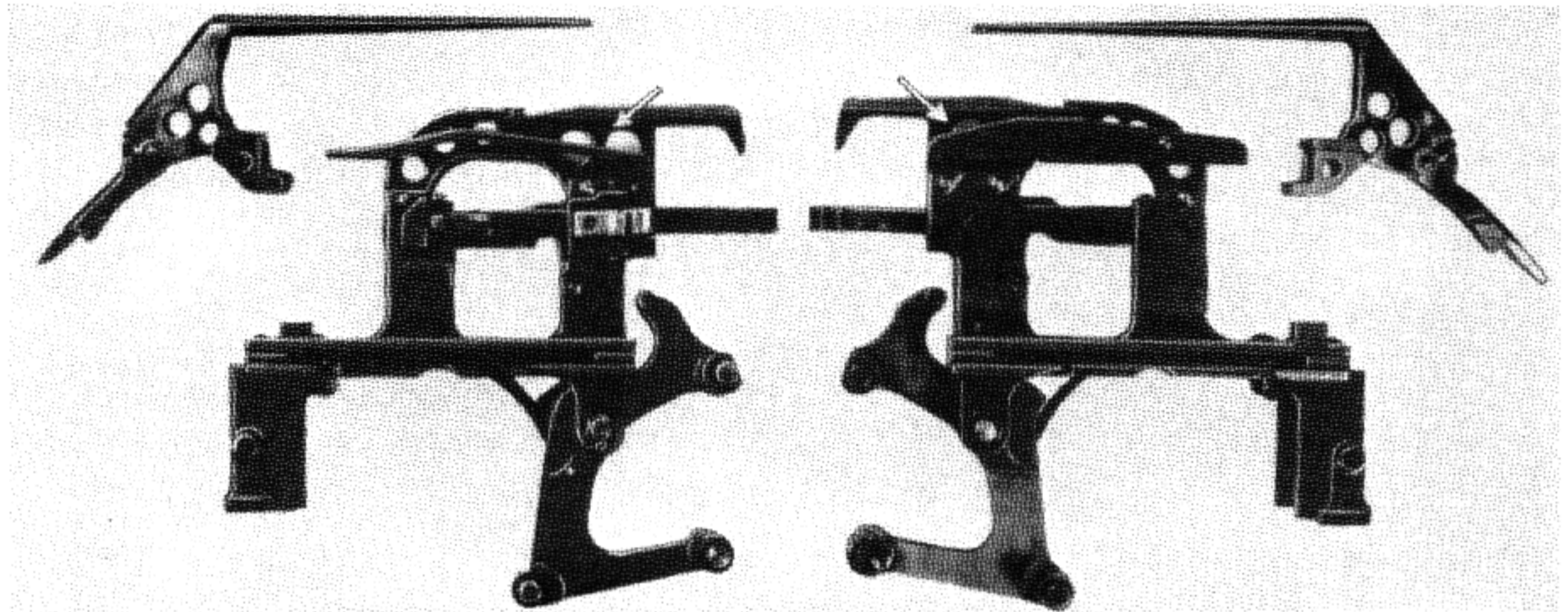


Figure 12-13. Comparison of different lock frame assemblies for 37-mm Browning guns (left, T20; and right, T20E2).

bottom of the side plates. These cams, by means of the guide pins and operating lever, actuate the breechblock assembly. The operating lever also carries a pin which is contacted by the shoe of the manual charger to provide for initial retracting of the lock frame, thus cocking the gun, or to allow manual extraction of a round from the chamber. A lobe on top of the operating lever actuates the cocking lever.

The hammer moves backward and forward in an opening of the lock-frame assembly. It has a latching hook on the right side which engages the sear. When the gun is cocked and the sear pivoted away from the hammer, a spring drives the hammer forward to fire the round.

The upper end of the cocking lever engages a notch in the hammer; therefore, when the lower end is pivoted forward by the operating lever, the cocking lever cams the hammer rearward past the latching hook of the sear.

A spring-loaded extractor is mounted on a removable pivot pin at the right front side of the lock frame assembly. The front end of the extractor is notched and beveled to facilitate engagement with the rim of the cartridge. At approximately the time the lock frame is contacted by the accelerator, the extractor starts to withdraw the cartridge case from the chamber.

The operating lever strut pivots on a pin in the operating lever. During recoil, the motion of the operating lever causes the strut to compress the

operating lever spring. Near the end of counter-recoil, this compressed spring assists the operating lever to lift the breechblock into battery position.

The major function of the lock-frame assembly is to force the cartridge into the chamber, actuate the breechblock, fire the round by means of the hammer striking the firing pin, and extract the cartridge case from the chamber.

#### REMOVAL.

1. Make sure that lock frame is in the battery position.
2. Remove the backplate assembly.
3. Disconnect the driving spring assembly from the lock frame.

#### INSTALLATION.

1. Release the carrier catch to lower the carrier.
2. Pull operating lever into rear position.
3. Install in reverse order of removal from gun.

**NOTE.** Always make sure a dummy round is being fed into the gun before allowing the lock frame to go forward under full force of the driving springs.

#### DISASSEMBLY.

1. Always release sear and place operating lever in forward (battery) position before disassembling lock frame.

2. Remove operating lever spring lock assembly, spring, and follower by engaging a screwdriver in slotted end of lock, forcing it in and turning counterclockwise as far as it will go. Lock assembly, spring, and follower can then be removed as a unit.

3. Remove cotter pin, operating lever pivot pin, and operating lever.

4. Remove operating lever strut by drifting out strut pin.

5. Remove cotter pin, compress sear spring, and remove pin and sear. Remove sear spring.

6. Remove cotter pin from hammer spring guide pin. Now compress hammer spring firmly with thumb while removing the hammer spring guide pin. Remove hammer spring guide and spring.

7. Remove cotter pin, cocking lever pin, and cocking lever.

8. Remove hammer.

9. Remove cotter pin, then compress extractor spring while removing extractor pin. Remove extractor and spring.

#### ASSEMBLY.

1. Place extractor spring in hole in right side of lock frame. Place extractor in position and compress spring while installing extractor pin, with head up. Install  $\frac{1}{16}$ - by  $\frac{5}{8}$ -inch cotter pin.

2. Place hammer in lock frame.

3. Place cocking lever in lock frame, with concave side forward and rounded end engaged in groove in hammer. Install cocking lever pin from the right side and lock with  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

4. Place hammer spring and guide in hammer. Compress spring firmly while inserting hammer spring guide pin through holes in lock frame body and spring guide, from the right side. Lock guide pin with a  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

5. Place sear spring in hole in lock frame, install sear and sear pin. Lock sear pin with a  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

6. Install operating lever strut in operating lever, with concave side toward rear. Install strut pin and stake in place.

7. Place operating lever in lock frame, with lobe on the rear side of cocking lever. Install pivot pin from the right side and lock it in place with a  $\frac{3}{32}$ - by  $\frac{5}{8}$ -inch cotter pin.

8. Swing end of strut into slot in lock frame. Place operating lever spring follower, spring, and lock assembly in lock frame, with the follower engaging end of strut.

9. Push lock in with screwdriver, engage lockpin in groove in lock frame, and lock it in position with one-fourth turn clockwise.

*Driving Spring Assemblies.* Two driving spring assemblies are used, one installed lengthwise on each side of the gun. They fit into guards along the outside of the recuperator cylinder and trunnion block body. Bronze bushings in the trunnion block body provide supports for the driving spring assemblies.

Each assembly consists of a long, narrow tube into which is fitted a rod, piston, spacer, and two springs. A connection, secured to the outside of the tube near its rear end, is attached to the bracket located on the lower front part of the tube extension. The end of the piston rod extends from the rear of the driving spring assembly and is provided with a hook that connects to a projecting lug of the lock frame rear driving spring bracket. Thus, when the lock frame is latched to the rear and the tube and tube extension return to battery on counterrecoil, the springs are energized.

The driving spring assemblies hold the lock frame against the carrier dog until the carrier is released by the carrier catch which is pivoted by the incoming round. The springs then drive the lock-frame assembly forward to chamber the round and operate the breechblock.

#### REMOVAL.

1. Remove the manual charger.

2. Remove the lock frame.

3. Disconnect the driving spring assemblies from the tube extension by pulling the driving spring tube connection pin knobs to the rear and twisting the driving spring tubes so that they are disengaged from the tube extension.

*INSTALLATION.* The assemblies are installed in the reverse order of removal.

#### DISASSEMBLY.

1. Unscrew driving spring tube connection pin knob by first removing lockpin, thus releasing connection pin and spring.

2. Remove cotter pin and pin from driving spring-rod connection, thus releasing the safety, rod hook, plunger, and spring.

*ASSEMBLY.* Both assemblies are identical except as outlined in note following.

*NOTE.* Driving spring assemblies are not interchangeable because of the driving spring rod hook safety, left and right.

1. Place hook spring and plunger in rod connection. Place hook in the connection, with dowel pin on same side as head of cotter pin in connection.

Install rod connection pin and safety on the same side. Secure connection pin with a  $\frac{3}{32}$ - by  $\frac{3}{4}$ -inch cotter pin with head up.

2. Place spring on driving spring tube connection pin. Install pin and spring in tube connection, compress spring, and screw knob on the pin until lockpin hole is through the knob. Install tube connection pin lockpin, bending ends around connection pin. Unscrew knob tight against lockpin.

#### CARE.

1. No adjustments are provided for the driving springs. Dents in the housing assemblies or bent rods may cause the gun to malfunction. Also, a malfunction may result from accidental sealing of the vents in the driving spring tube end caps with heavy grease or foreign matter.

2. A critical point in the operation occurs when the forward movement of the lock frame ceases and the breechblock is forced into firing position. At this point the driving springs cease to function and give over to the small operating lever spring in the lock frame itself. Dirt in the cam grooves, burrs on the breechblock, dirt or grit on the lock frame or side plate flanges, weak driving springs, or a weak operating lever spring may result in a failure of the breechblock to close. It is important that the connections of the driving spring assemblies to the tube extension and lock frame be properly locked and secure at all times.

*Tube.* The gun tube is of one-piece construction threaded into and locked to the front of the tube extension. Splines are machined at the muzzle end for application of a wrench for removing and replacing the tube. The breech end has a deep notch to accommodate the extractor and a shallow groove to provide clearance for the charger.

The function of the tube is to direct the discharged projectile, the lands and grooves cause the projectile

to rotate to maintain direction and to prevent tumbling.

#### REMOVAL.

1. Retract the lock frame. This is very important; otherwise damage to the extractor will result.

2. Remove the trunnion block bushing retaining screws.

3. Place tube wrench on the splines at the muzzle end, push tube lock depressor to the rear as far as it will go, and unscrew the tube counterclockwise approximately five turns. After about one-quarter turn the tube lock depressor can be released and the tube unscrewed by hand. If considerable force is required, it is probably due to binding of the threads which may be avoided by lifting slightly on the muzzle end and turning only when the tube rotates freely.

4. Slide the tube and trunnion block bushing from the trunnion block and remove bushing from the tube.

#### INSTALLATION.

1. Retract the lock frame.

2. Place trunnion block bushing over the tube and against the rear shoulder, with flanged end of bushing toward muzzle.

3. Coat threads of tube with light graphited grease to prevent damage to the threads.

4. Carefully insert the tube and bushing into trunnion block, align holes, and install the two trunnion block bushing retaining screws.

5. Push the tube rearward until it contacts the tube extension. Maintaining pressure rearward, slowly turn tube counterclockwise until a slight bump is felt, indicating that the end of the thread on the tube has indexed with the thread in the tube extension. Turn tube clockwise approximately five revolutions by hand until the tube is seated. Do not

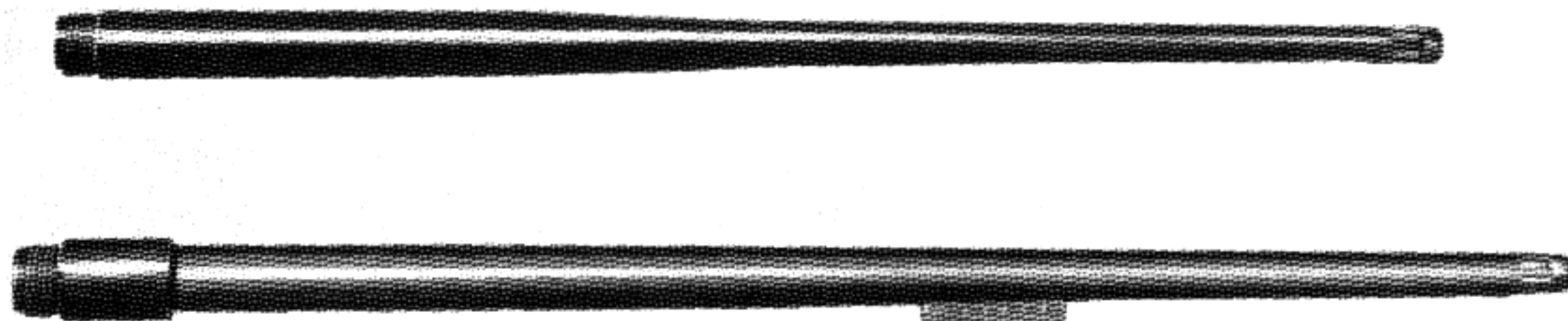


Figure 12-14. Comparison of tubes for 37-mm Gun M9E1 (above) and 37-mm Gun M9 (below).

depress the tube lock because it must snap into the groove in the tube just as the shoulder contacts the tube extension. Check this lock engagement by looking through the sighting hole.

**CAUTION.** Tube should thread into tube extension freely. If it does not, do not force it with the wrench. Remove the tube and examine threads on tube and in extension for burrs or rough spots, which should be removed with a fine stone.

**NOTE.** If the recuperator piston rod nut has been removed or loosened during repairs to gun, it should not be reinstalled until after the gun tube has been installed. When indexing the tube threads with this nut off, it will be necessary to hold the tube extension forward either by hand or with a suitable wooden wedge inserted between the lower flange of the side plate and the tube extension.

*Top Plate Assembly.* The serial number of the gun is stamped into the top plate which is a flat steel plate attached by four screws to the upper ends of the trunnion block assembly side plates. This top plate serves to align the rear ends of the side plates and keeps them from spreading. It also mounts a hinged, quick-operating clamp to position and secure the solenoid.

#### REMOVAL.

1. Remove cotter pin and solenoid plunger pin from trigger operating arm.

2. Remove top plate with solenoid attached by removing four screws threaded into side plates.

**INSTALLATION.** Reverse the removal procedure to install top plate.

#### DISASSEMBLY.

1. Remove solenoid connecting pin at trigger operating arm.

2. Remove solenoid by loosening clamp eyebolt wing nut.

3. Remove nuts, lockwashers, and bolts which secure solenoid clamp to the top plate.

**ASSEMBLY.** Reverse the disassembly procedure.

*Carrier Bearing Brace.* The carrier bearing brace is a flat steel plate mounted on top of the side-plate flange. It is positioned by a dowel, is secured by two screws, and functions to reinforce the carrier bearing in the feedbox. There are two noninterchangeable braces, 1 for the left-hand feed gun and 1 for the right. In a left-hand feed gun the brace is attached to the right side plate, while in a right-hand feed gun it is on the left side plate.

The top flange of each side plate is drilled and tapped to permit installation of the brace on either side.

#### REMOVAL.

1. Remove feedbox.

2. Remove the two attaching screws and lift the carrier brace from the dowel in the top of the trunnion block side plate flange.

**INSTALLATION.** Installation is in the reverse order of removal. There are two noninterchangeable carrier bearing braces. One brace is mounted on the left side plate flange of a right-hand feed gun, and the other is mounted on the right side plate of a left-hand feed gun.

**CAUTION.** When replacing feedbox, always make sure rear end of carrier bearing brace, when installed, contacts extension of carrier bearing. If brace is too short, a new part, which is supplied, approximately one-sixteenth inch longer, should be fitted in place.

*Tube Lock Depressor.* The tube lock depressor and spring are housed within the tube lock compressor body. This is attached by 2 short screws and 1 long screw to the top of the left side plate just forward of the feedbox. When pushed rearward, a lower projection of the depressor engages the tube lock and moves it rearward. This action disengages the lock from the recess in the tube, thus unlocking the tube so it may be unscrewed from the tube extension.

**REMOVAL.** Remove the 1 long and 2 short fillister-head screws which secure the tube lock depressor body to the side-plate flange, and remove the body, depressor, and spring.

**INSTALLATION.** Installation is in the reverse order of removal.

*Breechblock Assembly.* The breechblock assembly, actuated by the operating lever, slides up and down on lands in the tube extension. These lands and the mating grooves in the breechblock are inclined forward  $1^{\circ} 30'$  from vertical, to provide a wedging effect as the breechblock travels to battery position. This wedging action, in conjunction with a beveled radius on the front upper face of the breechblock, acts to completely chamber the cartridge before it is fired.

The breechblock carries the firing pin, spring, and stop pin. The firing pin protrudes through a hardened steel bushing which is pressed into a hole in the

front face of the breechblock and ground flush. Holes machined in the rear side of the breechblock decrease weight.

A safety feature incorporated in the design of the trigger mechanism prevents firing the round until the breechblock assembly is in battery position.

The breechblock assists in the final chambering of the round, closes the breech, and actuates the trigger trip. It also provides a mounting for the firing pin.

#### REMOVAL.

1. Disengage the driving-spring assemblies from the lock frame.
2. Pull the lock frame to the rear.
3. Pull outward on the breechblock stop retaining pin knob. Swing breechblock stop forward and remove breechblock assembly.

#### INSTALLATION.

1. Reverse the procedure for removal of the breechblock.
2. When replacing the breechblock and the breechblock stop, be sure that the breechblock is resting on the breechblock stop before returning the lock frame to battery position.

#### DISASSEMBLY.

1. Hold a finger over the back part of the firing pin.
2. Drift out the firing-pin stop pin which is lightly staked in place.
3. Remove the firing pin and firing-pin spring.

**ASSEMBLY.** Assemble in the reverse order of disassembly. Be sure that the flat on the firing pin will line up with the firing pin stop pin.

**Tube Extension.** The tube extension consists of the front portion which contains the tube receptacle, tube lock, driving spring front brackets, breechblock plunger, and breechblock stop. Two vertical side plates extend rearward and assist in the movement for the incoming cartridge. They also provide a mounting for the accelerator, trigger levers, ejector, feed-lever operating studs, and trigger trip.

The tube receptacle is a threaded opening at the front end of the tube extension into which the breech end of the tube is threaded. A vertical opening directly in back of the tube receptacle acts as a guide for the breechblock, as the latter moves up and down during the operation of the gun.

The spring-loaded tube lock engages a notch provided in the rear outer circumference of the tube. The lock can be released, when the tube extension

is in battery position, by pushing the tube lock depressor to the rear as far as it will go.

A breechblock plunger positions the breechblock and holds it in the open (out of battery) position, when the gun or plane is in an inverted position.

The driving spring front bracket is located at the lower front end of the tube extension. This bracket has two projections to which the driving spring tubes are attached.

The breechblock stop, hinged on a removable pin at the lower front end of the tube extension, is locked in place by the spring-loaded breechblock stop retaining pin. The stop limits the downward movement of the breechblock and positions it where the operating lever of the lock frame may enter the T-slot.

Two bronze shoes are inserted in the lower front surface of the tube extension, and similar shoes are inserted in the top surface at the rear end. These shoes, together with a round auxiliary bronze shoe on the left side, provide a bearing between the tube extension and the side plates.

Two feed lever operating studs are provided (one on each side) so that the tube extension assembly can be used with either a left- or right-hand feed. As the tube extension recoils, this stud passes to the rear of the feed lever. On counterrecoil the stud pivots the feed lever forward, thus actuating the entire feeding mechanism and feeding a new round into the gun.

An accelerator assembly and plunger are located near the rear left side of the tube extension. This assembly has a roll which rides up the cam surface of the accelerator during recoil. The rotating accelerator contacts a square lug of the lock frame assembly and accelerates its rearward motion, insuring its traveling rearward sufficiently to be caught by the carrier dog.

The ejector pivots on a stud and is located on the inside of the left side plate of the tube extension. As the cartridge case is extracted from the cartridge chamber, a cam located in the left side plate of the trunnion block assembly operates the ejector so that it pushes the case out through the bottom of the gun.

The trigger lever assembly, trigger lever spring, and plunger are located on the right side of the tube extension. The trigger trip is also located on the right side in a recess provided in the right side plate top flange and transmits the motion of the trigger



to the sear through the trigger levers. The trigger trip is pivoted on a pin, so that when its front end is raised by the breechblock its rear end is held down to serve as a stop for the trigger lever connector. The trigger lever spring and plunger serve to return and hold the trigger, trigger bar, and trigger lever assembly forward when the trigger is released.

The tube extension guides the rear end of the tube and provides a means of connecting the tube to the recuperator mechanism. The recoil and counter-recoil of the tube extension actuate the feed mechanism, and relative movement between the tube extension and lock frame extract and eject the empty cartridge case.

#### REMOVAL.

1. Remove the breechblock assembly.
2. Remove the lock frame assembly.
3. Disconnect driving spring assemblies from the tube extension bracket.
4. Remove the gun tube.
5. Remove the accelerator cam assembly.
6. Remove feed-lever pin assembly by pushing lower end of lock counterclockwise until the short end of lock is clear of lock screw and pulling pin from feedbox side.
7. Lift feed lever assembly up and out of feedbox.
8. Pry carrier-pin lock out slightly and push it counterclockwise until short end is clear of lock screw, then remove the pin and lock assembly.
9. Lower carrier assembly down between the side plates.
10. Remove recuperator piston-rod nut by means of recuperator and piston-rod nut wrench.
11. Pull tube extension out through rear end of gun, lifting it during removal to clear hooked end of trigger bar.

#### INSTALLATION.

1. Slide tube extension into position between the side plates and push it forward, lifting it to clear the hooked front end of the trigger bar.
2. Turn recuperator piston rod to align the notch in collar of the rod with the piston rod screw in the tube extension. This alignment must be exact, to avoid damage to these parts when piston rod nut is installed.
3. The recuperator piston-rod nut should not be tightened before the gun tube is screwed into the tube extension. If, when the tube extension is in place, the tube does not seat properly in its socket,

the recuperator piston-rod nut should be removed and a further attempt made to seat the tube in place. If the gun tube is still not properly seated or if the gun tube cannot be seated, remove the tube extension and assemble the gun tube to the tube extension outside of the gun. The tube and tube extension will then have to be put into the trunnion block through the backplate opening. The recuperator piston-rod nut can then be assembled to the recuperator piston rod by means of the proper wrench. When assembling the recuperator piston-rod nut, its final setting should be such that a flat surface is parallel to the breechblock stop. When the breechblock stop is rotated to its closed position, the stop acts as a lock for the recuperator piston-rod nut.

#### DISASSEMBLY.

1. Remove cotter pin and remove breechblock stop pin and breechblock stop.
2. Remove recuperator piston-rod screw.
3. Remove breechblock stop lockpin, unscrew knob from breechblock stop retaining pin, and remove retaining pin and spring.
4. Remove tube lock plate assembly by depressing tube lock plate plunger through the small hole in front face of tube extension. Then remove tube lock spring and lock.
5. Remove trigger trip pin and trigger trip.
6. Remove trigger-lever pin, compress trigger-lever plunger and spring, and hold fully compressed by means of wire looped over front end of plunger, or by holding rear end of plunger with pliers. If pliers are used, care must be exercised not to burr the plunger. Remove trigger-lever assembly, spring, and plunger.
7. Remove cotter pin and castellated nut from ejector stud and remove ejector and spring.
8. Remove accelerator retainer screw (staked) and retainer. Depress accelerator spring plunger and remove accelerator assembly. Remove plunger and spring.
9. Remove breechblock plunger screw, spring, and plunger. The screw is staked in place.
10. Riveted parts of the tube extension will not be removed by using arms. Replacement of these parts will be made only by authorized personnel.

#### ASSEMBLY.

1. Install breechblock plunger, spring, and screw in left side of tube extension until screw is slightly below surface. Screw must not be screwed in until

it bottoms spring and binds the breechblock. Stake screw in place.

2. Install accelerator spring and plunger, and hold compressed while installing the accelerator assembly. The small end of plunger must engage in the groove in accelerator body. Install accelerator retainer and stake retainer screw in place.

3. Install ejector spring and ejector, with the flanged edge of ejector under the bronze shoe. Install castellated nut and  $\frac{1}{16}$ - by  $\frac{5}{8}$ -inch cotter pin.

4. Place trigger lever spring and plunger in the trigger lever stud on tube extension. Hold the spring fully compressed by drawing back on a wire looped over the front end of the plunger while installing the trigger lever assembly. Install trigger lever pin.

NOTE. As an alternative, the spring may be held fully compressed by pliers on the rear end of the plunger. However, when using this method, care must be exercised to avoid burring the plunger.

5. Install trigger trip and pin with offset end of trigger trip to the rear.

6. Install tube lock and spring. Install tube lock plate assembly with tongue on the rear end downward to engage groove in tube extension body.

7. Install breechblock stop retaining pin spring and pin; screw knob on pin until lock wire hole is through knob. Install breechblock stop lockpin and bend ends flat against retaining pin. Unscrew knob tight against lockpin.

8. Install recuperator piston rod screw.

9. Install breechblock stop and pin. Lock the pin with  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

#### *Trigger and Trigger Bar.*

##### REMOVAL.

1. Remove cotter pin, trigger pin, and trigger.
2. The trigger bar is removed from the gun after the lock frame and tube extension have been removed. Slide the trigger bar in its groove in the upper right-hand portion of the trunnion block to the rear to disengage it from the two trigger bar guides.

##### INSTALLATION.

1. Place trigger bar all the way to the rear in the groove on the under side of the top flange of the right side plate. The notch which is closer to one end of the bar must lie toward the front of the gun. Slide the bar forward to engage the tongues on the

bar under the two trigger bar guides on the side-plate flange. Be sure that the small bent end at the rear of the trigger bar points upward and through the hole behind the feedbox.

2. Place the trigger in position with notch in trigger engaging the hooked rear end of the trigger bar. This is important; otherwise the gun will not fire or will fire without a pull on the trigger.

3. Install the trigger pin and cotter pin.

*Backplate Latch Assembly.* A latch slide is attached by screws to the lower rear end of the right side plate flange. This houses the backplate latch slide which extends under the backplate housing to hold the assembly in place.

REMOVAL. Remove the six fillister-head screws which secure the backplate latch body to the side-plate flange, and remove the body, latch slide, and spring.

INSTALLATION. Installation is the reverse of removal.

*Feedbox and Feeding Mechanism.* The feedbox, a rectangular, boxlike structure about half the length of the trunnion block assembly, is approximately centered and is attached to the top of the side plates by six screws. The feedbox has an opening in one side through which the cartridges enter and a smaller opening in the opposite side for the ejection of the belt links. The top of the box has a hinged cover that may be opened by releasing a latch. The feeding mechanism housed within the feedbox governs the movement of the ammunition belt and removes the rounds from it.

The function of the feed mechanism is to draw belted ammunition from a box or magazine and feed it into the gun automatically as the gun is fired. The feedbox provides a mounting for the feed mechanism, trigger levers, feed chute, and link chute.

The principal difference between the left-hand feed and the right-hand feed 37-mm M9 guns is the construction of the feedbox. The gun can be changed from a left- to a right-hand feed, or vice versa, by replacing the feedbox group and the carrier bearing brace. In the left-hand feed, the cartridges enter the feedbox from the left side and the belt links are ejected through an opening in the right side. The cartridges enter the feedbox on the right-hand feed from the right side and eject the links from the left. Therefore, many of the corresponding parts of the feeding mechanisms are not inter-

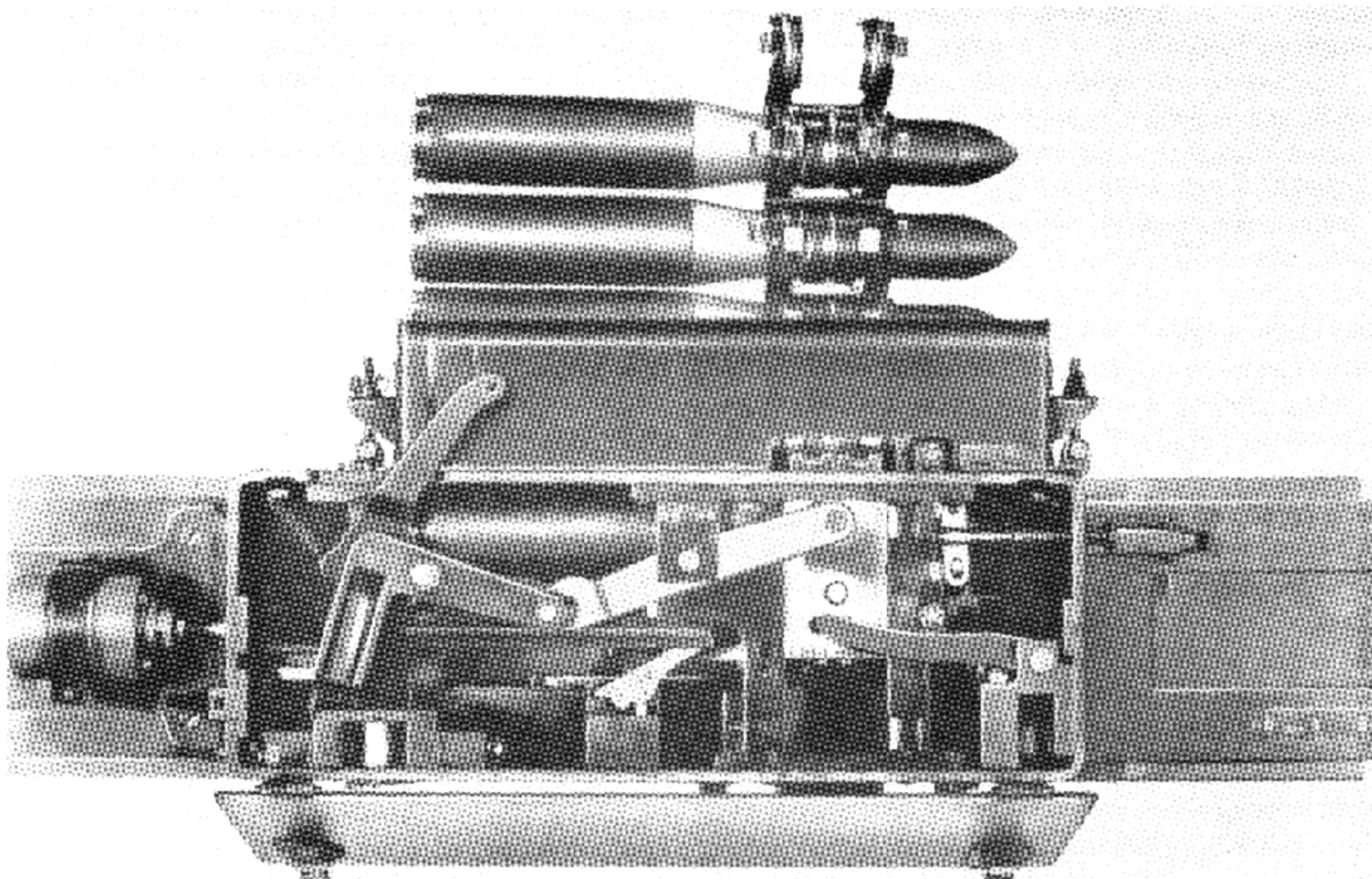


Figure 12-15. Representative 37-mm Browning gun with cover removed. Top view.

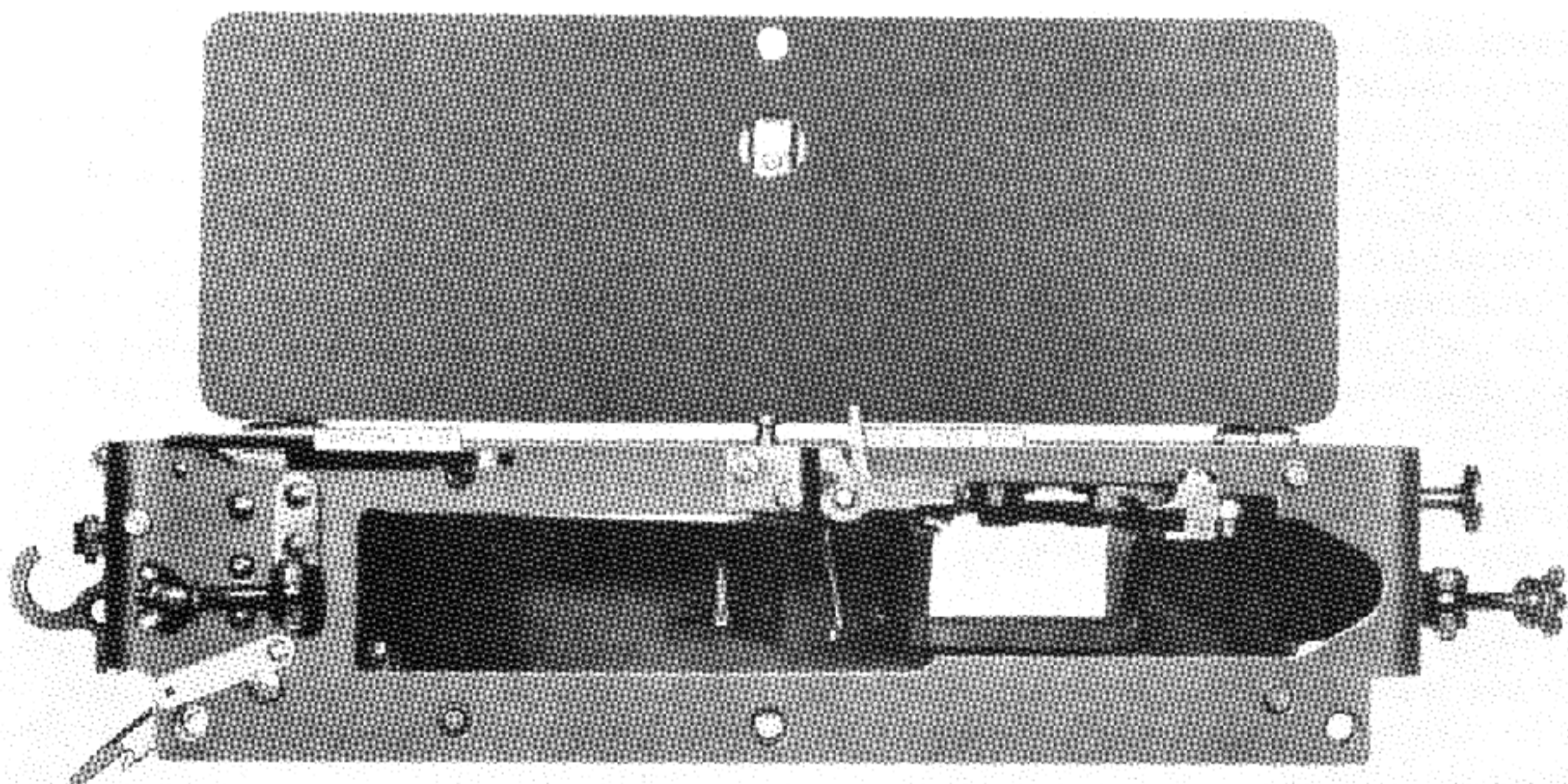


Figure 12-16. Representative feed box assembly for a 37-mm Browning gun. The feed chute is not shown.

changeable, but differ only in that they are mirror images of each other.

Enclosed in the feedbox are the following principal parts: feed lever; feed crank; feed-slide lever; feed slide and feed pawl; feed-slide return lever; cartridge feeder stop and holding pawls; stripper cam; carrier assembly and carrier catch; loading lever and spring; interlock; trigger and trigger operating arm; feedbox cover. Attached to the feedbox is the external stop pawl assembly and part of the trigger mechanism. A feed chute and a link ejection chute are attached by wing nuts and eye-bolts on opposite sides of the feedbox.

**FEED LEVER.** This is a long-pointed lever pivoted in the right rear corner of the feedbox on a left-hand feed gun and in the left rear corner on a right-hand feed gun to actuate the feeding mechanism. A swivel stud mounted on the feed lever engages the feed crank and transmits motion of the feed lever to the feed crank. The feed lever is pivoted forward during counterrecoil of the gun by a stud mounted on the rear of the tube extension and is returned by force of the feed slide return lever plunger spring. The feed lever is checked at either end of its travel by the feed lever plungers and springs. The rear plunger and spring also return the feed lever to its initial operating position by overcoming the force of the slide return spring.

**FEED CRANK.** This is a large right-angled lever having a stud which transmits the motion of the feed lever to the feed-slide lever.

**FEED-SLIDE LEVER.** This lever actuated by the feed crank moves the feed slide to bring the ammunition into the feedbox.

**FEED SLIDE AND FEED PAWL.** These two parts move together in guides just below the upper surface of the feedbox. The feed pawl pivots downward from the slide and a projection engages the ammunition belt. As the feed slide and feed pawl are moved by the feed slide lever, the feed pawl feeds the belt into the mechanism. A finger release tab on the pawl extends beyond the end of the feed slide to provide for manual release.

**FEED SLIDE RETURN LEVER.** This is a lever which is pivoted on a pin located in the upper front corner of the feedbox. When moved by the feed slide, the return lever compresses its spring and

plunger. At the end of the stroke, the spring and plunger cause the lever to move and feed pawl and feed slide back to the initial position for feeding the next round.

**CARTRIDGE FEEDER STOP AND HOLDING PAWLS.** The cartridge feeder stop and holding pawls are pivoted to the feed slide front guide by means of shouldered studs and castellated nuts. The pawls are held in the proper position for engagement with the ammunition belt by a connector attached to both pawls. A spring-loaded connector shaft is attached at the middle of the connector and is provided with a button-type handle extending through a hole in the front end of the feedbox frame. Pulling forward on the handle retracts both pawls. The spring on the connector shaft pushes both pawls into their operating position.

**STRIPPER CAM.** A stripper cam with two camming surfaces is riveted to the side of the feedbox. As the belt moves in, this cam forces the cartridge from the belt links and down into position for chambering.

**CARRIER ASSEMBLY AND CARRIER CATCH.** The carrier is a long flat lever which pivots vertically on a pin extending through the sides of the feedbox. The carrier dog is a short flat-edged piece which pivots on a pin through the lower rear end of the carrier and is positioned by a spring and plunger located in the carrier body. During recoil the lock frame cams the carrier dog up, compressing the spring and plunger. The compressed spring forces the dog downward so that it will engage a notch in the top of the lock frame and thus hold the lock frame in the rearward position. In this position the compressed carrier spring causes the carrier to exert a downward force on the carrier catch. The carrier catch is so positioned that it holds the carrier in a horizontal plane just above the incoming cartridges. As the cartridge is stripped from the belt link, it pushes the carrier catch against a spring and plunger, thus freeing the carrier to push the cartridge down into the gun mechanism. During this downward movement of the carrier, the carrier dog is released from the notch in the lock frame, thus releasing the lock frame, which drives the cartridge forward into the chamber. The carrier is raised above the carrier catch by the carrier lifter cam during the forward movement of the lock frame.

**LOADING LEVER AND SPRING.** A loading lever and return spring are located near the rear of the feedbox, the lever pivoting about the bearing of the feed crank and operating through a slot in the side of the feedbox. This lever engages a pin in the feed crank to actuate the feeding mechanism during manual loading.

**INTERLOCK.** An interlock mechanism, consisting of an interlock body, plate, and spring, positioned at the rear of the feedbox, prevents operation of the loading lever unless the lock frame is in the retracted position.

**TRIGGER AND TRIGGER OPERATING ARM.** The trigger mechanism, consisting of a horizontal trigger operating arm and a vertical trigger, is pivoted on pins through brackets riveted to the outside rear end of the feedbox. The trigger is actuated by a solenoid mounted on the top plate. The lower notched end of the trigger engages the trigger bar.

**FEEDBOX COVER.** The feedbox cover is a flat steel plate hinged on removable pins. A slide latch and knob assembly operates in a housing riveted to the cover and, when latched, engages a stud on the feedbox which locks the cover in the closed position.

#### REMOVAL.

1. Loosen the wing nuts and remove the feed and link chutes.
2. Remove cotter pin from trigger pin, then remove trigger pin and trigger.
3. Remove the six attaching cap screws and lift feedbox from gun.

**NOTE.** Since the cap screws attaching the feedbox to the gun are staked in place, the feedbox will normally be disassembled in place and not removed from the gun.

#### INSTALLATION.

1. Place feedbox on gun and, using a soft hammer, tap the corners of the box lightly until correct position is obtained.
2. Install the six feedbox screws.
3. Install trigger, trigger pin, and cotter pin.
4. Install feed and link chutes.

#### DISASSEMBLY.

1. Raise feedbox cover assembly by pushing sideways on the knurled cover latch knob to release lock from pin.

**NOTE.** Cover assembly may be removed from the feedbox by removing the two cover hinge pins retained by cotter pins, on the side. These are located on the right side for the left-hand feed and on the left side for right-hand feedboxes. Feed chute and link ejection chute eyebolts and wing nuts may be removed by removing cotter pins and pins; however, removal of these parts is not necessary for disassembly of the feedbox.

3. Remove two fillister-head screws attaching external stop pawl assembly. Disassemble external stop pawl assembly by sliding pawl from bracket and removing the stop pawl bracket spring and plunger. Drift out stop pawl plunger stop pin; remove external stop pawl plunger and spring.

4. Remove feed slide return lever pin and feed slide return lever while depressing the spring and plunger.

5. Push the feed slide to the inner side of feedbox and remove feed-slide lever pin and feed-slide lever.

6. Remove feed lever pin assembly by rotating the long end of lock until short end is clear of lock screw. Lift feed assembly out of feedbox.

7. Rotate feed crank assembly to clear the feed lever bracket and lift it out of feedbox.

8. Depress feed lever spring plungers and springs, remove cotter pins, and carefully remove the springs and plungers.

9. Pull feed slide assembly out of feedbox. Disassemble feed slide assembly by removing cotter pin and drift out feed pawl pin. Remove feed pawl and spring.

10. Pry carrier pin lock out slightly and rotate until short end is clear of lock screw; then remove the pin and lock assembly. Lower the carrier assembly down between the side plates.

11. Hold carrier catch spring and plunger depressed while removing the carrier catch. Remove plunger and spring.

12. Remove cotter pin and castellated nut from the cartridge feeder holding pawl (outer) and remove pawl and cartridge feeder pawl connector.

13. Remove cotter pin and castellated nut from the cartridge feeder stop pawl (inner) and remove the pawl.

14. Remove cotter pin; unscrew cartridge feeder pawl handle from the cartridge feeder pawl con-

necter shaft assembly. Remove handle, spring, and shaft from the feedbox.

15. Remove trigger operating arm and trigger by removing cotter pins and pins.

16. Remove loading lever by unhooking loading lever return spring and lifting out lever. Remove spring and anchor pin from feedbox.

17. Remove cotter pin from the feed slide return lever plunger pin. Compress plunger and spring, remove the pin, then the plunger and spring.

18. Unscrew interlock body. Remove spring and interlock plate.

#### ASSEMBLY.

1. Install interlock spring and body through feedbox rear tie (interlock bracket). Position interlock plate on top of tie, and screw body tight to plate with wrench applied to flats on lower end of interlock body. Stake body to plate.

NOTE. The interlock spring must be positioned in the lower end of the opening through the feedbox tie.

2. Place feed slide return lever spring and plunger in bracket at front corner of feedbox. While compressing spring and plunger, install plunger pin. Lock pin with a  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

3. Install trigger operating arm and pin. Lock pin with  $\frac{1}{16}$ - by  $\frac{5}{16}$ -inch cotter pin.

4. Place rear end of cartridge feeder pawl connector shaft assembly in hole in feed slide guide. Place spring between front end of shaft and feedbox. Screw feeder pawl handle into connector shaft through hole in feedbox and through the spring. Align the cotter-pin holes and install a  $\frac{1}{16}$ - by  $\frac{5}{8}$ -inch cotter pin.

5. Install stop pawl (inner pawl) in the feed slide guide. Install castellated nut and  $\frac{1}{16}$ - by  $\frac{5}{8}$ -inch cotter pin. Be sure that pawl swings freely.

6. Hold cartridge feeder pawl connector in position to engage pins on stop pawl and connector shaft while installing holding pawl (outer pawl) on outer end of feed slide guide. Install castellated nut and  $\frac{1}{16}$ - by  $\frac{5}{8}$ -inch cotter pin. Be sure that pawl swings freely.

7. Place carrier catch plunger and spring in carrier catch bracket in feedbox frame. Depress plunger with end of screwdriver so that carrier

catch can be installed. Check for free movement of carrier catch.

8. Place carrier assembly in feedbox, from below, with carrier dog toward rear. Install carrier pin assembly through feedbox and carrier. Press pin in and turn lock until short end is engaged under the head of the carrier pin lock screw. Check for free movement of carrier.

9. Assemble feed slide by inserting feed pawl spring into spring seat and install pawl with spring entering spring seat. Line up hole in pawl and slide and install feed pawl pin and cotter pin  $\frac{1}{16}$ - by  $\frac{1}{2}$ -inch.

10. Install feed pawl assembly (pawl down and to outside) by releasing stop pawl and inserting slide in grooves in feed slide guide.

11. Install feed lever springs and spring plungers in feed lever bracket (rear corner of feedbox) and lock the plungers in place with  $\frac{3}{32}$ - by  $\frac{1}{2}$ -inch cotter pin.

12. Install loading lever by inserting long end through slot in side of feedbox and place inner end over shoulder on feed crank bearing; install return spring anchor pin and spring.

13. Place feed crank assembly in position, with yoke and to rear of feed lever bracket.

14. Place feed lever crank assembly in bracket, from above, with swivel stud engaged in the yoke end of the feed crank. Insert feed lever pin assembly through feedbox and upper end of feed lever. Press pin in and turn lock until short end is engaged under the head of lock screw on feedbox.

15. Push feed slide to the inner side of feedbox. Install feed slide lever and pin, with the forked rear end engaging stud on feed crank, and stud on front end engaged in large slot in top surface of the feed slide.

16. While depressing plunger and spring, install feed slide return lever and pin, with stud on rear end of lever in slot at inner end of feed slide.

17. If feedbox cover assembly was removed from feedbox, on disassembly, install this assembly with cover hinge pins.

18. Assemble external stop pawl assembly by placing the stop pawl plunger and spring in pawl, compressing spring sufficiently to permit installation of plunger stop pin which should be staked in place.

Place stop pawl bracket spring and plunger into bracket, compress spring, and install external stop pawl into position on the bracket. Attach external stop pawl assembly to feedbox with two fillisterhead screws.

19. Install feed chute and link ejection chute over dowels provided, and tighten in place securely with the attaching eyebolt wing nuts.

**CARE.** The many parts of the feedbox assembly and feeding mechanism must be kept clean and free from dirt, grit, and moisture. All studs, pivoting parts, holes, and plungers must be kept clean, properly lubricated with special preservative lubricating oil, and free from dents and burrs. Cotter pins should always be bent close to their pins or nuts so that no projecting parts will interfere with the operation of the mechanism.

*Driving Spring Tube Guards.* The driving spring tube front guards are placed lengthwise of the recuperator cylinder, one on each side. These are attached to the front and rear yokes by cap screws. The guards support and align the front end of the driving spring tubes.

#### REMOVAL.

1. Remove driving springs.
2. Remove driving spring guard front yoke by removing four screws.

#### INSTALLATION.

1. Place driving spring tube guards on the recuperator cylinder with projecting portion of guards engaged in the recesses in the cylinder. Secure rear ends of the guards to the rear yoke, with two screws in each guard. Do not tighten screws.

2. Install driving spring tube guard front yoke with four screws extending through the yoke and the guards into the expansion tube socket.

3. Now tighten all screws securely.
4. Replace driving spring assemblies.

*Recuperator Group.* The recuperator group consists principally of an oil-filled recuperator cylinder, bushing, two end caps and packings, piston, piston rod, stuffing box packings, expansion tube, two recuperator recoil springs, and a bronze separator.

The recuperator cylinder is threaded into the lower front opening of the trunnion block and

houses the piston rod, piston, recuperator recoil springs, recoil oil, and recuperator bushing. A bronze socket containing openings for the expansion tube, relief screws, and filler screws is attached to the front end of the cylinder.

The front end cap is of steel and contains a packing at its outer edge to seal the front end of the recuperator cylinder. This cap has two holes on its front surface to receive the special wrench used in its removal and installation.

The rear end cap made of bronze accommodates a packing at its outer edge and is threaded to screw into and seal the rear end of the cylinder. Two holes on its rear face are provided to fit the end cap wrench. To effect an oil seal where the piston rod passes through the rear end cap, a stuffing box is provided containing chevron-type packings, a gland, spring, and spring holder.

There are four chevron-type packings used, each consisting of a concave knife-edged composition washer with a rubber filler inserted in the bottom of the recess between the two knife edges. These packings fit into a corresponding recess in the rear end cap, and are pressed into contact around the piston rod by the force of the spring which is held in place by a spring holder screwed into the rear end cap.

The piston is screwed on the front end of the piston rod to which it is locked by a cotter pin. Four equally spaced steel seats are riveted to the rear side of the piston to form a locating seat for the recuperator recoil front spring.

The piston operates in a long steel bushing which is provided with three elongated slots, tapered at both ends, so as to hydraulically assist in the control of recoil and counterrecoil. The bushing is retained in the front end of the recuperator cylinder by a shoulder in the cylinder and the front end cap. It is prevented from rotating by a spring lock which engages a notch in the cylinder.

The piston rod extends through the rear end cap and is threaded to accommodate a piston rod nut by which the rod is attached to the tube extension. A shoulder near the rear end of the rod is provided with a groove which indexes with a piston rod screw in the tube extension to prevent the rod from turn-

ing. As the tube and tube extension recoil, the piston moves rearward, compressing the recuperator recoil spring and forcing the recoil oil through the slots of the recuperator recoil spring and forcing the recoil oil through the slots of the recuperator bushing. The tube and tube extension are carried forward to battery by the force of the recoil springs acting upon the recuperator piston.

A recuperator expansion tube is screwed into a socket at the front end of the cylinder and extends upward and to the rear at an angle of  $21^\circ$  from the centerline of the gun. The recuperator socket is provided with a threaded opening for the expansion tube on each side of the gun; the hole not being used is fitted with a closing plug. The socket also provides holes for the oil filler screw and relief screw on both sides. The filler screw on the expansion tube side is fitted with an oil indicator (dip stick). The removal of the relief screw from the expansion tube side vents the tube and the opening serves as a drain to prevent overfilling. The recuperator cylinder is provided with connecting passages to allow complete filling and venting. The hollow expansion tube provides space for the increase in the volume of oil resulting from temperature changes. There is space for the collection of air which may get into the recuperator system and impair its functioning.

The two identical recuperator recoil springs are positioned on the piston rod between the piston and the rear end cap. They are separated by a bronze separator. When assembled with the piston, rod, and end cap, the springs are under approximately 365 pounds compression. During recoil of the gun, these springs are further compressed. The expansion of the springs returns the piston, piston rod, and recoil to their initial positions, thereby returning the tube and tube extension to battery.

**NOTE.** The recuperator spring will not be removed from the recuperator piston rod by the using arms.

The recuperator mechanism hydraulically controls the recoil and counterrecoil of the tube and tube extension, and serves to return these parts to battery position.

**CARE.** The recuperator piston rod nut should be screwed on the recuperating piston rod so that the nut seats solidly on the shoulder of the tube

extension and the flat on the nut is in line with the top surface of the breechblock stop. This latter provision is necessary to prevent the nut from shaking loose on the piston rod.

The recuperator spring must move the weights of the tube, the tube extension, and the piston and piston rod and, in addition, force the oil past the piston. It has very little power in excess of that required for these functions. The use of recoil oil of improper viscosity or the development of undue friction, due to dirt, old grease, or improper lubricants, may cause the gun to fail to return completely into battery. If this failure does not exceed one-eighth inch, the gun will fire safely. When the lock frame is more than one-eighth inch out of battery, the breech lock cannot close and the gun will not fire.

Great care should be exercised in maintaining the correct amount of oil in the mechanism. With too little oil it is possible to have excess recoil to the extent that the recuperator piston drives against a solid column of the compressed springs, which will severely damage the gun.

There is no manual adjustment provided for the stuffing box packing in the rear end of the cylinder. The development of excess leakage should be reported to ordnance personnel.

*Trunnion Block Group.* The trunnion block assembly on which the feedbox is mounted is composed principally of the trunnion block body and two side plates.

**TRUNNION BLOCK ASSEMBLY.** The block body is open at the front to accommodate the tube and trunnion block bushing, and a second lower opening serves to mount the recuperator cylinder. The two side plates are flanged inward at the top and bottom, have an integral longitudinal rib at the center on the outside, and are grooved vertically at the rear ends to secure the back-plate assembly. They are open at the bottom sufficiently to permit ejection of the empty cartridge case. The side plates are attached to the trunnion block body by 28 tapered pins. The longitudinal ribs carry the load of recoil and counterrecoil of the gun in its mount. The lower flanges of the side plates serve as a track for the tube extension and lock frame as they move back and forth during recoil and counterrecoil. The left plate top flange incorporates a cam to operate the ejector, while the



right plate top flange has a channel machined in its bottom surface for installation of the trigger bar. Both side plate top flanges are slotted to accommodate the feed lever so that a right-hand or a left-hand feedbox may be used with the same trunnion block assembly. A keyhole slot is cut near the rear end of the left side plate to accept the accelerator cam stud which holds the accelerator cam assembly in place. A sighting slot is provided at the top of the trunnion block body to check the engagement of the tube lock with the recess in the tube.

**TRUNNION BRACKET ASSEMBLIES.** A trunnion bracket assembly, incorporating a close fitting key, is attached to each side plate by four  $\frac{7}{16}$ -inch cap screws. The bracket fits closely over the longitudinal rib and its key is forced into the tapered slot of the rib by an adjusting screw. This key securely positions the bracket which has an accurately machined boss to fit the airplane mounting brackets.

The trunnion block group may be considered the housing of the gun. In addition to providing for mounting the gun, it supports the operating mechanism, consisting of the tube and tube extension, recuperator group, lock-frame assembly, backplate assembly, driving-spring assemblies, and the feedbox and feeding mechanism.

**OPERATING CAM ASSEMBLIES.** Two front and two rear operating cam assemblies are attached by screws to the bottom side of the trunnion block assembly side-plate flanges. These cams are contacted by the guide pins of the operating lever during recoil and counterrecoil of the lock frame. The guide pins follow the camming surfaces and thus actuate the operating lever which in turn cocks the hammer and raises and lowers the breechblock. Both front and rear cams have bronze inserts secured by pins at points of high bearing load to increase the lift of the parts. Each rear cam also incorporates a spring-loaded switch near the rear end of its cam groove to insure proper tracking of the short guide pins during the movement of the lock frame in its return to battery.

**TRUNNION BLOCK BUSHING.** This is a single piece bronze bushing securing in the front end of the trunnion block body by two retaining screws to form a supporting bearing for the tube. Grooves are cast in the internal bearing surface and these

are packed with a graphite compound for lubrication.

#### REMOVAL OF TRUNNION BRACKET ASSEMBLIES.

1. Remove lock wires, the attaching socket-head cap screws, and the bracket assemblies.
2. Remove trunnion key.
3. Remove the set screw and long screw from the tapped hole in the trunnion.

#### INSTALLATION.

1. Place trunnion bracket key in slot provided between the front and rear sections of the side-plate longitudinal rib. The key must be positioned with the recessed side having the large beveled inner edge rearward, in order to mate properly with the tapered slot in the longitudinal rib.

2. Install trunnion bracket over the key and longitudinal rib and attach securely to the trunnion block with the four socket-head cap screws wired with figure-eight locking wires.

3. Install the long trunnion bracket screw in the tapped hole provided through the trunnion, and tighten it securely to seat the trunnion key firmly in its slot.

4. Install the cup point set screw.

## Functioning of the Gun

*General.* The series of operations and motions of the various parts of the gun occur in a definite and interrelated manner. Each part receives its motion from another part, and each functions in a definite and specific moment of the entire cycle. To describe the actions and functions of the various recoiling and nonrecoiling parts of the gun during one complete cycle, the entire operation has been broken into the following motions and each discussed in detail, giving the events as they normally occur: cocking and loading; trigger action; recoil action; breechblock action; recuperator action; lock-frame action; extraction and ejection; driving-spring action; feeding.

*Cocking and Loading.* When the manual charger is operated by pulling the cable, the shoe of the manual charger contacts the pin on the operating lever of the lock frame and causes the lever to rotate. This cams the hammer rearward beyond the latching hook of the sear, thus permitting the firing-pin spring to retract the firing pin. The

breechblock is lowered until it rests against its stop at the bottom of the tube extension. The rotation of the operating lever also forces the strut back against the follower, thus compressing the strut spring located in the body of the lock frame. The lock frame moving rearward compresses the driving springs. The lock frame continues rearward until it passes under the carrier dog and contacts the plunger of the backplate. With the release of the charger cable, the lock frame moves forward until the carrier dog engages the notch in the top of the lock frame.

The initial round is fed into the gun by pulling the loading lever rearward. This actuates the feeding mechanism, bringing the incoming round into contact with the stripper cam, which pulls it downward out of the links of the ammunition belt. At this instant, the rear end of the cartridge is positioned on the two prongs of the carrier which hold it in the path of the charger on the lock frame. Just before the cartridge is stripped from the links, it contacts the carrier catch moving it sufficiently to release the carrier. This allows the carrier to snap downward under force of the carrier spring. As the front end of the carrier pushes the cartridge downward, the carrier dog releases the lock frame.

As the lock frame goes toward battery under force of the driving springs, the charger (assisted by the extractor) forces the round into the cartridge chamber. The lug on the front end of the operating lever enters the T-slot in the lower end of the breechblock at the same time that the short guide pin on the operating lever comes in contact with the rear surface of the front operating cams. This rotates the operating lever which raises the breechblock toward battery position. The compressed operating lever spring acting on the rear end of the strut assists in completing this movement. The gun is now ready to fire when the trigger is pulled. The final chambering of the round is completed by the wedging action of the beveled radius on the front upper face of the breechblock as it slides up behind the cartridge. During final chambering, the extractor is cammed away from the rim of the cartridge by a cam surface on the front end of the extractor contacting a corresponding surface in the breech end of the tube.

#### *Trigger Action.*

**MANUAL FIRE.** As the breechblock moves into battery position, it raises the front end of the trigger trip. The rear end of the trigger trip is held downward to serve as a stop for the front end of the trigger lever connector. The trigger engages the rear end of the trigger bar while the forward end of the bar hooks over the upper end of the trigger lever. The trigger, trigger bar, trigger lever, and connector are all held in a forward position by the trigger lever spring and plunger.

When the trigger is pulled to fire the initial round, the trigger bar pulls the upper end of the trigger lever rearward, causing it to rotate on the trigger lever pin. Since the front end of the trigger lever connector is held down by the trigger trip, the connector is moved rearward. The rear end of the connector contacts the outer arm of the sear, causing it to rotate out of engagement with the latching hook of the hammer. The hammer is then driven forward by force of its spring, striking the firing pin to fire the round.

**AUTOMATIC FIRE.** If the trigger is held in the firing position, the gun will continue to fire automatically. As the breechblock is lowered, it releases the trigger trip and the front end of the trigger lever connector.

The connector is then rotated out of contact with the sear by force of the trigger lever spring and plunger. When the breechblock returns to battery position, it pivots the trigger trip which in turn rotates the connector so that the rear end of the connector again contacts the sear to release the hammer and fire the next round.

*Recoil Action.* When the cartridge in the chamber is fired, the reaction of the expanding gas is in all directions. As the projectile is driven forward through the tube, an equal force is applied in the opposite direction against the front face of the breechblock, which is mounted in the tube extension. Thus, the recoiling parts, the tube and tube extension, breechblock, lock frame, driving-spring assemblies, piston and piston rod are all driven to the rear together. This takes place because the tube is screwed into the tube extension, the breechblock is engaged in the lands in the forward end of the tube extension, the lock frame rests against the rear face

of a spacer (bridge) on the tube extension, the driving-spring assemblies are connected to both the tube extension and lock frame, and the piston rod is connected to the tube extension. All the recoiling parts remain together during part of the distance of recoil. The total recoil travel of the tube, tube extension, breechblock, piston and rod is approximately 10 $\frac{3}{4}$  inches.

*Breechblock Action.* The breechblock is lowered (breech opened) during recoil. The operating lever long guide pin, following the front cams, causes the operating lever to rotate, bringing the breechblock downward. Rotation of the operating lever during recoil causes a lobe on top of the lever to move the lower end of the cocking lever forward. As the lever pivots in the lock frame, the upper end operating in a recess in the hammer, cams the hammer to the rear, releasing the firing pin, and allowing the firing-pin spring to retract the pin. This movement compresses the hammer spring and forces the latching hook on the hammer past the hooked end of the sear, thus cocking the hammer. The short guide pin enters the ramps of the rear cams and is carried above the two switches into the horizontal grooves of the rear cams. This completes the downward movement of the breechblock which is now resting against the breechblock stop. As the breechblock moves downward, it releases the trigger trip and the front end of the trigger connector as previously explained under "Trigger Action."

*Recuperator Action.* The recuperator piston rod is pulled rearward by the tube extension during recoil. The piston, on the front end of the rod, is drawn rearward in the recuperator bushing. This bushing, secured in the front end of the recuperator cylinder, has three elongated slots tapered at each end, although the rear ends of the slots are longer and more gradually tapered than those of the front.

The fluid on the rear side of the piston is forced through these slots to the front side as the piston moves rearward. Therefore, the long tapered rear ends of the slots restrict the bypassing of oil as the tube and tube extension near the rear end of their travel. The tapered slots provide an increasingly greater restriction to the flow of oil on the last part of the recoil stroke, and the rearward movement

of the tube and tube extension is decreased accordingly.

During this action the recuperator springs are compressed. When the land of the piston reaches the end of the slots, the passage of oil has been entirely blocked, thus providing an almost solid stop against the confined fluid. The tube and tube extension are returned to battery position by the force of the recuperator recoil springs.

The movement of these parts near the forward end of their travel during counterrecoil is controlled by the taper of the slots in the front end of the recuperator bushing in the same manner as the recoil action is controlled. Three shallow grooves (approximately 0.030 inch deep) extend from the slots to the front end of the bushing to bypass oil after the piston passes the front end of the slots, to assure these parts going completely into battery with a minimum of shock. Drilled passages from the front ends of two of the elongated slots are connected with the expansion tube which is screwed into a socket on the outside of the recuperator cylinder.

The air-filled chamber of this expansion tube provides for expansion and contraction of the recoil oil in the cylinder due to temperature changes. Two slots in the front end of the bushing allow the escape of air to the expansion tube chamber when the recuperator is being filled with oil, or when air might otherwise be trapped in the cylinder during firing.

*Lock Frame Action.* The lock-frame assembly is not affected by the retarding action of the recuperator, since it was unlocked from the tube extension by the downward movement of the breechblock. Therefore, as the tube and tube extension near the end of their rearward travel, the lock frame separates from these parts and continues rearward because of its inertia and the action of the accelerator.

An accelerator is mounted on the tube extension to assure the lock frame continuing rearward, after separating a sufficient distance to permit the carrier dog to engage the notch in the top of the lock frame and thus latch the lock frame in its retracted position. The accelerator is actuated by a removable cam mounted at the rear end of the left side plate. At approximately the point of separation, the roll on the rear arm of the accelerator rides upward on the

inclined surface of the cam. The lower arm of the accelerator pushes rearward against a lug on the lock-frame body, thus giving the lock-frame assembly an accelerated movement rearward to the backplate buffer plunger.

The rear of the lock-frame body strikes the buffer plunger, compressing the ring spring and pressing the two friction pieces upward and outward against the inside of the backplate housing. Thus, the remaining recoil force of the lock frame is transferred to the back assembly.

The lock frame rebounds from the buffer plunger due to the action of the buffer ring springs. After traveling a short distance forward, the carrier dog engages the notch in the top of the charger (on the lock frame) holding the lock frame stationary, while the tube and tube extension continue forward toward battery.

*Extraction and Ejection.* Initial extraction occurs during the separation of the lock frame from the tube extension. The rim of the cartridge case is engaged by the extractor hook and, as the lock-frame assembly separates from the tube extension, the case is partially withdrawn from the cartridge chamber.

When the lock frame is held in its rearward position and tube extension has gone forward on counterrecoil to a point where the empty case is entirely extracted from the chamber, the ejector is pivoted downward by a cam on the upper flange of the left side plate. The flanged rear end of the ejector deflects the empty case downward between the side plates and out of the gun.

*Driving Spring Action.* The driving-spring assemblies are used to drive the lock-frame assembly to battery position. As the tube extension travels forward on counterrecoil, the driving spring housings are also carried forward. The rods are connected to the lock frame, which is held back by the carrier dog; therefore, the four driving springs are compressed. These compressed springs act on the driving spring rods to force the lock-frame assembly forward into battery position when it is released by the carrier dog.

*Feeding.* During the forward travel of the lock frame, the carrier lifter cam on the lock frame en-

gages a surface on the carrier and raises it above the carrier catch which holds the carrier in the upper position.

During recoil, the feed lever operating stud on the side of the tube extension contacts the lower end of the feed lever, pivoting it rearward. The stud passes under the end of the lever which then snaps back into position in front of the stud, by force of the feed lever rear spring and plunger. During counterrecoil, the operating stud pushes the lower end of the feed lever forward.

The feed lever swivel stud actuates the feed crank which in turn moves the feed slide lever, forcing the feed slide toward the inside of the feedbox against the force of the feed slide return lever and spring. The spring-loaded feed pawl on the underside of the slide engages the inner ears of the link holding the first round. Therefore, as the slide moves inward, the belt is moved with it, bringing this round farther into the feedbox.

Near the end of this motion of the feed slide, the stop pawl on the front feed slide guide drops off the tongue of the slide and engages the outer ear of the link, positioning the round.

The external stop pawl engages the outer ear on the opposite side of the belt, one round back. This stop pawl differs in action from the first as it does not disengage from the link ear when the feed slide returns, thus preventing overfeeding when there is a heavy load tending to push the rounds inward. The holding pawl on the front feed slide guide slides behind the outer link ear of the following round, preventing the belt from moving backward as the feed slide returns to engage the next link to feed in another round.

The stop pawls are operated by beveled surfaces on the feed slide, while the holding pawl is operated by the outer ears of the belt links. When the tube extension is near battery position, the feed lever operating stud passes under the lower end of the feed lever. The feed slide return lever, plunger, and spring then force the feed slide toward the inlet side of the feedbox to pick up the next round. This movement carries the feed slide lever, feed crank, and feed lever back to initial feeding position.

As the cartridge is fed into the feedbox, it is stripped from the belt.

SECTION 5. 37-MM AUTOMATIC GUN M10

Functioning of 37-mm Automatic Gun M10

with the functioning of 37-mm automatic gun M4, in section 3 of this chapter.

Functioning of this weapon is described along

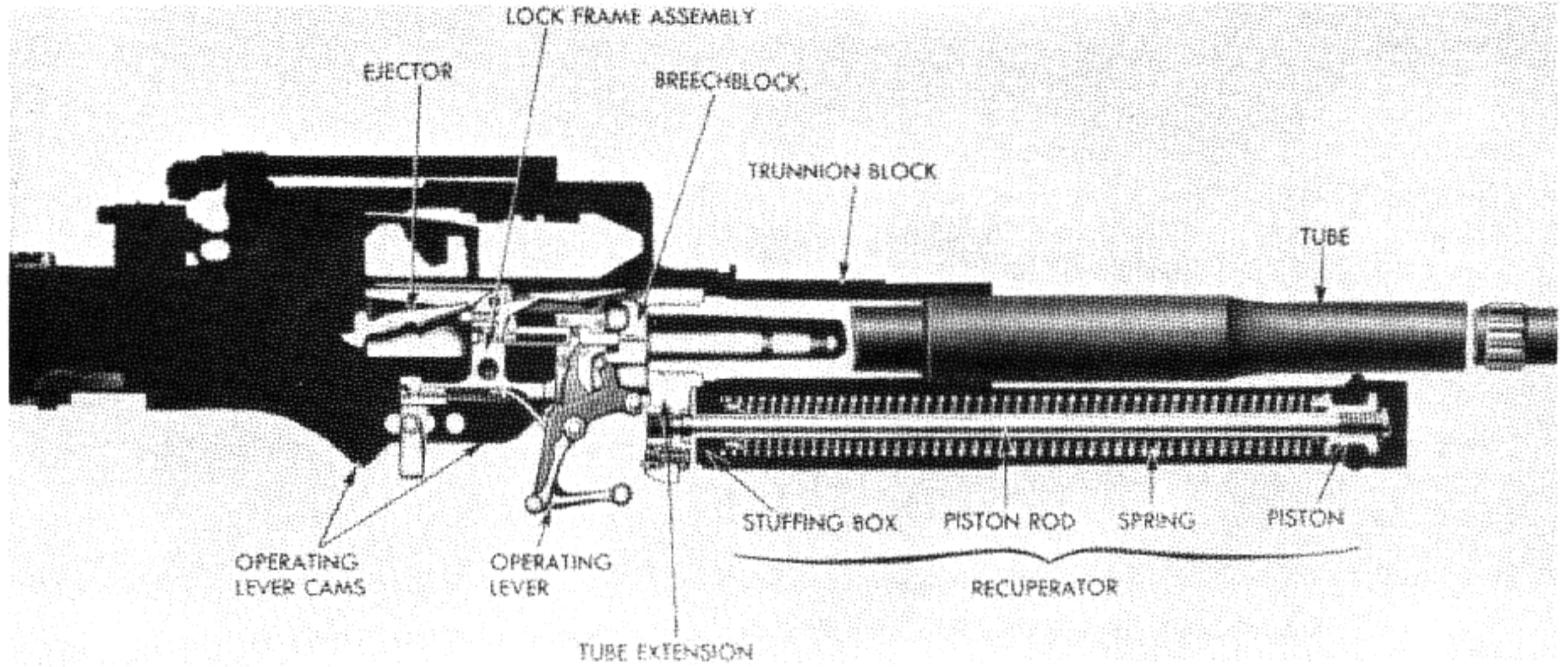


Figure 12-17. 37-mm Gun M10. Sectional view. Light area indicates recoiling parts.

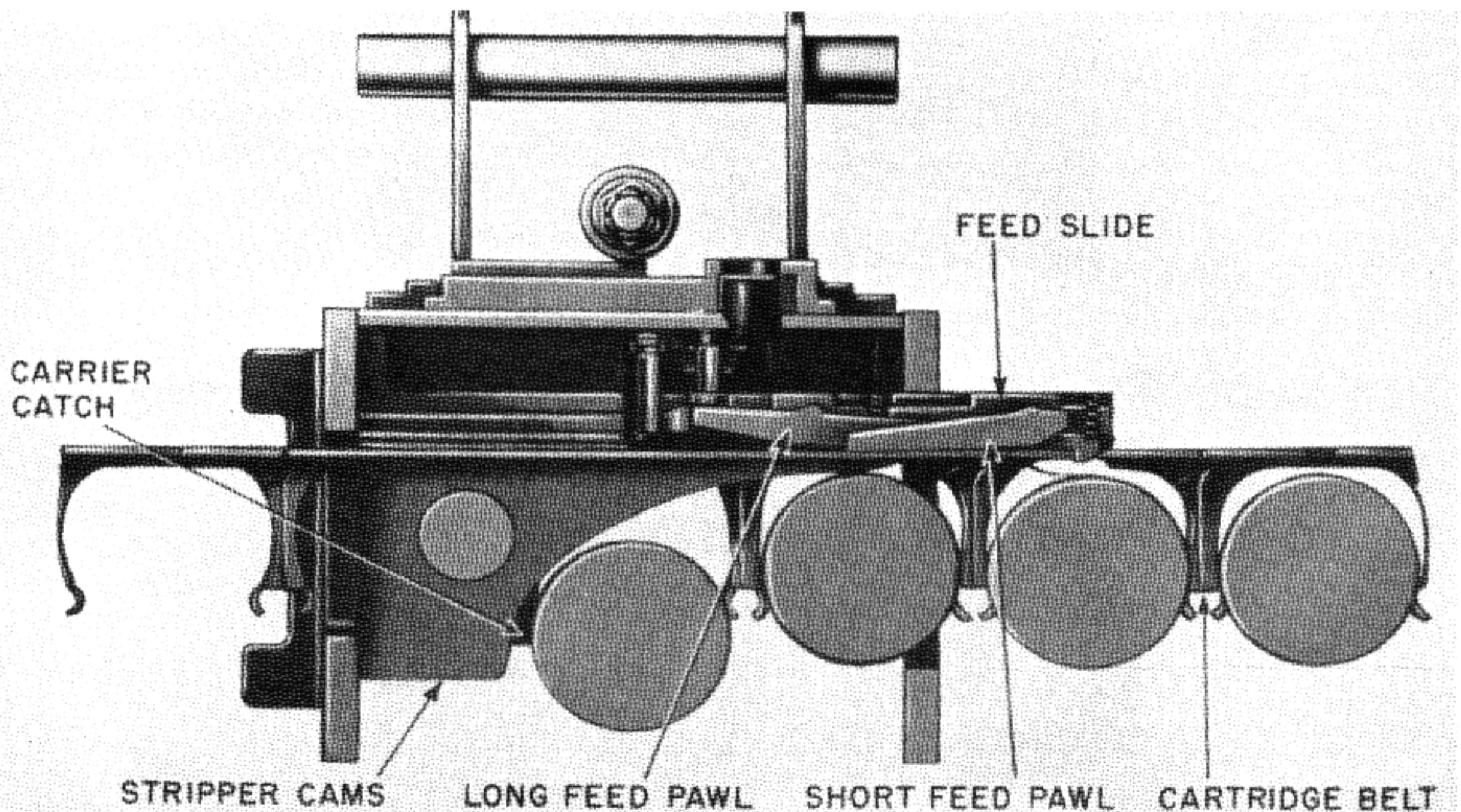


Figure 12-18. 37-mm Gun M10. Action of stripper cam.

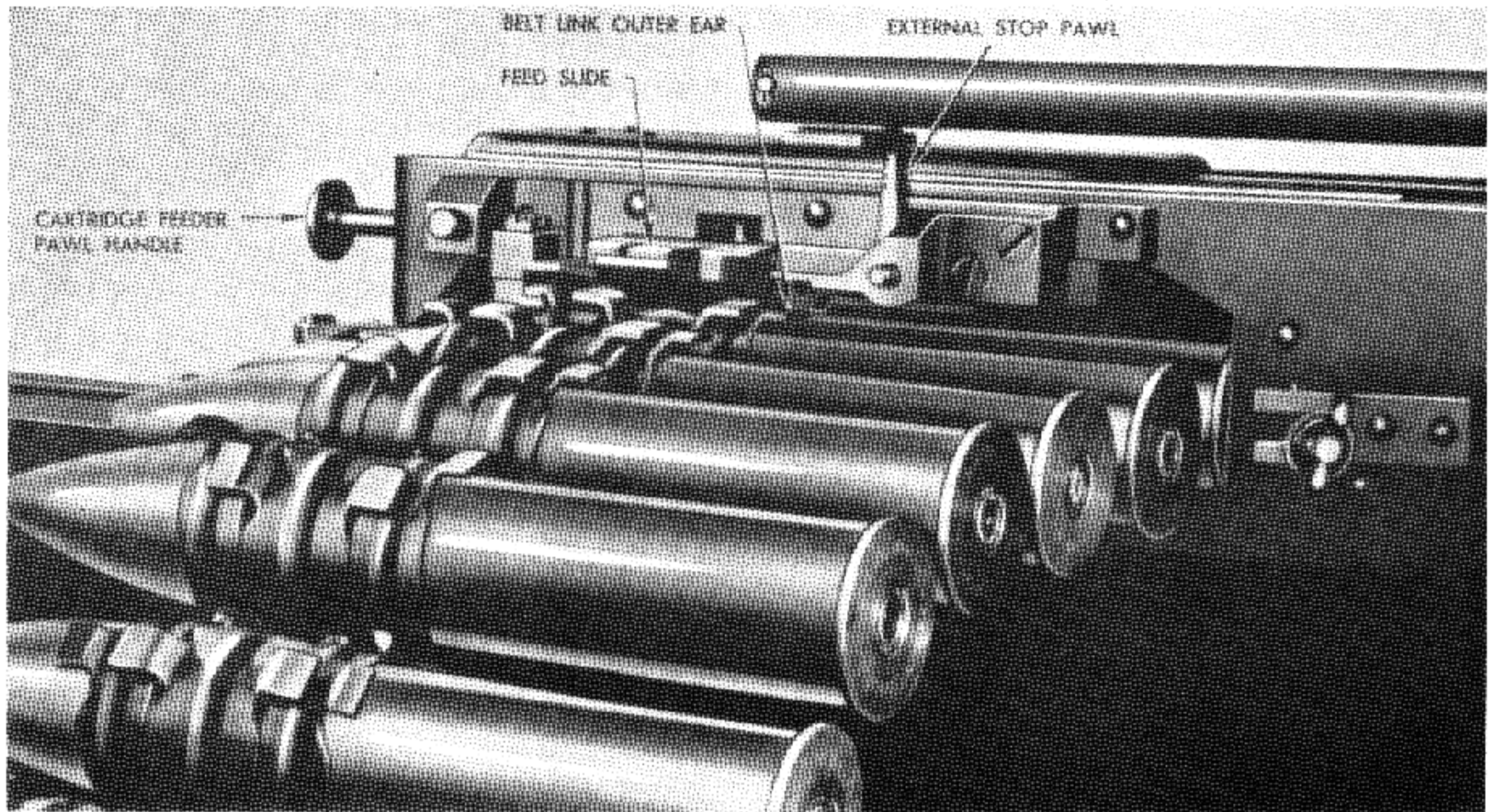


Figure 12-19. 37-mm Gun M10. External stop pawl contacting outer ear of belt link.

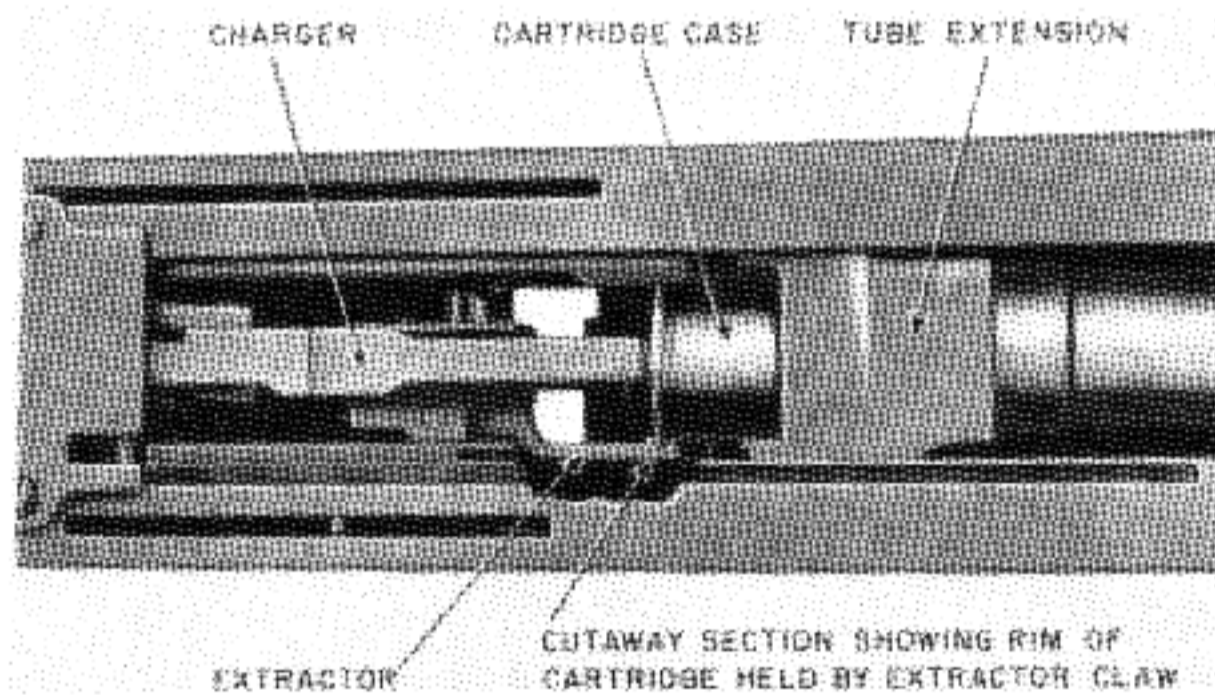


Figure 12-20. 37-mm Gun M10. Initial extraction, during separation of lock frame and tube extension.

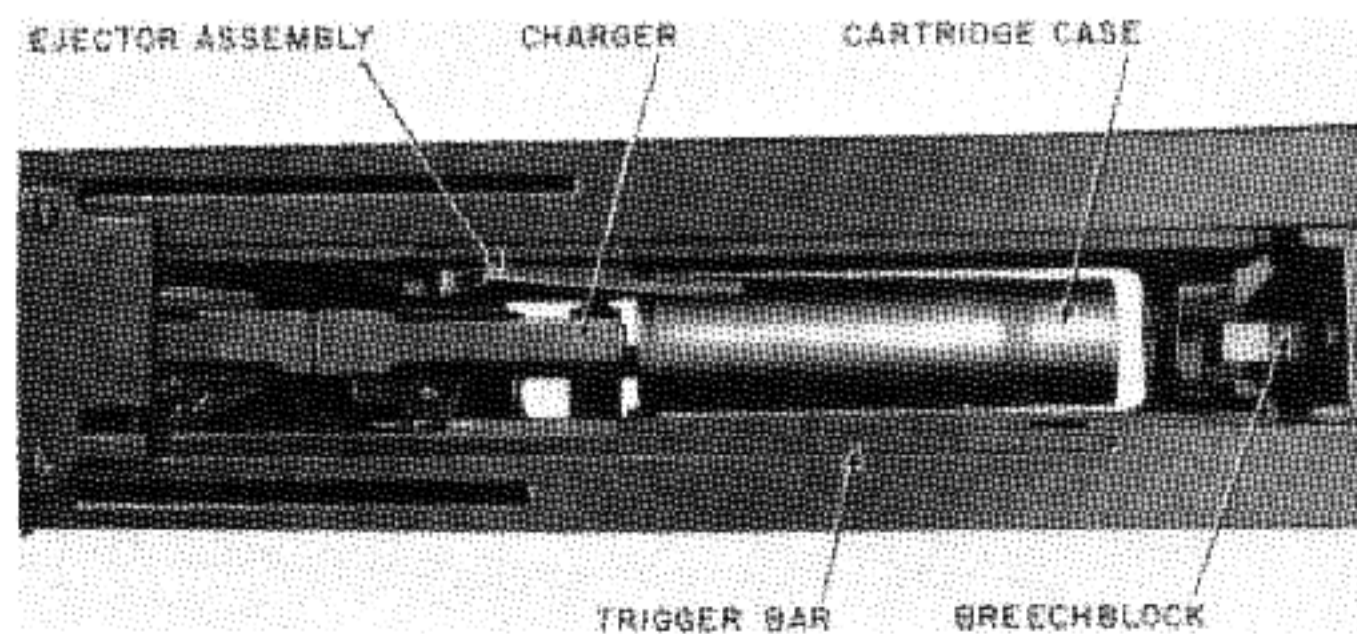


Figure 12-21. 37-mm Gun M10. Ejection.

## Chapter 13

# UNITED STATES AIRCRAFT CANNON DEVELOPMENT BASED ON THE BIRKIGT TYPE 404 (HISPANO-SUIZA)

## SECTION 1. HISTORY AND BACKGROUND

In 1936, the United States Navy turned its attention to the procurement of an automatic weapon heavier than the caliber .50 machine gun. The Navy's overseas attachés were instructed to check all tests being conducted in Europe with a view to finding a suitable weapon that was readily available.

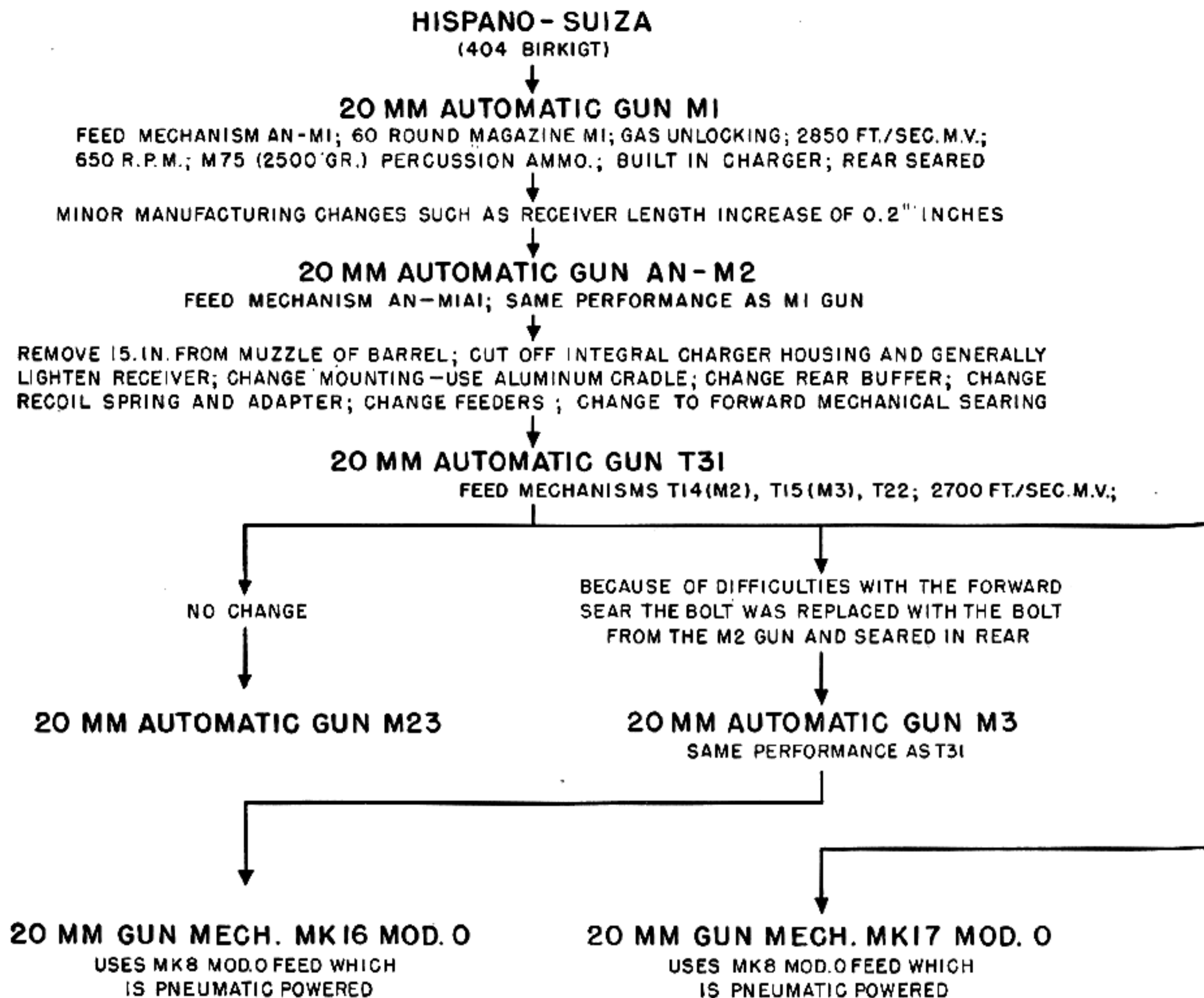
As a part of this program, the development of the Birkigt type 404 20-mm automatic gun was followed closely in France by both the Navy and the Army. In 1937 negotiations were begun to procure a sample gun for tests. In 1940 the United States acquired the rights to manufacture the gun, and production was begun under the designation "type M1." The details of this phase of the weapon's history are given in volume 1 of *The Machine Gun* (pages 562-577), along with an account of American modifications through the year 1943, when Gun, automatic, 20-mm, T31 had evolved. The action of this gun is the parent of two of the Navy's recent 20-mm weapons: Gun, automatic, 20-mm, T34; and 20-

mm gun mechanism Mk 12, which is also known officially by the Army designation Gun, Automatic, 20-mm T118. These two weapons are described in detail in this chapter.

Technical data regarding some of the predecessors of the T31 are included in this chapter to supplement the history of the development of these models which is presented in volume 1 (pp. 577-590). Other 20-mm models antedating the T31 which are discussed in volume 1 are, in addition to the Type M1: M2, AN-M2, T25, T26, T27, T28, and T29.

Other related 20-mm models may be identified by means of the short descriptions in chapter 1. These are: T16, T18, T19, T20, T21, and T23.

The chart showing the important stages in the American development of the Hispano-Suiza gun summarizes the evolution and development of this automatic firing mechanism. In addition to the chart, illustrations give a pictorial history of the many modifications made in attempts to produce the optimum weapon.

**NOTE:**

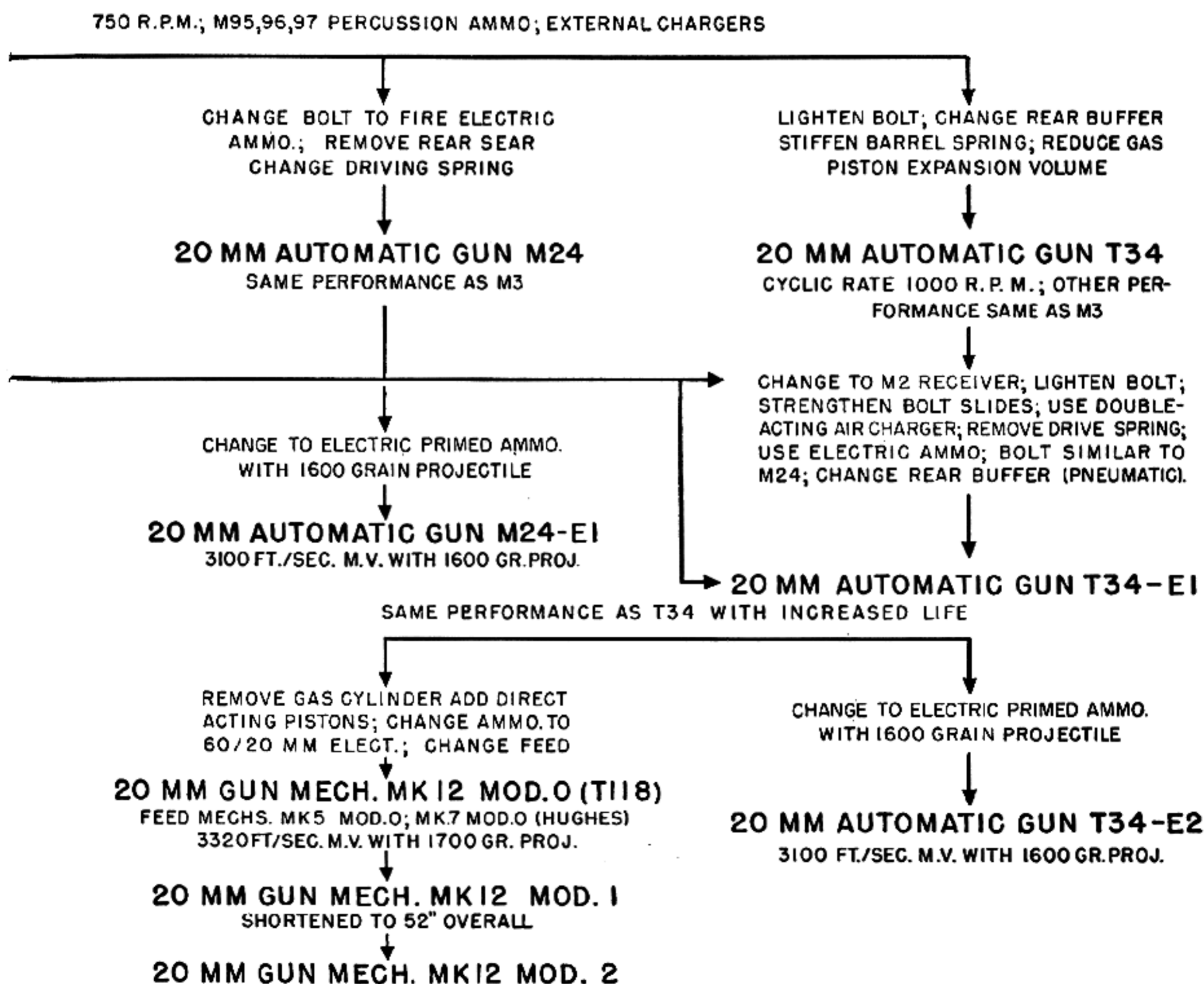
*WEAPONS LISTED AS AUTOMATIC GUNS  
ARE ORD. CORPS (ARMY) DEVELOPMENTS.*

*THOSE SHOWN AS GUN. MECH. ARE BU.ORD.  
(NAVY) VERSIONS.*

Figure 13-1. Schematic summary of important stages



# IMPORTANT STAGES in the AMERICAN DEVELOPMENT of the HISPANO GUN



in the American development of the Hispano-Suiza Gun.



Figure 13-2. Production engineering the American version of the Birkigt Type 404 Gun.

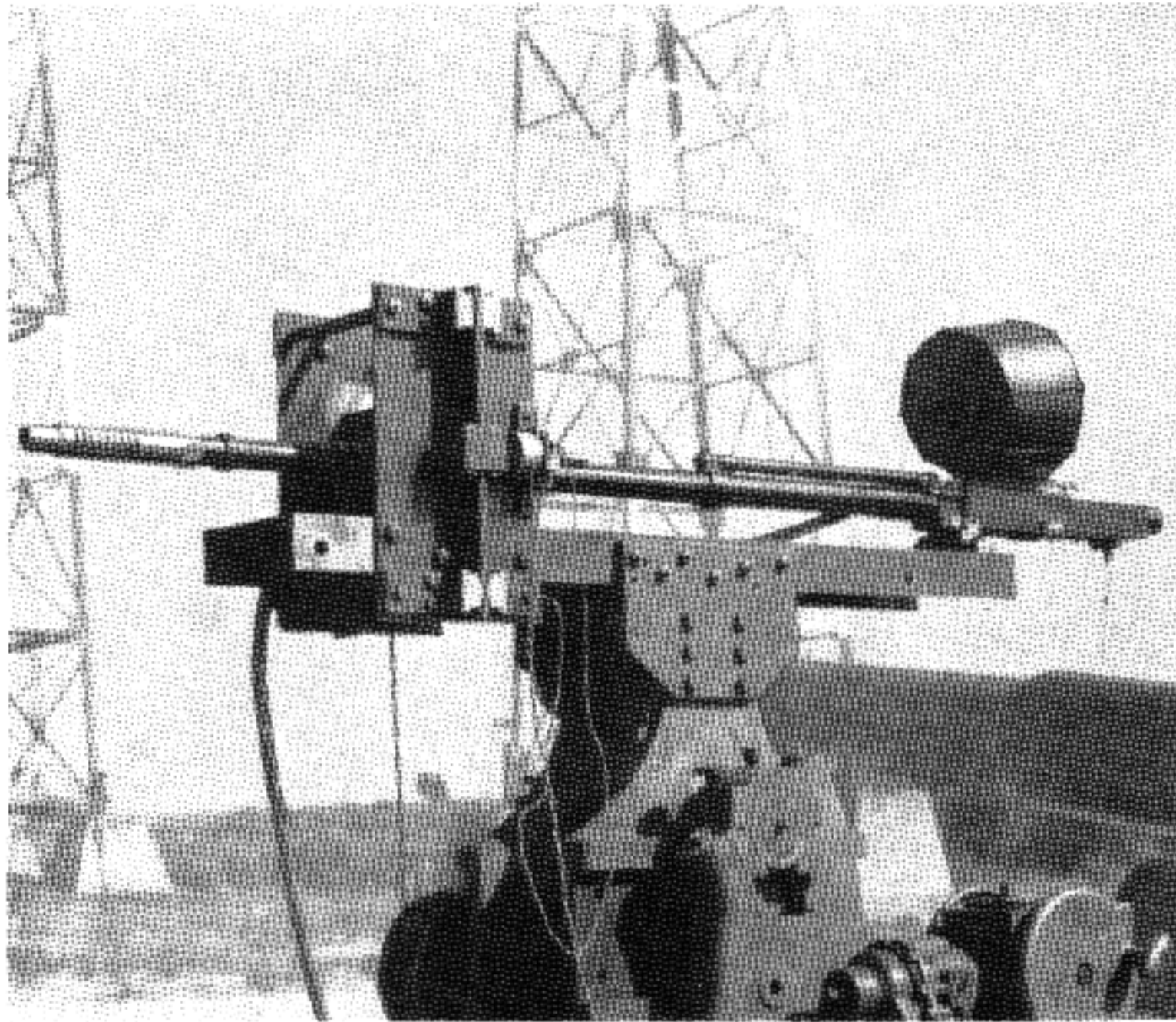


Figure 13-3. Birkigt Type 404 Gun at the Naval Proving Ground, Dahlgren, Va., during test firing in 1940.

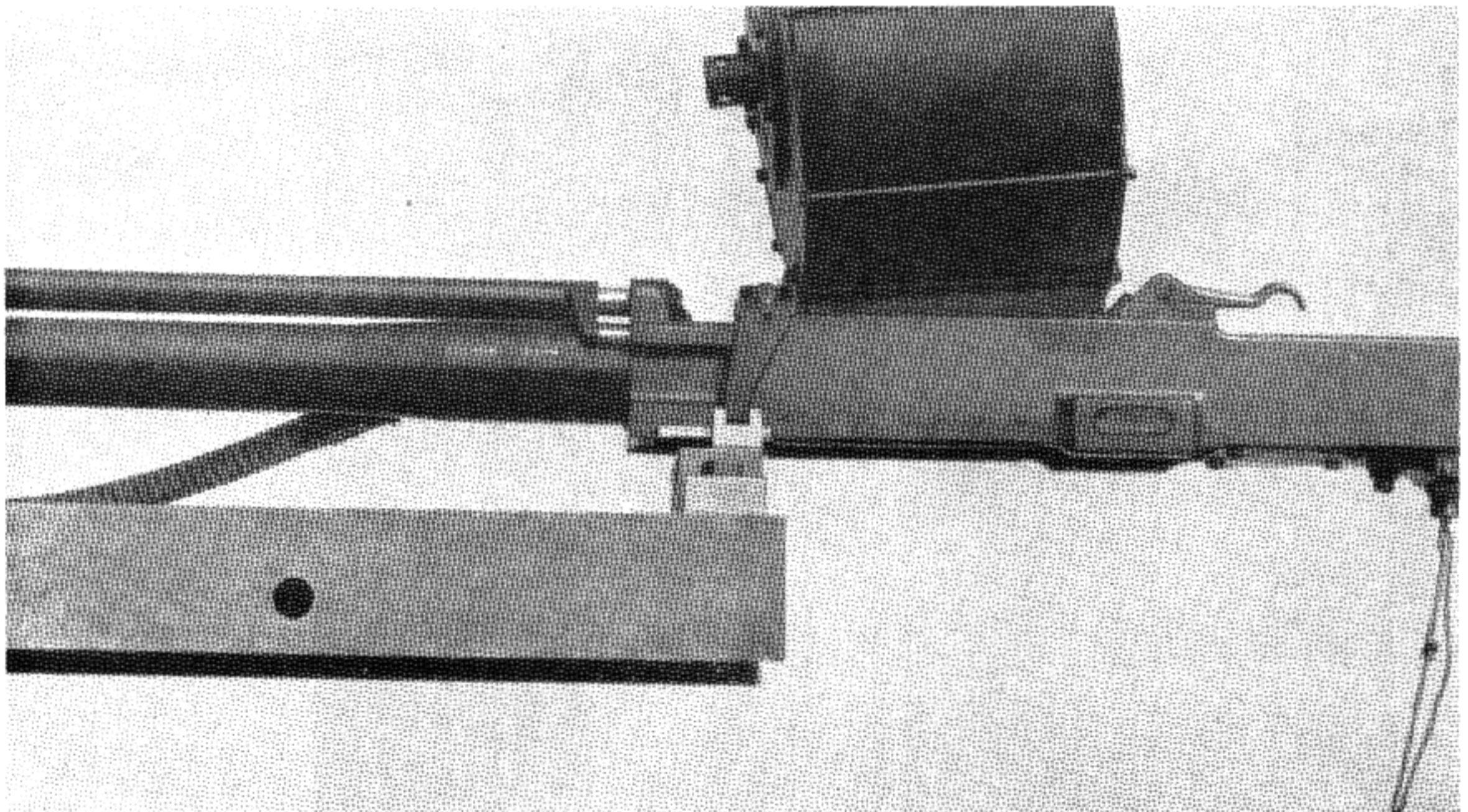


Figure 13-4. Birkigt Type 404 Gun. Closeup view taken at the Naval Proving Ground, Dahlgren, Va.

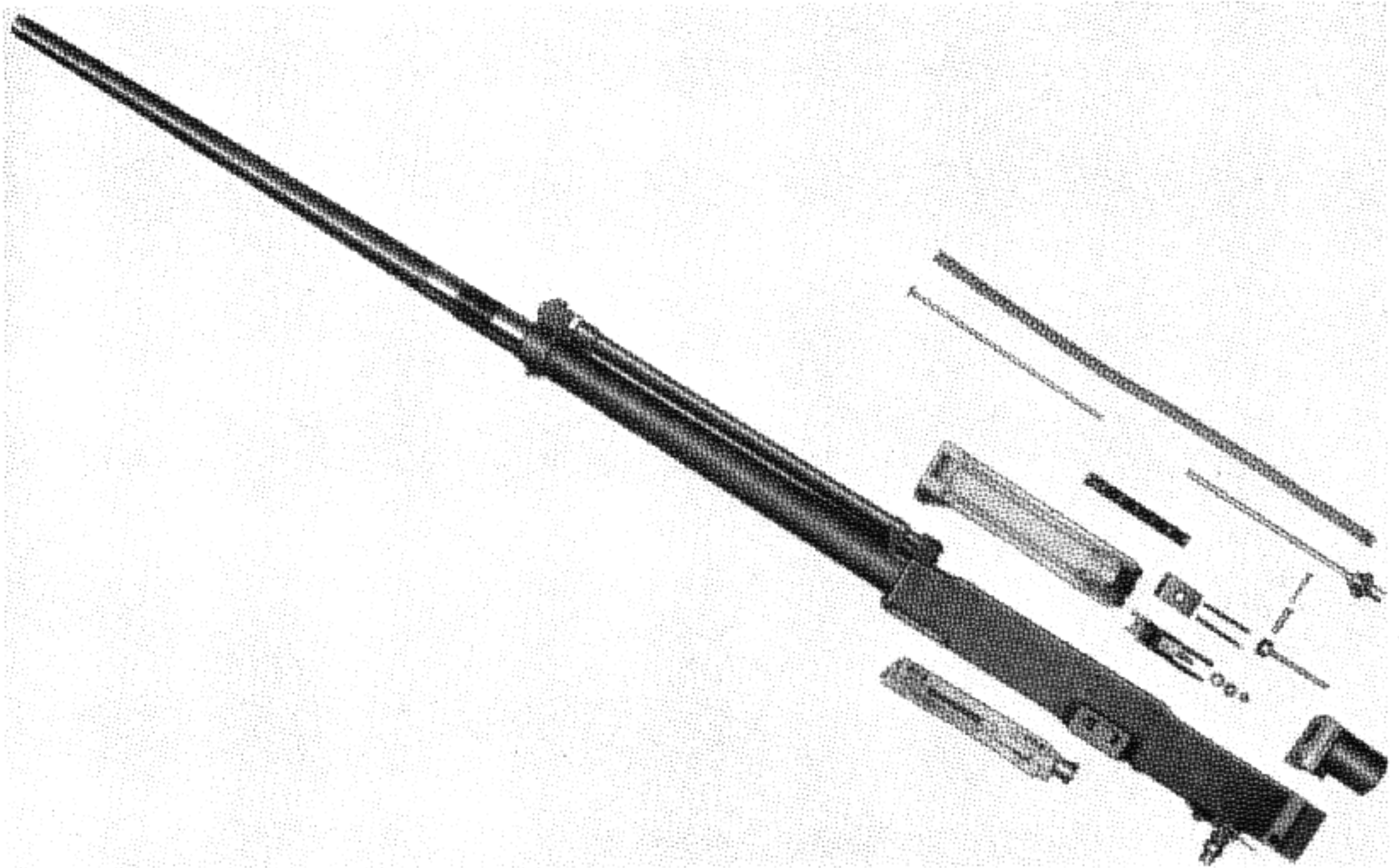


Figure 13-5. 15-mm Bendix Machine Gun. Disassembled view.

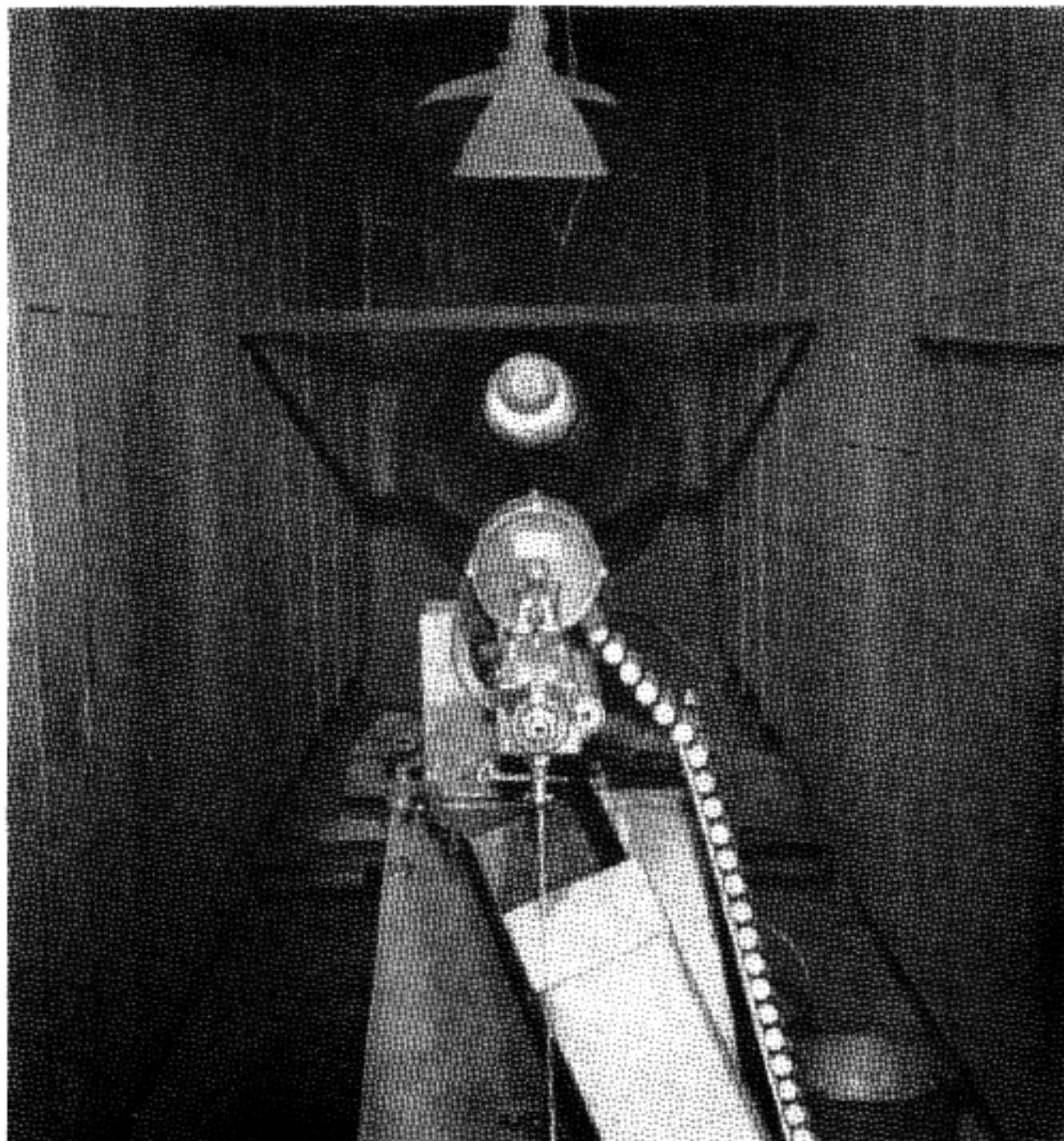


Figure 13-6. Proof-firing Gun, Automatic, 20-mm M1 at the Eclipse Plant.

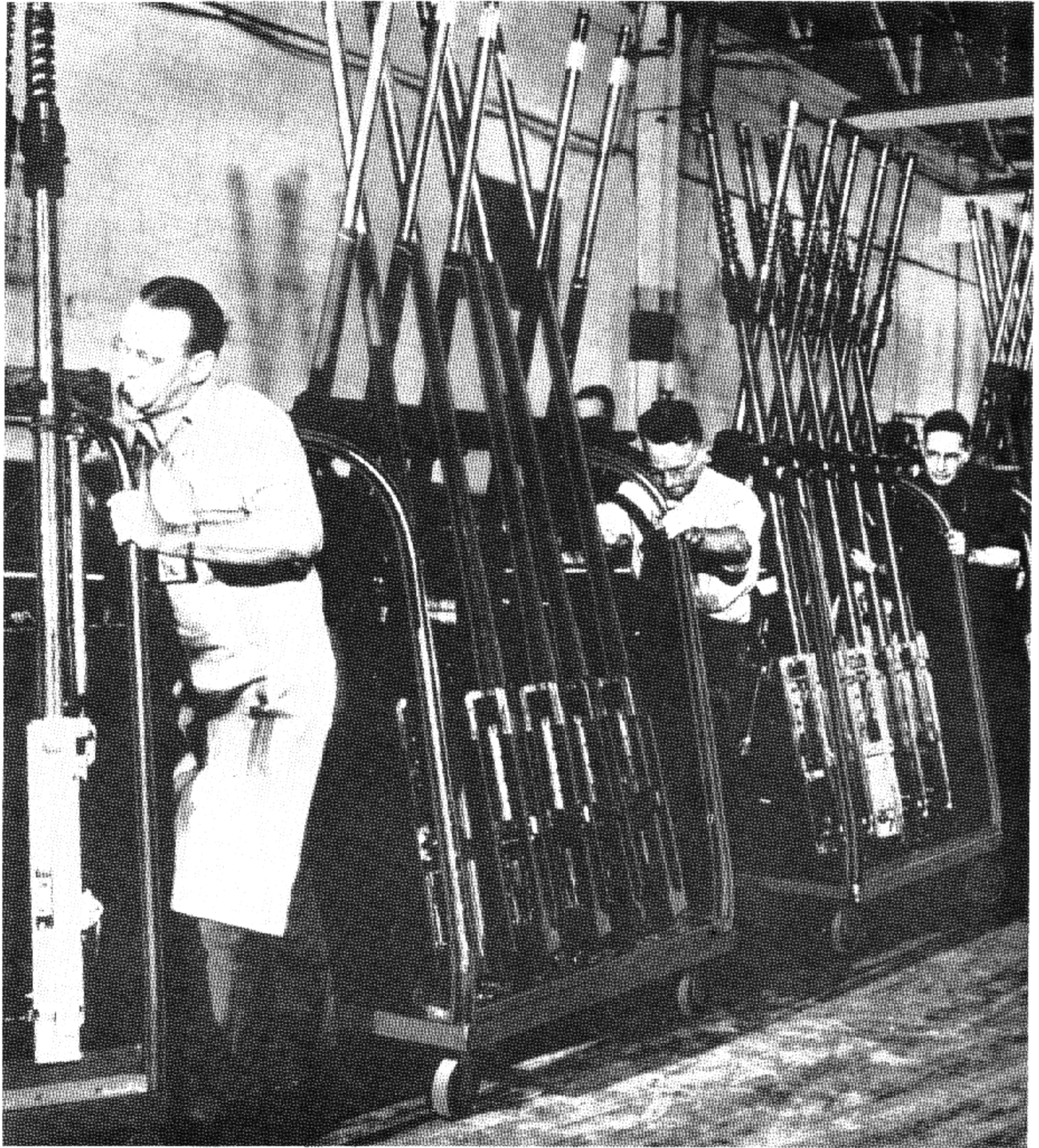


Figure 13 7. Gun, Automatic, 20-mm M2 coming off the production line.

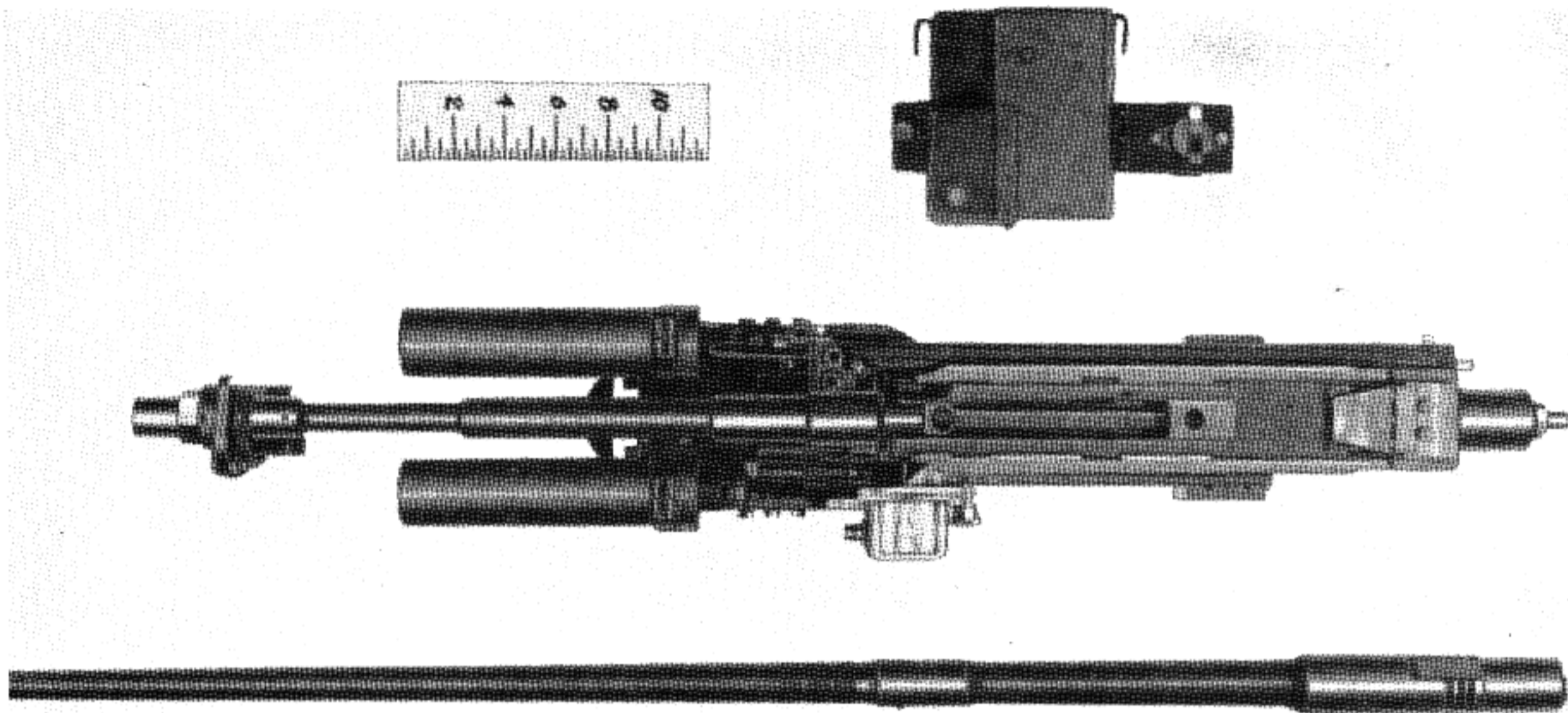


Figure 13-8. Gun, Machine, Aircraft, Caliber .60, T18E1, with barrel and feeder detached.

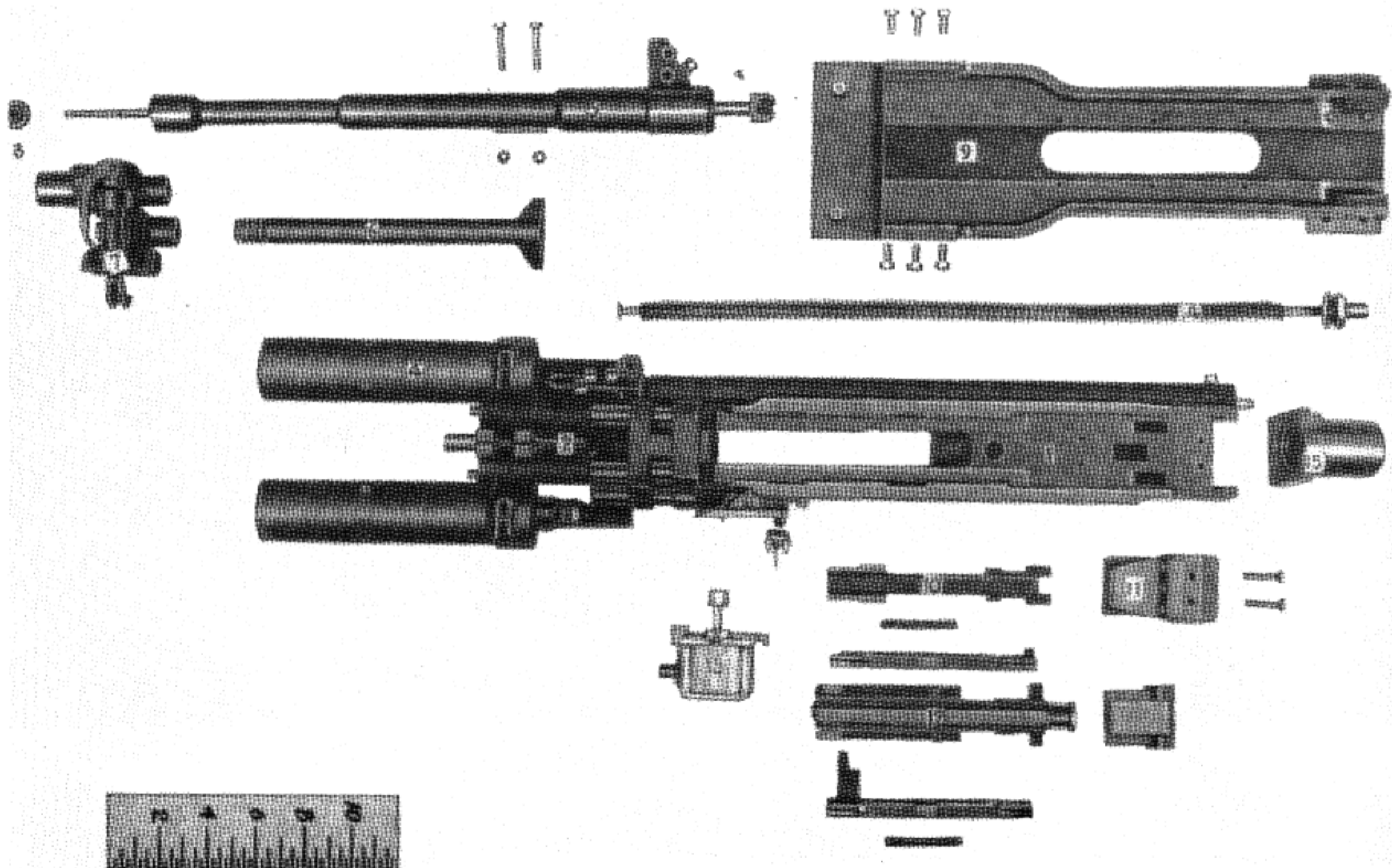


Figure 13-9. Gun, Machine, Aircraft, Caliber .60, T18E1, partially disassembled.

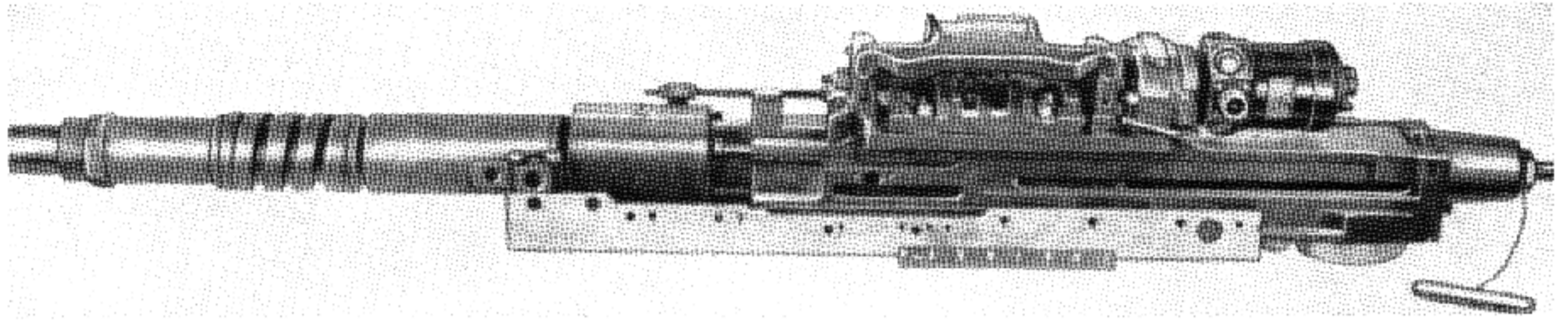


Figure 13-10. Receiver of 20-mm Gun T32. Left side view.

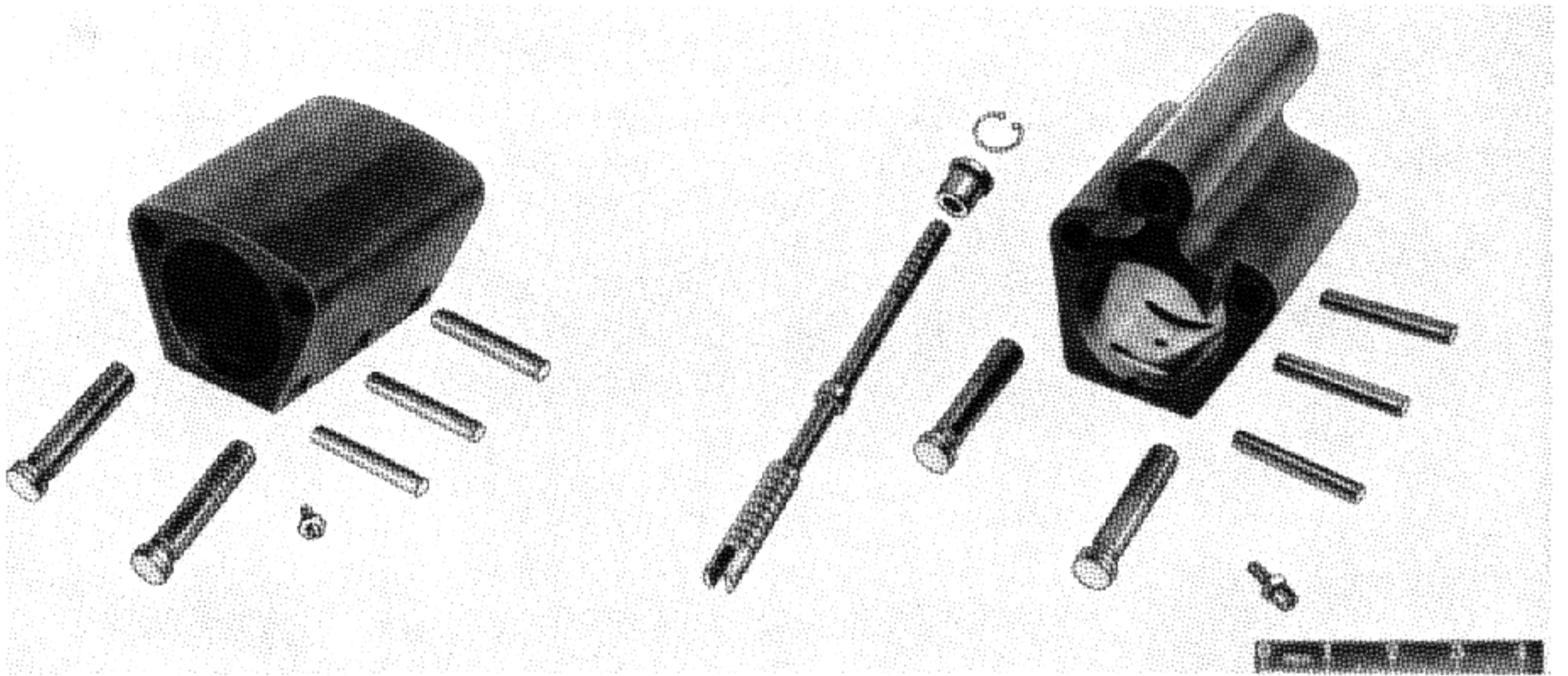


Figure 13-11. Gas systems for 20-mm Gun T32. Exploded view. Left, unlocking system. Right, gas unlocking system and modification whereby gas is employed for operation of feeder.

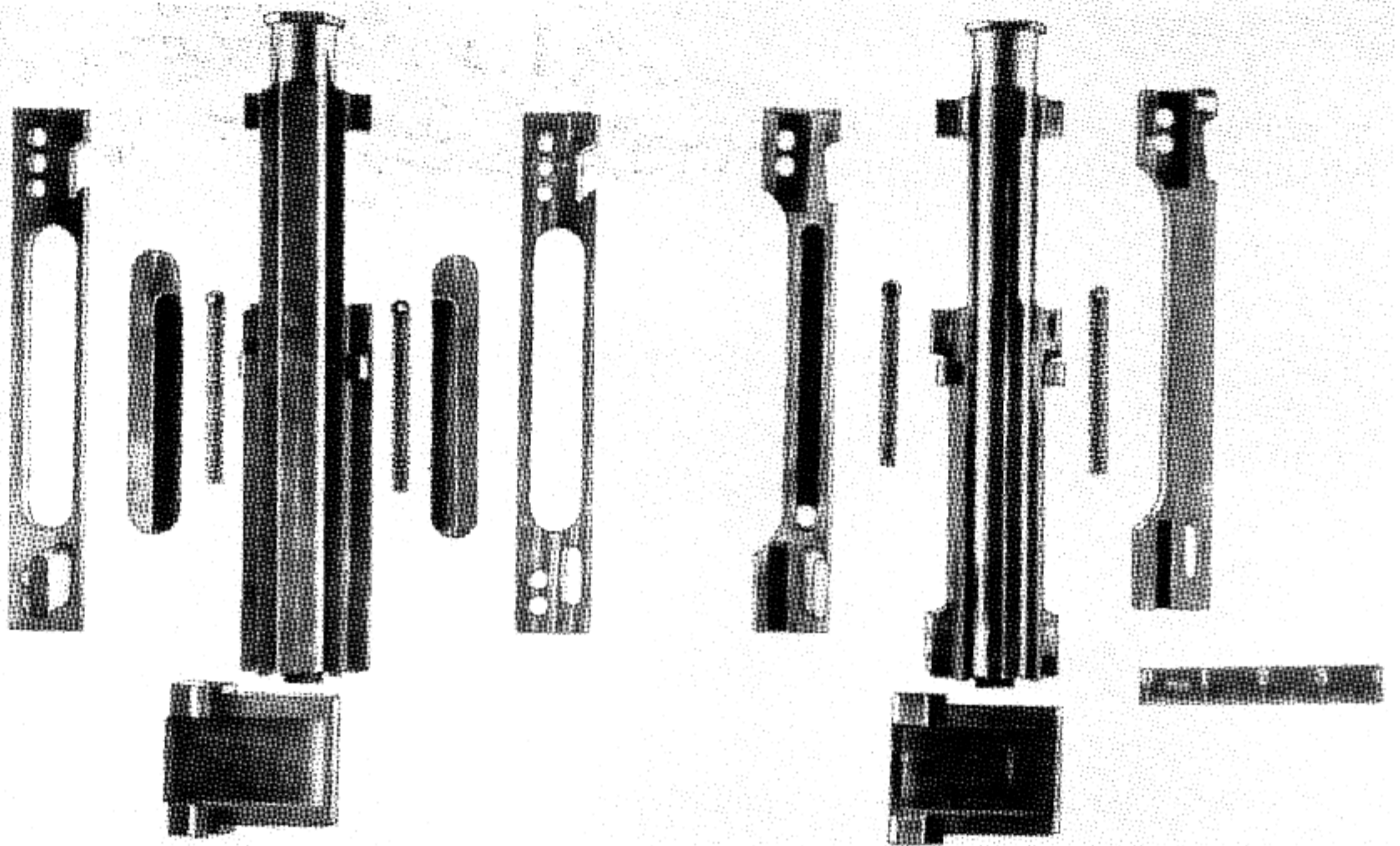


Figure 13-12. Bolt components of 20-mm Gun M3 (left) compared with those of 20-mm Gun T32 (right).

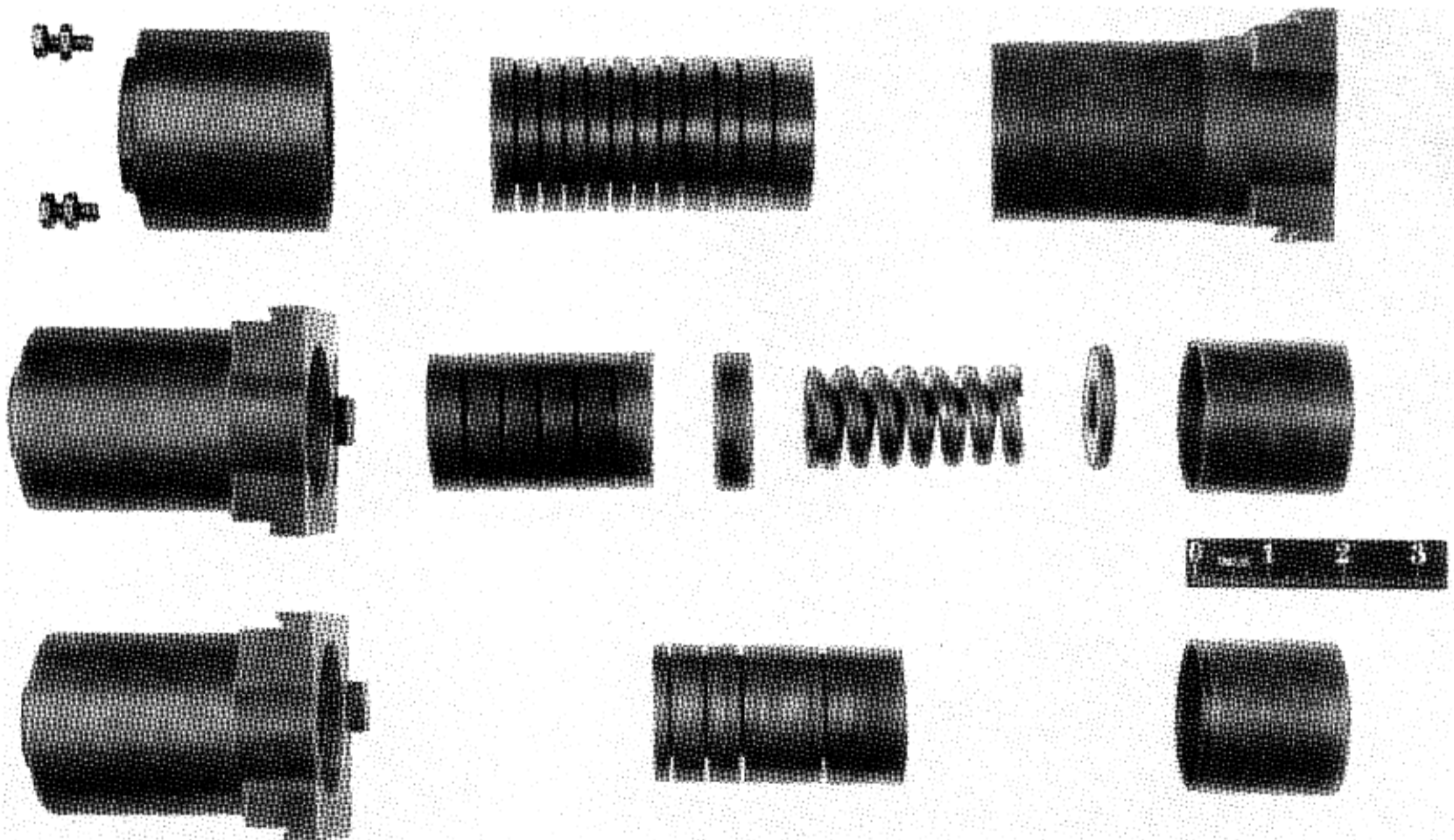


Figure 13-13. Development of buffers. Top to bottom: experimental Belleville washer type; standard type for M3 Gun; Belleville washer type for T34 Gun.



## SECTION 2. DEVELOPMENT OF GUN, AUTOMATIC, 20-MM, T31 (M3) SINCE 1943

## General

The 20-mm T31 is an outgrowth of modifications and attempts at standardization of the Birkigt type 404 20-mm cannon in both the United States and England. In physical appearance it shows many refinements of earlier modifications and it forms the basis for development work on models designated gun, automatic, 20-mm, T34 and 20-mm gun mechanism Mk 12 (which is also known as the T118).

The 20-mm automatic gun T31 is a combination blowback, gas unlocked, aircraft cannon. A developmental progress report early in 1944 showed that it weighed 99½ pounds without the feed mechanism and was furnished with a cradle mounting designed for installation in the wing, fuselage, or turret of an airplane. The cyclic rate was 750 to 850 rounds per minute, and the gun was so designed that it could be synchronized to fire between the propeller blades of the airplane. The ammunition used was

a complete family of matched projectiles which included AP, API, I, and HE rounds.

Among other military characteristics, the T31 gun was to be capable of synchronization by means of separate, interchangeable actions, one to fire percussion-primed ammunition and one to use electrically primed ammunition. However, in April 1944 the Navy, then the major customer for 20-mm guns, requested that its guns be delivered with a rear seared mechanical percussion bolt, in order to expedite delivery of guns required for production aircraft. This led to the typing of the T31 gun as follows:

T31 (M3), rear seared percussion fired gun.

T31 (M23), forward seared percussion fired gun.

T31 (M24), forward seared electrically fired gun.

In 1944, the Air Force advised the Ordnance Corps that it was actively engaged in a number of experimental armament installations in various bombardment and fighter aircraft intended for use

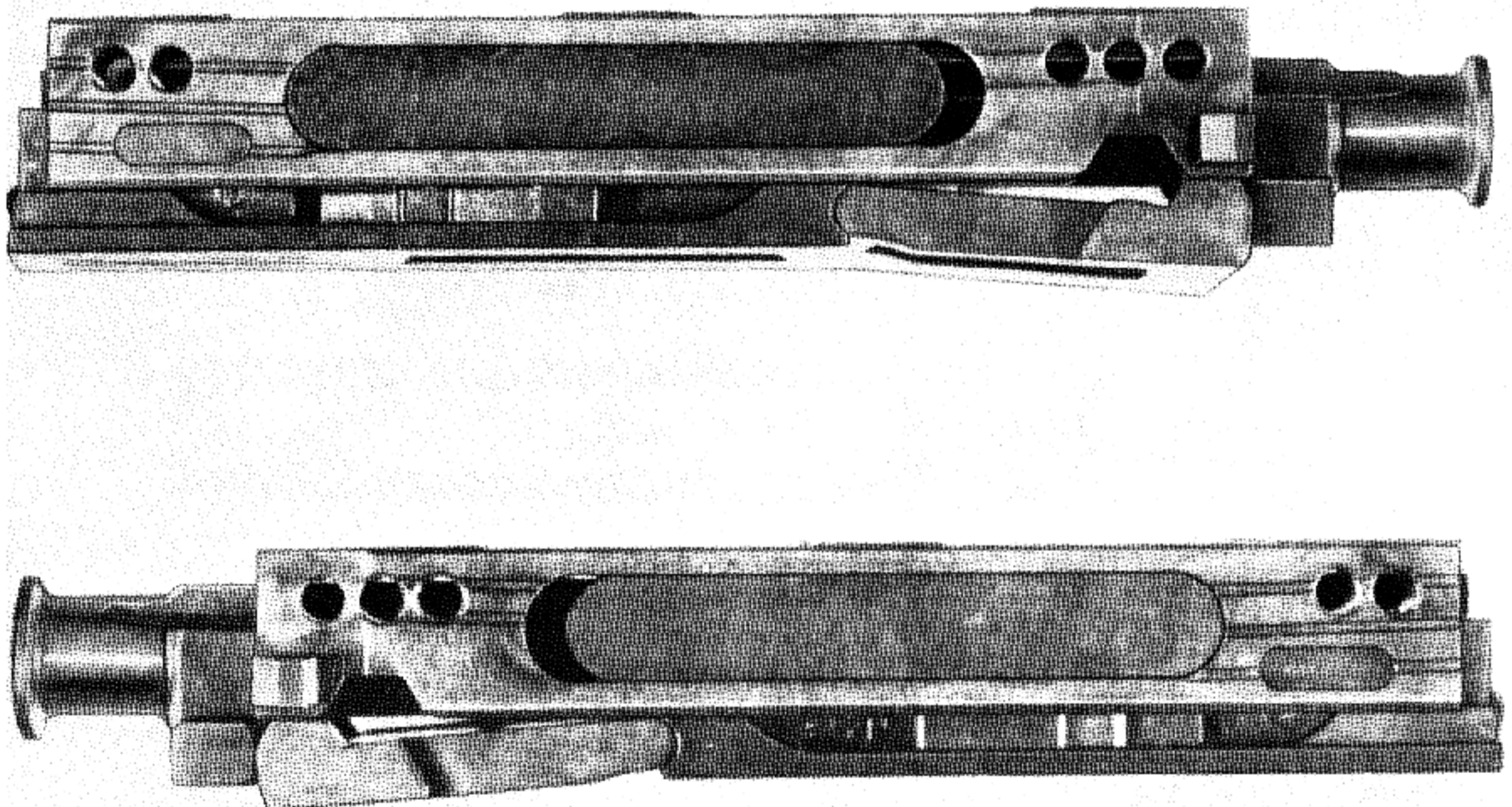


Figure 13-14. The bolt of the 20-mm M23 Gun, which was one of the developments in the T31 program.

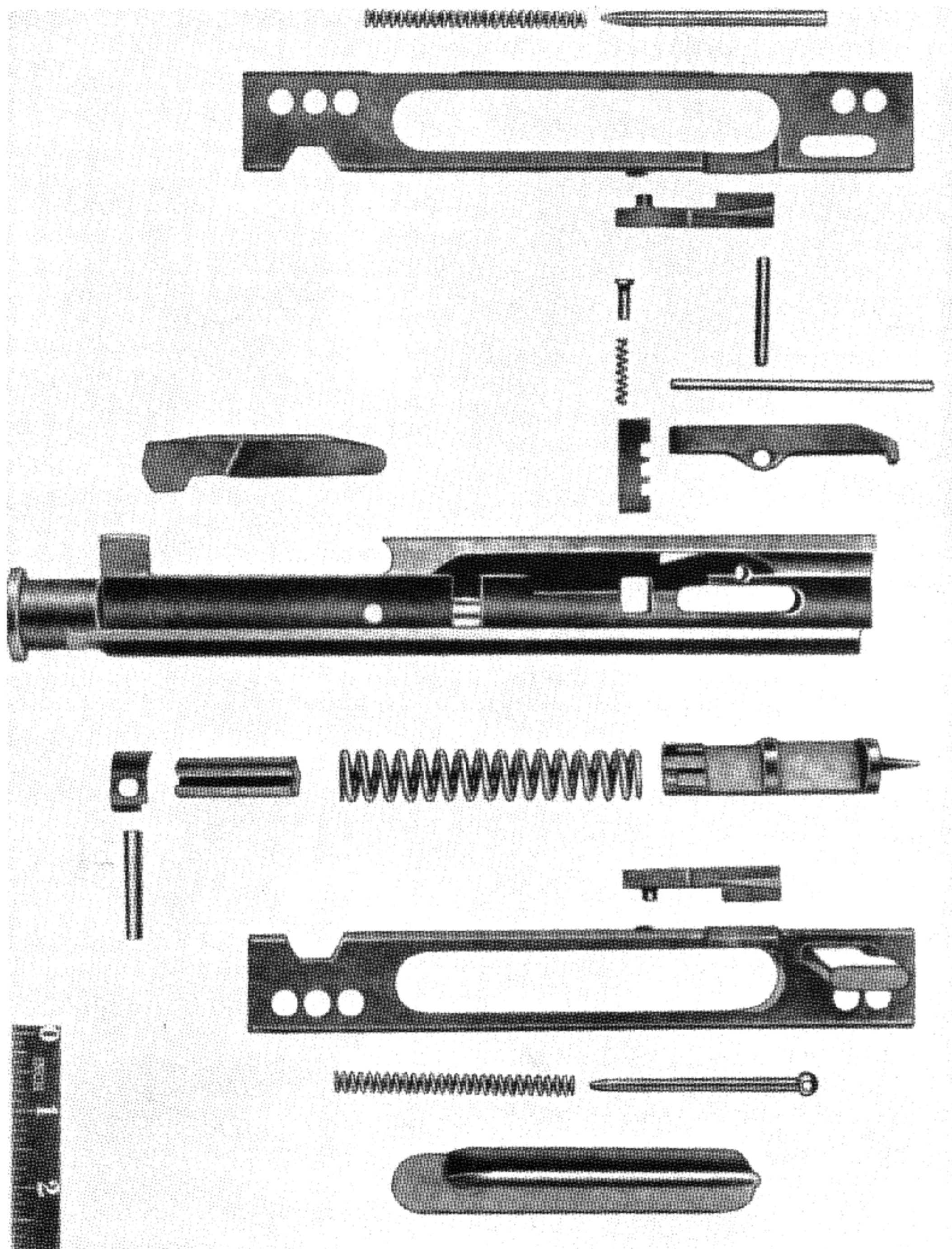


Figure 13-15. Components of the bolt of 20-mm Gun M23.

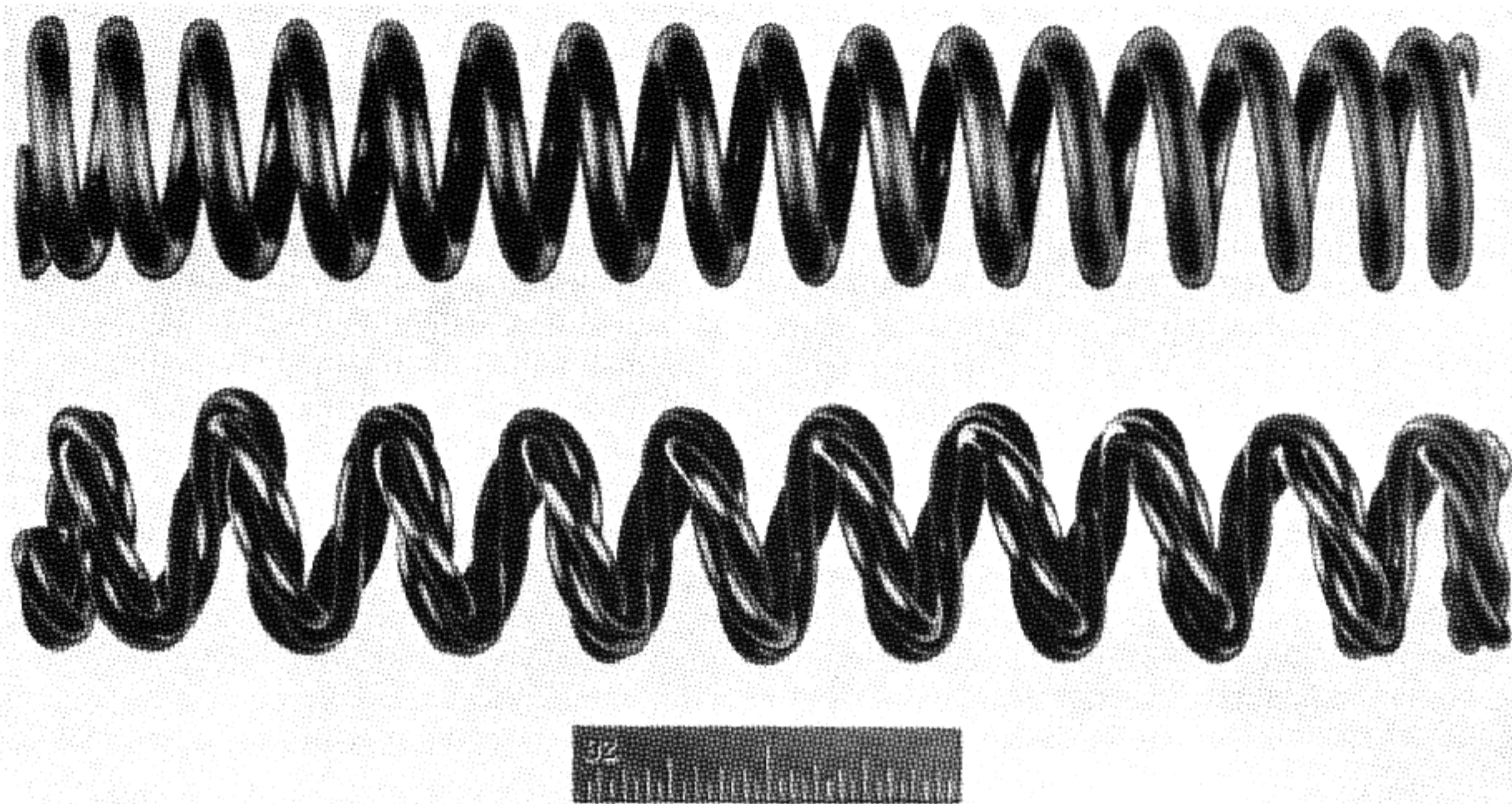


Figure 13-16. Comparison of the original firing pin spring and a braided spring developed later for the 20-mm T31 Gun.

with the 20-mm automatic gun T31. To expedite the development of mounts, turrets, and other related aircraft equipment, they requested 500 T31 guns by July 1944, each supplied with a percussion firing device, an electric firing device, a manual charger, a heater, a solenoid (for percussion firing device), and a receptacle (for electrical firing device). Also 50 of each of these items were to be supplied as spares. OCM 23039, dated 2 March 1944, classified the T31 gun as a limited procurement item in order to meet the above requirements.

At the request of the Bureau of Ordnance, the T31 gun was equipped with a bolt mechanism from the standard 20-mm AN-M2. The left slide of this bolt was modified by the addition of a lug so that the bolt mechanism could be charged from either side. The gun fitted up in this manner made another model of the T31 gun, in addition to the two already established. After tests were completed on the use of this standard bolt in the T31 gun, it was seared in a rear position. The Navy established its requirements for 22,826 such weapons and the Air Force established a requirement for 500, making a total of 23,326 guns in addition to the 500 guns previously ordered by the Air Force, which were to be

equipped with a forward seared mechanical bolt and electric bolt. In order to expedite this heavy procurement, the T31 gun classification was changed from restricted to unclassified on 30 March 1944.

Tests of the rear seared T31 gun by both the Army and Navy were successful, and on 12 July standardization of this weapon as gun, automatic, 20-mm M3 was approved.

In view of the fact that there are two additional types of T31 guns still under development, the nomenclature "gun, automatic, 20-mm T31E1" was assigned to the forward seared mechanical percussion bolt design and the nomenclature "gun, automatic, 20-mm T31E2", assigned to the electric bolt development. The nomenclature "gun, automatic, 20-mm M23" was reserved for standardization of the T31E1 gun, and "gun, automatic, 20-mm M24" was reserved for a corresponding standardization of the T31E2. The using services concurred with the Ordnance Corps in typing the guns in this manner.

Many projects were under way in conjunction with the T31 development, including electric heaters, chargers, several types of electric triggers,

gun adaptors, and cradles. A basic requirement was established that such accessories be designed in such a manner that they could be mounted interchangeably on either the right or left side of the weapon.

The trend at the end of 1944 was toward higher muzzle velocity. Efforts were being made then to increase it from 2,800 feet per second to 3,500 feet per second with the objective of improved armor penetration.

The general trend of research and development in the 20-mm Hispano automatic aircraft cannon in the United States for the period from the standardization of the M1 to January 1945, was toward higher firepower and increased reliability of functioning.

The early spring-operated feeds forcibly held the next round on top of the bolt when the gun was fired so that, after firing, the rearward motion of the bolt

was retarded. Positioning of the next round was delayed, holding down the rate of fire. Positive (mechanical) feeds were developed which lessened the force of the round on the top of the bolt. This materially reduced friction, making the gun more reliable under all climatic conditions and contributed to increase the cyclic rate from 600 to 850 rounds per minute.

Reduction in weight of the gun and accessories permitted additional rounds of ammunition to be carried, which were made available for action by disintegrating link belts of far greater capacity than the original 60-round magazine.

The cross-sectional area of feeding devices and accessories, normal to the axis of the gun, was reduced, permitting greater ease of installation in restricted locations in aircraft.

In June 1945, the T31 type gun was standardized as the M3 gun. At the same time, 20-mm

#### General Data: 20-mm Automatic Guns M1 and M2

Gun length: 93.7 inches.	Barrel length: 67.5 inches.
Gun weight:	Barrel weight: 47.5 pounds.
M2: without feeder 112 pounds.	Rate control: None.
M1: without feeder 105 pounds.	Barrel removal: Not quick disconnect.
NOTE: The 7-pound difference in weight is in the heavier construction of the receiver. See volume 1, page 576.	Chamber pressure: 42,000 p. s. i.
Rate of fire: 600-700 rounds/minute.	Bore:
Muzzle velocity:	Number of grooves: 9.
HEI or ball ammunition: 2,850 feet/second.	Groove depth: 0.015 inch.
AP ammunition: 2,950 feet/second.	Groove width: 0.205 inch.
System of operation: Gas unlock; blowback assist.	Pitch: 7° (equals 1 turn in 25.187 calibers and 1 turn in 20.137 inches).
System of locking: Swinging lock.	Direction of twist: Right hand.
System of feeding: Drum, or spring actuated; continuous feed employing metal disintegrating links.	Form of twist: Constant.
Method of headspace: Cannot be adjusted.	Width of lands: 0.068 inch.
Location of feed opening: Top of receiver.	Rifling length: 63.08 inches.
Location of ejection opening: Bottom of receiver.	Cartridge: 20-mm Hispano-Suiza (M75 series).
Method of charging: Manual, pneumatic.	Bore of tube:
Method of cooling: Air.	Across rifling lands: 7.787 inches.
Weight of 20-mm adaptor AN-M1: 11.3 pounds.	Across rifling grooves: 0.817 inch.
Weight of electric trigger AN-M1: 5 pounds.	Chamber pressure (maximum): 48,000 pounds/square inch.
Weight of hydraulic charger M1: 2.6 pounds.	Travel of projectile in tube: 63.68 inches.
Weight of 20-mm feed mechanism AN-M1A1: 18.5 pounds.	Weight of muzzle brake M1: 4.6 pounds.
Weight of 20-mm adaptor M6: 14 pounds.	Weight of sear mechanism M1: 1.3 pounds.
Weight of 20-mm adaptor M7 (with thread protector): 7.5 pounds.	Weight of manual charger M2: 1.5 pounds.
Weight of 20-mm adaptor M7 (with muzzle brake): 10.7 pounds.	Weight of 60-round 20-mm (empty): 22 pounds.

automatic gun AN-M2 was classified as limited standard.

The M3 gun is a light-weight version of the M2 weapon using the same breechblock mechanism, but having a tube 15 inches shorter and a recoil cradle for mounting purposes. A complete line of accessories, such as heaters, chargers, muzzle covers, and flash hidens, was standardized for the weapon.

After the standardization, the Navy carried on extensive tests resulting, first, in revealing certain weaknesses, and, second, in correction of some of them. Also, the use of ceresin-waxed ammunition was begun to eliminate extraction difficulties.

Air Force orders for the T31 gun included the interchangeable components for all three types; but in mid-1947, the requirement for the T31 (M3) and T31 (M24) components was dropped in favor of the T31 (M23) type. The latter type was abandoned, in turn, in late 1947 when extensive Air Force tests revealed that certain experimental turrets for a military aircraft then in production could not meet dispersion requirements unless a definite phase relationship of the guns to each other could be obtained, a requirement that was impractical for the T31 (M23). This fact resulted in a change in Air Force requirements to specify only the T31 (M24) gun. Extensive development of both the gun and the electric primed ammunition has continued since that time. For supply reasons, the T31

(M24) was made substitute standard in November 1947.

For comparative purposes, general data for the 20-mm M1 and the 20-mm AN-M2 are given along with a summary of the development of these two models. In February 1944 production of all M1 and AN-M2 cannon ceased. In October 1944 the M1 was declared obsolete.

### Standardization of the 20-mm M1 and AN-M2 (Summary)

In February 1942, a subdivision of the Joint Aircraft Committee recommended that 20-mm automatic gun type M2 as shown in Ordnance Corps list of drawings 51-107-1 be accepted as standard for use by the United States Army and Navy and by the British, and that this gun be designated 20-mm automatic aircraft gun AN-M2.

The principal components of the basic gun were the tube and the receiver, which housed most working parts. Working parts consisted of the gas cylinder and sleeve group, the magazine slide group, the breechblock assembly, the breechblock locking key, the scar block group, the rear buffer assembly, and the driving-spring guide group.

The differences between the AN-M2 and M1 were in manufacture only; they did not affect troop use or care, but were useful as a means of identifying the different models. The guns were identical

#### General Data: 20-mm Automatic Gun T31, or M3

Gun length: 77.7 inches.  
 Gun weight, without feeder: 99.5 pounds.  
 Rate of fire: 700-750 rounds/minute.  
 Muzzle velocity: 2,750 feet/second.  
 System of operation: Gas unlocking, blowback assist.  
 System of locking: Swinging lock.  
 System of feeding: Automatic spring-wound feeder employing metal disintegrating links.  
 Method of headspace: No provision made for adjustment.  
 Location of feed opening: Top, either right or left hand.  
 Location ejection opening: Bottom of receiver.  
 Method of charging: Hydraulic, air, manual.  
 Method of cooling: Air.

Barrel length: 52.5 inches.  
 Barrel weight: 26 $\frac{3}{16}$  pounds.  
 Rate control: None.  
 Barrel removal: Cannot be easily removed in field.  
 Chamber pressure, maximum: 42,000 p. s. i.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 inch.  
 Groove width: 0.205 inch.  
 Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Width of lands: 0.068 inch.  
 Distance across rifling lands: 0.787 inch.  
 Distance across rifling grooves: 0.817 inch.  
 Rifling length: 48.06 inches.  
 Travel of projectile in the tube: 48.66 inches.  
 Cartridge: Hispano-Suiza (M90 series).

in tube construction and working parts, the only difference being in the dimensions of the receiver. The AN-M2 receiver was 0.2 inch longer and 5 pounds heavier. Each receiver slide of the AN-M2 gun had a projection which fitted into a slot in the side of the receiver, and the receiver slide bolts were locked by cotter pins. In the M1 guns, the receiver slides had no flanges and were riveted, not bolted, to the receiver. The shoulders on the bottom faces of the receiver sides serve as further means of identifying the M1 gun.

In some M1 guns, each receiver slide has a flange which overlapped the side of the receiver, and the receiver slide bolts were locked by locking wires.

### Description of the 20-mm M3 Gun

The description of the 20-mm M3 gun is organized around the following components: cradle group; tube and receiver group; breechblock group; gas cylinder sleeve group; recoil group.

*Cradle Group.* The cradle assembly is the actual mount for the gun. It is so designed that it will allow the gun to move backward in recoil and forward in counterrecoil. The nonrecoiling recoil housing assembly of the gun, which fits around the recoiling gun tube, is secured to the mounting bracket of the cradle by means of two trunnion blocks and four trunnion block and mounting bracket screws safetied by a plate, the corner of which is bent up. The receiver, which is recoiling, engages one horizontally rotating roller and two vertically rotating rollers at the rear of the cradle. The rollers carry the weight and control the vertical movement of the gun.

The cradle also mounts the anchor support bracket to which the magazine slide is fixed by means of a magazine slide anchor. In this manner the magazine slide is made nonrecoiling, whereas the receiver, on which it is mounted, recoils during firing. This condition is utilized in the operation of the 20-mm feed mechanism AN-M2, which is recoil operated.

The sides of the cradle have drilled and tapped holes for mounting the various chargers.

*Tube and Receiver Group.* In the following description, these components are treated as parts of the tube and receiver group: gun tube; receiver; rear buffer, and driving spring guide.

**GUN TUBE.** The tube serves to accommodate the front mounting arrangements, recoil housing,

and the gas cylinder sleeve group. The threaded muzzle end is for attaching a flash hider. The threads to the rear of the threaded muzzle end serve for attaching certain types of British mounts but are not used for mounting the gun in United States airplanes. When these threads are not in use, they are protected by a thread protector sleeve and cap.

**RECEIVER.** The receiver houses most of the working parts. The front of the receiver is threaded internally to receive the tube. The guideway on each side of the opening on top of the receiver accommodates the magazine slide by means of which the feed mechanism is secured to the gun. The rear of the receiver has vertical dovetail grooves for attaching the rear buffer.

The rear underside of the receiver accommodates the sear mechanism. The front underside of the body is open to permit ejection of empty cartridge cases. Above the ejector opening are two receiver slides which are bolted to the sides of the receiver and serve to support the breechblock in its forward movement. The slides have cammed surfaces at the rear which engage corresponding cams on the breechblock lock, to cam it into the locked position with the assistance of the camming action of the breechblock slides. To the rear of the ejector opening, a transverse slot is cut in each side of the receiver body to accommodate the breechblock locking key. The breechblock locking key engages the breechblock lock when the lock is cammed down into the locked position.

The cradle mounting plate on the middle underside of the receiver serves to support the gun and control its vertical movement by means of cradle rollers fitted in the gun cradle.

The electric heater is installed on the breechblock locking key and receiver slides.

**REAR BUFFER AND DRIVING SPRING GUIDE.** The function of the rear buffer is to cushion the shock of the rearward movement of the breechblock and start the breechblock on its forward movement. These actions are accomplished by a series of ring springs guided by a sleeve and a coil spring placed inside the sleeve.

As the breechblock moves to the rear, it compresses the driving spring and much of the inertia of the breechblock is absorbed. As the breechblock hits the rear buffer, it transmits the shock of recoil to the springs. The springs absorb the remaining

shock and bring the breechblock to a stop. At this time, the rear buffer springs and the driving spring expand, forcing the breechblock forward.

**MAGAZINE SLIDE.** The magazine slide has a guide on each side. These guides provide for sliding engagement with corresponding guideways on the receiver. The feed mechanism is secured to the magazine at the front by two hook-shaped projections on the slide, and at the rear by the magazine slide latch.

The ejector fits into the lower two grooves in the magazine slide beneath the latch. It has two prongs projecting from a steel plate. The upper inner surfaces of the prongs are shaped to center the incoming round into the path of the breechblock as it moves forward. The top shoulder of the breechblock moves between the two prongs of the ejector. The prongs deflect the empty cartridge case downward as the breechblock moves to the rear.

The slide is connected by the magazine slide anchors and anchor support bracket to the cradle; it is, therefore, fixed while the gun recoils during firing.

**Breechblock Group.** The function of the breechblock group is to carry the round from the mouth of the feed mechanism into the chamber, fire the round, extract and eject the empty case, and support the case until it is deflected out of the receiver by the ejector. For detailed description of functioning, see Cyclic Functioning, which follows.

**Gas Cylinder Sleeve Group.** The function of the gas cylinder sleeve group is to unlock the breechblock so that it can be forced back by straight blow-back action. For details of functioning, see Cyclic Functioning, which follows.

**Recoil Group.** The function of the recoil group is to absorb the shock of recoil of the gun and return it to battery. For details of functioning of the group, see the following topic.

## Installation and Maintenance of the 20-mm M3 Gun

**Removal and Installation of Thread Protector Sleeve Cap.**

1. Unstake the thread protector cap.
2. Unscrew the thread protector cap and slide the thread protector sleeve off the gun tube.
3. To install, slide the sleeve on the tube, screw the cap in place, and stake the cap.

**Removal and Installation of Flash Hider M4.**

1. To remove flash hider, if assembled, proceed as follows: unscrew flash hider; unscrew the flash hider nut.

2. To install flash hider M4, proceed as follows: screw the flash hider nut on the tube; screw the flash hider on the tube.

**Tube and Receiver Group: Maintenance by Using Arms.** Gun tubes become copper fouled to less extent when cared for in the proper manner. Wear in the bore does not depend entirely upon the number of rounds fired; it also depends on the care given the bore in cleaning and cooling between periods of firing. Since the accuracy life of a gun tube is decreased by a fast rate of firing and the attendant heat, the gun should be allowed to cool and should be washed as often as practical. It is important that the gunner inspect the bore, whenever possible, to make certain that it does not contain extraneous particles that might cause damage to the gun.

1. Note general appearance of gun bore for wear and deformation of lands and grooves and for pitting and pastilles. Examine for evidence of powder fouling and rust. A clean bore is not necessarily a shiny bore and may frequently have a dull gray appearance. A shiny, polished bore might indicate that abrasives have been used in cleaning operations. If the lands and grooves are excessively pitted or deformed, the gun should be turned over to ordnance maintenance personnel for replacement of the gun tube.

2. Before firing, wipe the bore clean if expandable muzzle covers have not been installed or if the bore has previously been heavily oiled.

3. To clean the bore after firing, run several wet patches of bore-cleaning cloth impregnated with rifle-bore cleaner through the bore from the breech end. Remove the patch from the cleaning rod and attach the cleaning brush. Run the brush through the bore several times. Make certain that the brush goes all the way through before reversing the direction.

**Tube and Receiver Group: Maintenance by Ordnance Maintenance Personnel.**

1. Perform maintenance operations given above whenever necessary.

2. To clean the gas port, remove the gas cylinder vent plug and bracket plug and clean with No. 16 American Wire Gage (DWG-0.0508-inch diam-

eter). Make certain that no bits of the wire are left in gas port.

3. To replace a gun tube, proceed as follows: remove cradle; remove gas cylinder sleeve group; extract the cotter pin and remove tube locking pin with tube lock removing tool; place receiver in receiver vise and clamp securely; install the tube clamp over the tube as close to the receiver as possible; unscrew the tube and clean the threads in the front of the receiver; before installing a new tube, examine the threads and coat them with a light film of graphited grease (light) to aid in assembly; install the tube and align hole in the receiver with hole for the tube locking pin; ream a hole in tube to  $\frac{25}{64}$  inch; install the tube locking pin and secure with a cotter pin.

*Receiver: Maintenance By Using Arms.*

1. Clean the receiver, particularly the portion near the tube, with rifle-bore cleaner to remove all primer salts. Wipe with a cloth dampened with oil.

2. Inspect the receiver for cracks, dents, or other damage; if any are found, notify ordnance maintenance personnel.

3. Check for burs, particularly on the receiver slides, breechblock locking key, and dovetail grooves for the rear buffer. Remove burs with crocus cloth or a fine oilstone. Do not remove more metal than is necessary.

4. If breechblock locking key is loose, notify ordnance maintenance personnel.

*Receiver: Maintenance by Ordnance Maintenance Personnel.*

1. Perform maintenance operations given above, whenever necessary.

2. Check condition of breechblock locking key. If loose or excessively worn, replace as follows: remove locking wire, the two cap screws, and the lockwashers from the breechblock locking key; remove the locking key plate and tap the breechblock key from the receiver with a brass drift and a hammer; when fitting a new key in place, make sure it is a snug fit in the receiver. Replace the receiver if key slot is elongated sufficiently to prevent a tight fit with a new key which meets specified dimensions; lay the plate on the key as an indication for positioning the key correctly; when proper alignment is obtained, secure the key and plate with cap screws

and lockwashers; secure the cap screws with locking wire.

3. Check receiver slides for alignment and inspect the cam surfaces for damage. If slides are misaligned or cam surfaces damaged, replace the slides as follows: extract the cotter pins and remove the castle nuts, lockwashers, and bolts to release the slides; clean the sliding surfaces of the receiver and slides thoroughly; install new slides in place, positioning them carefully; when slides are positioned correctly, install bolts and nuts; install cotter pins and bend the ends out of the way; install breechblock and see that it operates freely.

4. Check condition of all threaded holes in receiver and chase out if necessary.

*Rear Buffer and Driving Spring Guide Removal.*

1. With a blunt chisel, straighten the rim of the driving spring guide retainer so that it does not engage the driving spring guide head. Similarly, disengage driving spring guide cap lock plate from cap (if used), unscrew cap, and remove plate.

2. Insert the driving spring assembling tool through the driving spring guide head. Push the tool forward until it engages the driving spring guide plunger.

3. Unscrew the driving spring guide sleeve assembly, using the special rear buffer wrench. Remove the guide with the driving spring and plunger.

4. Retract the rear buffer lock plunger and remove the rear buffer group by sliding it out of the dovetail grooves in the receiver.

5. Keep the driving spring guide retainer with the rear buffer.

NOTE. Disassembly of rear buffer prohibited.

*Rear Buffer and Driving Spring Guide Installation.*

1. Slide the rear buffer up in the dovetail grooves of the receiver.

2. Retract the rear buffer lock plunger and slide the buffer upward until the plunger snaps into position in the slot in the receiver.

3. Position the driving spring retainer (old type) on the rear buffer so that pin on the retainer fits into hole on the rear buffer. New type retainer does not have a pin but has a flange which fits under the rear buffer.

4. Insert the split end of the driving spring assembling tool into the driving spring guide plunger.



5. Place the driving spring over the tool and plunger. Insert the driving spring guide into the driving spring so that it fits over the tool.

6. Insert the assembled unit into the receiver through the opening of the rear buffer, making certain that it slides into the bore of the breechblock.

7. Place the rear buffer wrench on the guide, press the guide in until it contacts the rear buffer, and then turn the tool to screw the guide into the buffer.

8. Bend the rim of the retainer on a flat of the guide.

9. Assemble cap lock plate (if used) on guide, screw cap onto guide, and bend rim of plate on a flat of the cap.

*Rear Buffer and Driving Spring Guide: Maintenance by Using Arms.*

1. Examine the rear buffer for rough or bruised surfaces on dovetail connections. Remove all rough spots with crocus cloth or fine oilstone to make a good push fit to the receiver. If fit is too tight, it will tend to spread the receiver; if too loose, it will cause the buffer to hammer the receiver.

2. Wipe the dovetail surfaces clean with a dry cloth but do not dip the rear buffer in any cleaning fluid. The rear buffer is lubricated with graphite at assembly and fluid will wash the graphite out and thus impair the functioning of the buffer.

3. Check the functioning of the rear buffer lock. If the lock malfunctions or if the buffer is otherwise damaged, replace the rear buffer. Remove all burrs from the lock plunger but take off no more metal than is absolutely necessary; removal of excess metal will cause the plunger to fit loosely and allow the rear buffer to move vertically in the receiver.

4. Examine the retainer assembly for condition; note whether pin on face of retainer is broken, bent, or missing. If any of these conditions exist, replace the retainer.

5. Note condition of threads on the driving spring guide; if mutilated or excessively worn, replace the guide.

6. Check the guide tube for looseness in head and for deformation. If loose or bent, replace the guide.

7. Examine driving spring for any sharp kinks or offset of coils which might cause binding or excess friction and replace if these conditions exist or if free length is less than 23.5 inches.

8. Check driving spring guide plunger for straightness and note general condition and look for cracks or indications of fracture just in rear of head. Test to see that plunger moves freely in and out of guide. If plunger is bent or shows cracks, replace it.

*Rear Buffer and Driving Spring Guide: Maintenance by Ordnance Maintenance Personnel.*

1. Perform maintenance operations given above, whenever necessary.

2. Check for broken rear buffer spring by firing a burst of 10 or 15 rounds. If rear buffer gets heated up, the spring is broken and the rear buffer assembly should be replaced.

3. Check functioning of rear buffer lock spring. If weak or broken, drive out lock plunger pin, remove lock collar, plunger and spring, replace spring, and assemble.

*Rear Buffer and Driving Spring Guide: Disassembly.*

1. Unscrew the two magazine slide anchor front nuts.

2. Remove the rear buffer.

3. Remove the cotter pin from the ejector stud.

4. Unscrew the ejector stud nut.

5. Withdraw the ejector, taking care not to lose the two ejector springs.

6. Remove the ejector stud nut, washer (steel) and ejector stud washer (fiber).

7. Remove the lock wire and unscrew the magazine slide backplate screws, keeping the screws even.

8. Remove the backplate and the two latch springs.

9. Remove the cotter pin from the magazine slide to the rear and off the receiver.

10. Slide the magazine slide to the rear and off the receiver.

11. Remove the cotter pin from the anchor securing screw.

12. Remove the anchor screw lockwasher.

13. Unscrew the anchor securing screw and withdraw the magazine slide anchor from the magazine slide.

*Rear Buffer and Driving Spring Guide: Assembly.*

1. Fit the magazine slide anchor to the magazine slide. The threaded end of the anchor should point away from the front end of the slide. The anchor

should be on the same side with the anchor support bracket.

2. Screw in the anchor securing screw, replace the anchor screw lockwasher, and secure with the cotter pin.

3. Slide the magazine slide (anchor) leading on the gun.

4. Place the magazine latch on the upper grooves in the rear of the magazine slide. The sharp end of the latch should point toward the muzzle of the gun so that the angle surface on the latch can be seen when looking down.

5. Position the magazine slide lever on the magazine latch. The ball on the lever should fit into the hole of the latch, the lever handle should point to the rear, and the holes in the magazine slide should align with the hole in the lever. Push in the lever pin and secure with the cotter pin.

6. Insert the two latch springs into their seats in the rear of the latch.

7. Place the magazine slide backplate flush against the latch springs and screw in the two magazine slide backplate screws. The screws should be screwed in evenly. Lock-wire the screws.

8. Insert the two ejector springs into their seats in the rear of the ejector. Position the ejector in the two grooves of the magazine slide below the latch and slide it to the rear until the ejector stud protrudes through the hole in the backplate.

9. Place the fiber ejector stud washer on the ejector stud, follow with the steel ejector stud nut washer, and then screw on the ejector stud nut. Secure the nut to the stud with a cotter pin.

10. Replace the anchor front nuts.

*Rear Buffer and Driving Spring Guide: Maintenance by Using Arms.*

1. Check movement of magazine slide on receiver. Remove any burs from guideways on slide. If magazine moves with excessive slide play, replace the slide.

2. Check functioning of magazine latch springs. If springs are weak, check free length and replace if necessary.

3. Check free length of ejector springs and replace if necessary.

4. Check movement of magazine latch in grooves of slide; it must slide freely. Remove any burs from the angle surface of the magazine latch and from the ejector.

5. If the ejector horns or the ejector stud show signs of fracture, replace the ejector.

6. Inspect the ejector for wear on the slides and on the two prongs. Use a smooth stone to remove burs from the prongs. The ejector must slide freely in the grooves of the magazine slide, but should have a minimum amount of side play. Replace ejector if stud is loose or threads damaged.

7. Replace the fiber washer on the ejector stud, if it is deformed.

*Rear Buffer and Driving Spring Guide: Maintenance by Ordnance Maintenance Personnel.*

1. Perform maintenance operations given above, whenever necessary.

2. Chase out thread holes in magazine slide whenever necessary.

3. If ejector stud is damaged or loose, drive out the ejector stud pin, unscrew the ejector, and examine condition of threads in ejector. Chase out if necessary, replace ejector, and pin securely.

*Removal of Breechblock.*

1. Remove the rear buffer.

2. Back up the two magazine slide anchor rear nuts all the way and move the magazine slide forward as far as it will go.

3. Place the breechblock unlocking tool on right side of breechblock in receiver and manipulate the tool so that the projection on the arm of the tool engages the front face of the right breechblock slide, and the other arm of the tool is along the top of the breechblock with its end against the receiver.

4. Press the lever of the tool forward until the breechblock is unlocked.

5. Move the breechblock to the rear of the receiver. As soon as it starts to come out, grasp the breechblock lock and hold it in the unlocked position. Failure to do this may cause the breechblock to get jammed in the rear portion of the receiver as it is being pulled out. Pull the breechblock out of the receiver. Do not drop the breechblock lock.

NOTE. If the special tool is not available, force the gas cylinder push rods rearward to unlock the breechblock or actuate with charger.

*Installation of Breechblock.*

1. Assemble the breechblock lock to the breechblock by forcing the breechblock slides rearward and, at the same time, exerting pressure against the lock until it is in the unlocked position.

2. Hold the breechblock firmly in this position and push it into the receiver as far as it will go so that the lock will not spring out of position.

3. Push breechblock home.

4. Replace rear buffer and adjust magazine slide.

#### *Removal of Sear Mechanism.*

1. Remove the cradle from the gun.

2. Straighten the 2 mounting screw lock plates, unscrew the 4 screws, and remove the cradle mounting plate from the receiver.

3. Insert the sear buffer retaining tool into the hole in the sear block. Push the tool through the sear block so that it fully engages the circumferential grooves on the sear buffer spring plungers.

4. Carefully lift the sear block and sear out of the receiver with the retaining tool in place. Remove the steel and fiber sear buffer blocks from the receiver.

#### *Installation of Sear Mechanism.*

1. Replace the sear with sear block in receiver. Do not remove sear buffer spring retaining tool.

2. Replace sear buffer steel block in receiver adjacent to the sear block.

3. Replace the sear buffer fiber block in receiver next to steel block with flat side adjacent to steel block.

4. Hold down the sear block and remove the sear spring retaining tool.

#### *Disassembly of Breechblock.*

1. Remove the breechblock lock. Remove the left and right inertia blocks.

2. Withdraw the left breechblock slide, being careful not to let the breechblock slide spring and guide fly out. Then withdraw the breechblock slide plate assembly, taking care not to let the spring and guide fly out. Do not remove the breechblock slide key except for replacement.

3. Press the extractor against the extractor spring and drift out the extractor pin. Withdraw the extractor and extractor spring. Lift the front end of the breechblock and allow the firing pin to slide out through the rear. Do not drop the firing pin.

#### *Assembly of Breechblock.*

1. Insert the firing pin in bore of breechblock, slide it forward, and position it so that slot in firing pin aligns with the recess for the breechblock slide key.

2. Install the extractor spring and extractor and secure with extractor pin.

3. Install the right-hand breechblock slide assembly, making certain that the slide key engages the slot in the firing pin. Install the left-hand breechblock slide.

4. Mount one breechblock slide spring on the guide. Position the rear end of the spring (and guide) into the hole of the breechblock pin, and force the plunger and spring against pin and sideways into slide until the ball on guide is seated in circular seat in the slide. Similarly, install the second spring and guide.

5. Install the inertia blocks.

#### *Disassembly of Sear Mechanism.*

1. Withdraw the sear pin to detach the sear from the sear block.

2. Place the sear block in the sear block assembling tool, so that the radial bearing surface of the sear block contacts the jaw of the tool, while the plungers which protrude from the sear block engage the hook-shaped projection at the front of the tool. The sear buffer spring retaining tool should enter the hole in the sear block assembling tool.

3. Turn the handle of the sear block assembling tool sufficiently to take the tension off the sear buffer spring retaining tool. Remove the retaining tool. Gradually turn the handle of the tool to release the tension of the springs. Remove the plungers and springs. If the special sear block assembling tool is not available, an ordinary vise will serve. If the retaining tool is not available, use a slightly tapered steel rod which nearly fills the hole.

#### *Assembly of Sear Mechanism.*

1. Insert the sear buffer springs in their recesses in the sear block.

2. Replace the plungers with their hollow ends against the springs.

3. Place the unit on the sear block assembling tool with the flanged side of the sear block up, and with the radial bearing surface against the jaw of the tool. Compress the springs until the sear buffer spring retaining tool can be inserted to engage the grooves of the plungers.

4. Loosen handle and remove the sear block with retaining tool from the assembling tool.

5. Attach the sear to the block so that the forked end of the sear is on the same side as the flanged side of the sear block.

#### *Breechblock: Maintenance by Using Arms.*

1. Check freedom of movement in receiver.

2. Disassemble and clean breechblock.

3. Examine front face of bolt for erosion and wear, and note condition of firing-pin hole. If firing-pin hole is enlarged sufficiently to cause blown primers, replace the bolt.

4. Check for cracks on longitudinal shoulders of bolt. If shoulders are cracked, replace the bolt.

5. Remove all burrs and rough spots from surface of bolt.

6. Examine breechblock slides for burrs or rough surfaces on cam; remove burrs or rough surfaces. Check for swedging near front end of slot for inertia block. Check for cracks around cam surface.

7. Check movement of firing pin in bolt. Remove any burrs. Examine firing pin for pitting, deformation, or cracks. If firing pin is broken or bent, it should be replaced.

8. Examine inertia blocks for general condition. Check movement of blocks in breechblock slides. Remove any burrs or rough spots.

9. Examine breechblock lock carefully for condition of cams on both sides and for wear or roughness on hinging locking surfaces. Check under side for wear.

10. Test tension of breechblock slide springs; replace if broken or shorter than allowable free length.

#### *Sear Mechanism: Maintenance by Using Arms.*

1. Examine sear mechanism for general condition.

2. Check for wear or roughness on sear surface.

3. Check plunger for burrs or rough surfaces around the disassembling recesses.

4. Remove all rough spots and burrs.

5. Check tension of sear buffer springs; replace if broken or shorter than allowable free length.

#### *Breechblock Group: Maintenance by Ordnance Maintenance Personnel.*

1. Perform maintenance operations on breechblock and sear mechanism whenever necessary (see two preceding topics).

2. Measure diameter of firing-pin hole, which should be 0.156 inch + 0.004. A No. 22 (0.157) standard drill can be used to clean the firing-pin hole to proper size.

3. Measure firing pin protrusion; it should be 0.100 to 0.110 inch. If protrusion is less, discard firing pin.

4. Note condition of breechblock slide key; see whether taper pin is in place or loose. If taper pin in key is loose, replace with a new pin.

5. Note condition of breechblock pins. If loose or damaged, drive out breechblock pin taper pins and replace breechblock pins and taper pins.

6. Measure radius of sear. If radius is less than 0.04 inch, replace the sear.

#### *Gas Cylinder Sleeve Group: Disassembly.*

1. Remove cotter pin and lockwasher from gas cylinder guide and unscrew gas cylinder sleeve spring.

2. Remove gas cylinder sleeve spring.

3. Remove locking wire from gas cylinder bracket plug and then remove the gas cylinder lockwasher. Unscrew gas cylinder bracket plug.

4. Remove gas cylinder lock plate and unscrew gas cylinder with the sleeve.

5. Push the gas cylinder sleeve to the rear and remove gas cylinder with the sleeve.

6. Withdraw the gas cylinder sleeve push rods.

#### *Gas Cylinder Sleeve Group: Assembly.*

1. Insert the gas cylinder sleeve push rods into their recesses in the receiver.

2. Assemble gas cylinder to the gas cylinder piston on the sleeve, position the unit on the gun tube, and slide it forward so that the gas cylinder fits in the opening in the gas cylinder bracket.

3. Screw in the gas cylinder vent plug and replace the gas cylinder lock plate.

4. Screw in the gas cylinder bracket plug, replace the gas cylinder lockwasher, and secure with locking wire.

5. Replace the gas cylinder sleeve spring.

6. Screw in the gas cylinder guide, replace lockwasher, and secure with the cotter pin.

#### *Gas Cylinder Sleeve Group: Maintenance by Using Arms.*

1. Examine all parts for condition. If sleeve is bent, replace it.

2. Check tension of gas cylinder sleeve spring; if kinked or shorter than allowable free length, replace it.

3. Check movement of gas cylinder sleeve guide in sleeve. Guide should have a medium close fit in sleeve. If clearance is excessive, replace with new parts.

4. Check gas cylinder vent plug for looseness; if loose, replace it. Whenever replacing the vent plug,

use the new type of vent plug (larger vent hole) which can be identified by the part number stamped on its face.

5. Remove all carbon and any other foreign matter from cylinder, piston, bracket, and plugs.

6. Remove burrs from piston if not burred excessively. If it is excessively burred, replace gas cylinder sleeve with piston.

7. Check movement of push rods in their recesses in the receiver. Remove all burrs from push rods.

*Gas Cylinder Sleeve Group: Maintenance by Ordnance Maintenance Personnel.*

1. Perform maintenance operations given above whenever necessary.

2. Guns that were converted to the T31 (M3) included both long and short chamber tubes. To provide proper chamber length, approximately two threads of length were removed from the long chamber tube before installation in the weapon, which resulted in a misalignment between the tube gas port and the bracket gas port. This misalignment was originally compensated for by applying a 45° chamfer to the bracket gas port.

### Cyclic Functioning of the 20-mm M3 Gun

The cyclic functioning of the weapon as a whole, from the firing of one round to the next, is described in the following paragraphs. For purposes of explanation, the cyclic functioning is divided into the following actions: recoil action; breechblock unlocking action; extraction and ejection; rear buffer and driving spring action; cocking action; feeding and chambering; breechblock locking action; and firing action.

*Recoil Action.* When the round is fired, the pressure of propellant gases in the tube forces the gun to recoil to the rear for about 1 inch. As the gun recoils, the recoil spring front seat located on the gun tube moves to the rear and compresses the recoil spring. Since the compression of the ring spring in the recoil housing assembly is greater than the final force of the recoil spring, it can thus be seen that during this phase of the recoil, the recoil spring alone will offer resistance to the rearward movement of the gun. The action will continue until the gun has recoiled for about seven-eighths inch. At this point, the rear end of the recoil spring front seat contacts the front end of the recoil spring rear seat, thus stopping the compression of the recoil spring.

While the recoil spring rear seat begins to compress the ring spring of the recoil housing assembly which absorbs the remaining shock of recoil, the recoil spring begins to recover. The recovery of the recoil spring returns the gun to battery.

The ring spring of the recoil housing assembly will act as a counterrecoil buffer if the gun should travel past its battery position. The ring springs will be compressed in the same manner as during recoil movement of the gun, but the action of the parts will be reversed.

*Breechblock Unlocking Action.* The breech is unlocked by the action of the gas cylinder sleeve group. At the moment of firing, the breechblock is held in its forward position by the action of the breechblock lock. The lock engages the breechblock and bears against a surface of the breechblock key. The breechblock slide engages the lock, thus preventing the lock from being forced upward prematurely.

As the round is fired, the projectile is driven forward in the tube, passing the gas port. A portion of the expanding gases enters the gas port and passes through the gas cylinder vent plug into the gas cylinder. As the gas expands against the gas cylinder piston, it forces the piston and the gas cylinder sleeve (integral with it) to the rear, compressing the gas cylinder spring.

As the sleeve is forced to the rear, the yoke on the sleeve contacts the two push rods which, in turn, move the breechblock slides rearward to unlock the breechblock. The slides are connected to the slide key which engages a slot in the bottom of the firing pin. As the slides are forced rearward by the push rods, the key retracts the firing pin. The moment the breechblock is unlocked, it is forced to the rear by blowback action with a resultant drop of gas pressure in the tube. As the gas pressure drops, the gas cylinder sleeve spring expands, returning the sleeve and piston to the original position.

*Extraction and Ejection.* When the breechblock assembly is forced to the rear, the empty cartridge case, which has been forcing the bolt back by blowback action, is contacted on the upper edge by the two prongs of the ejector, forcing the cartridge case to pivot about and force downward the forward end of the extractor. The cartridge case leaves the lip of the extractor and moves through an opening in the bottom of the receiver, completing the ejection

of the empty cartridge case. When the cartridge case frees itself from the extractor, the extractor is returned to its normal position by the action of the extractor spring.

*Rear Buffer and Driving Spring Action.* As the breechblock is driven rearward, it compresses the driving spring. When the breechblock nears the end of its rearward movement, it strikes the rear buffer washer which transmits the shock of recoil to the buffer springs which absorb the remaining force of recoil and bring the breechblock to a stop. As the breechblock comes to a stop, the inertia blocks continue to move rearward in their slots in the breechblock slide until they reach the end of the slots. By this time the breechblock has started forward again, and the inertia blocks remain in a rearward position with respect to the breechblock slides during the forward motion of the breechblock. The rear buffer springs and the driving spring expand, forcing the breechblock forward.

*Cocking Action.* As the breechblock is forced to the rear by blowback, it passes over and depresses the sear; then, when the breechblock starts forward and the sear is released, the sear will engage the breechblock lock and hold the breechblock in the rear position. The shock produced when the sear and breechblock engage is absorbed by the sear buffer springs and the sear buffer plates. If the sear is held down by actuating the trigger, the breechblock will move forward into the locked position under the force of the driving spring.

*Feeding and Chambering.* When the recoiling breechblock is sufficiently far to the rear to clear the feed mechanism, a new round is forced downward into the mouth of the feed mechanism. As the breechblock is forced forward by the driving spring, it engages the new cartridge which has been positioned in the mouth of the feed mechanism. As the cartridge is forced forward, it drops into the recess in the bolt where it is gripped by the lip of the extractor as it enters the chamber.

*Breechblock Locking Action.* As the breechblock reaches the end of its forward motion, it seats against the end of the tube, closing the chamber. The momentum of the slides and the action of the slide springs cause the slides to continue to move forward, releasing the breechblock lock. At the same time, projecting cams of the lock are engaged by cam surfaces on the receiver slides which, to-

gether with the action of the cams on the bevel of the lock, cam the lock downward. The lock seats against the breechblock key and is locked in its downward position by the lower surface of the breechblock slides, which move over the rear end of the lock.

*Firing Action.* As the slides approach the end of their forward motion, the firing pin is carried forward by the slide key and the driving spring to fire the round. When the slides have reached the end of their forward motion the inertia blocks continue to move forward for a short distance, striking against the forward end of the slot, thereby counteracting any tendency to rebound that the slides or pin might have.

## Development of the M24 Series of Guns

As outlined earlier in this section, the T31 (M24) designation was chosen to represent the T31 gun made to synchronize by means of separate interchangeable actions and to fire electrically primed ammunition. For supply reasons the T31 (M24) gun was made substitute standard in November 1947. The designation M24 was then officially given.

*20-mm M24A1 Gun.* Intensive development of the M24 gun began in late 1947, following urgent requests from the Air Force that certain requirements be met. Tests at Aberdeen Proving Ground revealed a number of deficiencies and resulted in development tests and adoption of various new components culminating in the release for production of M24A1 guns. This model contained all prior improvements as well as additional changes which necessitated the revised nomenclature. Comparison of the M24 gun as it was constructed in 1947 with the M24A1 gun reveals the following improvements in the later model: Pawl-type bolt to aid in extraction and ejection of misfired rounds; a receiver made from a new forging instead of by modification; an improved gas system which reduced leakage, had fewer parts, had greater durability, and required less maintenance; redimensioning of the firing-pin parts to eliminate time delays in synchronization and the possibility of momentary "shorts"; various components having greater durability, including a two-piece driving spring and corresponding guide, breechblock lock and locking key, firing-pin contact, gas-cylinder return spring, breechblock slide

springs, firing cable, and various locking devices. In addition, the M24A1 gun incorporates provisions for a chamber plunger required by the Air Force in connection with new charger developments for a synchronizing switch which was still under development.

*20-mm M24A2 Gun.* One change to the M24 gun consisted of the addition of a plunger to the top rim of the chamber and the removal of some metal from the top of the bolt body as developed by the Air Force and incorporated in all M24 guns used in the B36 aircraft. Guns so modified were designated M24E2.

The purpose of this modification was to eliminate failures to charge out a misfired round in the B36 aircraft. However, although improvements resulted, tests showed the operation of the gun in charging to be marginal in the B36 and unsatisfactory in other circumstances, and all M24E2 guns would eventually be replaced by the M24A1. The charging failures experienced in the B36 aircraft caused double feeding, which not only put the gun out of action but also occasionally resulted in explosions caused by ignition of the misfired electric primer by the nose of a practice projectile. In addition to development of the pawl bolt used in the M24A1 gun the following measures were taken:

1. To prevent double feeding, a study of means necessary to prevent double feed rounds caused by failures to charge or extract led to development and tests of a so called "antidouble feed device". The first attempt was unsuccessful.

2. A study was also initiated to determine whether there was actual danger of explosion when an HEI round was involved instead of a practice round. Incomplete results indicated that the danger was very slight.

*20-mm M24E1 Gun.* This nomenclature was assigned to the M24 gun when modified to fire 1,600-grain projectiles. Some preliminary testing was accomplished indicating that only minor changes would be required, including changes to the gas vent plug and filler pieces added to the feed mechanism because of the reduced projectile length. Further testing was suspended due to the urgency of work on the M24 gun.

*Tests Conducted in 1948-1949.* Along with the intensive development of the M24 gun begun late in 1947, various firing tests were initiated. In May

1948, a stock of old electric ammunition (N3 primed), which had been located at the Picatinny Arsenal, was fired. Two new guns were started using the Navy-manufactured firing-pin parts and one example each of two designs of slide key (heat treatment changes designed to increase the impact properties of the steel). Results of 1,500 rounds per gun are as follows:

Due to gun: One cable failure at less than 500 rounds; firing-pin guides peened and had to be deburred after each 250 rounds of firing.

Due to defective link: One link tab broke, causing failure to feed.

Due to ammunition: Four primer failures, four small leaks in first 500 rounds per gun.

New cables were ordered from Watervliet Arsenal incorporating changes suggested by General Electric. The Magnavox Co. was approached on the fabrication of several experimental cables incorporating their suggestions.

New firing-pin contracts incorporating suggestions of Aberdeen Proving Ground and of the Ordnance Corps were secured from Watervliet Arsenal.

Slight modifications of the firing-pin guide and slide key, designed to replace line contact between the tube by area contact, were developed.

Twisted wire slide springs were ordered from Eaton Manufacturing Co.

Perhaps the most critical phase of this development was that involving the electric primer, which was under ORDTM. Following is a brief summary of events in this field from October 1947 to October 1948.

1. T44N10 primer was tested and appeared satisfactory at ambient temperatures. The primer was standardized as M52.

2. Test of the M24 gun at  $-65^{\circ}$  F. revealed that the ammunition had excessively high-pressure peaks at low temperatures, the difficulty being traced to the quantity of primer mix. A reduction from 4 to 2.5 grains of mix was found to eliminate this difficulty, and this primer (the T44N10E) was in turn standardized as the M52A1.

3. Turret tests with guns synchronized revealed the inadequacy of the M52A2 primer under these conditions, the difficulty being attributed to the fact that the primer button was unsupported. This difficulty resulted in greatly accelerated development of

new types, including the T44N11, the M52A1 with a supporting cup added, and the T44N13.

4. Limited tests of the T44N11 were not completely satisfactory.

5. Limited tests of the M52A1 with supporting cup were more promising and resulted in its standardization as the M52A2 and instructions to Picatinny Arsenal to convert to it as soon as possible.

Kinematic studies and analyses of the gun revealed that there were several possibilities for momentary "shorts" and that slide bounce would interfere with synchronization at rates of fire near the gun's free rate. Changes in the firing pin parts to eliminate these difficulties were devised, tested, and incorporated in future production.

A considerable volume of endurance firing during the year resulted, first, in a fairly complete knowledge of the weaknesses of the gun, and, second, in considerable progress toward correcting them. In addition to the changes in firing-pin parts, several changes in locking devices were approved for production, and certain other parts appeared satisfactory but were still under tests.

Only limited endurance firing was possible in the latter part of 1948 because of shortage of ammunition, and firing was then stopped completely until ammunition was received. This condition was expected to be corrected in the immediate future since a total of a hundred thousand rounds of ammunition was reportedly in route to Aberdeen Proving Ground at the time.

The M52A2 primer continued to show improvement. However, no air firing had been conducted at this time and that was, of course, the necessary final test of the primer. Meanwhile, arrangements had been made to test fire 5,000 rounds of T44N13 primed ammunition for endurance. Preliminary tests of the latter primer indicated satisfactory results.

Evidence at hand at this time showed that the only completely satisfactory method of firing any of the primer types was by condenser discharge. In this connection, the General Electric's electronic synchronizer, developed at the B36 turret, had been found inadequate for low resistance primers. Since the specification for the M52A2 primer permitted a resistance as low as 500 ohms and the majority of the primers were below 10,000 ohms, the circuit therefore required modification.

Production waxing of ammunition had resulted in several failures to extract due to too little wax. It was found that a spraying process was being used and that a thickness of coat of 0.0003 inch maximum was specified, but no minimum. As a temporary measure, the arsenal was instructed to maintain a coat thickness as close to the maximum as possible. Meanwhile, arrangements were being made for a test of ammunition waxed to thicknesses of 0.0003, 0.0005, 0.0007, the object being to determine the maximum thickness that could be specified without excessive residue so that a range of thickness could be specified. The high-altitude tests were to begin at the Naval Proving Ground at Dahlgren and when completed, all reports to be studied.

In 1949, an M3 gun with a fluted chamber was air fired 5,000 rounds using dry ammunition. The test was conducted at Dahlgren. There were no extraction stoppages. However, failures to feed occurred, probably due to drying out the oil on the parts of the gun firing dry ammunition. The air firing of the M3 gun showed excellent results.

In March 1949, in ground firing at Aberdeen, Md., 14,500 rounds were expended and parts life according to the existing parts replacement schedule was further substantiated. Nylon insulation of the firing pin and firing-pin guide failed consistently before a satisfactory number of rounds had been fired. Cold test firing revealed no arcing in 1,800 rounds, and two misfires experienced were attributed to short-circuited primers. The Ballistic Research Laboratory firing circuit was used for 300 rounds, and the remainder of 1,500 rounds were fired with the dynamotor unit.

Investigations at Picatinny Arsenal on waxed ammunition resulted in a satisfactory method of gaging the thickness of ceresin wax and a dipping process had been set up by utilizing production methods. Ammunition was being wax coated with a slightly less than 0.0003 inch coating which is a maximum figure under the present specification. Further tests were made to ascertain whether the existing specification (0.0003 inch) should be changed.

In the spring of 1949, agreement was reached between the Air Force and the Ordnance Corps to the effect that the Air Force firing circuits would henceforth employ the condenser discharge method of firing upon which the design of both the primer



and gun had been based. This agreement grew out of reports of a high instance of misfires.

The Ordnance Corps also agreed to assist the Air Force by providing two General Electric control boxes modified to incorporate the condenser discharge circuit developed by the Ballistic Research Laboratory and previously submitted to the Air Force. This work was done by Armour Research Foundation, which was provided with two General Electric control boxes and the necessary circuit information. The first of the boxes were expected to be completed within the first month and were sent to the Consolidated-Vultee Aircraft Corp. for tests, accompanied by Armour and BRL personnel.

From study and analysis of the tests conducted there, the following changes designed to improve life of the parts was adopted.

1. Firing-pin contact: A new design, good for 2,500 rounds or more, was substituted for the former standard part which required replacement after each disassembly.

2. A change in the bolt body was made to make possible easier disassembly of the firing-pin contact. A special tool had been adopted for use in connection with the modified bolt body.

3. Extraction failures were believed to be eliminated by production ammunition which had an

adequate wax coating. However, tests were under way to determine the maximum film thickness that would permit firing of 1,000 rounds without removal of wax deposits from the gun.

In 1939, after the Air Force had experienced several instances in which a round was double fed on top of a misfire which failed to be extracted out of the gun, resulting in ignition of the primer and damage to the gun, a test was run to determine the effect of this malfunction if HEI and I rounds were involved. Although I rounds were found to be unaffected, HEI rounds exploded causing considerable damage. Accordingly, Armour Research Foundation was requested to undertake a study to determine what change to the gun would be necessary to eliminate or diminish this possibility.

It was pointed out that with improvement in primers and firing circuits, an adoption of one or the other of the designs which were in process to make charging of live rounds more positive, the odds against this type of malfunction could become quite large.

Attempts to fire rounds assembled with the T59E1 primers were unsuccessful, due to the small primer button coupled with accumulated tolerances and clearances in the gun.

### SECTION 3. DEVELOPMENT OF THE 20-MM T34 SERIES OF GUNS

In April 1945, an urgent request was received from the Bureau of Ordnance, Navy Department, for a high cyclic rate 20-mm automatic gun to be used for antiaircraft fire against Japanese suicide planes. The nomenclature T34 had been assigned in November 1944 as one approach to a high-cyclic-rate operation and many of the principles of this weapon had been tested using standard 20-mm ammunition. Ordnance Committee action was taken to delete the high-velocity requirements in order to fulfill the Navy requirements, and the T34 gun was converted to standard ammunition. The Navy request of April 1945 called for 200 such guns.

The T34 weapon was based on experiments carried on at the Naval Air Test Center at Patuxent River, Md. Modifications of existing components were made to speed up the action of the gun. A Belleville spring buffer was substituted for the conventional spring buffer. The bolt was skeletonized,

and the weight was accordingly reduced. The piston was plugged to within 0.202 inch in order to create a high-compression stroke. The functioning of the gun, the detail description of components, and the general data for the T34 are the same as for the T31.

By V-J Day, 12 T34 guns with a claimed parts life of 1,500 rounds with 2 exceptions had been delivered.

Tests revealed numerous deficiencies, chiefly short-lived parts such as driving spring, firing pins, gas piston rings, receiver slides, and slide keys.

The original models of the T34 were built by Oldsmobile. The principal importance of the model is the fact that it was the connecting link between the M3 and the Mk 12 guns. Before this high-speed weapon could be perfected, World War II ended, and all activity concerning the development of the T34 was dropped. There was a lull

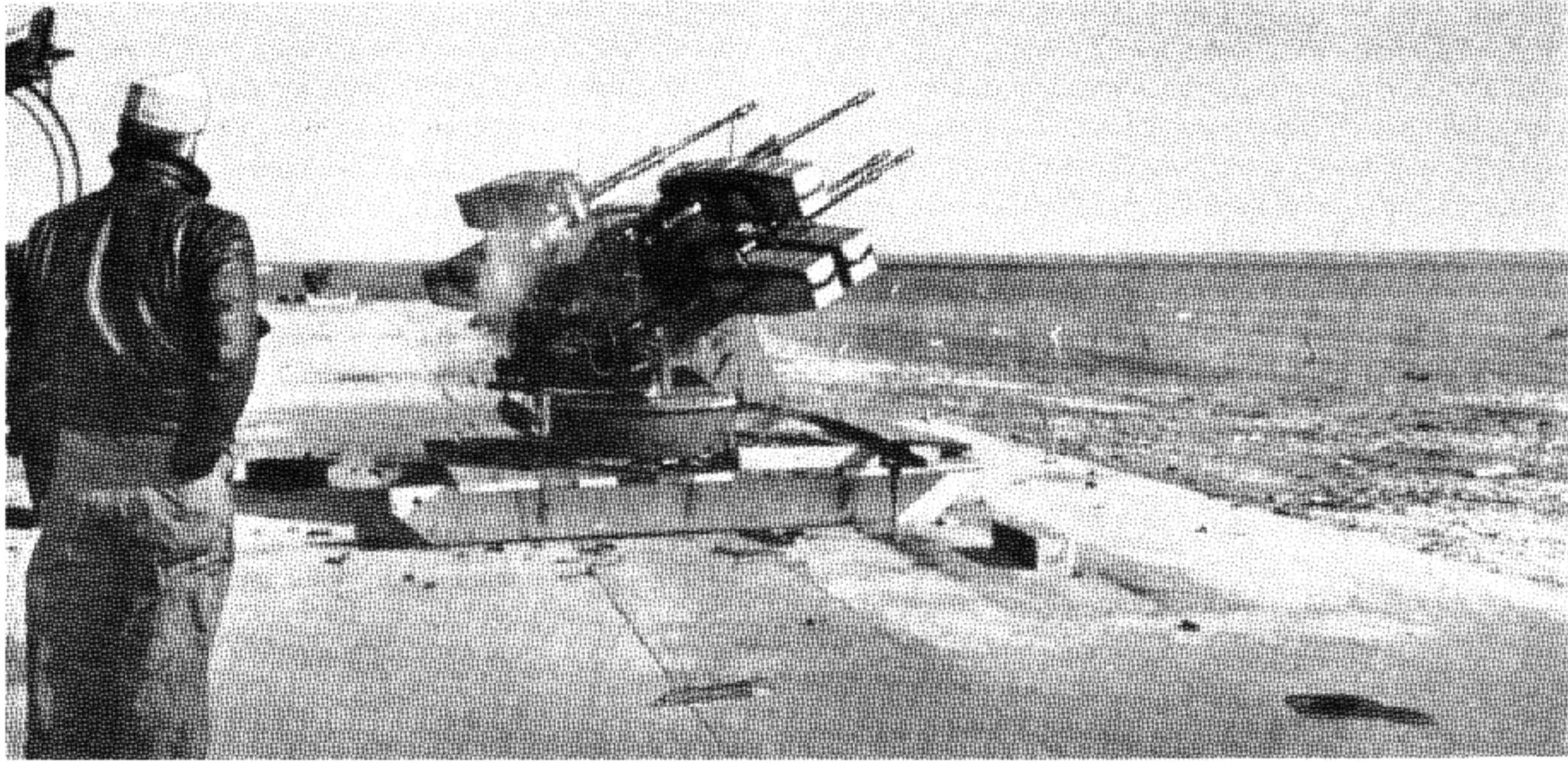


Figure 13-17. Prototype of Gun, Automatic, 20-mm T34 on an anti-Kamikaze mount nicknamed the "blizzard buggy".

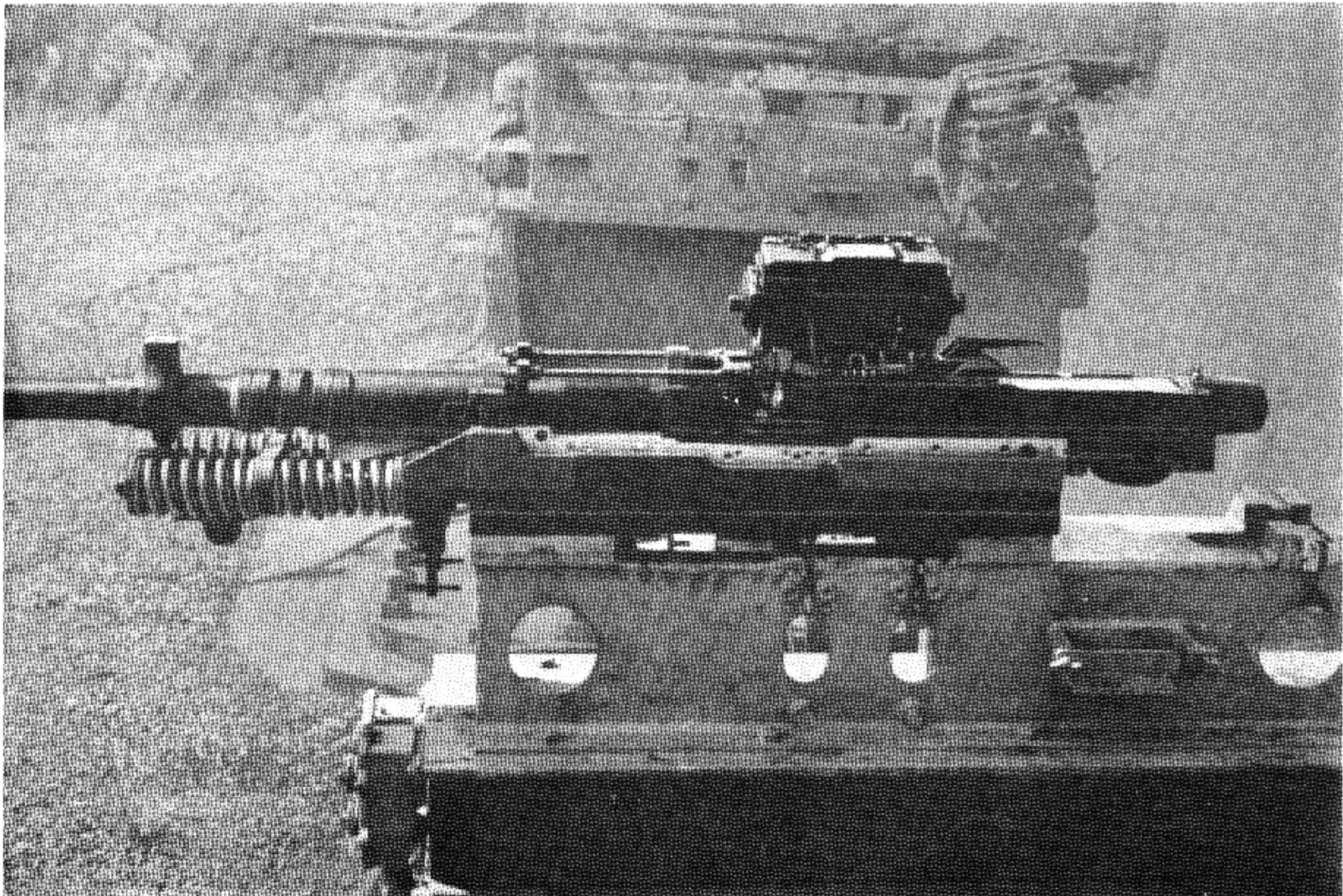


Figure 13-18. 20-mm Gun T34. Gun No. 25119 mounted on a test stand having spring of 7,600-pound-per-inch rigidity.

of 3 years, from 1945 to 1948, before any further development work was undertaken.

*Development of the T34E1 Gun.* This weapon was an electrically fired version of the T34, development of which was commenced in 1948. The purpose of the project was to meet a Navy requirement for high-cyclic-rate, electrically fired guns. Early changes eliminated two of the most serious T34 deficiencies. The receiver weakness was eliminated by utilizing a modified M2 receiver of which a large stock was available, and the driving spring was removed by utilizing a double-acting pneumatic

charger fitting into the new receiver. Later changes which appeared to correct nearly all known deficiencies included a new pneumatic buffer, double slide key with internal slide spring, and a new type firing pin assembly having a buffer which floats against the rear slide key.

*Development of the T34E2 Gun.* This nomenclature applied to the T34E1 gun when modified to fire 1,600-grain projectiles using a standard Hispano-Suiza cartridge case. The development was held in abeyance pending solution of difficulties on the T34E1 gun.

## SECTION 4. DEVELOPMENT PROGRAM FOR 20-MM MARK 12 GUN

### General Description

This high-cyclic-rate, high-velocity, aircraft automatic cannon is intended for both air-to-ground and air-to-air combat. The two versions of the gun vary in barrel length. The longer version is designated Mk 12 Mod 0 and is discussed in detail in this section. The shorter gun, with an overall length of 52 inches, was designed primarily for turret use and is designated Mk 12 Mod 1. It is presented here only in the form of an illustration, as the basic operating principles are identical with the Mk 12 Mod 0.

The cannon is similar to the 20-mm automatic gun T34E1 as to the principle of operation, but it fires a lighter projectile with a larger powder charge

at a higher rate of fire and an increased muzzle velocity. The 20-mm gun mechanism Mk 12 Mod 0 with the 20-mm gun barrel Mk 11 Mod 0 may be substituted, as a unit, for the 20-mm automatic gun M24, provided that the physical characteristics of the installation can withstand the increased trunnion loading and increased rate of fire, and that the necessary compressed air is available.

The basic design of the weapon features a combination of blowback and gas operation to open the breechblock. The breechblock is unlocked by gas operation and opened by blowback. The breechblock is returned to its closed position by a pneumatic buffer at the rear of the receiver. The

### General Data: 20-mm Gun Mechanism Mk 12

Gun length: 75.187 inches.  
 Gun weight, with feeder (Mk 7): 88 pounds.  
 Rate of fire: 1,000-1,100 rounds/minute.  
 Muzzle velocity: 3,200-3,400 feet/second.  
 System of operation: Gas operated.  
 System of locking: Swinging lock.  
 System of feeding: Pneumatic feeder, metallic belt.  
 Method of headspace: None.  
 Location of feed opening: Right- or left-hand side of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Air.  
 Method of cooling: Air.  
 Gun width, without feeder: 5.690 inches.  
 Gun height, without feeder: 5.276 inches.

Barrel length: 48.042 inches.  
 Barrel weight: 31.5 pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 inch.  
 Groove width: 0.205 inch.  
 Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: 20-mm T130 series, high velocity.  
 Trunnion reaction (based on 95,000 pounds/inch rigidity test mount):  
 Recoil: 3,300 pounds.  
 Counterrecoil: 5,000 pounds.

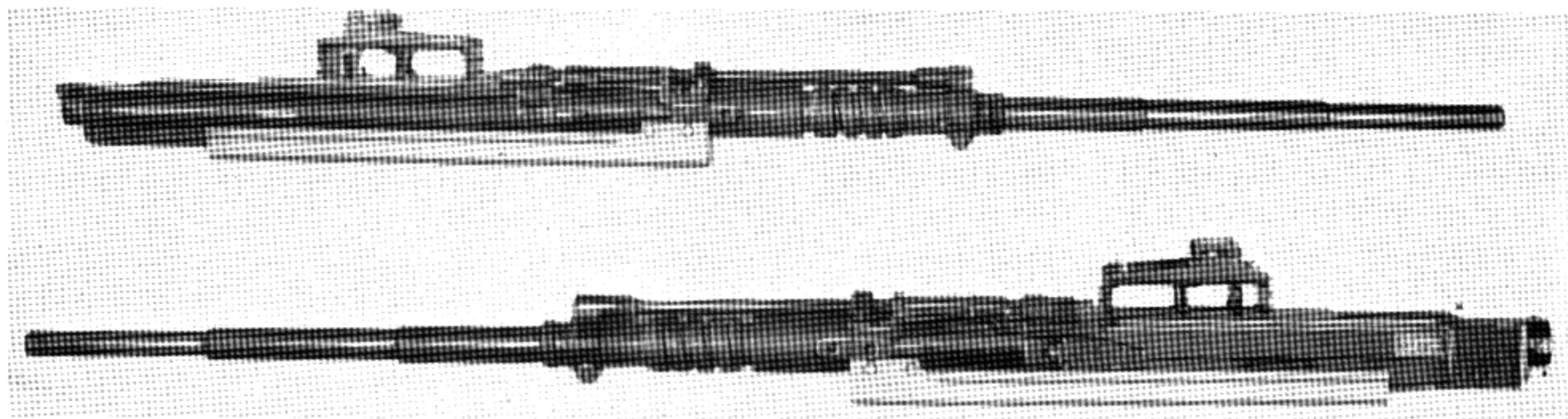


Figure 13-19. 20-mm Machine Gun Mechanism Mk 12 Mod 0.

gun is automatically electrically fired and will continue to fire as long as the firing circuit is closed and ammunition is available.

This weapon uses external power for feed to prevent lowering rates of fire due to (1) diversion of recoil energy, and, (2) increased loads at low temperatures. Pneumatic buffers, using a reasonably small air bottle and air compressor, appear satisfactory when a piston-type feeder motor is used. A new type electric motor drives the electric feeder when this type is used. This motor, under development in 1950, employs a magnetic clutch and should overcome the deficiency of former ones employing the solid clutch which had a time lag in starting under load. There was also under development in 1950 new type recoil feeders to provide sufficient recoil energy to operate the feeders satisfactorily.

The gun mechanism is supported in the cradle, and the cradle has fixed mountings in a support designed for mounting in either turret or fixed mounting. The cradle guides the gun mechanism in recoil and counterrecoil. Nonrecoiling parts of the gun mount are the cradle and the recoil housings of the recoil mechanism.

### Detail Description

*Components.* The weapon consists of the following components: gun barrel, gun mechanism, recoil mechanism, receiver, breechblock, cradle, charger, gas mechanism, and buffer assembly.

*Gun Barrel.* 20-mm gun barrel, Mk 11 Mod 0 is a tubular alloy steel forging. Threads on the breech end of the gun attach it to the receiver. A locking pin hole on the under side of the breech end is engaged by a locking pin in the receiver assembly, preventing rotation of the gun barrel after assembly with the receiver.

The breech end of the gun bore is internally machined to the shape of the cartridge to form the chamber. The chamber has 16 longitudinal grooves machined in the sides to insure proper extraction of the cartridge case. The rear walls of the chamber are smooth to insure proper gas sealing.

Rifling grooves are cut in the bore from just forward of the chamber to the muzzle, interrupted only by the gas port drilled through the top of the barrel.

The exterior of the barrel is tapered in steps from the breech end to the muzzle. An external thread is machined near the center of the gun for attaching the gas bracket and retaining the recoil mechanism.

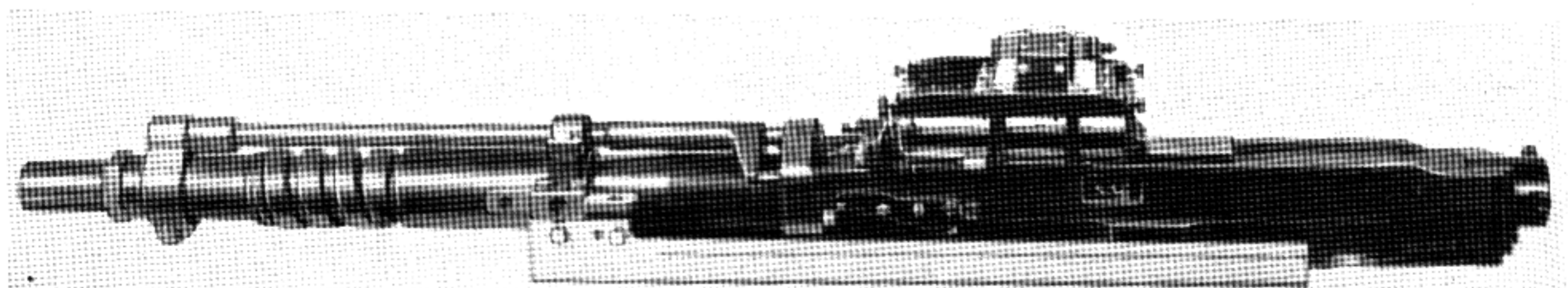


Figure 13-20. 20-mm Machine Gun Mechanism Mk 12 Mod 1, left side view.

To the rear of this thread, the gas port is drilled through the top of the barrel.

*Gun Mechanism.* The gun mechanism includes the recoil mechanism, the receiver, the breechblock, the cradle, the charger, the gas mechanism, and the buffer assembly.

*Assembled Arrangement.* The cradle is a mounting unit for the recoiling receiver. The receiver is the main structural member of the gun mechanism. It houses and acts as a guide for the reciprocating breechblock and charger. The charger is on the right side of the receiver and actuates the breechblock for first-round loading and round-clearing actions. The gas mechanism is attached to the gun; it actuates the breechblock slides to unlock the bolt after firing. The buffer is mounted at the rear of the receiver to absorb the force created by the movement of the breechblock rearward and to return the breechblock to battery position.

*Recoil Mechanism.* The recoil mechanism is a spring mechanism that checks the movement of the recoiling parts and returns them to battery. The arrangement consists of: two spring assemblies; an external, flat, helical, recoil spring assembly; and a housed ring spring assembly.

**RECOIL SPRING ASSEMBLY.** The recoil spring assembly consists of a front seat, recoil spring, a rear seat, and a spacer.

The front seat is a flanged cylindrical sleeve that fits over the gun barrel. The flanged, rear end seats the forward end of the recoil spring; the front of the seat is held by the gas bracket attached to the gun barrel.

The recoil spring is a heavy, helical spring positioned around the gun barrel between the front and rear seats. During recoil, the front seat moves back with the gun to compress the spring against the rear seat. The spring has 4.6 coils, 2.6 active. Its free length is  $4\frac{7}{8}$  inches, and its inside diameter is 2.188 inches. A force of 350 pounds is required to compress it to 4.375 inches in length. To compress it to 3.50 inches, 1,200 pounds are required.

The rear seat is concentric with the gun barrel and is free to move along the barrel. The rear of the recoil spring fits against the forward end of the rear seat. The after end of the rear seat contacts the spacer inserted between the forward follower of the recoil ring spring assembly.

**RECOIL HOUSING ASSEMBLY.** The recoil housing assembly houses an arrangement of the ring spring, forward and rear followers, and a sleeve. The housing is a cylindrical steel tube concentric with the gun barrel. It is secured to the nonrecoiling aircraft mounting by horizontal cylindrical trunnions at the rear.

The ring spring is an arrangement of internal and external rings. During recoil, these rings are forced together, tending to flatten the V-shaped cross sections of the rings to absorb the final recoil movement.

Ring-spring followers are enclosed in the housing forward, aft, and to the rear of the ring spring to hold the rings in position. The forward follower transmits the recoil load from the recoil assembly spacer to the ring spring. In recoil, the rear follower functions as a spring seat as it is held by the sleeve. In counterrecoil, the rear follower transmits the counterrecoil forces from the gun barrel shoulder to the ring spring. The sleeve is an externally threaded steel cylinder that screws into the rear of the housing. It positions, preloads, and retains the ring spring in the housing.

**RECEIVER.** The receiver houses or supports all working parts of the gun mechanism and provides attaching surfaces for the feed mechanism.

**RECEIVER BODY.** The body is a hollow, rectangular-shaped member, partially open on the bottom and top and fully open at the rear. It is approximately  $23\frac{3}{4}$  inches long,  $4\frac{1}{2}$  inches wide, and  $4\frac{1}{2}$  inches high. The front of the receiver is internally threaded for attachment to the gun barrel and has a machined hole on the under side for the gun barrel locking pin. At the top front is a threaded hole for attaching the gas mechanism sleeve guide. The underside is open from the front to approximately the center to permit ejection of empty cartridge cases. The breechblock locking key is mounted in oval-shaped transverse slots in a swelled-out section of the body sides just rear of the ejection slot. The left side is machined to attach the synchronizing switch. A longitudinal cylindrical protrusion on the right side is bored to house the gun charger assembly. At the rear are machined two dovetailed slots for attaching the buffer.

**RECEIVER PLATE.** The plate is a machined rectangular-shaped part that attaches in the bottom

rear of the receiver. It provides sliding surfaces in the rear of the receiver for the breechblock.

**RECEIVER SLIDES.** The receiver slides are thin plates bolted to the right- and left-front inner sides of the receiver body. With the receiver plate and the breechblock key, they guide and support the breechblock. At the rear of each slide is a protruding cam which assists in forcing the breechblock lock down during the locking action.

**BREECHBLOCK LOCKING KEY.** The locking key is a solid metal block that fits into the elongated slots on either side of the receiver body. Two tapped holes provide attachment for a retaining plate to hold the key in place. The key provides the bearing surface for the breechblock lock during firing and acts as an abutment for the lock in the locked position.

**GAS CYLINDER SLEEVE GUIDE.** The sleeve guide is a cylindrical rod fastened to the lug on top and in the front end of the receiver by means of the threaded hole. It guides the gas-cylinder sleeve.

**Breechblock.** The breechblock is the reciprocating assembly that brings the loaded cartridge into the gun, closes the breech, fires the round, and removes the empty cartridge case. The following components comprise the breechblock: bolt, breechblock slides, firing-pin assembly, extractor, breechblock lock.

**BOLT.** The bolt is the main component of the breechblock. It closes the breech when firing and houses the firing-pin assembly. In the bolt, two horizontal slots are machined, one at the front and the other about halfway to the rear. These slots provide an opening for assembly of the forward and rear slide keys and are elongated to allow motion backward and forward during unlocking and locking action of the breechblock. A longitudinal hole through the bolt houses the firing-pin assembly, slide spring, and plug. The hole tapers in the front to permit protrusion of the firing-pin tip. Two long shoulders, one on either side at the bottom of the bolt, form bearing surfaces for the breechblock assembly in the receiver. A machined surface in the bottom of the bolt provides a pivot for the breechblock lock. On the left side, to the rear of the front slide key slot, is a machined groove for the firing pin contact.

**BREECHBLOCK SLIDES.** Two breechblock slides, one on each side of the bolt, support and guide the

bolt in the receiver. They function to interlock firing and breechblock locking actions. Each is a similar steel piece about  $8\frac{1}{2}$  inches long with a rectangular cross section. The forward and rear slide keys extend between the two slides through the breech bolt. The right slide has a lug at the rear that contacts the charger latch to actuate the breechblock. The left slide has an insulated contact wire that contacts two wires of the synchronizing switch to complete the firing circuit when the slide is completely forward.

**FIRING-PIN ASSEMBLY.** The firing-pin assembly completes the electrical circuit for discharging the ammunition. The assembly consists of a firing pin, guide bushing, guide sleeve, contact, guide insulator, insulating washer, spring plug, and spring, all housed in the bolt. The firing-pin contact connects the firing pin to the synchronizing switch.

The firing pin is arranged within the bolt so that it is electrically insulated from the bolt whenever the pin is retracted or the bolt is in battery with the cartridge in the chamber.

The firing pin is retracted by the forward slide key. The key extends between the right and left breechblock slides through the guide sleeve and bushing. When the slides are moved rearward by the gas mechanism, the guide sleeve and bushing are moved rearward carrying the firing pin to a retracted position. On return to battery, the breechblock slides move forward to release the firing pin allowing it to be extended by the firing-pin spring.

**EXTRACTOR.** The extractor removes the cartridge from the chamber when the breechblock begins its rearward movement. It is held in place on the forward underside of the bolt by a pin through the bolt and to the volute springs. The springs pivot the extractor to engage the cartridge and to protect the extractor lips when hit by the cartridge.

**BREECHBLOCK LOCK.** The lock is rectangular in shape and flat, with a thin cross sectional area. It has a rounded forward edge which fits into a similarly shaped slot in the rear under side of the bolt. Two lugs at the rear and on either side of the lock engage the receiver cams, forcing the lock down when the bolt assembly comes forward into battery. The lock is then held in place by the rear of the breechblock slides, bearing on the top surface of the lock lugs.

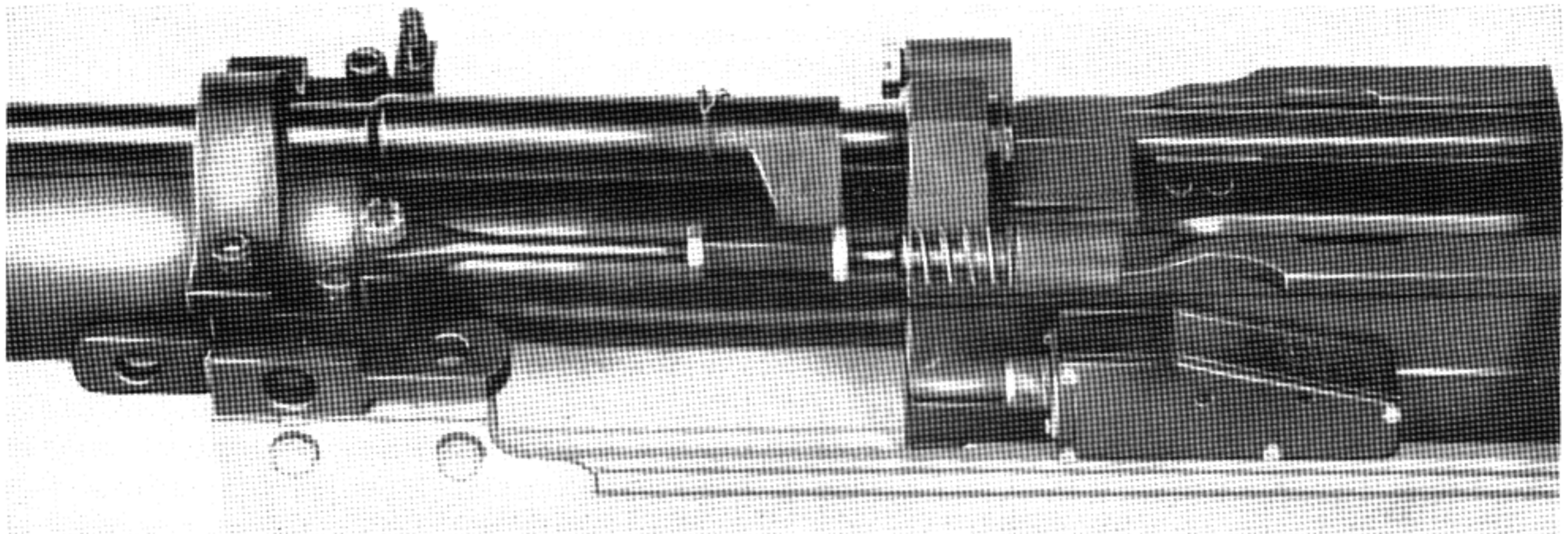


Figure 13-21. 20-mm Machine Gun Mechanism Mk 12 Mod 0. Closeup view of cradle mounting assembly.

**Cradle.** The cradle is a mount for the gun. It is designed to allow recoil and counterrecoil of the gun and gun mechanism and to transmit the resulting forces to the gun support structure. In addition, it provides anchoring surfaces for the feed mechanism. It consists of a cradle body, bracket, trunnion box, anchor support brackets, and anchor assemblies.

The cradle body is an aluminum channel, shaped to guide and support the receiver. It is machined at the forward end to provide for attaching the steel cradle bracket. Tapped holes in the bottom provide for mountings to support members and for attaching the case chute to carry away empty cartridge cases.

The cradle bracket is a semicircular forging secured to the receiver ring-spring housing in the front of the cradle body to support the gun. The top surfaces are machined for attaching the trunnion blocks, the anchor support bracket bolts, and the gas cylinder sleeve bracket. Trunnion blocks mounted on the recoil spring housing are bolted to each side of the cradle bracket to secure the gun mechanism. Each is a square block with a flat part on either end, one vertical and the other horizontal.

On the top and bottom of each block is a tongue that mates with the grooves in the cradle support and anchor support brackets. At the assembly point on either side of the tongue is a drilled hole to permit passage of the anchor-support-bracket bolt. The anchor support brackets are L shaped with a rectangular cross section. A stud screwed into the shorter leg provides attachment for the anchor as-

sembly. The anchor assemblies are turnbuckle, quick-disconnect devices for attaching the feed mechanism.

**Charger.** The charger is a pneumatic mechanism that provides remote-control power operation of the breechblock for first-round loading or for round clearing. The charger piston is actuated by 1,000-p. s. i. air pressure from the aircraft supply. The charger consists of a charger tube, piston, ram head, and a dumping valve. The entire assembly is housed in a tubular housing on the right side of the receiver.

**CHARGER TUBE.** The charger tube is a steel cylinder that fits into the forward end of the charger housing. Six drilled holes near the rear of the two provide air inlets to the piston within the tube. Air, to the rear of the piston head, enters through a hose connection on the charger housing, passes through the housing, then through the six holes into the charger tube. Air is prevented from escaping out of the housing by an O-ring seal at each end of the tube. The dumping valve assembly is screwed into the forward end of the tube.

**PISTON AND RAM HEAD.** The piston is a hollow tube with a piston head at the front end and the ram head at the rear. The piston is moved by pneumatic pressure, moving the ram head which engages a lug on the right-hand breechblock slide to charge the gun. A lug on the bottom of the ram head rides in a groove in the charger housing to prevent rotation of the piston and ram head.

**DUMPING VALVE.** The dumping valve, in the forward end of the charger tube, is arranged to re-

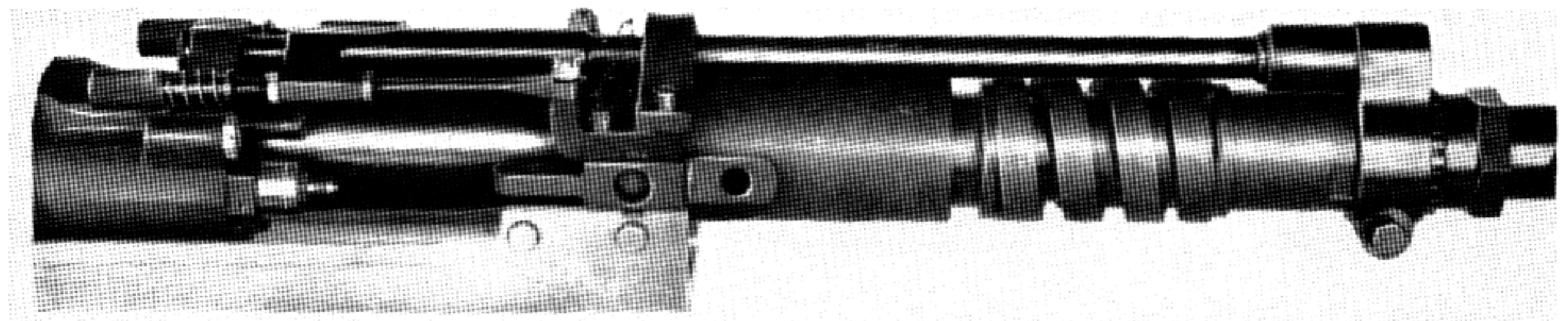


Figure 13-22. 20-mm Machine Gun Mechanism Mk 12 Mod 0. Closeup view of gas-cylinder and recoil assembly.

lease quickly the air used to move the piston rearward before the return strike. It consists of a nylon charger seat and valve assembly. During the piston's rearward movement, compressed air seats the valve to hold it closed. On the return stroke, the compressed-air supply is cut off and the valve is opened by the air in the charger tube to exhaust quickly the air forward of the piston head.

**Gas Mechanism.** The gas mechanism furnishes the force necessary to unlock the breechblock at the proper time and to start it rearward. The gas bracket assembly consisting of a bracket and a vent plug is secured against the shoulder on the gun by the gas bracket nut. The proper angular position of the gas bracket is maintained by a key fitting in the slot on the bottom of the gun barrel and the slot in the bottom of the bracket. The key also acts as a locking device for the bracket nut by engaging one of the slots in the rear of the nut. The key is held in place by the gas bracket clamping screw. The cylinder portion of the gas bracket guides the piston end of the gas cylinder sleeve assembly. The piston and piston ring insure a gas seal between the sliding sleeve and the chamber of the gas bracket, thereby maintaining full effect of the gas pressure transmitted through the vent plug. The rear of the sleeve assembly is directed by the guide attached at the top of the forward end of the receiver. The guide also acts as a stop for the gas cylinder sleeve spring. When the sleeve is forced to the rear by the gas pressure, it contacts a push rod in either side of the receiver. The push rods are aligned with the breechblock slides and they unlock the breechblock when forced to the rear by the gas cylinder sleeve.

**GAS BRACKET.** The bracket is a forged housing with a hollow cylinder extending toward the rear on the top side. A hole from the top of the inner diameter extends through to the cylinder. The in-

side end of the cylinder is tapped to attach the vent plug. A hole extends transversely through two lugs machined on the split bottom side of the bracket to permit passage of the clamping bolt and position the key. The vent plug is cylindrical and is drilled to permit passage of the necessary gas pressure for breechblock unlocking.

**GAS CYLINDER SLEEVE.** The gas cylinder sleeve is a piston and piston rod extending between the gas bracket and a guide mounted on the receiver. The piston end of the sleeve in the gas bracket is actuated by the firing gases to move the sleeve rearward. Forked arms at the rear of the sleeve contact push rods to move the breechblock slides. This action unlocks the breechblock and starts it moving rearward. The rear end of the sleeve fits over a cylindrical guide on the receiver that guides the movement of the sleeve and seats the sleeve return spring.

**GAS CYLINDER GUIDE.** The guide is a short, hollow cylinder attached to the receiver to guide the sleeve. The sleeve spring bears against the face of the guide.

**GAS CYLINDER SLEEVE SPRING.** The gas cylinder sleeve spring is a three-wire, twisted-strand spring fitting inside the sleeve and bearing against the sleeve guide for returning the sleeve forward.

**PUSH RODS.** Two push rods, one in either side of the receiver, extend forward, from the front face of the breechblock lock slides, to the legs on the gas cylinder sleeve.

**Buffer Assembly.** The buffer is a pneumatic device which, by means of internal air pressure, retards the rearward motion and supplies forward acceleration to the reciprocating breechblock. The buffer housing has an accurately machined internal cylindrical surface closely fitting a reciprocating buffer piston. Assembled on the rear of the piston



are an O-ring and two leather backup rings held in place by a collar threaded on the piston. The O-ring provides the seal to prevent escape of the air pressure fed to the rear of the piston. An externally threaded sleeve retains the piston in the buffer housing. The air inlet at the rear of the piston provides a constant pressure through the check valve, which seals the area behind the piston when it is forced rearward by the breechblock. The trapped air is thus compressed until rearward motion of the breechblock is stopped, at which time it expands, thereby thrusting the breechblock forward.

**HOUSING.** The housing is internally machined and threaded to receive the plunger and sleeve. A drilled and tapped boss protrudes from the internal rear face of the cylinder to house the check valve assembly. Drilled holes in the housing connect to the air supply through an air inlet fitting into a bleeder valve. The bottom extension of the housing is machined to house a spring-loaded plunger that positions and locks the buffer to the rear of the receiver.

**PISTON.** The piston has a raised shoulder against which the O- and backup rings bear. The rear is externally threaded for attaching the collar and thus holding the backup ring in place.

**VALVE.** The check valve consists of two parts: A ball supported by a spring, and a valve plug. The plug is screwed into the rear of the housing with the spring and ball assembled behind it. The intake fitting and the check valve may be interchanged for right- and left-hand assembly.

**Firing Circuit.** In a single free-firing gun installation, current flows from the supply source to the synchronizing switch. When the left breechblock slide is approximately 0.25 inch from its locked position, contact is made and the bolt contact completes the circuit.

When two guns are wired in synchronized firing, current is supplied to the synchronizing switches of both guns. Current flow through the circuit allows both guns to fire together.

If either gun jams, or if breakage prevents use, the FREE-SYNC firing switch should be turned to FREE. This permits current flow directly to the usable gun. In this condition, firing takes place immediately when the firing pin contacts the cartridge primer.

**Synchronizing Switch.** The synchronizing switch is composed of three contacts which operate with the breechblock to complete the firing circuit. The case is composed of two halves bolted together. The receptacle assembly consists of two connectors and the connecting wires.

**Feed Mechanism.** The feed mechanism Mk 7 Mod 0 is a pneumatic, piston-type feeder. Its prime purpose is to pull the ammunition belt through the feeder, strip the belt links, and place the cartridge in a position to be pushed into the gun chamber by the reciprocating breechblock.

**Mounting.** The feed mechanism is mounted on top of the receiver. Two slots on the forward top side of the receiver permit passage of the feeder feet downward. The feed mechanism is then pushed forward with the feeder feet engaged in the slots in the sides of the receiver. The feeder is then secured to anchor rods, and is a nonrecoiling mechanism.

## Preparation for Operation

**Safety Checks.** The following checks are mandatory for safe and effective tactical operation of the weapon.

1. Make certain the master armament switch is OFF.
2. Check the air supply to the buffer by pressing the buffer piston inward.
3. Check the air supply to the charger by actuating the charger valve.
4. With the breech open, check the gun bore for obstructions.
5. Check the anchor assemblies to see that the connections to the feed mechanism are secure. The extreme back end of the feed mechanism should be in line with V notches on the gun.
6. Check the trunnions to be sure they are secure in anchors.

**Loading.** Load the gun mechanism as follows:

1. Shut off air supply to the feed mechanism.
2. Bleed off air to the feeder if the shutoff valve is not self-bleeding.
3. Attach the ammunition chute to the feeder by opening the cover on the chute side and placing the chute ends on the supports on the front and rear end plates. Close the cover, securing the ammunition chute.

4. Move ammunition through the chute to the feeder. When loading right-hand feeders, start the belt with an empty link.

5. Lead the first link on the guides located on the under side of the cover.

6. Push the first round over the retaining pawls engaging the link and round on the stripper.

7. Check by pulling on the belt.

8. Turn on the air supply.

9. Charge the gun mechanism.

*Charging.* After feeding the first round into the feed mechanism, actuate the charging valve by turning the gun charging switch to SAFE. This will retract the breechblock. Wait at least 2 seconds, and turn the charging switch to READY to move the breechblock forward. In moving forward, the breechblock picks up the first round and drives it into the gun chamber.

*First Round Loading Action.* To initiate automatic firing, it is necessary to place the first round in the gun chamber as follows: With the ammunition belt fed into the feed mechanism, actuate the charger valve to force the breechblock to the rear and then forward. As the breechblock moves forward, it will push the round from the feeder tray into the open chamber.

## Cyclic Actions

The firing of a round of ammunition occurs in the following sequence, and the cycle is divided into six actions. These actions are indicated by parentheses, as indicated in the following list. Each round requires a total of 60 milliseconds.

1. Recoil gun (0.013 second).
2. Breechblock unlocking (slide unlocking: 0.002 second).
3. Breech opening (bolt movement to the rear: 0.028 second).
4. Case extraction.
5. Case ejection.
6. Breechblock buffing.
7. Counterrecoil (0.032 second).
8. Breechblock closing.
9. Breechblock locking (bolt movement forward: 0.026 second; slide locking 0.003 second).
10. Firing.

*Recoil Gun.* When the gun is fired, the propellant gases in the barrel force the gun to recoil to the rear. During recoil, the front recoil-spring seat

and gun move to the rear, compressing the recoil spring. This action continues until the rear end of the front recoil-spring seat contacts the front end of the rear recoil-spring seat after travelling about five-eighths inch. This contact prevents further compression of the recoil spring. The rear end of the rear recoil-spring seat is in contact with the spacer which contacts the front follower ring of the recoil housing assembly. As the ring-spring assembly is compressed, it absorbs the remaining recoil energy. After maximum recoil has been reached, both the recoil spring and the ring-spring recover to return the gun to battery. When the battery position is reached, a shoulder on the gun barrel contacts the rear follower of the ring spring, thereby compressing the ring springs and absorbing counterrecoil energy.

*Breechblock Unlocking.* When the breech is closed, the breechblock is held forward by the breechblock lock which bears against the locking key in the receiver. The breechblock slides prevent the lock from disengaging until after firing or charging. As the projectile is driven forward in the barrel, it passes the gas port, allowing the propellant gases to enter the port and move the gas cylinder sleeve assembly to the rear.

As the gas cylinder sleeve moves to the rear, it forces the push rods back, moving the breechblock slides rearward. During this action, the forward slide key retracts the firing-pin guide to retract the firing pin. Simultaneously, the rear slide key retracts the firing-pin spring plug to compress the breechblock slide spring. As the slides approach the end of the unlocking stroke, the rear end of the lock is uncovered and it is allowed to rise clear of the locking key to unlock the breechblock.

At the end of its stroke, the gas cylinder sleeve strikes the receiver and is returned to its original position by the gas cylinder sleeve spring.

*Breech Opening.* After unlocking, the breechblock is started to the rear by the blowback action of the gases in the gun barrel. The extractor lip engaging the cartridge aids in withdrawing the empty case from the chamber.

*Case Ejection.* As the breechblock moves to the rear, the empty cartridge case is blown back with it by the blowback action and also by the lips on the extractor and bolt face. Near the end of the breechblock rearward movement, the cartridge case is contacted by two ejector prongs on the feed mechanism.

This action forces the cartridge case to pivot about the extractor down out of the weapon through the ejection slots in the receiver. The extractor, which is forced down during ejection, is returned to its usual position by spring action.

*Breechblock Buffering.* At the end of the breech-opening movement, the breechblock contacts the piston of the pneumatic buffer at the rear of the receiver. As the piston is moved in by the impact of the breechblock, the air pressure within the buffer compresses and finally stops the rearward movement of the breechblock. The compressed air then expands, pushing the piston out to return the breechblock forward. A continuous supply of compressed air is maintained through the air-hose connection.

*Breechblock Closing.* Expansion of the air trapped within the buffer forces the rubber piston forward, starting the breechblock forward to close the breech. This accelerating force is sufficient to move the breechblock and a round of ammunition completely forward to load the gun and close the breech for the firing of the next round. During the closing stroke, the breechblock picks up the next round in the feed mechanism. As the breechblock continues forward, it carries the round with it and forces the round into the gun chamber. As the round is chambered, the cartridge case lip is engaged by the extractor in readiness to fire.

*Breechblock Locking.* When the breechblock reaches the end of its forward motion, it seats against the rear face of the gun barrel, closing the chamber. Simultaneously, the breechblock lock is forced to rotate downward by the action of the cam surfaces on the forward end of the receiver slides and the pressure of the breechblock slides, which continue to move forward by inertia and the force of the breechblock slide spring within the breechblock. The lock seats against the locking key in the receiver and is held in this position by the lower rear ends of the breechblock slides.

*Firing.* When the breechblock is approximately one-eighth inch out of battery, the bolt contact engages the ignition squib of the synchronizing switch. As the breechblock slides move forward, the firing-pin guide is carried by the forward slide key, allowing the firing-pin spring to bring the firing pin into contact with the electric primer 0.25 inch before the slides reach their full forward position. Simultaneously, the synchronizing switch contact in the

left breechblock slide bridges the gap between the synchronizing squibs. When the three synchronizing switch contacts are made and the firing pin is in contact with the primer, the round is electrically fired. In a synchronized pair of guns, these conditions must be met in both guns before firing occurs. The two guns then fire simultaneously.

### Detailed Maintenance of Gun Barrel

Bore wear depends upon cleaning, preservation, cooling between periods of firing, and number of rounds fired. Whenever possible, the bore should be examined for foreign material, including copper fouling and propellant residue, deformation of lands or grooves, indentations resembling pits in castings and pitting of the lands or grooves. It is not necessary that the bore be shiny to be clean. A clean bore may have a dull, gray appearance.

*Before-Firing Maintenance.* Wipe the bore clean if no covers are installed or if the bore was previously excessively oiled.

*After-Firing Maintenance.* Thorough cleaning is extremely important and should be carried out as soon as possible after firing. When a gun is fired, the gas pressure forces a deposit of primer salts into the pores of the bore and chamber. These salts are extremely corrosive and, if not properly removed, will result in pitting and other forms of corrosion. The salts are water soluble but will not dissolve in petroleum distillate. Removal can be effectively accomplished by use of Rifle Bore Cleaner JAN-C-372.

NOTE. The rifle bore cleaner contains water, so all traces must be removed with a dry cloth. Incomplete drying may result in malfunctioning at low temperatures. If the specified rifle bore cleaner is not available, an emergency substitute of  $\frac{1}{2}$  to 1 pound of soda or sodium carbonate, Federal Specification O-S-571, to 1 gallon of boiling water, may be used. Thereafter, the bore must be rinsed in fresh water and thoroughly dried. After cleaning the bore, apply a thin coating of preservative Lubricating Oil JAN-L-644. If the gun is to be temporarily inactive, apply a coating of Lubricating Oil OS 1363. If the chamber becomes excessively fouled, polishing Tool R40-D-510 (see OP 1910) may be used.

*Erosion Indicator.* The bore-erosion gage is placed in the barrel chamber to determine the amount of erosion caused by the burning ammuni-

tion gases. When the gage can protrude forward into the chamber beyond the maximum allowable depth reading, the barrel should be replaced.

*Barrel Removal and Replacement.* For removing the barrel, the following procedure should be followed:

1. Remove the gas mechanism.
2. Remove the recoil mechanism.
3. Using the gun-locking, pin-removal tool, remove the barrel-locking pin.
4. Unscrew the barrel from the receiver.

**NOTE.** If there is seizing between the barrel and receiver, use the barrel wrench applying torque while tapping the barrel near the receiver with a rawhide hammer.

### Detailed Maintenance of Receiver

The receiver houses and guides most of the working parts of the gun mechanism and is the major strength member resisting rearward and spreading forces. Careful inspection and maintenance are therefore essential for long service life and operation.

*Cleaning and Lubrication.* Clean all foreign particles from the breechblock ways in the sides of the receiver and keep coated with a thin film of oil JAN-L-644.

After firing, always clean the portion of the receiver near the barrel with Rifle Bore Cleaner JAN-L-372, wipe and dry and coat with JAN-L-644.

*Inspection.* Inspect the receiver for cracks or spreading of receiver plates in vicinity of dovetail grooves for attaching the rear buffer. Check for burrs, particularly along the slides or buffer dovetail grooves, and remove with crocus cloth or a very fine oilstone. If the receiver has welded inserts at the gas mechanism sleeve guide bracket, check for breakage.

### Detailed Maintenance of Breechblock Assembly

Generally check the freedom of movement of the breechblock in the receiver. After disassembly and cleaning, perform the following checks:

1. Examine all components for damage and remove burrs with crocus cloth or fine oilstone.
2. Check for enlargement of the firing-pin hole. If sufficiently large to cause blown primers, replace the bolt.

3. Check for cracks around forward seat of breechblock lock or either slide key. Replace if necessary.

4. Check for cracks around breechblock lock cam surfaces and cracks or roughness on breechblock locking surfaces.

5. Check for firing-pin guide breakage or set.

6. Check for extractor and extractor-pin breakage.

7. Check for damaged, broken, or permanently set springs. Replace if necessary.

8. Check electrical components for broken insulation on bolt contact, firing-pin guide, and firing pin.

*Cleaning and Lubrication.* Clean the front face of the bolt and slides with a cloth dampened in Rifle Bore Cleaner JAN-C-372, wipe dry, and coat with light film of Oil JAN-L-644 to prevent corrosion of the parts exposed to the primer salts during firing. When disassembled, all parts, except electrical insulation, may be wiped clean and oiled in a similar manner.

*Removal.* To remove the breechblock, first remove the rear buffer. Then, using the bolt-unlocking tool:

1. Place the tool on the right side of the bolt so that the projection of the arm of the tool engages the front face of the right slide and the other arm of the tool fits along the top of the bolt with its forward end bearing on the receiver.

2. Press the handle of the tool forward until the breechblock is unlocked.

3. Move the breechblock rearward out of the receiver, being careful to place one hand below the unit to prevent the lock from falling.

**CAUTION.** Make certain air pressure to the charger is off. Actuation of the charger could project the assembly out of the gun with excessive force, resulting in possible injury to personnel or to the mechanism or both.

*Installation.* To install the breechblock, use the breechblock assembly tool and hold the lock in its unlocked position with the slides rearward. Holding the assembly in this manner, push it into the move toll and push the breechblock forward into its locked position.

*Disassembly and Assembly.* When the breechblock is removed from the receiver, the lock falls free. Further disassembly is as follows:

1. Remove pin from the slide spring plug pin and bolts.
2. Unscrew the slide-spring plug from the bolt. The slide spring will fall out.
3. With the rear of the bolt held against a soft surface, such as wood or cardboard, use a screwdriver to pry the left-hand slide away from the bolt. The rear slide key, which is pinned to the left side, will come with it, and the firing pin spring plug will be ejected from the bolt.
4. Remove the firing-pin spring.
5. Pry the right-hand slide away from the bolt and remove it with the forward slide key which is pinned to it.
6. Press out the extractor pin by pressing on the small end. The extractor will be forced out by the extractor spring.
7. Remove the bolt contact using the contact extractor bolt.
8. Remove the firing pin and firing-pin guide.
9. If necessary, due to breakage, remove the slide keys from the slides by driving out the spring pins with a punch and light hammer.

To assemble, reverse the foregoing procedure.

### Detailed Maintenance of Charger

Careful maintenance of the charger is very important. A faulty charging system may cause loss of use of the gun in combat.

*Cleaning and Lubrication.* Since most of the working parts are totally enclosed, cleaning and lubricating are essential only when the charger is disassembled.

1. Give a very close inspection to the internal parts for presence of any foreign material in the air port or on the tube internal surfaces.
2. Inspect the condition of all O-rings and backup rings for wear or breakage.
3. Inspect all metal parts for damage or breakage.
4. Remove all burrs with a fine oil stone.
5. Lubricate O-rings with Grease MII.-G-15793 at reassembly. Coat all other components of the charger with a light film of Oil JAN-L-644.

*Inspection.* Operate the charger valve to see that the charger cycles the breechblock freely without sticking or hesitating action.

*Removal.* To remove the charger assembly, take the following steps:

1. Cut off the air pressure to the charger and remove the air hoses. Hose connection should be removed carefully to allow for escape of air pressure.
2. In the receiver, remove the locking wires, screws, and latch cam.
3. Unscrew the retaining nut.
4. Withdraw the assembly from the rear carefully to prevent damage to the external tube O-rings.

*Installation.* Installation is the reverse of the procedure just given. Be careful not to damage the O-ring when starting the assembly into the receiver housing and while passing surface interruptions.

*Disassembly.* The disassembly procedure is as follows:

1. Remove the two pins in the ramhead. The latch and spring will be ejected.
2. Slide the ramhead off the piston.
3. Unscrew the charge tube cap from the charger tube, and remove the piston by pushing it from the rear.

4. Unscrew the valve body from the tube cap, being careful not to drop the valve and shuttle. Do not remove the shuttle seat unless it is to be replaced.

*Assembly.* The assembly procedure is the reverse of disassembly. Successful assembly is largely dependent on the careful insertion of O-rings and proper positioning of the shuttle valve.

### Detailed Maintenance of Gas Mechanism

Maintenance of the gas mechanism is exceedingly important to insure the proper rate of fire:

1. Check the sleeve assembly. If bent, replace.
2. Check the gas cylinder sleeve spring. If set or broken, replace.
3. Check free movement of gas cylinder sleeve assembly on the guide. If binding, replace the guide or sleeve.
4. Check the gas cylinder vent plug for erosion or fouling. If eroded, replace the gas bracket. If fouled, clean and reinstall.
5. Remove light burrs from the piston end of the sleeve. Replace if excessively worn.
6. Check the piston ring. Replace if broken, set, or excessively worn. To replace, remove pin from gas cylinder sleeve and unscrew gas cylinder sleeve.

7. Remove burs from push rods. Replace if excessively pined on the ends.

*Cleaning.* Inspect and clean carbon from the vent plug and piston ring after firing frequently.

*Removal.*

1. Remove the cotter pin and lockwasher.
2. Unscrew the sleeve guide from the receiver lug.
3. Remove the trunnion securing screws through the gas cylinder bracket.
4. Remove the gas cylinder sleeve bracket.
5. Remove the cotter pin from the gas bracket screw.
6. Unscrew the castellated nut and slide out the gas bracket screw.
7. Unscrew the barrel nut. Note: This allows the recoil-spring to expand and force the gas bracket forward. If the bracket remains stationary as the barrel nut is loosened, tap the bracket until it is free to follow the nut.

*Installation.*

1. Place the gas cylinder bracket on the barrel butting against the recoil-spring seat.
2. Screw the sleeve guide into position but do not install lockwasher and cotter pin.
3. Slip the yoke of the gas cylinder sleeve onto the guide, leaving out the gas cylinder sleeve spring. Fit the piston end of the sleeve into the cylinder of the gas-cylinder bracket.
4. Screw the barrel nut onto the barrel in front of the gas cylinder bracket, and tighten.
5. Install the screw, nut, and key, but do not tighten down.
6. Lightly tap the gas cylinder bracket to rotate it as far as the key will permit, and, at the same time, slide the gas cylinder sleeve in and out. Leave the bracket in the position at which the sleeve moves easiest.
7. Tighten the nut to secure the gas cylinder bracket, and insert the cotter pin.
8. Check free movement of the sleeve.

9. Remove the gas cylinder sleeve guide and install the sleeve spring. Reinstall the guide. Install lockwasher and cotter pin on the guide.

10. Install the gas cylinder sleeve bracket.

### Detailed Maintenance of Buffer Assembly

To check the buffer action, bleed the air pressure by loosening the bleeder plug on the left rear end of the buffer housing.

1. Check free movement of the piston. If it binds or sticks excessively, replace the buffer.
2. Check the buffer lock plunger.
3. When the buffer is disassembled, check to see that the O-ring is not worn or broken.

*Cleaning and Lubrication.* When disassembled, precaution should be taken to prevent any dirt or foreign substance from entering the housing. The parts, before assembly, should be thoroughly wiped with a lint-free cloth and the piston O-ring and backup rings should be lubricated with Grease MIL G-15793 at reassembly. All other components of the buffer must be coated with a light film of Oil JAN-L-644.

*Disassembly.*

1. Remove the locking wire.
2. Bleed all air pressure through the bleeder valve.
3. Disconnect the air hose and remove the air inlet fitting. Do not remove the valve seat and ball check valve unless necessary.
4. Unscrew the bleeder valve.
5. Force the piston to the rear, and drive out the sleeve pin.
6. Unscrew the buffer sleeve and remove the piston assembly.
7. Further disassembly is apparent.

*Assembly.* Assembly is the reverse of the procedure just given, except that the buffer piston and sleeve should be installed before the air inlet fitting and bleeder valve.

## SECTION 5. GUN, AUTOMATIC, 20-MM, T118

After World War II, both the Navy and the Army were interested in a high-velocity 20-mm weapon based on the Hispano-Suiza principle. The design developed by the Navy, the 20-mm Mk 12, is described in the preceding section. Early in the

development program the Navy and Army disagreed on the cartridge design. The Army was interested in using its caliber .60/20 ammunition, which incorporates a 1,600-grain projectile in a caliber .60 cartridge case. The designation Gun, Automatic,

20-mm, T118 was established in the latter part of 1948 to identify a T34E1 gun rechambered and modified to use this ammunition.

The Navy, however, favored a round which consists of a 1,700-grain projectile and a cartridge case similar to the caliber .60 case but approximately 0.266 inch longer in the body. The Navy adopted this round under the designation T130 for use in its 20-mm Mk 12 gun.

Because of the difference in the ammunition, two development programs have been carried on concurrently. Approximately 20,000 rounds have been fired in tests of the T118 gun. However, the larger part of the development work has been carried on in the Mk 12 program, since the Navy has the primary interest in the 20-mm series of guns. Accordingly only the details of the development of the Mk 12 are given in this chapter.

## Chapter 14

# ORDNANCE CORPS LIGHT MACHINE GUN, 7.92-MM

## SECTION 1. HISTORY AND BACKGROUND

In World War II, paratroop soldiers of the German army were equipped with a very lightweight 7.92-mm machine gun capable of delivering at a high rate of fire or single shot with extreme accuracy. The gun was known as the FG-42 and was designed and produced by the Krieghoff Waffenfabrik in Suhl, Germany. (See volume 1, pp. 489-491.)

After the war, a project was initiated by the United States Ordnance Corps to refine and im-

prove the design of the Krieghoff 7.92-mm FG-42 and, if possible, to convert it from clip to belt feed, employing the feed system of another popular German light machine gun, the MG-42. (See volume 1, pp. 484-488.) This work was carried on under the designation "Gun Machine, Light, 7.92-mm T44" by the Bridge Tool and Die Works.

By December 1946, the mechanical solution for the conversion had been completed.

## SECTION 2. GUN, MACHINE, LIGHT, 7.92-MM T44

### Description of Components

*Receiver Group.* The receiver body in which the essential parts of the gun operate is a sheet metal fabrication. The barrel is permanently mounted into the forward end, and the receiver swaged circumferentially into a recess around the rear end of the barrel and secured by a locking ring, likewise swaged. The hinge member about which the feed mechanism rotates is welded to that portion of the receiver body directly rearward from the swaged area, thereby making the receiver body, barrel, and hinge member an integral unit.

Holding the receiver body in a normal firing position, there is an opening on the left-hand side running longitudinally from the welded hinge member for the length of the housing. This opening is bridged at a point located approximately 4 inches rearward from the hinge member by the ejector assembly. The resultant opening between the hinge member and the ejector assembly permit the receiver plate to position the cartridge for insertion into the barrel. Directly opposite this opening there is a similar smaller opening through which cartridge cases are ejected.

Further description of the receiver body is given in connection with the following descriptions of components.

*Muzzle Brake Group.* The muzzle end of the barrel accommodates the muzzle-brake assembly, bipod, and front sight.

The front sight is held in radial alignment by a milled surface along the top side of the barrel and locked in place by the muzzle brake mounting ferrule, which at the same time serves as a mounting for the bipod.

The muzzle brake is threaded onto the muzzle brake mounting ferrule and locked in place by a spring latch attached to the front sight which registers in a milled slot in the end of the muzzle brake. The function of the muzzle brake is to absorb a part of the recoil.

*Gas Cylinder Group.* The gas cylinder is tube-like in appearance and is mounted beneath the barrel. It is attached on the forward end by a collar. The rear end of the gas cylinder is turned for a slip fit into the rear end of the barrel. The gas cylinder is held in place by the gas cylinder locking nut, which is threaded onto the barrel.



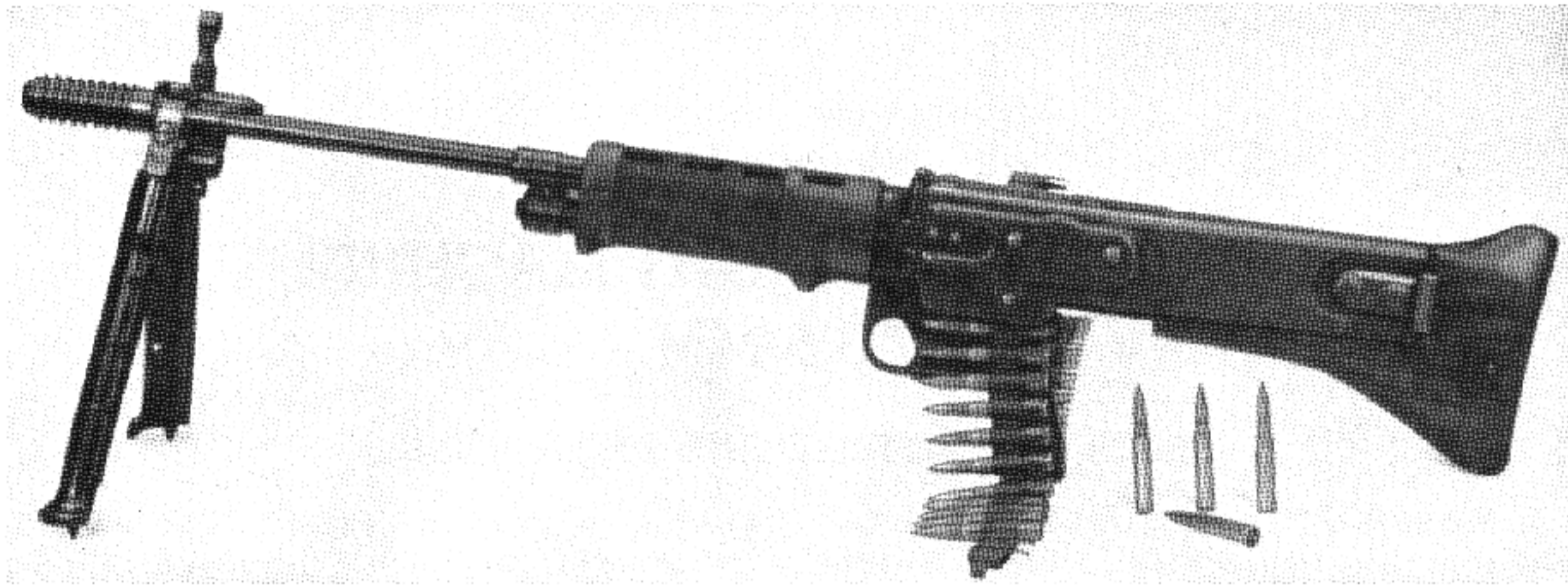


Figure 14-1. United States 7.92-mm Light Machine Gun T44.

When the gas cylinder is in place, a port in the collar end of the cylinder lines up with a similar port in the barrel. This port is for conducting the flow of gas from the barrel into the gas cylinder during the firing cycle. The amount of gas to flow is determined by the radial positioning of the gas cylinder orifice selector, which is inserted through the collar portion of the gas cylinder.

The gas cylinder orifice selector is screwlike in appearance. The head is cross slotted, and the body portion has three notches in radial alignment with the cross slots in the head. The notches increase in size from zero (or no notch) to about one-sixteenth inch deep by three-thirtyseconds inch wide. The four quadrants formed by the cross slotting of the head are center punched in depth to correspond with the size of the notch in radial alignment. It is

therefore possible to determine, by the position of the center punches, the size of the orifice between the barrel and gas cylinder, and to increase or decrease the size accordingly.

The gas cylinder orifice selector is retained in position by the gas cylinder orifice selector retainer, which is a U-shaped spring yokelike on one end and on the other end is shaped to fit into the cross-slotted head of the gas cylinder orifice selector.

The gas cylinder orifice selector retainer serves a dual and reciprocal service with the gas cylinder pressure regulator, fitting itself by spring action into radial slots milled into the perimeter of the gas cylinder pressure regulator. The gas cylinder pressure regulator is threaded into the gas cylinder on the forward end, thereby regulating the headspace in the gas cylinder as the milled slots in the perimeter

#### General Data: 7.92-mm Krieghoff FG-42

Gun length: 39 inches.  
 Gun weight: 14 pounds.  
 Rate of fire: 500-600 rounds/minute.  
 Muzzle velocity: 2,850 feet/second.  
 System of operation: Gas piston actuated.  
 System of locking: Rotating bolt head.  
 System of feeding: Clip holding 20 rounds.  
 Method of headspace: Factory established; cannot be adjusted in the field.  
 Location of feed opening: Left side of receiver.  
 Location ejection opening: Right side of receiver.  
 Method of charging: Manual.  
 Method of cooling: Air.

Barrel length: 19.3 inches.  
 Rate control: Trigger can be set to deliver single shot or full automatic fire.  
 Barrel removal: Cannot be removed in the field.  
 Bore:  
 Number of grooves: 4.  
 Groove depth: 0.007 inch.  
 Groove width: 0.027 inch.  
 Pitch: 1 turn in 10 inches.  
 Direction of twist: Right hand.  
 Form of twist: Constant.

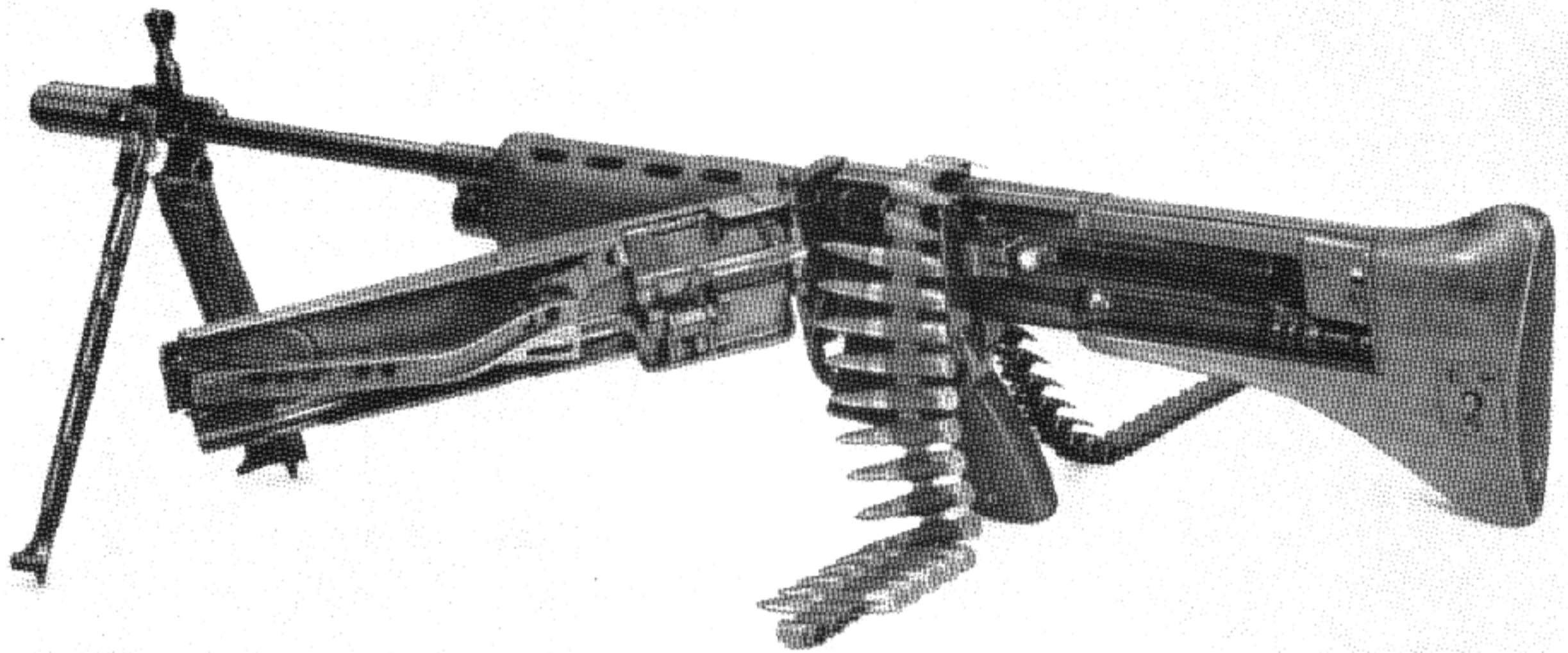


Figure 14-2. United States 7.92-mm Light Machine Gun T44, with feed open.

become engaged with the spring action of the gas cylinder orifice selector retainer. By this method the depth of penetration can be controlled without the full seating of its machined surfaces, thereby giving adjustment for regulation, at the same time serving its reciprocal role, that of retaining the gas cylinder orifice selector retainer.

The gas cylinder has four radial ports located a sufficient distance from the forward end to permit the piston rod in its rearward action to unlock the bolt before uncovering these ports, which then permit an air intake into the gas cylinder as the blowback action of the bolt comes into effect.

*Piston Rod Group.* The piston rod is tubelike in appearance, closed on the forward, or piston,

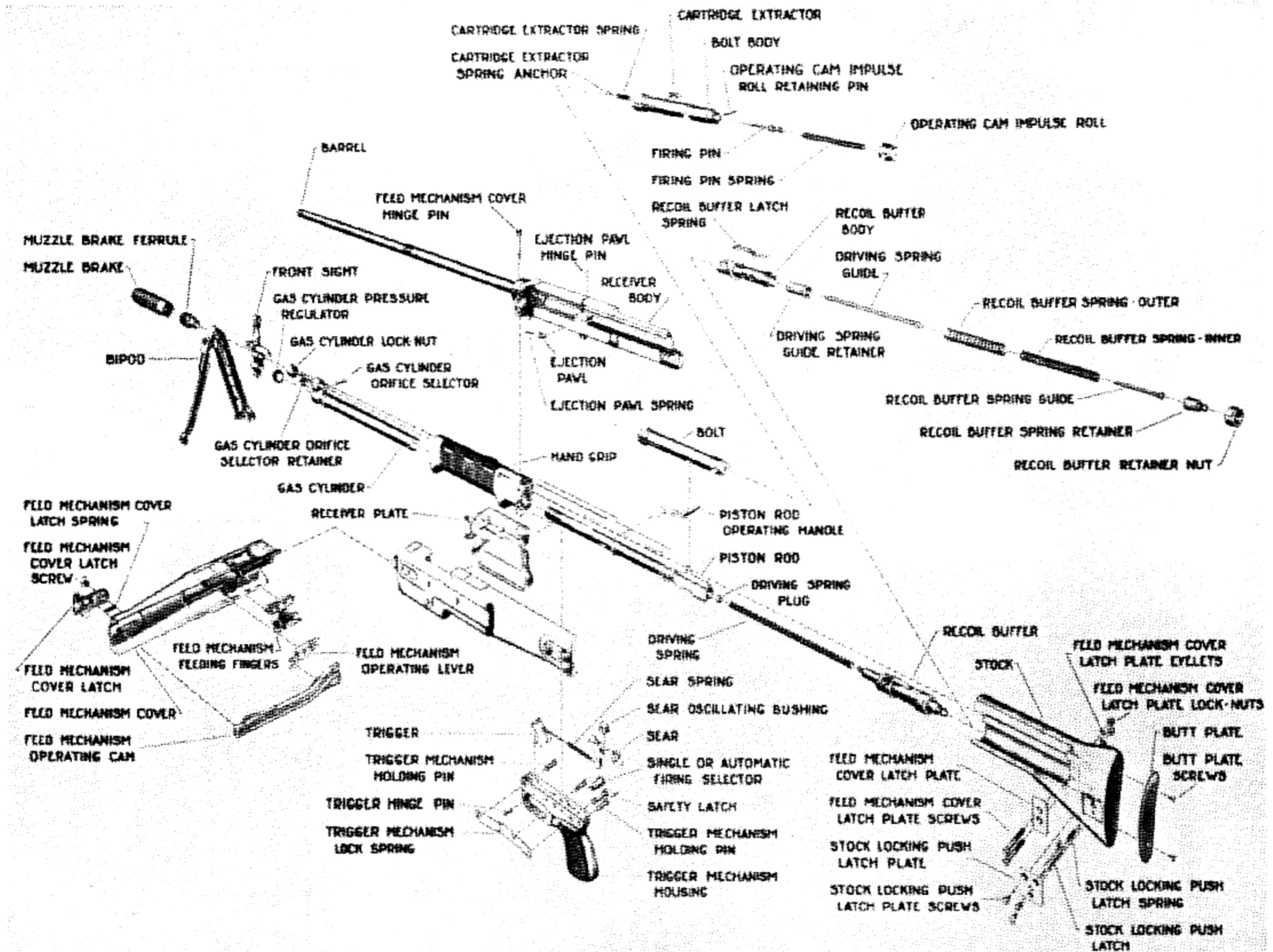
end. The rear portion has a tongue rising up from the top side which is yoke-shaped at its end to accommodate the firing pin, thereby controlling its forward and rearward movements within the bolt. The rear portion underneath side is machined in such a manner that the sear will either lock and hold back, or permit to ride over, depending upon the setting of the sear, thereby giving choice to either single or automatic firing cycles. At a point just forward from the midpoint of the piston rod is machined a double **D**-shaped hole to accommodate the piston rod operating handle, thus supplying the means for cocking the gun.

The piston rod operating handle is held in its slot by the driving spring plug, which registers in a re-

#### General Data: 7.92-mm Light Automatic Machine Gun T44

Gun length: 39 inches (approximate).  
 Gun weight: 14 pounds (approximate).  
 Rate of fire: Single shot to 500 rounds/minute.  
 Muzzle velocity: 2,850 feet/second.  
 System of operation: Gas-operated blowback combination.  
 System of feeding: German 20-shot clip converted by U. S. engineers to employ metallic links for continuous feed.  
 Method of headspace: Factory established.  
 Location of feed opening: Left side of receiver.  
 Location ejection opening: Top of receiver.  
 Method of charging: Manual.  
 Method of cooling: Air.

Barrel length: 19½ inches.  
 Rate control: Trigger setting can be made to deliver full automatic fire or single shot.  
 Barrel removal: Swaged permanently to receiver.  
 Bore:  
 Number of grooves: 4.  
 Groove depth: 0.015 inch.  
 Groove width: 0.035 inch.  
 Pitch: 1 turn in 15 inches.  
 Direction of twist: Right hand.  
 Form of twist: Constant.



## GUN, MACHINE, LIGHT, CAL. 7.92 MM. T-44

Figure 14-3. Gun, Machine, Light, 7.92-mm T44. Exploded view.

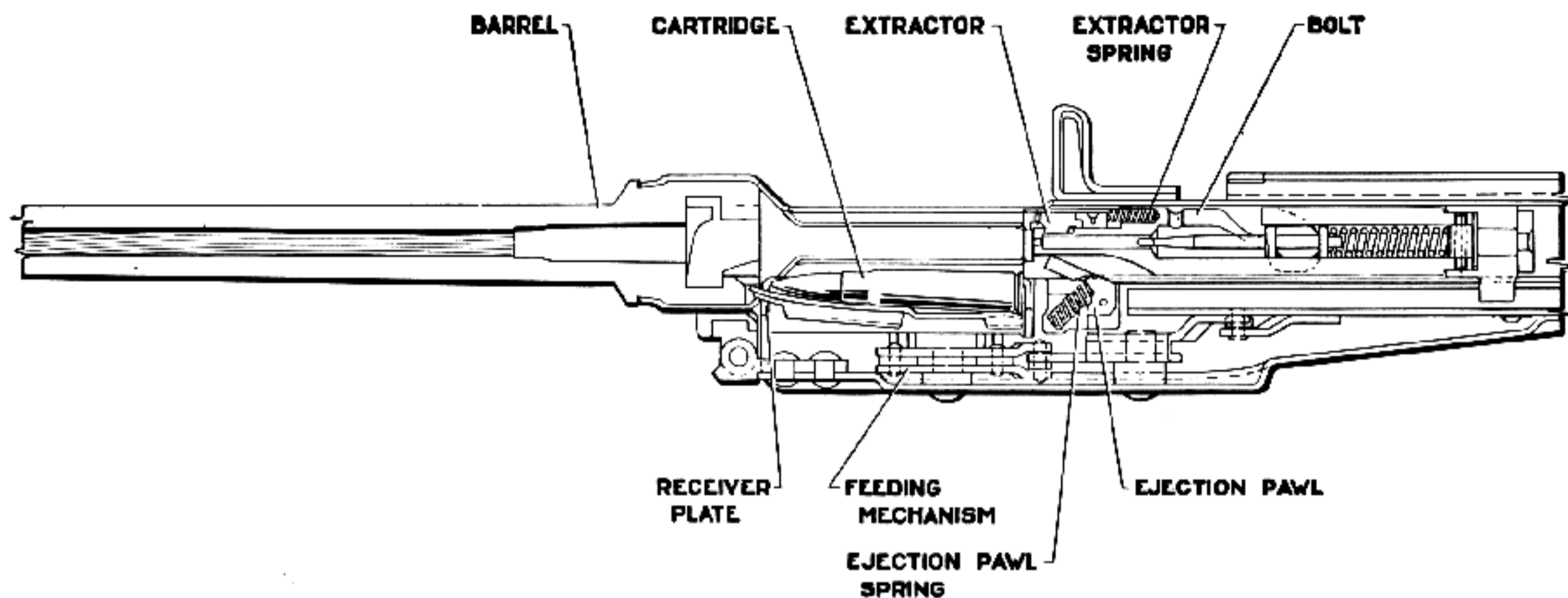


Figure 14-4. Gun, Machine, Light, 7.92-mm T44. Stripping a round.

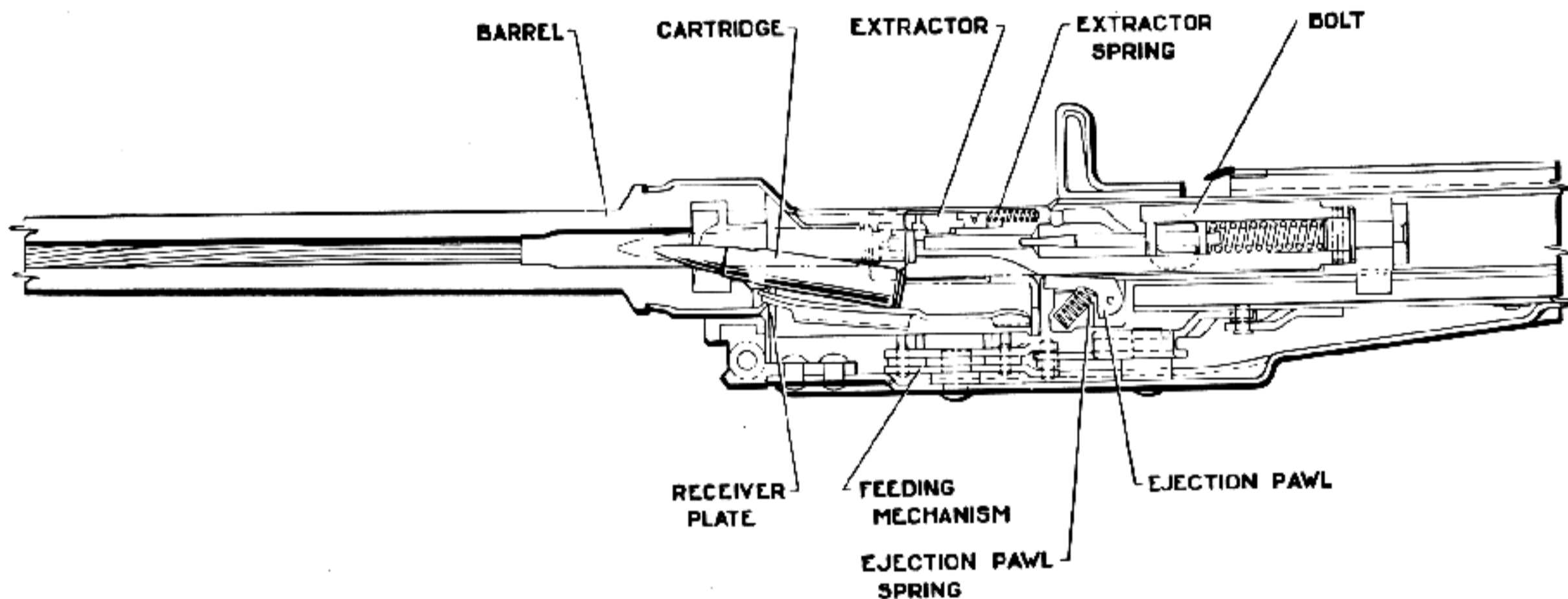


Figure 14-5. Gun, Machine, Light, 7.92-mm T44. Ramming action.

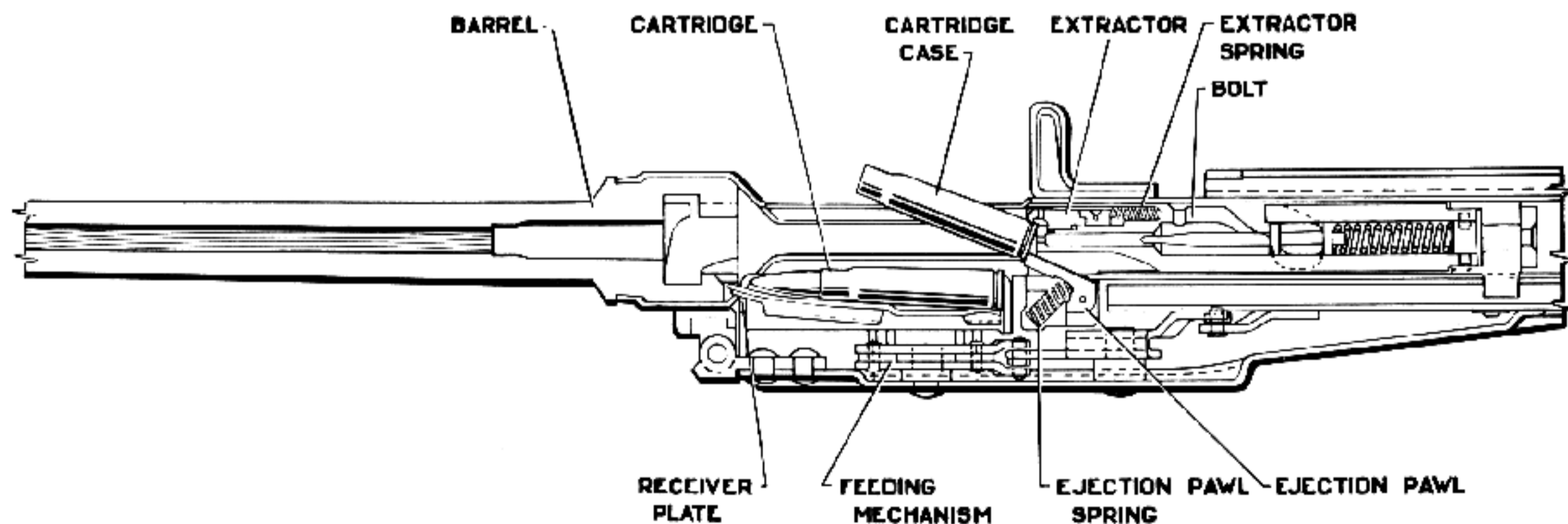


Figure 14-6. Gun, Machine, Light, 7.92-mm T44. Ejection phase.

cess of the piston rod operating handle and is held in place by pressure from the driving spring.

*Driving Spring Group.* The driving spring is located around the driving spring guide and inserted into the rear end of the piston rod. The forward end of the spring is obstructed within the piston rod by the piston rod operating handle, and contained within the receiver body by the recoil buffer. Its function is to store energy, developed during the rearward travel of the bolt, to be used to drive the bolt forward to start the firing cycle.

*Recoil Buffer Group.* The recoil buffer group is mounted into the lower portion of the rear end of the receiver body, its position being directly rearward of the piston rod. The recoil buffer is inserted into the receiver body and rotated through 90°. The recoil buffer latch spring then positions itself into a slot in the receiver body, thereby resisting any turning movement of the recoil buffer unless the recoil buffer latch spring is in turn depressed.

The recoil buffer body houses the driving spring guide retainer which is shouldered against the forward end of the recoil buffer body, thereby restricting its movement. The driving spring guide is shouldered on its rearward end and in turn is inserted into the driving spring guide retainer, and retained in its forward movement by means of this shoulder.

The shock from this piston rod during recoil is absorbed by the recoil buffer through its inner and outer recoil buffer springs, which are guided and retained within the recoil buffer body by means of the recoil buffer spring guide, recoil buffer spring retainer, and recoil buffer retainer nut. The recoil buffer retainer nut is secured by threading it onto an external diameter of the recoil buffer body and prevented from loosening itself by a detent on the rear end of the recoil buffer latch spring.

*The Bolt Group.* The bolt is inserted from the rear into the upper portion of the receiver body, and is positioned radially by cams, protruding radially from the forward end of the bolt, which ride in rectangular sections of the receiver body, thereby permitting the bolt a guided lateral movement. Motion is imparted to and received from the bolt through the yokelike section rising up from the rearward end of the piston rod.

This yokelike section is inserted into a cam developed opening through the side of the bolt at its

midportion, and by acting against this cam surface rotates the bolt at a time when the forward or rearward progress of the bolt is resisted. By this rotary action, the protruding cams on the forward end of the bolt lock and unlock in the barrel.

The firing pin, which is inserted into the bolt, has two turned shoulders which straddle the yokelike section of the piston rod, thereby causing the firing pin to act in accordance with the piston rod. The firing-pin spring is confined by the rear end of the firing pin and the inside section of the operating cam impulse roller, which in turn is secured to the rear portion of the bolt by the operating cam impulse roll retaining pin.

The function of the firing-pin spring is to impart energy into the firing pin, moving it forward and firing the primer.

The extractor parts are fitted into a milled slot located on the side and forward portion of the bolt. The cartridge extractor, by spring pressure, engages the rim on the cartridge case, and, as the bolt is moving rearward, withdraws the cartridge case from the barrel.

A slot is milled opposite the extractor slot and parallel with it to provide an opening for the ejection pawl to operate through and eject the cartridge case through an opening in the receiver body.

*Feeding Mechanism Group.* The feeding mechanism group parts are housed in and mounted on the feed mechanism cover. This is a sheet metal fabrication channel-shaped in appearance, mounted by a welded hinge member on the forward end and secured by a latch on the rearward end. There are various studs secured to the inside of the feed mechanism cover about which the various members operate.

The entire feeding motion is a reciprocating action developed through the operating cam impulse roller moving laterally in the feed mechanism operating cam. This motion is transferred through the feed mechanism operating lever to the feed mechanism feeding fingers, thereby causing them to move with a reciprocating motion. This motion causes the cartridge belt to advance across the receiver plate, one cartridge space with each cycle of the bolt.

The cartridge belt is guided as it advances from bottom to top with each cycle of the bolt, across the receiver plate, thereby positioning the cartridge in a fitted opening in the receiver plate. The car-

tridge is held against this opening by the shell guide which is spring-loaded with sufficient pressure to permit the bolt in its forward progress to push the cartridge out of its belt retainer into the barrel.

The shell guide is hinged onto the feed mechanism cover and serves a dual purpose. It applies pressure to the cartridge and gives direction as the cartridge is launched by the bolt.

*Trigger Mechanism Group.* The trigger mechanism housing is a sheet metal fabrication, with left- and right-hand sections, bead-welded together. The hand grip is made of two plastic sections riveted onto the metal housing. The unit is mounted to the receiver body by two trigger mechanism holding pins; these, in turn, are secured by the trigger mechanism lock spring.

The unit houses the sear, firing selector, and safety latch. The sear, protruding through the receiver body, acts against the underneath side of the piston rod, and controls the single and automatic firing cycles.

*Stock Group.* The stock is of wood construction, machined so as to fit around the rearward portion of the receiver body. The stock has a machined opening along one side to permit the feed mechanism cover to position itself laterally and parallel with the receiver body. Mounted on the stock at the end of this opening is the feed mechanism cover latch plate, which positions and secures the feed mechanism cover.

The stock is held in place by means of a spring-loaded push latch, which positions itself into a recess in the recoil buffer spring retainer and is readily removable by depressing the stock locking push latch.

The stock is protected on the rearward end by a steel butt plate, retained in position by two wood screws.

### Functioning of the 7.92-mm T44 as a Whole

The following is an account of a complete firing cycle from the explosion of one propelling charge to the next.

At the moment of firing, the projectile starts down the barrel, propelled by the expanding gases. The firing pin is in its forward position, having struck the primer of the cartridge. The bolt is held in its

forward position, due to the bolt having rotated and the protruding cams having locked in the barrel.

As the projectile moves forward, it passes the gas port. A portion of the expanding gases enters the gas port, passes through the orifice formed by the gas cylinder orifice selector, enters the gas cylinder, and exerts pressure on the piston rod. This piston rod moves rearward, carrying with it the firing pin which is contained by the yokelike section on the rear portion of the piston rod. As the yokelike section moves back in the bolt, it starts to act against the cam opening of the bolt, causing the bolt to rotate counterclockwise, thereby unlocking the protruding cams in the barrel. When the rotating is complete, the bolt is unlocked and is forced rearward by direct blowback.

As the bolt is forced to the rear, the empty cartridge case is contacted on the rim by the ejector pawl operating through a slot in the bolt, causing the cartridge case to pivot about the extractor. The cartridge case leaves the hook of the extractor and moves through an opening in the side of the receiver body, completing the ejection of the fired case.

The first part of the rearward travel of the bolt causes the feed mechanism cam to operate. This motion advances the cartridge belt so that a cartridge is now in position in the receiver plate opening.

In recoiling, the bolt compresses the driving spring. As the bolt nears the end of its blowback, it compresses the recoil buffer springs, which absorb the remaining force of recoil and bring the bolt to a stop.

The recoil buffer spring and driving spring expand, forcing the bolt forward. The side of the front surface of the bolt engages the new cartridge, which has been positioned on the lips of the receiver plate. As the cartridge is forced forward, it leaves the feeding belt, is directed by the shell guide into the path of the ramming bolt, and is gripped by the hook of the extractor as it is rammed into the chamber.

As the bolt reaches the end of its forward motion, it seats against the face of the barrel. However, the piston rod has not reached the end of its forward progress, and as it continues forward, the cam action of the yokelike section against the bolt causes the bolt to rotate, thereby locking the bolt. As the bolt completes its rotating, the piston rod is in position

to move forward with the firing pin. The necessary energy is provided by the firing-pin spring. The firing pin strikes the primer of the cartridge, firing it and starting the cycle all over again.

To stop firing the gun, release the trigger mechanism. The sear is forced upward by the sear spring. This engages the underneath side of the piston rod and blocks the forward motion.

### Disassembly and Assembly

*General.* To facilitate complete disassembly and assembly, the procedure as outlined in the following paragraphs should be followed. The disassemblies and assemblies have been divided into four main classes.

1. Disassembly into major parts and subassemblies.
2. Disassembly of subassemblies.
3. Assembly of subassemblies.
4. Assembly of gun from subassemblies and major parts.

The construction of this gun is such that all parts may be disassembled and assembled without the use of special tools.

#### *Disassembly Into Major Parts and Subassemblies.*

##### FEED MECHANISM COVER GROUP.

1. Unlock feed mechanism cover by pushing the feed mechanism cover latch forward.
2. Rotate feed mechanism cover 90° about feed mechanism cover hinge pin and away from receiver body.
3. Remove feed mechanism cover hinge pin. (It will be noted that both the feed mechanism cover and the retainer plate are retained by the feed mechanism cover hinge pin.)

**STOCK REMOVAL.** Push stock locking latch completely in and draw stock to the rear.

##### RECOIL BUFFER GROUP.

1. Depress recoil buffer latch spring.
2. Rotate recoil buffer 90° and draw rearward.

##### DRIVING SPRING.

1. Remove recoil buffer group.
2. Elevate forward end of gun and driving spring will fall free.

##### PISTON ROD.

1. Draw the piston rod operating handle to the rear for the complete throw of the bolt.
2. Remove the piston rod operating handle by pulling it away from the receiver body.

3. Elevate forward end of gun and remove piston rod. (It will be noted that the piston rod is interlocked with the bolt. One cannot be removed without the other.)

**BOLT GROUP.** Removal of the bolt group is precisely the same as the removal of the piston rod.

##### MUZZLE BRAKE.

1. Place gun in such a position as to look down forward end of barrel.
2. Lift muzzle brake locking latch, integral with front sight.
3. Rotate muzzle brake counterclockwise until threads release.

##### MUZZLE BRAKE FERRULE.

1. Rotate muzzle brake ferrule in a counterclockwise direction until free.

##### BIPOD REMOVAL.

1. Remove muzzle brake ferrule.
2. Remove bipod from muzzle brake ferrule.

##### FRONT SIGHT.

1. Remove bipod.
2. Slide front sight off barrel.

##### GAS CYLINDER LOCKING NUT.

1. Revolve gas cylinder locking nut in a counterclockwise direction, until free.
2. Slide gas cylinder locking nut over barrel.

##### GAS CYLINDER GROUP.

1. Remove gas cylinder locking nut.
2. The gas cylinder group is free.
3. Slide gas cylinder group over barrel.

##### HAND GRIP.

1. Remove gas cylinder locking nut.
2. Remove gas cylinder group.
3. Slide hand grip over barrel.

##### TRIGGER MECHANISM GROUP.

1. Remove trigger mechanism locking spring by depressing and pushing spring away from the barrel, toward the trigger until slots are free from pins.
2. Remove front trigger mechanism holding pin.
3. Remove safety latch by pulling it away from trigger group.
4. Remove rear trigger mechanism holding pin.
5. Pull trigger group away from retainer body.

#### *Disassembly of Subassemblies.*

##### BOLT GROUP.

1. Place bolt with rear pointing toward operator.
2. Grasp piston rod and apply pressure to rear of bolt until bolt is full forward.
3. Hold pressure and lift bolt free of piston rod.

4. Rotate operating cam impulse roller assembly clockwise through 45°.

5. Apply pressure to rear of operating cam impulse roller assembly and hold, to counteract spring pressure within bolt.

6. Remove operating cam impulse roller retaining pin.

7. Remove operating cam impulse roller assembly.

8. Withdraw firing pin spring.

9. Elevate forward end of bolt and firing pin will fall free.

#### FEED MECHANISM COVER GROUP.

1. Place feed mechanism cover group so that the interior is in full view and the feed mechanism operating cam is pointing to the left.

2. Apply pressure on the shell guide to counteract spring beneath and move same to the left and release pressure.

3. Rotate shell guide about pivot pin through 90° to clear linkage.

4. Push the feed mechanism operating cam lock spring in as far as possible and lift feed mechanism operating cam, feed mechanism operating lever, and the feed mechanism operating fingers from studs. (It will be noted that the above named parts are interlocked and are removed as a unit.)

#### RECOIL BUFFER GROUP.

1. Remove recoil buffer latch spring by revolving recoil buffer retaining nut in a counterclockwise direction until it is not overlapped by the recoil buffer retaining nut.

2. Insert fingers under recoil buffer latch spring, lift spring up, and move forward approximately one-half inch.

3. Remove the recoil buffer retainer nut by turning the recoil buffer retainer nut counterclockwise. Note that constant pressure must be applied when removing recoil buffer retainer nut, to counteract spring pressure within recoil buffer assembly.

4. Withdraw recoil buffer spring retainer from recoil buffer spring nut.

5. Lift out recoil buffer spring guide.

6. Remove inner and outer recoil buffer springs from recoil buffer body.

7. Remove driving spring guide.

8. Slip driving spring retainer guide from recoil buffer body.

#### TRIGGER MECHANISM GROUP.

1. Pull out firing selector.

2. Lift out sear and sear oscillating bushing from the trigger mechanism housing.

3. Rotate sear oscillating bushing 90° and remove from sear.

4. Remove trigger hinge pin.

5. Invert trigger mechanism housing and both the sear spring and trigger will fall free.

6. Slip sear spring from rod on trigger.

#### GAS CYLINDER GROUP.

1. Remove the gas cylinder pressure regulator by rotating in a counterclockwise direction until threads become free of the gas cylinder.

2. Remove the gas cylinder orifice selector retainer from the gas cylinder orifice selector.

3. Pull out the gas cylinder orifice selector.

*Assembly of Subassemblies.* Prior to assembly, all parts must be free of dirt, rust, and other extraneous matter. Metal parts in contact must be covered with a light film of lubricating oil.

#### BOLT GROUP.

1. Insert firing pin and firing-pin spring into hole through the center of the bolt body.

2. Place piston rod yoke between shoulders of firing pin with both the piston rod and the bolt in operating arrangement.

3. Insert firing-pin spring.

4. Place operating cam impulse roller directly behind firing-pin spring, and compress.

5. When operating cam impulse roller is in position for assembly, rotate operating cam impulse roller until holes of the bolt body and the operating cam impulse roller come into line.

6. Insert operating cam impulse roller retaining pin.

#### TRIGGER MECHANISM GROUP.

1. Place sear spring on pin attached to trigger.

2. Holding the trigger mechanism housing with the pistol grip to the right and pointing toward the operator, insert the trigger into the trigger mechanism housing, until the holes in both the trigger and the trigger mechanism housing appear in line.

3. Insert trigger hinge pin.

4. Place the sear oscillating bushing in the recess and hole provided for it in the sear, and rotate the sear oscillating bushing 90°.

5. Insert the sear with the finger to the rear of the trigger mechanism housing, and insert in such



a manner as to engage the trigger spring pin in the hole in the sear.

6. Line up hole in sear oscillating bushing with corresponding holes through the trigger mechanism housing, and insert the firing selector.

#### RECOIL BUFFER GROUP.

1. Insert driving spring guide through the small hole in the driving spring guide retainer until it is shouldered against the inside of the driving spring guide retainer.

2. Place the small end of the driving spring guide retainer through the large bore of the recoil buffer body until it is seated against the shoulder.

3. Push the outer recoil buffer spring into the hole in the recoil buffer body until it contacts the driving spring guide retainer.

4. Insert inner recoil buffer spring inside the outer recoil buffer spring until it seats against the driving spring guide.

5. Slide the recoil buffer spring guide through the inner recoil buffer spring.

6. Insert the recoil buffer spring retainer with the smaller cylindrical sections entering first through the locating hole in the recoil buffer retainer nut until it shoulders within the recoil buffer retainer nut.

7. Place the recoil buffer retainer nut over the inner and outer recoil buffer springs, compressing the springs and revolving the recoil buffer retainer nut clockwise with the recoil buffer body facing away from the operator.

#### FEED MECHANISM COVER GROUP.

1. Locate the feed mechanism feeding fingers, the feed mechanism operating cam and the feed mechanism operating lever in such a manner that the holes provided in each member will correspond to the pivoting studs in the feed mechanism cover. It will be noted that the above-mentioned parts are interlocked and must be assembled as a unit.

2. Slip the feed mechanism feeding finger and the feed mechanism operating lever over their respective studs.

3. Depress the feed mechanism operating cam lock spring, and press the feed mechanism operating cam into position.

#### GAS CYLINDER GROUP.

1. Push the gas cylinder orifice selector into the hole provided for it at the front of the gas cylinder. Locate one of the slots on the head parallel with the

slot in the gas cylinder, and push the gas cylinder orifice selector in until it is seated on the counter-bored surface.

2. Slip the gas cylinder orifice selector retainer into position over the gas cylinder in such a manner as to confine the movement of the gas cylinder orifice selector.

3. Insert the gas cylinder pressure regulator into the front threaded section of the gas cylinder, and rotate the gas pressure regulator until it is locked into position by the gas cylinder orifice selector retainer engaging the slots located on the circumference of the gas cylinder pressure regulator.

*Assembly of Gun From Subassemblies and Major Parts.* Prior to assembly, all parts must be free of dirt, rust, and other extraneous matter. Metal parts in contact must be covered with a light film of lubricating oil.

#### GAS CYLINDER AND FORWARD SECTION OF GUN.

1. Slide the handgrip over the forward end of the barrel until it seats itself against the receiver body.

2. Slide the gas cylinder assembly over the forward end of the barrel and back over the piston rod into position.

3. Place gas cylinder locknut over barrel and tighten into position by revolving the gas cylinder locknut in a clockwise direction when looking into the muzzle of the gun.

4. Slide the front sight over the barrel so that the muzzle brake locking latch is forward and sighting ring is pointing up.

5. Place the holding ring of the bipod over the barrel of the gun and locating unit so that the arms are pointing down and will fold back to the rear.

6. Slip the muzzle brake ferrule over the barrel and screw into position by rotating the muzzle brake ferrule in a clockwise direction with the threads on the outside diameter away from the rear of the gun.

7. Place the muzzle brake over the muzzle brake ferrule and rotate the muzzle brake in a clockwise direction when looking into the barrel, until it is locked into position by the muzzle brake locking latch engaging the slot located in the muzzle brake.

#### PISTON ROD ASSEMBLY.

1. Insert both the bolt and the piston into the receiver body, moving the piston rod forward until the rectangular slot in the piston rod can be sighted

at the rear end of the clearance slot for the piston rod operating handle in the receiver body.

2. Insert the piston rod operating handle through the receiver body into the rectangular slot in the piston rod.

3. Move the piston rod operating handle forward until bolt locks into position.

**BOLT GROUP.** Assembly of the bolt group is precisely the same as the assembly of the piston rod.

**DRIVING SPRING ASSEMBLY.**

1. Insert driving spring plug into driving spring.

2. Insert driving spring with driving spring plug end first into the hole through the center of the piston rod.

**RECOIL BUFFER GROUP.**

1. Push the driving spring guide through the driving spring. It will be noted that the driving spring guide is assembled to the recoil buffer body.

2. Holding gun horizontally with the muzzle pointing to the left and the trigger mechanism assembly pointing down, apply pressure to the rear of the recoil buffer assembly to compress the driving spring, making sure to hold the recoil buffer assembly with the recoil buffer latch spring slot facing the operator.

3. Shoulder recoil buffer assembly against the rear of the receiver body and rotate through 90°.

4. Place recoil buffer latch spring into slot in receiver body and resting against and located in the hole in the receiver body.

5. Rotate the recoil buffer retaining nut clockwise until it overlaps and locks on the recoil latch spring.

**TRIGGER GROUP.**

1. Holding the receiver body firmly, push the trigger mechanism housing into position over the locating studs connected to the receiver body.

2. Holding the trigger mechanism with the pistol grip to the left and pointing toward the operator, insert front and rear trigger mechanism holding pins into their respective holes.

3. Insert the safety latch into its position in the trigger mechanism housing.

4. Holding the trigger mechanism with the pistol grip to the right and pointing toward the operator, slip the trigger mechanism lock spring so that the grooves in it slip around the recesses cut into the trigger mechanism housing locating pins, the single or automatic firing selector and safety latch, thus locking the assembly in position.

**STOCK ASSEMBLY.** Grasp the receiver body firmly. Depress the stock locking push latch and slide stock over the rear of the receiver into position, then release stock locking push latch.

**FEED MECHANISM COVER GROUP.**

1. Place the receiver plate so that the hinging fingers fit into the clearance slots of the feed mechanism cover mounting bracket, with the hand guard down and the receiver plate resting against the receiver body.

2. Place the feed mechanism cover with the hinge inserted into the locating slot in the feed mechanism cover mounting bracket so that its longitudinal axis is 90° to the longitudinal axis of the receiver body, with the feed mechanism feeding fingers pointing upward.

3. Line up the holes in the feed mechanism cover mounting bracket, the receiver plate, and the feed mechanism cover. Insert the feed mechanism cover hinge pin, so that the flats on the feed mechanism cover hinge pin locate on the sides of the elongated slot in the receiver plate.

4. Apply pressure to and depress the shell guide through its total movement. Hold pressure and move the shell guide to its maximum forward position.

5. Rotate the feed mechanism cover about the feed mechanism cover hinge pin toward the stock; as the feed mechanism cover swings back, insert the operating cam impulse roller into the feed mechanism operating cam and lock the feed mechanism cover against the stock.

PART IX

AUTOMATIC WEAPON DEVELOPMENT  
DURING AND AFTER WORLD WAR II  
BY OTHER WORLD POWERS  
(EXCEPT USSR AND HER SATELLITES)

## Chapter 15

## ROLLS-ROYCE AIRCRAFT CANNON

## SECTION 1. 40-MM TYPE BD NAVAL GUN

## General Description of the Basic Features of the Gun

The Rolls-Royce 40-mm type BD naval gun was originally a quick-firing single-shot weapon, modified to fire full automatic for aircraft use. Ease and safety of handling and simplicity of operation are its main features, while ease of maintenance and manufacture are also characteristic of the weapon.

The gun consists of a barrel and a breech ring and body in which a rectangular breechblock can reciprocate. This assembly is attached to the recoil and recuperator mechanism, which serves the several purposes of absorbing the recoil, returning the barrel to the firing position, and closing the breech. The main ram of the recoil mechanism is anchored in a cradle in which the barrel and recoil assembly is free to slide on three supports within the limits of recoil. The front support, besides allowing for

thermal expansion of the barrel, acts as a vibration damper.

Attached to the right-hand side of the cradle is a loading tray. A round placed in the tray may be swung up into the lips of the feed opening, whereupon the breechblock is automatically released, sweeping the round into the chamber. The loading tray is interconnected with a manually operated trigger, controlled from a twist grip conveniently mounted on the cradle. A safety device insures that this tray is in the unloaded position before the trigger is released. A safety position is also incorporated in the trigger mechanism.

The breechblock is designed to remain open on cease fire but may be opened manually when necessary with the aid of a tool supplied. A recoil guard is fitted to the rear of the cradle, and a suitable shoulder rest is provided.

## General Data: 40-mm Type BD Naval Gun

Gun length: 126 inches.  
 Gun weight: 336 pounds.  
 Rate of fire: 200-250 rounds/minute.  
 Muzzle velocity: 2,450 feet/second.  
 System of operation: Long recoil.  
 Maximum distance of recoil: 17 inches.  
 System of locking: Double swinging locks.  
 System of feeding: Drum; or recoil actuated system employing metallic links.  
 Method of headspace: Not adjustable.  
 Location of feed opening: Top, right hand or left hand.  
 Location ejection opening: Bottom of receiver.  
 Method of charging: Air, manual.  
 Method of cooling: Air.

Barrel length: 80 inches.  
 Barrel weight: 72 pounds.  
 Rate control: Single shot or full automatic.  
 Barrel removal: Can be removed easily.  
 Bore:  
 Number of grooves: 12.  
 Groove depth: 0.020 inch.  
 Groove width: 0.214 inch.  
 Pitch: 1 turn in 34 inches.  
 Direction of twist: Right hand.  
 Form of twist: Constant.

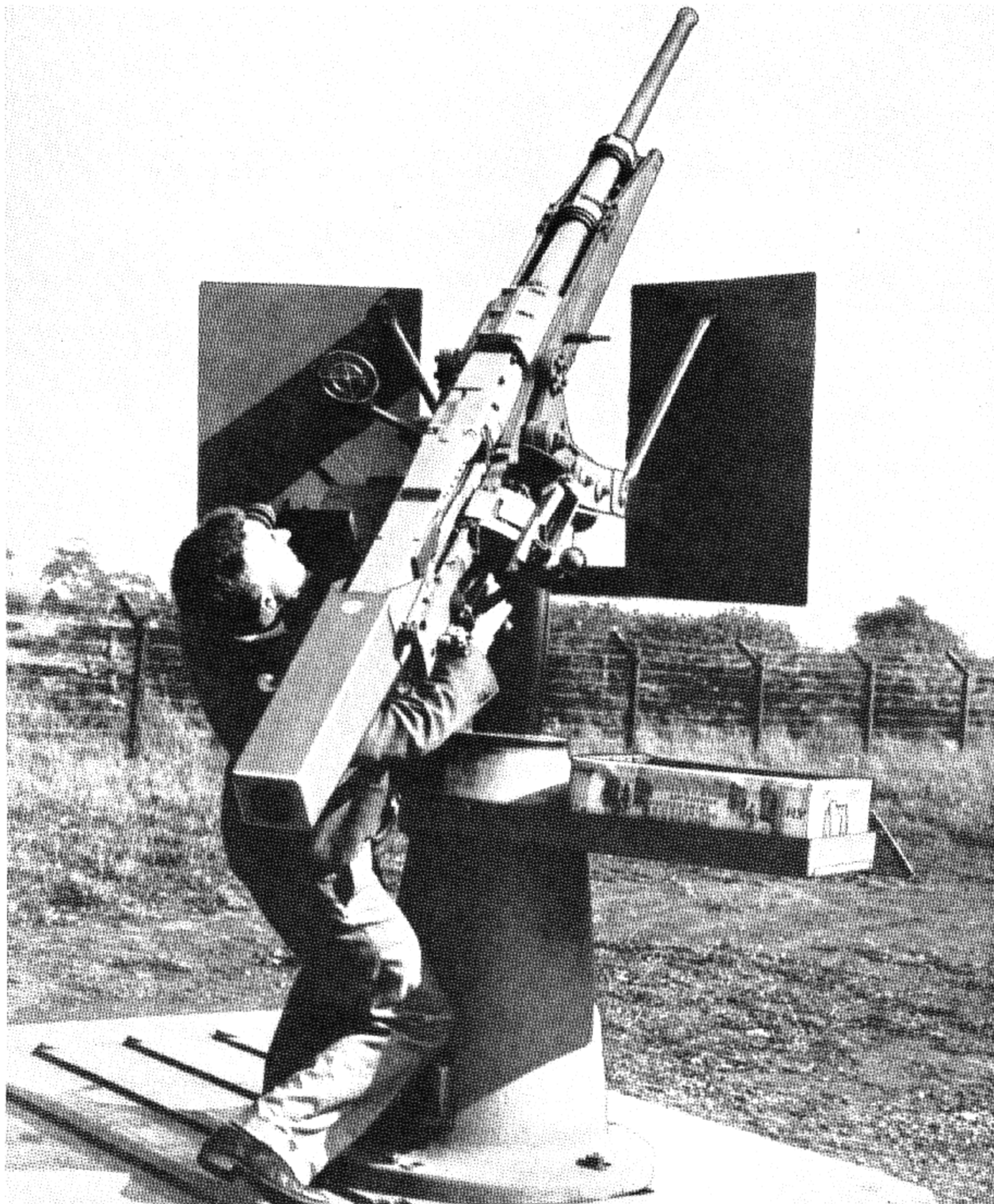


Figure 15-1. Rolls Royce 40-mm Type BD Naval Gun on cone mount. Right rear view.

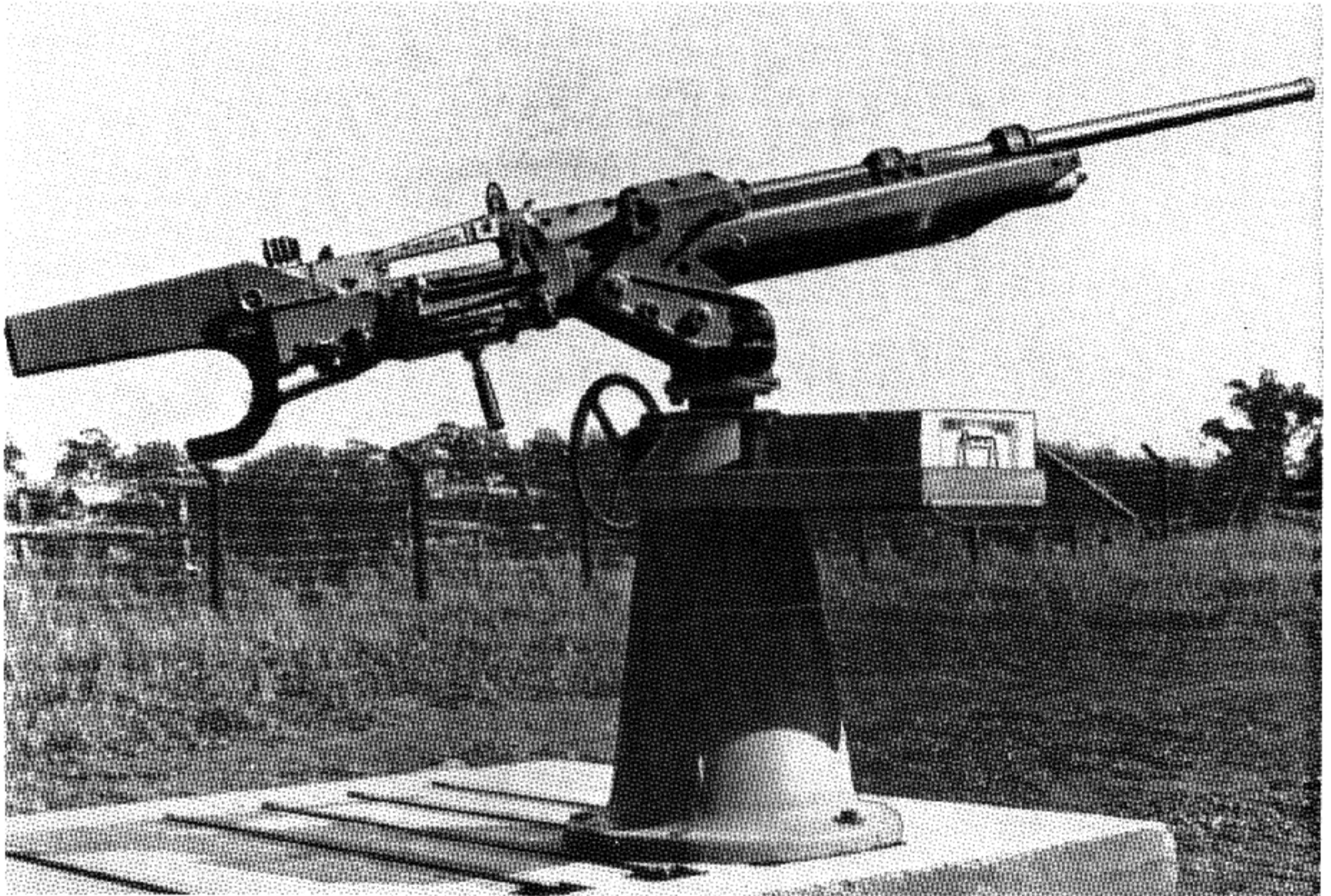


Figure 15-2. Rolls Royce 40-mm Type BD Naval Gun. Right side view.

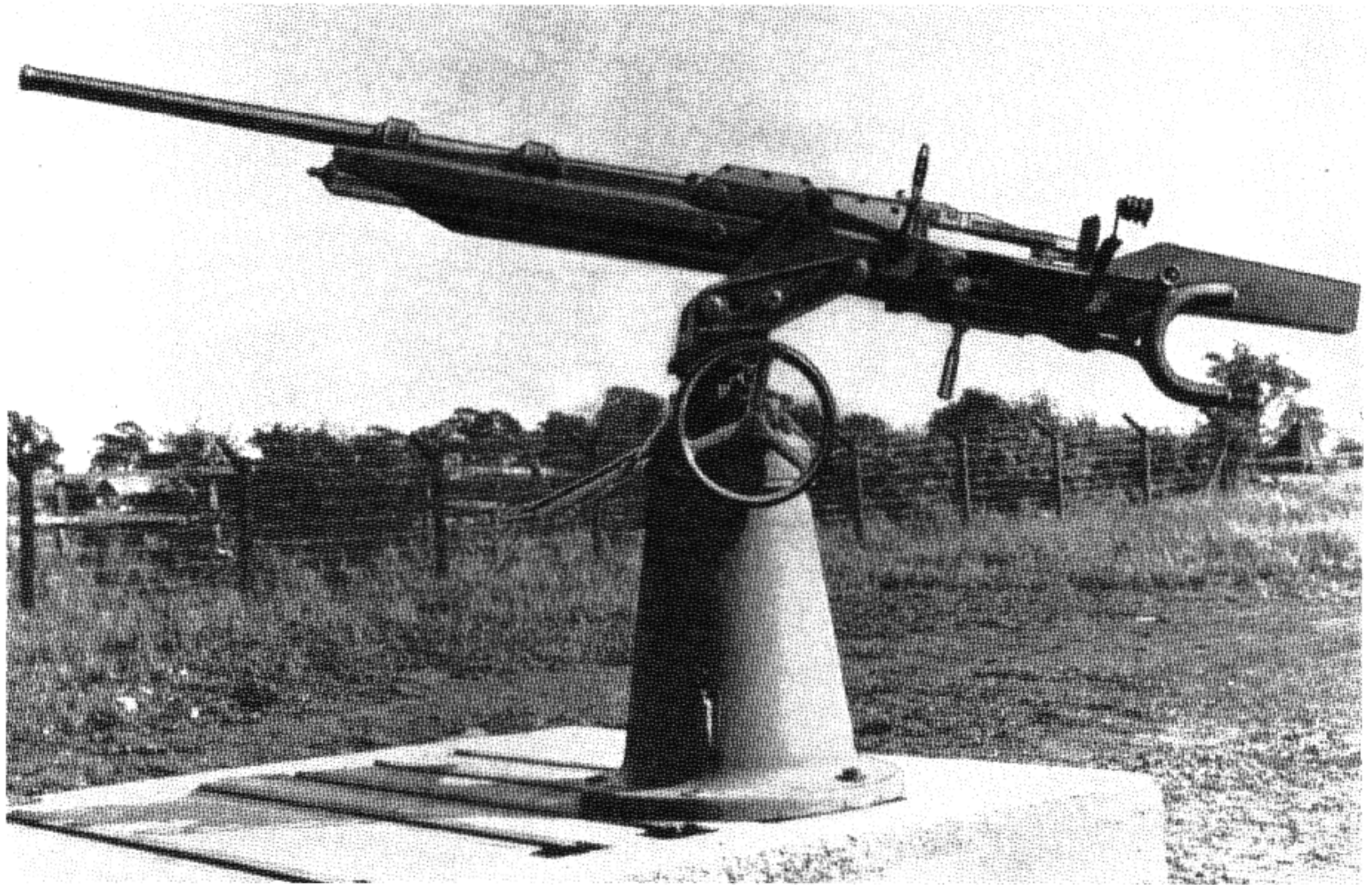


Figure 15-3. Rolls Royce 40-mm Type BD Naval Gun. Left side view.

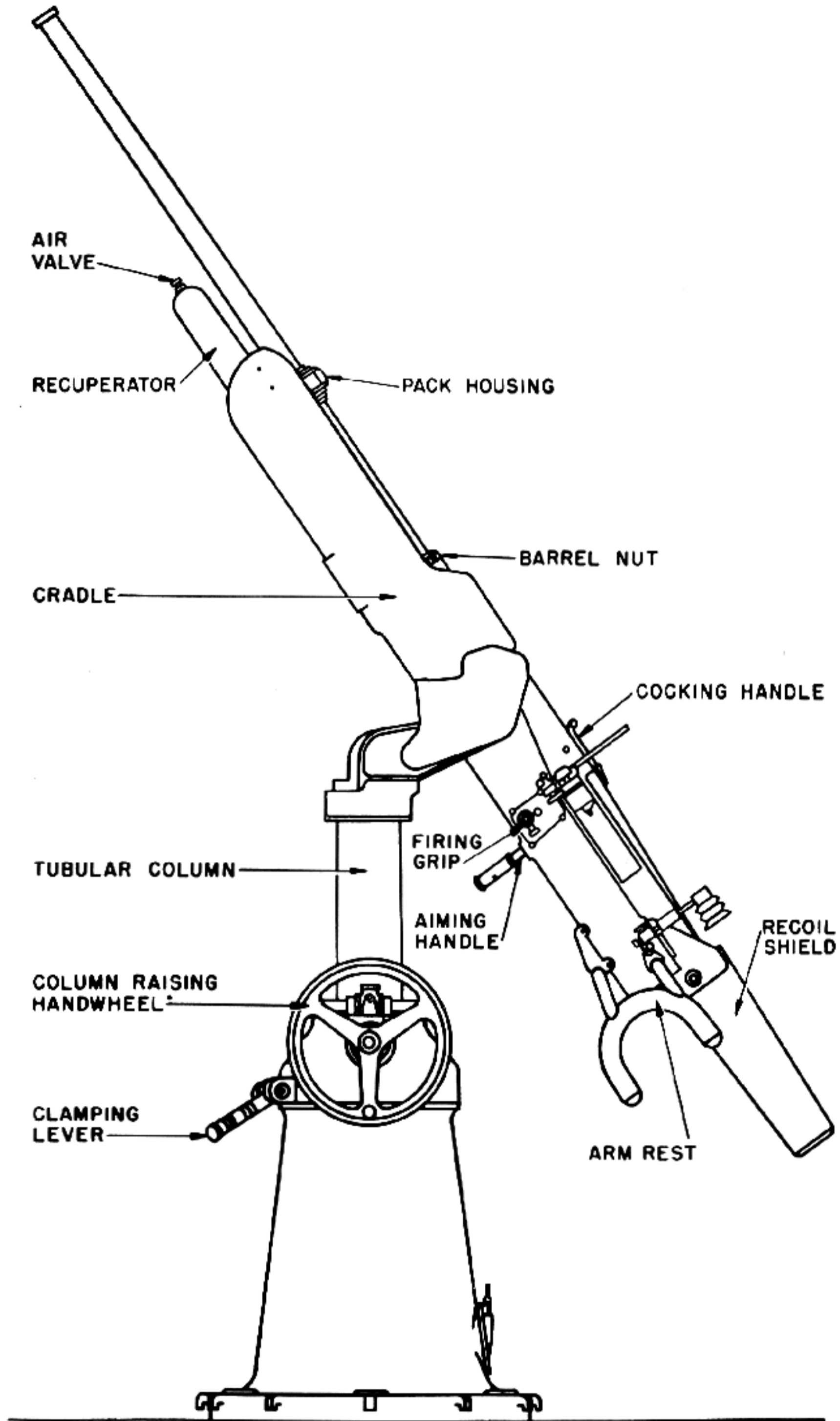


Figure 15-4. Rolls Royce 40-mm Type BD Naval Gun. Nomenclature.



## SECTION 2. 40-MM TYPE BH

**Similarity to the 40-mm Type BD Naval Gun**

The general description of the 40-mm type BD naval gun given in section 2 applies to the BH.

The components of both guns are essentially the same, and, accordingly the pictures of the BD naval gun shown in this section apply equally to the BH.

**Detail Description**

*Barrel and Breech Ring Assembly.* The barrel is machined from a nickel chrome molybdenum steel forging with two parallel portions to accommodate the barrel housings and a threaded portion of "buttress" form at the breech end to accommodate the breech ring. A screwed portion is also provided for locking the barrel to the recoil mechanism by means of a large nut.

The breech ring has an internal thread of similar form and is split in halves, being held together on the barrel and clamped thereto by means of eight bolts. The clamping effect is produced due to tolerances on diameters and the local recessing in the barrel, to clear some of the bolts, affords to some extent an additional means of locking the breech ring in position. Two slides, integral with the breech ring, support the breech end of the gun in the cradle. Two cylindrical locking shoulders are contained in the rear end of the breech ring and are retained by means of spring clips attached externally.

The barrel is mounted on three supports which are free to slide in corresponding grooves in the cradle. The two rear supports are rigidly connected to the barrel, one being integral with the breech ring and the other locked to the barrel by means of a retaining nut screwed to the barrel. The retaining nut is

held in position by means of a small lock plate attached to the housing.

The forward support is attached to the barrel by means of a self-aligning pack housing consisting mainly of a series of concentric split rings of V cross section interposed by similar split rings of inverted V cross section. The rings are contained in a housing and are also in contact with one of the parallel portions on the barrel. A strong coiled spring, retained in the housing by means of a nut, imparts an axial load to the split rings, the radial component tending to close the rings onto the barrel and housing. Thus the barrel is firmly supported in position. Should the barrel be deflected, the spring load insures a firm support, at the same time tending to return the barrel to its concentric position.

*Body Assembly.* The body is made up of rectangular sections and is attached to the breech ring by means of four studs. The interior of the body is machined to accommodate the breechblock, in which it is free to reciprocate. The rear end of the body is closed by means of an easily detachable cover.

In the body there is a steel adjusting plate for adjusting the protrusion of the firing pin. Steel lips for the cover opening are attached to the body by means of eight studs. A stop is included for limiting the travel of the firing stirrup. Also in the body are the cartridge ejector trip, ejector trip springs, and the cocking mechanism consisting mainly of a cocking lever, cocking slide, cocking slide spring, etc.

*Breechblock Assembly.* The breechblock assembly consists of a breechblock body, striker housing, striker housing arm, striker, firing spring, sear, firing stirrup, firing stirrup spring, struts, and cams.

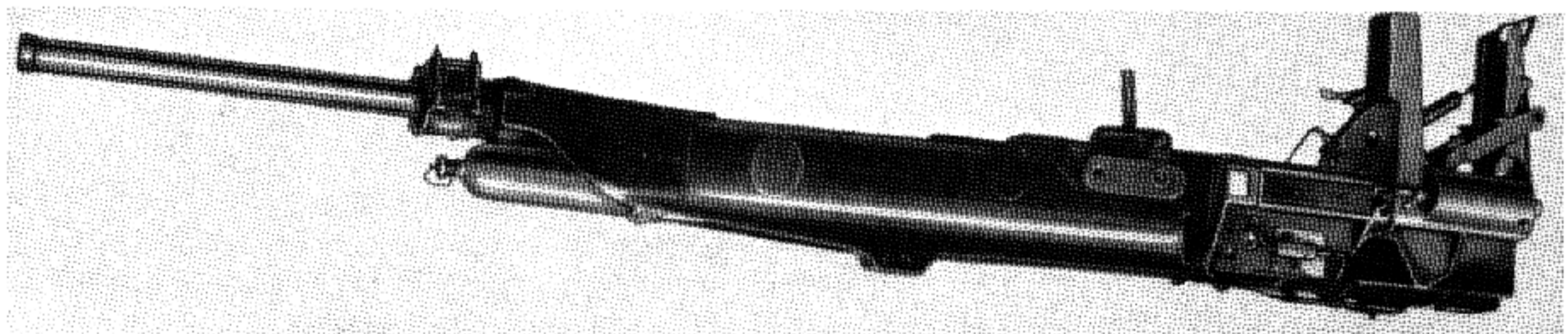


Figure 15-5. Rolls Royce 40-mm Type BH Aircraft Cannon. Left side view.

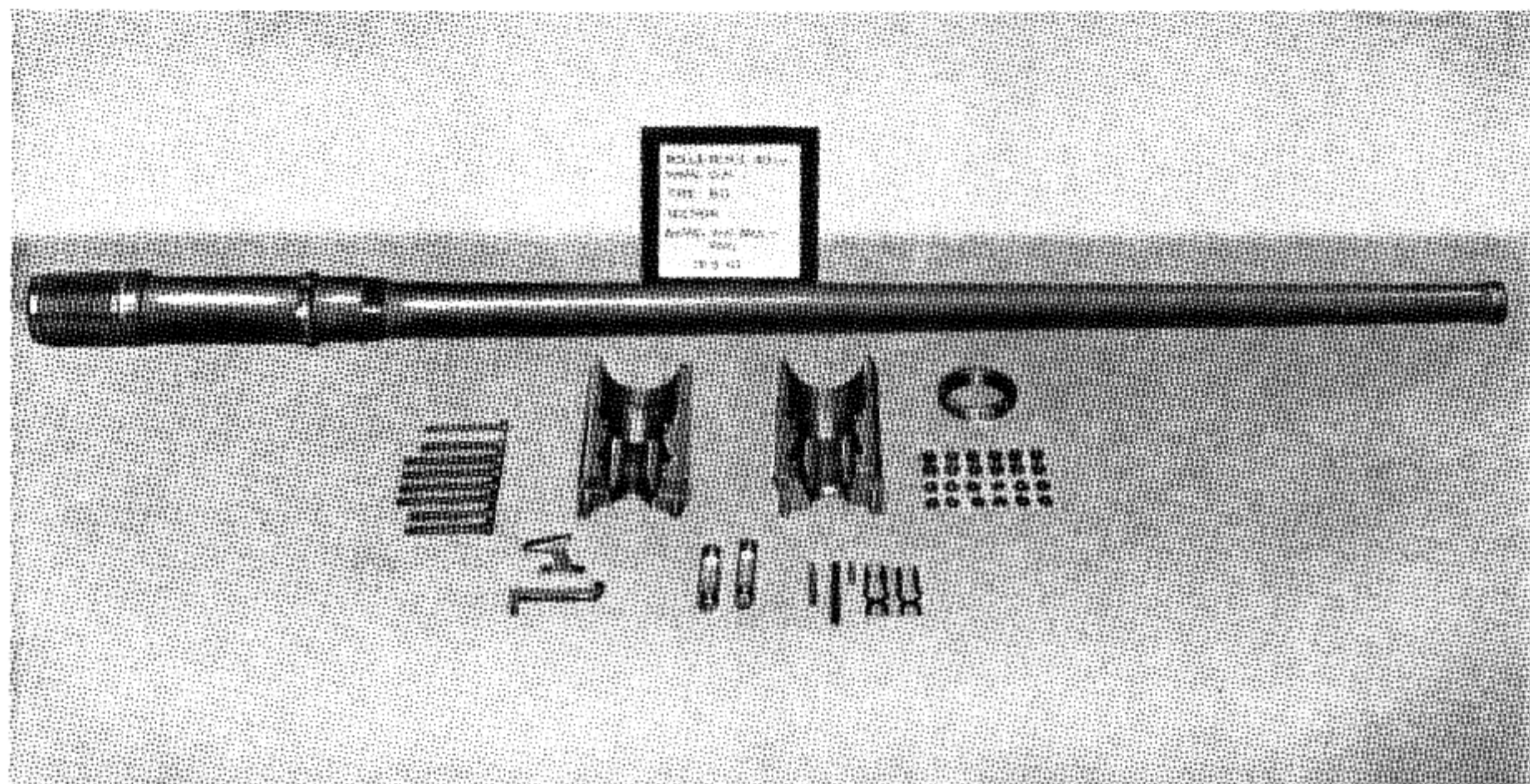


Figure 15-6. Rolls Royce 40-mm Type BD Naval Gun. Barrel and components of breech ring.

The breechblock body is of rectangular section and has an axial cylindrical hole to accommodate the striker housing. The striker housing is retained in the breechblock body by two floating cams which permit a limited relative axial movement between breechblock body and striker housing. The sear is pivoted in the breechblock body and engages the striker contained in the striker housing.

The striker housing arm is attached to the rear of the striker housing by means of a T-slot connection and is held in position by a thimble sliding in the striker housing, pressed into a registering hole in the arm by the firing spring.

The breechblock body accommodates two locking struts which are operated by the floating cams and engage the locking shoulders in the breech ring when the breech is closed.

The firing stirrup and firing stirrup spring are accommodated in the leg of the striker arm, the firing stirrup being carried on the tail of the sear.

*Recoil Mechanism Assembly.* The recoil mechanism assembly consists mainly of a recoil cylinder which is connected by means of studs to a recuperator cylinder but separated by a diaphragm that carries the adjustable control orifice and dashpot body.

The recoil cylinder has a main cylinder, in which the main ram operates, and a bypass, which is fitted with a restricting orifice at one extremity and a short controlling rod at the other. A floating piston operates in the recuperator cylinder which is fitted with an air valve for filling purposes and a control orifice adjusting gear.

One end of the main ram is anchored to a bridge piece attached to the cradle, and a floating piston is fitted to the other end. The rear end of the recoil cylinder is closed by a large screwed plug. Concentric with the main ram is the breechblock pull rod, which is connected to a glanded piston and has a tubular extension carrying a dashpot plunger.

The recoil mechanism is underslung from the barrel, being attached to the barrel supporting brackets.

*Cradle and Fittings.* The cradle consists of two castings bolted together, the joint face being through the centerline of the gun. Two grooves are machined along the full length of the cradle to accommodate the slides of the barrel supporting brackets. The main ram of the recoil mechanism is anchored to a bridge piece in the well of the cradle.

A feed mechanism is attached to the right-hand side of the cradle to the rear of the gun.

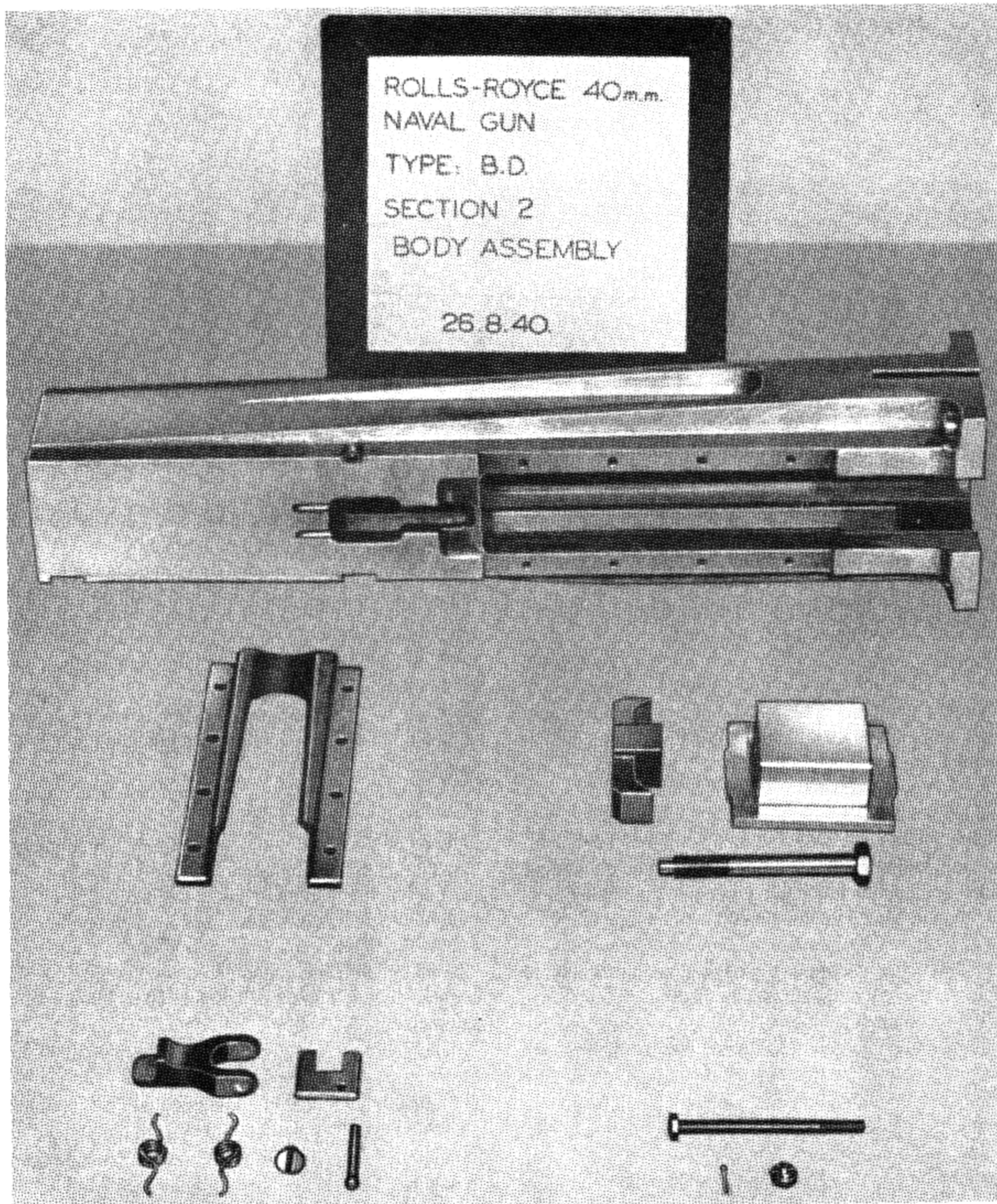


Figure 15-7. Rolls Royce 40-mm Type BD Naval Gun. Components of body assembly.

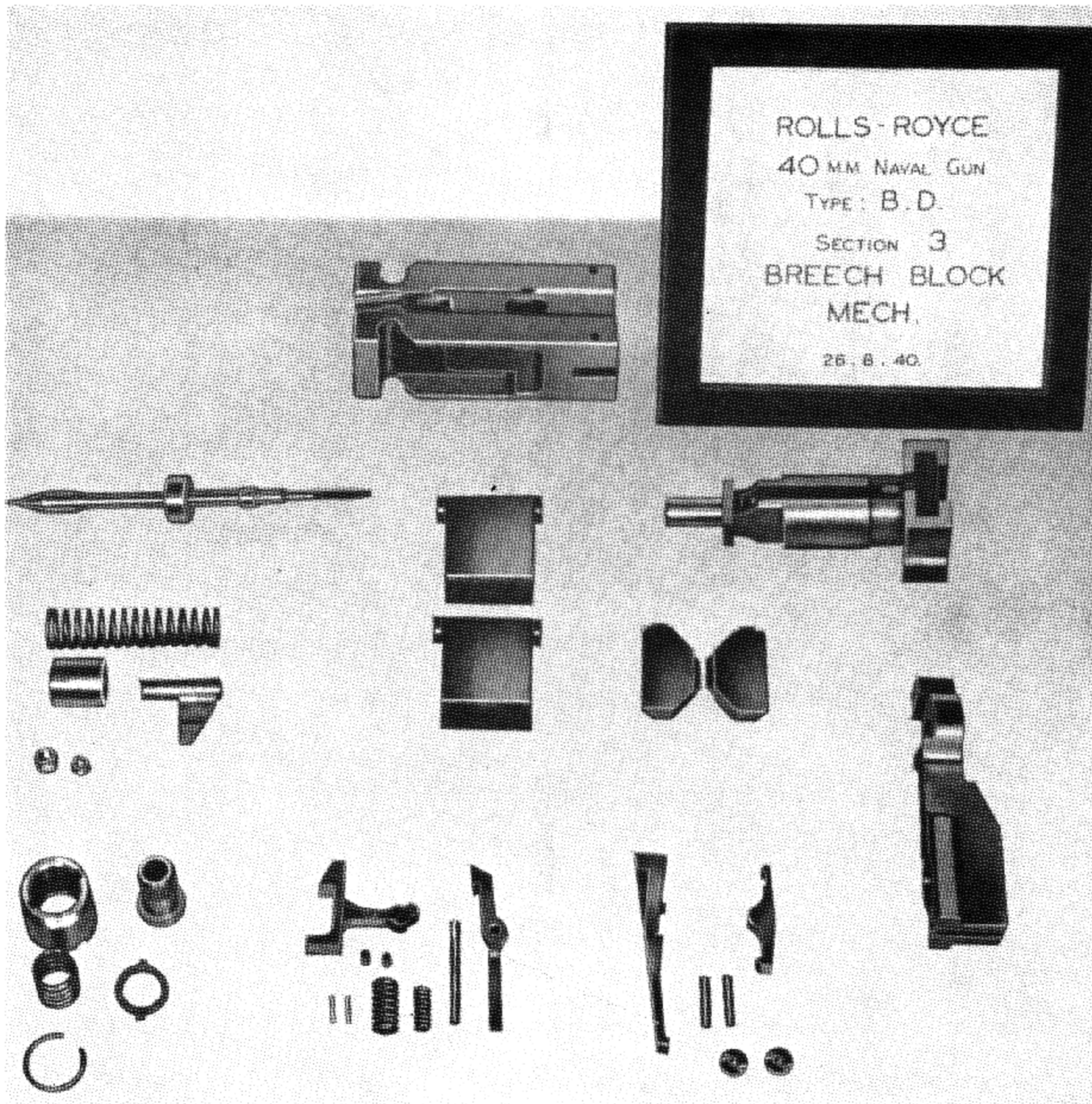


Figure 15-8. Rolls Royce 40-mm Type BD Naval Gun. Components of breechblock.

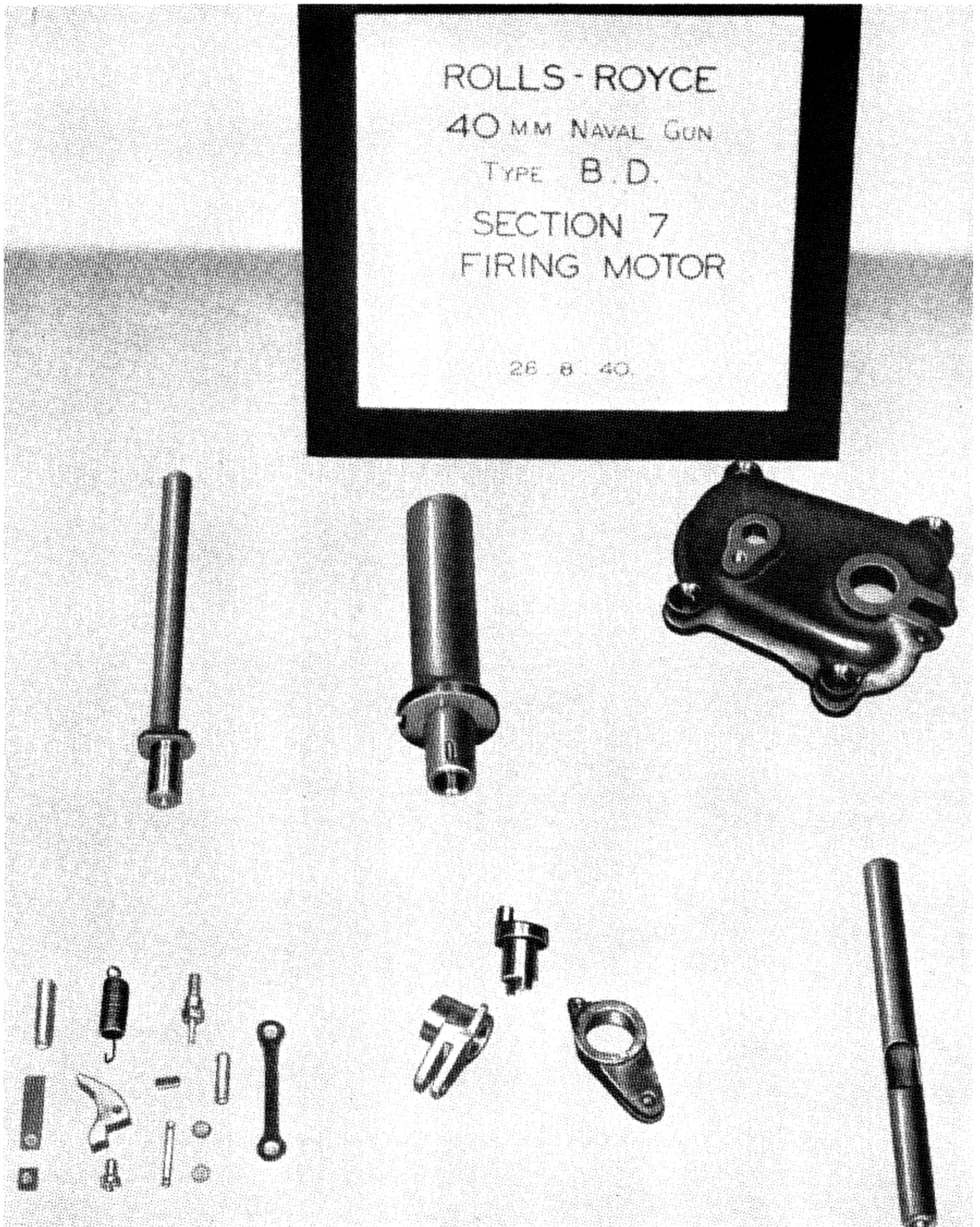


Figure 15-9. Rolls Royce 40-mm Type BD Naval Gun. Components of firing motor.

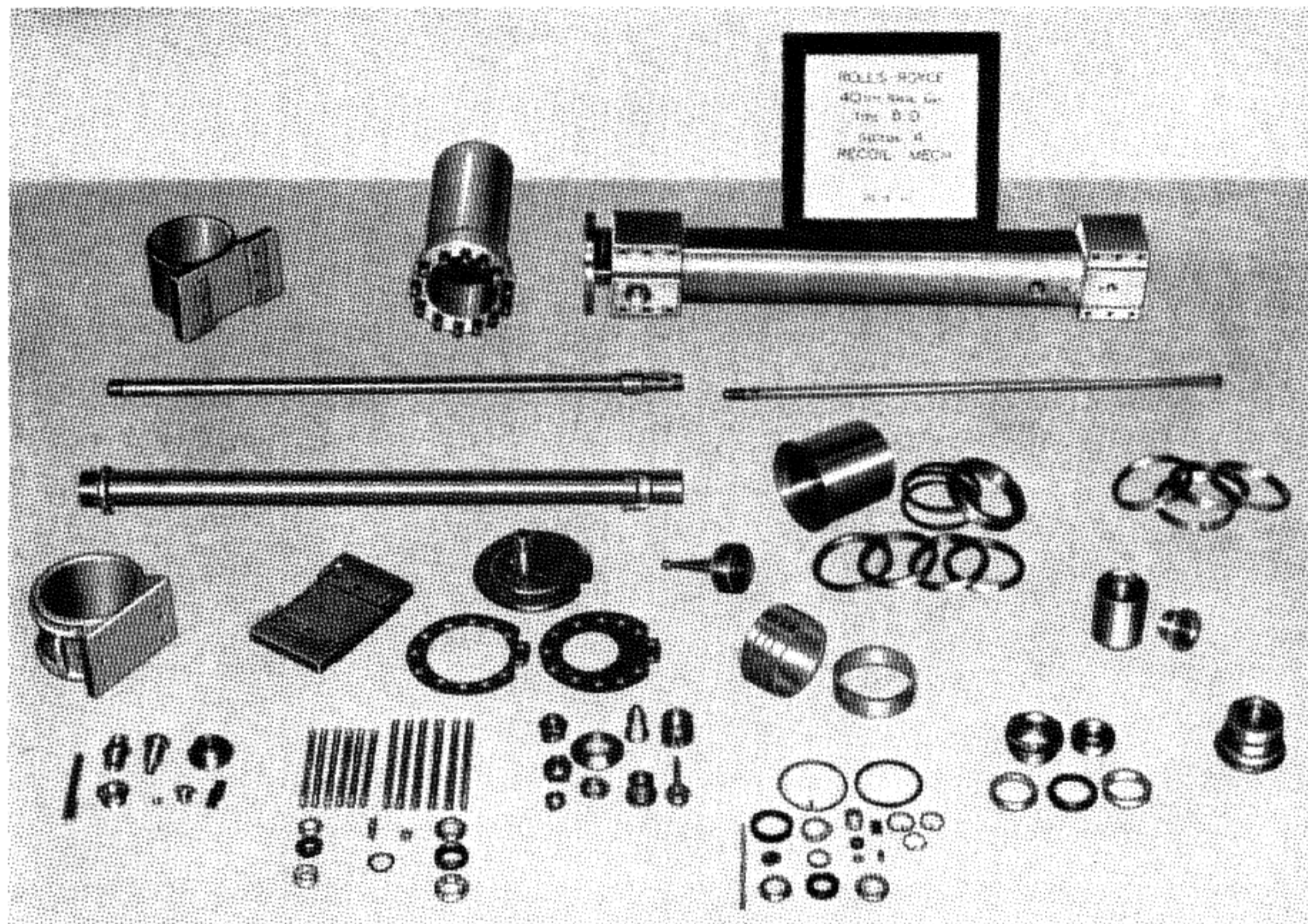


Figure 15-10. Rolls Royce 40-mm Type BD Naval Gun. Components of recoil mechanism.

An ejection chute is mounted on the cradle opposite the ejection opening in the body on the left-hand side of the gun.

A breechblock release mechanism is accommodated in the rear of the cradle. It comprises a spring-loaded release shaft mounted transversely in the well of the cradle and retained by means of a screwed plug and setscrew.

A rubber coated arm rest of tubular construction is attached to the rear of the cradle on the left-hand side of the gun.

A rubber buffer is suitably arranged on the underside of the cradle to cushion the gun when lowered to the rest position.

An aiming handle is also provided to assist the gunner in controlling the gun when firing.

*Hand Feed and Breechblock Release Mechanism.* The hand feed is essentially a loading tray, which

is machined from a simple U-shaped casting. The tray is carried on a shaft lying parallel with the axis of the barrel and supported by two brackets attached to the underside of the cradle on the right-hand side of the gun. Pivoted to the loading tray is a spring-loaded auxiliary tray. The movement of the tray is limited by a small stop plate attached to the main casting. Attached to the side of the cradle to guide the round into the feed opening are a quadrant on the guide plate and an end locating plate and bracket.

Interconnected with the hand feed mechanism is a breechblock release mechanism. This consists mainly of a cam, keyed to a short vertical spindle mounted in a bracket attached to the right-hand side of the cradle and operated by a lever connected to a universal joint on the rear end of the loading tray shaft.

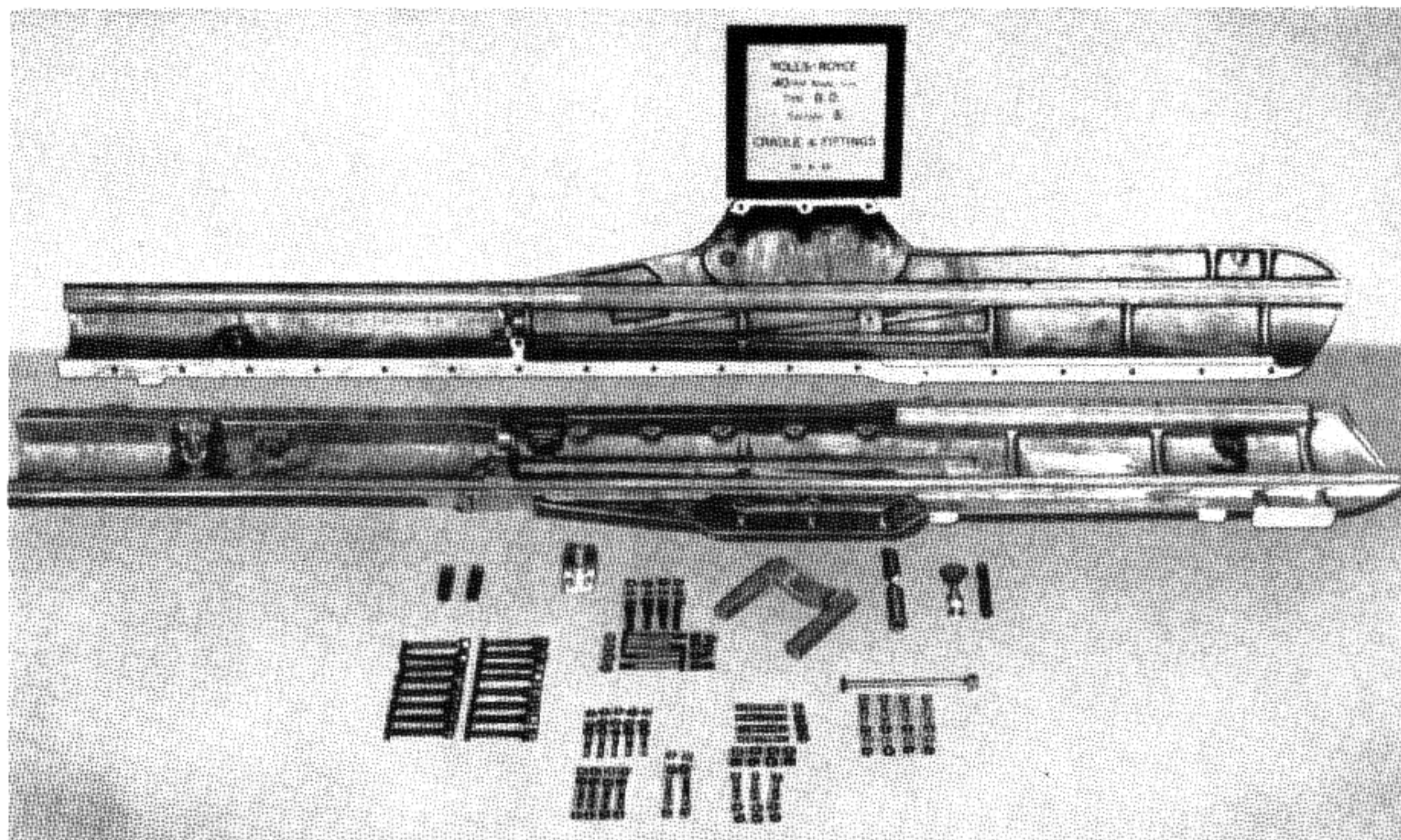


Figure 15-11. Rolls Royce 40-mm Type BD Naval Gun. Components of cradle assembly.

## General Principles of Operation

The general principles of operation of the gun are as follows:

1. The barrel, breech ring, body, breechblock, and recuperator mechanism constitute the recoiling parts.
2. The cradle, recoil shield, main recoil ram, hand loading tray, shoulder piece, and sights do not recoil.
3. The breechblock is closed by pneumatic pressure.
4. The breechblock is positively locked before firing.
5. The striker is inoperative until the breechblock is locked.
6. Energy of recoil is absorbed by a hydropneumatic recoil mechanism.
7. The barrel is returned to its firing position by pneumatic pressure.
8. The gun cannot be fired with the loading tray in the up position.
9. The firing grip must be released after firing each round.

## Principal Steps in the Cycle of Operation

*Breechblock Closed and Locked; Round Fired.* The breechblock is in the closed locked position, the trigger has been released and a round has been fired.

*Breechblock Closed and Locked; Gun Recoiling.* The breechblock remains in its locked position during recoil.

*Breechblock Closed and Locked; Gun Recoiled.* The breechblock, still in its closed locked position, has recoiled beyond the spring-loaded cross-shaft pushed aside by the striker housing arm.

*Barrel Running Out; Breechblock Unlocked and Held Back.* The barrel commences to run out and the striker housing arm is caught by the spring loaded cross-shaft, the initial relative movement causing the breechblock to unlock. Further movement causes the empty case to be extracted from the chamber.

*Barrel Run-Out; Empty Case Ejected.* During barrel runout, the empty case is presented to the ejection opening. After the case leaves the chamber, it is supported by the extractor and the breechblock face. In this position, the spring-loaded ejection

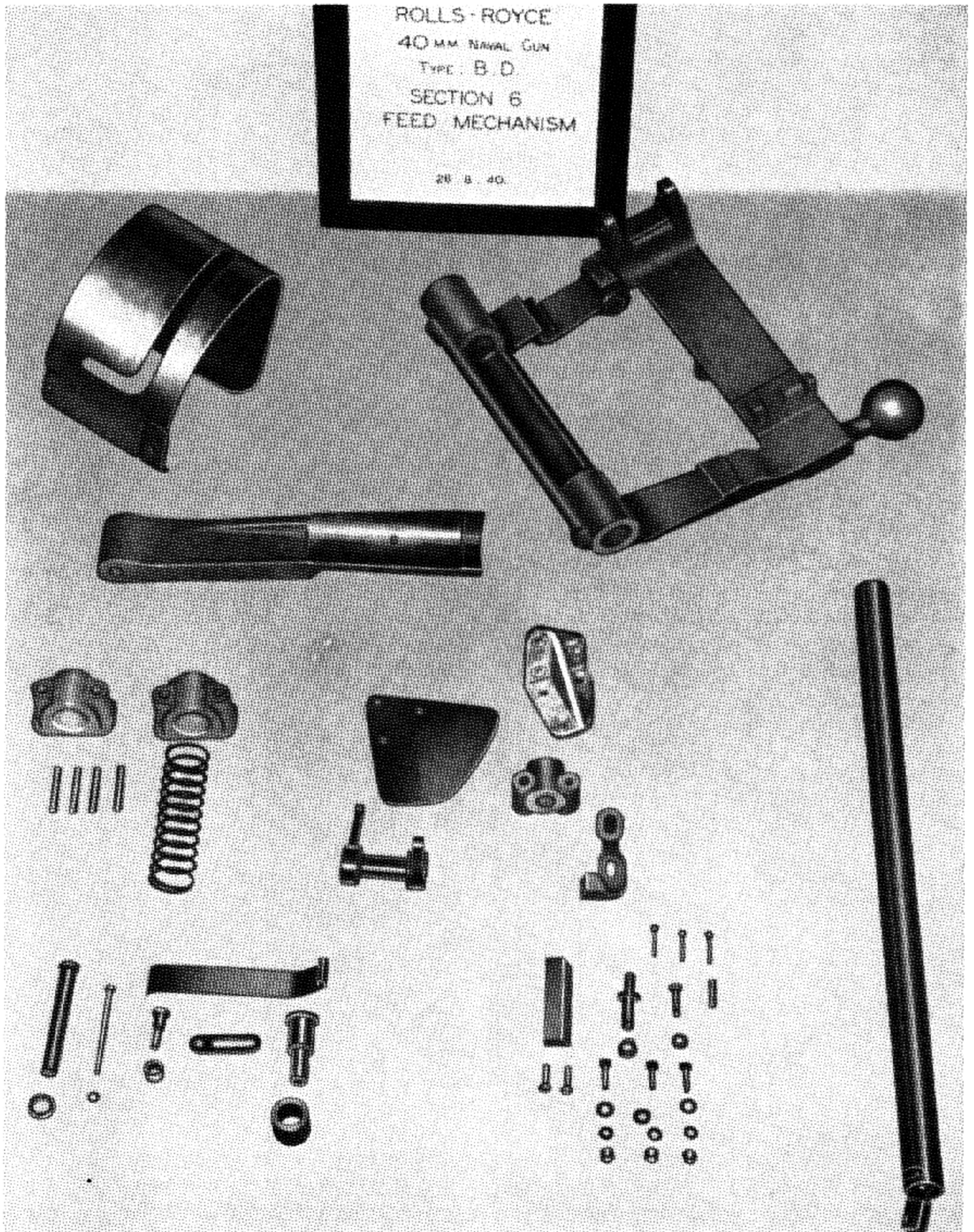


Figure 15-12. Rolls Royce 40-mm Type BD Naval Gun. Components of feed mechanism.



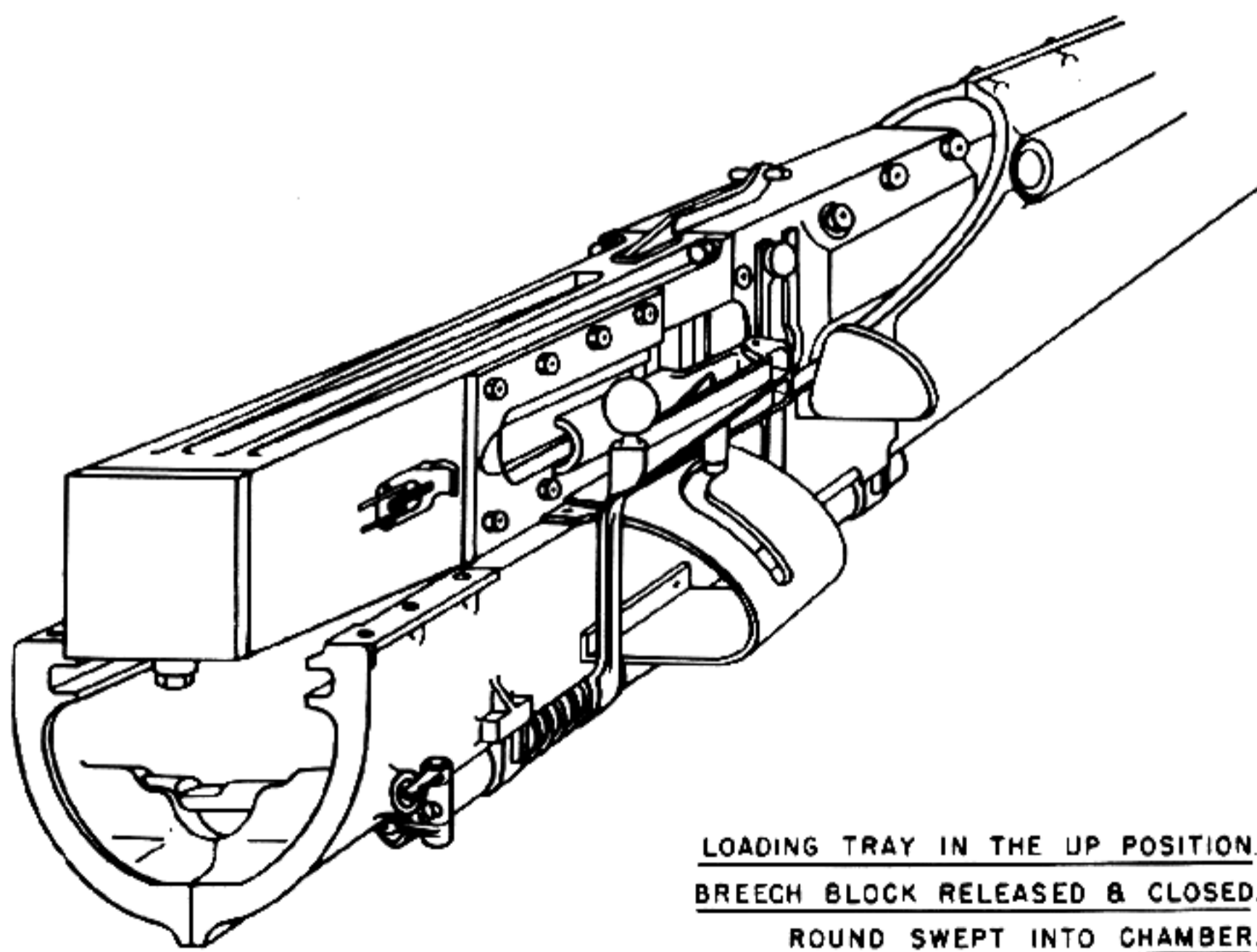
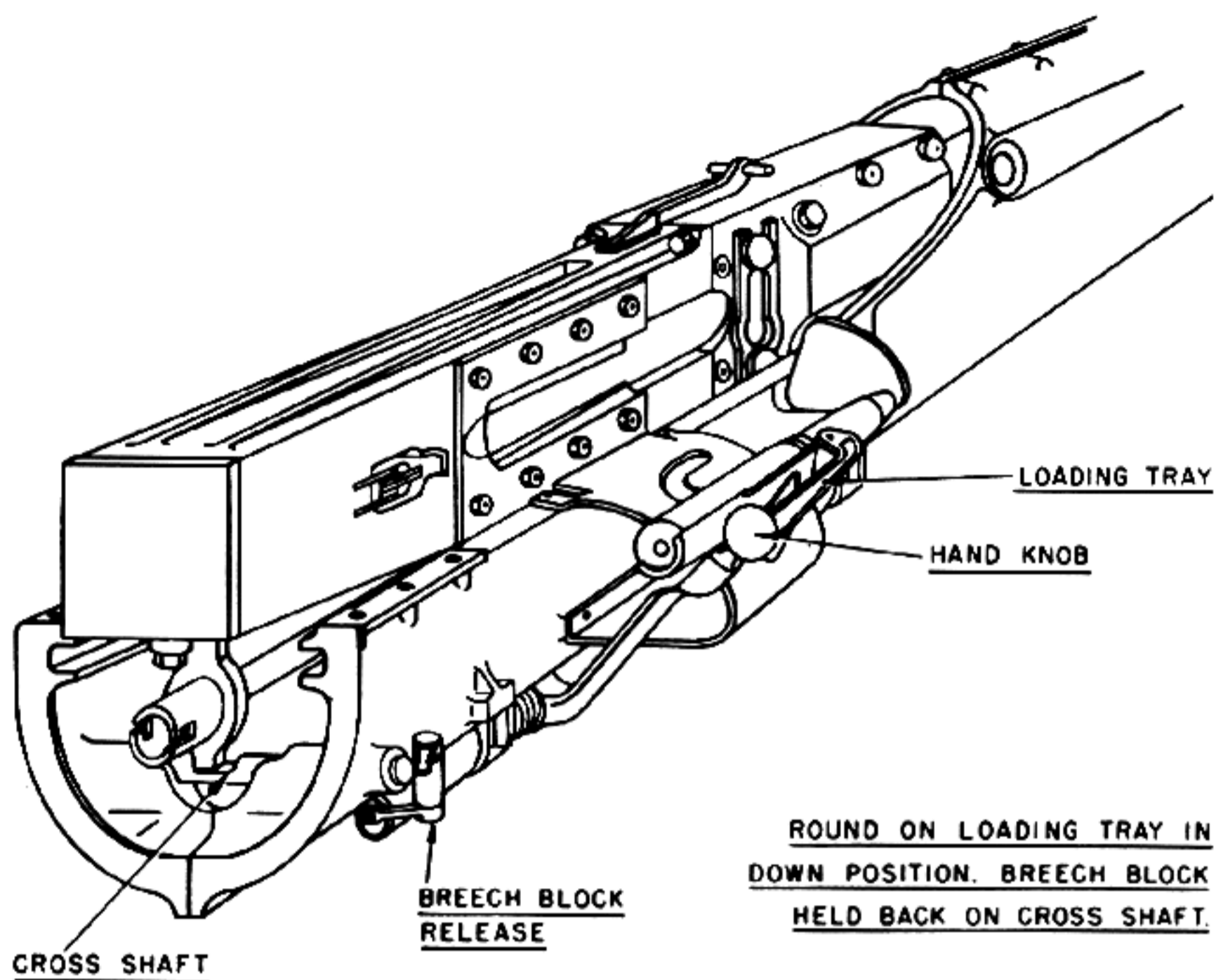


Figure 15-13. Rolls Royce 40-mm Type BD Naval Gun. Method of loading.

tor trip in the body catches the ejector in the breechblock, causing it to project beyond the breech face. The empty case is thus pushed away from the breechblock and, pivoting about the extractor, is thrown out through the ejector opening.

*Breechblock Released; Feeding Next Round.* The next round, placed in the loading tray, is fed into the loading position whereupon the breechblock is automatically released and the round swept from the lips into the chamber.

*Breechblock Closed and Locked Ready for Firing.* The breechblock automatically closes and locks on the feeding round, and the gun is once again loaded and armed ready for firing.

### Operation of the Gun

*Opening the Breech.* After the gun has been prepared for action, the breech, if not already open, should be opened manually with the aid of the tool supplied. The tool should be attached to the striker housing arm by means of a bayonet connection. The breechblock should then be pulled back against the pressure in the recoil mechanism until it is held in its fully open position by the cross-shaft of the breechblock release mechanism.

*Loading.* A round may then be placed on the loading tray and swung up into the lips of the feed

opening. When in this position, the loading tray is pushed forward a certain distance, automatically releasing the breechblock which sweeps the round into the chamber and locks when in the fully closed position.

*Firing the Gun.* If the trigger safety catch is on SAFE, it should be ready to fire. Having loaded as described, the gun is then ready to fire. This is done by rotating the twist group on the left-hand side of the cradle about one-fourth turn.

*Recocking.* Should the gun misfire, the striker may be cocked by hand by raising the cocking lever on the breech ring until the striker bent engages on the sear.

To ascertain whether the striker has gone forward, look for the cocking claw locknuts at the rear of the breechblock. These should be projecting approximately 1 inch from the rear of the breechblock when the striker is cocked and should almost disappear from view when the striker is released.

*Ejecting a Live Round.* Should there be a case of repeated misfires, the live round must be removed.

To do this, the breech should be opened in the normal manner as described in this section. Simultaneously, the ejector trip on the right-hand side of the body should be depressed so that the ejector is

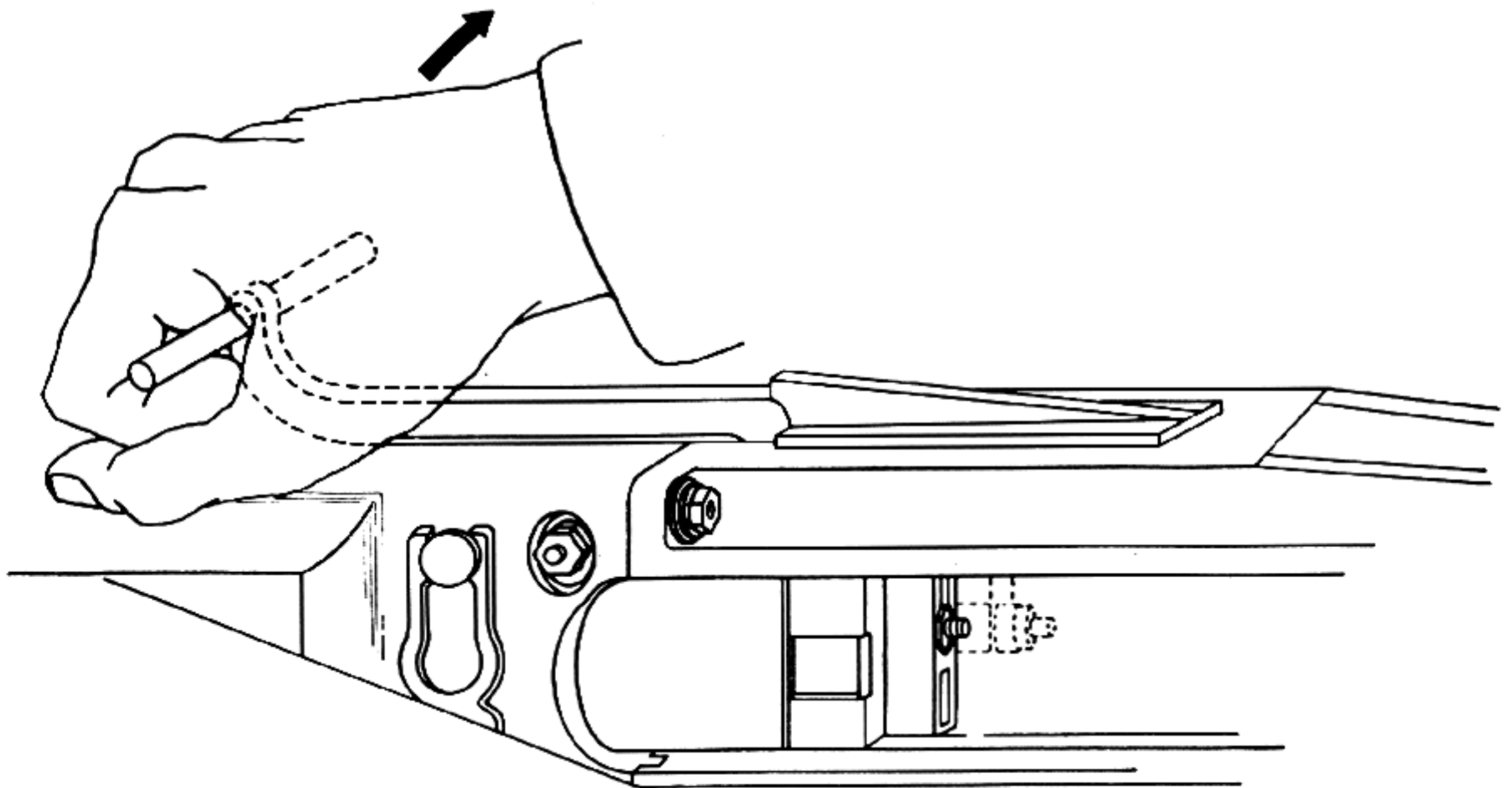


Figure 15-14. Rolls Royce 40-mm Type BD Naval Gun. Charging handle.

rendered inoperative. Having caught the breechblock up on the cross-shaft, the live round may be removed by hand, leaving the gun ready for loading another round.

### Functioning of the Weapon

*Breechblock Mechanism.* When the breechblock is in the locked position, the locking struts are engaged on the locking shoulders in the breech ring and are held there by the floating cams contained in the striker housing.

On firing, the axial load on the breechblock is transmitted to the locking struts, which distribute

the load partly to the breech ring through the locking shoulders and partly to the cams.

During recoil, the breechblock remains locked. At the end of recoil, it is caught up by the cross-shaft in the rear of the cradle.

At the beginning of runout, the breechblock body extends from the striker housing, which is held back by the cross-shaft, and the locking struts are drawn out of engagement with the locking shoulders due to the natural angle of their contacting surfaces and continue rearward until the breechblock strikes the buffer, where it is held momentarily.

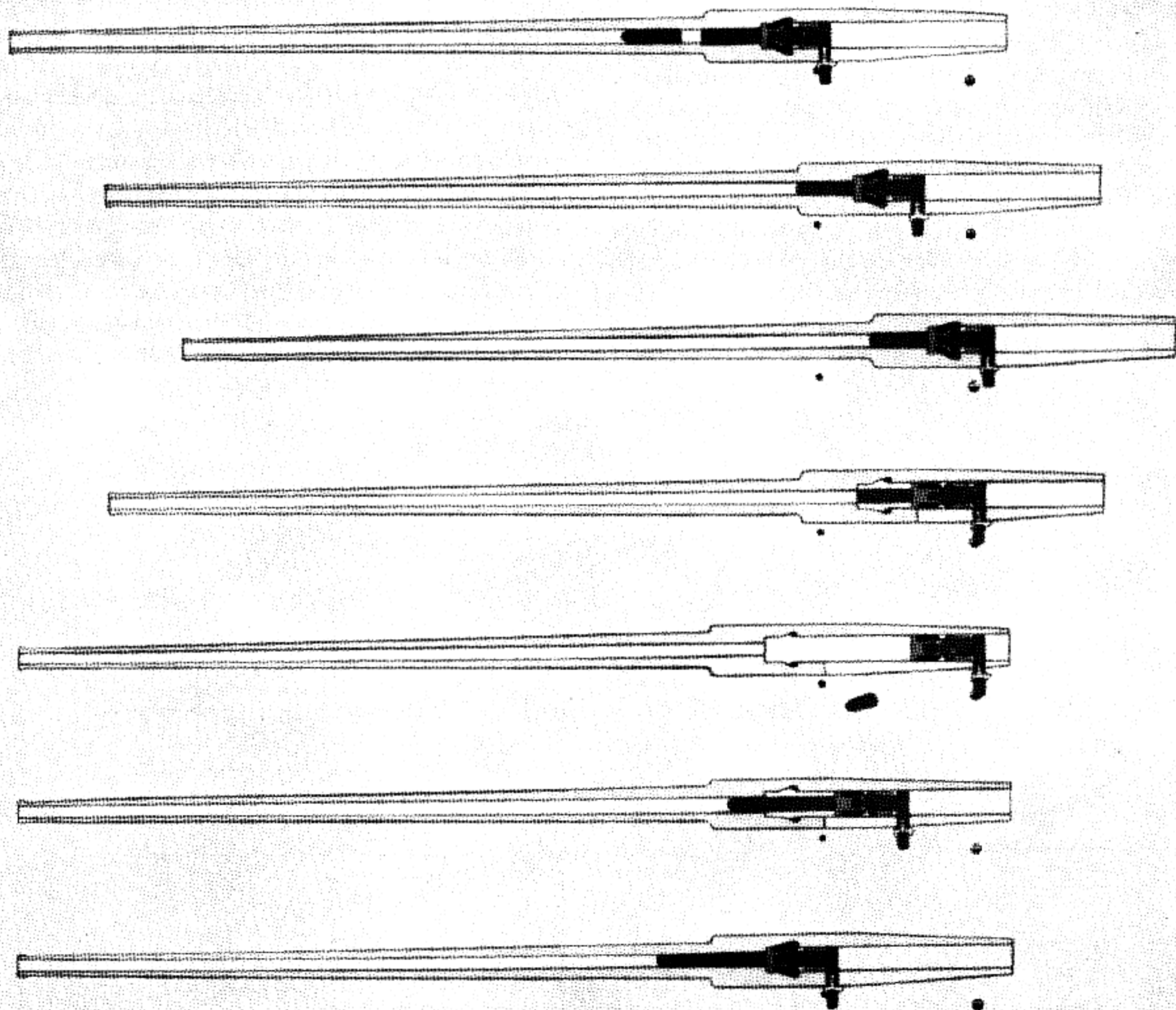


Figure 15-15. Rolls Royce 40-mm Type BD Naval Gun. Cycle of operation of breech.

When the breechblock is released, it travels forward in the extended position under the influence of the breechblock return rod, which is attached to the striker housing arm. When the breechblock body reaches the breech face, the former is arrested; but the striker housing continues to move forward, taking up the initial lost motion. During this operation, the floating cams, which are contained in the striker housing, come into contact with the locking struts, pushing them into engagement with the locking shoulders once more. Simultaneously, the striker, also contained in the striker housing, is caught by the sear which is pivoted in the breechblock body, and the lost motion is thus utilized to compress the firing spring and so again fire the gun.

*Breechblock Mechanism—Firing Mechanism.* The firing pin or striker, its axis coincident with the centerline of the gun, is accommodated in the striker housing, which is rigidly connected to the striker housing arm. The striker housing is contained in the breechblock body, which is free to slide in the body.

The sear, operating in the vertical plane through the centerline of the gun, pivots about a pin, contained in the breechblock body, whose axis is at right angles to the vertical plane.

The firing stirrup contained in the arm and lying in the vertical plane, though resiliently restrained by the stirrup spring which is also contained in the striker housing arm, is free to move vertically with reciprocating motion in guides and is free to rock in the same vertical plane, within the range available, on the tailpiece of the firing sear.

The breechblock locking principle introduces a connection between breechblock body and the striker housing to effect locking and unlocking of the breechblock. This lost motion connection between breechblock body and striker housing is utilized in the above mechanism to arm the gun, as follows.

Assume the gun has been fired, and is in a state where the breechblock is returning in readiness for firing the next round. By virtue of design, the breechblock is extended during return until the breechblock body reaches its furthest position, when the striker housing is free to close up once more, taking up the lost motion. The extent of this lost motion corresponds more or less to the movement of the striker housing. As the breechblock commences to close up, the firing sear catches on a

bent on the striker and restrains it from further movement.

Meanwhile, the lost motion is taken up; and since there is no relative movement between the breechblock body and the striker, the firing spring is compressed, thus arming the gun. It should be remembered that the striker does not project beyond the breechblock face during this operation.

The gun is fired by raising the leg of the firing stirrup. The firing stirrup is restricted to vertical movement during firings; thus, vertical movement is imparted to the tailpiece of the firing sear, which pivots about a pin and releases the striker.

When the gun has passed through this cycle of operation, the weapon is restored once more to its initial state provided the trigger is released after firing.

If, however, the trigger mechanism is not released, the operating member comes into contact with the leg of the firing stirrup as the breechblock closes. The firing stirrup pushed sideways, which it is free to do by virtue of the design, makes no attempt to move the sear and any effort to fire the gun is nullified until the trigger is released, whereupon initial conditions are reestablished.

*Operation of the Recoil Mechanism.* Energy of recoil is absorbed by a hydropneumatic recoil mechanism, which also incorporates a breechblock return mechanism in the system.

The recoil piston, floating on the extremity of the ram which is rigidly connected to the cradle, operates in the main recoil cylinder attached to the barrel. An adjustable orifice, externally controlled, restricts the left-hand extremity of the main recoil cylinder. A bypass connects the two extremities of the main recoil cylinder, the left-hand end of the bypass being restricted by a control orifice and the right-hand end by an orifice and a short rod. The left-hand end of the main cylinder is connected to the recuperator cylinder. A floating piston operates in the recuperator cylinder and acts as a separator between air on the left-hand side and oil in the remainder of the system.

The interior of the main ram accommodates a breechblock return piston which has an extension rod connected to the striker housing arm and a tubular extension carrying a dashpot plunger. Oil is free to pass from the main recoil cylinder to the recuperator cylinder and also to one side of the

breechblock return piston via the tubular extension. Thus one side of the breechblock return piston is subjected to the pressure prevailing in the main system and the other side is open to the atmosphere by the air vent.

On recoiling, the recuperator and recoil cylinders, being attached to the barrel, move toward the right relative to the main ram. Oil in the main recoil cylinder passes through the adjustable orifice into the recuperator cylinder, displacing the floating piston and compressing the air contained in the recuperator cylinder.

Meanwhile, some oil escapes through the control orifice and through the orifice in the recoil piston to the back of the main ram. The quantity of oil passing to the back of the main ram is governed by the differential areas of the ram and recoil piston.

Thus the energy of recoil is absorbed in the system, some being stored by the air for recuperation and the remainder lost either in internal or external work.

When all the energy has been absorbed, the barrel commences to run out by virtue of the air pressure in the recuperator acting on the main ram. Oil from behind the recoil piston is returned to the main cylinder via the bypass. Immediately before the barrel has returned to its original position, the recoil piston blanks off the right-hand bypass orifice and the remaining oil from behind the recoil piston escapes via the reed. The rod is designed to effect suitable buffering of the mechanism at the end of barrel runout.

The orifice in the recoil piston is open during recoil but closed during runout.

During recoil, the barrel and breechblock are locked together and hence the breechblock piston moves toward the right, relative to the breechblock return cylinder, in the main ram. Oil in this cylinder escapes along the tubular extension into the main cylinder.

During barrel runout, the breechblock is held back in the recoil position, no relative motion taking place between the breechblock piston and the main ram.

When the breechblock is released, the pressure difference on the breechblock return piston drives it forward into its original closed position. When

the breechblock is almost closed, the dashpot plunger chokes the opening in the dashpot and buffers the breechblock at the end of its travel, whereupon initial conditions are reestablished.

### Disassembly

*To Remove the Breechblock.* Swing the recoil-shield forward over the gun after slackening the two clamping nuts. Free the clamp on the end cover by loosening the bolt.

Close the breech automatically by placing the loading tray in the loading position. Disconnect the striker housing arm from the breechblock return rod. This may be done by standing behind the gun, inserting the serrated spanner in the bayonet socket on the striker housing arm, applying an axial pressure to release the serrated locking disk, and unscrewing in a counterclockwise direction.

The tool supplied for opening the breech by hand may then be used to withdraw the breechblock from the body, the end cover being removed automatically.

On no account should the striker housing arm be disconnected from the breechblock return rod with the breech open.

*To Strip the Breechblock.* Remove the locking struts and cams and withdraw the striker housing and arm assembly from the breechblock. Unscrew the cocking claw locknuts from the rear extension of the striker. This may be done by holding the striker housing arm in a vise and depressing the striker into the striker housing by means of a screwdriver handle when the locknuts will be rendered accessible.

Remove the cocking claw. With the aid of a screwdriver, depress the locking thimble in the rear of the striker housing until it is clear of the registering hole in the striker housing arm, then slide the two parts apart. The striker, firing spring, thimble, stirrup, and stirrup spring may then be removed.

This completes the dismantling of the breechblock assembly except for the sear, ejector, and extractor, which may be removed from the breechblock body by withdrawing their respective pins.

*To Remove the Barrel, Breech Ring, and Body Assembly.* Remove the breechblock as previously described. Remove the lockplate from the rear

barrel housing and unscrew the barrel retaining nut. The barrel, breech ring, and body assembly may then be withdrawn from the rear of the cradle.

Adequate support should be given to the barrel and cradle during this operation.

*To Remove the Recoil Mechanism Assembly.* Release the air in the recuperator cylinder by carefully inserting one end of the tommy bar of the adjustable orifice key in the union at the front of the recuperator cylinder and depressing the air valve. Push the recoil mechanism back a little to test whether any air has leaked into the recoil system. If there is air in the system, care must be taken when removing the front stop from the cradle because the recoil mechanism will tend to move forward a short distance. The bridge piece, mounted in the cradle, should then be disconnected by removing the four bolts. Then the recoil mechanism assembly may be removed bodily from the forward end of the cradle.

When disassembly has been accomplished to this point, routine cleaning and oiling operations can be carried out.

## Assembly

*To Replace the Recoil Mechanism Assembly.* Support the cradle in a convenient position for inserting the recoil mechanism assembly from the front. Enter the recoil mechanism assembly, main ram first, into the front of the cradle, taking care to guide the supports into their corresponding grooves and holding the recoil mechanism parallel to the cradle until it is fully supported. Replace the front stop in the cradle. Push the recoil mechanism back until the bridge attached to the main ram is in contact with the bridge in the well of the cradle, and bolt. Recharge the recuperator cylinder with air.

*To Replace the Barrel, Breech Ring, and Body Assembly.* Support the cradle in a suitable position and start the barrel, muzzle first, into the rear of the cradle. Having passed the muzzle through the rear barrel housing, thread the barrel locating nut onto the barrel with the serrated side facing the rear of the gun. Continue to pass the barrel into the cradle until the supports on the breech ring are about to enter. Carefully guide them into the grooves in the cradle, and push the barrel home. Screw up the barrel locating nut firmly with the

C spanner provided, and replace the lockplate on the barrel housing.

*To Reassemble the Breechblock.* Insert the ejector, thick end first, into the corresponding slot in the side of the breechblock body. Hold the ejector in position with the thick end projecting about one-fourth of an inch beyond the breech face, and replace the pin.

Place the two extractor springs in the hole in the breechblock body directly opposite the ejector, and place the extractor in position with the springs located in the seating provided and the claw of the extractor projecting beyond the breech face. With the aid of a hammer shaft, apply pressure to the extractor immediately above the pivotal point and insert the extractor pin.

Replace the sear in the breechblock body with the claw facing inward and nearest the breech face, and insert the sear pin.

Place the striker, followed by the firing spring and thimble, in the striker housing. Replace the firing stirrup and stirrup spring in the striker housing arm.

With the striker housing arm held in a vise, slide the striker housing into position. This should be done by engaging the forked end of the striker housing arm with the T-slot in the striker housing.

Meanwhile, the firing-pin spring should be depressed by applying a screwdriver to the thimble and pushing it into the striker housing to clear the arm, which can then be pushed home and the thimble allowed to register in its appropriate recess. The longitudinal slot in the striker housing should be facing the striker housing arm during the process of assembling.

Rotate the firing pin until the bent appears opposite the longitudinal slot in the striker housing. Then place the cocking claw on the rear of the striker.

Hold the striker housing arm in a vise and push the firing pin back into the striker housing with the aid of a screwdriver handle; the rear of the striker will then be accessible for placing the cocking claw in position and replacing the lock nuts.

Then replace the assembly in the breechblock body, guiding the sear in the longitudinal slot in the striker housing and threading the tail of the sear between the pins on the firing stirrups.

With the breechblock assembly closed, the two cams may be replaced and held in position by the locking struts.

*To Replace the Breechblock in the Body.* Extend the breechblock, taking care not to drop the loose parts, and insert it in the body. Replace the body end cover and clamp it in position.

The breechblock should then be pushed down the body to the breech face and the striker housing arm connected to the breechblock return rod. This may be done by inserting the serrated spanner in the bayonet socket on the striker housing arm, as before, and rotating in a clockwise direction, meanwhile applying an axial pressure to the tool to disengage the serrated locking disc.

The recoil shield should then be swung back into position and locked by means of the two clamping nuts.

## Adjustments

*Recharging the Recuperator with Air.* After the recoil mechanism assembly has been assembled in the cradle, the recuperator valve cap should be removed and the recuperator cylinder connected, by means of the piping supplied, to an air bottle. The recuperator cylinder should then be recharged with air to 400 pounds per square inch gage pressure. The piping may then be removed and the recuperator valve cap replaced.

### *Controlling Length of Recoil.*

**BY MEANS OF THE ADJUSTABLE ORIFICE.** The length of recoil may be increased or decreased within specified limits by opening or closing the adjustable orifice mounted on the recuperator cylinder.

This may be controlled externally with the aid of the key supplied. Turn clockwise to reduce recoil length and counterclockwise to increase recoil length.

If the recuperator cylinder air pressure has previously been lowered or the cylinder recharged, it is advisable to close the orifice down before firing. Should recoil be short, this can be adjusted by opening the orifice.

**BY VARYING THE RECUPERATOR AIR PRESSURE.** For large discrepancies in length of recoil, the air pressure in the recuperator should be lowered or increased in the recuperator accordingly.

Care should be taken not to lower the recuperator pressure below that which will cause the gun to recoil beyond 17½ inches.

**TO CHECK THE RECUPERATOR PRESSURE.** Remove the recuperator valve cap, and attach the pressure-gage unit to the union.

Screw down the air-release key, and read the gage pressure. Screw the air-release key back to its original position, disconnect the pressure-gage unit, and replace the recuperator valve cap.

### *Possible Stoppages and Method of Clearing.*

**FAILURE TO FIRE.** Striker failed to move forward, due to:

1. Sear not released from bent. (Check for sufficient trigger movement.)
2. Breechblock not fully closed. (Check for gummy lubricant or excess of lubricant; loss of pressure in recuperator; dirt or foreign particles in breechblock mechanism.)
3. Broken firing spring.
4. Broken striker nose wedging striker back. Striker moved forward too gently, due to:

1. Broken striker spring.
2. Weakened striker spring.
3. Gummy or congealed lubricant or excess of lubricant.
4. Striker prematurely released on closing movement of breech. (Check for: wearing or rounding of bent and sear; adequate stirrup spring strength; full return of firing shaft to rest position.)

### **INSUFFICIENT STRIKER PROTRUSION, DUE TO:**

1. Obstruction by foreign matter.
2. Accumulation of very stiff lubricant in forward end of striker passage.

**FAILURE TO EJECT.** Breechblock not caught up on cross-shaft, due to:

1. Insufficient recoil from weak round.
2. Insufficient recoil due to excessive resistance in recoil mechanism. (Check air pressure in recuperator cylinder, viscosity of fluid in recoil mechanism, freedom of sliding surfaces.)
3. Broken ejector stop.
4. Empty case falling off breechblock face on extraction, consequently not being held in ejecting position. (Check for extractor being free to close in until it bears with its full spring pressure on the edge of the rim, thus clamping the round against the opposite side of the breechblock face recess.)

5. Seizure of ejector, preventing its forward movement. Unlikely to occur, but would cause breakage of ejector trip.

**FAILURE TO EXTRACT.** Extractor riding over rim, due to:

1. Weak extractor spring.
2. Worn or rounded extractor claw.
3. Obstruction preventing extractor fully closing on rim.
4. Excessively tight round. Faulty ammunition.

**FAILURE TO FEED IN NEW ROUND.** Breechblock failed to move forward, due to:

1. Breechblock not released. (Check interconnection between loading tray and breechblock release.)
2. Breechblock not moved forward. (Check: pressure in recuperator system; connection between breechblock rod and striker housing arm.)

New round jamming on way to chamber, due to:

1. Premature release of breechblock before round is well into lips. (Check interconnection between loading tray and breechblock release.)
2. Tilting and binding of round by projecting ejector.

**FIRING WHEN BREECHBLOCK CLOSES.** Striker going forward on shock of breechblock closing, due to:

1. Inadequate hold of sear in bent. (Check: angle and condition of sear and bent; strength of stirrup spring; full return of trigger to nonfiring position.)

Striker permanently forward, due to:

1. Complete failure of sear to hold in bent. (Check: angle and condition of sear and bent; stirrup spring strength.)

This condition may cause failure to fire.



## Chapter 16

# VICKERS AUTOMATIC 40-MM AIRCRAFT CANNON ("S" GUN)

## SECTION 1. HISTORY AND BACKGROUND

When World War II was imminent, Great Britain was faced with the necessity of arming her aircraft with large bore automatic guns capable of destroying armored vehicles, tanks, and locomotives. As in the past, the first attempt was to adapt proved mechanisms until a development program could produce a weapon specially adapted for the existing need.

The British "S" gun, a 40-mm aircraft cannon, was designed by Vickers Armstrong, Ltd., to specifications furnished by the Royal Air Force in 1939. It was intended for air-to-ground work against armored fighting vehicles and other ground targets.

Although 20-mm Hispano-Suiza gun installations were intended primarily for air-to-air use, they were of course also used for air-to-ground attack against transport vehicles and shipping and other similar objectives. For air-to-ground attack of armored vehicles, however, the striking power was insufficient, and 40-mm gun installations were needed for this purpose in the interval before rocket installations came into use. The 40-mm "S" gun served this interim purpose.

Since this gun has a low rate of fire and long recoil, variations in gun kinematics caused little

trouble; accordingly, the development stages were not extensive. Only two changes proved to be necessary when the weapon was tested in aircraft: A change from an abnormally larger drum feed to the conventional type automatic feeder; and modification of the recoil system.

The hydraulic recoil system of this gun was first designed with a four-port liner to suit normal ball ammunition which weighed 1 pound 14 ounces. The operational use of the gun against armored vehicles, however, led to the use of 2½-pound and 3-pound A. P. projectiles. With these heavier projectiles, the recoil energy is higher and solid buffing occurred. This necessitated the introduction of a three-port liner to dissipate the additional energy and bring gun kinematics back to normal.

Another factor which had to be borne in mind was the temperatures in North Africa, where the weapon was intended to see service. Since these temperatures affect internal ballistics, special tropical propellants were used. The gun did extremely useful work against the lighter type of tank and against armored fighting vehicles in the North African campaign.

## SECTION 2. INSTALLATIONS OF THE "S" GUN

### Fixed Gun Installations

The muzzle energy of the 40-mm "S" gun is about eight times that of the 20-mm Hispano-Suiza gun; but since the rate of fire is only about 100 rounds per minute and the recoil stroke is about 17 inches, the time available for the dissipation of the recoil

energy is about seven times that of the Hispano-Suiza gun. Thus, the recoil forces and mounting loads are of a lower order than with the 20-mm gun, but the duration is much longer. The problem of mounting this gun in an aircraft was therefore a question of bulk rather than mounting strength.

### Wing Installations

The first installation of the 40-mm "S" gun reached the test stage by the end of 1941. This consisted of two guns in the Hurricane IID. One gun was mounted beneath each wing with the muzzles about 3 feet forward from the leading edge. The guns were supported from the front and rear spars and were fed from 16-round magazines. A belt feed was developed at a later stage.

A similar installation was also made in the Mustang at a later date, but it was not used to the same extent as that in the Hurricane.

Although the angle subtended at the eye by the gun muzzle was small, pilots complained of excessive dazzle while making dusk and dawn attacks. The addition of a flash eliminator to a gun of this caliber slung underneath the wing of an aircraft was clearly impractical, and the only solution was to suitably dope the propellants to reduce the flash. Similar methods to those used for the 20-mm Hispano-Suiza gun were used and gave satisfactory results for dusk and dawn firing.

### Fuselage Installations

Early in 1941, before the Hurricane installation had reached the test stage, the possibility was contemplated of using 40-mm guns in the fuselage of the Beaufighter. An installation was prepared by

the British aircraft armament group in collaboration with Bristol Aeroplane Co. for mounting two 40-mm guns in the position normally occupied by the 20-mm guns. This installation was designed to mount one Vickers "S" gun and one Rolls-Royce type BH gun for the purpose of comparing the performance of the two weapons under flying conditions. The idea of using the Beaufighter in service with 40-mm guns was abandoned, but much useful information was obtained from it as a flying test bed for tests on 40-mm guns.

Another installation of the Vickers "S" gun was in the nose of the Fortress.

### Free Gun Installations

The only free gun installation of the 40-mm "S" gun was in a turret designed by Vickers Armstrong Ltd., in a Wellington in the mid-upper position.

This was a "hydromechanical," fully rotating turret mounting one 40-mm "S" gun and equipped with rangefinder and redictor. The turret never went into production or service, but it is fully described in a report by the testing activity.

These guns were mounted beneath the wings at an angle that prevented the muzzles from being seen by the pilot gunner. Even so, pilots complained of excessive flash while making dusk and dawn attacks.

## SECTION 3. GENERAL DESCRIPTION OF THE "S" GUN

The 40-mm "S" gun is an automatic, recoil-operated weapon using the more or less orthodox big-gun principle of spring and hydraulic system to absorb the recoil energy. The weapon has a low rate of fire and long recoil stroke. As a result, efficient buffer systems are possible.

Energy is absorbed gradually during the recoil and return stroke of the barrel, barrel extension, and breech. The recuperator for the barrel, barrel extension, and breech consists of helical springs, and, in addition, the recoil stroke is buffered by a hydraulic buffer.

In the original buffer, the cylinder liner was provided with four tapering ports through which the oil was forced from the rear of the piston to the front. The tapered ports in the liner allow a quick flow of liquid during the first part of recoil; but,

because of the shape of the ports, the liquid is throttled as the barrel and barrel extension move farther to the rear, thus retarding recoil. When, however, 2½-pound AP ammunition was used instead of the original 1½-pound practice round, it was found that solid buffering occurred at the end of the recoil stroke. The number of liner ports was therefore changed from 4 to 3, and no further trouble occurred.

The gun consists of a fixed chassis, to which is attached the hydraulic cylinder; the barrel, around which is fitted the barrel return spring; the barrel extension, to which the barrel is permanently attached and to which the piston of the hydraulic system is connected; the striker frame; and the breech-block.

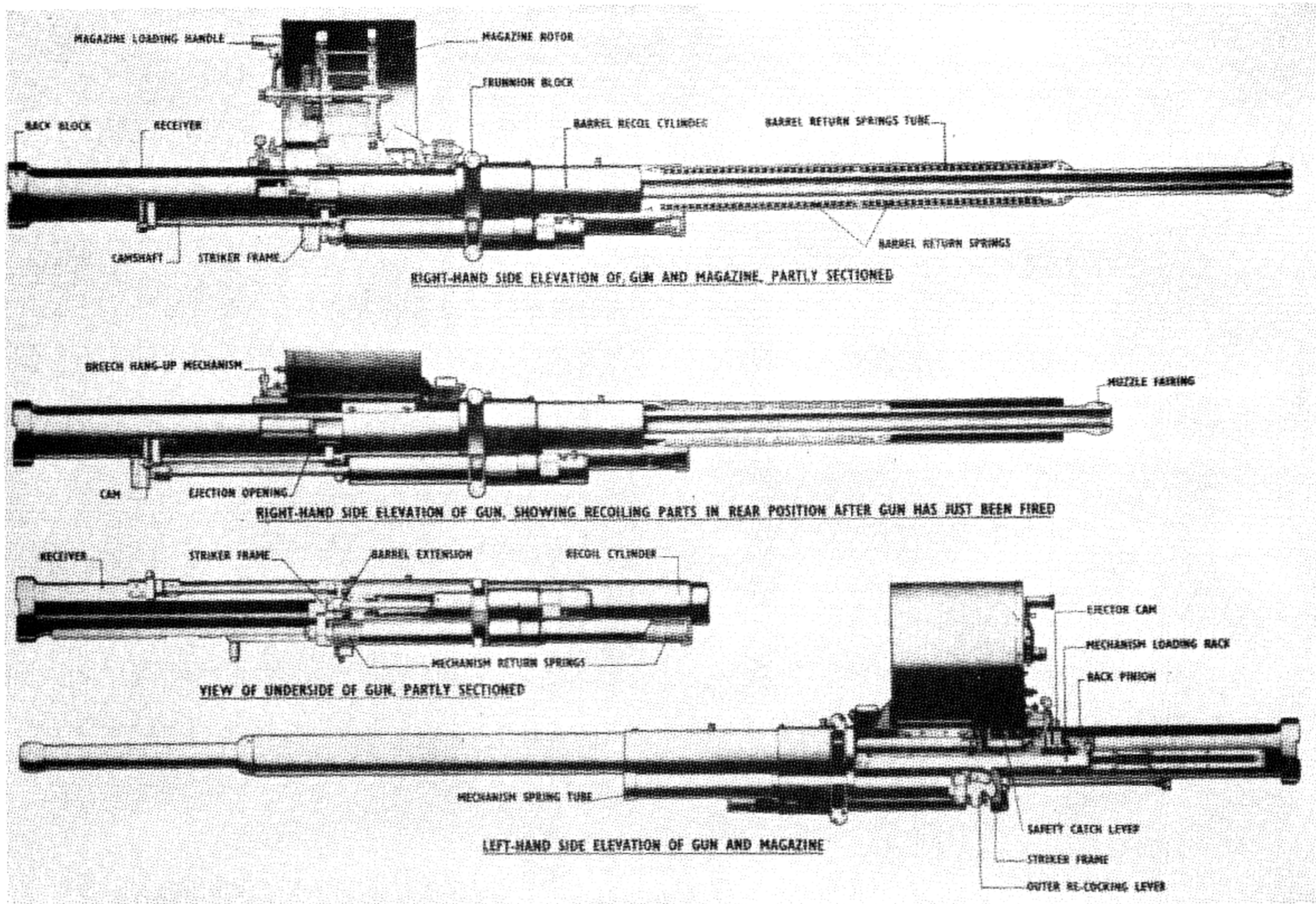


Figure 16-1. 40-mm Vickers "S" Gun. Assembly and nomenclature.

## General Data: 40-mm Vickers "S" Gun

Gun length, overall: 9 feet 9 inches.  
 Gun weight, complete: 285 pounds.  
 Rate of fire: 100 rounds/minute.  
 Muzzle velocity: 2,400 feet/second.  
 System of operation: Long recoil (approximately 17 inches).  
 System of locking: Camming of sliding breechblock. (Bolt seared automatically to rear after full recoil stroke.)  
 System of feeding: Spring-actuated 16-round drum or automatic belt feed employing metallic links.  
 Method of headspace: Factory established.  
 Location of feed opening: Top of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Air.  
 Method of cooling: Air.  
 Barrel length: 5 feet 7 inches.  
 Barrel weight: 88 pounds.  
 Rate control: None.  
 Barrel removal: Not quick disconnect.

Bore:  
 Number of grooves: 24.  
 Groove depth: 0.020 inch.  
 Gun-mounting unit: 3-port liner.  
 Installation in Hurricane IID:  
 Ammunition: 3-pound AP:  
 Peak load, recoil<sup>1</sup>: 5,000 pounds.  
 Peak load, return<sup>1</sup>: 3,500 pounds.  
 Installation in Mustang low attack wing:  
 Ammunition: 2.5-pound AP:  
 Peak load, recoil<sup>1</sup>: 4,000 pounds.  
 Peak load, return<sup>1</sup>: 2,000 pounds.  
 Ammunition: 3-pound AP:  
 Peak load, recoil<sup>1</sup>: 5,000 pounds.  
 Peak load, return<sup>1</sup>: 2,500 pounds.  
 Weight of projectile: 2 pounds.

<sup>1</sup> Measured on a ground stand. In the Hurricane and Mustang aircraft, the peak recoil and return loads were 6,500 and 4,500 pounds, respectively.

## SECTION 4. CYCLE OF OPERATION

When the gun is fired, the barrel, barrel extension, hydraulic piston, striker frame, and breechblock recoil backwards in the fixed chassis against the barrel return spring and the resistance of the oil in the hydraulic cylinder in which is fitted a variable port liner. The breechblock remains locked to the barrel extension, and the maximum recoil is governed by contact of the barrel extension with a buffer spring in the fixed back block.

On completion of the recoil stroke, the barrel return spring and mechanism return springs force the recoiling parts forward again; after about 2 inches of forward travel, a cam unlocks the breech from the barrel extension. The breechblock is then arrested by the striker frame while the barrel and barrel extension travel forward.

The empty case, still retained on the face of the breechblock, is extracted from the chamber as the barrel moves forward, then the case is ejected sideways by an ejector.

The cycle of operation may be divided into 9 distinct steps, as follows:

1. Recoiling parts in forward position, breechblock locked, striker spindle forward, gun just fired.
2. Recoiling parts in rear position, breechblock remains locked to barrel extension, holding it in the retracted position.

3. Recoiling parts are driven forward by the barrel return springs and mechanism return springs, striker frame abuts cam on camshaft to unlock breechblock from barrel extension.

4. Breechblock, unlocked, is held back by striker frame, and cam barrel and barrel extension are moved forward by the barrel return springs. Cartridge case withdrawn from chamber and held by extractor and retaining clip, breechblock to start.

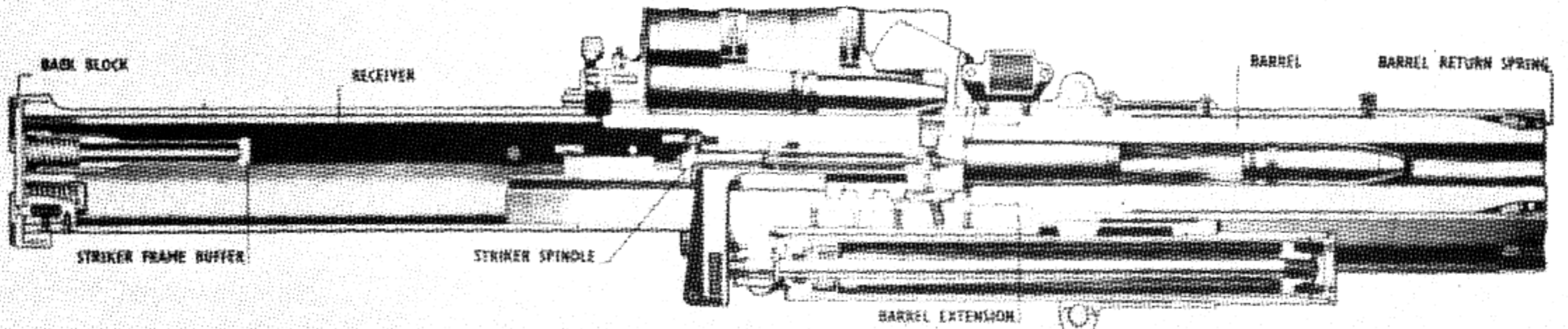
5. Lug on ejector engages ejector cam, causing ejector to rotate and push cartridge case through ejection opening.

6. Barrel extension almost home, cartridge nose deflector runs off end of barrel extension, pushing nose of next round down onto cartridge nose platform.

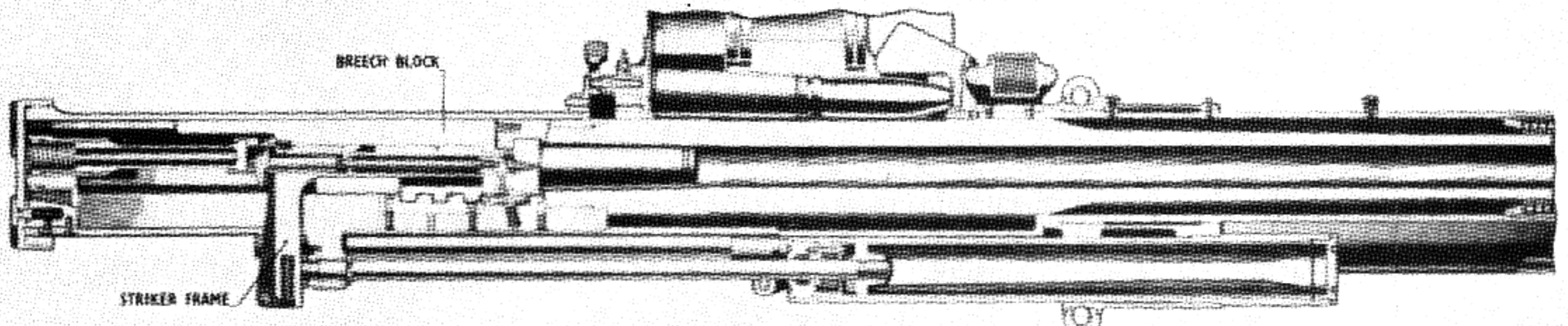
7. Ramp on barrel extension lug engages camshaft actuating lever, releasing striker frame and breechblock which are moved forward by the mechanism return springs. Front of extractor pushes round forward.

8. Breechblock raises cartridge nose deflector and pushes round toward chamber.

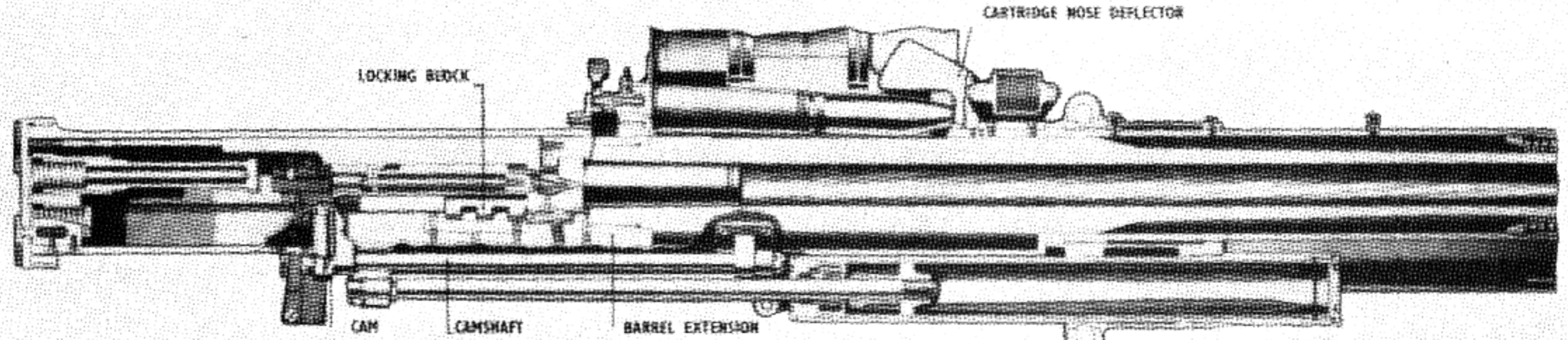
9. Cartridge rammed into chamber, breechblock abuts breech face to barrel. Striker spindle is held back by automatic sear as mechanism return



1. RECOILING PARTS IN FORWARD POSITION. BREECH BLOCK LOCKED, STRIKER SPINDLE FORWARD. GUN JUST FIRED

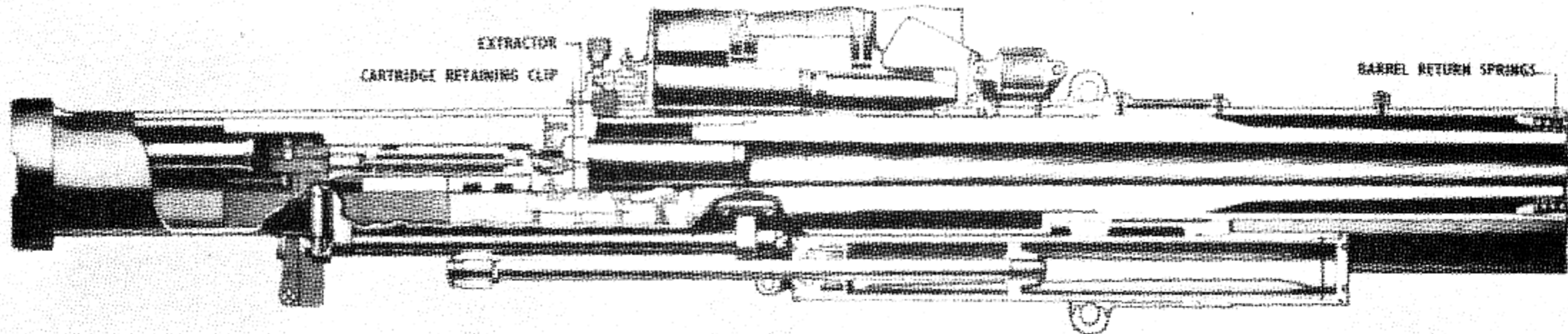


2. RECOILING PARTS IN REAR POSITION. BREECH BLOCK REMAINS LOCKED TO BARREL EXTENSION

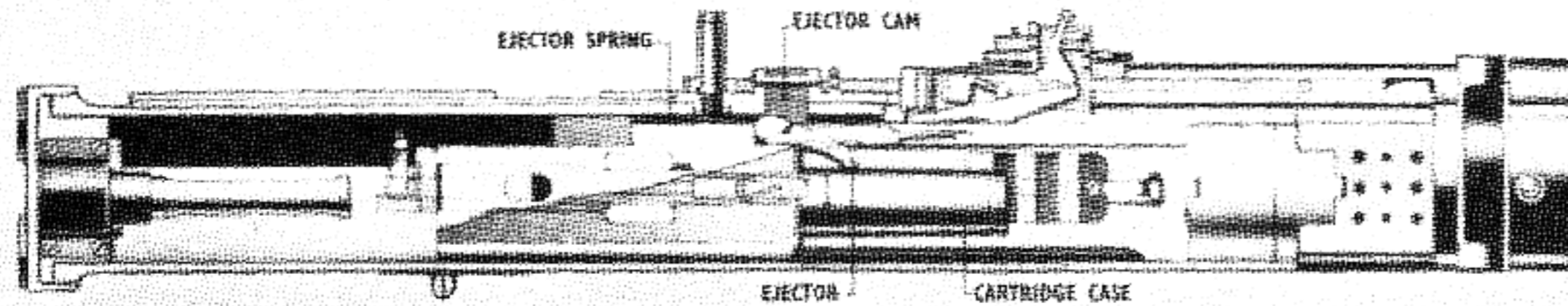


3. RECOILING PARTS ARE URGED FORWARD BY THE BARREL RETURN SPRINGS AND MECHANISM RETURN SPRINGS, STRIKER FRAME ABUTS CAM ON CAMSHAFT TO UNLOCK BREECH BLOCK FROM BARREL EXTENSION

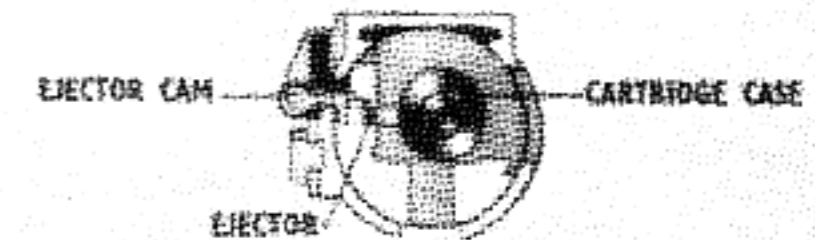
Figure 16-2. 40-mm Vickers "S" Gun. Barrel recoil phase.



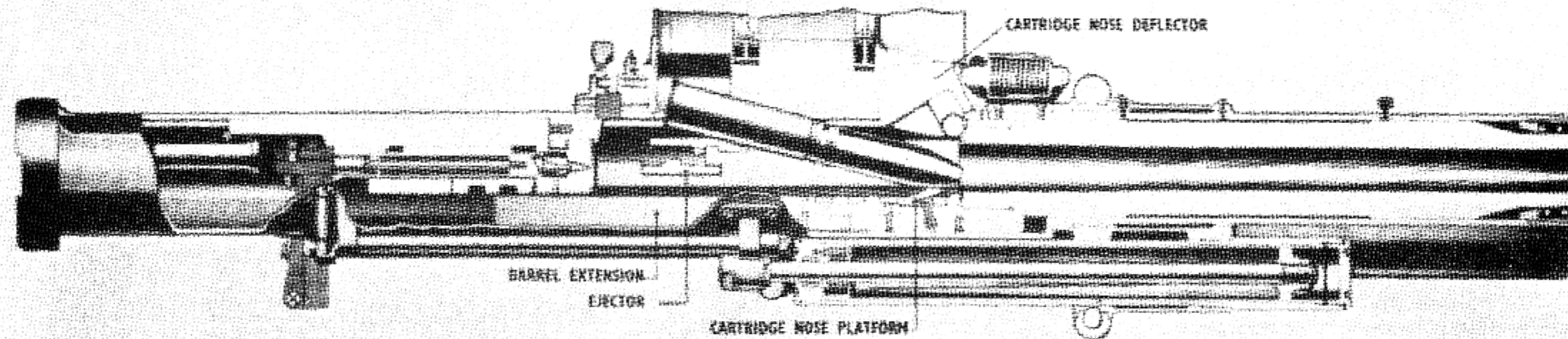
4. BREECH BLOCK, UNLOCKED, IS HELD BACK BY STRIKER FRAME AND CAM. BARREL AND BARREL EXTENSION ARE MOVED FORWARD BY THE BARREL RETURN SPRINGS. CARTRIDGE CASE WITHDRAWN FROM CHAMBER AND HELD BY EXTRACTOR AND RETAINING CLIP



5. (PLAN VIEW) LUG ON EJECTOR ENGAGES EJECTOR CAM, CAUSING EJECTOR TO ROTATE AND PUSH CARTRIDGE CASE THROUGH EJECTION OPENING.

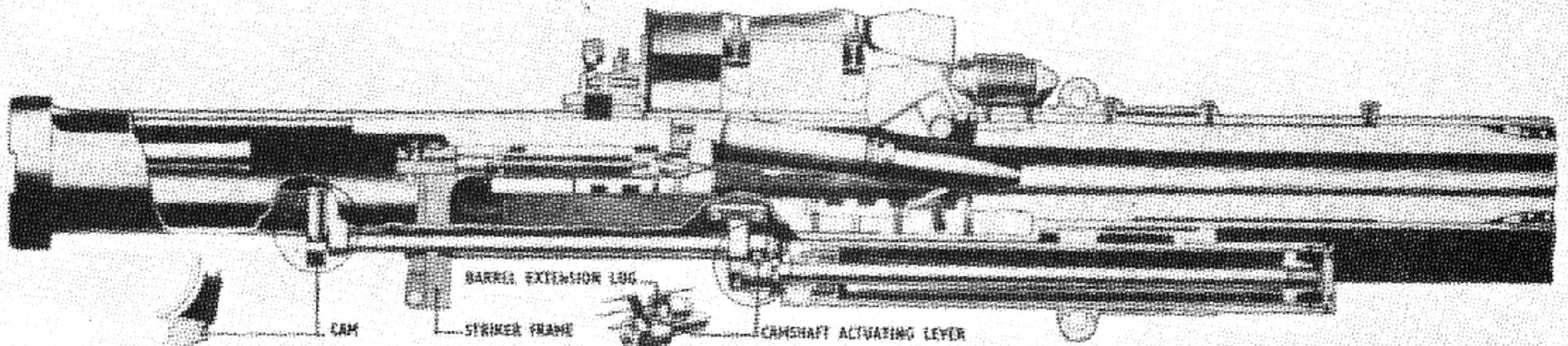


END VIEW OF EJECTOR AND CAM

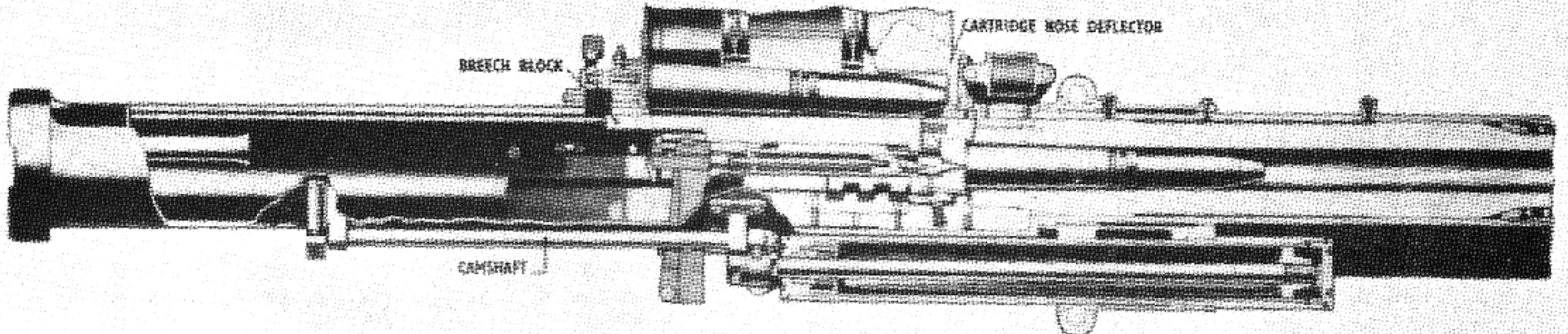


6. BARREL EXTENSION ALMOST HOME. CARTRIDGE NOSE DEFLECTOR RUNS OFF END OF BARREL EXTENSION, PUSHING NOSE OF NEXT ROUND DOWN ON TO CARTRIDGE NOSE PLATFORM

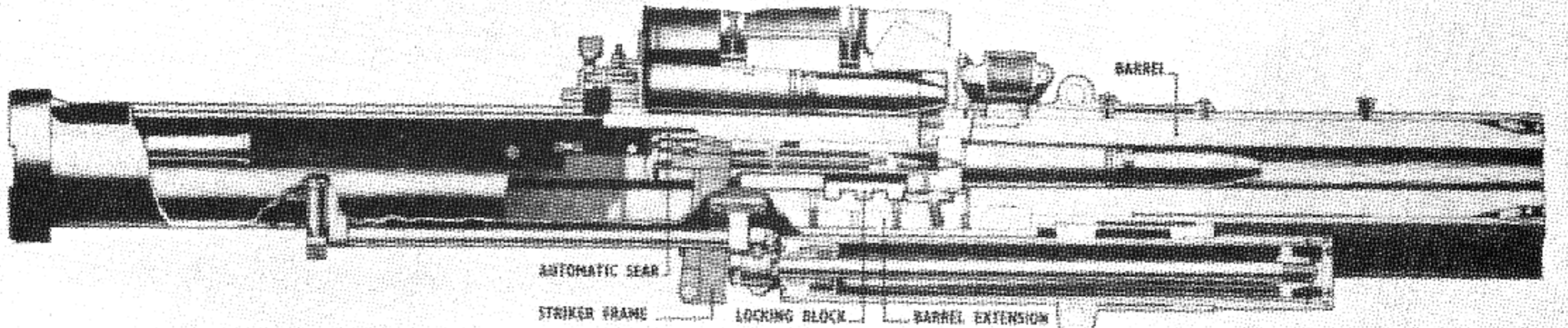
Figure 16-3. 40-mm Vickers "S" Gun. Barrel counterrecoil phase.



7. RAMP ON BARREL EXTENSION LUG ENGAGES CAMSHAFT ACTUATING LEVER, RELEASING STRIKER FRAME AND BREECH BLOCK WHICH ARE MOVED FORWARD BY THE MECHANISM RETURN SPRINGS. FRONT OF EXTRACTOR PUSHES ROUND FORWARD



8. BREECH BLOCK RAISES CARTRIDGE NOSE DEFLECTOR AND PUSHES ROUND TOWARDS CHAMBER



9. CARTRIDGE RAMMED INTO CHAMBER. BREECH BLOCK ABUTES BREECH FACE OF BARREL. STRIKER SPINDLE IS HELD BACK BY AUTOMATIC SEAR AS MECHANISM RETURN SPRINGS FORCE STRIKER FRAME FORWARD, LOCKING BREECH BLOCK TO BARREL EXTENSION

Figure 16-4. 40-mm Vickers "S" Gun. Ramming and locking action.

springs force striker frame forward, locking breechblock to barrel extension.

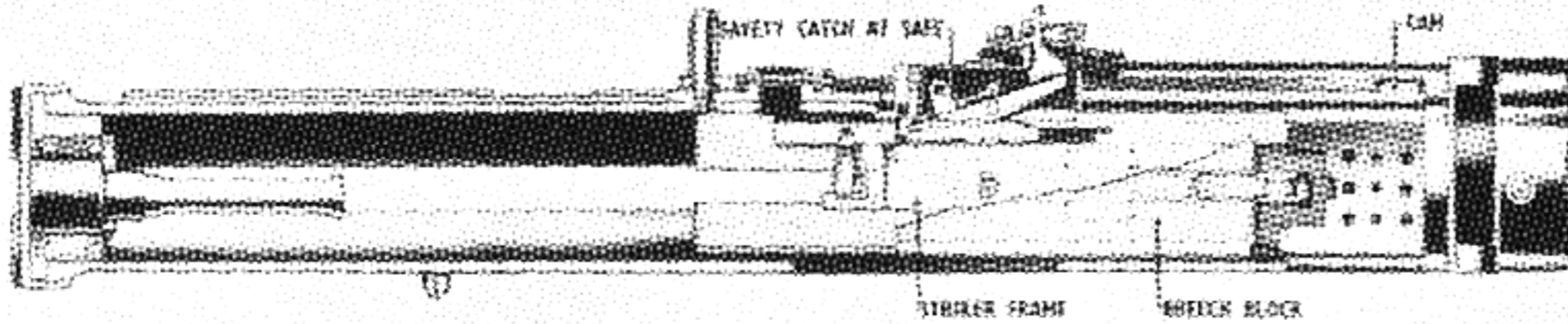
### **Action of the Sear Mechanism**

When the breechblock and striker frame move forward, the automatic sear mechanism holds the striker spindle in the retracted position. At this time, the breechblock abuts the breech face of barrel. This movement allows the striker frame to continue forward. The breechblock, which up until now has

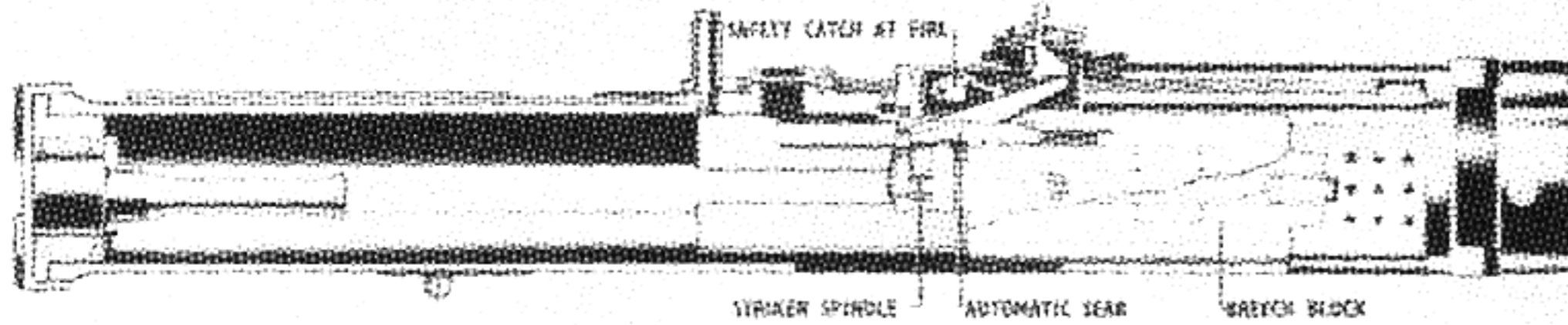
been locked to the barrel extension, starts in counter-recoil when the cam of the striker disengages the automatic sear from the striker spindle. When all operating parts have reached their furthestmost movement forward and are securely locked in the battery position, the striker spindle automatically moves forward to fire the chambered round. If the trigger remains depressed, the cycle will continue.



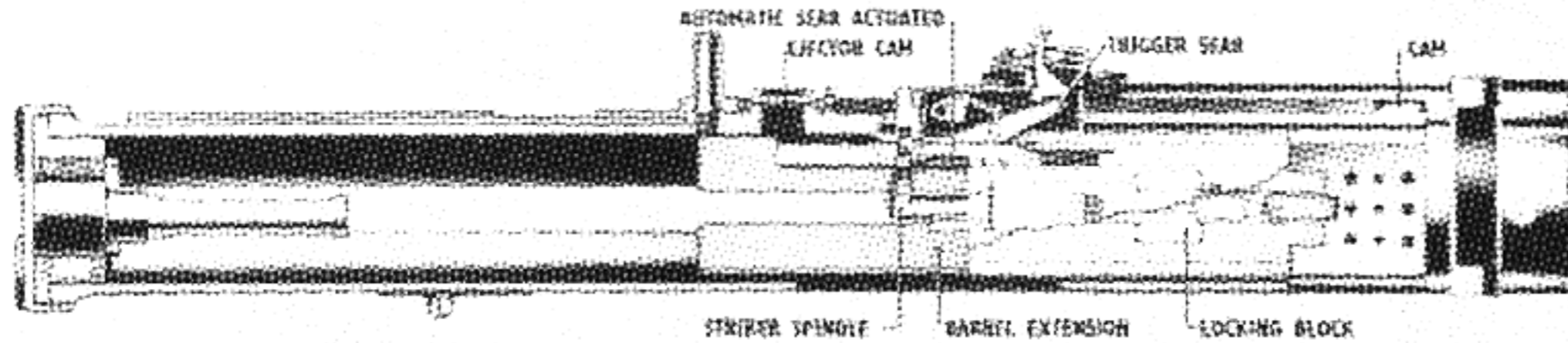
(PLAN VIEWS) ACTION OF TRIGGER MECHANISM



(A) BREECH BLOCK AND STRIKER FRAME MOVING FORWARD



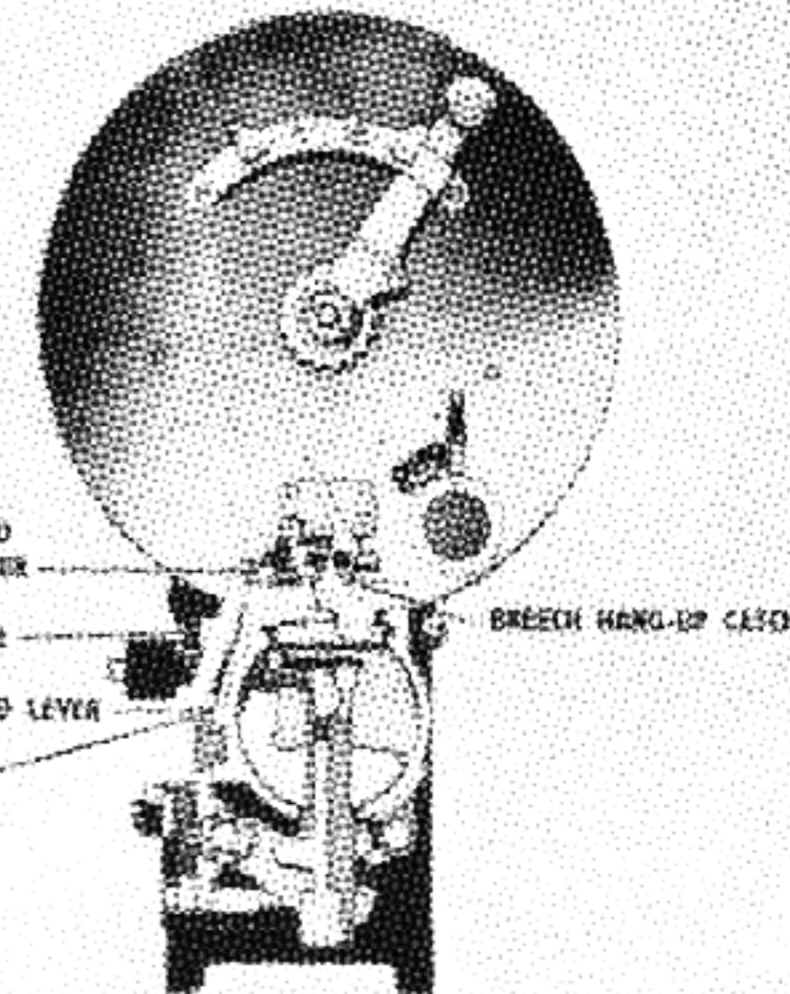
(B) AUTOMATIC SEAR HOLDS BACK STRIKER SPINDLE, BREECH BLOCK ABUTS BREECH FACE OF BARREL, STRIKER FRAME CONTINUES FORWARD



(C) BREECH BLOCK IS NOW LOCKED TO BARREL EXTENSION, CAM ON STRIKER FRAME DISENGAGES AUTOMATIC SEAR FROM STRIKER SPINDLE WHICH IS NOW HELD BACK BY TRIGGER SEAR

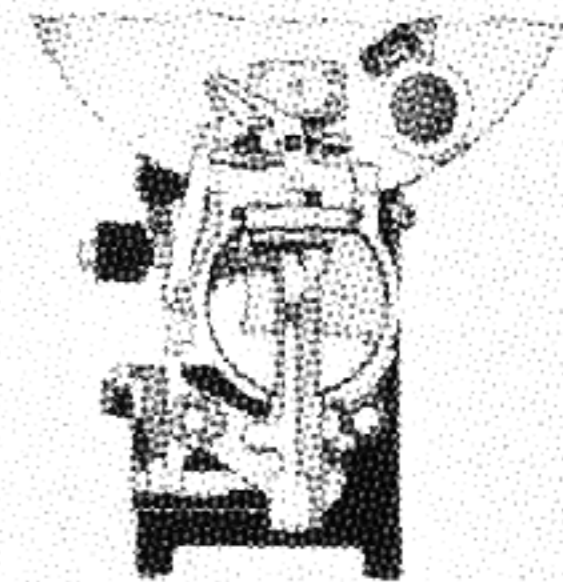


(D) TRIGGER SEAR ACTUATED BY FIRING MECHANISM, ALLOWING STRIKER SPINDLE TO MOVE FORWARD AND FIRE CARTRIDGE



SECTIONAL VIEW OF BREECH HANG-UP MECHANISM  
OPERATED POSITION

RACK PINION HAS BEEN HAND-OPERATED TO MOVE STRIKER FRAME AND BREECH BLOCK TO REAR, CAM OPERATES BREECH HANG-UP MECHANISM TO RETAIN BREECH BLOCK IN REAR POSITION



SECTIONAL VIEW OF BREECH HANG-UP MECHANISM  
NORMAL UNOPERATED POSITION

Figure 16-5. 40-mm Vickers "S" Gun. Searing.

## Chapter 17

**57-MM BRITISH AUTOMATIC AIRCRAFT CANNON****SECTION 1. DESCRIPTION OF THE WEAPON****General Description**

The weapon known in British Army circles as the 6-pounder class M gun was developed originally from the standard 6-pounder antitank gun, which is normally loaded and fired manually by a gun team. In order to increase the rate of loading and hence the rate of fire, the British Army initiated the development of an automatic feed and firing system by Messrs. Molins Machine Co., Ltd. The final and official designation of the weapon is O. Q. F. 6-pounder class M Mark I with automatic loader Mark III. It is also known unofficially by the British as the TSE-TSE 57-mm gun. This high-velocity weapon was subsequently used in the Mosquito installation.

Before this cannon went into British Army service use, the British Air Staff set up a requirement for a weapon of at least this caliber for use in aircraft against submarines, and it was decided to continue development of an existing and proved firing system with that end in view.

The principle of the gun follows the orthodox light artillery practice whereby the gun barrel recoils in a fixed chassis, which is rigidly attached to the gun carriage.

The recoil system consists of a hydraulic cylinder and a recoil spring for returning the piece after recoil, and the breechblock slides vertically downward on opening for ejection of the empty case.

The feed system consists of an electrically driven transporter mechanism which conveys vertical con-

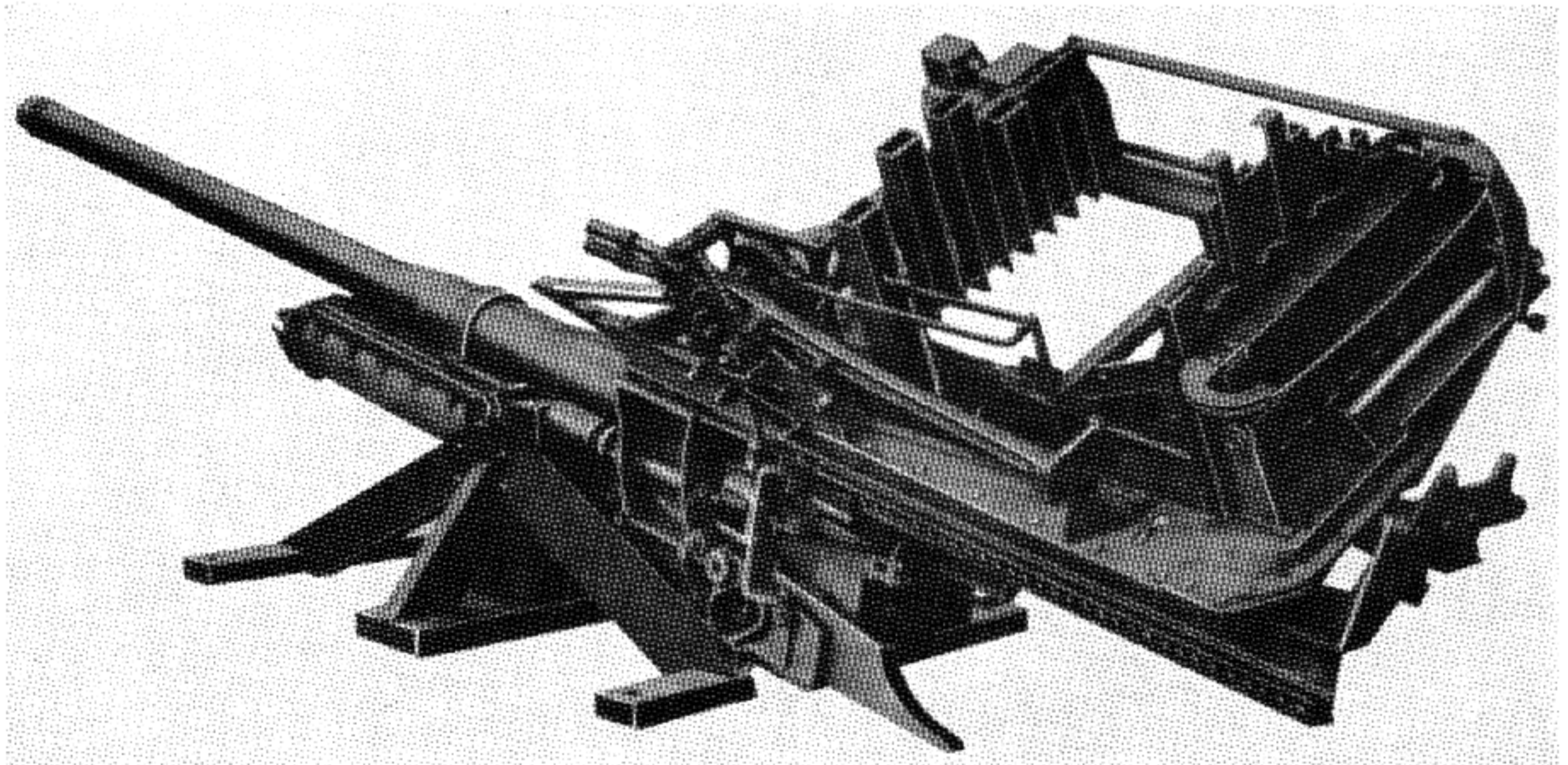


Figure 17-1. British 57-mm Automatic Aircraft Cannon. Left rear view.

secutive banks of cartridges to a position above the breech opening.

The cartridges in the first bank are pressed down by a spring-loaded arm; and when this row has been fired, the arm is lifted by cams while the next bank is transported to a position above the breech opening.

The semiautomatic arrangements of the basic gun provide for the opening of the breech and the ejection of the empty cartridge case toward the end of runout; and the closing of the breech after the round has been loaded. The opening of the breech compresses an actuating spring, against the reaction of which the breechblock is held by the extractors. When a round is loaded, the rim of the cartridge case engages the extractors and disengages them from the breechblock and the actuating spring closes the breech.

The firing mechanism consists of a percussion striker which is automatically cocked as the breech opens. Firing is effected by a lever mounted on the side of the gun which is operated by a solenoid.

The solenoid circuit is completed through a main switch and the pilot's firing button.

The gun is secured to the slipper by two bolts. The slipper slides along the top of a cradle, recoiling with the gun to a normal length of 30 inches. The recoil distance is controlled by a hydraulic buffer and a single bank recuperator spring, the latter returning the gun to the firing position. The buffer and recuperator are situated in the cradle beneath the gun.

The automatic loader is mounted above the rear of the gun and, after the breech has been opened by the semiautomatic gear, loads a round which releases the extractors and allows the actuating spring to close the breech. The first round, however, must be loaded into the gun by hand, but after this has been fired, the energy of recoil and runout along with power from an electric motor provide the necessary motive power for operating the loader. When the firing button is pressed, the first round is fired and the gun is reloaded. For a single shot, pressure on the button must be released

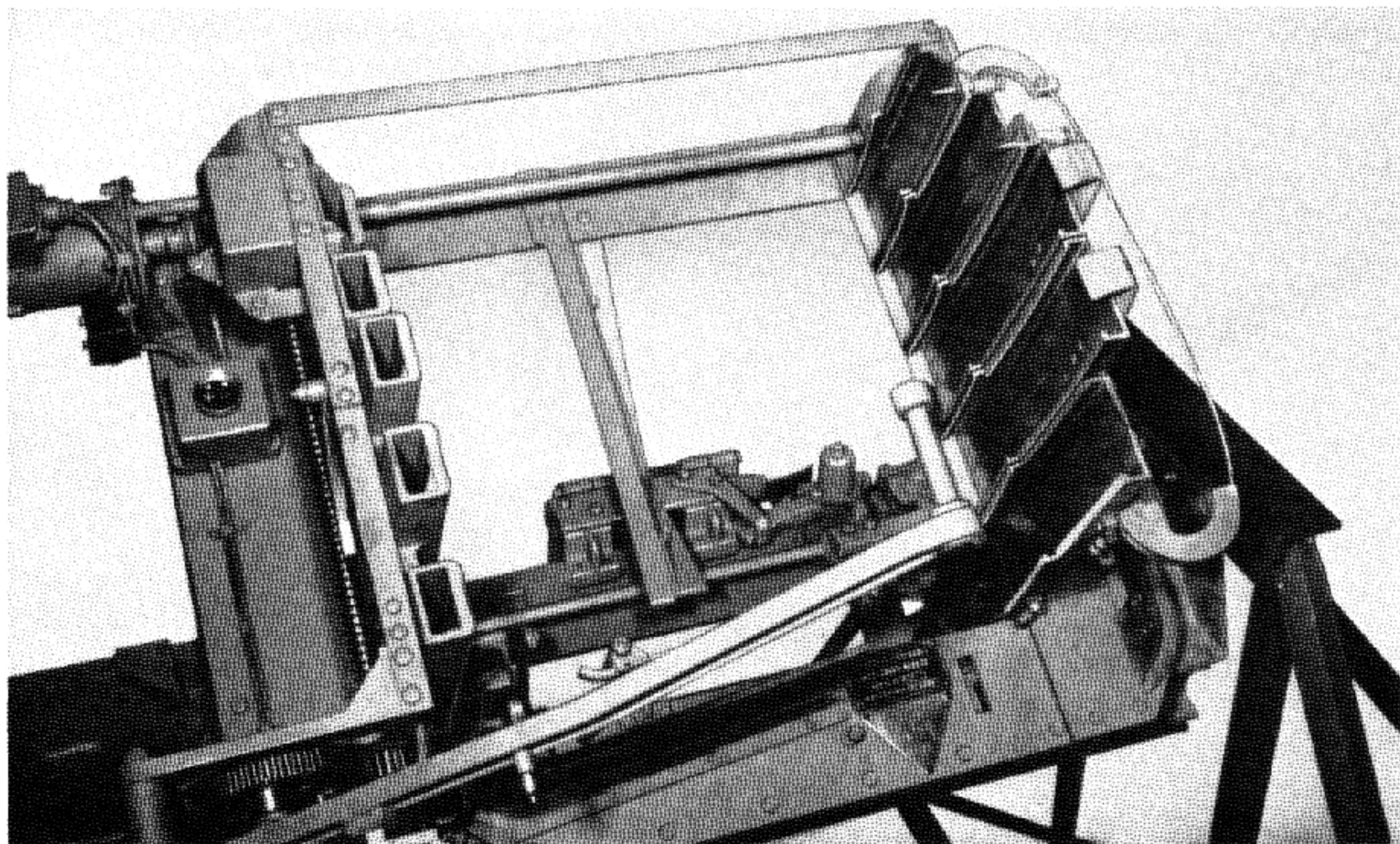


Figure 17-2. British 57-mm Automatic Aircraft Cannon. Closeup view of automatic loader, empty.

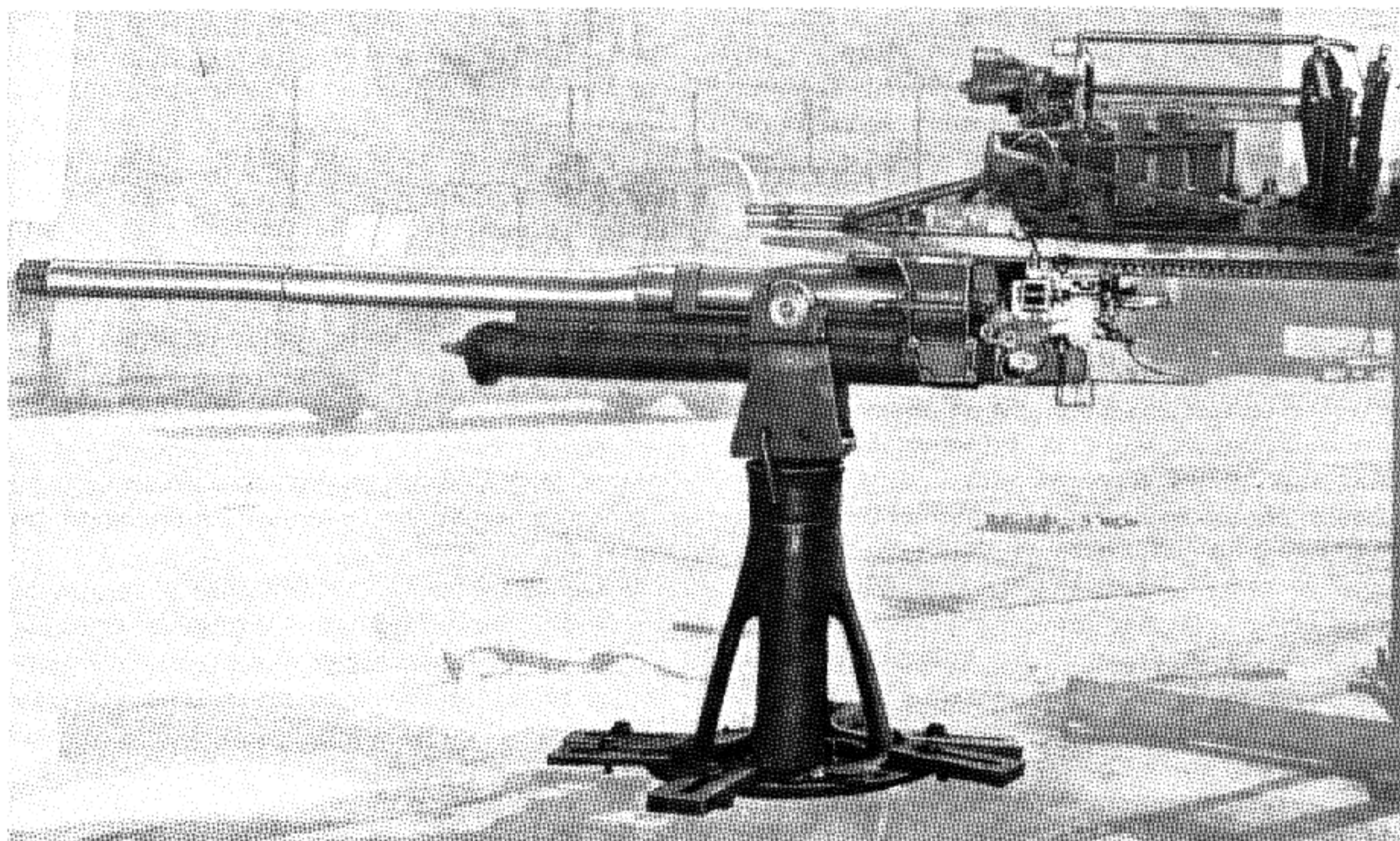


Figure 17-3. British 57-mm Automatic Aircraft Cannon on a test mount at U. S. Naval Air Test Center.

promptly. Automatic bursts can be fired by maintaining the pressure on the firing button. The gun will cease firing with a round in the chamber as soon as the firing button is released, or with the breech open when the ammunition is expended.

The principal parts of the gun are: gun body; gun slipper; cradle; recoil and recuperator systems; semiautomatic gear; breech mechanism; automatic loader.

*Gun Body.* The gun body consists principally of a barrel, breech ring, and muzzle recoil brake.

**BARREL.** The barrel is either an auto-fretted or a high-tension steel forging, prepared internally for most of its length with polygroove, plain section rifling, at the rear of the rifling being a coned chamber for the cartridge case. On the outside of the barrel at the rear, guides are formed to locate it in the gun slipper and a screw thread is cut for the breech ring. Two pockets are cut in the rear face of the barrel for the extractors. At the muzzle is a screw thread for the muzzle recoil brake which may or may not be fitted when the gun is mounted in an aircraft.

**BREECH RING.** The breech ring is a rectangular shaped block which screws on to the rear end of the barrel and is secured by a screw. A vertical mortice is cut in the breech ring for the breechblock to slide in. On each side of the mortice are inclined guideways to accommodate corresponding guides on the breechblock. A transverse hole is bored through the bottom of the breech ring for the breechblock actuating shaft, bronze bearings being fitted to provide bearings for the shaft. Clearances are cut in the front inside face of the mortice for the crank and extractors, and a stop face is provided to limit the downward movement of the crank on opening the breech.

A slot is cut in the left-hand side of the breech ring and two threaded holes are provided for securing the left-hand register plate of the automatic loader. In the right-hand side, there are a dovetailed slot and two threaded holes for securing the actuating spring case, and a slot and four threaded holes for the rammer lifting cam. Two threaded holes are provided in the top of the breech ring for

securing the rammer lifting cam and five for securing the cam track of the automatic loader.

A firing lever support plate is secured to the rear face of the breech ring by four screwed studs. Above the support plate is a stop stud for the firing lever and below it a firing lever axis stud.

Two holes are bored in the front of the breech ring, one on each side, the holes being threaded for the bolts which secure the gun to its slipper. The bolts are prevented from turning by spring washers.

*Gun Slipper.* The gun slipper, or chassis, consists of a number of steel plates welded together to form an elongated block and furnished with a base plate. Six bronze liners provided with lubricating grooves are secured, three on each side of the block, by screws and rivets. Formed on the upper part of the slipper are two circular bands which accommodate the gun, the rear band being provided with two guideways to accommodate the guides on the gun and prevent this from turning. On each side of the rear band a hole is bored for the bolts which secure the gun to the slipper. A lug having a cylindrical hole is formed on the under side of the rear band for the reception of the buffer cylinder which is prevented from turning by a feather and featherway. The gun slipper slides in guideways on the top of the cradle. The ingress of dirt to the cradle guideways is prevented by steel cover plates with leather packing strips, the cover plates being secured to the slipper by screws and rivets.

*Cradle.* The cradle is a built-up structure consisting of a tubular-shaped steel case to which the various component parts are welded. Along the top of the case are two slipper guides, one on each side, the guides being prepared with guideways to receive the gun slipper. Inside the case are left and right slides which accommodate the guide keys of the runout springs compressor, and support the buffer and recuperator during the recoil and runout.

Six lubricators are provided for lubricating the slipper guides and four for the left and right slides. Near the middle of the case and toward the rear a trunnion band with brackets and trunnion arms is welded, the trunnions providing mounting points for the gun in the aircraft.

At the rear of the case, a transom bracket is welded, the left-hand side of which is prepared to receive the semiautomatic cam bracket. The rear of the case is partially closed by a steel ring which

is welded to the transom bracket and forms a rear bearing for the buffer and recuperator. A bearing face ring of bronze, with an asbestos pad interposed, is secured to the rear of the steel ring by six screws. The pad absorbs the shock at the end of runout, forming a stop face for the lug on the underside of the gun slipper.

To the front of the case is riveted a band which has three sets of hinge lugs, the lugs being provided with a belt arrangement which secures the cradle front cap. The front cap has a central hole for the buffer piston rod which is secured by a nut and split pin and prevented from turning by corresponding flats. A hinged inspection cover on the side of the front cap gives access to the piston rod stuffing box gland.

*Recoil and Recuperator Systems.* These systems absorb the energy of recoil. The recuperator system returns the gun to the firing position and retains it there. The system is housed and supported within the cradle and is attached to the gun through the medium of the gun slipper.

The recoil system comprises a hydraulic buffer which consists of a steel cylinder, stuffing box, rear plug with runout adjusting valve, and piston.

The recuperator system consists of three runout springs, a buffer cylinder bushing, and a runout springs compressor.

**BUFFER CYLINDER.** The buffer cylinder is attached at the rear to the lug on the underside of the gun slipper, an integral collar on the front and a nut at the rear holding the cylinder in place, while a key engaging a keyway in the slipper prevents the cylinder from turning. The collar also enables the runout springs to be compressed when the system is not assembled in the cradle. Externally at the front and for the greater part of its length the buffer cylinder has a square-cut screw thread for the attachment of the runout springs compressor. Five longitudinal grooves are cut inside the cylinder for the passage of oil. These grooves are equally spaced but vary in depth so as to regulate the flow of oil past the piston head. The rear end of the cylinder is screw threaded internally for the rear plug, and the front end for the stuffing box. In addition, the front end has four spanner slots.

**STUFFING BOX.** The stuffing box screws into the front end of the buffer cylinder, a liquid-tight joint being made by a soft copper washer. A flange at

the front of the stuffing box has six spanner slots cut in it, one of these slots being engaged by a key attached to the runout springs compressor to prevent the stuffing box from turning after it has been assembled. Internally at the rear the stuffing box accommodates an L-shaped piece which is retained by a screwed bronze collar. In front of the L-shaped leather gasket and supported by a bronze packing collar on each side, is a compressed packing ring of asbestos. Holes are drilled in the packing collars to facilitate withdrawal. Screwed into the front of the stuffing box is a bronze gland which compresses and retains the packings. Six spanner slots are cut in the gland for the application of a spanner.

The rear plug screws into the rear of the buffer cylinder, a liquid-tight joint being made by a soft copper washer. The rear plug accommodates a filling hole plug, an air plug, and a runout adjusting valve. Screwed into the front of the rear plug and secured by a setscrew, is a steel cylinder into the front of which is screwed a bronze throttle bushing. The cylinder and bushing form a control chamber. The bushing also forms a bearing for the piston rod and is secured by a setscrew. An external flange at the front of the throttle bushing supports the bushing in the buffer cylinder, the bushing having six equally spaced slots to allow for the passage of oil.

**REAR PLUG.** The filling hole plug screws diagonally into the rear plug and closes a longitudinal hole which leads to the rear plug cylinder. A liquid-tight joint is made by a fiber washer.

The air plug screws into a hole in the right rear face of the rear plug, a liquid-tight joint being made by a fiber washer. When the air plug is partly unscrewed, a hole in the front face communicates with a radial hole in the rear plug and allows air to escape.

**RUNOUT ADJUSTING VALVE.** This valve consists of a spindle with valve head and gland and fits into a prepared hole in the top center of the rear plug. The spindle passes through round greased packing, which fits between two bronze neck valve rings held in position by a bronze valve gland screwed into the rear plug. Near the center of the spindle are screw threads which engage corresponding threads in the rear plug and permit adjustment, and near the front of the spindle is an integral collar on which are three flats to allow the oil to escape past

the valve. A central hole is bored in the spindle from the front to accommodate a spigot on the valve head. A hole is bored in the spindle behind the collar for a locking wire which secures the valve head to the spindle. The valve head is coned at the front and is formed with a spigot at the rear. Around the spigot is cut a cannelure for the locking wire which secures the valve head to the spindle, but allows the spindle to rotate independently of the valve head.

A valve locking plate, which is secured by a split pin, fits over the rear end of the runout adjusting valve gland and air plug, preventing them from turning when assembled.

**PISTON.** The piston consists of a steel rod and head. The piston rod is reduced in diameter at the front and is screw-threaded for a nut which secures it to the cradle front cap, the nut being secured by a split pin. On the reduced portion, behind the thread, is a flat which engages a corresponding flat in the hole in the cradle front cap and prevents the piston rod from turning. Toward the rear of the rod is a flange against which the piston head is secured by a nut. The rear end of the piston rod is reduced in diameter to form a control plunger, the end being tapered to facilitate entry through the throttle bushing of the rear plug cylinder. A tapering flat cut on the control plunger regulates the flow of oil and controls the runout of the gun.

To facilitate filling the buffer when the gun is mounted in the aircraft, an air plug has been fitted in the front end of the piston rod. The piston rod is bored and threaded to receive the plug, and a longitudinal and radial hole are provided to communicate with the buffer cylinder.

**RUN-OUT SPRINGS.** These springs are generally rectangular in section having a free length of 25.5 inches and consist of 2 left-hand-wound and 1 right-hand-wound springs. They are assembled over the buffer cylinder with the right-hand-wound spring in the midposition. Steel parting plates are situated between each spring to prevent them from interlocking and at each end to form bearing plates, the four plates being interchangeable.

**BUFFER-CYLINDER BUSHING.** This L-shaped bronze bearing is situated on the buffer cylinder between the rear spring bearing plate and the steel ring in the rear transom bracket of the cradle.

The runout springs compressor is cylindrical in shape and is prepared with internal square-cut threads to engage those on the buffer cylinder. Screwed and sweated, or sometimes welded, to the front end is an enlarged head having four slots to accommodate a spanner. Integral with the head and diametrically opposite to each other are 2 projections to which 2 guide keys are riveted. A stuffing box key is secured to the right projection by a screw. The guide keys engage the guideways in the cradle and, in addition to preventing the compressor from turning, form a support for the front end of the buffer cylinder.

*Breech Mechanism.* The breech is closed by a vertical sliding block which is accommodated in the mortice in the breech ring. The breech is opened automatically as the gun runs out and is held in the open position by the extractors against the reaction of a spring. The loading of a round releases the extractors and allows the spring to close the breech. Carried in the breechblock is a percussion striker which is automatically cocked by the opening of the breech. The striker is released by a firing lever which is operated by a solenoid.

The following are the principal parts of the breech mechanism: breechblock; breechblock operating mechanism; extractors; striker mechanism; firing mechanism.

**BREECHBLOCK.** The breechblock is rectangular in shape and has two inclined guides, one on each side, which mate with the inclined grooves in the breech ring and cause the breechblock to move forward slightly on closing to seat the cartridge case in the chamber. When the gun fires, the shock is taken on the guides. Stops are formed at the bottom of the guides to limit the upward movement of the breechblock.

Screwed into the front face of the breechblock, and secured by a fixing screw, is a firing-hole bushing. The front face of the firing-hole bushing when it is home is flush with the face of the breechblock. The top of the front face of the breechblock is beveled to push the cartridge into the chamber as the breech closes. On each side of the bevel are inclined recesses forming stops to engage hooks on the extractors and hold the breechblock in the open position. The bottom of the front face is relieved to clear the extractor lugs, an inclined surface and shoulder being formed at the top of the relieved

portion to actuate the extractors on opening the breech. Above the shoulders, the sides of the front face are cut away to allow the extractors to operate.

A slot is cut in the front of the breechblock at the bottom to form a crank recess. Above the crank recess and extending through the block is cut a recess for the cocking link, a guideway being cut at the top of the recess for a guide on the cocking link. The front of the cocking link recess is concentric with the axis of the crank when the breechblock is closed, permitting an idle movement of the crank after it has raised the breechblock to the closed position and before it commences to open the breech.

The breechblock is bored and recessed behind the firing hole bushing to accommodate the striker mechanism, interrupted thrust collars being formed at the rear to engage similar collars on the striker case and hold the striker in position. On the right of the striker recess is a radial groove, the bottom of the groove being inclined to accommodate the striker case retaining plunger during assembly. At the top of the recess is a hole which receives the end of the retaining plunger to retain the striker in position. Above the striker recess and extending to the left is a second radial groove which provides a clearance for the end of the safety catch plunger during assembly. A small recess is cut in the left of the rear face of the breechblock to clear a flange on the firing lever, permitting the firing lever to rotate and engage the striker sear only when the breech is closed.

The top of the breechblock is shaped to conform to the bottom of the chamber and provides a shell guide. In the front is cut a dovetailed recess in which is fitted a retaining piece to prevent the round from rebounding beyond the front face bevel after it has been loaded. The retaining piece is held in position by a spring-loaded plunger accommodated in a hole in the top of the breechblock. On each side of the top of the block, slots are cut to accommodate left-hand and right-hand packing plates which are secured by screws and project to the rear to form shell guides. The screws are secured by center punching. To the outside of the left-hand packing plate is welded a stop piece which disengages the locking lever from the firing lever when the breech is closed.

**BREECHBLOCK OPERATING MECHANISM.** The breechblock operating mechanism consists of an

actuating shaft, crank, striker cocking link, rack pinion, actuating shaft sleeve, spring case, rack, and breechblock actuating spring.

The actuating shaft is mounted in bearings formed in the underside of the breech ring, being retained in position by a slotted nut and split pin at its right-hand end. The left-hand end of the actuating shaft is cranked and carries a roller which engages the semiautomatic cam and breech cam on runout. Cut along the shaft for the greater part of its length are three feather ways which engage feathers on the crank, actuating shaft sleeve, and the rack pinion. The key ways are unequally spaced to insure correct assembly.

The crank is mounted on the actuating shaft to which it is feathered and operates in the recess in the breechblock. The upper end of the crank arm is forked to accommodate the striker cocking link. On the outside of the fork, lugs are formed to engage the upper and lower surfaces of the cocking link recess and raise or lower the breechblock, depending upon the direction of rotation of the actuating shaft. The tops of the lugs are flat and bear against the concentric portion of the recess to retain the breechblock in the closed position. The downward movement of the breechblock is limited by a boss on the crank contacting the breech ring.

The striker cocking link is rectangular in shape and has a guide on the top to engage the groove in the breechblock. At the rear of the guide is a projection which engages the striker cocking sleeve. At the front of the cocking link is a projection in which an elongated hole is cut for attachment to the crank fork by an actuating pin which is passed through the fork from the right. The elongated hole permits the striker to be withdrawn before the crank commences to open the breech and allows the crank link to continue to move after the breechblock has been closed.

The rack pinion is mounted on the right-hand end of the actuating shaft to which it is feathered. It is retained in position by the actuating shaft nut. Five teeth are cut on the outside of the pinion to engage corresponding teeth on the rack. A hole is bored in the rack pinion to enable a tommy bar to be applied for hand opening of the breech.

The actuating shaft sleeve and collar are mounted on the shaft between the rack pinion and the right-hand extractor and act as distance pieces.

The spring case is of bronze and is dovetailed to the right-hand side of the breech ring, being secured in position by two screws. The upper end of the case is screw-threaded internally for the spring case cap which, when screwed up, applies initial compression to the actuating spring, a disk being interposed between the spring and the cap. A check screw prevents the cap from turning. At the bottom, the case is cut away to allow the rack pinion to engage the rack.

The rack is accommodated in the bottom of the spring case, teeth being cut on it to mate with those of the rack pinion. The upper end of the rack has a small spigot which serves to center the actuating spring in the spring case.

The breechblock actuating spring is spiral in form, initial compression being applied by the cap and further compression by the action of the rack pinion and rack, when the former is rotated by the actuating shaft on opening the breech.

**EXTRACTORS.** The extractors are mounted, one on each side of the crank, on the actuating shaft about which they pivot. They are left handed, otherwise they are similar. The upper end of each extractor lever has a lip to engage the rim of the cartridge, and below the lip a hook is formed to engage the stops at the top of the breechblock when the breech is open. The lower end of the extractor is enlarged and has a hole bored through it for the actuating shaft. In rear of the hole is a lug which operates on the inclined surface and against the shoulder on the breechblock to unseat and eject the cartridge case.

**STRIKER MECHANISM.** The striker mechanism consists of a striker case with trigger sear, retaining catch, and safety catch; striker spindle with firing pin and main spring; cocking sleeve and cocking handle.

The striker case is in the form of a block with a front tubular extension, and is suitably bored and machined to accommodate the remainder of the mechanism. Accommodated in the top of the case are two rollers, which facilitate easy action of the trigger sear. Behind the rollers a slot is cut to accommodate the trigger sear, the right-hand end of the slot being closed by the trigger sear spring seat which is retained by a split pin. A hole is bored through the case on the left for the safety catch, a vertical hole being bored for the safety catch re-



taining pin. On the right is a hole for the striker retaining catch plunger. A hole is bored through the block and the tubular extension for the striker spindle, the tubular extension being counterbored to accommodate the main spring. Above the hole for the striker spindle is a rectangular slot in which the cocking sleeve operates. To the left of this slot is a safety catch stop. The top of the case is closed by a plate to which is welded a block, the top of the block being curved to conform to the contour of the top of the breechblock, thus forming an extension of the shell guide. At the rear of the tubular portion, interrupted thrust collars are cut to mate with those in the rear of the breechblock and hold the striker in position.

The trigger sear is in the form of a small bar and slides transversely in the top of the striker case, friction being reduced by the rollers. The rear face of the trigger sear has a recess cut in it to form a stop face to engage the cocking sleeve and hold the striker in the cocked position. The recess terminates in a slot which allows the cocking sleeve to move forward on firing. The right-hand end of the trigger sear is recessed to accommodate one end of the trigger sear spring, the other end of the spring being accommodated in the trigger sear spring seat which is pinned to the striker case. The left-hand end of the trigger sear is enlarged to form a bearing for the firing lever and to limit the stroke of the trigger sear.

The retaining catch consists of a spring-loaded plunger and is prevented from turning in the striker case by a feather and featherway. To the rear of the plunger is taper-pinned a head which has a lug to form a finger grip. When the striker is assembled in the breechblock, the plunger engages the hole in the rear of the block and prevents disengagement of the thrust collars.

The safety catch consists of a spindle, on the outer end of which is formed a head. Accommodated in the head is a small spring-loaded plunger which is retained by a split pin. The inner end of the plunger engages one of the two small recesses in the rear of the striker case to retain the safety catch in the SAFE or FIRE position, a finger piece being welded to the head to facilitate operation. The inner end of the spindle is shaped to prevent the striker from being removed unless the safety catch is set to SAFE. On the spindle is a flat which permits operation of the trigger sear when the catch is set

to FIRE, while the rounded portion of the spindle prevents movement of the trigger sear when the catch is set to SAFE. A groove at the rear of the spindle accommodates the retaining pin.

The striker spindle has an integral head which forms a bearing for the main spring. Two slots are cut in the head to form gas-escape channels, and the front of the head is recessed to accommodate the firing pin which is retained by a staple. The spindle is prevented from turning by being keyed to the cocking sleeve, and its rear end is threaded for the cocking handle.

The main spring is accommodated on the striker spindle and bears between the head of the spindle at the front and a shoulder formed inside the tubular portion of the striker case at the rear.

The cocking sleeve fits on the rear of the striker spindle where it is retained by the cocking handle. On the front of the sleeve are two arms, the upper of which engages the trigger sear and the lower the cocking link. The upper arm passes through the rectangular recess in the striker case and is relieved to clear the trigger sear on firing. The lower arm bears against the underside of the striker case and prevents the cocking sleeve from turning.

The cocking handle screws on to the end of the striker spindle, serves as an assembly nut, and places the main spring under initial compression. A cross handle enables the striker to be recocked in the event of a misfire, when firing is taking place on the ground.

**FIRING MECHANISM.** The firing mechanism consists of a firing lever, locking lever, bell-crank operating lever, and firing-lever support plate.

The firing lever is pivoted on an axis stud which is screwed into the breech ring on the left of the mortice, the lever being held in position by a slotted nut and split pin. A flange is formed on the side of the lever to prevent it from being operated until the breechblock is closed when a recess in the block is opposite the flange. An upper arm of the lever is enlarged and bored to accommodate a spring-loaded plunger which engages a stop stud on the breech ring and returns the firing lever to its normal position after firing. The right-hand end of the arm engages the trigger sear, and the left-hand end carries a roller which is engaged by the bell-crank operating lever. A recess in the underside of the arm accommodates a flange on the top of the sup-

port plate, which steadies the firing lever and limits its movement.

The locking lever is mounted on an extension on the firing lever roller axis and projects through a slot in a bracket which is attached to the left-hand round guide of the breech ring. When the breech is open, the locking lever engages the bottom of the slot; in this position the locking lever is held by a spring and prevents operation of the firing lever. When the breech is closed, the locking lever is lifted clear of the slot by a stud on the left-hand packing plate.

The bell-crank operating lever pivots between projections which are welded to the left-hand register plate of the automatic loader. The rear arm of the bell-crank lever engages the roller of the firing lever, and the front arm is engaged by the release lever of the firing solenoid when the gun is in the firing position.

The firing-lever support plate is held in position by four screwed studs and supports the upper arm of the firing lever. The studs project to the rear and are provided with integral distance pieces. Mounted on the outer ends of the studs is a block which carries a left-hand round guide. This guide projects to the rear and provides an extension to the breechblock left-hand packing plate. The locking lever bracket is welded to the round guide.

*Semiautomatic Gear.* The semiautomatic gear is mounted on a cam bracket, which is bolted to the left-hand side of the cradle rear transom. It consists of a semiautomatic cam, breech cam, and breech cam plunger and spring. The semiautomatic gear opens the breech during runout and assists in closing the breech after the gun has been loaded.

**SEMIAUTOMATIC CAM BRACKET.** The semiautomatic cam bracket is keyed to the rear cradle transom and is secured by four bolts and, in addition to carrying the semiautomatic gear, it provides a support for the magazine support. A slot is cut in the top of the cam bracket to receive the magazine support which is secured by bolts. A slot is cut in the cam bracket near the bottom to facilitate removal of the breech mechanism actuating shaft. On the outside of the semiautomatic cam bracket near the rear is a small projection to which the lower end of the firing solenoid bracket is secured and on the inside at the bottom is a stop for the gun.

**SEMIAUTOMATIC CAM.** The semiautomatic cam is mounted on a pivot on the inside of the cam bracket and projects to the rear. The end of the cam is suitably curved on its upper surface to engage a roller on the breech mechanism actuating shaft during runout and to open the breech. The front of the semiautomatic cam is cut away on the inside to allow the actuating shaft roller to rotate during hand operation and also when the breech is closing. Downward movement of the rear of the semiautomatic cam is limited by the stop on the cam bracket. During recoil, the semiautomatic cam is lifted off the stop by the actuating shaft roller which travels along the under side of the cam. When the roller is clear, the semiautomatic cam is returned to its position on the stop by the breech cam plunger spring.

**BREECH CAM.** The breech cam is mounted on a pivot on the inside of the semiautomatic cam bracket in front of the semiautomatic cam and projects to the rear above this cam. In its normal position, the rear of the breech cam bears on the semiautomatic cam, contact being maintained by the breech cam spring plunger which bears against a projection on the breech cam near the pivot. When the actuating shaft roller lifts the semiautomatic cam, the breech cam spring is further compressed and returns the components as soon as the roller is clear. When the roller rides along the top of the semiautomatic cam on runout, it passes under the breech cam and lifts this to further compress the breech cam spring, the reaction of the spring assisting to close the breech.

**BREECH CAM SPRING AND PLUNGER.** The breech cam spring and plunger are housed in a tube which is mounted in the semiautomatic cam bracket. The plunger head projects to the rear and bears against the breech cam, the spring bearing between the plunger head at the rear and the inside of the tube at the front. On the front of the plunger is a spacer and nut which secure the plunger and enable initial compression to be applied to the spring.

*Buffer Pump.* The pump for use in filling the buffer consists of a base, suction valve and hose, delivery valve and hose, barrel, and plunger with rod and handle.

The base is a casting which has two bars hinged to it for the operator to stand upon. In the center of the base is an opening to accommodate the lower

end of the barrel, both barrel and base being bored to form seatings for the suction and delivery valves. The base is prepared with nozzles which are screw threaded externally for the attachment of the suction and delivery hoses. Protecting caps are provided for the nozzles.

The valves consist of spring-loaded balls, the springs retaining the balls on their seatings and closing the outlets to the hoses.

The hoses are of flexible metal tubing, the suction hose being of 3-inch bore and having a strainer fitted to its outer end. The delivery hose is of 1/2-inch bore and has a union at its outer end for attachment to the buffer adapter. Both hoses are fitted with unions at their inner ends for attachment to the pump nozzles.

A pump adapter is provided for connecting the delivery base to the buffer cylinder filling hole, being screw threaded at each end for the attachment of the hose and for screwing into the filling hole.

The pump barrel is cylindrical and fits into a recess in the base to which it is secured. The upper end is closed by a screwed cover through which projects the plunger rod. Externally the barrel is surrounded with protecting gills.

The plunger consists of two cup-shaped leather washers attached to the lower end of the rod. At its upper end the rod is fitted with a handle by means of which the pump is operated.

### Automatic Loader

The automatic loader is mounted on brackets which are bolted to the gun cradle, the loader projecting to the rear of the gun where it is supported by being bolted to the aircraft structure. In addition to an automatic feed and loading mechanism, the loader provides accommodation for 23 rounds of ammunition.

The principal parts of the automatic loader are: magazine support and slide channel; feed mechanism; magazine; magazine drive mechanism; pusher arm mechanism; brake and switch mechanism; drive motor.

*Magazine Support and Slide Channel.* The magazine support and slide channel are mounted at the front on brackets, which are bolted to the gun cradle and carry the feed mechanism, magazine, magazine drive, and their associated components and fittings. The magazine support is on the

left-hand side and the slide channel on the right-hand side of the gun.

The magazine support is of channel construction and is secured by four bolts to the top of the cam bracket which has a slot cut in it to accommodate the magazine support. Any tendency of the magazine support to move in a longitudinal direction is prevented by hooked pieces welded to the magazine support and engaging the cam bracket. To the underside of the magazine support is welded a slide which fits in a bronze guide block bolted to the top of a register plate. A key on the register plate engages a slot in the breech ring. When the gun recoils and runs out, the guide block slides to and fro. Welded to the magazine support in front of the guide block is a small projection to which is bolted the upper end of a bracket which carries the firing solenoid.

At the front end of the magazine support is bolted a front tie bracket which is also bolted to the front end of the slide channel. Bolted to the rear ends of the magazine support and the slide channel is a slide channel spacing bracket. The magazine support and slide channel with the tie bracket and channel spacing bracket thus form a rigid assembly.

An anchorage for the magazine pusher arm spring is provided at the front end of the magazine support. Bolted to the top of the magazine support on the inside are three brackets which form bearings for a feed arm shaft. Pivoted on the center of these brackets is a spring-loaded, round-retaining pawl, the tension of the right-hand-wound spring being adjustable by a collar. The center bracket also carries a round nose guide. Bolted to the rear of the magazine support and in front of the channel spacing bracket, there is a left-hand cartridge rim guide with a welded plate at the rear to prevent the round slipping back and a welded plate underneath to prevent the base of the case from moving to the left during feed.

The slide channel is secured at the front by six bolts to the top of a support bracket which has a slot cut in it to accommodate the slide channel. The support bracket is secured by eight bolts to the right-hand side of the cradle in the rear of the cradle trunnion. Any tendency of the slide channel to move in a longitudinal direction, due to the action of the rammer mechanism, is prevented by hooked

pieces welded to the slide channel and engaging the support bracket at the front and rear.

A bracket is welded to the top of the slide channel toward the front, and to this bracket is bolted an angle support. To the rear of this bracket are welded tow-arm guide supports to which is bolted a center support plate. To the center support plate is bolted a center angle support which carries a round support, the latter supporting the ammunition in the magazine. A rear angle support is bolted to the channel spacing bracket with a packing piece interposed. To the three angle supports is bolted the right-hand side of the magazine. On the inside of the slide channel toward the rear is bolted a plate which prevents the base of the cartridge case from moving to the right during feed.

The rear of the slide channel spacing bracket is shaped to provide a means of attachment to the aircraft structure, four holes being provided for the securing bolts. To the front of the spacing bracket is bolted a support bracket, to which is welded a right-hand cartridge rim guide. Carried on the support bracket is a spring-loaded cartridge stop pawl, and a spring-loaded cartridge rim check lever.

The space between the magazine support and the slide channel forms a feedway through which the ammunition is fed to the gun, various pawls and guides in addition to those already mentioned being provided to control the movement of the rounds.

*Feed Mechanism.* The feed mechanism consists of a cam track, nose separator, feed-arm shaft, rammer and return springs, rammer lifting cam, and the conventional pawls and levers.

The cam track of steel is mounted on the top of the breech ring, being secured by five bolts, and projects to the front of the magazine. It is provided with two cams to engage the rollers of the round-nose separator, the left-hand track in addition engaging the roller of the feed-arm shaft. Bolted to the front of the camshaft is a support piece which bears on the left-hand gun guide key and supports the front end of the cam track.

The projectile nose separator consists of a hollow steel boss to which is welded a driving arm which projects to the rear. The separator controls the nose of the round on loading and separates it from the following round to prevent double loading. On the hollow boss are two arms, one of which projects to the front and the other to the rear. Each of these

arms carries a roller, the rollers being of different diameters. As the gun recoils and runs out, the front roller rides along the left-hand cam track and the rear roller along the right-hand cam track. Bronze bearings are fitted in the ends of the hollow boss, which is mounted on an eccentric cross-shaft passing through bearings on the magazine support and slide channel. The cross-shaft is adjusted in manufacture and is secured to the magazine support by screws. Interposed between the separator and the magazine support is a distance collar.

On the right-hand side of the separator is a tension tube which carries a torsion spring. Tension is applied to the spring by means of the tube, which, after adjustment, is locked to the separator by an anchor. The anchor is bolted to the driving arm of the separator and has a spigot which engages one of several holes in the tension tube. On the outside of the driving arm at the rear is a projection which engages between two projections on a projectile retaining lever mounted in a bracket on the inside of the slide channel.

The projectile retaining lever is attached by a connecting link to a projectile check lever that in turn pivots in the retaining lever bracket. The retaining lever bracket also carries a projectile nose guide which prevents the round moving to the right as it is pushed down. The two levers are shaped to engage the nose of the projectile in the bottom of the feedway and control its movement during loading and are operated by the driving arm of the separator through the engagement of their respective cams.

A separator connecting rod is connected to the front of the projectile nose separator by a separator fork joint. The rear end of the connecting rod is connected to the rammer release pawl link. Secured by screws and doweled to the connecting rod end is a check lever pusher which operates the spring-loaded cartridge rim-check lever situated on the support bracket at the rear.

The feed-arm shaft is carried in the brackets on the inside of the magazine support. Welded and keyed to the feed-arm shaft near the middle is a retract lever, and near the front end of the shaft is an integral collar. Between the collar and the retract lever is mounted a feed-arm spring. One end of the feed-arm spring engages a hole in the collar, the other end bears on the magazine support. Keyed

and pinned to the front end of the feed-arm shaft is a roller bracket carrying a roller which rides along the left-hand cam track. The retract lever carries a spring-loaded retract pawl, the tension of the left-hand-wound spring being adjustable by a collar. At the rear end of the feed-arm shaft is a feed arm carrying a spring-loaded feed pawl, the tension of the left-hand-wound spring being adjustable by a collar. The feed arm rides on a small roller on the top of the magazine support when the feed-arm shaft is rotated.

When the gun recoils, the feed-arm shaft roller rides down the front of the left-hand cam track and the feed arm spring is free to rotate the feed-arm shaft so that the retract lever and feed arm move inward and downward into the feedway. As the gun runs out, the feed-arm shaft is repositioned by the roller riding up the cam track. The feed-arm shaft roller and feed-arm spring thus act in opposition.

The rammer slides along the slide channel, being pushed to the rear when the gun recoils by a rammer slide pawl and being returned to the forward position at the end of runout by the rammer return springs. While the gun is running out, the rammer is supported by a catch and retained by a release pawl and link. The rammer consists of a slide, arms, claw, and a pawl connecting the slide to the return springs.

The rammer slide is a steel plate which is shaped to slide in the slide channel, its rearward movement being limited by a rammer stop block, which is bolted to the outside of the slide channel at the rear. On the top of the rammer slide is a rectangular projection the top front edge of which is beveled to engage the rammer release pawl toward the end of recoil. On the underside of the rammer slide at the front is a projection which is engaged by the rammer slide pawl during recoil. Felt lubricators are provided to lubricate the rammer slide in the slide channel.

The rammer arms are situated on the outside of the rammer slide and are mounted on pins about which they pivot. The arms are loosely connected at their lower ends by an arm tie link. On the inside of each arm at the bottom is a projection upon which the rammer claw is mounted. At the top of the rammer front arm is a small extension which projects to the rear and carries a small stud. The

extension and stud, in conjunction with an arm guide and hinge guide, help to control the movement of the arms and claw during the operation of the rammer.

The arm guide is bolted to supports which are welded to the slide channel, and carries the hinge guide which is spring loaded by a torsion spring. A stop on the arm guide limits the outward movement of the hinge guide while the spring keeps it pressed inward against the arm guide.

The rammer claw is secured in position on the rammer arms by Simonds nuts, the claw projecting to the front and being suitably shaped to loosely engage the base of the cartridge case. On the left of the claw, a small projection engages the rammer catch when the rammer is lifted at the end of recoil.

The spring-loaded rammer catch is bolted to the underside of the slide channel spacing bracket.

A shock absorber, to take the blow when the rammer is lifted, is bolted to the underside of the slide channel spacing bracket to the rear of the rammer stop block. The upward movement of the shock absorber is limited by a projection at the rear of the stop block to protect the rubber comprising the absorber.

Two rammer return springs are accommodated in tubes on the outside of the slide channel at the front. The tubes are held in position at the front by a tube clamp and clamp plate, and at the rear by a block welded to the slide channel. The block is suitably recessed to accommodate and form an abutment for the ends of the spring tubes. The return springs are mounted on rods which project through the rear of the spring tubes and the securing block. The springs bear between the ends of the tubes at the rear and the spring rod nuts at the front. The front ends of the tubes are closed by screwed caps. The rear ends of the spring rods are enlarged to form an abutment for a spring rods plate. On the plate is a projection which is engaged by the rammer return springs pawl.

The rammer return springs pawl is in the form of a hinged latch which pivots on a pin at the side of the rammer slide. At the front of the pawl a hook engages the projection on the return spring rods plate, in which position the pawl is held by a spring-loaded plunger. This arrangement enables the rammer to be disengaged from the return springs and moved to the rear by hand. An arm tie is at-

tached to the pivot of the rammer return springs pawl and to the pivot pin of the rammer front arm. The arm tie has a curved end to form a handle for hand movement of the rammer.

The rammer release pawl is mounted on a pivot on the top of the slide channel at the rear and is spring loaded by a torsion spring enclosed by a cover. On the outside, the pawl is hook-shaped to engage the rammer slide, and on the inside is a small projection which is engaged by the separator connecting rod end, to disengage the pawl from the rammer slide.

A magazine regulator, or positioner, is mounted on the inside of the slide channel at the rear. The regulator is integral with its spindle which is spring loaded, to the top of the spindle being secured to a regulator stop. The regulator holds the base of the cartridge case ready for engagement by the rammer claw during feed.

The rammer lifting cam is secured to the right-hand side of the breech ring by four bolts, a key on the cam engaging a slot in the breech ring. The rear of the lifting cam is suitably shaped to lift the rammer into engagement with the rammer catch toward the end of recoil.

The spring-loaded rammer slide pawl is mounted on a bearing at the top of the rammer lifting cam. The rear of the pawl is shaped to engage the rammer slide, and on the inside a roller engages a ramp on the underside of the slide channel, toward the end of recoil, and disengages the pawl from the rammer slide. An extension at the front of the pawl engages the rammer slide pawl ramp toward the end of runout.

The rammer slide pawl ramp is bolted to the slide channel below the rear ends of the return springs tubes. Its function is to reposition the rammer slide pawl ready to engage the rammer slide when this is returned by the return springs.

A right-hand round nose guide is bolted to a bracket which is welded to the inside of the rammer lifting cam at the rear. Welded to the round nose guide is a shock absorber, which takes the blow of the rammer at the end of the loading stroke.

*Magazine.* The magazine consists of a frame, shell, and cartridge clips, and clip guides. The frame carries the drive mechanism, which brings the ammunition clips into position over the feed-

way ready for loading the gun, and also operates the pusher mechanism.

The magazine frame consists of four steel plates bolted together, stiffening angles being bolted to the outside edges of the left-hand and right-hand plates, the whole forming a rigid assembly. The right-hand plate of the magazine frame is bolted to the three angle supports; the left-hand plate is bolted to a bracket on the magazine support at the front and to the channel spacing bracket at the rear. Packing pieces are interposed between the left-hand plate and its supports. When mounted, the magazine frame is inclined at an angle of  $30^\circ$  to the horizontal.

At the front right-hand corner of the magazine frame is bolted a drive front bearing bracket and at the rear a drive rear bearing bracket. At the front left-hand corner of the magazine frame on the inside is bolted a shell clip shaft bearing bracket (this bracket also provides an inner bearing for a cam gear), and on the outside a pusher arm bearing bracket (this bracket also provides an outer bearing for the cam gear). At the rear left-hand corner of the magazine frame is bolted a cartridge clip shaft bearing bracket.

Pivoted on a bracket on the inside of the left-hand frame plate is a spring-loaded round catch of bronze which prevents the round from lifting during feed.

The clip guides consist of upper and lower shell clip guides, and upper and lower cartridge clip guides with shell clip track and cartridge clip track. The shell and cartridge lower clip guides are bolted to the front and rear plates of the magazine, respectively; the shell clip track is bolted to the left-hand plate and the cartridge clip track to the rear plate. The shell upper clip guide is bolted to the tops of the two front bearing brackets and the cartridge upper clip guide to the tops of the two rear bearing brackets. On the right-hand side, the upper clip guides are connected by a tie angle piece. Supported on posts above the shell clip track is a box guide which forms an extension of the shell upper-clip guide.

Five shell clips, which are almost identical in shape, are supported between the shell clip guides and accommodate the noses of the shell, a shell retainer being brazed to the top of each clip. On the front of each clip are two projections having slots cut in them to mate with the upper and lower

shell clip guides. The upper projection is engaged by the brake bar which holds the clips during feed. The clips are hinged together at the top and bottom by hinge pins, the hinge lugs being integral with the clips. On the underside of the left-hand clip is a guide pin which, in conjunction with an extension on each lower hinge pin, guides the clips along the shell clip track when the clips are moved to the left by the drive and leave the shell clip guides. On the front of the right-hand shell clip is bolted an Acme bearing which travels along the shell clip drive shaft to move the clips to the left or to the right, depending upon the direction of drive.

Five cartridge clips are supported between the cartridge clip guides and accommodate the bases of the cartridge cases. On the rear of each clip are two projections having slots cut in them to mate with the upper and lower cartridge clip guides. The right-hand cartridge clip is in one piece, the remainder being in two pieces and hinged together to facilitate movement. The cartridge clips are hinged together at the top and bottom by hinge pins, the hinge lugs being integral with the clips. A hollow boss is secured to the top of the right-hand clip by three screws and accommodates a spring-loaded plunger cartridge retainer, a similar device being provided at the top of the second clip. The next two clips are provided with a cartridge retainer in the form of spring clips. The pusher arm serves to retain the cartridge in the last clip.

Attached to the right-hand and left-hand cartridge clips by clamps is a short piece of cable which passes around cable guides bolted to the top of the upper cartridge clip guide. The cable steadies the tops of the clips when they leave the top guide during their movement to the left. At the bottom of the left-hand clip is a small roller which travels along the clip track during this movement. On the rear of the right-hand cartridge clip is bolted an Acme bearing which travels along the cartridge clip drive shaft to move the clips to the left or to the right, depending upon the direction of drive.

The shell and cartridge clips convey the ammunition to the feedway and provide accommodation for 21 rounds which, with 2 rounds in the feedway itself, gives the loader a total capacity of 23 rounds of ammunition.

*Magazine Drive Mechanism.* The magazine drive mechanism moves the shell and cartridge clips

into position ready for feeding as soon as a pair of clips is empty, and it lifts the pusher arm ready to engage the top round in the next pair of clips. It is coupled to an electric motor which is automatically controlled by the brake and switch mechanism.

Front and rear coupling shafts are mounted in sealed ball-bearing brackets. The two coupling shafts are connected by a steel coupling tube, and each shaft carries a steel spiral gear having 18 teeth. Keyed to the front coupling shaft is a brake coupling which is connected to the drive motor by a motor coupling. Keyed to the rear coupling shaft is a handle clutch with flanged distance piece. Mounted on the distance piece, between the flange and the clutch, is a loose handle which has a small projection at its inner end to engage 1 of 2 slots in the clutch. Secured to the handle by a plate and two screws is a spring which retains the handle in the disengaged position. When the pusher arm is raised to the inoperative position, the handle clutch enables the shell and cartridge clips to be moved by hand for loading and unloading the magazine or for cleaning.

Drive shafts for the shell and cartridge clips are mounted in sealed ball bearings at the front and rear in their respective bearing brackets. Each shaft has an Acme thread cut in it throughout its length, and to the right-hand end of each shaft is keyed a gun metal spiral gear having 60 teeth. The drive shafts pass through the Acme bearings, on the shell and cartridge clips, and the gun metal spiral gears mate with the steel spiral gears on the coupling shafts. Keyed to the left-hand end of the shell-clip drive shaft is a cam drive gear which mates with the pusher arm cam gear.

*Pusher Arm Mechanism.* The pusher arm mechanism is mounted at the front left-hand corner of the magazine frame being supported between the shell clip shaft bearing bracket and the pusher arm bearing bracket. It consists of a pusher arm with spring, lifting cam, and ratchet lever.

The pusher arm is a straight bar mounted on a pivot which passes through the front of the bearing brackets at the top. Mounted on the inside of the pusher arm near the pivot is a cam roller which rides on the pusher arm lifting cam. Welded to the outside of the pusher arm and in rear of the cam roller, is a pusher arm ratchet pawl which normally engages the ratchet lever and prevents the pusher

arm from lifting. To the rear of the ratchet pawl is mounted a depressor roller which operates a depressor arm, when the pusher arm reaches the bottom of its travel, after pushing the last round into the feedway. To the free end of the pusher arm is welded a post to which is welded a pusher arm extension. The extension carries the pusher roller, of steel and rubber, which is mounted on a pin and secured by a cap. The roller presses on the top cartridge case in the clips which are in position for feeding.

A welded projection on the pusher arm near the pivot is attached to a spring rod by a connecting rod end. The spring rod carries the pusher arm spring which is housed in a tube, the front end of which is anchored to the front of the magazine support. The reaction of the spring causes the free end of the pusher arm to bear upon the rounds in the left-hand magazine clips.

The pusher arm lifting cam is mounted on a cam shaft which runs in sealed ball bearings carried in the bearing brackets. The lifting cam is bolted to the cam gear, which is keyed to the cam shaft, and is engaged by the cam drive gear on the end of the shell clip drive shaft. The lifting cam is cut away to give a clearance for the cam roller as the pusher arm moves downward when loading the gun. When the last round has passed from the clips into the feedway, the magazine drive rotates the lifting cam, causing it to engage the cam roller and lift the pusher arm clear of the ammunition clips, so that the next pair of full clips can be brought into position ready for feed. The cutaway in the cam again comes opposite to the cam roller and the pusher arm spring brings the pusher arm down on to the ammunition.

The ratchet lever pivots on a bracket bolted to the pusher arm bearing bracket, engagement between the teeth on the rear of the ratchet lever and the pusher-arm ratchet pawl being maintained by a torsion spring. To the top of the ratchet lever is welded a pusher arm support, which has a notch cut in it at the front to engage the ratchet pawl and hold the pusher arm clear of the clips to facilitate loading the magazine, the pusher arm being raised to this position by hand. A projection on the rear of the ratchet lever near the pivot is provided to disengage and hold the brake bar while the clips are being loaded or moved by hand. The engagement

of the projection with the brake bar coincides with the engagement of the pusher arm ratchet pawl with the pusher arm support.

At the bottom of the ratchet teeth is a ramp, which engages the pusher arm ratchet pawl as the pusher arm reaches the bottom of its loading stroke, and causes the ratchet lever to pivot forward slightly. The ratchet lever is retained in this position as the pusher arm lifting cam, rotated by a camming stud on the inside of the ratchet lever, engages the ratchet lever cam. This cam is keyed to the end of the lifting cam shaft. At the lower end of the ratchet lever is an extension which projects to the front and locks the safety lever of the brake bar mechanism until the last round is taken from the clips, in position for feeding.

*Brake and Switch Mechanism.* The brake and switch mechanism is situated at the front of the magazine and controls the drive motor. The mechanism consists of a brake and spring, switch bar and spring, brake bar and spring, depressor arm, locking and safety levers.

The brake is carried on a bell-crank operating lever, which is pivoted in a brake bracket bolted to the front of the magazine frame on the right, and operates between flanges on the brake coupling. The upper end of the operating lever is connected by a pin to the end of the brake spring rod. The other end of the brake spring rod passes through a slide pin bracket which is welded to the switch bar. The brake is applied through the medium of the brake spring, which enables the load to be adjusted. One end of the brake spring bears against a collar on the spring rod which abuts the slide pin bracket; the other end of the spring bears against an adjustable collar on the end of the spring rod, the collar being secured by a nut.

The switch bar has a slot cut in its right-hand end which engages the pin at the top of the brake operating lever to release the brake. The slide pin bracket, which is situated near the middle of the switch bar, also operates a switch slide to open and close the motor switch. The left-hand end of the switch bar is pinned to a connecting link which pivots on a bracket bolted to the top of the upper shell clip guide. Welded to the connecting link is a cocking lever for hand setting after the magazine has been loaded.



The switch bar return spring is attached at one end to a pin secured to the brake bar and at the other end to a pin which is welded to the upper end of the shell clip guide.

The brake bar is attached at one end to the connecting link by a pin, the other end of the brake bar projecting to the left of the magazine between the projection at the rear of the ratchet lever and the end of the safety lever. Near the middle of the brake bar is a notch which engages in turn the projection on the front of each shell clip, to hold the clips while the rounds are being fed to the gun. Below the notch is a stop which limits the total travel of the clips by engaging the Acme bearing. A projection toward the outer end of the brake bar bears on a sleeve which is supported by the brake-bar spring. The spring and sleeve are mounted on the front post of the box guide and lift the brake bar into engagement with the projections on the shell clips when the clips are in position ready for feeding.

The depressor arm is pivoted to a bracket which is bolted to the left magazine frame plate toward the front. The front end of the depressor arm rests on the top of the brake bar, the other end of the arm being suitably shaped to be engaged by the pusher arm depressor roller, as the pusher arm reaches the end of its downward stroke, and causes the front end of the arm to bear on the brake bar and disengage it from the shell clips.

The locking lever is pivoted on the outside of the pusher arm bearing bracket and can be set to **HAND** for loading the magazine and to **AUTO** (automatic) for firing. The locking lever, when set, is held in position by a spring-loaded plunger.

The safety lever is pivoted on an extension of the locking levers. The rear end of the safety lever engages under the brake bar and holds the brake-

bar notch in engagement with the projection on the shell clip when the locking lever is set to **AUTO**, preventing premature disengagement of the brake and closing of the switch. The safety lever is locked in this position by the projection at its front end engaging the extension at the front of the ratchet lever. When the ratchet lever pivots at the end of the downward stroke of the pusher arm, the safety lever is released and falls away from the brake bar allowing this to be disengaged from the shell clips by the depressor arm. When the locking lever is set to **HAND**, it carries the safety lever clear of the ratchet lever extension and allows the ratchet lever to pivot to the rear to support and hold the pusher arm when this is lifted to the inoperative position.

*Drive Motor.* The drive motor is a special 24-volt d. c. compound wound machine giving 0.6 h. p. at 1,820 r. p. m. It is mounted at the front right-hand corner of the magazine frame and is secured by bolts.

The motor switch is mounted at the right-hand end of the upper shell clip guide, being operated by the switch bar and switch slide, through the action of the brake bar and the switch-bar spring. The movement of the brake bar is governed by the position of the magazine pusher arm and the brake-bar spring.

A special junction block is mounted on the magazine frame to the left of the motor, connections being made to the switch and motor by short lengths of cable. The junction block is connected to the firing solenoid by two lengths of cable, to which is attached a two-pin plug for connecting with the two-pin socket of the solenoid. On the top of the junction block is mounted a socket to take the plug from the aircraft supply.

## SECTION 2. CYCLIC ACTIONS

### Preparation for Firing

To fire the gun, the pilot must first close the main switch and set the firing button to **FIRE**.

To fire single shots, press and release the firing button.

To fire a burst, press the firing button and maintain the pressure until the required number of rounds have been fired.

### WARNING.

1. The pilot must set the firing button to **SAFE** and open the main switch before coming in to land, and he must report stoppages.

2. The pilot must also set the firing button to **SAFE**, and must open the main switch immediately after a stoppage occurs.

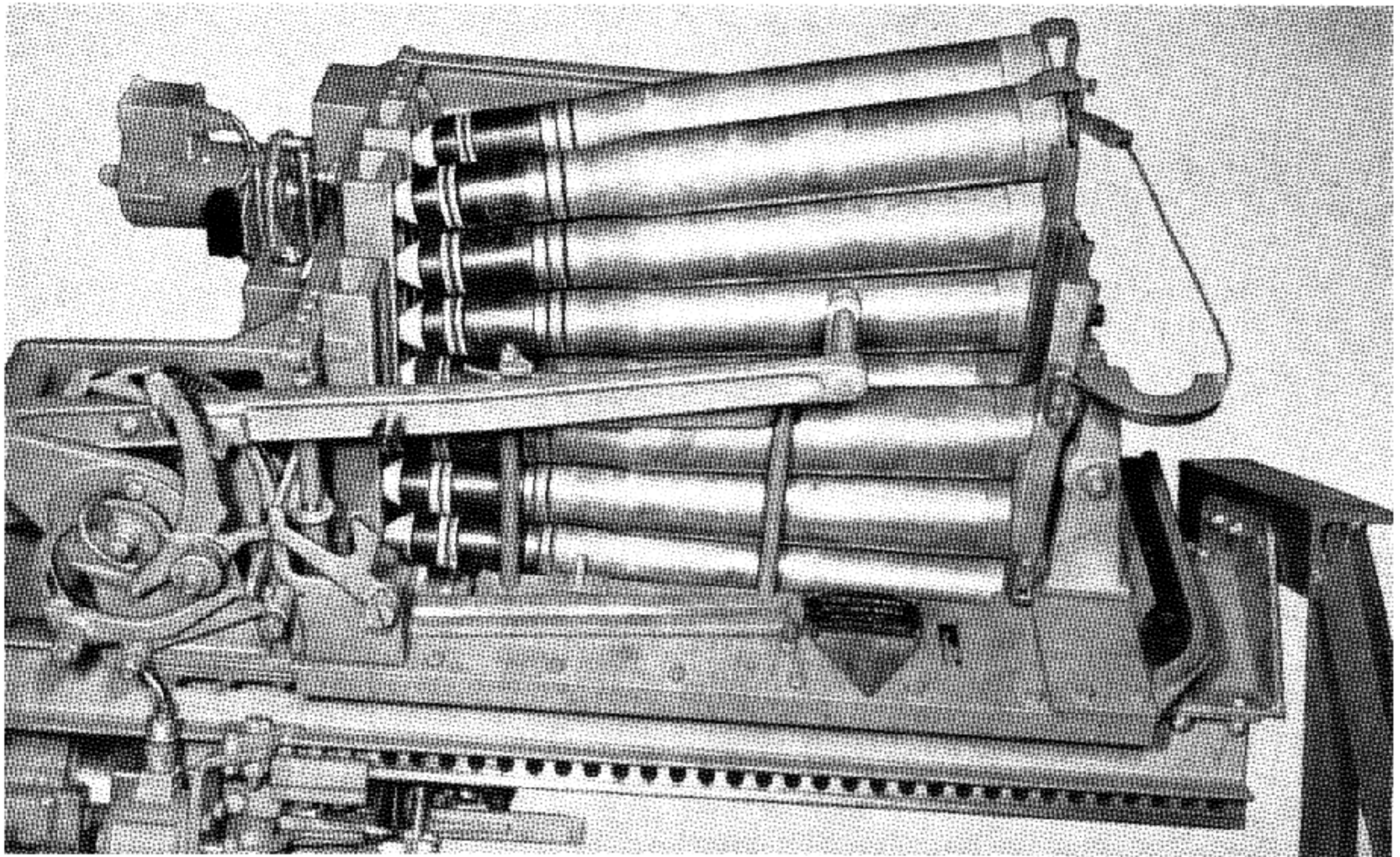


Figure 17-4. British 57-mm Automatic Aircraft Cannon. Closeup view of automatic loader, with ammunition.

### Action of the Automatic Loader

*Action of the Feed Mechanism During Recoil.* When the magazine is loaded, the bottom round in the feedway is positioned with the nose of the shell resting against the retaining lever and the cartridge case resting against the release pawl link and displacing the bronze stop pawl. The round is retained in this position by the weight of the rounds above and the pusher arm, the second round in the feedway bearing directly on the first round. The separator connecting rod is in the rear position and is engaging the rammer release pawl, and the connecting rod end has moved the release pawl link so that it projects into the feedway to hold the first round. The check lever pusher is engaging the cartridge rim check lever to hold the lever clear of the base of the cartridge case. The magazine regulator is in its normal position, ready to engage the first round when this is pushed down by the feed arm shaft.

As the gun recoils, the left-hand roller of the separator rides along the left-hand cam track and

the right-hand roller along the right-hand cam track, the separator spring maintaining the contact between the left-hand roller and the cam track until the right-hand roller comes into operation.

After the gun has recoiled about  $4\frac{1}{2}$  inches, the separator begins to rotate and lift the driving arm, the movement of the separator being controlled by the rollers and the separator spring. The movement of the separator causes the connecting rod to move to the front, the connecting rod end rotating the rammer release pawl link away from the cartridge case. The lug on the connecting rod end moving away from the rammer release pawl allows the rammer release pawl spring to react and rotate the release pawl, ready to reengage the rammer. The check lever pusher moves away from the cartridge rim check lever and allows the rim check lever to pivot under the influence of its spring, the rim check lever passing over the top of the first round and toward the second round.

After the gun has recoiled about 9 inches, the rammer release pawl is fully revolved and ready to

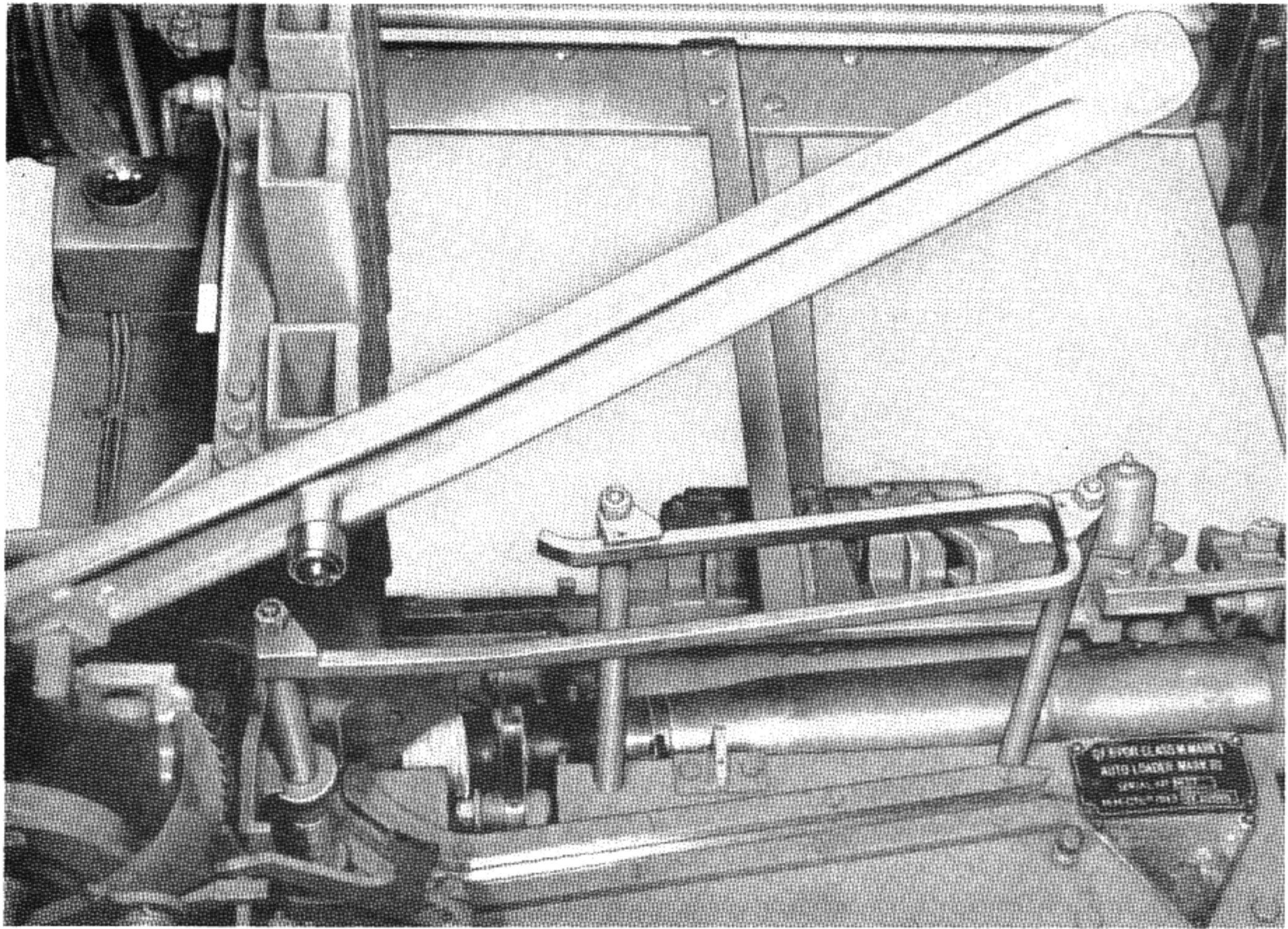


Figure 17-5. British 57-mm Automatic Aircraft Cannon. Oblique view of round in feeding position.

engage and hold the rammer. The rammer release pawl link is entirely clear of the first round, and the cartridge rim check lever has completed its movement and is holding the base of the cartridge case of the second round. At about this time, the separator driving arm commences to lift the retaining lever which lifts the check lever, the retaining lever moving clear of the nose of the first round. At the same time, the feed-arm shaft roller rides down the left-hand cam track and the feed arm spring rotates the feed-arm shaft. The feed arm in rotating carries the retract pawl and the feed pawl into the feedway toward the first round, the pawls passing under the second round.

When the gun has recoiled about 14 inches, the separator driving arm has lifted the retaining lever entirely clear of the nose of the first round, the round retaining pawl preventing the round from lifting

during the upward movement of the separator driving arm. The feed-arm shaft has continued to rotate under the influence of its spring and has pushed the first round to the right and downward until the nose of the shell is resting between the check lever, which has been lifted by the retaining lever and the left-hand nose guide. The base of the cartridge case is resting between the magazine regulator and the cartridge rim guide. The stop pawl, reacting as the round moves down, engages over the top of the cartridge case to prevent this from lifting. The pressure of the pusher arm on the rounds and the weight of the rounds themselves, if there is no negative  $g$  force being applied, causes the second round to follow the first, the nose of the shell resting on the first round and the base of the cartridge case against the cartridge rim check lever. (At about this time, the rammer slide pawl is disengaged from the ram-

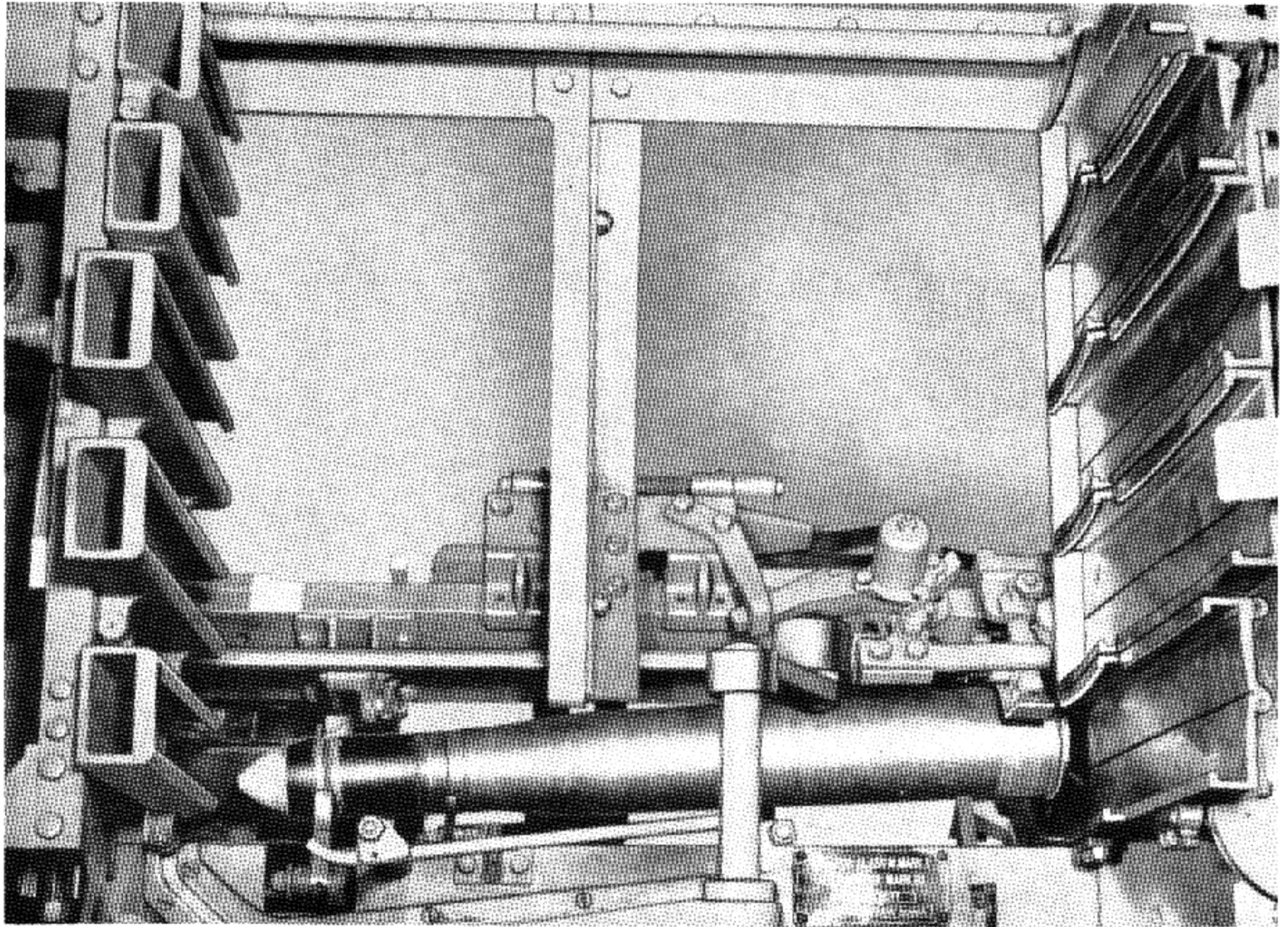


Figure 17-6. British 57-mm Automatic Aircraft Cannon. Vertical view of round in feeding position.

mer slide and the rammer slide is engaged and held by the release pawl.) The gun continues to recoil but no further movement of the above components takes place.

*Action of the Feed Mechanism During Runout.* During the first part of runout, no movement takes place in the feed mechanism. When the gun is about 14 inches from the firing position, the feed arm shaft roller commences to ride up the left-hand cam track and rotate the feed arm shaft. This action carries the retract pawl and feed pawl away from the first round and back to their normal positions. As the pawls pass the second round, their springs are compressed but react when the pawls are clear to reposition the pawls ready to engage the round on the next recoil stroke. The left-hand roller of the separator commences to ride up the left-hand cam track and rotate the separator, com-

pressing the separator spring. The separator driving arm moves downward and, engaging the retaining lever, pushes the retaining lever and the check lever downward. This action clears the check lever from the nose of the first round, which drops on to the top of the breech ring when the gun is about 6 inches from the firing position. The retaining lever being brought into contact with the nose of the second round prevents this from following the first round on to the breech ring.

In the meantime the breech has been opened by the semiautomatic gear.

Further movement of the gun toward the firing position allows the nose of the round to drop on to the top of the breechblock, the nose guides preventing the round from rolling to the left or right. The first round is now inclined at an angle with the nose of the shell resting on the top of the breechblock and

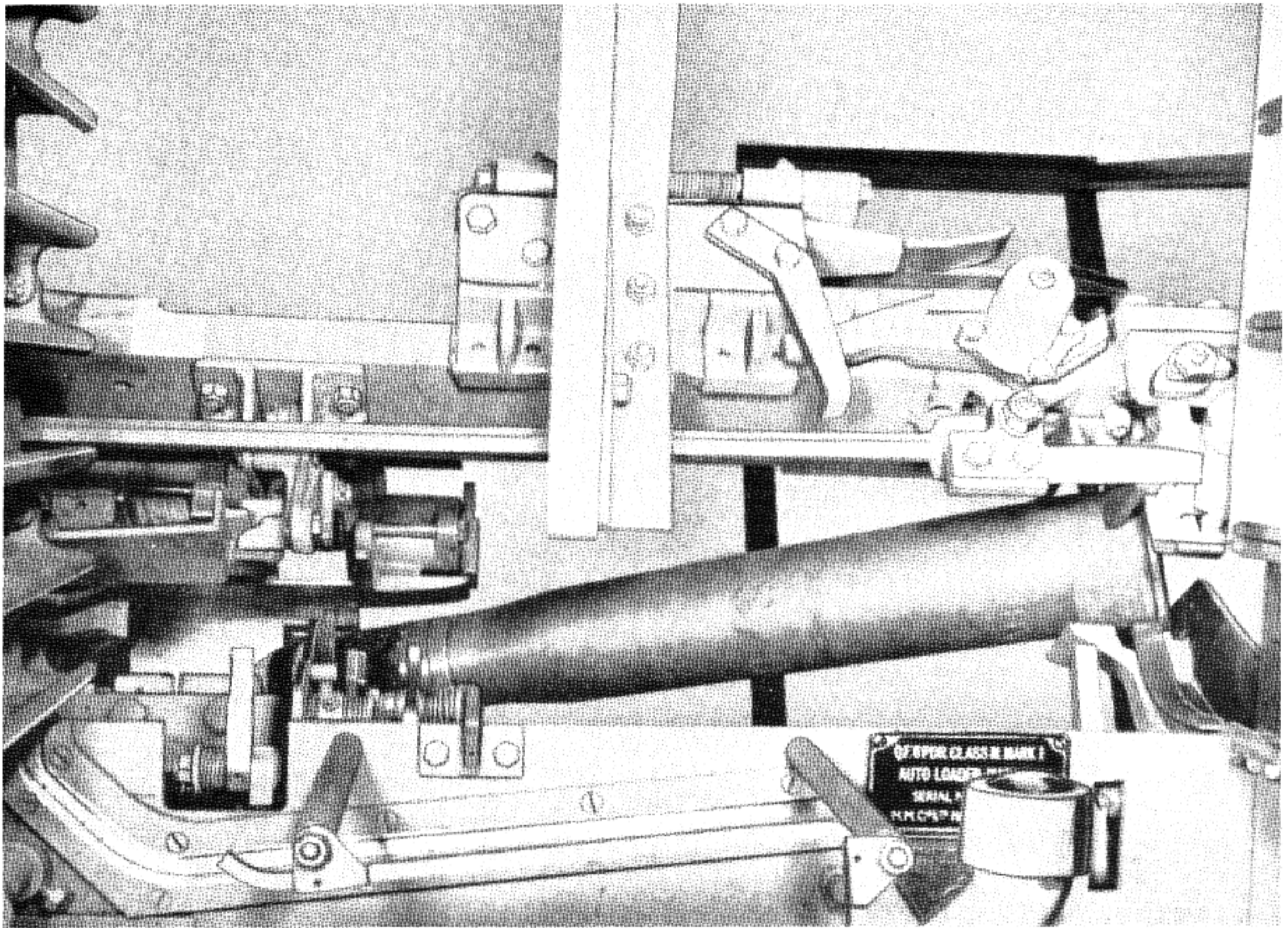


Figure 17-7. British 57-mm Automatic Aircraft Cannon. View through magazine showing round released from feedway into ramming position.

the base of the cartridge case supported between the magazine regulator and the cartridge rim guide, from which position it is rammed home toward the end of runout.

While this action of the separator is taking place, the connecting rod moves to the rear and the connecting rod end rotates the rammer release pawl link into position ready to engage the cartridge case of the second round when the round is released from the cartridge rim check lever. The lug on the connecting rod end, engaging the rammer release pawl, causes the rammer release pawl to pivot, compressing its spring and releasing the rammer which is returned by its springs to ram home the round. The check lever pusher engaging the cartridge rim check lever pushes this clear of the second cartridge case,

which drops against the release pawl link as the first round is rammed home.

The second round is now in the position which was occupied by the first round, resting against the retaining lever and the rammer release pawl link, and the bottom round in the left-hand pair of clips is pushed into the feed way by the magazine pusher arm to take the place of the second round.

*Action of the Rammer on Recoil.* When the gun recoils, the rammer slide pawl engaging the rammer slide pushes the rammer to the rear. The rammer slide, being connected to the return spring rods plate by the return spring pawl, pulls the rods to the rear and compresses the rammer return springs.

When the gun has recoiled about 12 inches, the rammer slide pawl roller contacts the end of the ramp, on the underside of the slide channel, and

causes the rammer slide pawl to pivot. By the time the gun has recoiled about 15 inches, the rammer slide pawl is completely disengaged from the rammer slide. By this time the rammer slide has passed the rammer release pawl. The slide is returned by its spring ready to engage and hold the rammer as soon as the rammer slide pawl is disengaged by the ramp, the rammer slide being brought into engagement with the rammer release pawl by the rammer return springs. During this part of the recoil, the rammer arms have been kept in a vertical position by the extension and stud on the front arm, engaging the underside of the arm guide and hinge guide, respectively. When the rammer release pawl engages the rammer slide, the extension and stud are clear of the arm guide and hinge guide and the rammer arms are free to pivot.

As the gun continues to recoil, the rammer lifting cam, engaging the rammer front arm, lifts the arms and rammer claw, the movement being completed by the time the gun has recoiled about 24 inches. The rammer claw engages the rammer catch, on the underside of the channel spacing bracket, and no further movement of the rammer takes place during the remainder of recoil.

*Action of the Rammer on Runout.* No movement of the rammer takes place until the gun is about 9 inches from the firing position, when the rammer release pawl begins to pivot under the action of the separator and its connecting rod, being completely disengaged from the rammer slide when the gun is about 4 inches from the firing position.

As soon as the rammer release pawl is disengaged from the rammer slide, the rammer return springs

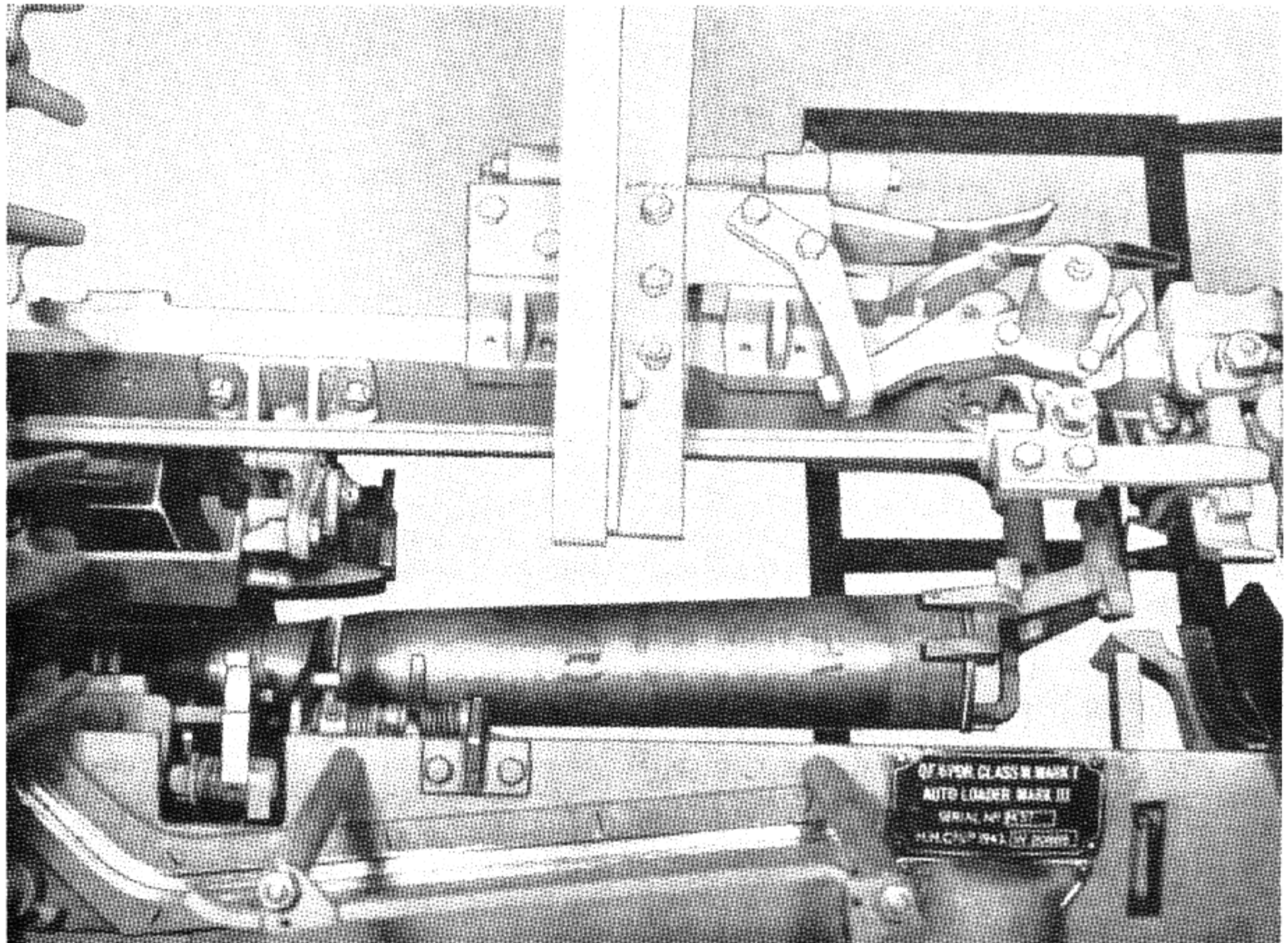


Figure 17-8. British 57-mm Automatic Aircraft Cannon. View through magazine showing round cleared from feedway by rammer.

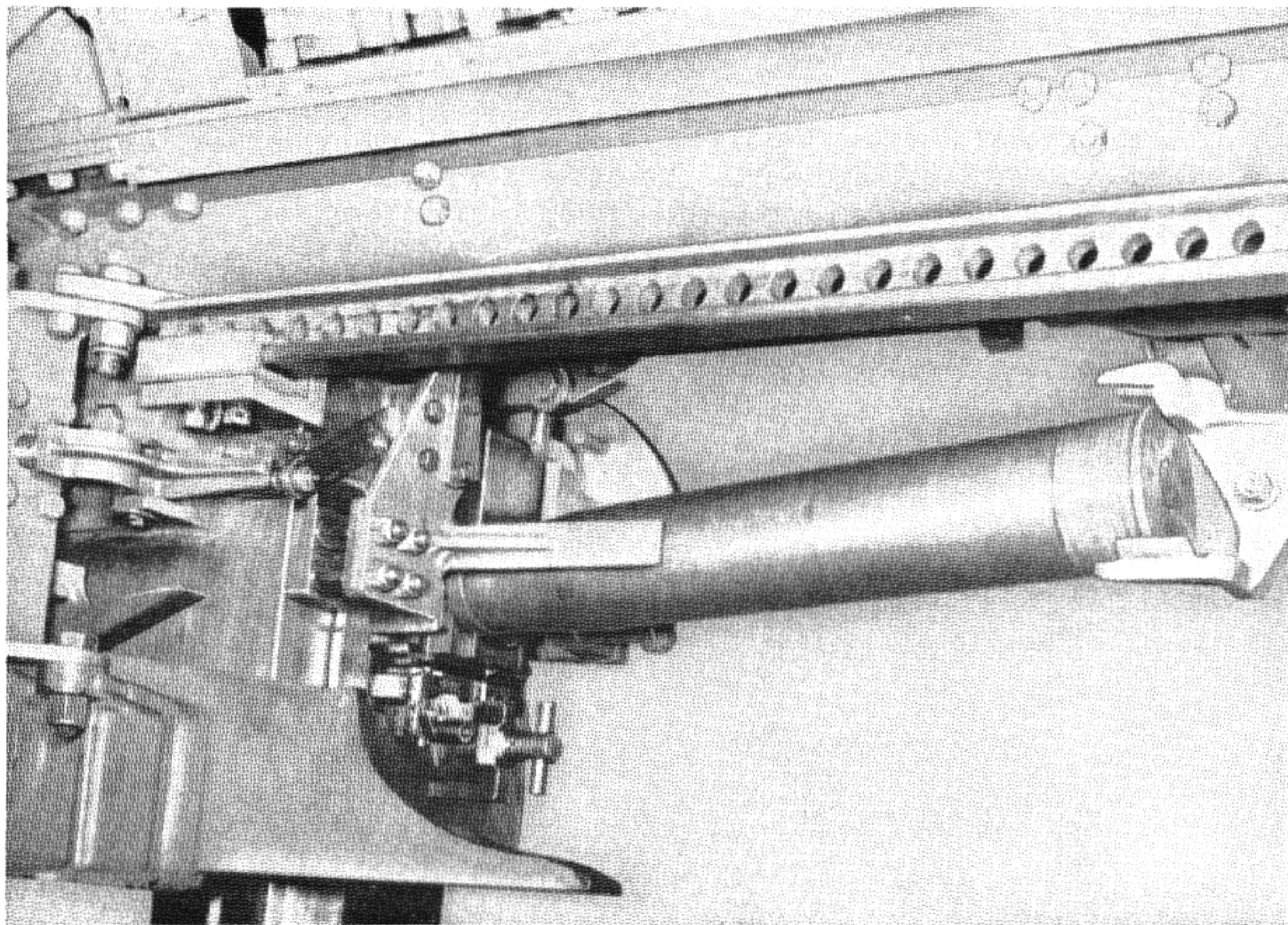


Figure 17-9. British 57-mm Automatic Aircraft Cannon. Left side view of breech showing ramming.

react and pull the rammer to the front. During the first few inches of its travel, the rammer retains its horizontal position, due to its engagement with its catch and to the front arm extension stud which rides along the top of the hinge guide at the rear. This movement enables the rammer claw to become accommodated around the base of the cartridge case of the first round. A projection on the right of the rammer claw now disengages the magazine regulator from the base of the case, and the stud on the front arm extension contacting an inclined piece on the hinge guide pushes the guide outward to release the rammer arms. The rammer swings down to the vertical position bringing the round into line with the chamber, the vertical position of the rammer being maintained by the extension and stud on the front arm engaging the underside of the arm guide and hinge guide. The rammer continuing to move

forward, under the influence of its return springs, rams the round into the chamber. The force of the blow of the rammer at the end of the stroke is taken on the shock absorber. The loading of the round closes the breech.

*Action of the Pusher Arm, Brake, and Drive Mechanism.* When the magazine is loaded, the pusher arm roller bears on the top round in the left-hand pair of clips, in which position it is retained by the ratchet pawl engaging the ratchet lever. The engagement between the ratchet pawl and the lever is maintained by the ratchet lever spring. The cut-away portion of the pusher arm lifting cam is underneath the cam roller, providing a clearance for the downward movement of the pusher arm, and the ratchet lever cam clears the stud on the ratchet lever. The brake is ON, the notch in the brake bar engaging the projection on the front of the left-hand

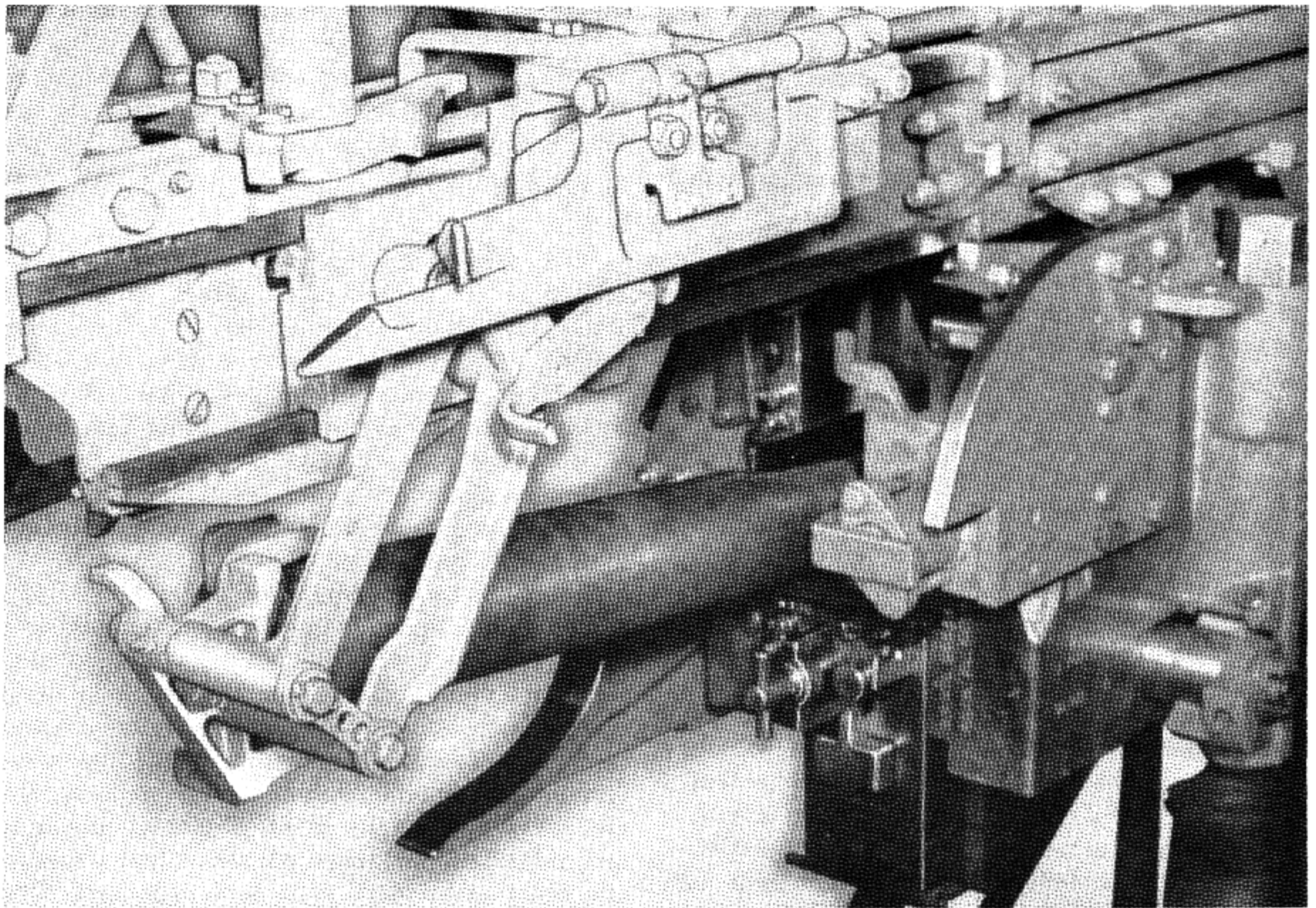


Figure 17-10. British 57-mm Automatic Aircraft Cannon. Right side view of breech showing ramming.

shell clip. The switch is OFF. The depressor arm rests on the top of the brake bar and the safety lever bears against the underside of the brake bar. The safety lever is prevented from moving by the projection at the front end of the ratchet lever engaging the small bracket on the extension of the safety lever, and by the locking lever which is held in the AUTO position by its spring-loaded plunger. The safety lever thus prevents any tendency of the brake bar to move downward and prematurely close the motor switch.

As the rounds are loaded into the gun from the feedway, the pusher arm spring causes the pusher arm to push the rounds in the left-hand pair of clips downward until the last round has passed from the clips into the feedway. When the pusher arm reaches the end of its downward stroke, the ramp at the bottom of the ratchet lever teeth is engaged by the ratchet lever pawl, and the ratchet lever pivots

forward slightly; the movement disengages the ratchet lever teeth and brings the stud on the inside of the ratchet lever into position ready to be engaged by the ratchet lever cam and also disengages the projection at the front end of the ratchet lever from the safety lever which falls away from the brake bar. The depressor roller engaging the depressor arm causes this to pivot forward and its front end to press downward on the brake bar and disengage the brake bar from shell clip, further compressing the brake bar spring. As soon as the brake bar is disengaged, the switch bar spring moves the brake bar and switch bar to the left, releasing the brake and closing the motor switch.

The motor now drives the coupling shafts which, through the spiral gears, drive the shell and cartridge clip drive shafts, causing the Acme bearings to travel to the left and move the next pair of full clips toward the feedway and the empty pair toward the clip



tracks. At the same time, the gear on the end of the shell clip drive shaft drives the pusher arm cam gear and the lifting cam, which in turn engages the cam roller. As soon as the depressor arm is freed by the lifting of the pusher arm, the brake bar spring tends to lift the brake bar but is prevented from so doing by the projection on the front of the empty shell clip.

When the projection on the front of the empty shell clip is clear, the brake bar is lifted by its spring ready to engage the projection on the front of the next shell clip. When this engagement takes place, the brake bar is forced to the left extending the switch bar spring and carrying with it the switch bar. The movement of the switch bar to the left opens the switch and compresses the brake spring, which reacts on the spring rod and applies the brake to stop the drive and arrest the movement of the shell and cartridge clips. The next pair of full clips are now in position ready for feeding, and the cutaway portion of the pusher arm lifting cam is once more under the pusher arm roller. As the roller leaves the end of the lifting cam, the pusher arm spring brings the presser clear of the stud, and the ratchet lever spring returns the ratchet lever to bring the teeth into engagement with the ratchet lever pawl. The front end of the ratchet lever engaging the small bracket on the front of the safety lever causes the safety lever to pivot slightly and bring its rear end once more into contact with the under side of the brake bar to lock this against premature disengagement.

**PRECAUTIONS.** The handling of ammunition must be done with great care, especially when actually loading or unloading the magazine. After the safety clips have been removed, the hand must be placed over the base of the cartridge case to afford maximum protection to the primer cap. The safety clip must be replaced as soon as a round is unloaded.

Two men are required to load the gun: one stands inside the gun bay to the port of and facing the installation and does the actual loading; the other removes the ammunition from the containers, takes off the safety clips, and hands the rounds one at a time to the loader. The reverse procedure is adopted when unloading.

All coating must be removed from the ammunition before it is loaded. Two special decoppering rounds must be loaded into each magazine. Both

the decoppering rounds and their ammunition boxes are marked "D. E. C."

Be sure that the gun is pointing in a safe direction, all personnel being warned to keep clear of the front of the aircraft.

### Action of the Recoil and Recuperator Systems

When the gun and slipper recoil, the buffer cylinder, which is attached to the slipper, recoils with it while the piston, which is attached to the cradle, remains stationary. The piston head is at the rear of the buffer cylinder when the gun is in the firing position, the space in front of the piston head being filled with oil.

*During Recoil.* The movement of the buffer cylinder causes the oil in front of the piston head to be forced through the longitudinal grooves in the buffer cylinder to the rear of the piston head. The work done in displacing the oil absorbs a portion of the recoil energy. As the greatest cross-sectional area of the grooves is at the rear, the least opposition to the passage of the oil takes place at the commencement of recoil, when the energy of recoil is greatest. As the buffer cylinder continues to move, the tapered grooves move past the piston head and present a diminishing opening to the oil; the oil flow is gradually restricted, resistance to motion increases, the energy of recoil is gradually absorbed, and the gun is brought to rest. The movement of the buffer cylinder draws the rear plug cylinder and throttle bushing off the control plunger, and oil enters the rear plug cylinder to take the place of the control plunger. At the same time, the runout springs compressor compresses the runout springs against the buffer cylinder bearing and the rest of the recoil energy is absorbed by the runout springs.

*During Runout.* As soon as the gun is brought to rest the runout springs reassert themselves and return the gun to the firing position. The oil behind the piston head now flows through the grooves in the buffer cylinder to the front, the runout being practically uncontrolled until the control plunger enters the control chamber. When the control plunger enters the throttle bushing and the rear plug cylinder, the oil therein is displaced and escapes over the tapered flat on the plunger and through the holes in the runout adjusting valve. The tapered flat gradually arrests the escape of oil through the throttle bushing until finally the hole in the bushing

is closed by the rear of the control plunger; at this time, the only passage hole in the bushing is closed by the rear of the control plunger and the only passage open to the escape of oil is past the runout adjusting valve. The last part of the runout is thus controlled, and the gun is gradually brought to rest, the shock as the gun reaches the firing position being absorbed by the bearing face ring packing at the rear of the cradle, which is struck by the lug on the gun slipper.

### Action of the Breech Mechanism and Semiautomatic Gear

*Opening the Breech, Hand Operation.* To open the breech by hand, place the tommy bar in the hole in the rack pinion and press it downward until the breechblock is held by the extractors.

As the rack pinion is actuated, it rotates the actuating shaft and also causes the rack to move upward and further compress the actuating spring against the spring cap. At the same time, the roller on the end of the actuating shaft, engaging the under side of the breech cam, lifts the breech cam which compresses the breech cam spring. The rotation of the actuating shaft rotates the crank, which is feathered to it. The rotation of the crank is in a downward direction and the bosses on the crank, bearing on the bottom of the cocking link recess, lower the breechblock, which moves to the rear slightly by reason of its inclined guides. When the block is almost clear of the base of the cartridge case, the inclined surfaces on its front face, engaging the lugs at the bottom of the extractors, cause them to pivot slightly and unseat the cartridge. As the breechblock clears the base of the cartridge case, the shoulders on its front face strike the lugs on the extractors a sharp blow, causing the extractors to pivot and eject the empty case from the chamber. The downward movement of the breechblock is arrested when the crank meets the breech ring. When the pressure is removed from the tommy bar, the actuating spring reacts and lifts the breechblock into engagement with the hooks on the extractors, which will hold the breechblock open until a round is loaded or until the hooks are released by hand.

*Opening the Breech, Automatic Operation.* When the gun fires, it recoils. The recoil takes place in approximately 0.25 second, the runout taking place in approximately 0.75 second. As the gun recoils, the actuating shaft roller rides against the

underside of the semiautomatic cam and lifts it upward. The semiautomatic cam lifts the breech cam which compresses the breech cam spring. When the roller leaves the end of the semiautomatic cam, the breech cam spring reasserts itself and repositions the cams ready for the runout stroke, the semiautomatic cam resting on the stop at the rear of its bracket.

During the runout movement, the actuating shaft roller meets and rides up the semiautomatic cam, causing the actuating shaft, crank, and rack pinion to rotate. The engagement between the actuating shaft roller and the semiautomatic cam takes place when the gun is about 18 inches from home. The rotation of the crank is in a downward direction; and the bosses on the crank, bearing on the bottom of the cocking link recess, lower the breechblock, the breechblock moving to the rear slightly by reason of its inclined guides. When the breechblock is almost clear of the base of the cartridge case, the inclined surfaces on its front face, engaging the lugs on the extractors, exert a powerful leverage on the extractors, causing them to pivot and eject the empty cartridge case from the chamber. The downward movement of the breechblock is arrested when the crank meets the breech ring.

The rotation of the rack pinion causes the rack to move upward and further compress the actuating spring against the spring case cap. After it has opened the breech, the actuating shaft roller travels along the top of the semiautomatic cam and then engages under the breech cam to lift this and further compress the breech cam spring. When the actuating shaft roller reaches the front of the semiautomatic cam, the breechblock is lifted by the springs into engagement with the hooks on the extractors which hold it in the open position against the weight of the springs.

*Closing the Breech.* The breech is always closed when a round is loaded, no matter whether it has been opened by hand or automatically.

When the round is loaded into the gun, the rim of the cartridge case engages the extractor lips, the extractors are forced forward causing their hooks to be disengaged from the stops on the front of the breechblock, and the breechblock is free to close. The actuating spring, reasserting itself, forces the rack downward, the movement of the rack being transmitted through the rack pinion to the actuat-

ing shaft which rotates the crank. The rotation of the crank is in an upward direction; and the bosses on the crank, bearing against the top of the cocking link recess, raise the breechblock to the closed position. The breech cam spring assists the actuating spring to close the breech by reacting on the breech cam, which bears on the actuating shaft roller.

During the upward movement of the breechblock, the bevel on the top and the forward movement of the block due to the inclined guides cause the cartridge to seat in the chamber, the upward movement of the block being limited by the stops at the bottom of the guides engaging the breech ring. After the breech is closed, the crank, by reason of the flats on the top and the concentric surface at the top of the cocking link recess, continues to move forward until its movement is arrested by the breech ring. This forms a positive lock, as any tendency of the breech to open accidentally would press the crank harder against the breech ring.

### Action of the Striker and Firing Mechanism

*Cocking.* As the crank rotates to the rear on opening the breech, it travels in the concentric portion of the cocking link recess and no movement of the breechblock takes place. The cocking link actuating pin, however, moving in the hole in the cocking link, forces the cocking link to the rear. The cocking link, engaging the lower arm of the striker sleeve, forces back the striker sleeve and striker spindle, compressing the main spring and withdrawing the firing pin inside the firing-hole bushing. The continued movement of the crank in opening the breech forces the cocking link further to the rear, and the cocking sleeve and the striker spindle are brought to the cocking position. The sear spring now moves the trigger sear to the left to engage the upper arm on the cocking sleeve and hold the striker in the cocked position. As the breechblock moves downward, the recess in the breechblock moves away from the firing lever flange and the stop piece moves away from the end of the locking lever. The locking lever is returned by its spring and engages the bottom of the slot in its bracket to lock the firing lever against operation. As the crank rotates to the front on closing the breech, the cocking link moves away from the cocking sleeve, but the cocking link would be

in a position to prevent the striker from going fully forward, until after the breechblock is home, because of the idle movement of the crank in the concentric. When the breechblock is home, the locking lever is lifted clear of the bottom of the slot in its bracket by the stop piece and the firing lever, the flange of which is now opposite the recess in the breechblock, is free.

*Firing.* When the firing button is pressed, the firing solenoid is energized and the bell-crank operating lever is actuated by the solenoid plunger. The bell-crank lever, pivoting about its pin, engages the end of the firing lever arm and pushes the arm to the right, the flange on the firing lever entering the recess in the breechblock. The firing lever arm engages the trigger sear and pushes this to the right also, compressing the trigger sear spring. The trigger sear is released from engagement with the cocking sleeve, and the main spring drives the striker spindle forward; the firing pin protrudes through the hole in the firing-hole bushing to strike and fire the primer. The gun recoils, the bell-crank lever is disengaged from the solenoid plunger after being returned with the firing lever by the firing lever plunger and spring. The flange on the firing lever is disengaged from the recess in the breechblock and, as the breechblock opens on runout, the stop piece moves away from the end of the locking lever, allowing the locking lever to be returned by its spring to engage the bottom of the slot in its bracket and lock the firing lever against operation.

The striker is cocked during the opening of the breech as previously described and, if the pressure is maintained on the firing button, the above cycle will be repeated, the breech being closed at the end of runout by the loading of a round.

*Safety Arrangements.* Unless the breech is properly closed, the gun cannot fire for the following reasons:

1. The flange on the firing lever is not opposite its recess in the breechblock, and the locking lever will be engaged with the bottom of its slot and will lock the firing lever; therefore, the firing lever cannot be operated to release the sear.

2. The crank will not be at the front of its recess in the breechblock, and the cocking link will, therefore, prevent the cocking sleeve and striker spindle from going fully forward.

3. The firing pin will not be in line with the primer.

Even when the breechblock is home, the gun cannot be fired unless the crank is right home, because

unless the crank is at the front of its recess the cocking link will prevent the cocking sleeve and striker spindle from going fully forward.

### SECTION 3. PRECAUTIONARY CHECKS

#### Visual Checks Prior to Loading

Insure that all switches are OFF and that the batteries are connected.

Set the brake bar locking lever to **HAND**, press the ratchet lever forward, raise the pusher arm and rest it on the support at the top of the ratchet lever, insuring that the notch engages the ratchet pawl.

Operate the handle clutch until all the ammunition clips are within the magazine.

Lift the pusher arm, press the ratchet lever forward, lower the pusher arm, and allow the ratchet pawl to engage the tooth at the top of the ratchet lever. Do not release the pusher arm.

**NOTE.** From here on, the pusher arm must be held against the weight of its spring; otherwise damage to the mechanism will result.

Cock the feed by lifting the cocking lever, insuring that the brake bar engages the projection on the front of the left-hand shell clip. Set the brake bar locking lever to **AUTO**.

Switch **ON** the gun master switch.

Carefully lower the pusher arm until it operates the depressor arm, holding it so that the hand is clear of the box guide. Maintain the hold on the pusher arm as it is lifted by the cam and then lower it, ready to engage the top tooth on the ratchet lever.

Repeat preceding paragraph until the clips have moved through a complete cycle, then switch **OFF** the gun master switch and lower the pusher arm.

#### Loading the Magazine and Gun

Insure that the main switch is **OFF** and the firing button at **SAFE**.

Open the gun-bay doors and secure the rear struts.

Test the efficiency of the retract lever, shell retainer, pawl, and stop springs by depressing the components and observing that the springs react and that the movement of the component is not sluggish.

Open the breech using the tommy bar, and insure that the breechblock is held by the extractors. Remove the tommy bar and place it in its housing at the rear of the magazine.

Set the safety catch of the striker to **SAFE**.

Set the brake bar locking lever to **HAND**.

Press the ratchet lever forward and raise the pusher arm. Rest the pusher arm on the support at the top of the ratchet lever, and insure that the notch engages the ratchet pawl.

Operate the handle clutch and wind back the shell and cartridge clips until there are three pairs of clips in position on the right of the feedway. If the gun is removed from the airplane, all the clips should be brought into position.

Carefully place 3 rounds in the right-hand pair of clips, then place 4 rounds in the second pair of clips and 5 rounds in the third pair of clips. The last round in the third pair of clips must be a special decoppering round. The decoppering rounds are marked "D. E. C." Insure that the noses of the top rounds are under the retainer plates and the bases of the cartridge cases under the catches.

Operate the handle clutch until all clips are in position inside the magazine.

Place five rounds in the fourth pair of clips. Insure that the nose of the top round is under the retainer plate and the base of the cartridge case under the catch.

Pass the next round through the last pair of clips and press the round into the feedway until the nose of the shell rests against the retaining lever and the cartridge case against the release pawl link, then place another round on the top of this one, and then four rounds in the last pair of clips. The last round in the last pair of clips must be a special decoppering round.

**NOTE.** There should now be 21 rounds in the magazine and 2 rounds in the feedway.

Lift the pusher arm, press the ratchet lever forward and carefully lower the pusher arm until the presser roller rests upon the top cartridge.

Lift the cocking lever to position the brake bar and safety lever, insuring that the brake bar engages the projection on the front of the left-hand shell clip.

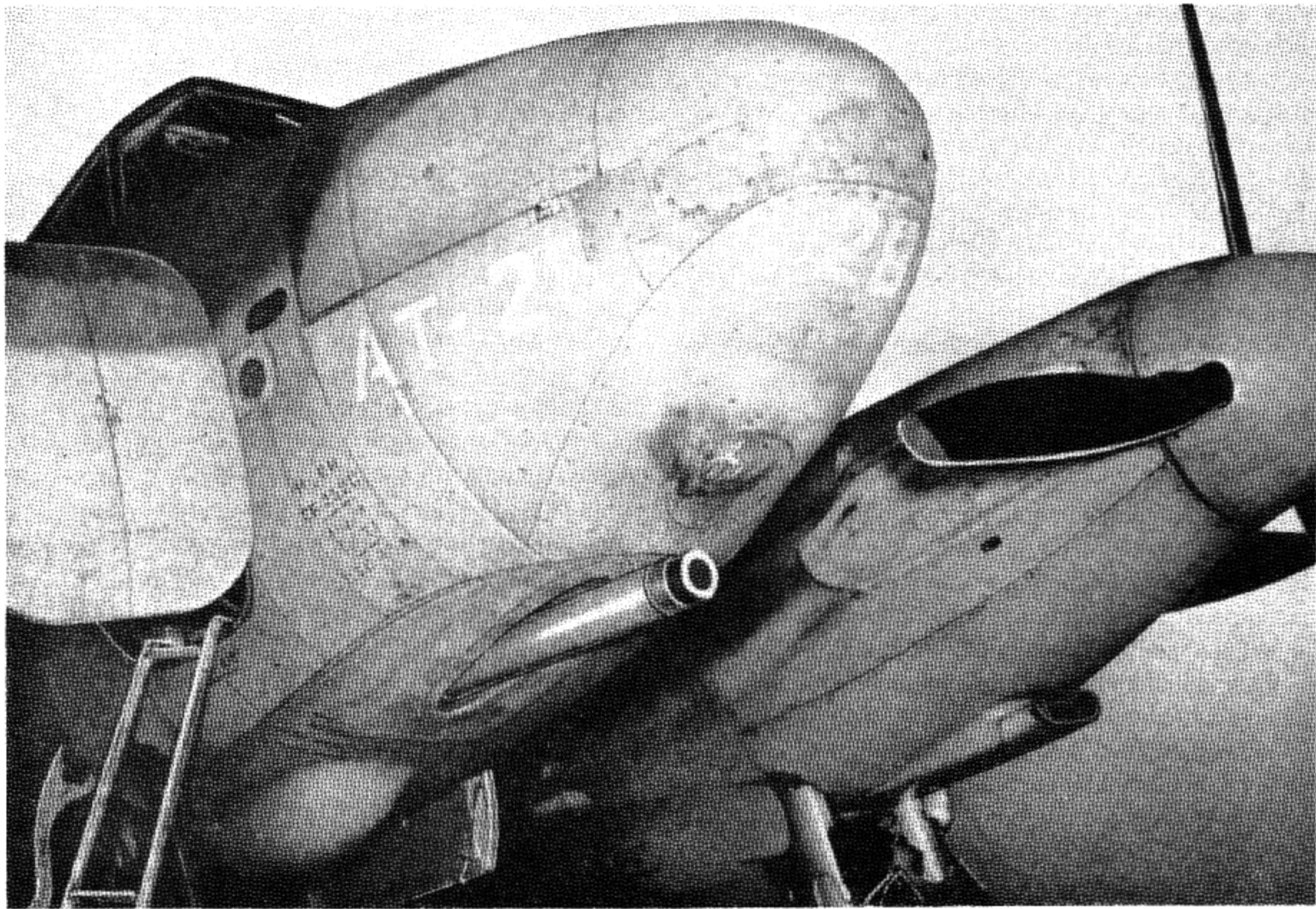


Figure 17-11. British 57-mm Automatic Aircraft Cannon mounted in an aircraft.

Set the locking lever to **AUTO** and insure that the extension on the front of the ratchet lever engages and locks the safety lever.

Just prior to takeoff of the aircraft, disengage the rammer slide from the spring rods plate by withdrawing the plunger and lifting the rammer return springs pawl, and slide the rammer to the rear. Place the nose of a round on the top of the breechblock and engage the base of the cartridge in the rammer claws. Place the hand behind the rammer and push it forward to load the round and close the breech.

Insure that the breech is fully closed by applying the tommy bar to the rack pinion and lifting it upward.

Engage the rammer return springs pawl with the spring rods plate and insure that the plunger engages its recess.

**WARNING.** The round must not be loaded in the gun until just before takeoff of the aircraft.

Set the safety catch of the striker to **FIRE** and close the gun bay doors.

### Unloading the Gun and Magazine

**WARNING.** The gun must be unloaded as soon as the aircraft lands.

Insure that the firing button is set to **SAFE** and that the main switch is **OFF**.

Set the safety catch of the striker to **SAFE**.

Disengage the rammer return springs pawl and slide the rammer to the rear.

Open the breech carefully, using the tommy bar, and receive the live round as it is ejected.

**WARNING.** Do not open the breech too quickly, otherwise the live round may be thrown clear with possible danger of the primer being struck and the round fired.

Set the brake bar locking lever to **HAND**.

Press the ratchet lever forward and raise the pusher arm. Rest the pusher arm on the support

at the top of the ratchet lever and insure that the notch engages the ratchet pawl. Remove the rounds from the left-hand pair of clips and from the feedway.

Remove the rounds from the remaining clips in order. If it is not possible to empty the right-hand pair of clips because of fouling the aircraft structure, the clips should be wound to the left by operating the handle clutch.

Inspect the bore to see that it is clear.

Release the extractors from engagement with the breechblock by taking the weight of the actuating spring with the tommy bar and pressing the extractor lugs upward from the underside of the breech ring. Allow the breechblock to close by easing the pressure on the tommy bar. Remove the tommy bar and place it in its housing at the rear of the magazine frame.

Set the striker safety catch to FIRE and operate the bell-crank lever by hand to ease the striker.

*If the breech is closed, examine the gun to see:*

1. If it is properly run out or not.

2. If the gun is properly run out, inspect to see if the breechblock is right home and whether the striker has been released or not. (This will have been indicated by failure to set the safety catch to SAFE.)

*If the gun is not properly run out, the striker will be cocked due to failure of the solenoid plunger to engage the bell-crank operating lever, and there will be a live round in the chamber, the stoppage being due to incomplete run-out. Proceed as follows:*

1. Unload the gun.

2. Push the gun into the firing position and check the recoil. Take necessary action.

*If the gun is run out, but the breechblock is not right home, the striker will be cocked due to the firing lever being inoperative and there will be a live round in the chamber. The stoppage is probably due to fouling in the chamber, fouling on the breechblock, or breech ring, or to a weak breechblock actuating spring. Proceed as follows:*

1. Unload the gun.

2. Remove the breechblock; clean the chamber; clean the breechblock, paying particular attention to the front face and the cocking link recess, clean the breech ring; and test the breech mechanism actuating spring and adjust as necessary.

*If the gun is run out and the breech is closed, but the striker is cocked, there will be a live round in the chamber. The stoppage is due to a fault in the firing mechanism. Proceed as follows:*

1. Unload the gun.

2. Test the firing mechanism and take necessary action.

*If the gun is run out, the breechblock closed, and the striker released, there will be a live round in the chamber, the primer cap of which has probably been struck. The stoppage is due to a misfire. Proceeds as follows:*

1. Unload the gun and inspect the cap to see whether it has been struck or not.

2. If the cap has been struck, the misfire was caused by defective ammunition or by a weak force of blow. Take necessary action.

3. If the cap has not been struck, the misfire was caused by a faulty striker. Remove the striker and examine it for a broken firing pin; clean the striker recess in the breechblock and the striker; gage the protrusion of the firing pin; test the force of blow; take necessary action to correct the fault.

*If the breech is open, examine the gun to see—if the rammer is right home; if a round is supported by the rammer and the breechblock; if the rammer is in the extreme rear position.*

*If the rammer is right home, there will be a loose round on the breechblock, the stoppage being caused by failure to ram with sufficient force to release the extractors due to excessive friction. Proceed as follows: unload the gun; test the rammer slide for freedom of movement by sliding it to and fro along the slide channel, and inspect the slide channel and rammer slide for burrs, which if present must be removed by stoning; clean and lubricate the slide channel and rammer slide.*

*If the rammer is not right home and there is a round supported by the breechblock and rammer, the stoppage is caused by failure to ram. Proceed as follows:*

1. Take the weight off the rammer return springs by pressing against the rammer return springs rod plate with the handle of a mallet and disengage the rammer slide from the plate; release the return springs.

2. Remove the round from the rammer claws and unload. If it is necessary to work the separator

mechanism to clear the jam, take out the split pin and unscrew the gun securing nut. If the gun is not fully run out, the runout adjusting valve should be unscrewed one-sixth turn. Carefully push the gun to the rear by hand and insure that it does not travel more than 30 inches, otherwise there is danger of it slipping out of the cradle. As soon as the round is clear, return the gun to the firing position and replace the gun securing nut and split pin.

3. Inspect the feed mechanism for breakages and damage, and take necessary action.

*If the rammer is in the extreme rear position, the stoppage is caused by failure to feed. Proceed as follows:*

1. Take the weight off the rammer return springs by pressing against the rammer return springs rod plate with the handle of a mallet and disengage

the rammer slide from the plate. Release the return springs.

2. If a round has become jammed in such a position that it cannot be removed until the feed and separator mechanisms are operated, take out the split pin, remove the gun securing nut and push the gun to the rear. Take care to insure that the gun is not allowed to travel more than 39 inches to the rear, otherwise there is danger of it falling out of the cradle. As soon as the round has been cleared, return the gun to the firing position and replace the gun securing nut and split pin. If the gun is not right home, the runout adjusting valve should be closed to insure that the buffer cylinder does not spring forward with excessive force before removing the gun securing nut.

3. Inspect the magazine and feed mechanism for breakages and damage, and take necessary action.

### SECTION 4. PREVALENT MALFUNCTIONS IN RECOIL AND RECUPERATOR SYSTEMS

#### Faults in the Recoil and the Recuperator Systems

Fault	Cause	Remedy
Violent excessive recoil.....	Air in buffer cylinder.....	Release air and refill buffer.
	Insufficient oil.....	Refill buffer.
	Weak or broken runout springs.....	Exchange defective springs.
	Piston head worn.....	Exchange piston.
Short recoil.....	Damaged gun slipper or cradle slides..	Examine and repair.
	Gland packings too tight.....	Slacken gland; if oil leaks, exchange packing.
Incomplete runout.....	Adjusting valve incorrectly set.....	Open the valve.
	Damaged gun slipper or cradle slides..	Examine and repair; remove obstructions.
Violent runout.....	Defective springs.....	Exchange springs.
	Insufficient oil.....	Refill buffer.
	Adjusting valve incorrectly set.....	Close the valve.
Failure to runout.....	Buffer too full.....	Drain off $\frac{1}{36}$ pint of oil.
	Runout adjusting valve closed.....	Open valve.
	Defective springs.....	Exchange springs.
	Gland packing too tight.....	Push gun to firing position; slacken gland. If oil leaks, exchange the packing.

NOTE. Should the gun fail to run out completely, it is nearly always possible to bring it to the firing position by depressing and pushing it forward; then

any necessary adjustment can be made to the runout adjusting valve.

## SECTION 5. INSTALLATION, DISASSEMBLY, AND ASSEMBLY

**Dismantling and Assembling, Removing and Installing the Gun and Automatic Loader**

The removal and installation of the gun and automatic loader must be undertaken when the aircraft is on level ground.

A type D or E bomb trolley should be used as a mobile platform on which to lower the gun and the loader, the breech of the gun and the cradle being rested upon suitable blocks of wood placed across the floor of the bomb trolley.

When the gun is raised or lowered, great care must be taken to insure that the starboard extremity of the automatic loader does not catch on and damage the petrol pipes running down the starboard side of the gun bay.

*Removing the Gun and Loader.* Insure that the gun master switch is OFF.

Open the gun-bay doors and secure the rear struts.

Unload the gun and close the breech.

Disconnect the electrical supply cable from the automatic loader.

Remove the front detachable panel by undoing the securing screws and sliding the panel forward over the muzzle.

If the gun is to be moved away from the aircraft, position a mobile trolley under the gun bay ready to receive the gun.

Connect the shackle on the end of the lifting cable to the lifting eye of the gun and loader.

Take in the slack of the cable on the winch.

Remove the securing bolts which attach the channel spacing bracket of the loader to the fork end of the vertical rear suspension rod.

Loosen the lateral locknuts on the trunnion mountings and remove the clamping bolts from each of the two trunnion mounting caps so that their lower sections are free to swing downward about their pivots. The weight of the gun and loader is now being taken on the winch cable.

Lower the gun slowly and carefully, steadying and guiding the gun and loader as they descend.

Detach the winch cable from the lifting eye.

*Installing the Gun and Loader.* Open the gun-bay doors and secure the rear struts.

Remove the front detachable panel.

Run the gun and loader under the gun bay, insuring that it is correctly positioned for lifting, and attach the winch cable to the lifting eye.

Raise the gun slowly and carefully, steadying and guiding the gun and loader into the gun bay.

When the gun is correctly positioned, secure the two trunnion mounting caps with their clamping bolts and tighten the lateral locknuts.

Replace the channel spacing bracket securing bolts to secure the loader to the fork end of the vertical rear suspension rod.

Lock all nuts with new split pins.

Disconnect the winch cable from the lifting eye.

Replace the front detachable panel and secure it.

*Pulling Back the Gun Body.* Place the gun in a horizontal position or at a slight angle of depression.

Disengage the rammer return springs pawl, slide the rammer to the rear, and engage it with its catch.

Take out the split pin and remove the gun securing nut from the rear of the buffer cylinder.

Carefully pull or push the gun body to the rear a distance of not more than 30 inches.

**WARNING.** Great care must be taken to insure that the 30 inches is not exceeded, otherwise the gun slipper will become disengaged from the cradle. The gun should not be kept in this position longer than is necessary to complete any cleaning or inspection, unless it is supported under the breech ring.

To return the gun to the firing position, carefully push it forward; replace the gun securing nut and the split pin.

**Buffer and Recuperator**

**NOTE.** Before any of the following operations can be carried out the gun and automatic loader must be removed from the aircraft.

*Removing the Buffer and Recuperator from the Cradle.* Place the gun at an angle of depression and secure it to the cradle. Remove the split pin and piston rod nut, and the cradle front cap.

Remove the split pin and the gun securing nut from the rear of the buffer cylinder, using the spanner provided. Remove the buffer and recuperator from the front of the cradle.

*Removing the Runout Springs.* Remove the buffer and recuperator from the cradle.

Replace the gun securing nut and split pin, and remove the stuffing box key.



Using the spanner provided, unscrew the runout springs compressor, holding the gun securing nut with its spanner to prevent the buffer cylinder from turning.

Remove the runout springs compressor, runout springs, parting plates, and buffer cylinder bearing.

*Assembling the Runout Springs.* Assemble the buffer cylinder bearing over the front of the buffer cylinder with the flanged portion toward the front.

Assemble the rear parting plate against the bearing, then the left-hand wound spring, a parting plate, and the right-hand wound spring.

Place the front parting plate over the runout springs compressor from the rear, then the other left-hand-wound spring and parting plate.

Smear the threads with graphited lubricating grease, and place the runout springs compressor, as assembled in the previous paragraph, over the front of the buffer cylinder and screw it home, using the spanner provided and holding the gun securing nut with its spanner to prevent the buffer cylinder from turning. Replace the stuffing box key.

*Assembling the Buffer and Recuperator in the Cradle.* Smear the runout springs with graphited lubricating grease, and remove the gun securing nut if it is in position.

Lubricate the left and right cradle slides with antifreezing grease.

Place the buffer and recuperator in the cradle from the front, taking care not to damage the guide keys on the runout springs compressor when engaging them with the left and right cradle slides. Care must also be taken to insure that the rear of the buffer cylinder is not damaged when passing it through the hole in the gun slipper.

Replace the gun securing nut and split pin.

Replace the cradle front cap and the piston rod nut and split pin.

## Breech Mechanism

**NOTE.** The breech mechanism can be dismantled and assembled with the gun installed in the aircraft.

*Dismantling the Breech Mechanism.* Apply the tommy bar to the rack pinion and open the breech by pressing the tommy bar downward.

Set the safety catch to **SAFE**, withdraw the retaining catch plunger, rotate the striker through an

angle of 60° to the right, and remove it from the breechblock.

Take the weight of the actuating spring by pressing the tommy bar downward, release the extractors from engagement with the breechblock by pressing the extractor lugs upward from underneath the breech ring. Allow the breechblock to close by carefully easing the pressure on the tommy bar.

**WARNING.** Never attempt to release the extractors unless the weight of the actuating spring is taken on the tommy bar.

Remove the split pin and actuating shaft nut. Remove the rack pinion and collar.

Support the breechblock and extractors and withdraw the actuating shaft to the left. Remove the breechblock with crank and the extractors from the breech ring.

Disconnect the cocking link from the crank by removing the actuating pin and remove the cocking link from the rear of the breechblock.

Remove the two fixing screws and tap the actuating spring case downward. Remove the actuating shaft sleeve.

To dismantle the spring case, turn the check screw, unscrew the spring case cap, remove the bearing disk, actuating spring, and rack.

To remove the round retaining piece, depress the spring plunger through the access hole, using a drift, and slide the retaining piece out of its recess. Take care to restrain the plunger spring by placing the thumb over the plunger as the retaining piece is removed.

*Dismantling the Firing Mechanism.* Turn the safety catch to **FIRE**.

Release the striker by grasping the cocking handle in one hand and the striker case in the other and pressing the trigger sear. Remove the split pin and unscrew the cocking handle. Remove the cocking sleeve from the rear, and the striker spindle and main spring from the front, of the striker case.

To remove the safety catch, take out the retaining pin and remove the catch.

To remove the trigger sear, take out the split pin, remove the trigger sear spring seat, spring, and trigger sear.

To remove the retaining catch, remove the split pin and the retaining catch head from the rear, and the plunger and spring from the front.

*Assembling the Firing Mechanism.* Place the retaining catch plunger and spring in the front of the case, replace the head and split pin.

Insert the trigger sear, spring, and trigger sear spring seat in the striker case, and replace the split pin.

Insert the safety catch and secure it with its retaining pin. Set the safety catch to FIRE.

Press the trigger sear to the right, insert the cocking sleeve and push it home.

Assemble the main spring on the striker spindle and insert the spindle in the striker case from the front, taking care to engage the key and keyway. Replace the cocking handle and secure it with its split pin.

Cock the striker by holding the striker case in one hand and pulling the cocking handle with the other. Set the safety catch to SAFE.

*Assembling the Breech Mechanism.* Coat the actuating spring with antifreeze grease, place the rack and actuating spring in the spring case, place the bearing disk on the top of the spring, and screw home the cap.

Replace the actuating shaft sleeve and the spring case, and secure the case with its two fixing screws.

Place the crank in the front of the breechblock with the arm toward the rear of the block. Assemble the cocking link in the rear of the breechblock and connect it to the crank with the actuating pin.

To assemble the round retaining pin, insert the spring and plunger, engage the retaining piece in its recess, depress the plunger, and slide the retaining piece into position. Insure that the plunger engages and holds the retaining piece.

Enter the actuating shaft in the left of the breech ring.

Hold the two extractors against the breechblock and crank, insert the assembly in the breech ring from the underside, push the breechblock into the closed position, and hold it.

Insure that the cocking link is flush with the rear of the breechblock, push the actuating shaft into position, and assemble the collar and rack pinion. Replace the actuating shaft nut and split pin, and open the breech.

Insure that the striker is cocked and the safety catch is at SAFE. Insert the striker in the breechblock, press it forward, and turn it through 60° to the left; at this point, the retaining catch plunger will engage in its recess.

Adjust the tension of the actuating spring by releasing the check screw and turning the cap. The actuating spring must be adjusted so that it closes the breech smartly but without undue violence. When the spring is correctly adjusted, lock the spring case cap with the check screw.

Examine the bore to see that it is clear, release the extractors, and close the breech. Operate the firing gear to ease the striker main spring.

## SECTION 6. TESTS OF THE BRITISH 57-MM AND AMERICAN 75-MM AT UNITED STATES NAVAL AIR TEST CENTER

### The 57-mm Gun Installation in the Mosquito

The 57-mm gun in the Mosquito Mk XVIII is mounted in the gun bay in lieu of the four 20-mm gun installations of the normal Mosquito fighter-bomber aircraft.

The axis of the gun is  $3\frac{15}{16}$  inches to the starboard of the aircraft centerline. The muzzle projects a distance of 2 feet  $1\frac{1}{2}$  inches beyond the fuselage beneath the nose of the aircraft. The gun is installed parallel to the fore-and-aft line of the aircraft and depressed 3° downward from the rigging datum line. A small, limited range of vertical and horizontal adjustments of the gun is provided to compensate for manufacturing tolerances.

The nearest point of the starboard and port propeller blade planes to the axis of the gun is 2 feet  $1\frac{3}{4}$  inches and 2 feet  $9\frac{1}{4}$  inches, respectively.

The weight of the gun is carried directly on the center section of the main spar. The side loads are carried by 2 struts, 1 of which is connected to the port extremity of the armor plating beneath the pilot's cockpit, and the other is connected to the starboard side of the fuselage toward the rear of the gun bay. The main recoil and runout loads are carried by other struts which are fitted to the horizontal armor plating beneath the pilot's cockpit. The rear of the gun and the feed mechanism are steadied by a further attachment to a strong point in the overhead of the rear part of the gun bay compartment. This

Comparative Data: 6-Pounder Class M 57-mm British High-Velocity Field Gun and 75-mm Aircraft Gun AN-Mk 5 (T31E1)

Gun Specification	57-mm	75-mm
Gun length . . . . .	116.95 inches . . . . .	129.238 inches.
Gun weight:		
Unloaded . . . . .	1,073 pounds, without loader . . . . .	763 pounds (no automatic loader).
Unloaded . . . . .	1,400 pounds with loader (approximate) . . . . .	
Loaded . . . . .	1,712 pounds with loader (approximate) . . . . .	1,189 pounds (no automatic loader but includes weight of crewmen).
Rate of fire . . . . .	55-60 rounds/minute . . . . .	20 rounds/minute for 4- to 5-round bursts.
Muzzle velocity . . . . .	3,000 feet/second . . . . .	1,970 feet/second.
System of operation . . . . .	Long recoil . . . . .	Semiautomatic, long recoil.
System of locking . . . . .	Sliding vertical block . . . . .	Sliding vertical block.
System of feeding . . . . .	Automatic loader . . . . .	Manual.
Method of headspace . . . . .	Breechblock so designed as to take up excessive headspace.	Factory established.
Location of feed opening . . . . .	Right rear . . . . .	Rear of breech.
Location of ejection opening . . . . .	Rear of breech . . . . .	Do.
Method of charging . . . . .	Manual and pneumatic . . . . .	Manual.
Method of cooling . . . . .	Air . . . . .	Air.
Barrel length . . . . .	112.2 inches (50 calibers) . . . . .	37.5 calibers.
Barrel weight . . . . .	616 pounds . . . . .	628 pounds.
Rate control . . . . .	None . . . . .	None.
Barrel removal . . . . .	Not quick disconnect . . . . .	Not quick disconnect.
Chamber pressure . . . . .	46,000 p. s. i. . . . .	38,000 p. s. i.
Bore:		
Number of grooves . . . . .	24 . . . . .	24.
Groove depth . . . . .	0.026 . . . . .	0.02.
Groove width . . . . .	0.147 . . . . .	0.248.
Pitch . . . . .	1 turn in 30 calibers . . . . .	Sloping 7°.
Length of rifling . . . . .	94.18 inches . . . . .	96.22 inches.
Direction of twist . . . . .	Right hand . . . . .	Right hand.
Form of twist . . . . .	Constant . . . . .	Constant.
Recoil system . . . . .	Hydraulic buffer with spring recuperator . . . . .	Hydraulic spring, concentric.
Quantity of oil in buffer . . . . .	3 pints . . . . .	Data not available.
Length of recoil . . . . .	30 inches (approximate) . . . . .	21 inches.
Firing mechanism . . . . .	Percussion (electrically controlled) . . . . .	Percussion (electrically controlled).
Distance the CG, gun unloaded, is forward of the rear face of breech . . . . .	20 inches . . . . .	No data available.
Distance the CG, gun loaded, is forward of the rear face of breech . . . . .	15 inches . . . . .	Do.

attachment also serves to carry the loads of the moment introduced by the offset of the recuperator mechanism from the main gun mounting points.

The gun may be raised and lowered into position by means of a winch, which weighs 25 pounds and is installed in the overhead of the gun bay.

The normal ground gun has been suitably modified for installation with aircraft mountings and for the attachment of the automatic loader.

Access to the gun bay is obtained through two gun-bay doors which are similar in principle to those on the normal Mosquito fighter-bomber. They are not, however, hydraulically operated. The starboard door is wider than the port door, permitting the installation of the ejection chute on the starboard side of the gun bay.

A detachable panel immediately ahead of the gun-bay doors is provided to allow the gun to be removed

Comparative Data: Loaders, Ammunition, and Mountings for 6-Pounder Class M 57-mm British High-Velocity Field Gun and 75-mm Aircraft Gun AN-Mk 5 (T31E1)

Loader Specification	57-mm	75-mm
Capacity . . . . .	23 rounds . . . . .	21 rounds carried in racks.
Method of operation . . . . .	Electrical and mechanical . . . . .	Hand loaded.
Weight . . . . .	322 pounds . . . . .	Weight allowed for crewman loader, 170-200 pounds.
Height, maximum, with pusher arm up . . . . .	32 inches . . . . .	Not pertinent.
Length . . . . .	72 inches . . . . .	Do.
Width . . . . .	32 inches . . . . .	Do.
Ammunition Specification	57-mm	75-mm
One round . . . . .	13 pounds . . . . .	19.3 pounds.
Full load of ammunition . . . . .	312 pounds . . . . .	426 pounds.
Mounting Specification	57-mm	75-mm
Overall length . . . . .	149 inches . . . . .	129.24 inches.
Width . . . . .	32 inches . . . . .	No data available.
Height, maximum, with breech open and pusher arm up . . . . .	49 inches . . . . .	Do.

or installed. A blister is formed in the panel and in the forward part of the starboard gun-bay door to provide clearance for the gun buffer.

The nose of the aircraft is protected by a metal blast plate, 0.126 inch thick, which incorporates a circular metal access panel for the removal of empty cases and links from the caliber 0.303 guns.

The ejection chute, incorporating a deflector plate, is fitted to the upper side of the starboard door. The bases of the ejected cases strike this deflector plate and are deflected base downward through the opening in the door and out into the slipstream.

A firing solenoid is fitted to the gun and operates the firing pin mechanism through a system of rollers and levers. A solenoid-operating relay is incorporated in the circuit. Firing is controlled by a firing lever at the top of the control column.

A gun-and-feed master switch protected by a safety flap is installed on the instrument panel.

The standard Mosquito fighter-bomber installation consisting of 4-caliber .303 guns in the nose of the aircraft has been retained. This installation is fired by means of a firing button on top of the

control column. For the purpose of the tests described here, this installation was removed.

The standard British gun sight Mk 2L was retained and used throughout the tests. This sight is similar in principle to the United States Navy Mk 8 illuminated sight.

### Automatic Loader of 57-mm Installation

The magazine is a component of the automatic loader and consists of a rectangular framework secured to the feedway. The magazine is set at an angle of 30°, sloping to the left-hand side of the feedway. The automatic loader has several main parts, which are described in paragraphs which follow.

*Cartridge Clips.* There are five sets of cartridge clips, which are made of phosphor-bronze. The forward clip houses and positions the projectile nose, the rear clip guides the rim of the cartridge. The loader is rearmed by an ordnanceman, who stands inside the bomb bay and places the rounds in the clips.

*Pusher Arm.* The pusher arm is situated on the forward left-hand side of the magazine. The

pusher arm is lightly spring loaded on a cam and pushes the rounds downward from the clips into position over into the feedway.

*Motor Drive, Brake, and Switch Mechanism.* The electric motor (24-volt d. c., specially wound) operates the clips and repositions the pusher arm. Its intermittent operation is controlled by the brake and switch mechanism. The motor is automatically switched on at the bottom of the downward stroke of the pusher arm and is switched off by the completion of one movement of the cartridge clips.

### 75-mm Gun Installation in the PBJ-1H Airplane

The gun used in the PBJ-1H installation is the 75-mm aircraft gun AN-Mk 5 (T13E1). This is a special light-weight gun developed for aircraft use. The gun is located in the lower forward section of the fuselage. The muzzle protrudes from a 12- by 16-inch recess in the nose and is approximately flush with the contour of the nose of the aircraft. The main gun loads are carried on trunnions which are connected into the fuselage structure through a set of heavy brackets.

The gun is jugged into the airplane parallel to the longitudinal axis of the fuselage and is located 10 $\frac{1}{4}$  inches to port of the centerline. It cannot be bore sighted in azimuth. The elevation adjustment is made on the rear mount. Powder gases are prevented from entering the airplane by a micarta partition and baffle aft of the muzzle opening in the fuselage.

The ejected cases strike a deflector, which is built into the fuselage. They then drop through a pair of spring-loaded doors into the slipstream.

### Loading System of the 75-mm Gun

This installation is hand loaded. Twenty-one rounds are carried in a rack on the left-hand side of the gun. The loader, or cannoneer, picks the rounds out of the rack and throws it forward into the breech. It is possible for an experienced cannoneer to load 5 rounds in 14 to 15 seconds.

The effort required to throw the 20 pounds into the breech and trip the extractors is quite high in view of the fact that ram air is coming down the barrel at 170 to 220 knots.

### Automatic Loader Operation for 57-mm Gun Installation

During firing, the following sequence of operations takes place.

During recoil, the lower round in the feedway drops into the ramming position. The round above it in the feedway has been retained by a series of pawls, thus preventing double feed. The pressure applied to the rounds in the feedway during recoil is applied indirectly by the pusher arm and directly by the feed-arm shaft. The rammer is forced to the rear by the recoiling barrel, rotated, and stowed in a horizontal position. It is retained by a pawl controlled from the connecting rod indirectly driven by the cam tracks on the top of the breech ring, through the separator mechanism.

During counterrecoil, when the gun has moved forward sufficiently, the breech opens, the empty case ejects, and the nose of the round in the ramming position drops down into the top of the breechblock. The rammer is released by the retaining pawl and moves forward, contacting the cartridge and driving it into the breech. The extractors are tripped, the breech closed, and, if the firing mechanism is being operated, the gun will fire. At the same time, the rounds in the feedway will move down one position. When the pusher arm is at the bottom of its stroke, indicating that the clip in position over the feedway is empty, the operation of the magazine mechanism takes place concurrently with the cycle of operation just described. The motor is switched on automatically, the pusher arm is raised, and the next clip slides down into position over the feedway. The pusher arm rides down on the top round. The switch mechanism is recocked, and the driving motor is switched off.

### Object of the Tests

The tests described here were arranged at United States Naval Air Test Center, Patuxent River, Md., as a material evaluation of the 57-mm gun installation in the RAF Mosquito Mk XVIII airplane in comparison with other installations of comparable weight, size, and effectiveness of fire. The one comparable American installation is the 75-mm gun in Model PBJ-1H airplane.

*Summary.* The installation of the 57-mm gun in the Mosquito aircraft appears to be the result of a military exigency, as the gun is basically a ground

weapon which has been adapted for aircraft use without major redesign. The installation is well adapted to the aircraft and is, in general, an excellent one. It is particularly free from malfunctions. In contrast to this, it is heavy and cumbersome. The automatic loader is of special interest in comparison with the hand loading of the 75-mm gun. No tactical evaluation was conducted as such; however, it was noted that this installation, like all present large-caliber gun installation in aircraft, suffers from the lack of effective fire control. A fixed reticle for mil-ring sighting is the sighting method employed.

### Conclusions

It was concluded that the 57-mm gun operated satisfactorily both as installed in the RAF Mosquito Mk XVIII airplane and as set up for ground-stand firing, and that the following topics indicate relative comparisons between the 57-mm gun installation in the RAF Mosquito Mk XVIII and the 75-mm gun installation in the PBJ-1H type aircraft.

*Reliability.* Both installations were equally reliable.

*Rate of Fire.* The automatic loader of the Mosquito installation made possible a more rapid rate of fire.

*Complement of Crew.* Since the 57-mm installation on the Mosquito airplane is automatically loaded, no loading crew is required. In the 75-mm installation, one cannoneer for loading the gun is required.

*Ease of Gun Removal.* The removal of the 57-mm installation from the Mosquito airplane can be accomplished in considerably less time than the removal of the 75-mm gun from the PBJ-1H airplane. The 57-mm gun may be removed by 2 men in 25 to 30 minutes; whereas, the 75-mm gun may be removed by 3 men in 10 to 12 hours.

*Weight.* The 75-mm installation is 620 pounds lighter in the loaded condition and 637 pounds lighter in the unloaded condition.

*Maintenance.* The 57-mm and the 75-mm gun installations are each comparatively easy to maintain. The automatic loader of the 57-mm requires but little added maintenance.

*Rearming.* The 75-mm installation is more quickly rearmed (the 75-mm installation may be rearmed in 5 to 7 minutes while rearming the 57-mm installation requires about 15 minutes).

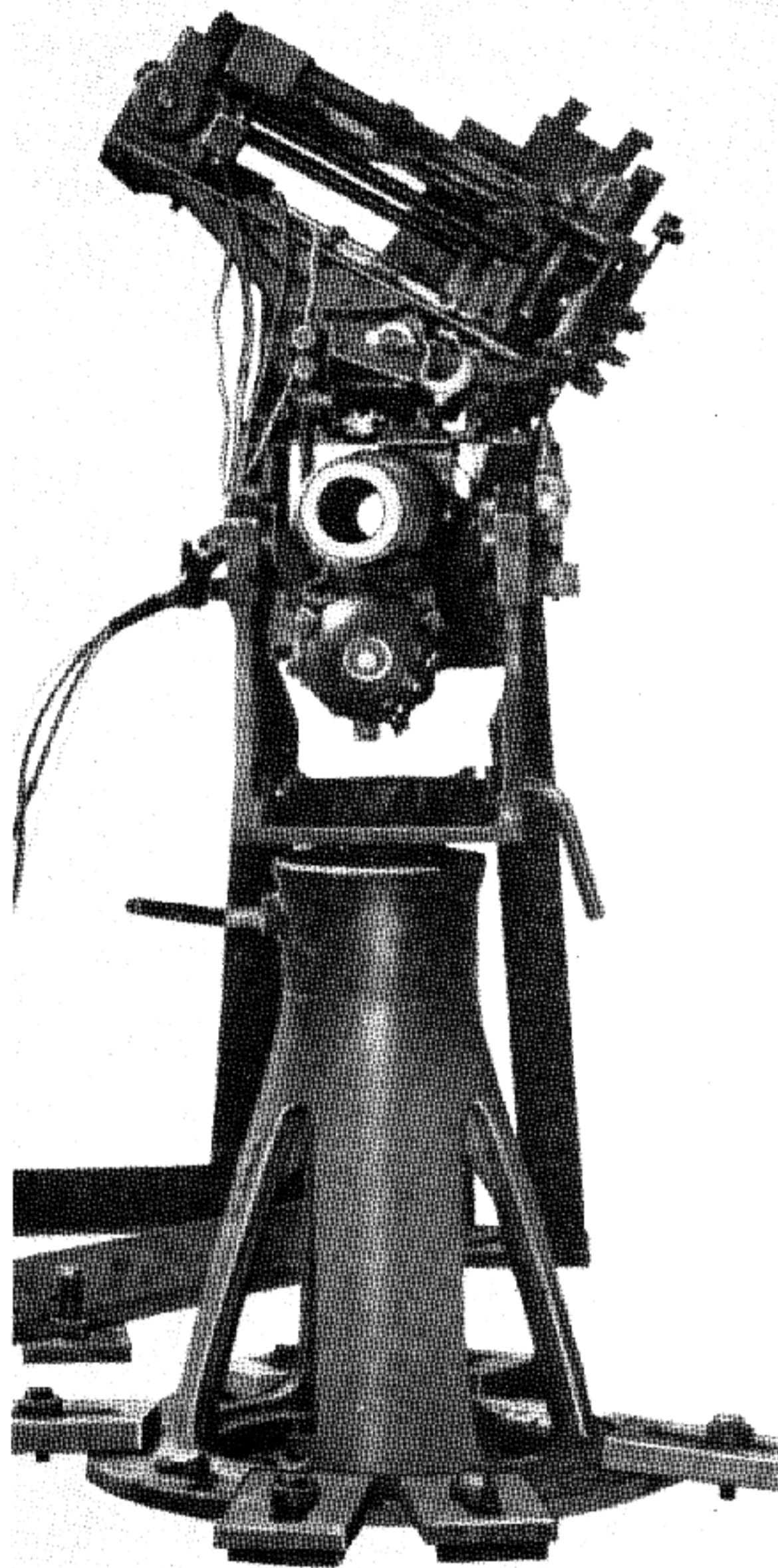


Figure 17-12. British 57-mm Automatic Aircraft Cannon on a test mount. Front view.

*Tactical Use.* The PBJ 75-mm cannon installation is considerably restricted in a tactical approach because of the difficulties encountered in manually loading the ammunition during evasive maneuvers or under the effects of  $g$ 's. Fairly violent evasive action and 2.5 positive  $g$ 's does not cause stoppages in the Mosquito installation.

## Recommendations

Recommendations were: (1) That if future tactical trends in combat aircraft demand a large caliber, automatically loaded gun, the principle of the 57-mm automatic loader be considered satisfactory for such use; and (2) that the principle of the Mosquito 57-mm loader be considered for adaptation to the use of spin stabilized rocket or recoilless cannon installations.

## Discussion of Tests of the 57-mm Gun

*Arrival of Equipment.* The Mosquito airplane incorporating the 57-mm installation was delivered on 30 April 1945, and the gun installation was inspected. The project, however, was inactive until the ammunition and special tools arrived from England.

It was stated by the RAF gunner assigned to the project that ground firing of the gun in the airplane

would not be advisable. Steps were accordingly taken to procure a second gun, and the necessary ground mounting for the Naval Proving Ground, Dahlgren, Va. A special ground stand was manufactured for purposes of cleaning and studying the cannon.

*Ground Firing.* Between 9 and 11 August 1945, 209 rounds were ground fired from the gun.

There were two stoppages during the first load which were caused by incorrect firing procedure and one other stoppage which was caused by an over-filled buffer system which did not allow the gun to return to battery. These faults were corrected.

Rates of fire were observed on 10-round bursts with a stopwatch. The rate of fire varied between 50 and 55 rounds per minute.

Motion pictures on 35-mm film at 125 frames per second in 18- to 20-cycle sequences were obtained of both sides of the gun during firing. Both sequences

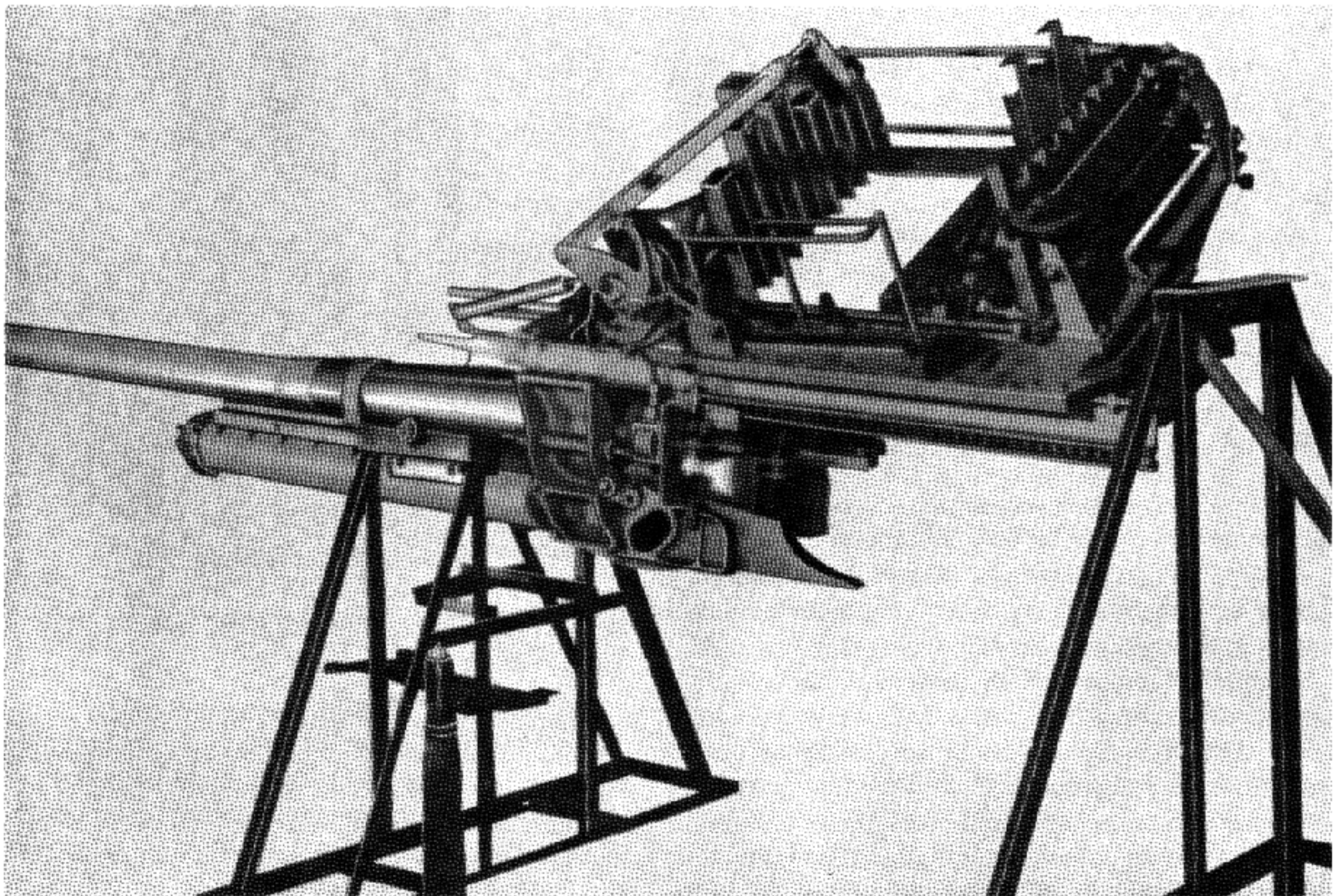


Figure 17-13. British 57-mm Automatic Aircraft Cannon. General view of gun and loader on maintenance stand.

give a comprehensive picture of the gun and feeder in operation.

Jump cards of the ground mounted 57-mm gun were fired at a 500-yard target. Two firings were attempted. On the first, the sighting point was too low and one shot was lost. The data for the second target is as follows:

Rounds fired: 5.

80 percent circle: 2.5 mils diameter.

100 percent circle: 3.9 mils diameter.

*Air Firing.* Air firing was started on 6 July 1945. A total of 240 rounds were air fired. Four rim-lock stoppages occurred in six flights; then this defect was corrected. A rim lock occurs when the cartridge rim jams in the rear cartridge clip, because of burred or bent clip surfaces. These clips are made of soft bronze and should be replaced by harder clips made of soft steel. One other stoppage was

caused by a broken solenoid plunger. The remainder of the air firing was without malfunction.

The rate of air firing was calibrated during 6-, 7-, 8-, and 10-round bursts by a stopwatch. The rate of fire of the 57-mm gun in the air varied between 50 and 55 rounds per minute.

All attacks were made in relatively shallow dives of 15 to 35 degrees. Speeds during firing were between 260 and 300 miles per hour. The altitudes of entrance into the attack varied from 2,000 to 4,000 feet. The number of rounds fired in any one attack ranged from single rounds to 6- or 8-round bursts.

Test firing during flights in all instances was satisfactory. The most outstanding observation was that while the gun recoil was noticeable, it did not affect the flight altitude of the plane. After each shot, the pilot was able to hold his point of aim.



## Chapter 18

## 30-MM BRITISH AIRCRAFT CANNON (ADEN)

## SECTION 1. HISTORY AND BACKGROUND

The 30-mm British Aircraft Cannon (Aden) is a revolver type weapon of British design similar to the German MK 213 gun. The designation "Aden" stands for "Armament Development Enfield."

The first six Aden guns were made in 1949. Numbers assigned to these guns were A1 to A6. At this time, a change was made in the link, and 35 guns of this second model were made (numbers A7 through A41).

In February 1950, the Ordnance Corps requested the United Kingdom to lend one 30-mm Aden aircraft gun for test. In September 1950, one gun of the second model (gun number A37) and 5,000

rounds of ball ammunition were shipped to Aberdeen Proving Ground where functional and performance tests were conducted from 20 December 1950 to 30 November 1951. One additional gun was received from Wright-Patterson Air Force Base, Dayton, Ohio, to furnish replacement gun components as required. A summary of the results of these tests is given in section 3 of this chapter.

Refinements were continued in Britain until a satisfactory preproduction model had been fabricated and subsequently the gun was put in production at a royal ordnance factory.

## SECTION 2. DESCRIPTION OF THE 30-MM ADEN GUN

## General Description

The 30-mm Aden gun is a heavy caliber revolver type machine gun with a high rate of fire and is designed for use in a fixed position in aircraft. The gun is fired electrically, and cooling is effected by air flow over the barrel. The weight of the gun is approximately 193 pounds.

Ammunition is fed to the gun in a belt, which may be of any length depending on the stowage space available. Provision is made for left- or right-hand feed, and the change from one feed to the other can be carried out by repositioning certain components.

The gun is gas operated. The slide and feed slide are forced to the rear by the gas piston, compressing

## General Data: 30-mm Aden Gun

<p>Gun length: 116 inches.  Gun weight: 176 pounds.  Rate of fire: 1,150-1,200 rounds/minute.  Muzzle velocity: 2,000 feet/second.  System of operation: Gas operated, revolver principle.  System of locking: Stationary breech.  System of feeding: Gas actuated.  Method of headspace: Stationary anvil (set headspace).  Location of feed opening: Ammunition enters from lower left side of receiver.  Method of charging: Electro-pneumatic.  Method of cooling: Air.</p>	<p>Barrel length: 52 inches.  Barrel weight: 64.2 pounds.  Rate control: None.  Barrel removal: Not quick disconnect.  Chamber pressure: 40,700 p. s. i., maximum.  Bore:  Number of grooves: 16.  Groove depth: 0.0177 inch.  Groove width: 1.45 inches.  Pitch: 5 degrees 30 minutes.  Direction of twist: Right hand.  Form of twist: Progressive.</p>
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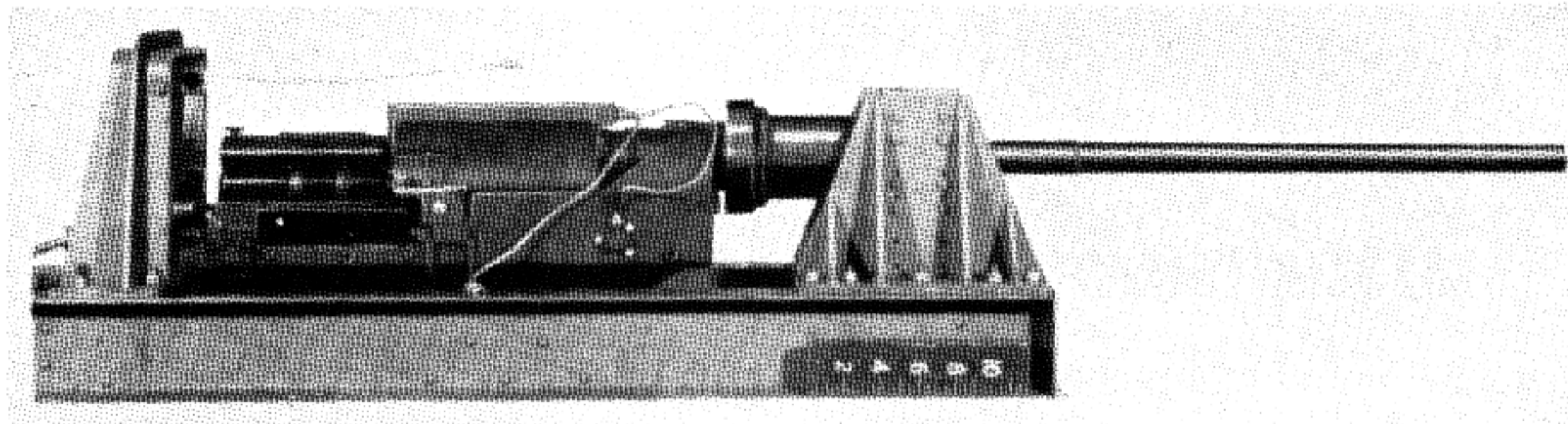


Figure 18-1. 30-mm British Aden Gun.

the return springs between the slide and the rear of the cradle, at the same time rotating the breech cylinder. The combined efforts of the expanding return springs reasserting themselves and the inertia of the breech cylinder camming upon the slide carry the slide and feed slide forward completing the 72-degree rotation of the breech cylinder and firing a round. During the counterrecoil of the feed slide, a round is stripped from its link, a second round is chambered, and the empty case of the round originating the cycle is ejected.

When a round is fired, the barrel, breech cylinder housing, and breech cylinder recoil a maximum of three-fourths of an inch. The feed mechanism is coupled to the breech cylinder and rotates with it. At the moment of ejection, the feed mechanism sprockets are clear of the ejection opening. The rounds are driven through the links by the rammer face of the feed slide, the links being ejected through the feed mechanism link ejection opening.

The gun may be divided into two groups, the non-recoiling portions and the recoiling portions. The nonrecoiling portions are: Cradle and fittings; feed mechanism; and buffer housings. The recoiling portions are: Barrel; breech cylinder; breech cylinder housing; gas cylinder; buffer spindle; slides; and feed slide.

### Description of Components

*The Cradle.* The cradle is the fabricated framework of the gun. Provision is made on the sides of the cradle for mounting the breech cylinder housing. At the rear of the cradle is a lug in which the feed mechanism anchorage pin engages. At the front of the cradle are two holes for anchoring the buffers. The cradle also accommodates the block, the cam

lever guide, the return springs and rods, the feed mechanism, and the buffers.

**THE BLOCK.** This part is riveted to the bottom of the cradle and houses the cam lever guide. It also provides a surface for the slide and feed slide to work upon.

**THE CAM LEVER GUIDE.** This part is positioned in a recess in the forward end of the block and is secured to the cradle by two bolts. Machined in the cam lever guide are a track in which the cam lever plunger travels and the alternative positions for housing the cam lever springs which are pinned at their forward end to the cam lever guide.

**RETURN SPRINGS AND RODS.** The return springs and rods are positioned between the return spring rod seatings in the rear of the cradle and the recesses in the rear of the slide. The return spring rods pass through the return springs and are pinned to the return springs knurled knobs by means of locking pins. These locking pins engage the locking screws in the rear of the cradle.

**FEED MECHANISM.** Operation of the feed mechanism is automatic in that its rotation is governed by the rotation of the breech cylinder. It is fabricated, having a front casing and outer casing welded as one component. The casing accommodates the feed opening and is slotted for ejection of the links. It is also formed to allow for empty case ejection. The front and rear casings incorporate bearings for the feed mechanism spindle. On the spindle are mounted two sprockets positioned by a distance piece and collar. The front end of the spindle is machined to engage the slot in the breech cylinder. At the rear of the mechanism on top of the casing is a spring-loaded plunger which engages the feed mechanism spindle.

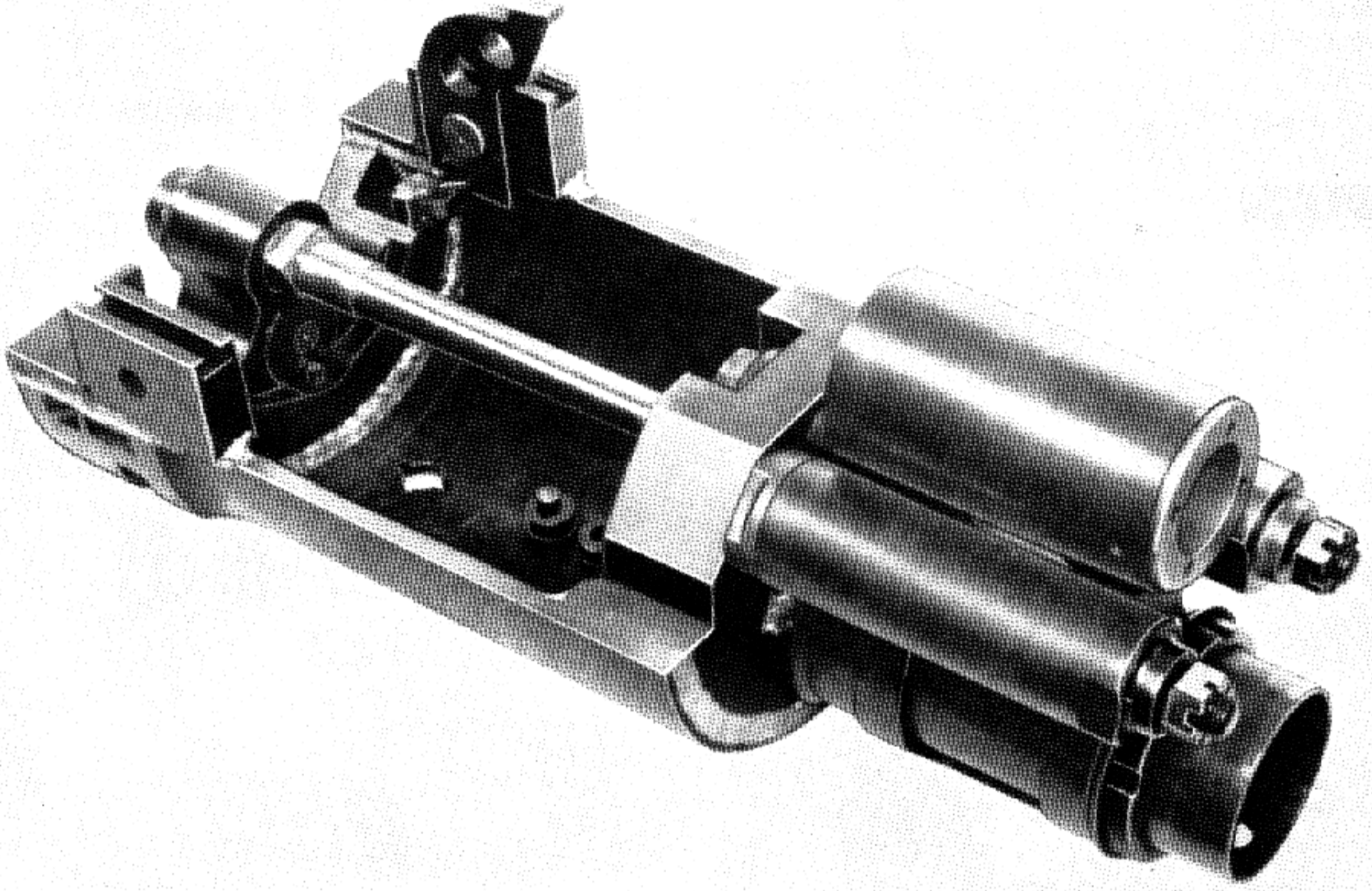


Figure 18-2. 30-mm British Aden Gun. Cylinder housing

**BUFFERS.** The buffers are situated between the front of the cradle and the front face of the breech cylinder housing. Assembled on the buffer spindle is the buffer housing. Between the spindle washer and the buffer housing plug are 29 Belleville washers, each 0.090 inch thick, in pairs. A single Belleville washer at one end is placed with its concave surface facing outward.

**Barrel.** The barrel is ribbed at the breech and has an interrupted thread to engage a corresponding thread in the breech cylinder housing, and there is a slot forward of the interrupted threads for the engagement of the barrel catch. A gas hole is drilled in the underside of the barrel connecting with the gas cylinder.

**Breech Cylinder.** The breech cylinder has five chambers 72 degrees apart. The cylinder rotates on a spindle which is supported in bearings at each end of the breech cylinder housing, the rear end of the spindle being slotted to engage the feed mechanism spindle. Machined into the front end of each cylin-

der is a recess to accommodate a gas sealing sleeve. This component forms a gas-tight seal between the breech cylinder and barrel face when the round is fired.

On the circumference of the cylinder are five rollers, equally spaced between the chambers, which engage the slide and cause rotation of the breech cylinder. Machined into the circumference are two sets of ten recesses which are engaged by the anti-rotation plunger. The front set are utilized for left-hand feed and the rear set for right-hand feed.

**Breech Cylinder Housing.** The breech cylinder housing provides front and rear bearings for the breech cylinder spindle. The housing is attached to the cradle by means of two trunnions which engage ribs on the cradle side plates. At the top front of the housing is the barrel catch. Also at the front are two tapped holes into which screw the buffer spindles and a bracket which supports the gas cylinder. At the rear of the housing are recesses which contain the cartridge retainer and a housing for the

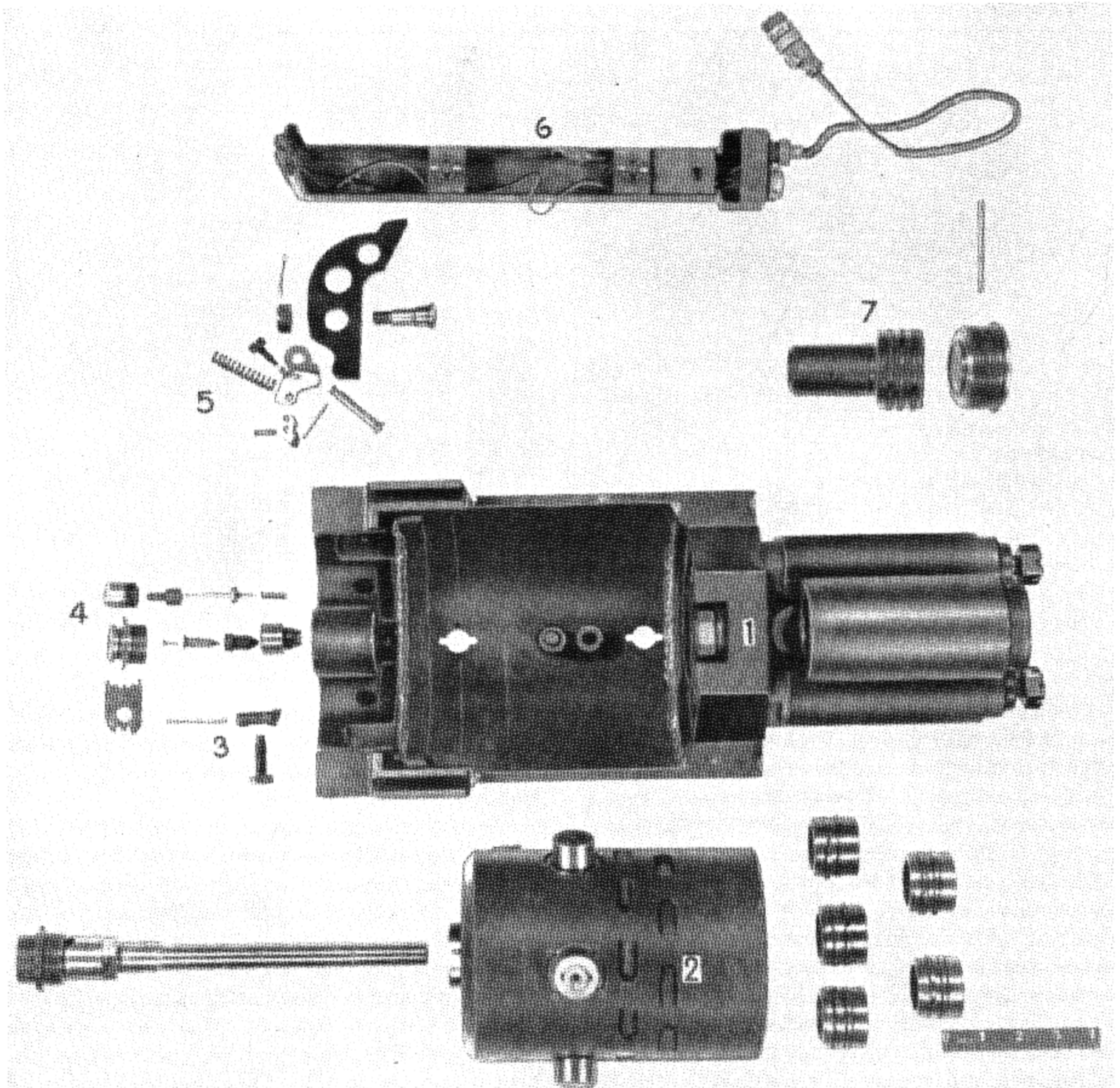


Figure 18-3. 30-mm British Aden Gun. Disassembled view of cylinder housing group. (1) Cylinder housing. (2) Cylinder group. (3) Round retainer assembly. (4) Firing pin assembly. (5) Extractor assembly. (6) Electric housing unit. (7) Gas piston and plug.

firing unit. Machined into the sides are seatings for the ejection assembly and the stud for the ejector actuating arm. The breech cylinder spindle is locked into position by the firing unit nut, which is, in turn, positioned by the tap washer and the cartridge retainer bolt. In the top of the housing are two recesses for the breech cylinder anti-rotation plunger and spring. One of the contact firing boxes is attached to the top of the housing by two quick-release studs, and at the rear of the box is the switch which contacts the firing unit plunger. The firing contact of the firing unit is insulated from the cylinder breech housing. At the front and rear of the top of the housing are the recesses for the barrel plunger switch and the round in chamber plunger, respectively.

*Gas Cylinder.* The gas cylinder houses the gas piston. At the front end of the cylinder is a plug which is locked in position by a pin passing through the plug and the cylinder body. The gas piston has three piston rings. The gas from the gas port in

the barrel passes along a channel in the bracket to the gas cylinder and piston.

*Slide.* The slide is the mechanism which rotates the cylinder. The feed slide is connected to the slide by a connecting rod and pin. Slots are machined in the top of the slide to take either the plate right or left according to the feed required. At the front of the slide is an axis pin for the cam lever. Under the cam lever is the cam lever plunger, which protrudes through the slot in the slide and engages the cam lever guide.

*Feed Slide.* The feed slide is attached to the slide by a connecting rod and pin. The movement of the feed slide is governed by the movement of the slide. The feed slide travels under the feed mechanism. The curved pusher at the rear of the feed slide contacts the base of the rounds and drives them out of the links into the breech cylinder, and the pusher face forces them fully home into the cylinder. Feed slides are left- or right-handed.

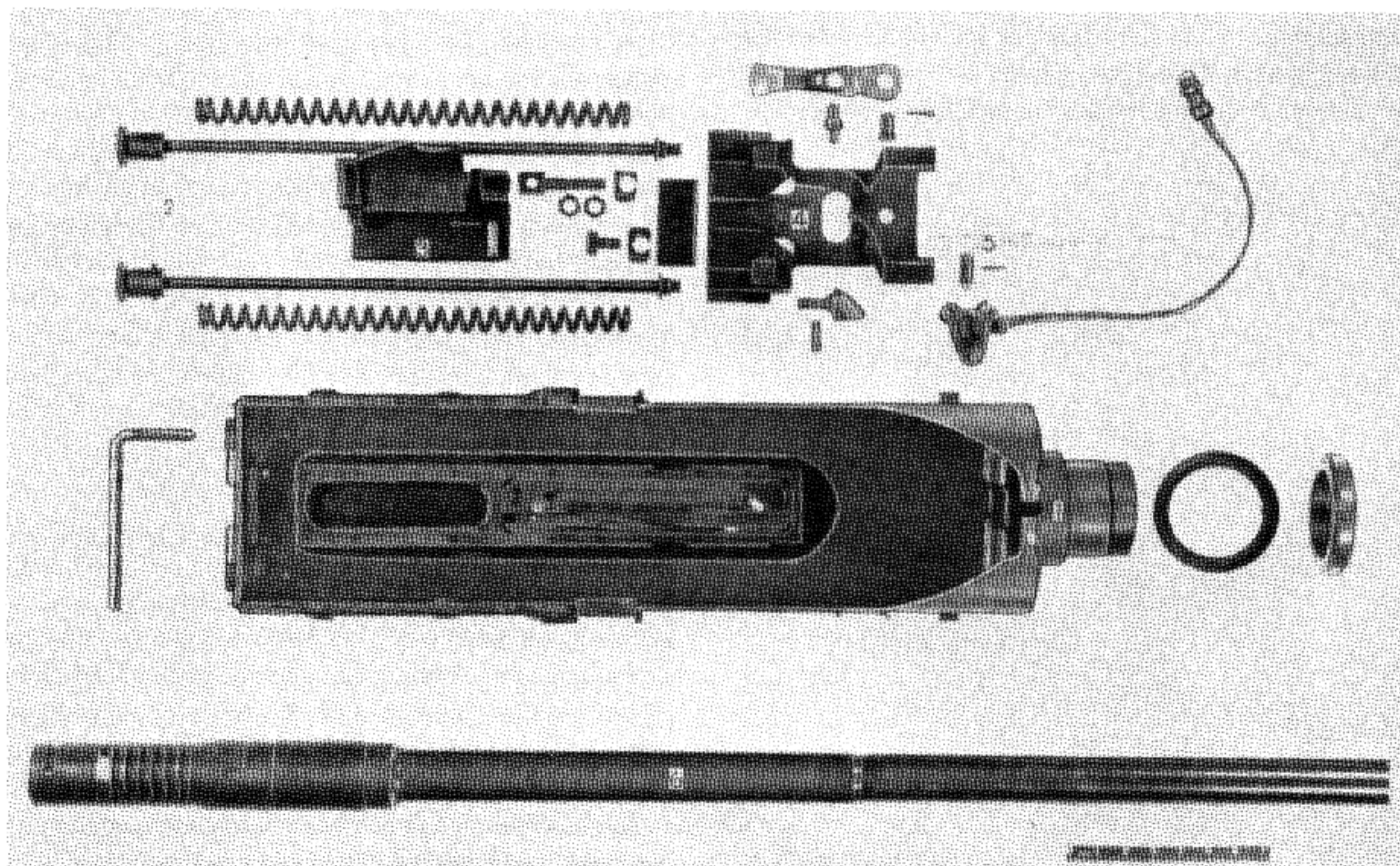


Figure 18-4. 30-mm British Aden Gun. Disassembled view. (1) Receiver. (2) Return springs and guides. (3) Feed slide unit. (4) Slide unit. (5) Receiver slide electrical contact. (6) Barrel.

### Functioning of the 30-mm Aden Gun

**Recoil Action.** Assume that a belt is in position and a round is in the firing chamber of the breech cylinder. When the firing switch is operated, the firing circuit is completed and the round is fired.

The projectile passes from the chamber into the barrel and the driving band forces the gas-sealing sleeve hard against the rear face of the barrel, thus sealing the chamber and preventing loss of gas pressure. When the base of the projectile has passed the gas vent in the barrel, some of the gases pass along the gas channel to the gas cylinder emptying upon the head of the gas piston and driving it to the rear.

On the firing of the round, direct recoil moves the barrel breech cylinder housing and breech cylinder to the rear a maximum distance of approximately three-fourths inch, the breech cylinder housing running on guides on the side of the cradle and the bearing in the barrel trunnion housing. The buffers are anchored between the front of the cradle and the front of breech cylinder housing. As recoil takes place, the buffer spindles are withdrawn and compress the Belleville washers between the head of the spindles and the buffer housing end cap.

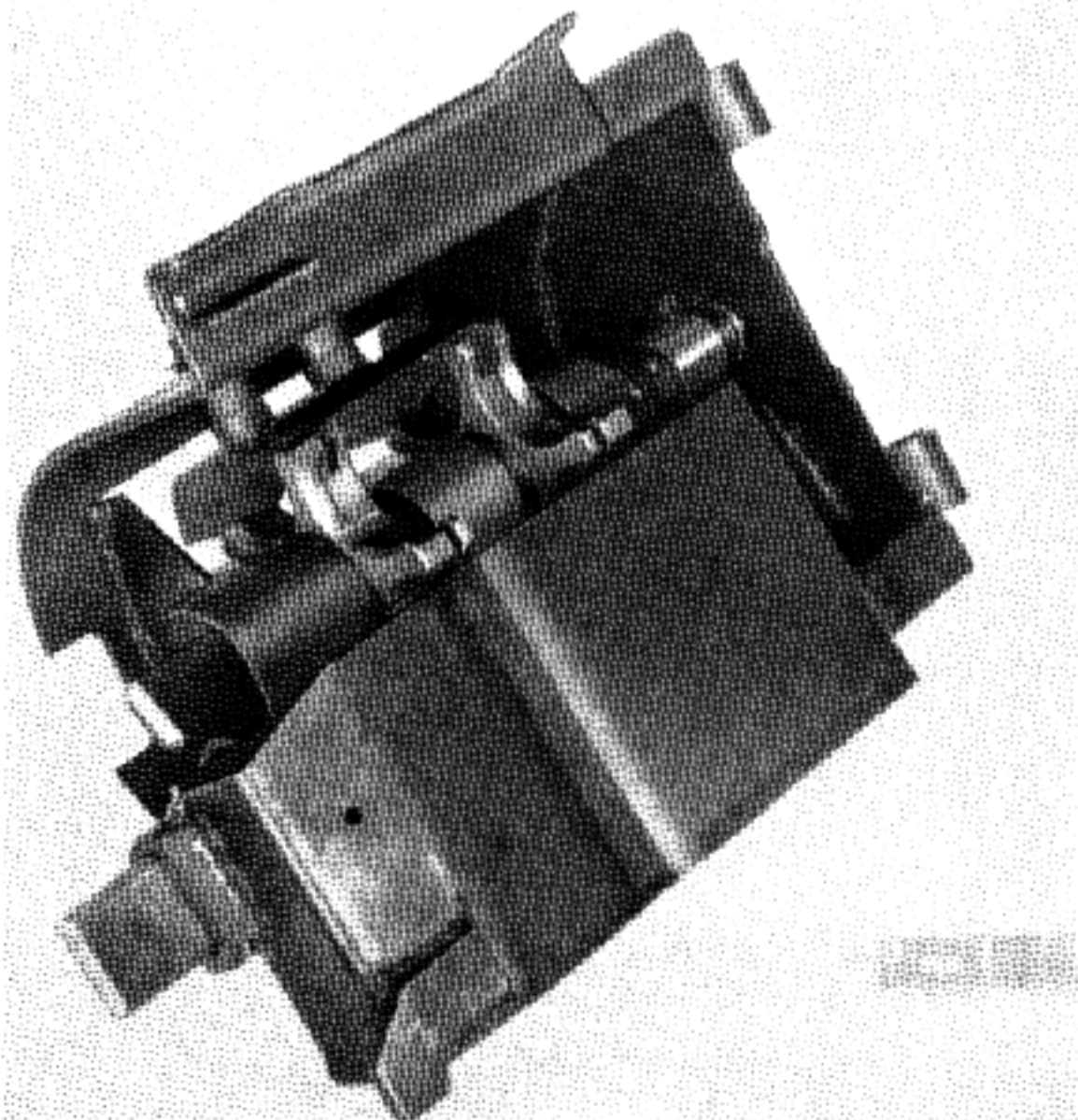


Figure 18-5. Feed mechanism of 30-mm British Aden Gun. Bottom view showing feed sprockets and link chute guide.

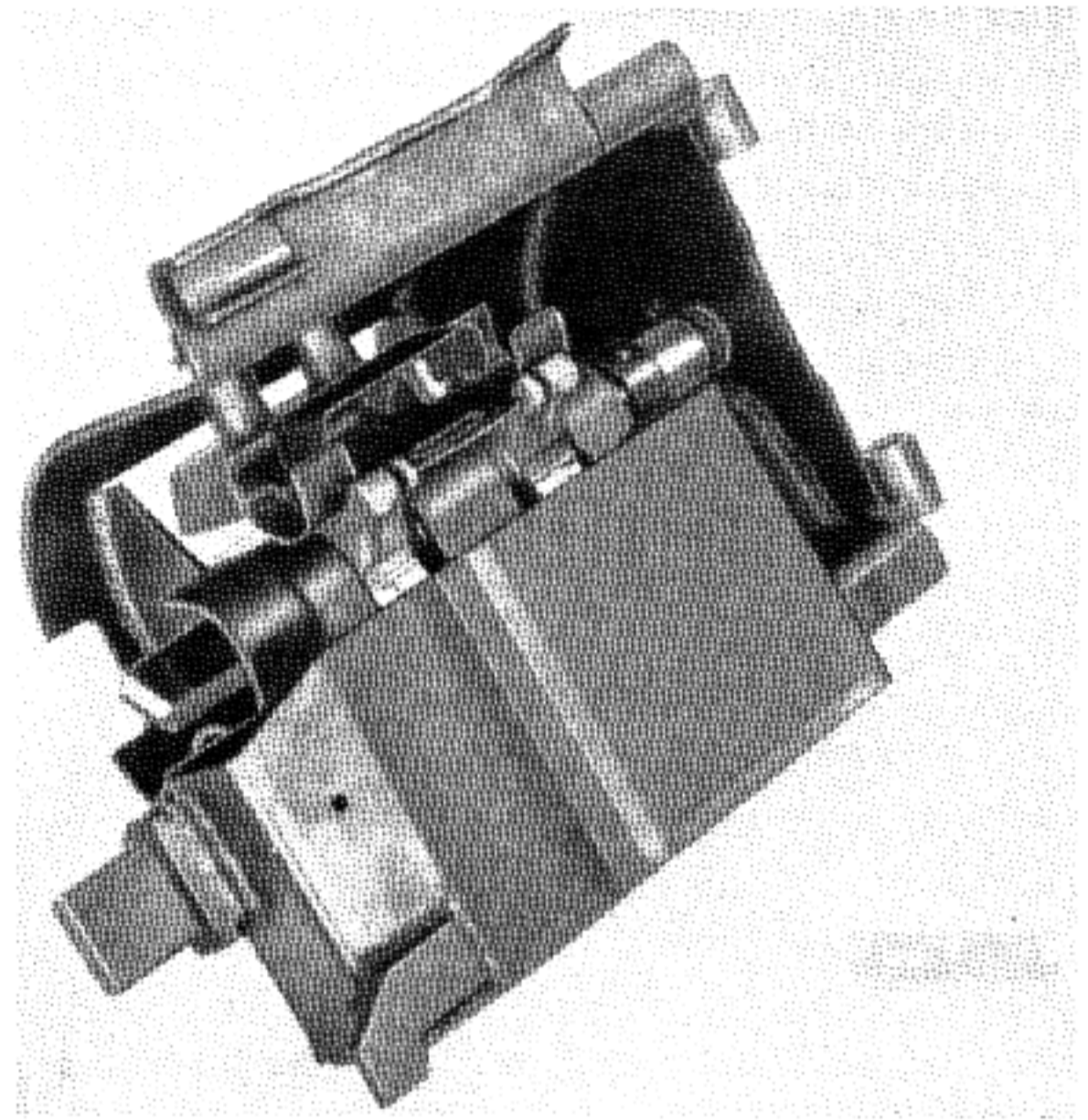


Figure 18-6. Feed mechanism of 30-mm British Aden Gun. Bottom view showing a link entering the feed chute guide.

As the gas piston moves to the rear, it comes into contact with the front face of the slide, drives it to the rear and compresses the return springs. During this movement, the breech cylinder is prevented from rotating until the slide has recoiled  $1\frac{3}{4}$  inches. The cam lever plunger is running in the track of the cam lever guide, and when the slide has recoiled  $1\frac{3}{4}$  inches, the roller is free to move. A further movement of the slide brings the curved face of the cam lever in contact with the roller, rotating the breech cylinder  $36^\circ$  and bringing the next roller into contact with the ramp at the front of the slide. At this stage, the two rollers are engaged by ramps on each side of the slide, the cam lever plunger is forced by the springs to move across the slide, and the cam lever is moved. The feed slide is linked to the slide by means of the connecting rod; and, as a result of the action just described, the feed slide has moved to the rear and the rammer faces have been positioned behind the rounds to be fed from the feed mechanism into the breech cylinder.

As the slide moves to the rear, the ejector actuating arm disengages from the ejector ramp on the slide. The ejector, which is in contact with the actuating arm, is returned to its housing by the

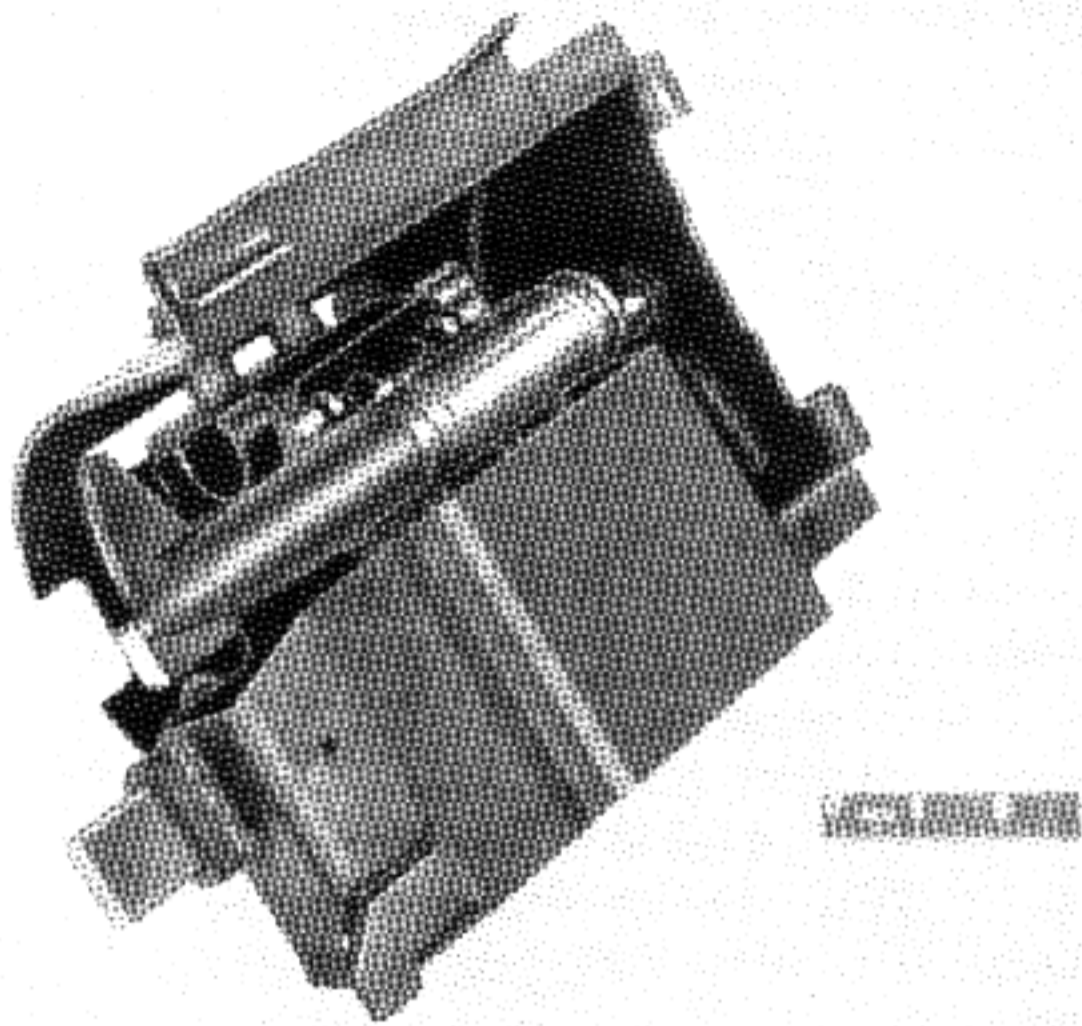


Figure 18-7. Feed mechanism of 30-mm British Aden Gun. Bottom view showing a round in position for stripping.

ejector spring, forcing the actuating arm to its lowest position.

The feed mechanism spindle is connected to the breech cylinder spindle; therefore, as the cylinder rotates, the feed mechanism sprockets will also rotate and feed into the ammunition belt. At all times, the feed mechanism sprockets are in alignment with the breech cylinder chambers.

The breech cylinder housing recoils; and the round in the chamber of the breech cylinder which will, on completion of the gun cycle, be in the firing position, is retained in the chamber by the cartridge retaining plunger, engaging behind the base of the round. This action prevents the base of the round from fouling the rear of the cylinder housing as the cylinder rotates.

**Counterrecoil Action.** The return springs force the slide and feed slide forward. The curved pusher face of the feed slide is positioned behind a round in the feed mechanism. As the feed mechanism moves forward, it pushes the round out of the link into a chamber of the breech cylinder. On the next forward movement, the front rammer face will ram the round further home into the chamber and the cartridge retainer will engage behind the base of the round.

The Belleville washers, under compression, exert themselves and return the breech cylinder housing, breech cylinder, and barrel to the runout position.

The inertia of the cylinder in rotation acting through the cylinder roller as it cams along the cam lever, together with the efforts of the compressed return spring, drive the slide forward. As the slide counterrecoils, the cam lever plunger is engaged in the track of the slide. The cylinder continues to rotate an additional  $36^\circ$ , and the roller is guided into the straight slot at the rear of the slide by riding along the cam lever. The plate, in guiding the roller during firing and during charging, rotates the cylinder through the remaining  $36^\circ$  of its cycle. As the cylinder rotates, the next round to be fired is brought into position with the barrel and firing unit. When the roller has entered the slot at the rear of the slide, the cam lever plunger has traveled along the track in the cam lever guide and is at that point deflected by the curved ramp on the track. This moves the cam lever on its axis to the opposite side of the slide. The front face of the slide comes into contact with the rear face of the gas piston, forcing it fully forward into the gas cylinder.

When the slide has almost completed its forward movement, the ejector ramp on the slide contacts the ejector actuating arm, which, in turn, rotates the ejector on its axis. The ejector claw engages the rim of the empty case, which has been brought into engagement with it by the rotation of the cylinder, withdraws the case from the chamber, and ejects it to the rear between the sprockets of the feed mechanism.

The links are retained by the feed mechanism link guides and fall away from the link ejection opening at the top of the feed mechanism.

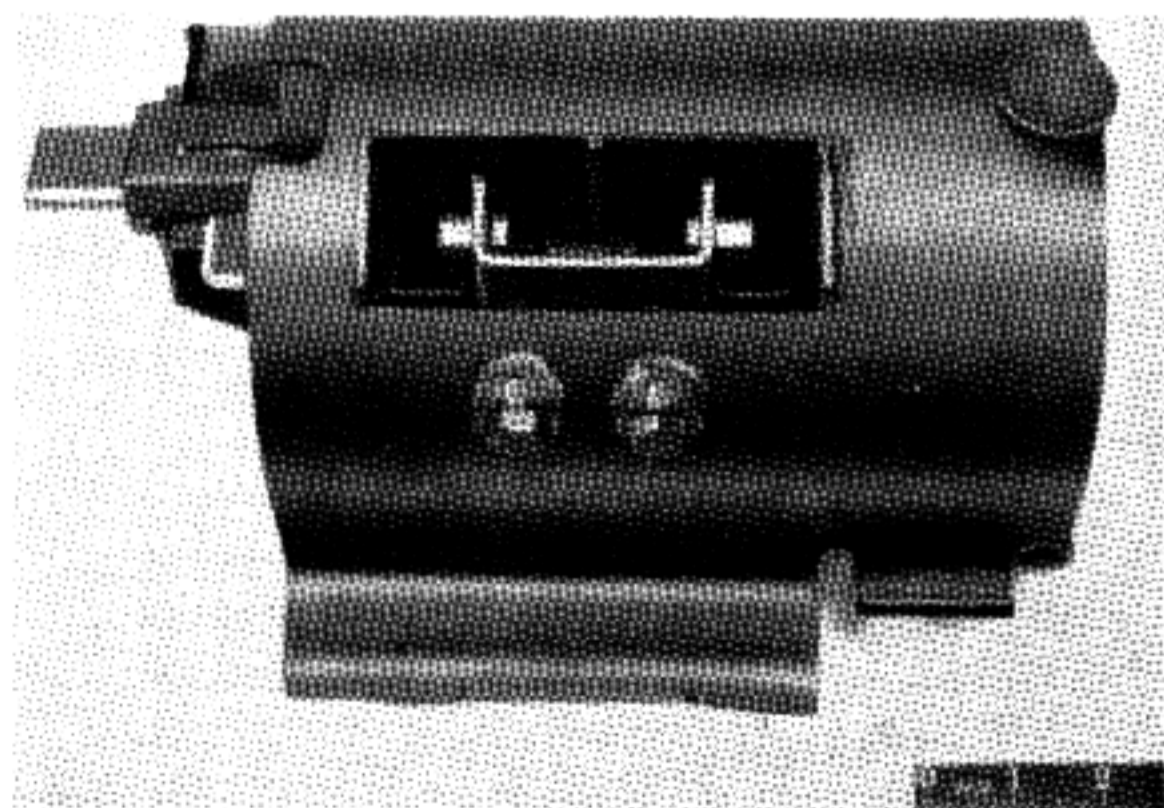


Figure 18-8. Feed mechanism of 30-mm British Aden Gun. Top view showing a link in the feed chute guide.

The barrel, when correctly in position, raises the barrel operating plunger, which closes a switch in the top contact box. When the slide enters its bat-

tery position, contact is made which completes the circuit and fires another round, provided the firing switch remains closed.

### SECTION 3. TESTS CONDUCTED AT ABERDEEN PROVING GROUND, MARYLAND

#### Objectives

The object of these tests was to obtain functional and performance information concerning the 30-mm Aden gun and other information of value to ordnance gun designers.

#### Summary of Test Results

A total of 1,106 rounds was fired to obtain basic functional data such as muzzle velocity, rate of fire, target dispersion, trunnion reaction, and time-displacement of moving parts. High-speed movies of certain gun actions were taken. Muzzle velocities were slightly above the 2,020 feet per second specified in British reports. However, the rates of fire obtained were below the 1,200 rounds per minute rated for the gun. Stoppages were excessive, and parts failures high. Target dispersion, though initially extremely high, was improved somewhat by modification of the mount.

#### Details of Test Procedure

After inspection and repair of the gun, as received from England, testing was started. The procedures followed are discussed by test item or subject as follows:

*Rate of Fire.* Individual and overall rates of fire were recorded by camera chronograph during all test phases. Rounds were magnetized and fired through 20-inch solenoid coils.

*Dispersion and Yaw.* Dispersion and yaw were taken at 1,000 inches by firing through cardboard targets during all phases. A plastic scale prepared from measurements of a projectile was used for determining yaw in degrees.

Attempts were made to reduce dispersion through the use of a barrel stabilizer.

*Muzzle Velocity.* Muzzle velocity was recorded by camera chronograph on approximately 100 rounds during burst fire and 17 rounds single shot. The rounds were magnetized and fired through solenoid coils.

*Physical Measurements and Calibrations.* Weights and measurements of the gun and gun components were taken.

*Time-Displacement, Time-Pressure (Gas Cylinder) Trials.* A time-displacement (revolving drum) camera was utilized in recording travel versus time of recoiling parts. Reflectors were mounted on the cylinder housing and the feed slide, and sufficient light was focused on their path of travel. A slot was cut longitudinally in the feed mechanism and a link deflector provided. The travel of the reflectors was recorded on film records containing time calibrations. The distance calibrations were placed on the same film by an additional step using a calibration bar with reflectors spaced at 2-inch intervals.

Time-pressure of the gas cylinder chamber was recorded on film record by means of C-AN pressure-resistance gages. Timing markers were synchronized with the time-displacement camera for simultaneous records that could be plotted with the same time constant. The gas cylinder plug was replaced with an adapter for installing the gage. Only the base of the gage housing, which contains the ferrule, was utilized. Considerable difficulty was experienced with existing C-AN pressure-resistance gages due to gun shock. The principal point of breakage was at the junction of the fine wires of the ferrule and the lead-off wires. The porcelain-like insulation was discarded and the single-lead wires replaced with multistrand fine ductile copper wires. Gages fabricated in this manner were able to withstand the shock. Piezo-electric gages were found unsatisfactory. Two gages were damaged in test trials. A neoprene washer approximately 1/8-inch thick was placed in the cylinder to act as a buffer in eliminating the shock of contact between the piston and the metal shoulder of the cylinder at the rearmost point of piston travel.

Trials were made with the standard Aden gas piston and three gas pistons supplied by Armour Research Foundation. The latter had diameters of 2.147 inches, 1 5/8 inches, and 1 1/8 inches, respectively. The trials were then repeated with a gas-port restriction plug containing an orifice of 0.140-inch



diameter, thereby reducing the cross-sectional area of the gas port by one-half.

*Velocity of Ejected Cases.* A 16-mm ultra-high-speed-motion picture camera was utilized. The velocity was taken between the centers of the feed-sprocket slots.

*Recovery of Projectiles.* Several rounds were fired for recovery in cotton waste for examination of rotating bands.

*Chamber Pressure.* Ten rounds were disassembled and each reloaded with a copper crusher gage, for determining chamber pressure. A spring-wire clip was utilized to retain the gage in the base of the case. The round was fired through burlap to retard the gage in the event it left the tube. Alternate rounds without gages were fired for comparison of muzzle velocities.

Piezo-electric chamber pressure was recorded on 18 rounds fired from a Mann barrel, utilizing an instrument trailer with cathode ray oscilloscopes and recording cameras. Approximately one-half the rounds were fired with the British converter firing circuit and the remaining with the 250-volt condenser unit. The firing circuit output was also recorded on the film record.

A strain patch was placed on the firing cylinder of the 30-mm Aden gun during one phase of the trunnion-reaction test for use in the study of gun action. This gave a film record of the powder pressure curve that could be tied in with other time-displacement data. However, magnitude could not be determined in this manner.

*Time-Travel of Firing Cylinder Rotation.* A 16-mm ultra-high-speed motion picture camera was utilized to photograph the action. A graduated steel tape was fastened to the outside circumference of the firing cylinder, and a hole was cut in the cylinder housing through which the tape could be photographed.

*Time-Travel of Muzzle.* A stylus was attached to the gun barrel, 1 inch from the muzzle. A grid was positioned on one side of the muzzle and the motion of the stylus recorded on motion picture film through the use of an ultra-high-speed camera.

*Gas Leakage.* Access to the supposed points of leakage was obtained by cutting holes in the cylinder housing (junction of cylinder sleeve and tube) and in the receiver (junction of gas cylinder and slide).

The ultra-high-speed camera was utilized in recording the gas leakage.

Comparison firing was accomplished with and without gas check rings. Rates of fire and muzzle velocities were recorded. The "A" gas piston of 2.147-inch diameter was modified locally to simulate the characteristics of the Aden piston. The weight of the "A" piston was reduced by 3½ ounces, the piston face edges chamfered and gas escape ports drilled in the piston shaft. One burst was fired with the modified unit in this test phase.

*Effects of Feeding, Stripping, and Chambering upon the Round.* In these trials, the firing switch was released during the bursts and the unfired rounds remaining in the chambers and feed were inspected and photographed.

*High-Speed Movies.* High-speed movies of the following gun actions were recorded in addition to those previously referred to:

Path of ejected cases.

Action within feed mechanism.

Action of ammunition belt within feed chute.

Impact of projectiles upon target.

*Comparison of Firing Circuits.* British Joint Services Mission, Technical Services (Air) Washington, D. C., Report dated 19 January 1949 states that British electric primers have resistances between 20 and 200 ohms; that firing circuits have frequencies of 1,500 cycles per second using a "square" wave; that approximately 1,500 microjoules of energy are required to insure functioning (however, no time limitation specified); and that British primers should work satisfactorily with electrical firing arrangements envisaged by the United States.

No information is available as to the method of obtaining the above requirements nor is a diagram of the Aden gun firing circuit available.

Firing was accomplished with the locally assembled 1,500-cycle a. c. circuit and the 250-volt condenser discharge circuit, and rates of fire were recorded. Efficiency of the units in firing low resistance primers was observed. Very little firing was accomplished with the British converter unit, since it was not available until the test was nearing completion.

To determine the suitability of the gun for controlled fire, a burst (10 rounds) was attempted with

the 250-volt condenser discharge fire control unit set at 800 rounds per minute.

*Primer Resistance.* A standard ohmmeter was used to obtain primer resistance of 12 complete rounds and six rounds with projectile and propellant removed. With the gun in full battery position and the round in the chamber, readings were recorded from the gun lead wires, the resistance of the gun circuit being deducted from the meter reading.

*Trunnion Reaction Test.* The gun was mounted in the trunnion reaction mount, assembled with strain resistance gages. Recordings during single and burst fire were made on film record in the instrument trailer equipped with cathode ray oscilloscopes. Displacement-time records of the motion of pertinent moving parts, as previously described, were obtained to aid in the interpretation of the force records.

The gages were bridged individually to scopes for recording strains on the individual gages both with and without the key in the front-mounting adapter. The purpose of the key in the adapter was to introduce maximum torque to be picked up by the gages.

The three pairs of gages, front horizontal, front vertical, and rear vertical, were each bridged oppositely, utilizing only three scopes in attempts to pick up torque forces directly with and without the adapter key.

In reducing the records, because of the difference in speed of the various cameras, it was necessary to enlarge the pressure records and then reduce them to the required size. When the records were reduced directly to the required scale, considerable difficulty in reducing the records to a common time constant was experienced. For the final charts, the pressure records were increased 8 to 1. Then the curves were

traced on the record sheet to the desired scale with the aid of a pantograph. The reduction was accomplished on a round-to-round basis, since the speed of the individual camera increased during the burst. The time scale of the 35-mm pressure records was adjusted to coincide with that of the time-travel records.

In order to increase accuracy, the forces listed on the tabulation sheet were computed from direct film readings at 15 to 1 enlargement.

*Belt-Pull.* Trials were attempted with the common weight and pulley arrangement for adding loads to a 10-round belt (followed by 5 dummy rounds) with and without a spring in the linkage.

Another and seemingly more successful method was the use of a 50-round tray placed at a 16° incline from ground to gun. Varying and increasing loads of linked dummy rounds were added to a 10-round belt, and the rate of fire of the gun observed.

**Results of Tests**

*Rate of Fire.* The rate of fire has been summarized as follows for bursts of 10-20 rounds.

Circuit	Number rounds considered	Rate (Rds/Min)	
		Highest	Average
1,500 cycles a. c. circuit . . . . .	139	1, 154	1, 114
250-volt Cond. d. c. circuit . . . . .	59	1, 197	1, 138

A summary of individual and overall rates with gas pistons of various sizes follows.

	Overall rounds per minute	High individual rounds per minute	Low individual rounds per minute
Four-round burst with standard Aden gas piston . . . . .	1, 176	1, 176	1, 126
	1, 169	1, 182	1, 144
	1, 161	1, 169	1, 086
Four-round burst with "A" gas piston of 2.147-inch diameter . . . . .	1, 118	1, 120	1, 079
	1, 098	1, 110	1, 036
	1, 078	1, 098	1, 048
Four-round burst with "A" gas piston of 1 5/8-inch diameter with adapter . . . . .	989	1, 022	974
	951	1, 009	892
Four-round burst with "A" gas piston of 1 5/8-inch diameter with gas-port restriction plug (orifice area reduced by 1/2 inch) . . . . .	896	909	865
Four-round burst with "A" gas piston of 2.147-inch diameter with gas-port restriction plug . . . . .	968	972	972

*Dispersion and Yaw.* This information is summarized as follows:

**Target Dispersion of 1,000 Inches (Bursts of 10-20 Rounds)**

Type of mount	Average extreme spread (inches)
Navy mount (British drawings) . . . . .	22.0
Navy mount, single shot, 10 rounds . . . . .	3.3
Navy mount, rear supports locked with clamps . . . . .	14.4
Rigid front adapter and rear slides . . . . .	34.4
Navy front socket support and rear slides . . . . .	14.3

*Note.* Yaw at 1,000 inches. Amount of yaw ranged from 0° to 6° from the target checked. No excessive yaw (15° or greater) was noted.

**Dispersion at 1,000 inches for 10-Round Burst Without the Tube Stabilizer**

Horizontal spread (inches)	Vertical spread (inches)	Extreme spread (inches)	Main point of impact
13.65 . . . . .	19	19	Low and right.

Dispersion at 1,000 Inches for 10-Round Burst with Tube Stabilizer

	Horizontal spread (inches)	Vertical spread (inches)	Extreme spread (inches)	Main point of impact
Mounted 33 $\frac{7}{8}$ -inches from muzzle . . . . .	5. 10	15. 15	15. 20	Center and high.
Mounted 28 $\frac{1}{2}$ -inches from muzzle . . . . .	9. 36	7. 52	10	Center.
Mounted 9 $\frac{3}{4}$ -inches from muzzle; tube held in center of $\frac{3}{8}$ -inch vertical play . . . . .	8. 21	5. 65	8. 85	Low.
Mounted 9 $\frac{3}{4}$ -inches from muzzle; tube held at top of $\frac{3}{8}$ -inch vertical play <sup>1</sup> . . . . .	7. 41	4. 05	7. 80	Center.

<sup>1</sup> Vibrations were introduced in the receiver when stabilizer was mounted near the muzzle during firing.

*Muzzle Velocity.* A summary of single and burst fire rounds follows.

	Number of rounds fired	Muzzle velocity (feet/seconds)		
		High	Low	Average
Bursts of approximately 10 rounds . . . . .	66	2, 073	<sup>1</sup> 1, 986	2, 042
Bursts of approximately 4 rounds . . . . .	47	2, 076	2, 014	2, 044
Single rounds . . . . .	17	2, 055	2, 015	2, 037
Aggregate . . . . .	130	2, 076	1, 986	2, 042

<sup>1</sup> Only 1 round below 2,000 feet per second.

*Physical Measurements and Calibrations.* The total weight of the gun was 192 pounds 12 ounces. Weights of the recoiling gun assemblies were as follows:

Cylinder housing, tube, cylinder assembled: 125 pounds 12 ounces.

Slide and feed slide: 14 pounds 4 ounces.

*Time-Displacement, Time-Pressure (Gas Cylinder) Trials.* The time-travel records are tracings from the original film while the pressure curves are plotted from film records. The following is a brief summary of the slide cycle time and gas cylinder pressure.

*Velocity of Ejected Cases.* The average velocity of the ejected cases for the three inches of travel

between the centers of the feed sprocket slots was 45 feet per second, computed from the eleven cases which encountered no interference. Six of 17 cases struck a feed sprocket or the feed sprocket cover.

*Recovery of Projectiles.* No sheared bands were found during this test phase. However, one rotating band was found imbedded in a velocity coil during the latter part of the firing program.

*Chamber Pressure.* Average pressure in ten trials with three combinations of gages and copper cylinders was: 26,800 p. s. i. obtained with non-precompressed coppers and 30,200 p. s. i. with precompressed coppers.

Round numbers	Gas piston type	Slide		Gas cylinder pressure	
		Time required for 4 cycles (milliseconds)	Shortest cycle (milliseconds)	Average of 4 rounds (p. s. i.)	High Ind. (p. s. i.)
306-309 . . . .	Standard Aden . . . . .	211	51	1, 568	1, 765
318-321 . . . .	"A" of 2.147-inch diameter . . . . .	230	56	1, 836	2, 198
326-329 . . . .	"A" of 1 $\frac{3}{8}$ -inch diameter with adapter . . . . .	<sup>1</sup> 253	60	1, 991	2, 439
331-334 . . . .	"A" of 1 $\frac{3}{8}$ -inch diameter with gas port restriction plug.	272	65	1, 354	1, 489
335-338 . . . .	"A" of 2.147-inch diameter with gas port restriction plug.	248	60	1, 316	1, 420

<sup>1</sup> A seven-milliseconds delay of second round primer deducted.

It was anticipated that addition of the gage would increase pressure and therefore velocity, in view of the change in density of loading. However, it appears that the pressure of the gage is suppressing, possibly through ignition interference, since an average velocity decrease of approximately 25 feet per second was obtained with the gage round. The reduced bullet-pull caused by disassembly and reassembly of the round could also affect the velocity and pressure.

*Time-Travel of Firing Cylinder Rotation.* The velocity of the firing cylinder at full momentum is approximately 3,000° per second. The cylinder is in full battery position at least five milliseconds before and after firing.

*Time-Travel of Muzzle.* Muzzle movement was within the limits of 0.4 inch above and 0.2 inch below (approximately) the before-firing position. The muzzle completed approximately one and one-half cycles between rounds. The second round of the burst fired near the peak of the second muzzle cycle. This resulted in a very irregular cycle pattern since further upward movement was restricted. The third round fired near the original position and a fairly regular cycle followed.

*Gas Leakage.* Since inherent variations exist in rates and velocities, these data were not extensive enough to be conclusive. In general, the gun rates and velocities were maintained under each condition except for a slight drop in cyclic rate with the rings removed from the Aden piston. Removal of

the breech cylinder sleeve insert rings appeared to have little effect upon gun operation. Performance of the "A" piston, which contained gas-check grooves, after modification, was comparable with that of the standard piston.

Review of the high-speed movies of gas leakage revealed that there were two points of leakage. They are, firstly, the junction of the tube and the cylinder sleeve and, secondly, the junction of the tube gas-vent hole and the channel leading to the gas cylinder. This gas escape was in the form of high-speed jets and varied in intensity from round to round. In the former, since the gases were in jet form and varied widely in intensity, they evidently emitted from between the junction of the tube and the sleeve rather than around the sleeve by the rings.

The gas escape from the gas cylinder (around the gas piston) appeared negligible. The accumulation of gases was not of a sufficient quantity to obscure vision of the slide movement.

In all cases the gases quickly dissipated, and the view of the gun was not obscured.

The amount of gas leakage of the two points previously discussed depends upon how well two metal surfaces mate. The barrel whip test indicate a vertical movement of 0.4 inch above the original muzzle position and 0.2 inch below. The degree of mating depends greatly upon the position of the barrel at the time of firing.

*Effects of Feeding, Stripping, and Chambering Upon the Round.* The rounds remaining in cham-

bers and feed are referred to as No. 1 through No. 5 in counterclockwise order from the round in firing position.

**ROUNDS NO. 1 AND NO. 2.** Projectiles were found to be from zero inch to 0.060 inch forward of original position in the case. Any looseness present was within the above limits of movement. These rounds were fully chambered and contained markings on the base of the case made by the forward face of the rammer.

**ROUND NO. 3.** This round had been stripped from the link in the initial stage of ramming and was found to be approximately three-eighth inch out of battery in each case. The projectile contained impressions from impact on the chamber mouth as did the first two rounds.

**ROUNDS NO. 4 AND NO. 5.** These rounds remained in their links within the feed mechanism and contained neither looseness nor markings. Cases and rotating bands of stripped rounds were found scratched. One band scratch was fairly deep. One sheared rotating band was observed. It was possible that a heavy link scratch contributed to the failure. The projectile remained secured by the crimped case in all instances.

**Comparison of Firing Circuits.** A total of seven stoppages caused by misfires were encountered, all of which occurred while utilizing the locally assembled 1,500-cycle circuit. The resistance of the primers checked ranged from 10 to 45 ohms. The 250-volt condenser circuit fired all primers including 1 primer with 10 ohms resistance which failed to fire with the former circuit.

A cyclic rate of 755 rounds per minute was attained (fire control set at 800 rounds per minute) in controlled fire. A stoppage occurred after eight rounds when the slide and feed slide separated due to the right segment of the feed slide breaking after the connecting rod belt drifted partly out. This re-

sulted from cotter pin failure. It appears that controlled fire is too harsh on gun parts since the slide must strike battery position and bounce (no locking arrangement present) after each round with metal-to-metal contact. In uncontrolled fire, the buildup of gases in the gas cylinder probably affords some cushioning.

**Primer Resistance.** Results of trials are summarized as follows:

Component Tested	Number of Items	Resistance (ohms)		
		High	Low	Average
Complete round . . . . .	12	215	50	103
Case with primer . . . . .	6	80	30	52

Resistance of circuit, 5 ohms.

**Trunnion Reaction Test.** A summary of forces from the trunnion reaction test is presented below. Two tables summarize the test results, as follows:

**Gages Bridged Oppositely, Gage Force 100 Pounds**

	Gage pair	Tension		Compression	
		High	Average	High	Average
Unkeyed	Front horizontal.	46	33	32	30
	Front vertical. . .	26	22	37	33
	Rear vertical. . . .	15	15	15	14
Keyed	Front horizontal.	45	32	32	29
	Front vertical. . .	28	25	37	30
	Rear vertical. . . .	31	31	26	20

Gages Wired Individually, Gage Force 100 Pounds

	Gage pair	Left				Right				Total			
		Tension		Compression		Tension		Compression		Tension		Compression	
		High	Average	High	Average	High	Average	High	Average	High	Average	High	Average
Unkeyed	Front horizontal . . . . .	38	31	76	68	30	26	73	59	68	57	149	127
	Front vertical . . . . .	34	34	21	18	39	37	22	19	73	71	43	37
	Rear vertical . . . . .	32	29	27	19	28	18	18	17	60	47	45	36
Keyed	Front horizontal . . . . .	44	34	73	67	31	29	84	80	75	63	157	147
	Front vertical . . . . .	33	27	23	15	19	16	22	22	52	43	45	37
	Rear vertical . . . . .	24	24	22	17	36	28	22	22	60	52	44	39

*Stoppages and Parts Failure.* A total of 40 stoppages was encountered. The principal ones were: failure to eject, misfire, failure to chamber, and link separation.

A total of 47 parts failures occurred during the test. The principal ones were: Cam lever; circlips and cotter pins; slide electrical contact; cam lever plunger and firing pin spring; rollers and firing cylinder.

**CAM LEVER.** The slide was found binding in the slideway several times during the test. This condition was caused by battering of the rollers against the lever near the pivot point. It was necessary to grind down the uneven surfaces and remove burrs.

**CIRCLIPS AND COTTER PINS.** Failures of these items in the slide and feed slide caused stoppages and failures of larger gun parts.

**SLIDE ELECTRICAL CONTACT.** Excessive set in the contact wires resulted in unsatisfactory contact. Breakage of the wire loop was the primary cause for failure; the first breakage occurred after 558 rounds.

**CAM LEVER PLUNGER AND FIRING PIN SPRINGS.** The former was found broken after 481 rounds, and the latter was noted to register excessive set after 731 rounds, allowing the firing-pin assembly to become loose.

**ROLLERS, FIRING CYLINDER.** All rollers contained indentations and scoring. One roller unit

was found binding, caused by excessive wear. The remaining contained excessive play.

**CONTACT POINT OF THE FIRING PIN.** This was worn considerably after 1,088 rounds of firing. Firing pin protrusion measured 0.036 inch as compared with 0.052 inch protrusion of the firing pin from a comparatively new gun.

**Observations**

The following observations were made:

1. Extractor adjustment appears critical, not only from the standpoint of properly ejecting the empty case, but also from the pressure exerted upon the slide by the extractor arm. Adjustment is difficult since the extractor spring must be removed and is subject to breakage during this operation.

2. The extractor arm engages the slide during counterrecoil at the extreme right side. Since the slide has a certain amount of play on its rails, which increases with wear, these parts have a tendency to bind when engaged by the extractor arm and accordingly the rate of fire is slowed down.

3. The forward face of the cylinder housing and the buffer housing contact each other when the gun is in battery position. Upon recoil these units separate at that point. There is no provision for buffering when these parts meet after counterrecoil. The metal-to-metal contact results in severe gun shock.

In addition, there appears to be no positive buffering as the slide returns to battery. The slide including feed slide, which weighs 14 pounds 4 ounces, returns to battery position with a momentum of approximately 175 p. s. i. The only possible buffer action is perhaps some gas buildup in the gas cylinder before the slide makes actual metal-to-metal contact with the gas cylinder. This condition probably contributes greatly to the increased dispersion during burst fire.

4. In the conventional gun due to accelerated rates of fire, the breechblock occasionally unlocks before all the powder has burned. This unburned powder is ignited to produce breech flash or burning in the receiver. This is not probable in the revolver-type gun since the case continues to perform obturation until all the powder has burned and the gases dissipated. The case remains in the chamber after firing for almost a complete cycle before being ejected as the slide returns to battery. Only a very small amount of the gas escapes with the ejected case. The rest of the gas comes out of the gas mechanism, obturating sleeves, and the cartridge case; when firing at 1,400 rounds per minute, this latter amount is considerable.

5. Since the receiver is fabricated of light metal, there is a certain amount of flexing possible during firing. The cylinder housing, which mounts the tube, recoils within the receiver which is supported by two short rails in the rear and the tubular neck in the front. There is considerable looseness in this assembly. The loose fit of the tube in the cylinder housing provides another source of wide dispersion. The method of securing the tube which permits quick changing does not provide for a firm fit. The muzzle end can be moved freely three-eighths inch in the vertical plane.

6. A certain amount of looseness in the assembly of the projectile and case is present in some rounds after chambering. However, this evidently has little adverse effect upon gun operation in view of the fairly consistent muzzle velocities obtained. A small amount of projectile separation occurs during initial ramming and stripping. However, the greater loosening effect comes with final ramming and chambering. The projectile ogive strikes the chamber mouth wall during initial ramming. However, since the windshield of the ball round is

of soft metal, the impressions made probably do not represent a serious deficiency.

## Conclusions

The following conclusions were reached:

1. The rate of fire is slightly lower than the 1,200 rounds per minute indicated for the gun.

2. Barrel whip is excessive, causing high target dispersion. The loose fit of the barrel and recoiling assemblies contributes to the high dispersion. There is a lack of positive buffer arrangements to provide smooth action as the cylinder housing and the slide units return to battery position; this condition induces excessive shock in the gun, contributing to the high dispersion during automatic fire and causing premature failure of parts.

3. Because of the light structure of the gun and the loosely fitting assemblies, a certain amount of flexibility in the mount as provided by the front socket assembly is necessary.

4. The slide rear supports are preferable to the link suspended supports, in view of the improved accuracy with the slide arrangement.

5. The muzzle velocity is slightly greater than the 2,020 feet per second indicated for the gun.

6. Tube wear and driving spring loss of efficiency are negligible after the firing of approximately 1,000 rounds.

7. Bullet pull requirements are high in this weapon. Since no forcing cone is present, the cartridge case performing the seating function, particular emphasis must be placed upon the crimping of the rounds.

8. Chamber finish is excessively rough, necessitating oiling rounds for proper extraction.

9. Chamber pressures appear somewhat greater than indicated by British drawings.

10. Improvement of slide camming angles to provide smoother firing cylinder deceleration before entering battery position is desirable to reduce the wear of critical components.

11. The principal points of gas leakage are at the junction of the firing cylinder sleeve and the tube, and at the junction of the tube gas vent hole and the channel leading to the gas cylinder. The gas check rings do not play a direct role in these points. The loose fit of the "quick-change" barrel contributes to the gas leakage.



12. The 250-volt condenser discharge circuit is satisfactory for use with the gun. However, the gun is unsuitable for controlled rate fire. A buffer and/or locking unit for the slide would be necessary if controlled fire were desired.

13. Primer resistance in the British round is considerably lower than that of small caliber American rounds (M52A3 primer).

14. Trunnion forces of approximately 7,000 pounds in tension and 15,000 pounds in compression can be expected. Torque loads of approximately 4,500 pounds in tension and 3,500 pounds in compression appear to exist.

15. Existing test equipment is not adequate to record belt pull in this gun.

16. The revolver principle offers good possibilities in the field of heavy caliber machine guns. However, certain design changes and fabricating techniques appear necessary in the Aden gun to insure proper functioning in sustained firing.

17. The circlips and cotter pins used in securing components of the slide and feed slide are unsatisfactory.

18. The existing method of adjusting connecting rod clearance is unsatisfactory.

19. Stoppages involving jammed and deformed rounds or cases require excessive efforts to clear; this condition would be extremely difficult in a plane installation.

20. Utilization of spring tension to secure the firing pin assembly internally is unsatisfactory.

21. The strength and wearing quality of the cam lever and firing cylinder roller units are unsatisfactory.

22. Gun electrical switches and wiring are not substantial enough to withstand sustained firing.

23. Although the stoppage rate experienced in this test was excessively high, it may be reduced somewhat in future tests when the emphasis may

be placed upon gun performance rather than special test phases.

24. From the limited firing accomplished in these tests, it appears that the 30-mm Aden gun is unsatisfactory in its present stage of development. Numerous improvements in the design and durability of components are necessary to insure gun dependability.

### Recommendations

The following recommendations were made:

1. That looseness in the mounting of recoiling assemblies be reduced and that additional support be provided for the barrel.

2. That the receiver be strengthened through the use of light metal alloys.

3. That the strength and wearing quality of the slide switch lever and the cylinder rollers be improved.

4. That slide camming angles be redesigned.

5. That cotter pins and circlips be replaced in the slide with more adequate securing devices.

6. That finer adjustments in the connecting rod be provided.

7. That a more positive means of locking the firing-pin assembly internally be provided.

8. That a positive means of locking the buffer shafts after preset adjustment be provided.

9. That chamber finish be improved to decrease the necessity of oiling rounds.

10. That provision be made for releasing the anti-rotation plunger of the firing cylinder housing from the exterior of the gun to facilitate clearance of gun stoppages.

11. That the electric system be simplified and more durable electrical switches provided.

12. That development work be expedited on the Navy magnetic-clutch, belt-pull apparatus for possible use in recording belt pull with guns of this type.

## Chapter 19

## 25-MM HOTCHKISS AUTOMATIC GUN

## SECTION 1. HISTORY AND BACKGROUND

At the conclusion of World War I, the French Air Ministry was faced with deciding on an improved aircraft cannon to arm France's outstanding Air Force. The choice was not easy, but attention was eventually focused on the reliable Hotchkiss system that had served France so faithfully throughout the years. In the opinion of the French, this automatic firing mechanism when made in rifle caliber resulted in the most dependable machine gun in the world, and they could see no logical reason why it would not prove to be just as successful if scaled up to handle a larger cartridge. All development work done on this aircraft cannon version was carried on in the greatest secrecy.

After a decision was reached to produce a weapon using a 25-mm cartridge, it was next decided that the prototype should be demonstrated and tested as an antitank or antiaircraft version. The French thought that they could get in the necessary function firing without revealing to foreign observers their intended use for the weapon.

Work progressed very slowly on the weapon because of lack of finances. It was as late as 1928 when a prototype made its appearance on a French proving ground, a huge weapon weighing 237 pounds and capable of being mounted on shipboard as an antiaircraft gun.

The gas orifice was purposely set so as to deliver a rate of fire between 150 to 200 rounds a minute. In armor piercing tests, 1½ inches of the best armor plate was pierced at 700 yards as was ¾-inch plate at 2,000 yards. After satisfying themselves that the operating principles were sound, French engineers proceeded with the refinement of the bulky pilot model and engineered a low-silhouette, highly streamlined, light-weight, well-balanced automatic firing mechanism capable of producing an acceptable rate of fire. This gun showed great promise; however, all work on it stopped when the Germans overran France in the early days of World War II.

## SECTION 2. DESCRIPTION OF THE WEAPON

This 25-mm automatic gun is gas-operated, magazine and belt-fed, and is designed for both anti-tank and aircraft use. The breech bolt has a mechanical linkage-operated positive lock.

**Tube**

The tube is screwed into the receiver and held by a locking screw. This type of assembly results in very slow tube changing. A flash hider extends from the muzzle. The tube has a sleeve with the conventional fin arrangement that furnishes increased area for radiation. The gas cylinder that houses the gas piston is also secured to the tube.

**Receiver**

The receiver has an opening in the top to accommodate the feeder. The device for attaching the feeder is held in the front by a projection extending into the receiver and at the rear by a pin. The ejection slot is machined in the bottom of the receiver to allow the empty cases to be ejected downward and out of the gun.

The backplate is fastened to the receiver by a pin and acts in the dual capacity of buffer and housing for the sear. Two rods extend forward from the backplate to act as a guide and support for the driving springs.

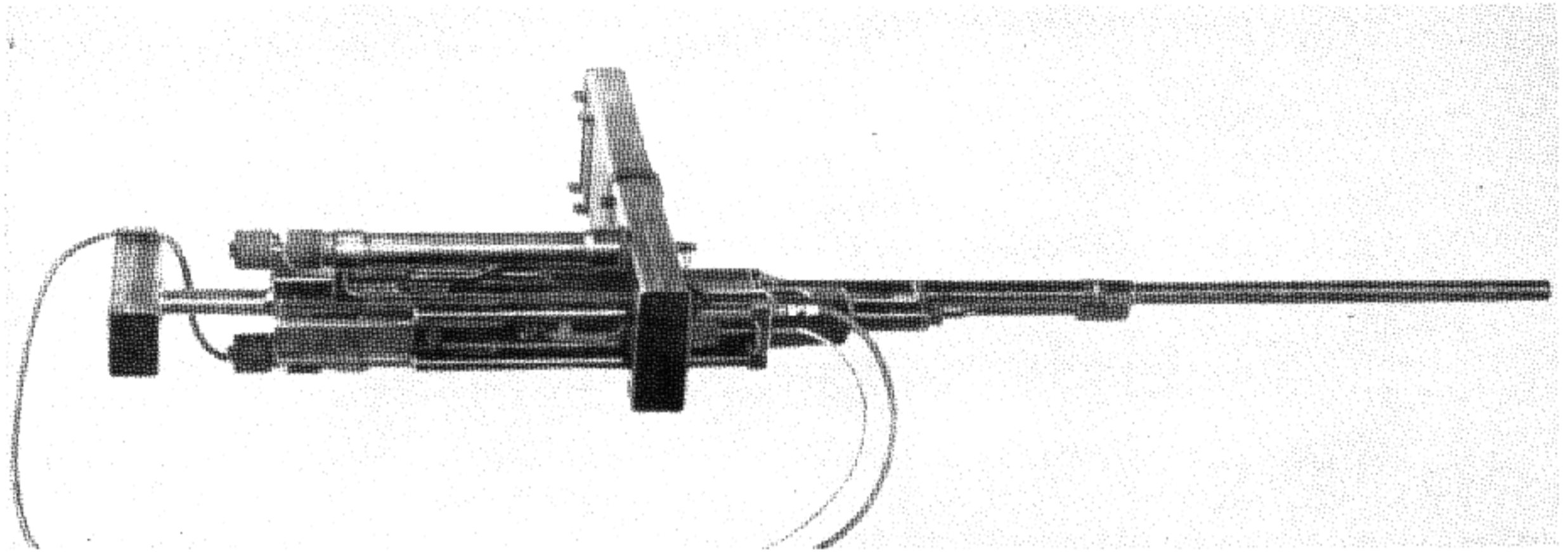


Figure 19-1. 25-mm Hotchkiss Automatic Gun.

The helical driving springs are made in two sections and are held together by a short rod. The springs ride in slots in the side walls of the receiver.

The actuation slide has a projection on each side to engage the drive springs. The front of the slide is the gas piston which operates the gun. About a third of the distance from the rear is the platform which engages the breech bolt and carries it rearward after unlocking. The actuator slide has a vertical opening to accommodate the link which

connects the locking dogs and the actuator slide. The rear of the slide has a hole with a slot to hold the firing pin.

The breech bolt rides on the actuator slide and has a projection on the bottom to engage the platform of the slide on unlocking. The two locking dogs are pinned to the bolt, and the firing pin rides in the bolt.

The top of the bolt is grooved to allow passage of the ejector. The bolt has a claw extractor which is pivoted and spring loaded.

#### General Data: 25-mm Hotchkiss Automatic Antitank Gun (French)

Gun length, overall: 96.25 inches.  
 Gun weight, total: 135 pounds.  
 Rate of fire: 600-700 rounds/minute.  
 Muzzle velocity: 2,700 feet/second.  
 System of operation: Gas piston actuated.  
 System of locking: Swinging lock (with linkage).  
 System of feeding: Actuated by gas piston; employs metallic links.  
 Method of headspace: Factory established.  
 Location of feed opening: Top of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Pneumatic and hydraulic.  
 Method of cooling: Air.  
 Muzzle energy: 39.6 foot-tons.  
 Barrel assembly weight: 80 pounds 10 ounces.  
 Bolt weight: 9 pounds 4 ounces.  
 Actuating slide weight: 21 pounds 2 ounces.  
 Driving springs weight: 1 pound 11 ounces.  
 Recoil springs length: 46 inches.  
 Recoiling parts weight: 32 pounds 1 ounce.  
 Receiver length: 32.75 inches.

Barrel length: 59 inches.  
 Barrel assembly weight: 80 pounds 10 ounces.  
 Rate control: None.  
 Barrel removal: Not quick disconnect.  
 Bore:  
 Number of grooves: 8.  
 Groove depth: 0.022 inch.  
 Groove width: 0.145 inch.  
 Pitch: 5°30'.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Projectile weight: 0.7 pound.  
 Weight of round: 1.8 pounds.  
 Magazine:  
 Weight empty: 14 pounds 15 ounces.  
 Weight filled (10 rounds): 34 pounds 6 ounces.

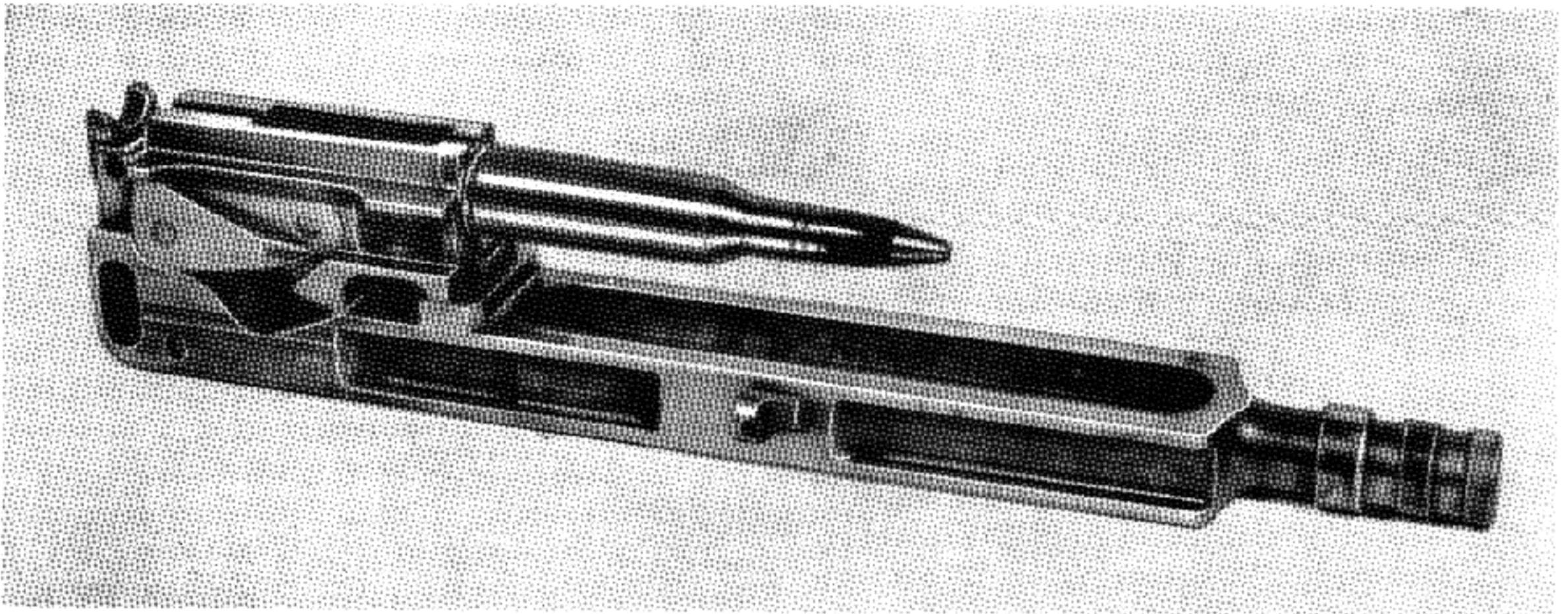


Figure 19-2. 25-mm Hotchkiss Automatic Gun. Breechblock and operating slide showing lock in locked position.

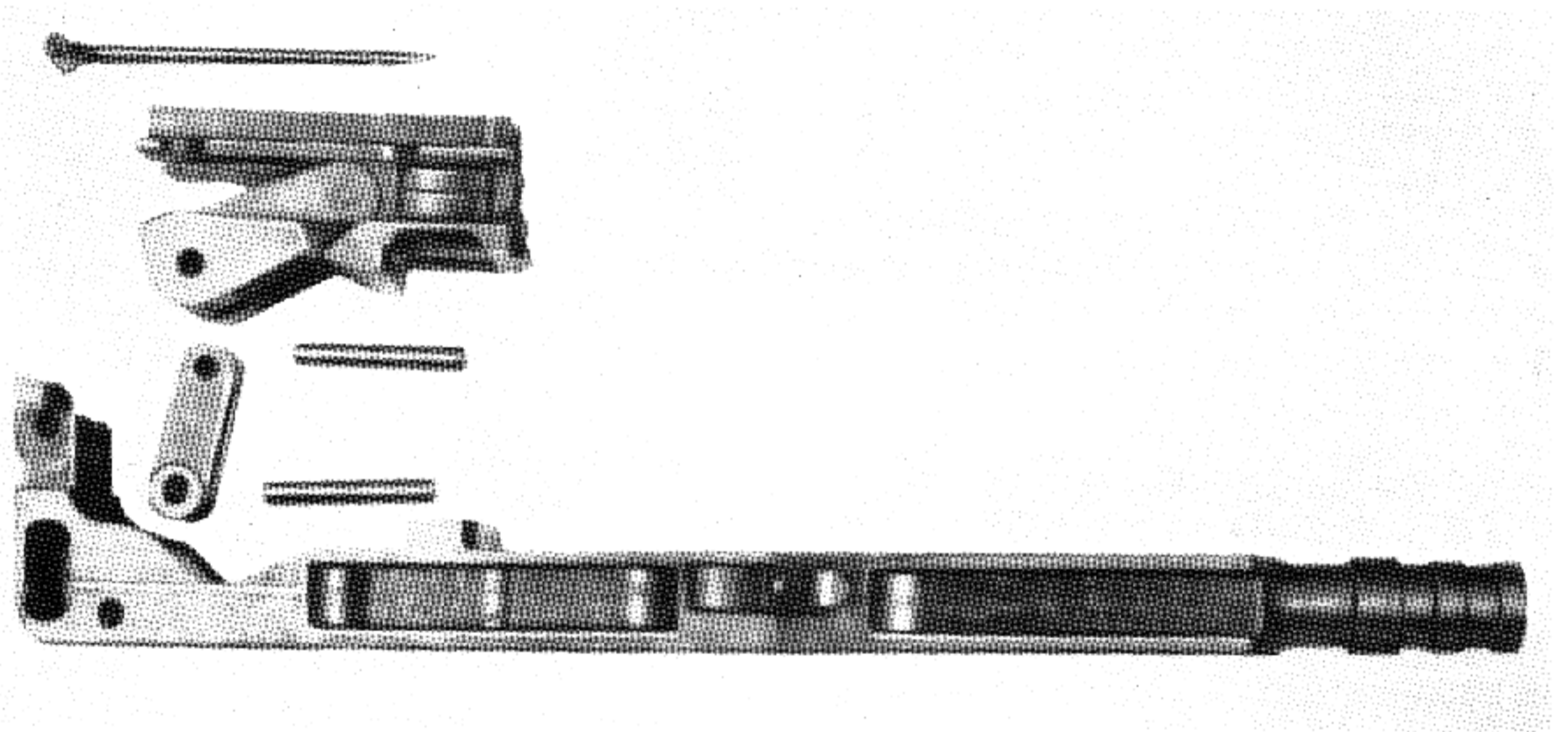


Figure 19-3. 25-mm Hotchkiss Automatic Gun. Operating group, disassembled, showing relationship of link, lock, slide, and breechblock.

## Feeder

Cartridges are contained in a vertical box-type feeder with a 10-round capacity. As a round is stripped from the feeder by the bolt on its forward

movement, the succeeding round is positioned by means of a follower and a spring contained in the feeder. The feeder is held in position in its housing by a latch attached to the top of the receiver.

## SECTION 3. CYCLE OF OPERATION

### Initial Charging

A gear rack rides in the slot on the bottom right side of the receiver and engages a driving spring lug

on the side of the actuator slide. As the charging handle is drawn back, the rack draws the actuator slide also, compressing the driving springs until the

spring-loaded hook sear in the backplate engages the actuator slide. The charging handle is returned to the original position.

### Actuation

The trigger is pulled, depressing the sear and releasing the actuator slide. The breech bolt assembly moves forward under power of the compressed driving springs.

### Loading

As the breech bolt passes under the feed mouth, a cartridge is stripped from it and carried into the chamber. As the round is seated into the chamber, its base is forced on the spring-loaded, pivoted extractor in the bottom of the face of the breech bolt.

### Locking

After the bolt comes to rest against the face of the breech, the actuator slide continues to move forward a distance of  $2\frac{1}{4}$  inches, causing the link, connected to the slide, and locking dog to be rotated. This action cams the locking dogs up, in front of the locking abutments, securely locking the bolt in its forward position.

### Firing

A rigid firing pin is mounted in a slot in the top of the actuator slide and rides in its tunnel in the breech bolt body. The final forward movement of the slide, after the bolt is locked, forces the firing pin forward, exploding the powder charge. The firing pin cannot protrude through the hole in the face of the bolt until the slide is 0.16 inch from being fully forward; the bolt, however, is completely locked when the slide has advanced 0.53 inch from the forward position.

### Unlocking

As the projectile passes a point  $3\frac{3}{4}$  inches from the breech end of the barrel, a portion of the gases is metered through a port into a cylinder beneath the barrel. These gases impinge on the head of the piston of the actuator slide and force the slide to the rear. As the slide moves aft, the link is rotated in

the opposite direction, pulling the locking dogs down from in front of the locking abutments. At the same time, the firing pin is withdrawn from the primer. The entire breech mechanism is driven to the rear by the force brought to bear on the piston, compressing the driving springs. The final rearward movement of the slide and bolt is arrested by the buffer, putting the operating parts into counterrecoil.

The velocity at which this assembly moves to the rear is controlled by ports of different sizes in the gas regulator, which is attached to the front end of the gas cylinder. Turning the regulator counterclockwise permits gas to be metered to the face of the piston in varying amounts through a controlled orifice located in the front end of the piston.

### Extraction

As the breech bolt is driven rearward, the extractor engages the lip of the empty case and withdraws it from the chamber.

### Ejection

The ejector, attached to the top of the receiver, and riding in a slot in the top of the bolt, collides with the rim of the empty cartridge case, kicking the empty cartridge case down and out through an opening in the bottom of the receiver.

### Magazine Interlock

The magazine latch is an accessory of the magazine housing. If a magazine type of feed is used, when the last round is stripped from the feed mouth, a lug on the follower trips the latch and releases the magazine. Release of the latch causes a stop to be projected down in front of a clearance cut in the top of the bolt. As the bolt starts forward, it is arrested by this stop at a position slightly to the rear of that required for the slide and sear to become engaged. Installation of a charged magazine withdraws the stop and allows the mechanism to move forward and engage the sear. Both the magazine latch and the bolt stop are equipped with levers so that they may be operated by hand at will.

## Chapter 20

# HISPANO-SUIZA AIRCRAFT CANNON DEVELOPMENT IN SWITZERLAND AND GREAT BRITAIN

## SECTION 1. DEVELOPMENT BY THE PARENT HISPANO-SUIZA CO.

### History and Background

The Hispano-Suiza Co. of Geneva, Switzerland, has had great international influence on the development of aircraft armament. Founded early in the century as an automobile plant with factories in Switzerland, Spain, and France, it branched into aircraft engine and automatic weapon design. The story of the development of the Hispano-Suiza type 404 aircraft gun and its adoption as a basic weapon by Great Britain and the United States in World War II is given in *The Machine Gun*, volume I, chapter 14, pages 562-590. Since World War II, the firm has centered its research activities in its Swiss headquarters.

### Post-World War II Weapon Design

After World War II the outstanding machine gun design of the parent Hispano-Suiza Co. was the 20-mm Hispano (Birkigt) type 404 aircraft gun.

Postwar development work included not only refinement of standard models and the usual pursuit of the new patentable ideas but also an intent perusal of captured German documents for ideas that might be used in future development. For example, the Rheinmetall MG-151 attracted the interest of the Hispano-Suiza Co. as well as of American ordnance engineers. Both the Hispano-Suiza Co. and the United States armed services developed weapons bearing a close resemblance to the German gun.

### 20-mm Hispano-Suiza Type 804

The following description of this weapon was taken from a brochure of the Hispano-Suiza Co.

The AA cannon type 804 is a weapon of automatic fire with mechanical locking of the breech. The recoil is taken up by the whole of the weapon. Before starting to fire, the breechblock must be

pulled to the rear and is then held back with the sear. The return spring is thus compressed. When starting to fire and as soon as the trigger is moved, the breechblock with its percussion and locking system incorporated in it is driven forward by the return spring and starts the cartridge toward the chamber. At the moment of locking, the locking pieces move downward and release the unlocking slides, driving the firing pin forward. Continued movement of the firing pin with respect to the now stationary breechblock stops the locking pieces and locks the breech. Ignition is produced at the end of the movement by the unlocking plates. During the interval when the projectile is in the barrel, the recoil of the rearward traveling mass is checked by a heavy spring which also assures the return into position of the weapon. An oil cushion checks the last movement forward and thus avoids abnormally heavy shocks. The moment the projectile leaves the gun barrel, a powerful muzzle brake absorbs a great part of the kinetic energy of the recoiling mass. A gas piston unlocks the breechblock. The remaining gas pressure drives it to the rear at high speed, the cartridge case then driving the breechblock rearward. The ejection of the cartridge case takes place during the recoil of the breechblock as the rim of the case strikes the ejector. The recoil of the breechblock is checked in part by the return spring, and at the end of the travel by the large buffer spring. The accumulated energy in the spring alters the movement of the breechblock and drives it at very great speed forward with the aid of the driving spring. This is a very important feature in connection with obtaining a high rate of fire with the weapon. The magazine or feeder fixed on the weapon does not recoil with the action. The interrupted threaded

joint of the barrel permits the latter being changed rapidly.

**20-mm Hispano-Suiza Type 820**

Engineers of the Hispano-Suiza Co. developed a more powerful cartridge for a 20-mm cannon and a more rugged mechanism to fire it, giving this version the official designation type 820. It was based, however, on the same principle as the well known and thoroughly seasoned original Hispano-Suiza action. The most important features on the refined weapon are an initial velocity of 3,400 foot per second and a rate of fire in the neighborhood of 1,000 rounds a minute. These improvements were obtained with little increase in weight, the new gun weighing 112 pounds or 20 pounds more than the original model.

The barrel is 85 calibers long and weighs 52 pounds, and with certain exceptions it is possible to change the length of the barrel and to adapt the gun to different needs of aircraft. The weapon can be fed either from a magazine or by belt of the disintegrating link type with the aid of a powered belt-feed mechanism.

The Hispano-Suiza Co. improved considerably the striking effect of the 20-mm ammunition intended for use in type 820. The original ammunition (standard) can also be used in the British Mark V, the French 404, and the American M3 gun. New types of projectiles included (1) high-explosive incendiary with high-blast effect, (2) double-effect shell incendiary type Mark IDA, and (3) incendiary and armor piercing incendiary shell type Mark ORC.

**General Data: 20-mm French Hispano-Suiza Type 804**

<p>Gun length: 100 inches.                  Gun weight, without magazine: 99.2 pounds.                  Rate of fire: 750-800 rounds/minute.                  Muzzle velocity: 2,785 feet/second.                  System of operation: Retarded blowback.                  System of locking: Swinging lock.                  System of feeding: Drum, or spring-actuated feed employing links.                  Method of headspace: None.                  Location of feed opening: Top of receiver.                  Location ejection opening: Bottom of receiver.                  Method of charging: Pneumatic, manual.                  Method of cooling: Air.</p>	<p>Barrel length, with muzzle brake: 87 inches.                  Barrel weight: 53 pounds.                  Rate control: None.                  Barrel removal: Quick disconnect.                  Bore:                  Number of grooves: 12.                  Groove depth: 0.015 inch.                  Groove width: 0.205 inch.                  Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).                  Direction of twist: Right hand.                  Form of twist: Constant.                  Length of rifling: 80 inches.</p>
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**General Data: 20-mm French Hispano-Suiza Type 820**

<p>Gun length: 98 inches.                  Gun weight: 112 pounds.                  Rate of fire: 1,000 rounds/minute.                  Muzzle velocity: 3,280 feet/second.                  System of operation: Gas and retarded blowback.                  System of locking: Swinging lock.                  System of feeding: Drum or spring-actuated continuous feed.                  Method of headspace: None in weapon design.                  Location of feed opening: Top of receiver.                  Location of ejection opening: Bottom of receiver.                  Method of charging: Pneumatic.                  Method of cooling: Air.</p>	<p>Barrel length: 68 inches.                  Barrel weight: 52 pounds.                  Rate control: None.                  Barrel removal: Quick disconnect.                  Bore:                  Number of grooves: 9.                  Groove depth: 0.015 inch.                  Groove width: 0.205 inch.                  Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).                  Direction of twist: Right hand.                  Form of twist: Constant.</p>
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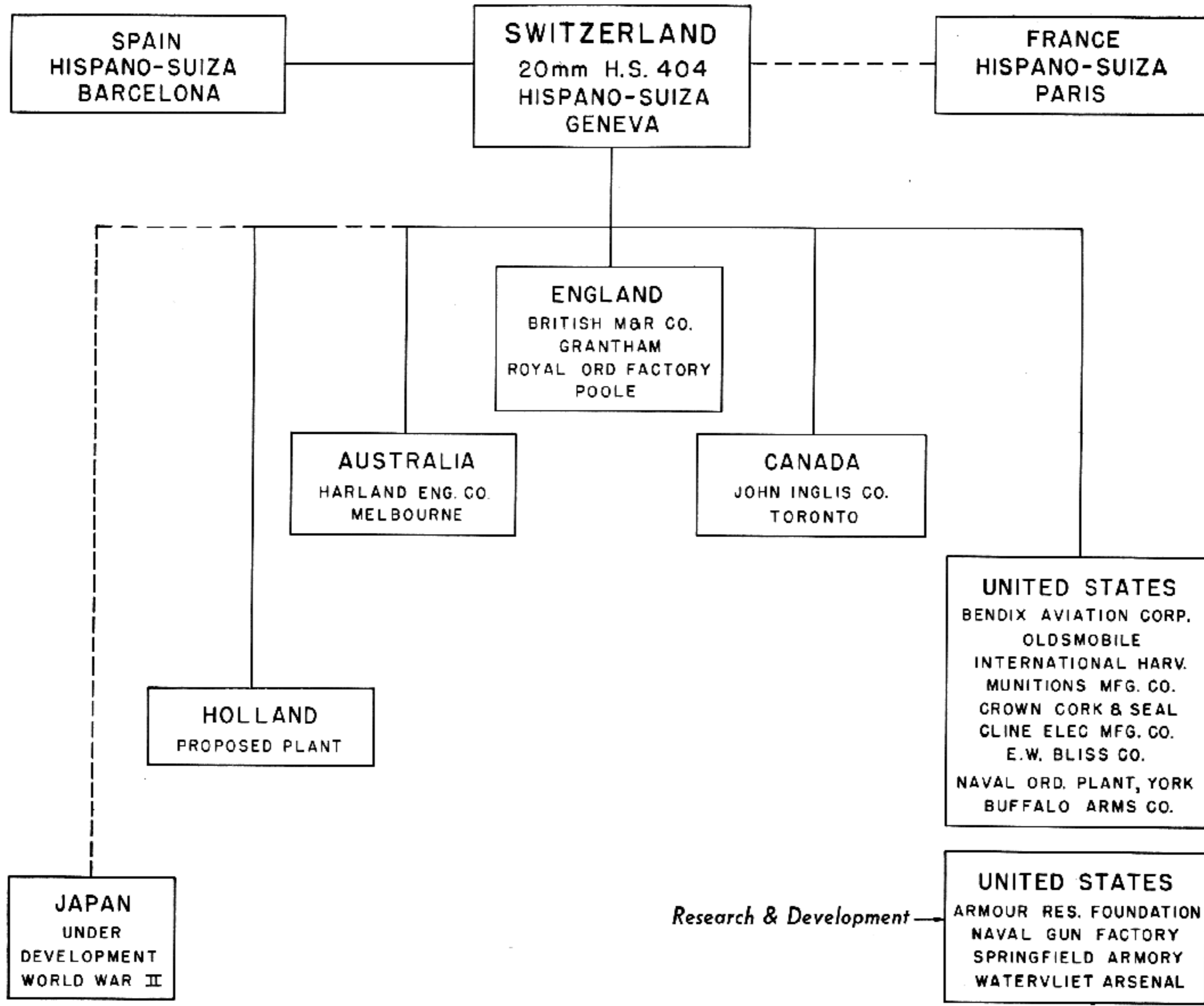


Figure 20-1. Facilities for manufacture of Hispano-Suiza Guns.



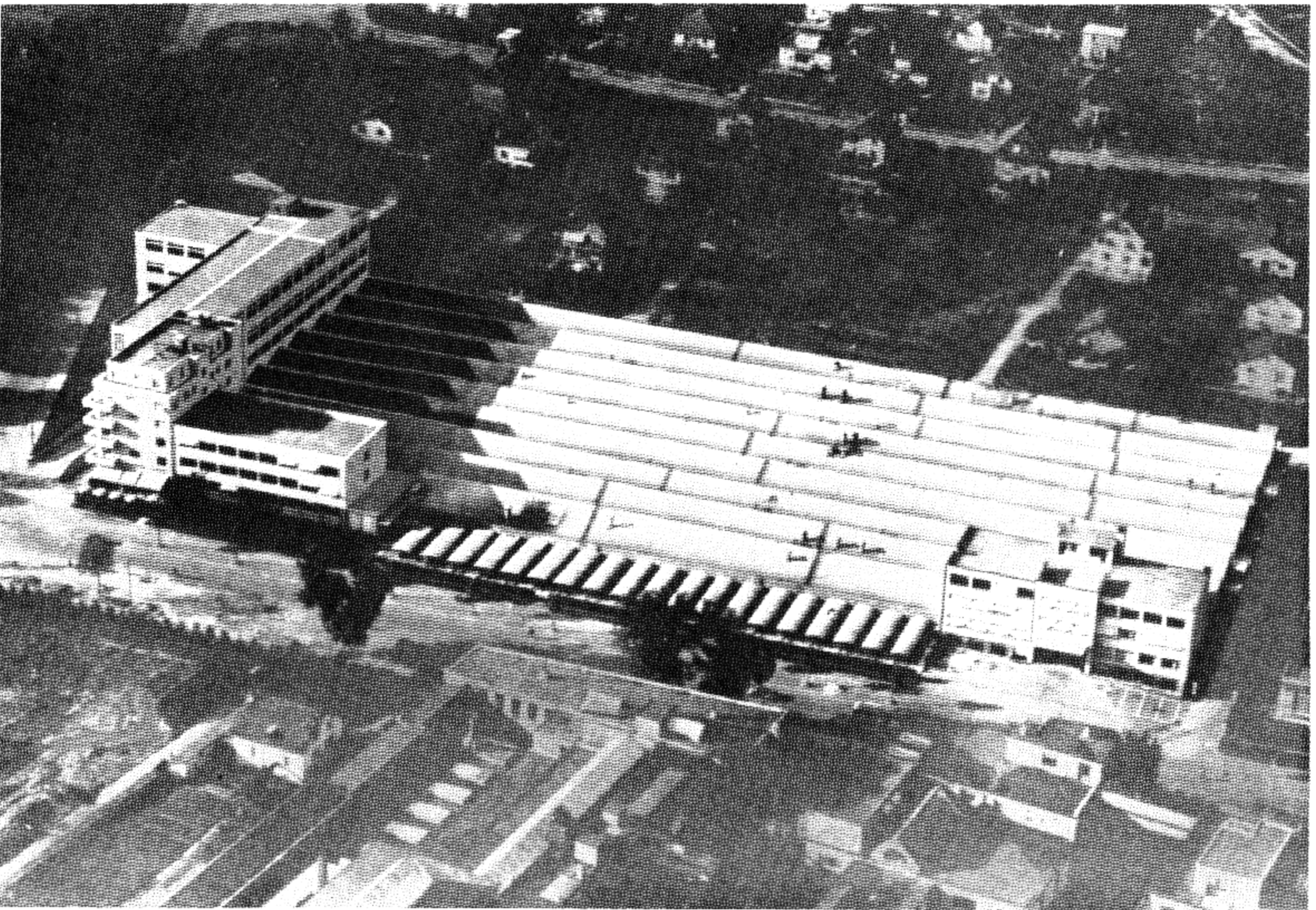


Figure 20-2. Aerial view of the Hispano-Suiza factory in Switzerland.

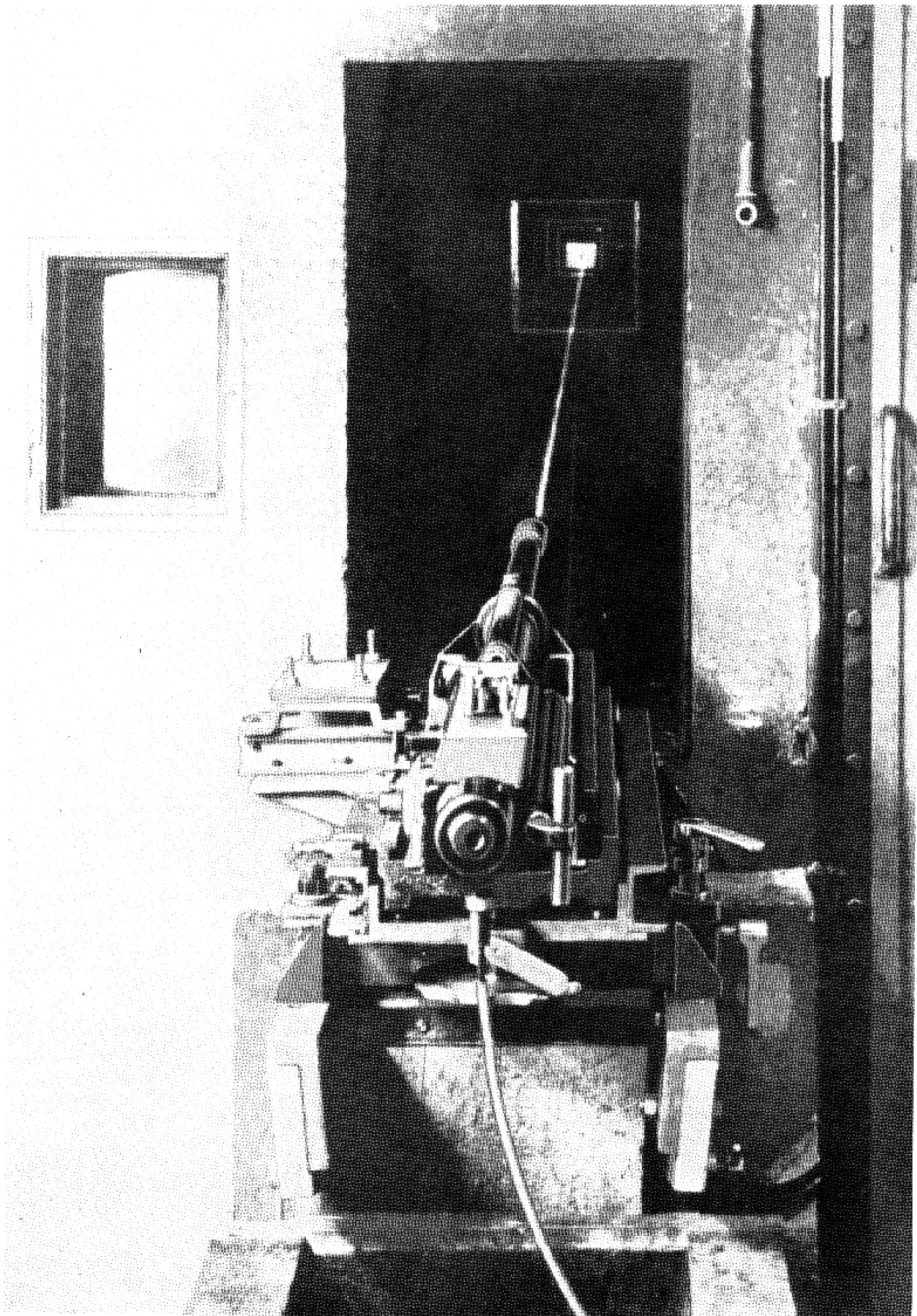


Figure 20-3. Automatic cannon undergoing proof testing at the Hispano-Suiza factory in Switzerland.

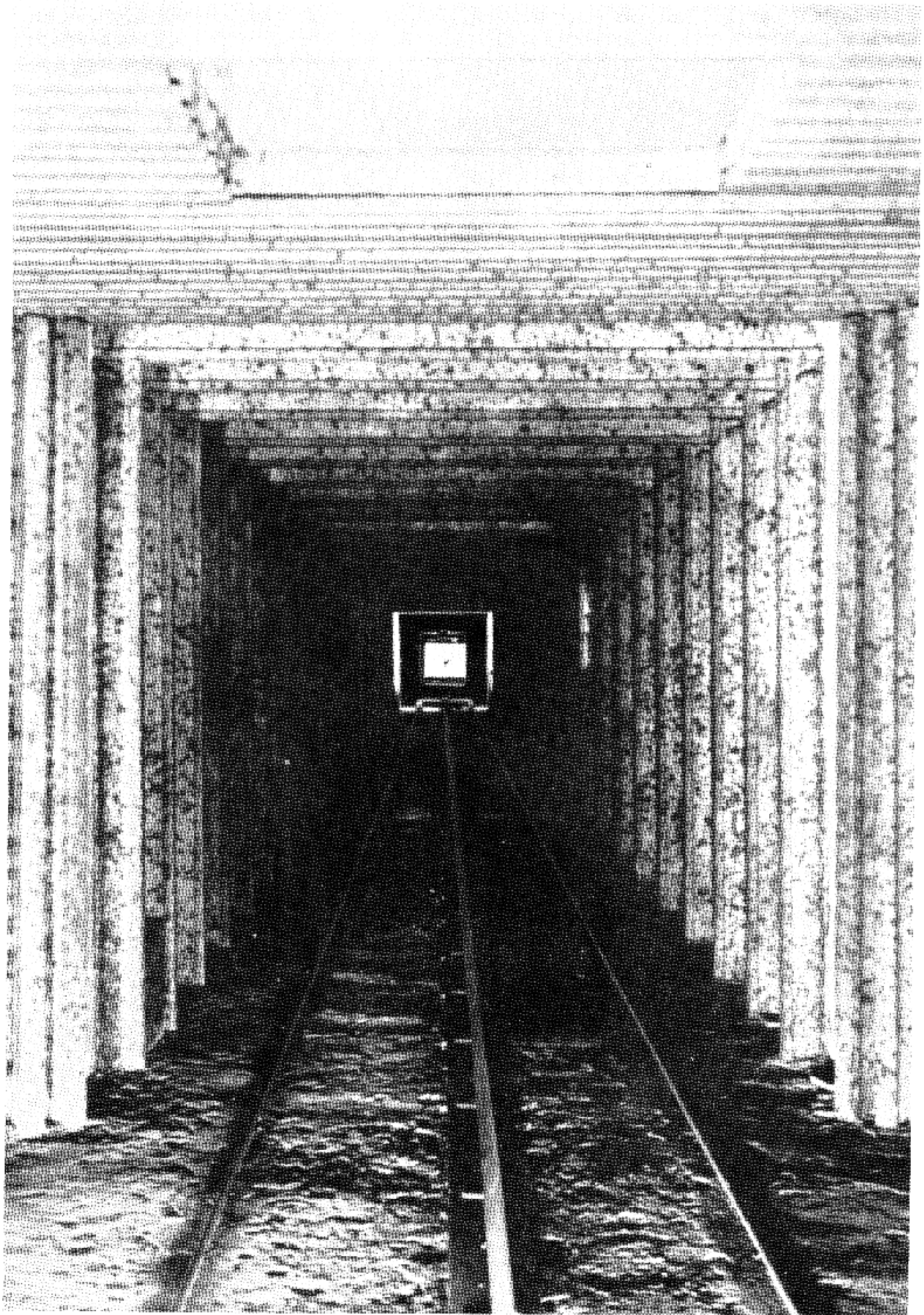


Figure 20-4. Firing tunnel at the Hispano-Suiza factory.

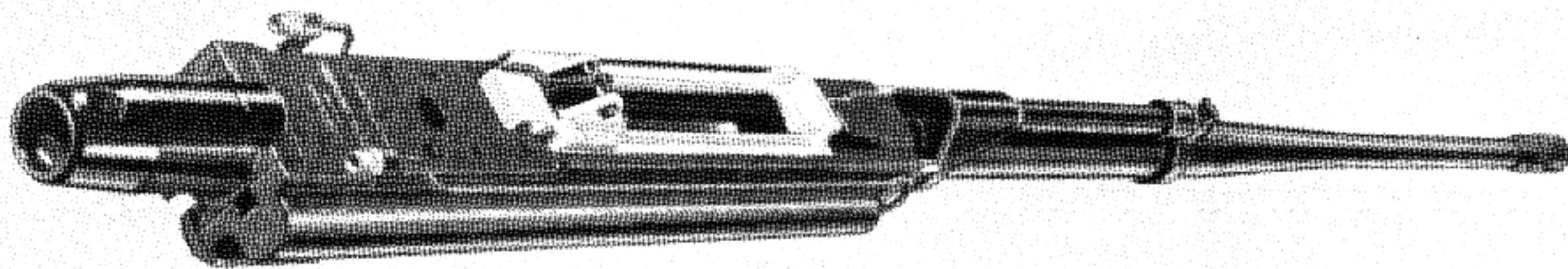


Figure 20-5. 20-mm Hispano-Suiza Aircraft Cannon Type 804. This is a wing gun with pneumatic charging.



Figure 20-6. 20-mm Hispano-Suiza Antiaircraft Cannon Type 804.

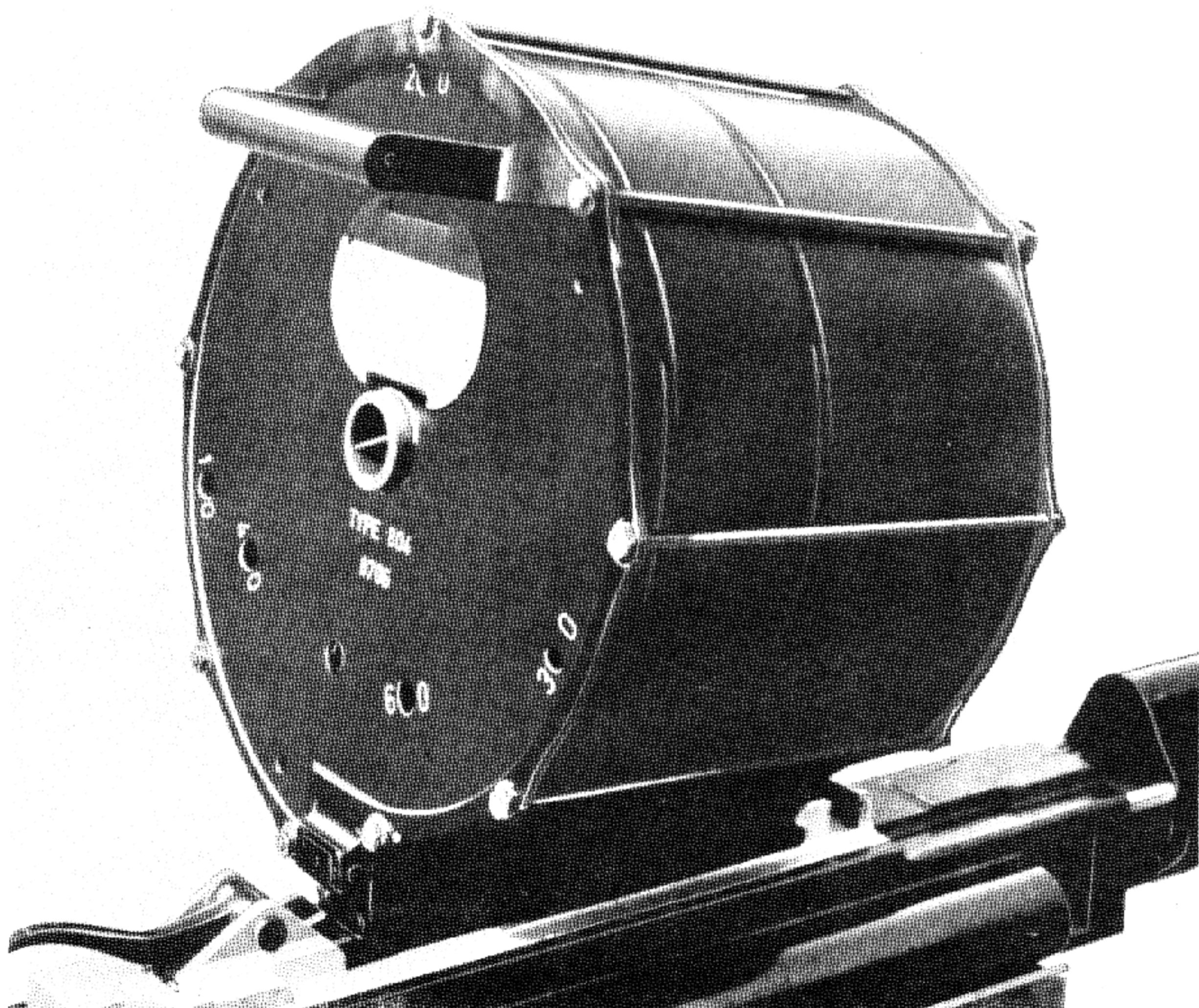


Figure 20-7. 20-mm Hispano-Suiza Aircraft Cannon Type 804 with drum feed attached. Closeup view.

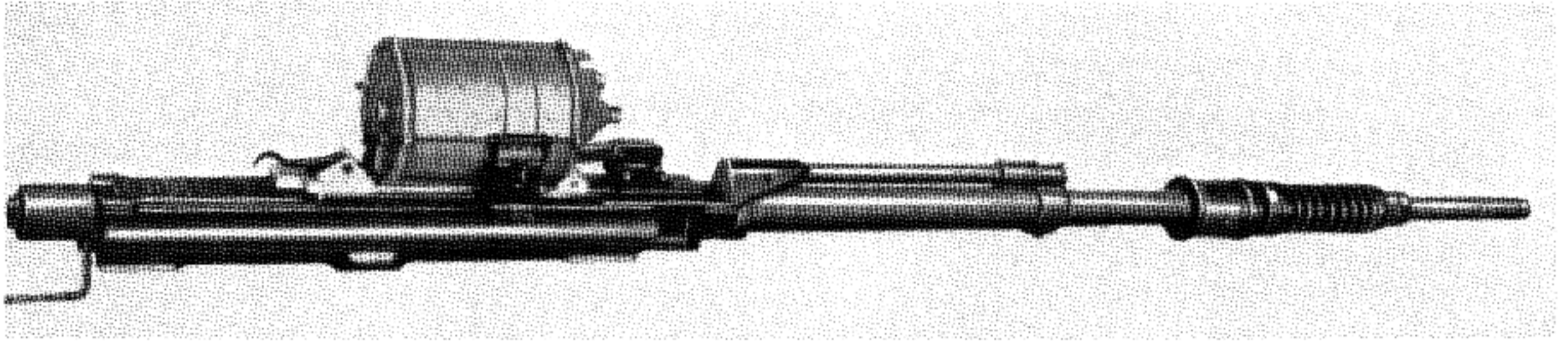


Figure 20-8. 20-mm Hispano-Suiza Aircraft Cannon Type 804. Barrel length, 65 calibers with manual charger.

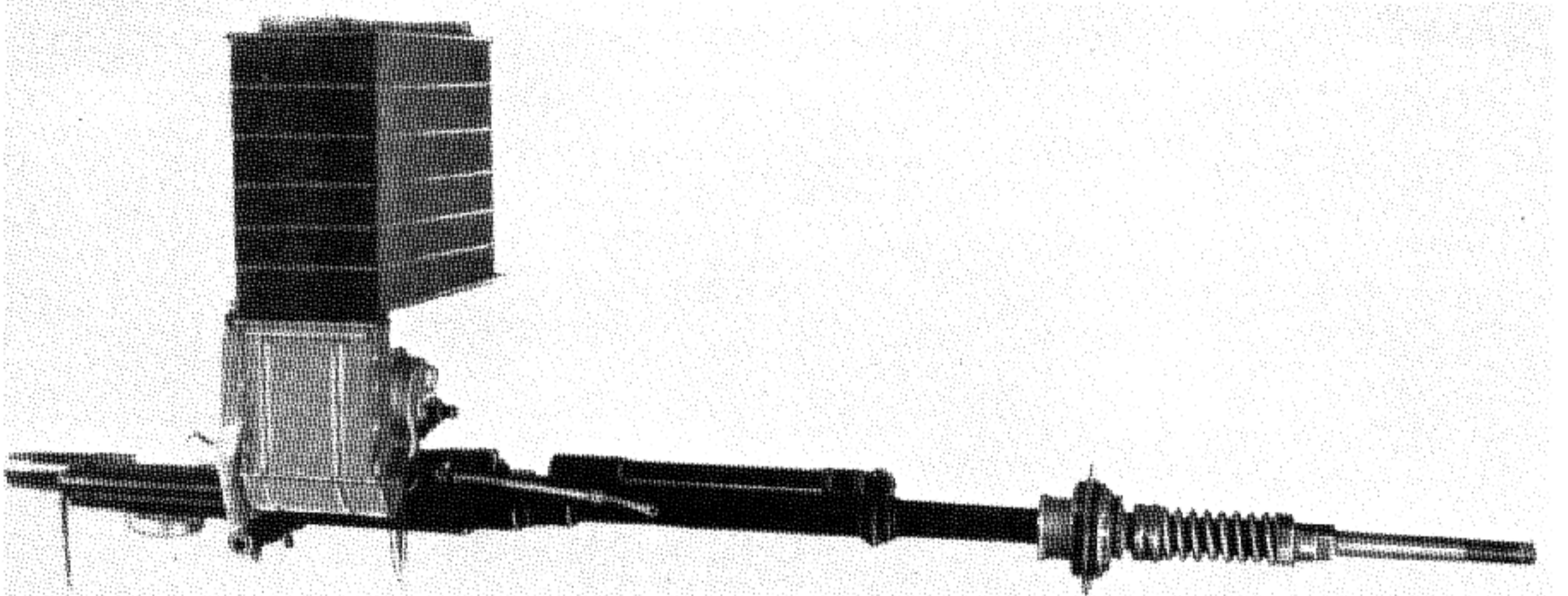


Figure 20-9. 20-mm Hispano-Suiza Aircraft Cannon Type 804. Barrel length, 70 calibers with feeder.

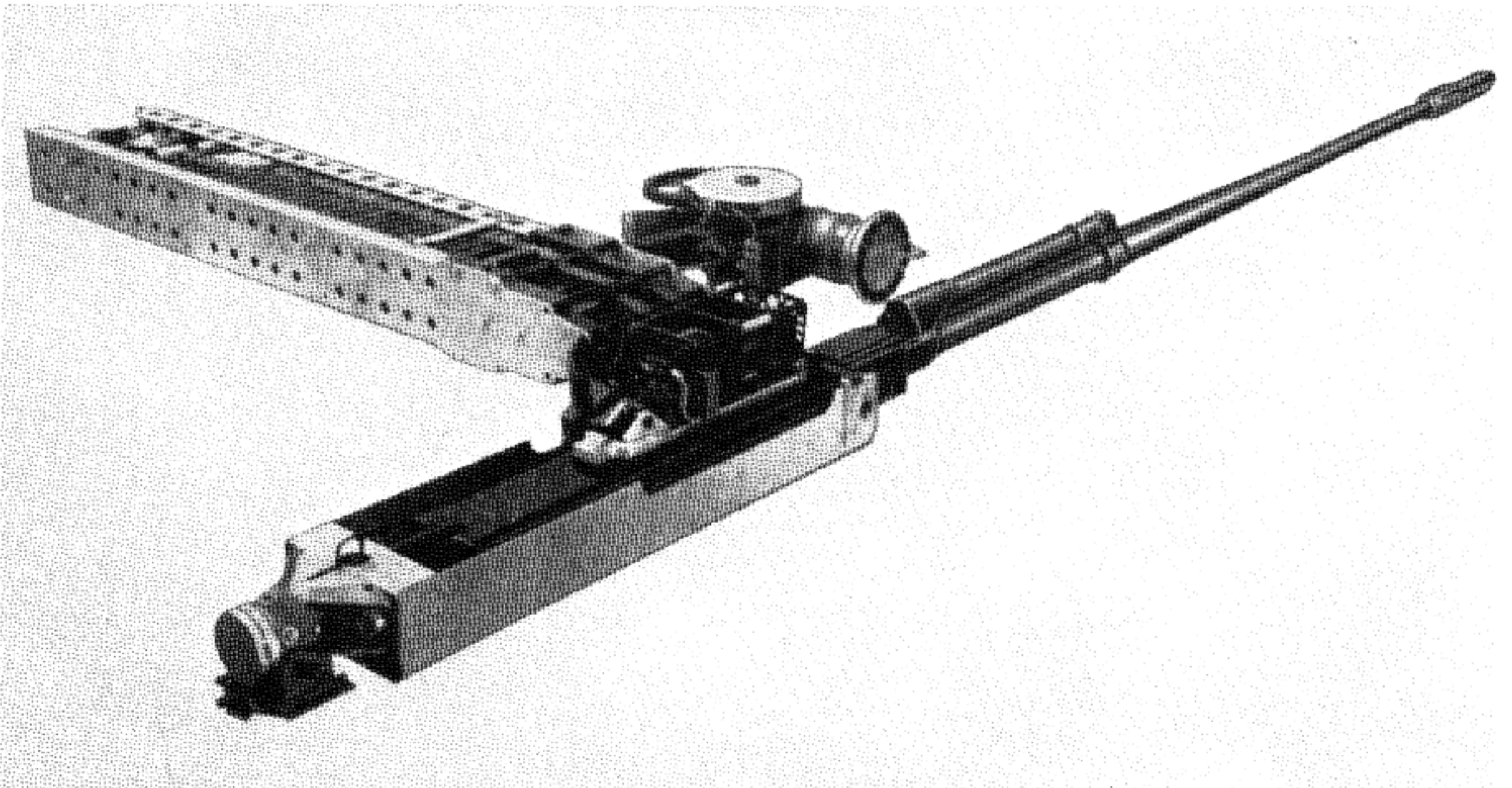


Figure 20-10. Wing magazine holding 200 rounds for 20-mm Hispano-Suiza Automatic Gun Type 804.

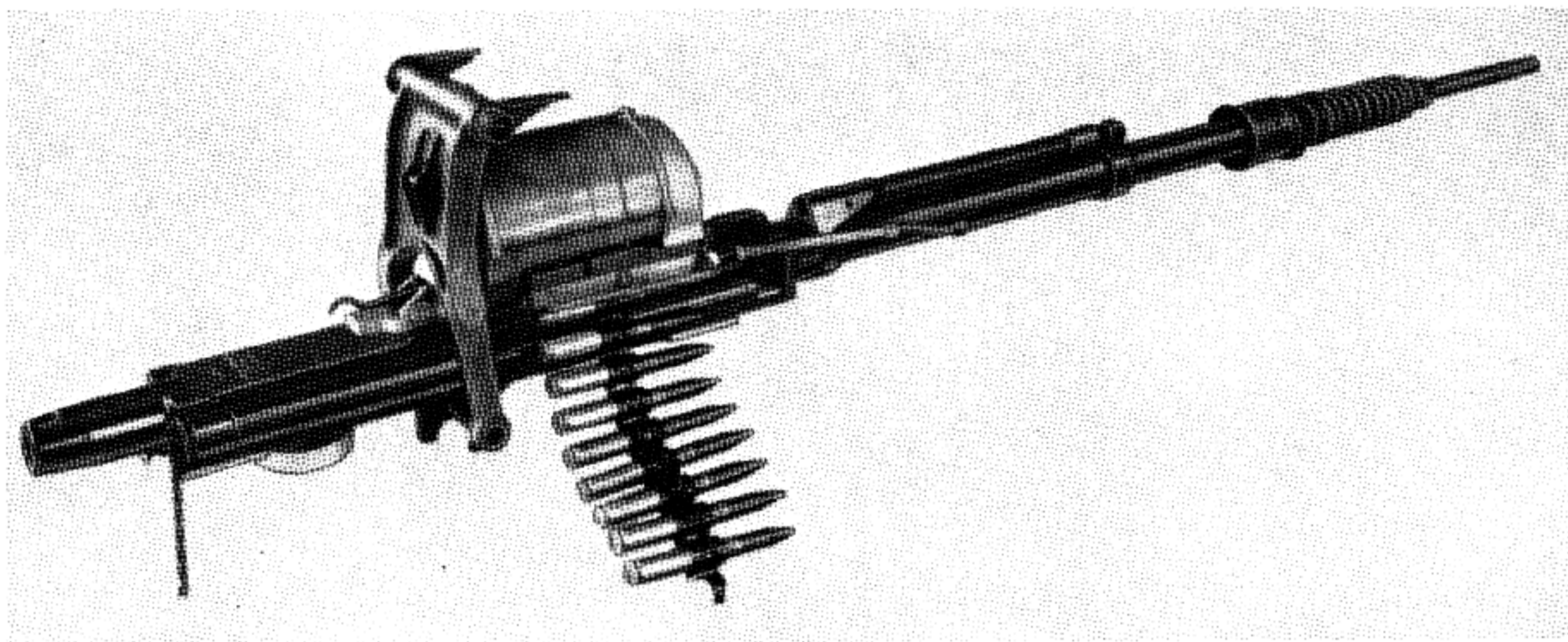


Figure 20-11. 20-mm Hispano-Suiza Aircraft Cannon Type 804, showing front and rear mountings.

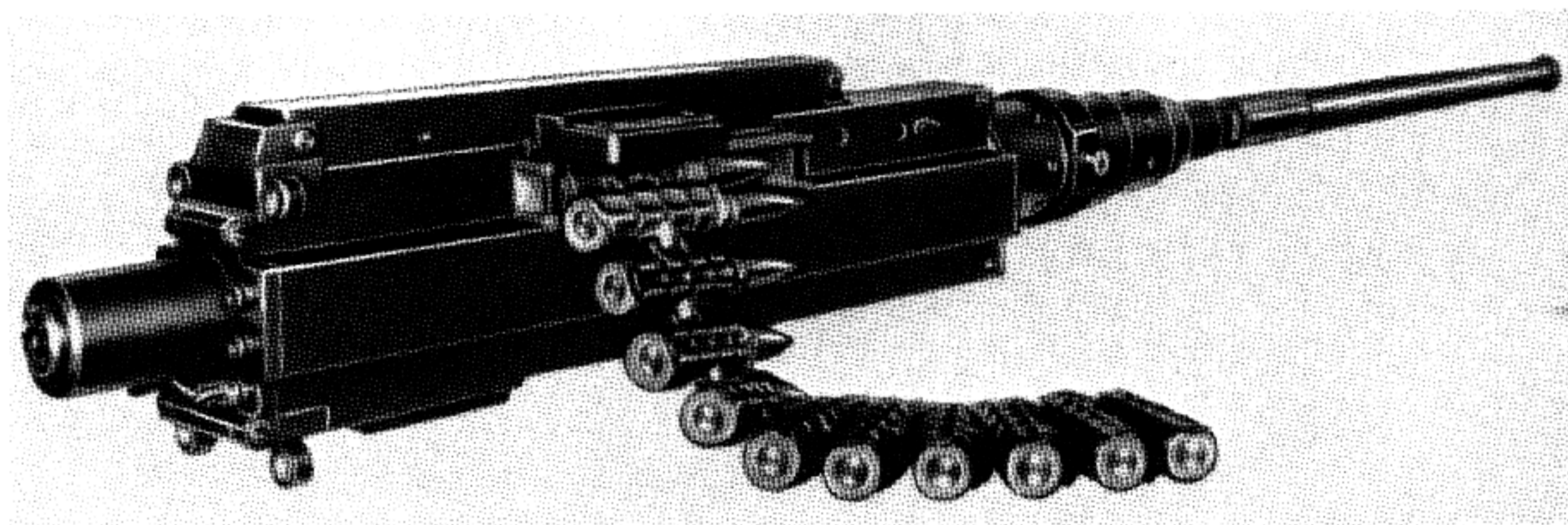


Figure 20-12. 37-mm Hispano-Suiza Automatic Cannon Type 606.

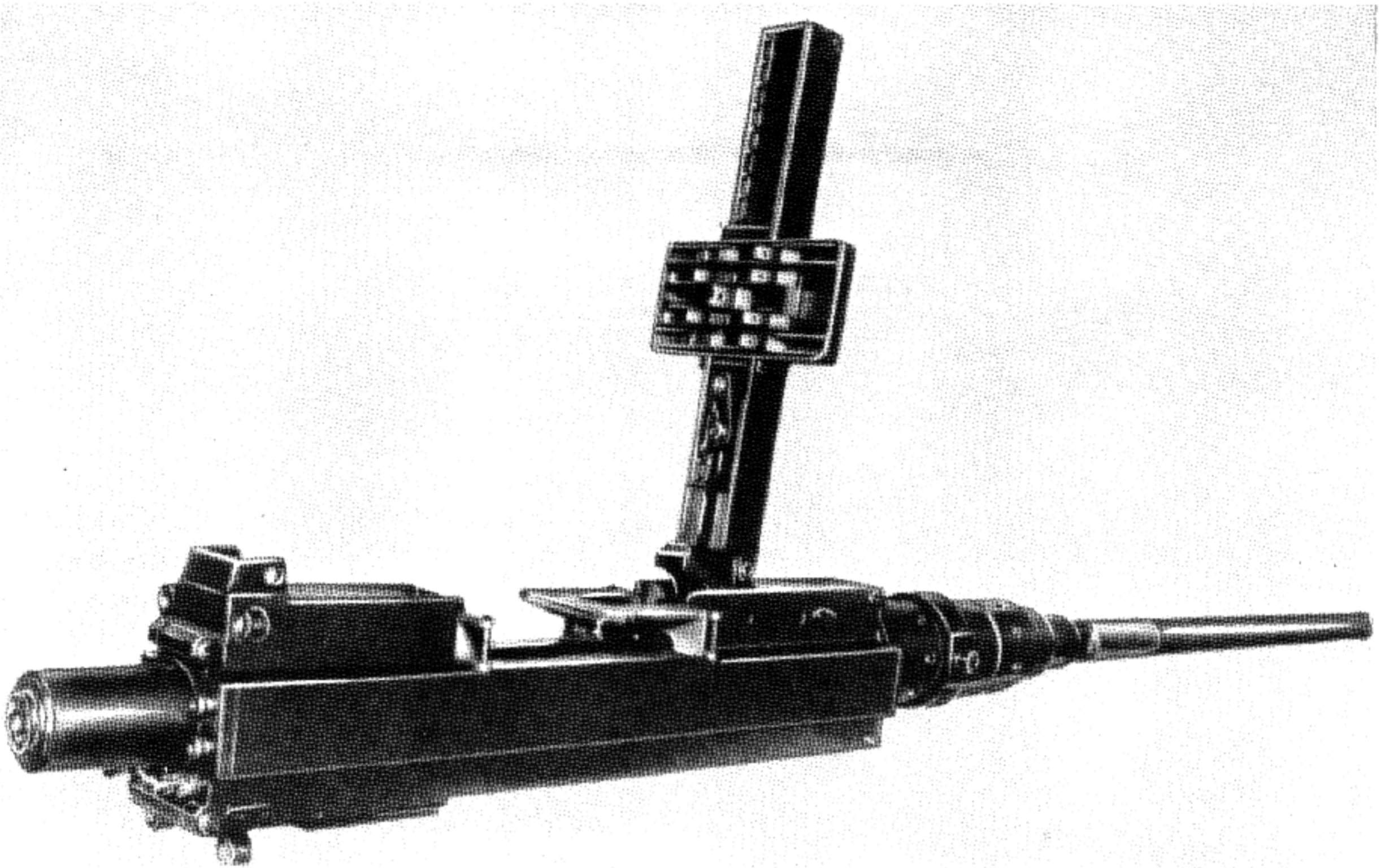


Figure 20-13. 37-mm Hispano-Suiza Automatic Cannon Type 606, with cover open.

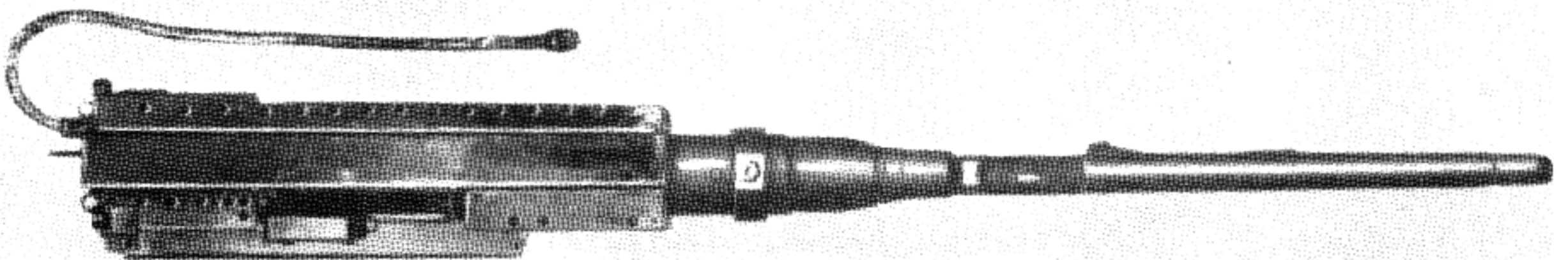
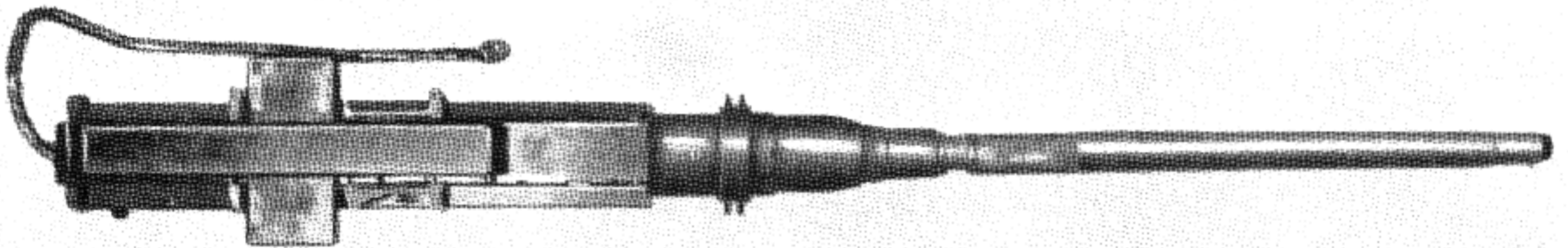


Figure 20-14. 30-mm Hispano-Suiza Automatic Cannon Type 603.

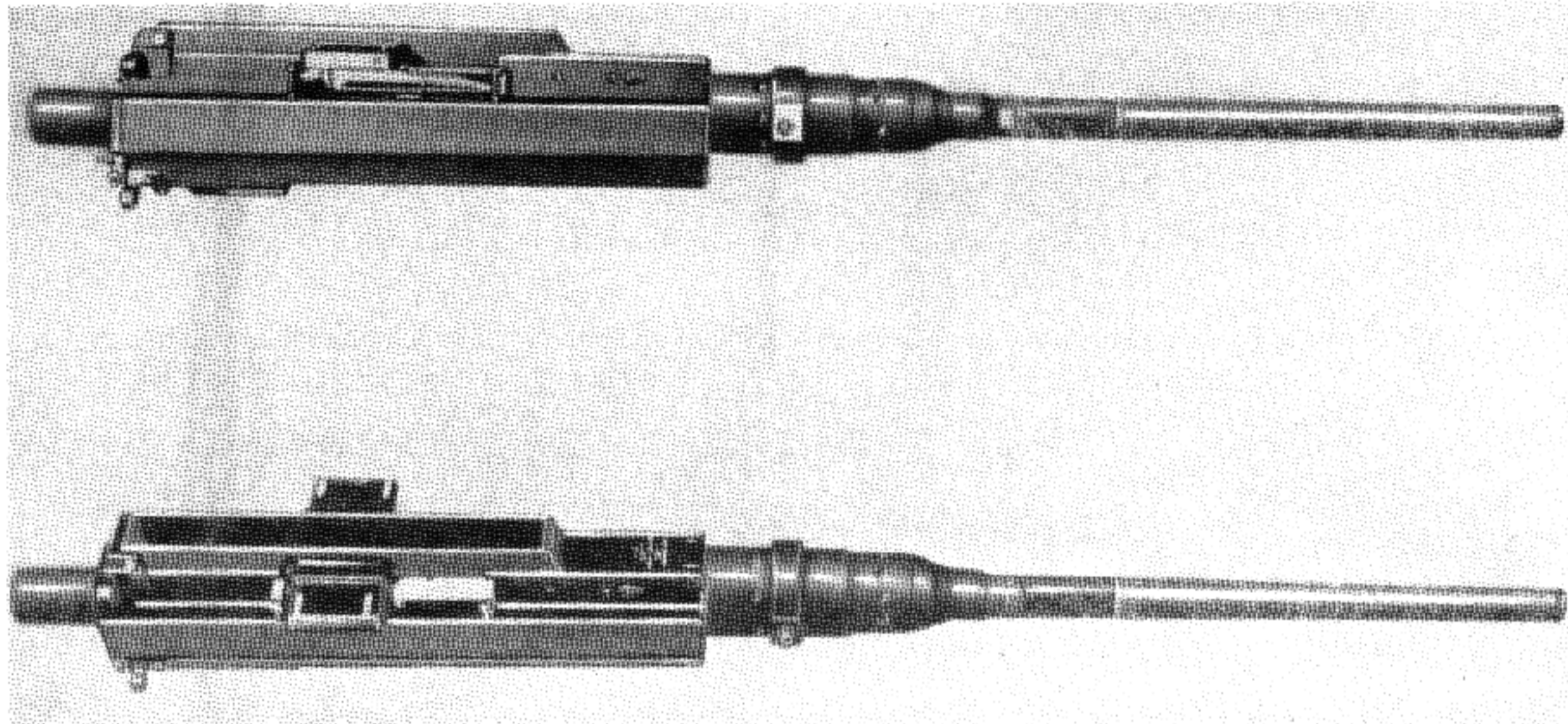


Figure 20-15. 30-mm Hispano-Suiza Automatic Cannon Type 603.

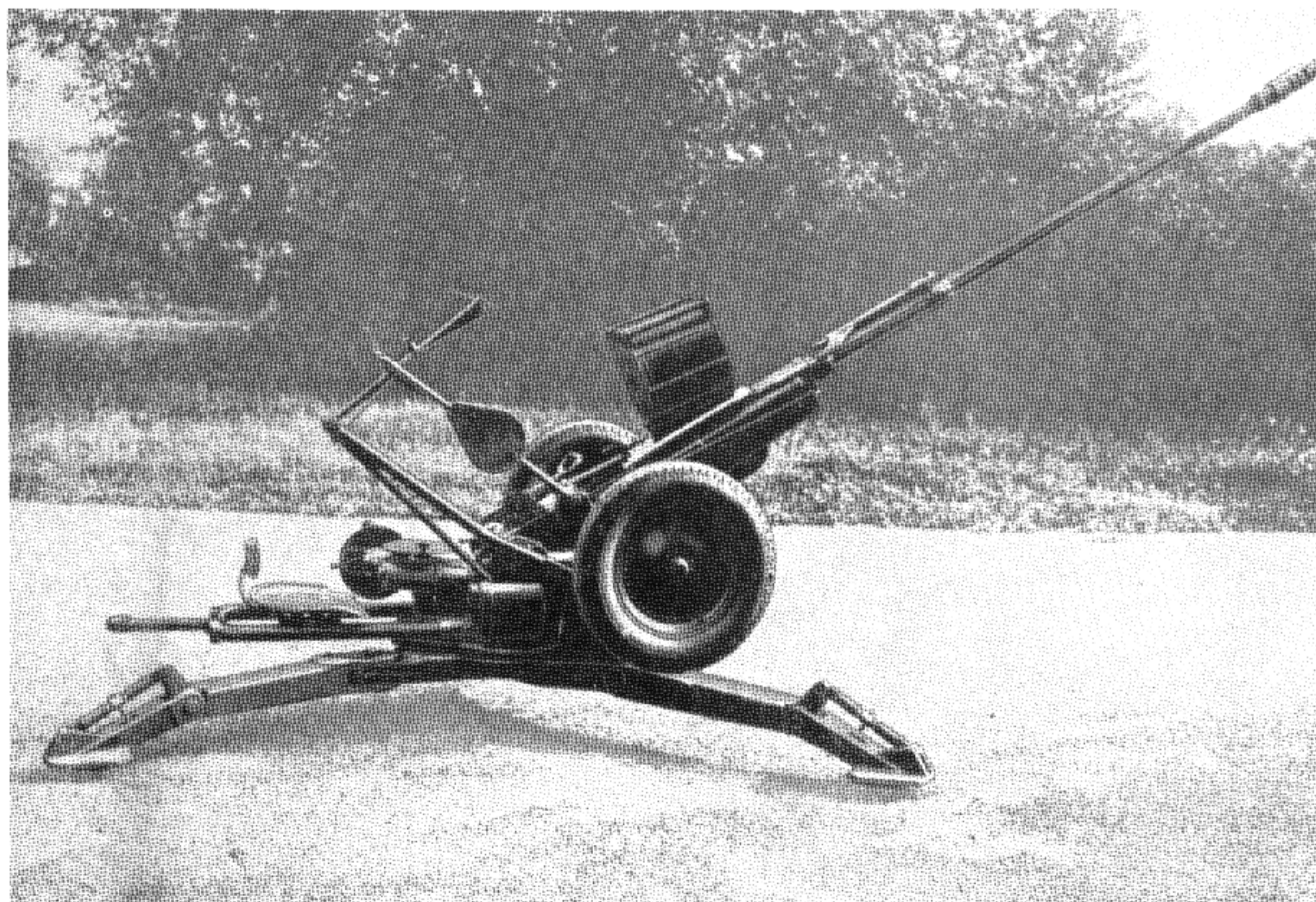


Figure 20-16. 30-mm Hispano-Suiza AA Cannon Type 830.



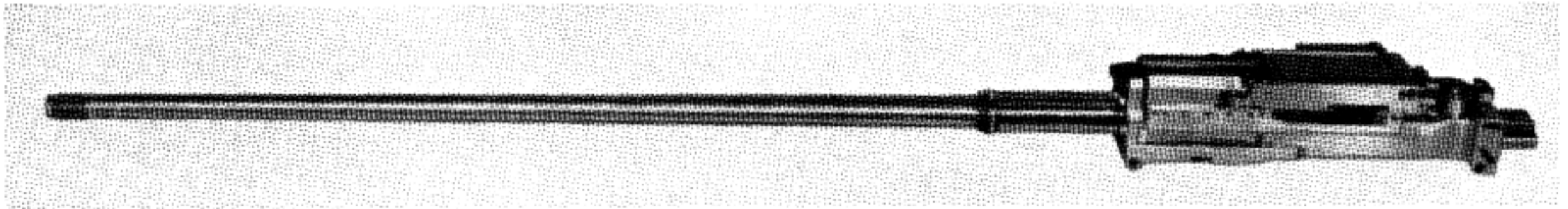


Figure 20-17. 30-mm Hispano-Suiza Aircraft Cannon Type 825. Left side view.

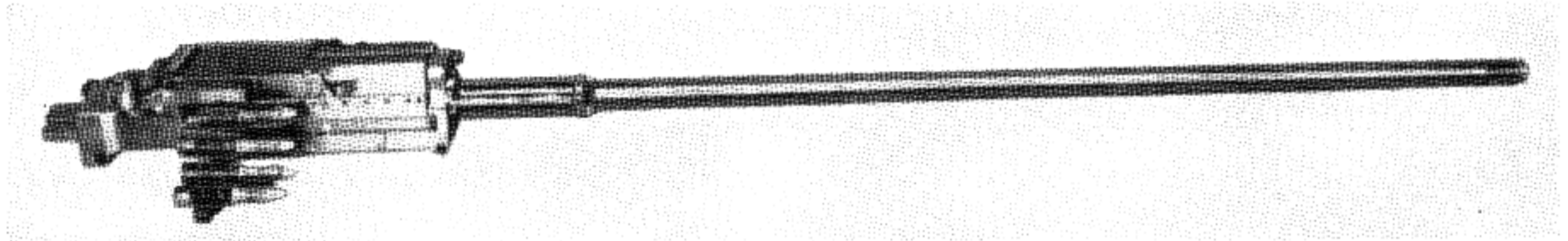


Figure 20-18. 30-mm Hispano-Suiza Aircraft Cannon Type 825. Right side view.

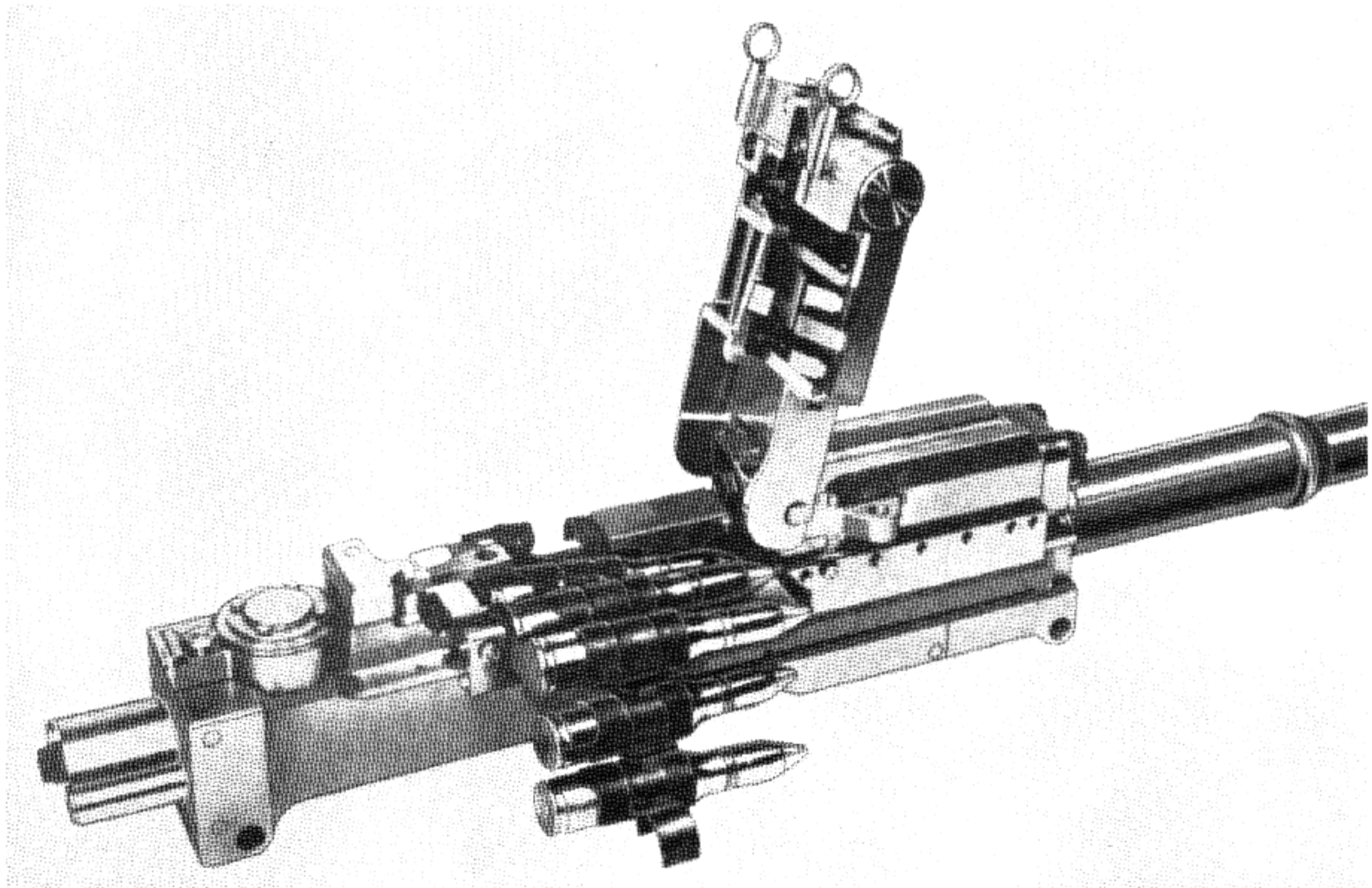


Figure 20-19. 30-mm Hispano-Suiza Automatic Cannon Type 825. Closeup of feedway.

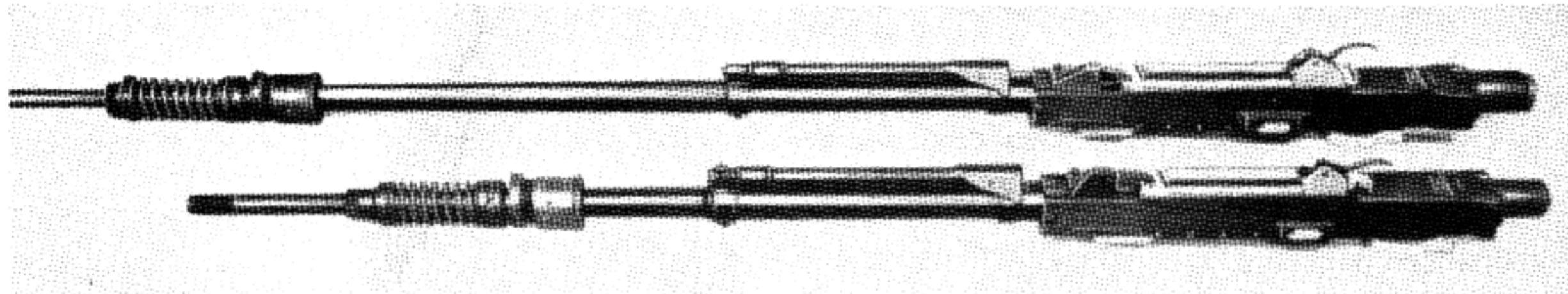


Figure 20-20. 20-mm Hispano-Suiza Type 820 Aviation Gun (above) and 20-mm Hispano-Suiza Type 804 (below).



Figure 20-21. The basic 20-mm Hispano-Suiza Type 820 Gun (above) and the basic 20-mm Hispano-Suiza Type 804 Gun.

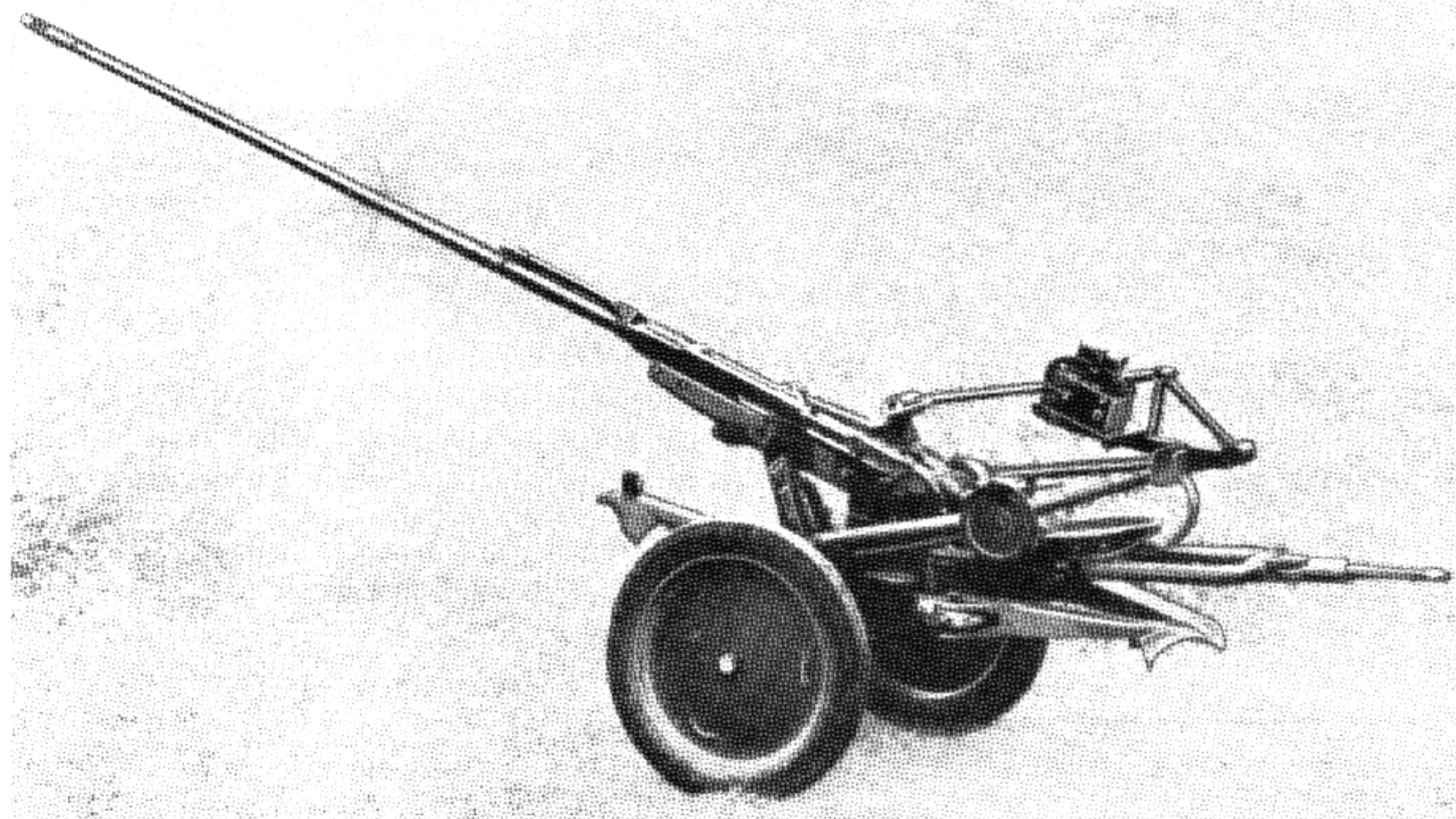


Figure 20-22. 20-mm Hispano-Suiza Type 820 Gun in traveling position.

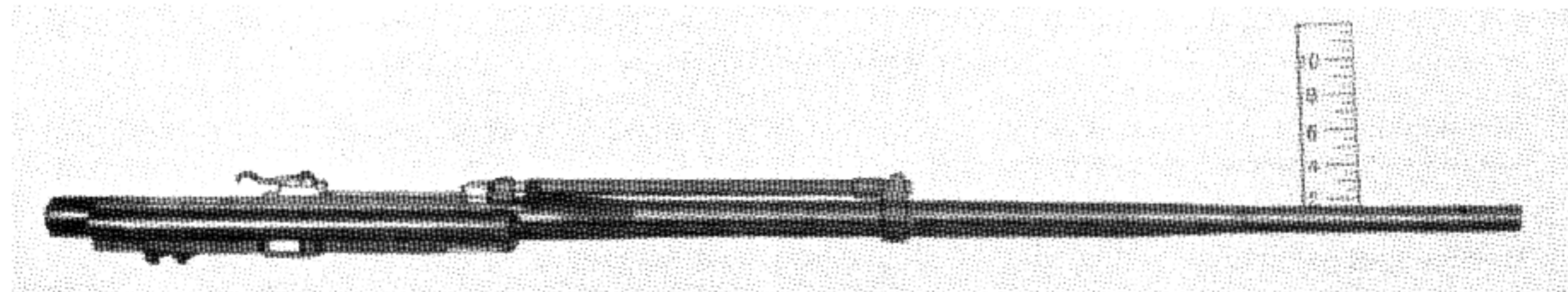


Figure 20-23. 20-mm Hispano-Suiza Cannon Type 404, manufactured for the French Government in World War II.

## SECTION 2. BRITISH DEVELOPMENT AND PRODUCTION PROGRAM

## History and Background

In 1936 the British commission became interested in the Hispano-Suiza Birkigt type 404. Negotiations for the purchase of six of these cannon by the British were completed in 1936, and the first gun was delivered in January 1937.

Early in 1937 the Hispano-Suiza Co. proposed the establishment of a Hispano-Suiza plant in England if given a token order for 400 cannons. This plant was opened in December 1938 under the name of British Manufacture & Research Co. The British produced gun was called the Hispano-Suiza type 404 in contrast to the designation identifying the model made in France, which was the Hispano-Suiza Birkigt type 404.

The initials of the British company were utilized to form the short identification "Mark" for the British-produced gun, and subsequent manufacture of the gun and development work to improve it were carried on under the designation "Mark" followed by a suitable Roman number.

In Canada, the Hispano-Suiza was manufactured under license by the John Inglis Co. of Toronto.

The story of the development of the Mark I and the Mark II is given in some detail in The Machine Gun, volume I, chapter 14.

There follows a short description of Mark I through Mark V for the purpose of identifying them.

## 20-mm Automatic Gun Mark I

This was the gun as first manufactured in Great Britain from the original French drawings. It was

manufactured on a small scale because of production difficulties with the original drawings.

## 20-mm Automatic Gun Mark II

This gun was first manufactured in Great Britain to a new set of British drawings to suit large-scale production. It included a number of minor improvements such as: return spring guide to prevent buckling of the spring; triple strand breechblock return spring; inertia blocks in breechblock to prevent breechblock bounce; increased overrun to rear by 5 mm for breechblock, for the purpose of increasing energy on feed stroke and increasing time for feeding of round into feed lips; improved firing pin and scar; and continuous ribs on the gun body.

## 20-mm Automatic Gun Mark III

This was a design having a fabricated gun body to cheapen production and reduce weight. This design never went into production.

## 20-mm Automatic Gun Mark IV

The design of this weapon was identical to the Mark II except that the barrel was 12 inches shorter and a shoulder was 9 inches further to the rear. It was intended chiefly for turret guns and never went into large-scale production.

## 20-mm Automatic Gun Mark V

This design represented the stage of development of the 20-mm Hispano-Suiza gun reached by the end of World War II. It was 25 percent lighter than the Mark II and had a rate of fire up to 50 percent greater, and the barrel was 12 inches shorter. It saw service as a fixed gun and in turrets.

## General Data: British 20-mm Automatic Guns Marks I through IV

Gun length: 93.7 inches.  
 Gun weight, without feeder: 102 pounds.  
 Rate of fire: 600-650 rounds/minute.  
 Muzzle velocity: 2,850 feet/second.  
 System of operation: Gas unlock, blowback assist.  
 System of locking: Swinging locks.  
 System of feeding: Drum and later Chatellerault automatic spring-wound feeder.  
 Method of headspace: Cannot be adjusted.  
 Location of feed opening: Top of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Manual and hydraulic.  
 Method of cooling: Air.

Barrel length: 67.5 inches.  
 Barrel weight: 47.5 pounds.  
 Rate control: None.  
 Barrel removal: Not quick disconnect.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 inch.  
 Groove width: 0.205 inch.  
 Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: 20-mm Hispano-Suiza (M75 series).  
 Rifling length: 63.08 inches.

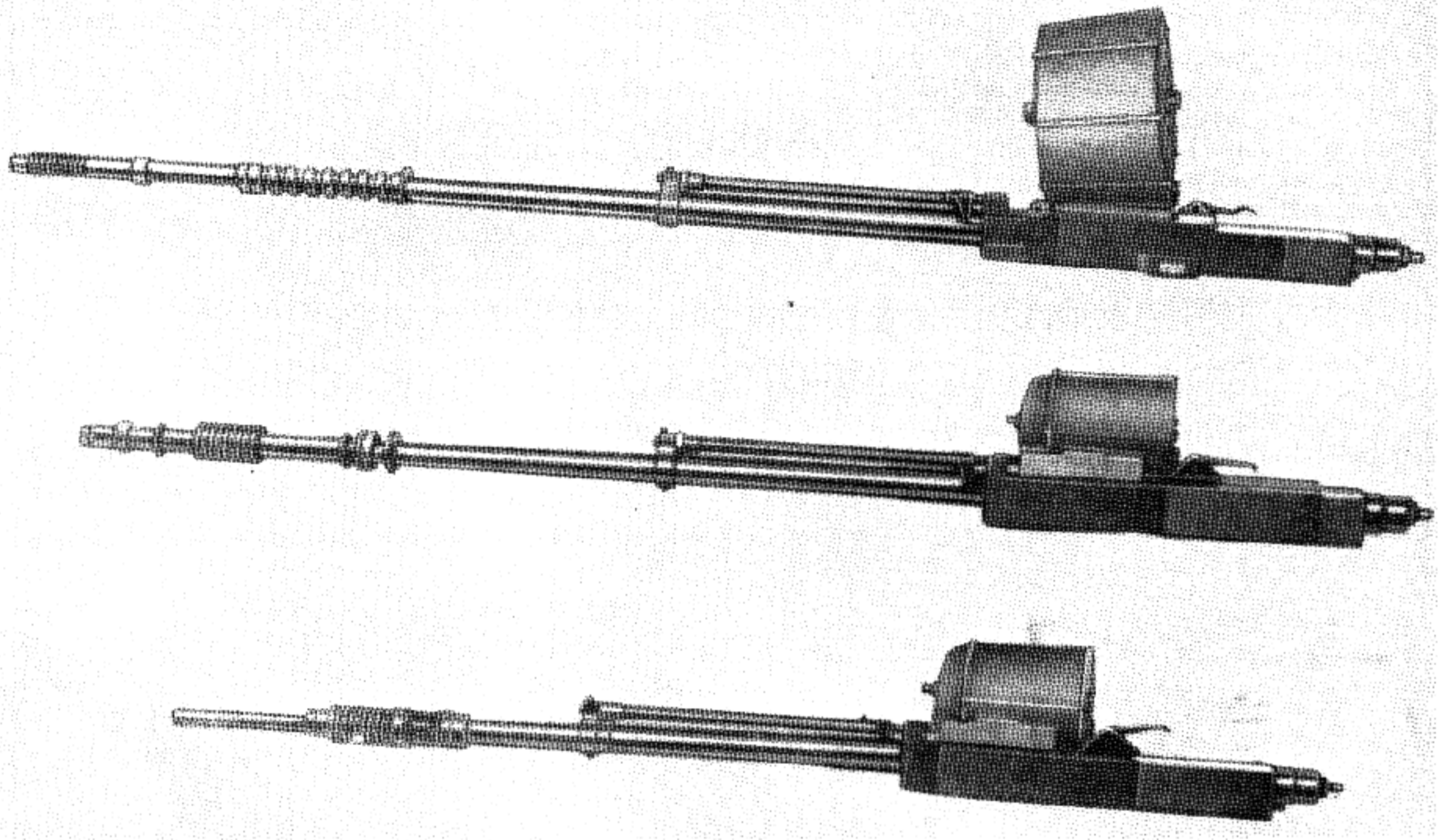


Figure 20-24. British Hispano-Suiza Guns, top to bottom: Mark I, Mark II, Mark V.

General Data: British 20-mm Automatic Gun Mark V

<p>Gun length: 77 inches.                  Gun weight: 99.5 pounds.                  Rate of fire: 700-750 rounds/minute.                  Muzzle velocity: 2,850 feet/second.                  System of operation: Gas unlocked, blowback assist.                  System of locking: Swinging lock.                  System of feeding: Automatic spring-wound feeder employing metallic links.                  Method of headspace: No provision made for adjustment.                  Location of feed opening: Top of receiver.                  Location of ejection opening: Bottom of receiver.                  Method of charging: Hydraulic, pneumatic, manual.                  Method of cooling: Air.</p>	<p>Barrel length: 52.5 inches.                  Barrel weight: 26¾ pounds.                  Rate control: None.                  Barrel removal: Cannot be removed easily in field.                  Chamber pressure: 42,000 p. s. i.                  Bore:                  Number of grooves: 9.                  Groove depth: 0.015 inch.                  Groove width: 0.205 inch.                  Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).                  Direction of twist: Right hand.                  Form of twist: Constant.</p>
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John Inglis Gun



Figure 20-25. The John Inglis 20-mm Gun. Left side view.

## General Data: Canadian 20-mm John Inglis Gun

Gun length, with flash hider: 97 inches.  
 Gun weight, with feeder attached: 155 pounds.  
 Rate of fire: 750–800 rounds/minute.  
 Muzzle velocity: 2,750 feet/second.  
 System of operation: Gas unlocking, blowback assist.  
 System of locking: Swinging lock.  
 System of feeding: Gas operated, employing metallic disintegrating link.  
 Method of headspace: Governed by tolerances of components.  
 Location of feed opening: Top of receiver, either right- or left-hand side.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Hydraulic.  
 Method of cooling: Air.

Barrel length: 67.5 inches.  
 Barrel weight, without flash hider: 47½ pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect type.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015 inch.  
 Groove width: 0.205 inch.  
 Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Cartridge: 20-mm Hispano-Suiza (M90 series).

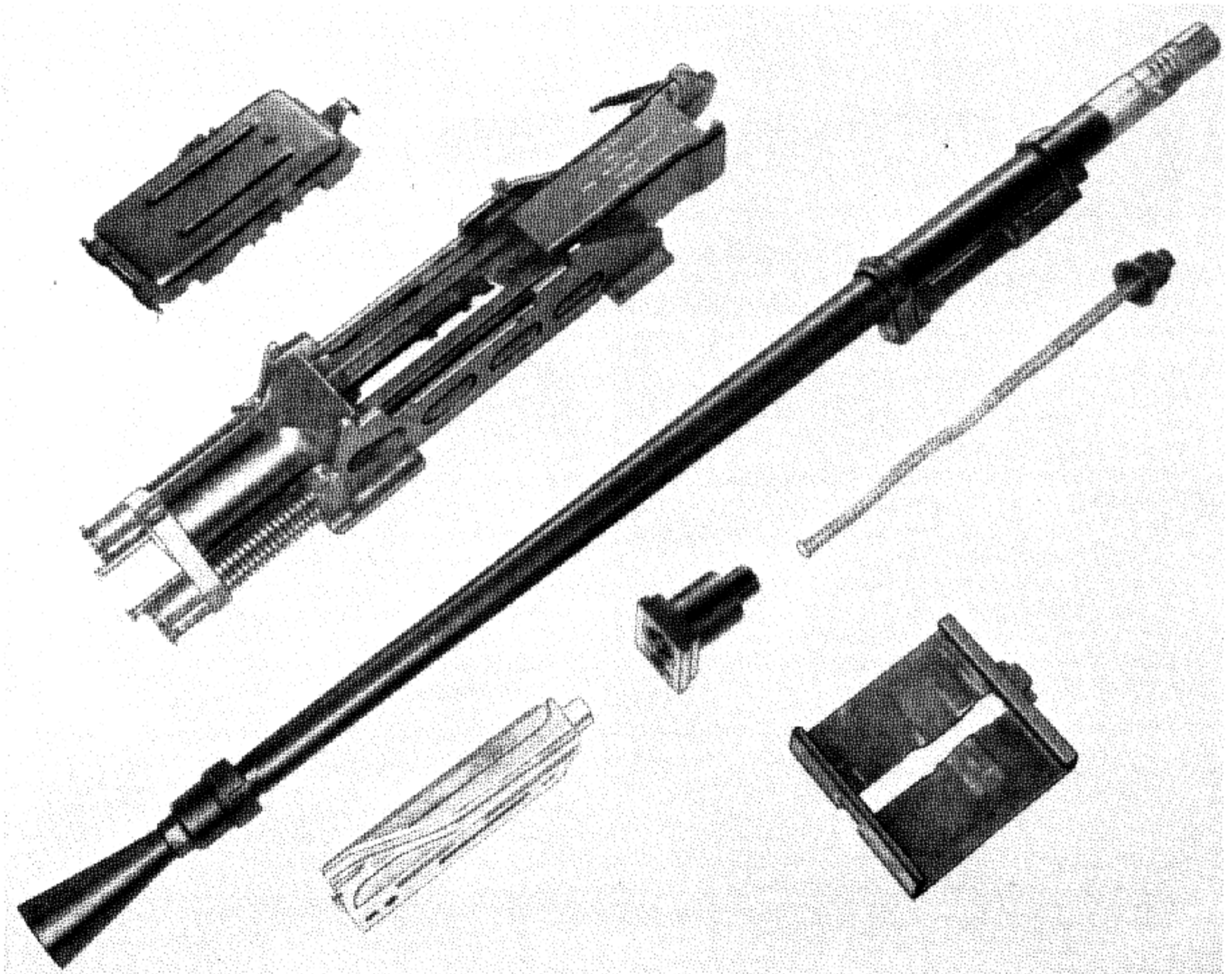


Figure 20-26. The John Inglis 20-mm Gun. Disassembled view.

## Chapter 21

## OERLIKON AUTOMATIC CANNON DEVELOPMENT

## SECTION 1. HISTORY AND BACKGROUND

For more than a century, the town of Oerlikon, Switzerland, has been known in the engineering and machine tool fields.

In the early 1900's, the firm built the first electric railway in Switzerland. Electrical engineering became the primary business; the machine-tool section, which was much older, was separated from the Oerlikon Engineering Works and set up as an independent company known as the Oerlikon Machine Tool Works. The production of machine tools was the main endeavor of the tool works, but in 1911 the first Swiss aircraft engine was built. The project was a financial failure and engine building was dropped. In World War I, the company stepped up its production of machine tools; but with the termination of hostilities, demand fell off sharply and the tool works was in financial difficulties.

In October 1923, the Oerlikon Machine Tool Works was purchased by a German firm, the Magdeburg Machine Tool Co. The new manager was Emil Georg Buehrle, onetime officer of a machine-gun unit in the army of the Kaiser. Financial retrenchment was his first order of business. The firm's books were weighted with an inventory of finished tools for which there was little demand. The number of workers was 80.

Buehrle continued the production of machine tools, but he was also alert to the need of diversifying the output of the plant. He recognized the inherent potentialities of a machine gun of which Germany had produced several prototypes toward the close of World War I and which had been flown in combat. The gun was the 20-mm Becker machine cannon. The gun was currently undergoing development at another Swiss firm, Maschinenbau A. G. Seebach. However, this firm also met financial difficulties and went into bankruptcy. In 1924, Buehrle purchased the patent rights for the SEMAG, the name the



Figure 21-1. Emil Georg Buehrle, the proprietor of the Oerlikon Co.

Becker gun had been given. In the 3 years that followed, Buehrle's faith in the Becker gun had begun to be vindicated. Guns had been shipped to many countries, although no major power had purchased a large quantity of guns.

At the end of the hostilities of World War I, the victorious Allies had examined German weapons, among them the 20-mm Becker machine cannon. They made a superficial check of the gun at Puteaux and relegated it to the museums.

In 1927, Buehrle began buying into the Oerlikon Machine Tool Works. By 1929, he was the principal stockholder and the number of employees had increased considerably.

In the early 1930's, interest in cannon armament for aircraft was reviving, and Buehrle saw an opportunity to push the development of the 20-mm SEMAG. A German designer, Fritz Herlach, was hired to work on a new version of the gun. A salesman was employed to introduce the gun to foreign governments. The man selected for this work was Antoine Gazda, an Austrian who had served as a pilot in World War I. In the capacity of "Export Manager, Oerlikon Works" he sold 40 guns and a license to the Japanese Navy. In the same year, 1935, he sold several guns to the United States Navy for test.

When a representative of the United States Ordnance Corps visited Oerlikon in 1935, he reported that the plant employed 800 persons—10 times as many employees as in 1923, when Buehrle assumed management. Two hundred of these workers were engaged in weapons manufacture. The new FF types were then appearing. These were designed primarily for mounting in aircraft having radial air-cooled engines for installation in or under the wings. The old F type, on the other hand, had been intended for engine mounting.

In 1936, Buehrle became sole owner of the company, which was renamed Werkzeugmaschinenfabrik Oerlikon, Buehrle & Co. The Swiss Federal Government stopped the shipment of production equipment to Japan in 1937, but the Dai Nippon plant was already in production. The Japanese license agreement was an important factor in the continued solvency of the Oerlikon Co.

About the same time, the British Army conducted tests of the Oerlikon as an antitank gun, but the War Office was critical of the blowback action and doubtful of the success of guns requiring greased ammunition. Then came the Spanish Civil War, where the nations rushed their new developments to the front for the ultimate test. Competent observers agreed that the gun was excellent when handled with reasonable care. The French Army of the Air liked the gun and put a quantity of 400 into service. At the opening of World War II, the Axis Powers had some of these weapons.

In 1937, the British Royal Navy considered this

gun for shipboard AA defense. Tests were conducted of this and other weapons for the defense of merchant vessels, trawlers, minesweepers, and similar craft against dive bombers and close range air attack. One of the other weapons tested, the Hispano-Suiza, failed to meet the requirement that the gun be capable of operation by nonspecialist personnel such as merchant seamen and fishermen. Following the tests, a contract was negotiated with the Oerlikon plant for the manufacture and supply of guns, but only a small number of guns were delivered to the British from this source. Records indicate that only 100 guns were at sea in November 1940. The fall of France cut off the supply from Switzerland, but the Admiralty had anticipated such a possibility and had concluded a license agreement providing that Oerlikon would supply complete data for the manufacture of guns and ammunition in any part of the empire.

In June 1940, shortly before the German success in France, the British had decided to establish a facility for the manufacture of Oerlikon guns in the United States. In 1939, the Oerlikon company had appointed Alfred Altman of New York as its representative in the United States. He was to receive a 5 percent commission on guns, mounts, and ammunition sales, and a 10 percent commission on all license transactions. The latter transactions were limited to use in and for the United States. It was further provided that extension of any license agreement after the last day of 1940 was contingent upon Altman's concluding "transactions amounting to at least 500,000 United States dollars."

In May 1940, Gazda returned to the United States. He entered into negotiations with officials of the British Purchasing Commission, proposing to manufacture at a rate of 2,000 guns per year by establishing an assembly plant and using subcontractors as needed to maintain this production rate. Gazda was successful in finding a New York banking firm to back his organization.

While both Altman and Gazda were United States representatives of the Oerlikon Machine Tool Co., Gazda had power of attorney for the company. Accordingly, he negotiated a license agreement for the manufacture in and for the United States and export to the United Kingdom of the Oerlikon guns type SL and SS and ammunition types HL, SG, UL, and UG.

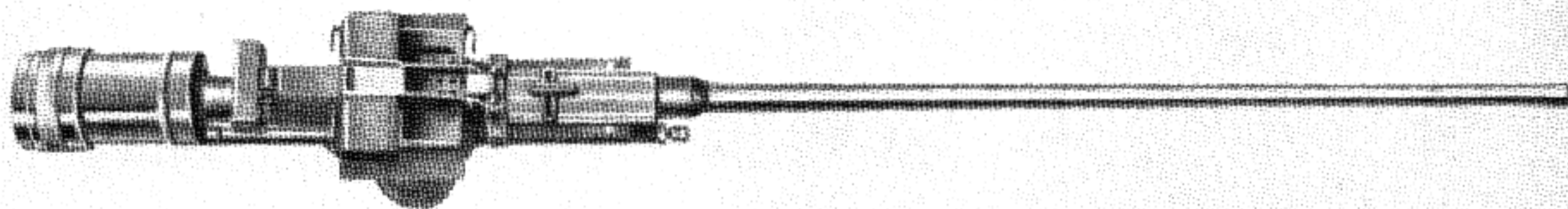


Figure 21-2. United States Ordnance Corps Caliber .60 Automatic Gun T31, an Oerlikon type developed by Gazda. Top view.

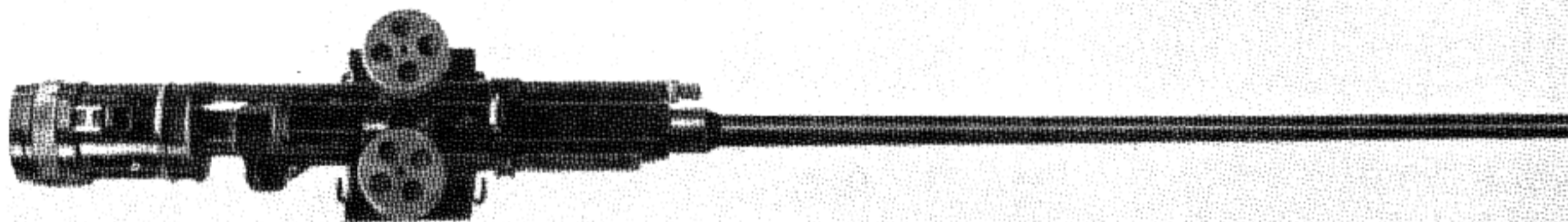


Figure 21-3. Caliber .60 Automatic Gun T31. Bottom view.

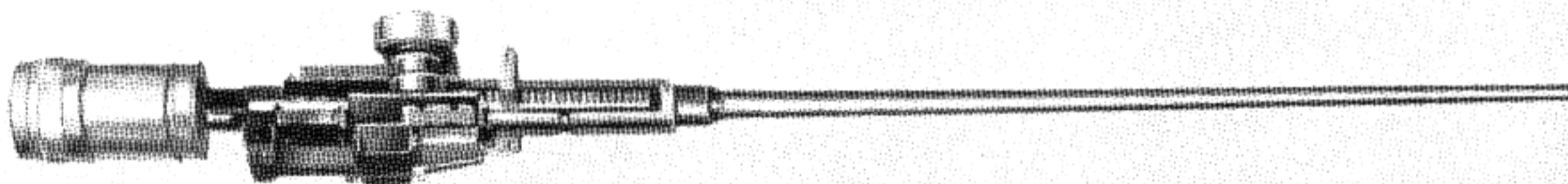


Figure 21-4. Caliber .60 Automatic Gun T31. Left side view.

This agreement was preceded by disagreement between the British Admiralty and the President's Liaison Committee on the relative merits of the Oerlikon and the Hispano-Suiza AA weapons. The difference of opinion came to an end when, on 9 November 1940, the United States Navy adopted the Oerlikon as its light shipboard AA defense. By the end of World War II almost 150,000 guns had been produced. This astronomical figure makes the 20-mm AA gun program the greatest single ordnance project in the building of the world's largest Navy.

The Axis Powers fought with Oerlikon aircraft guns using a shorter case with a reduced powder charge. Some Oerlikon weapons used by Japan were made in Switzerland, but the majority were of domestic manufacture. After the fall of France, the pressures of political, geographic, and military expediency brought about a closer liaison between

Oerlikon and the Wehrmacht. This situation put the company on the Allied blacklist and resulted in the tying up of Oerlikon financial resources in the international banks. After 1943, shipments to the Axis Powers tapered off.

The international character of the production of Oerlikon guns is seen in the accompanying chart showing the main plant, its subsidiaries, and other firms which manufactured certain versions of Oerlikon weapons throughout the world. For additional details, see *The Machine Gun*, volume I, pages 512 to 521.

At the end of World War II, the Oerlikon plant had some thousand 20-mm guns in stock. Most of these were disposed of to governments engaged in minor military activities in various parts of the world before the Swiss Federal Council curtailed the munitions export trade by an embargo. This measure became effective in 1946. The main reason for





Figure 21-5. Test of the Oerlikon Type SS Gun at the Naval Proving Ground, Dahlgren, Va., in 1940.

this was to avoid the political embarrassment that the arms trade with Germany and Italy caused during World War II and with the U. S. S. R. in the postwar period.

The curtailment order did not completely hamstring the arms industry in Switzerland, however. Provision was made for the Federal Military Department to grant permits for export of certain classes of munitions. The most important of these, as far as the Oerlikon plant was concerned, were AA defense weapons up to 35-mm bore. The effect of this policy has been to permit shipment of trial orders to such countries as Great Britain, the United States, Sweden, Norway, and Canada—countries which have adequate arms industries and which are more interested in acquiring manufacturing rights to new Swiss weapons than in purchasing large quantities of Swiss-made guns.

With this incentive to continue weapon development, the Oerlikon plant turned its attention to new

designs. Although guns with blowback action had played an important part in World War II, it was obvious that something better was needed. The competition of Hispano-Suiza was, no doubt, an important incentive at this time. The universal demand for a high rate of fire led to the setting of a requirement of one thousand rounds per minute in any new gun mechanism. Thereupon, the chief engineer of the firm proposed a method of operation which he named "power reserve loading." The gun produced to this design was called the 5TG. Although it seemed promising at first, it failed to meet fully the current requirements for an aircraft and antiaircraft high-speed cannon. The Oerlikon Co.'s progress seemed stymied, when new life was injected into the design department from outside sources.

About this time the impact of the defeat of the Axis powers was beginning to be felt. The victorious nations claimed all military inventions as

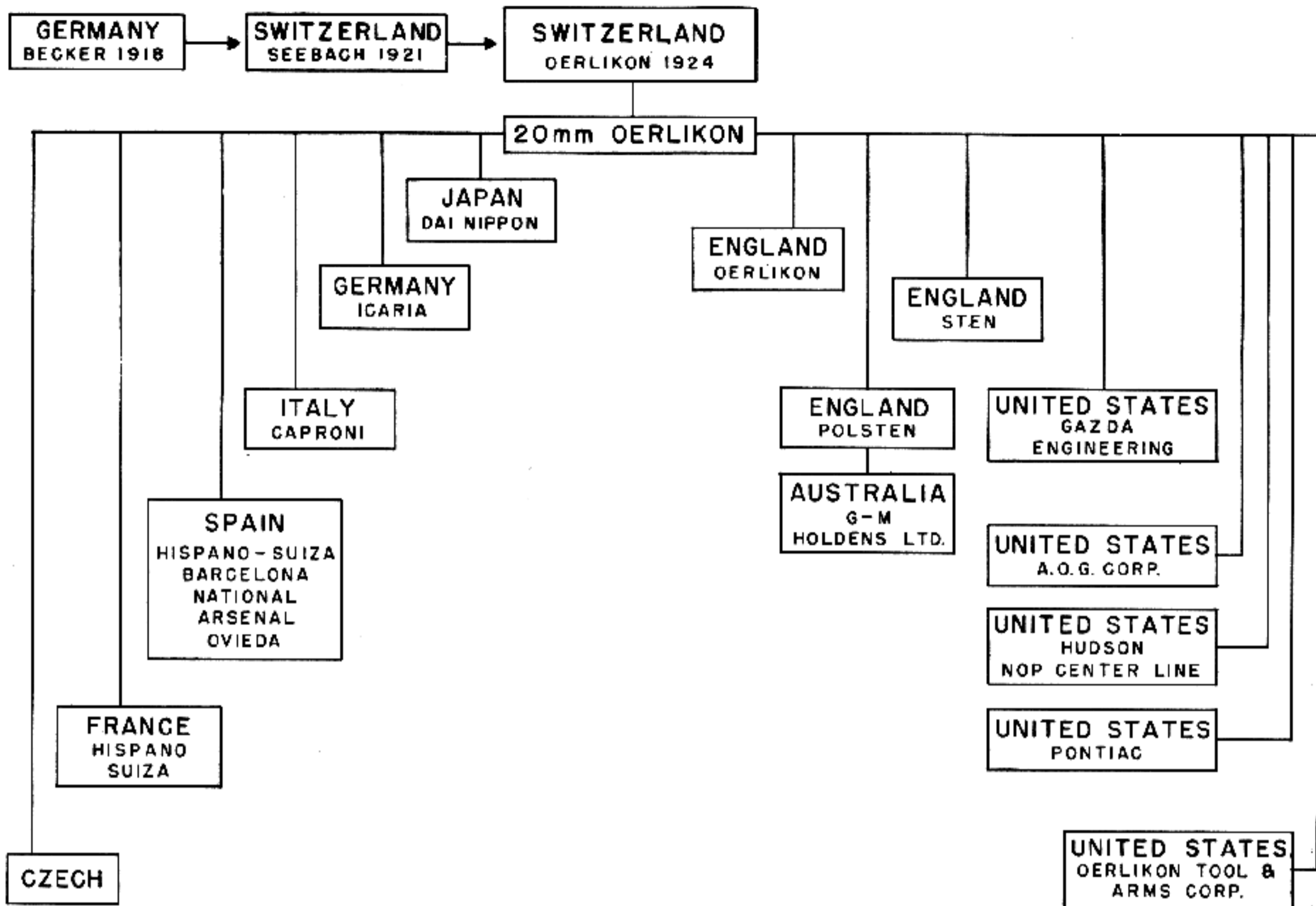


Figure 21-6. The present Oerlikon designs stem from the Becker gun of World War I. Adaptions from this parent mechanism are indicated in this chart.

booty of war. German gun models and data were evacuated by the Allied Technical Intelligence services and many German gun-design personnel became employees or prisoners of the victors. Others left Germany for neutral countries, and, of these, an important group went to the Oerlikon works. Among this group were Linder and Herlach—the same Fritz Herlach who had been hired by Buehrle to work on a new version of the 20-mm SEMAG in the thirties. These two men and others, who were hired, had worked on advanced designs which Germany was preparing when she collapsed.

Under the guidance of these men, hit-and-miss methods in research and development were replaced by more efficient procedures geared to produce more certain results. Several of the later designs which had been in the prototype stage in Germany were revived. In addition to development of 20-mm guns, design studies were made in the field of 30-mm weapons. Among these are the 30-mm automatic aircraft gun type 301 FK, shown in an accompanying figure, the 30-mm revolver gun 302 RK, and the 40-mm caseless gun HO 301. Important projects were also undertaken in the field of ammunition, rockets, and guided missiles.

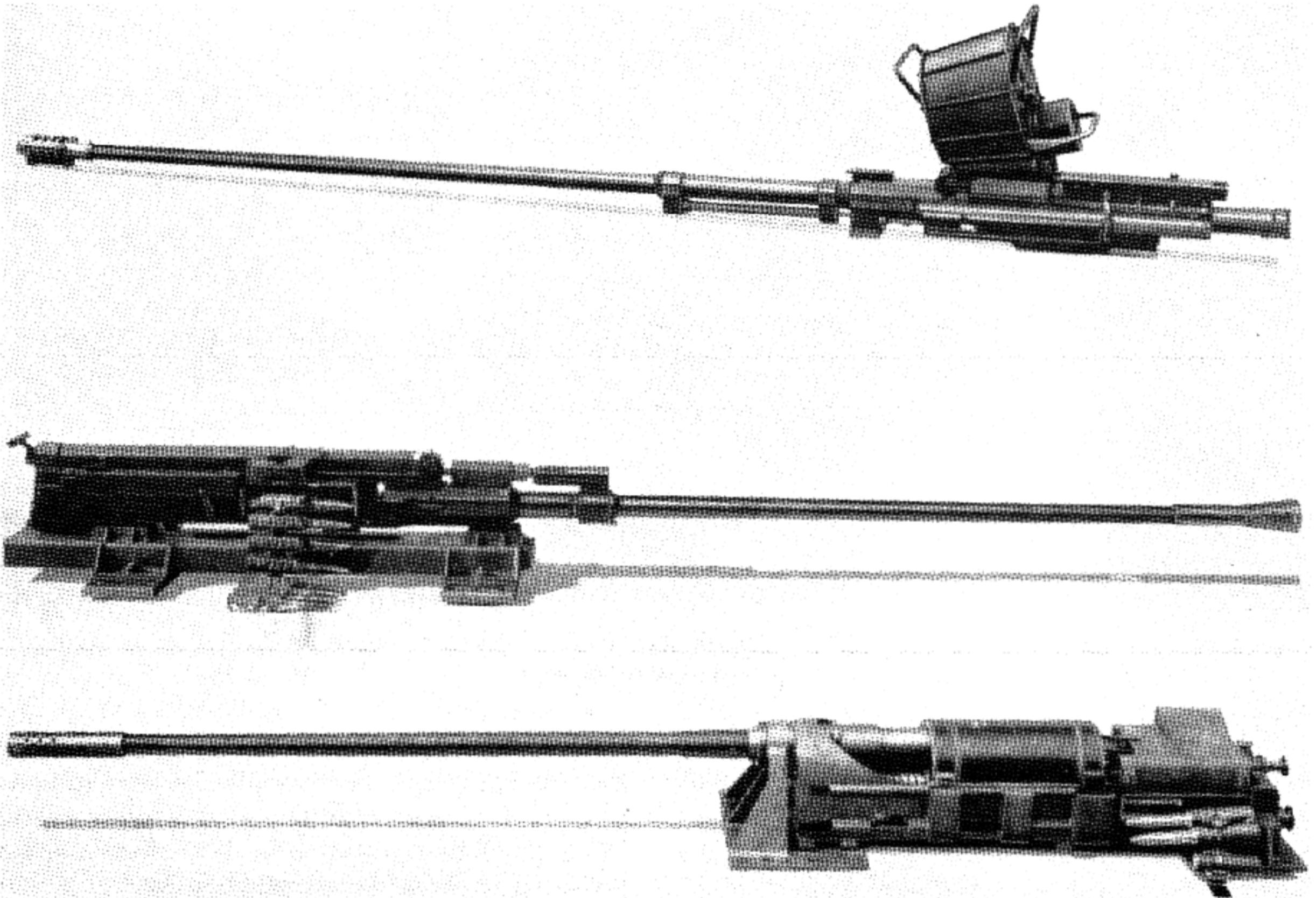


Figure 21-7. Automatic Cannon Types under development at the Oerlikon Factory since World War II. Top to bottom: 20-mm Automatic Gun Type 5TG; 20-mm Antiaircraft Gun Type 204 GK; 30-mm Revolver Cannon 302 RK.

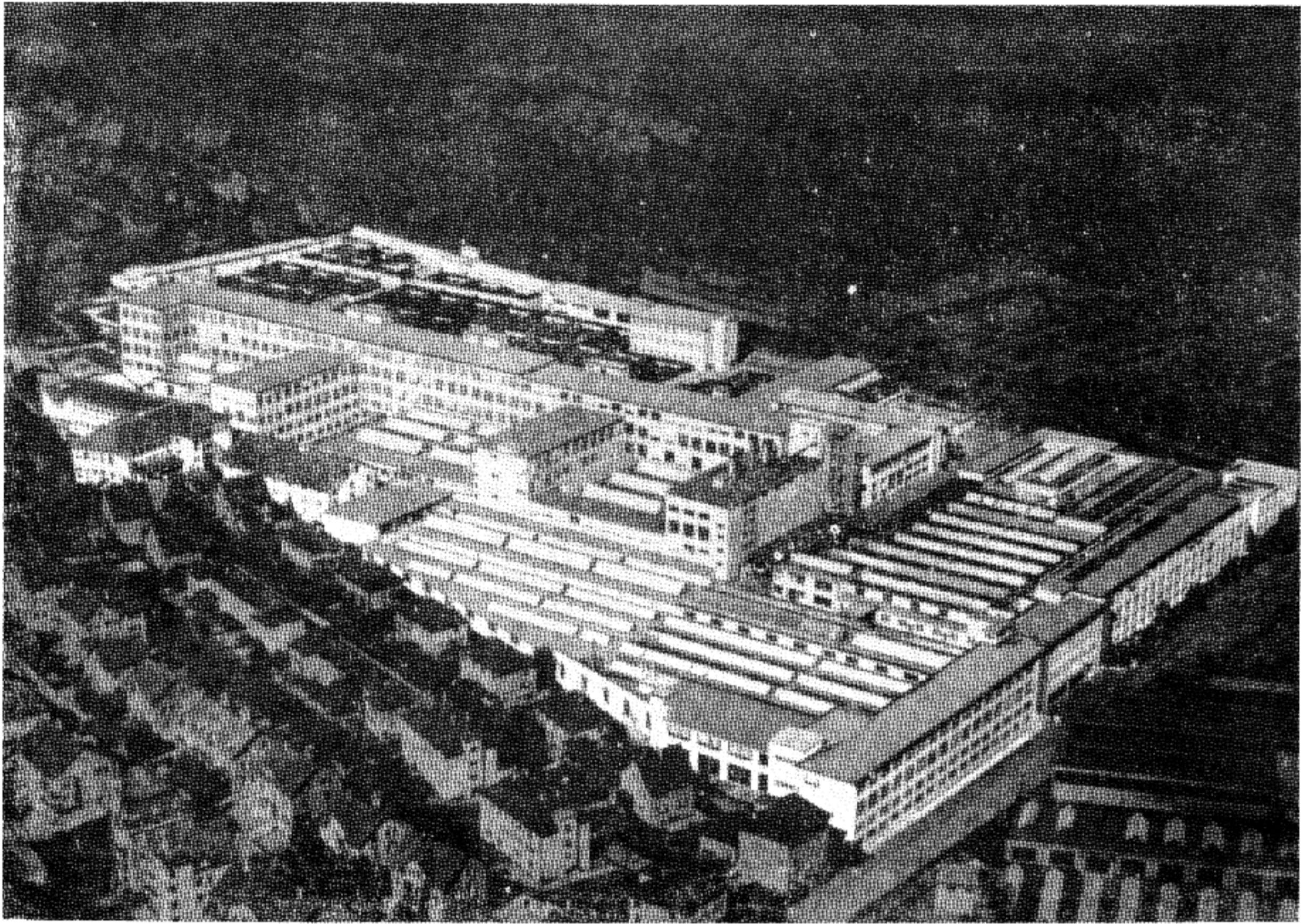


Figure 21-8. Aerial view of the Oerlikon factory in Switzerland.

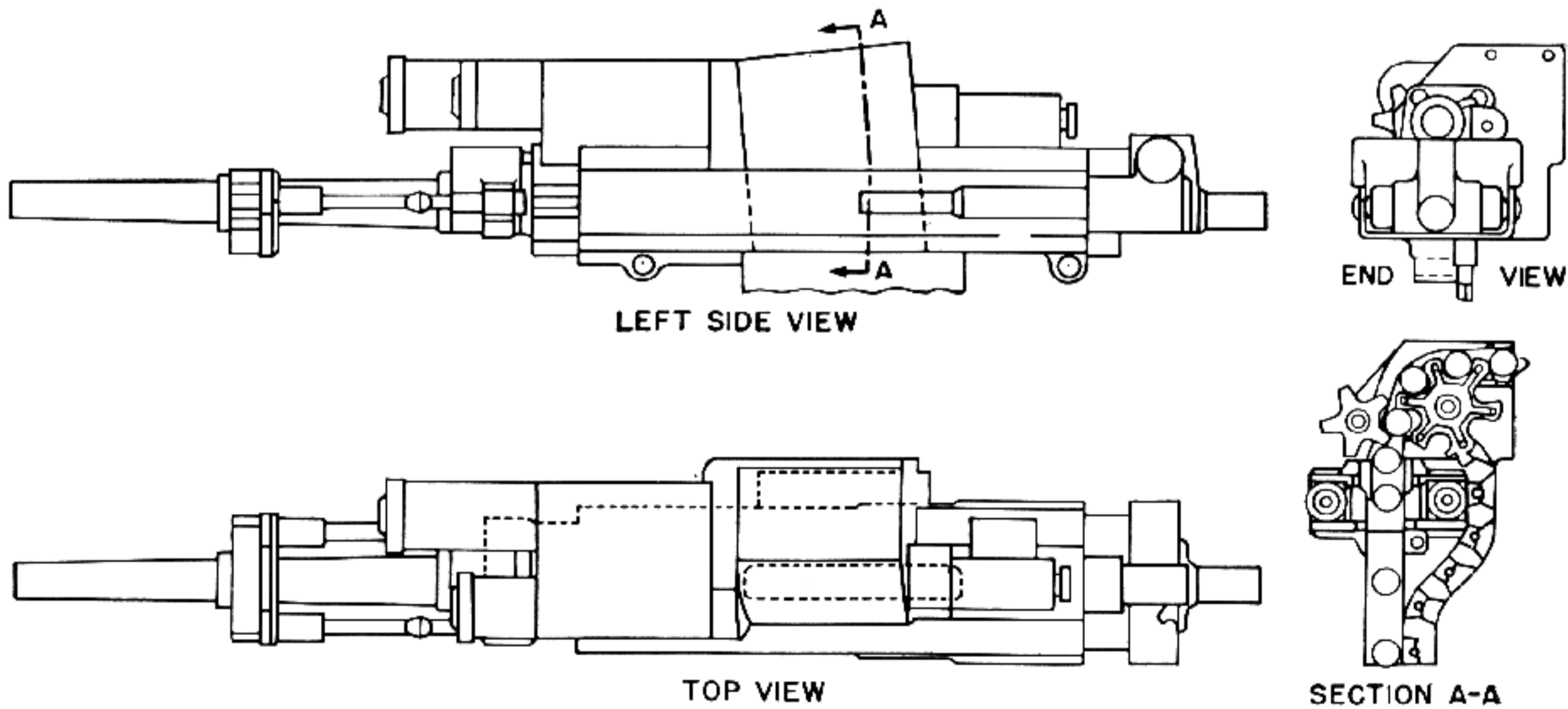


Figure 21-9. Oerlikon 30-mm Automatic Cannon Type 301 FK, a postwar design that was discarded in the development stage.

## SECTION 2. 20-MM AUTOMATIC GUN TYPE 5TG

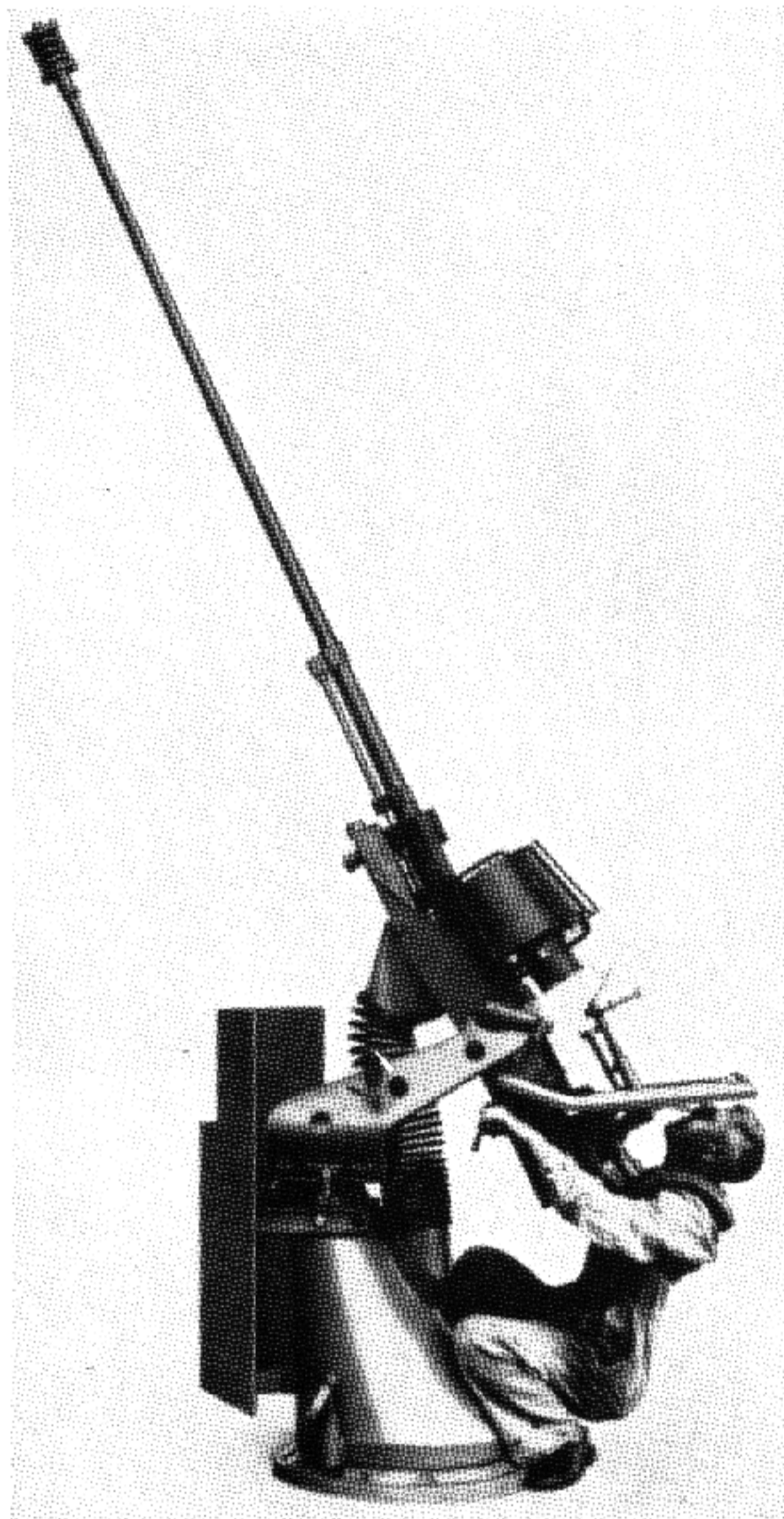


Figure 21-10. 20-mm Automatic Gun Type 5TG on a cone mount, for use as a light AA gun.

The 20-mm automatic gun type 5TG, developed after the close of hostilities of World War II, was the first Oerlikon gun design that differed radically from the original Becker design. The 5TG was first made with a drum feed. An Oerlikon Co. brochure describing the gun states that the gun can be adapted for pneumatic or electric-driven feeder,

pneumatic or electric charger, and that searing and ignition can be made electrical. Available information indicates that the prototypes are still drum fed. The following quotation presents observations on 20-mm guns for firing against aircraft as given in the brochure just mentioned.

“The destructive power of a single 20-mm shell is comparatively small. Several hits are therefore required to down an airplane. The initial velocities and trajectory times encountered with the usual 20-mm automatic guns require intolerable prediction distances when firing against fast jet-propelled aircraft.

“The density of the cone of fire with the conventional rates of fire is no longer sufficient because of the high airplane speeds. The probability of hitting thus becomes very small.

“When low-flying aircraft are to be fought, the time available for firing is very short. Apart from the small probability of hitting, with the conventional rates of fire this time is mostly too short to fire a sufficient number of shells into the target to effect its destruction.”

Based on these propositions, Oerlikon designed the 20-mm 5TG for a rate of fire of 1,000 rounds per minute and a muzzle velocity of 3,700 feet per second. It is noteworthy that during a demonstration in England held from 6 to 8 May 1949, a rate of fire of only 800 rounds per minute was attained although the muzzle velocity was recorded at 3,600 feet per second.

The improved performance of the 20-mm 5TG over the conventional automatic guns of the same caliber naturally had some constructional consequences. The increase in the muzzle velocity from the customary 2,790 feet per second to 3,700 feet per second—practically tantamount to twice the muzzle energy—necessitated on the one hand a longer barrel and on the other, a heavier propelling charge and consequently a larger and heavier cartridge. The barrel length of 7.88 feet—equivalent to 120 caliber—could be kept at the size permissible for operational and technical reasons. Yet, in order to obtain the desired high rate of fire in spite of the larger and heavier cartridge, a different approach had to be tried in the design and construction of the breech system. Only by reducing all oscillating

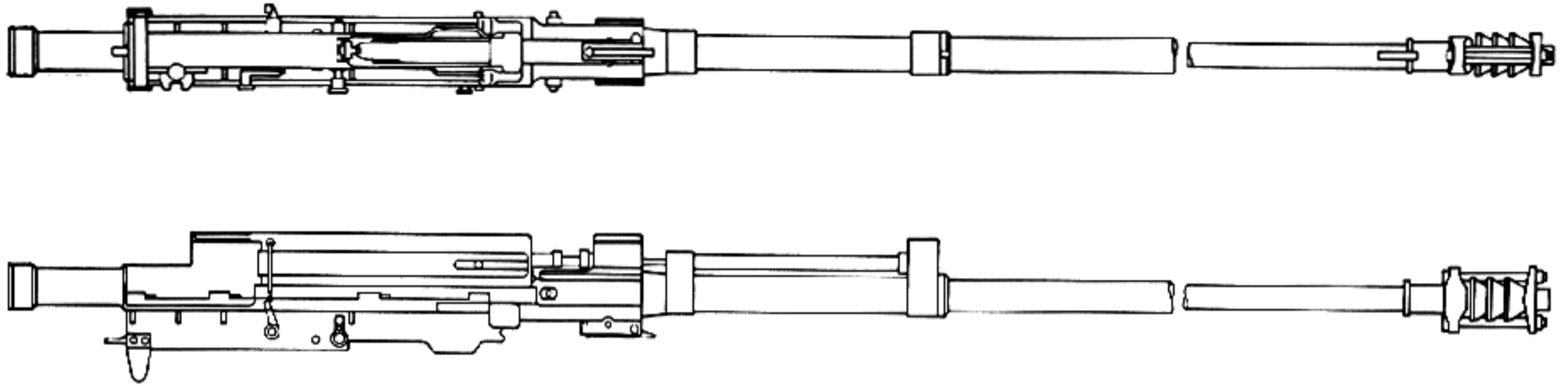


Figure 21-11. Oerlikon 20-mm Automatic Gun Type 5TG. Assembled view.

masses to a minimum and by designing all parts as simply as possible in regard to shape and action, could the high rate of fire of 1,000 per minute be reached.

The 5TG gun has a one-part breech which, during firing, is rigidly supported by a lock located in the breech casing. The energy necessary for locking is taken from a spring tensioned by the breech during the last part of its forward run. As the energy thus won during the breech's forward movement cannot be utilized immediately for actuating the bolt, it has to be stored for a short time in the spring acting as a power reserve. Since this function is an outstanding feature of the new gun, the breech system was given the name of "power-reserve-loader."

When the forward moving breech has reached its foremost position, the power reserve spring expands

and by transferring its energy to the locking bar, swings the bolt into the locking position and finally actuates the firing pin. In this way the danger of premature ignition, with the breech unlocked, is wholly eliminated. The breech is unlocked by a gas piston operated by powder gases expelled through a vent in the barrel. The gun is triggered with the breech in open position, that is, rear seared.

The breech is kept in the rear position by the trigger catch lever against the pressure of the recuperation spring. The lock is secured in its lower position by the two rebound slides. The latter are acted upon by the accumulator springs, resting against the locking slides. The locking slides are held in place by the bolt through the locking bar. On activating the trigger, the catch lever rotates around its pin and releases the breech, which is now

#### General Data: 20-mm Automatic Gun Type 5TG

Gun length: 132.04 inches.  
 Gun weight: 208.37 pounds.  
 Rate of fire: 1,000 rounds/minute.  
 Muzzle velocity:  
 Of HE shell, 4.16 ounces: 3,708 feet/second.  
 Of armor-piercing shell, 5.29 ounces: 3,282 feet/second.

Barrel length:  
 With muzzle brake: 100.67 inches.  
 With cartridge chamber: 94.48 inches.  
 Barrel weight, with muzzle brake: 91.51 pounds.

Overall height of gun less magazine: 7.28 inches.  
 Overall width of gun less magazine: 5.0 inches.  
 Weight of 50-round drum magazine, empty: 48.51 pounds.  
 Weight of 50-round drum magazine, full: 85.99 pounds.  
 Weight of one cartridge with HE shell: 0.7497 pounds.  
 Weight of one cartridge with armor-piercing shell: 0.8159 pounds.  
 Flight time of HE shell at 3,282 feet: 0.5 second.  
 Flight time of HE shell at 4,923 feet: 1.1 seconds.  
 Flight time of HE shell at 6,564 feet: 3.0 seconds.

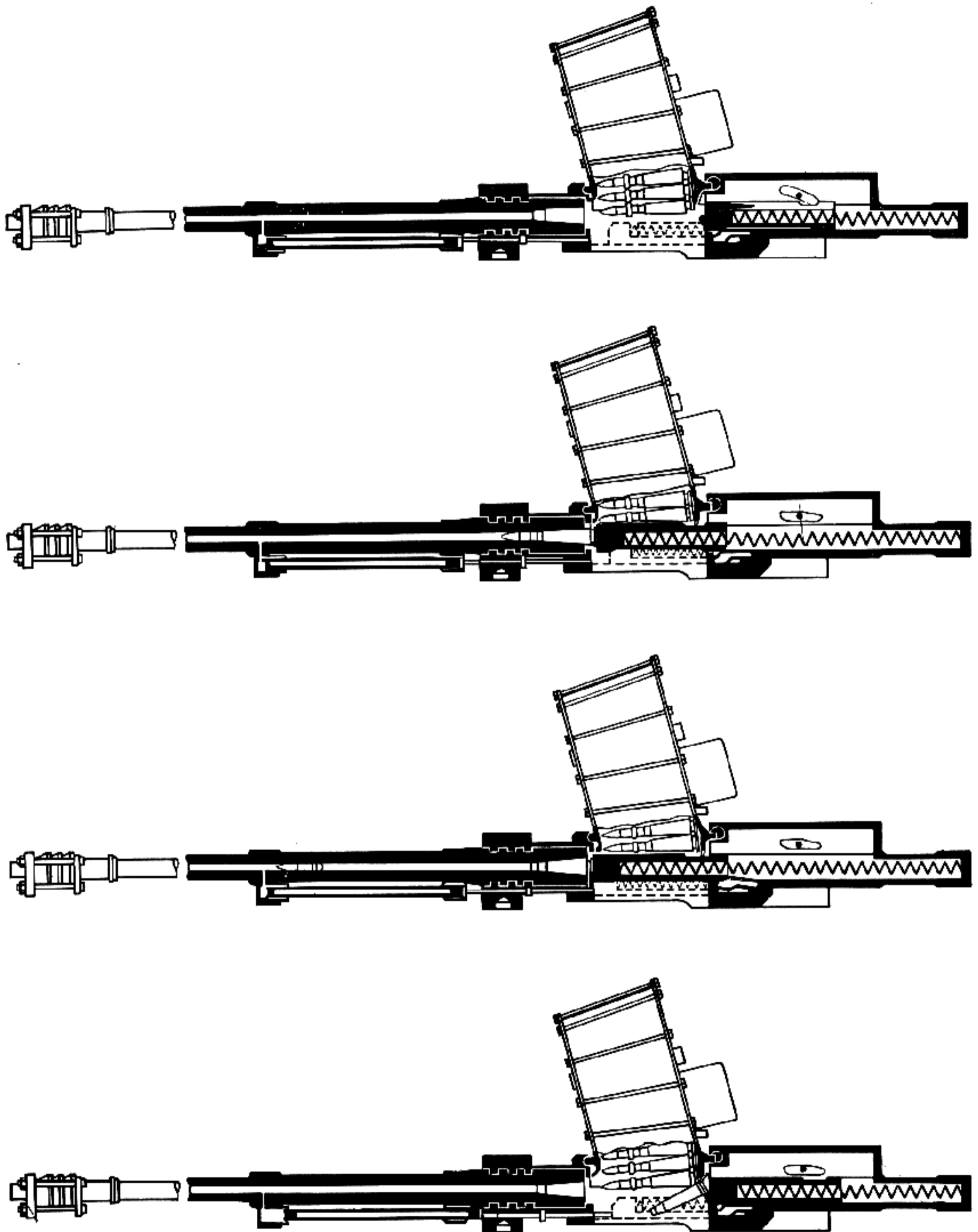


Figure 21-12. Cycle of operation of 20-mm Automatic Gun 5TG. Top to bottom: cocked; counterrecoil and feed; ignition recoil and eject.

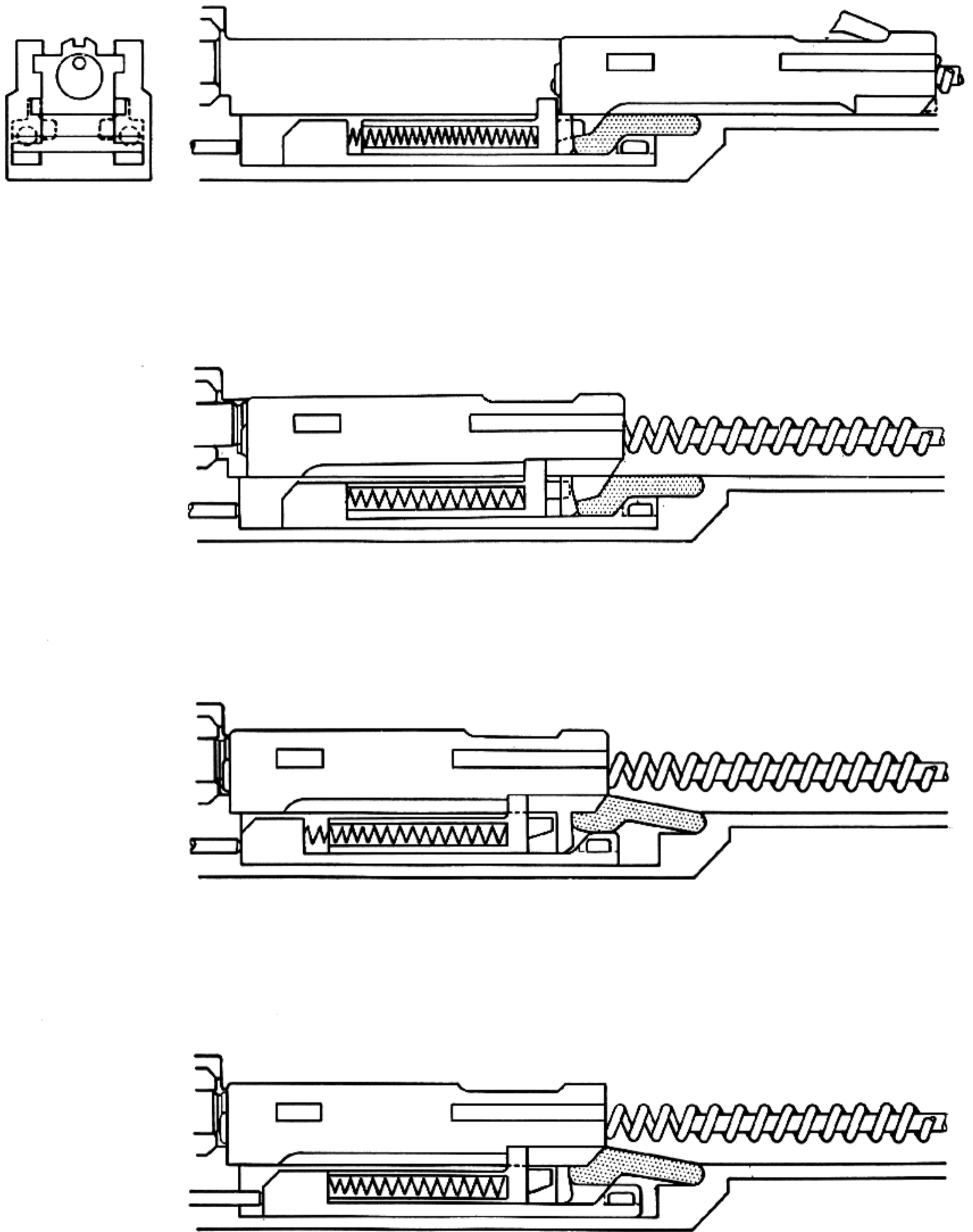


Figure 21-13. Locking action of 20-mm Automatic Gun 5TG. Top to bottom: bolt cocked; bolt advances; lock rises; unlockin commences.



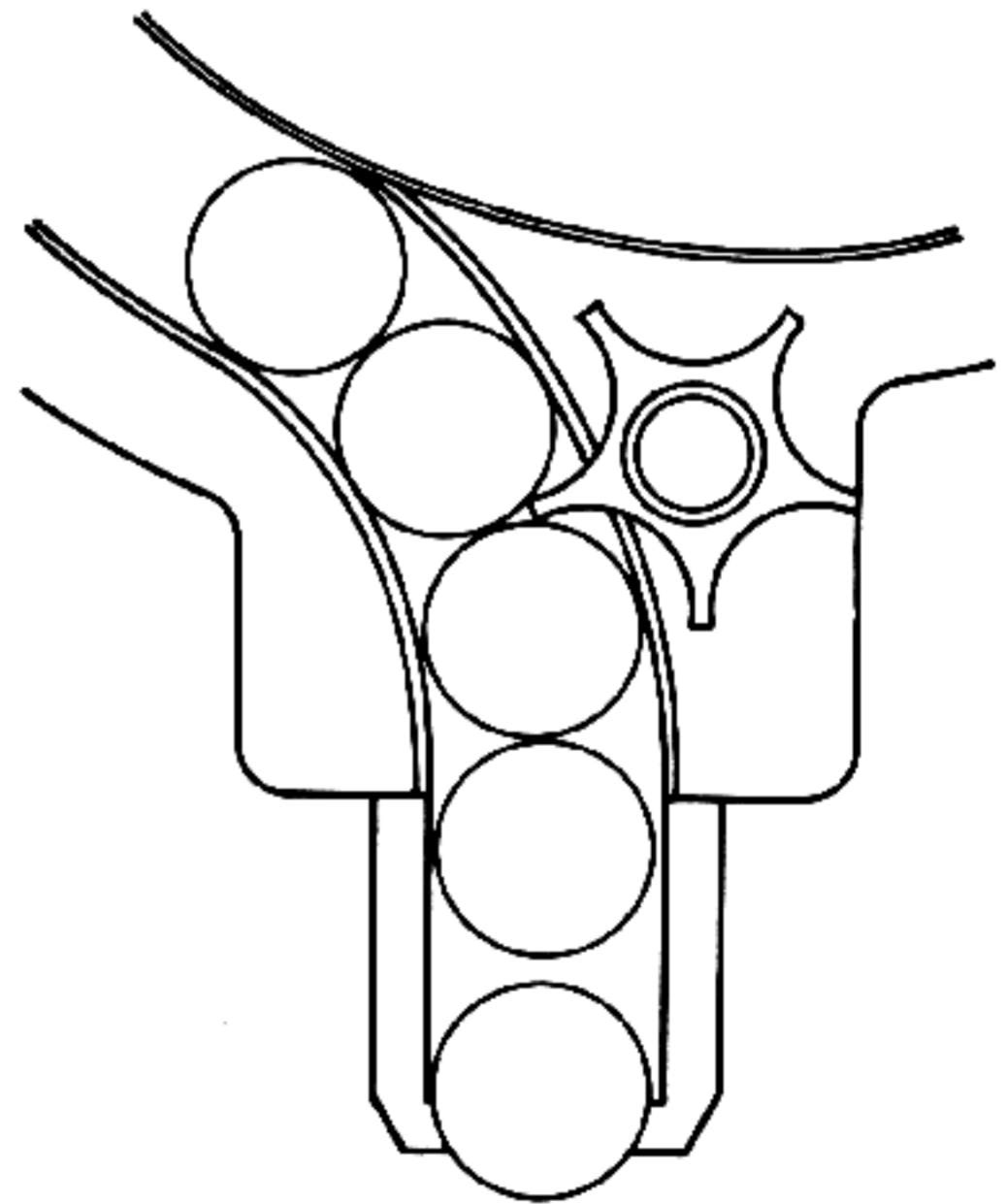
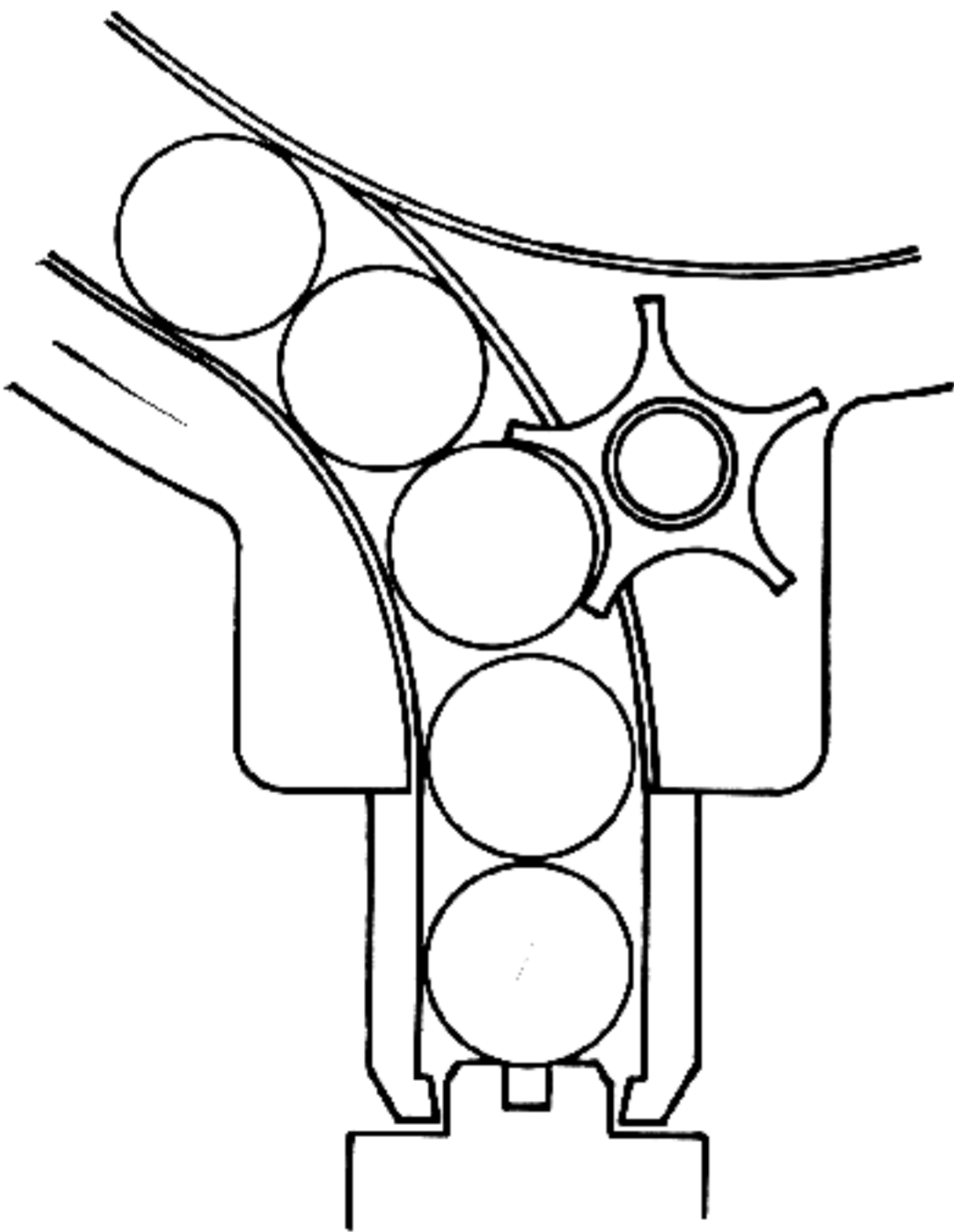
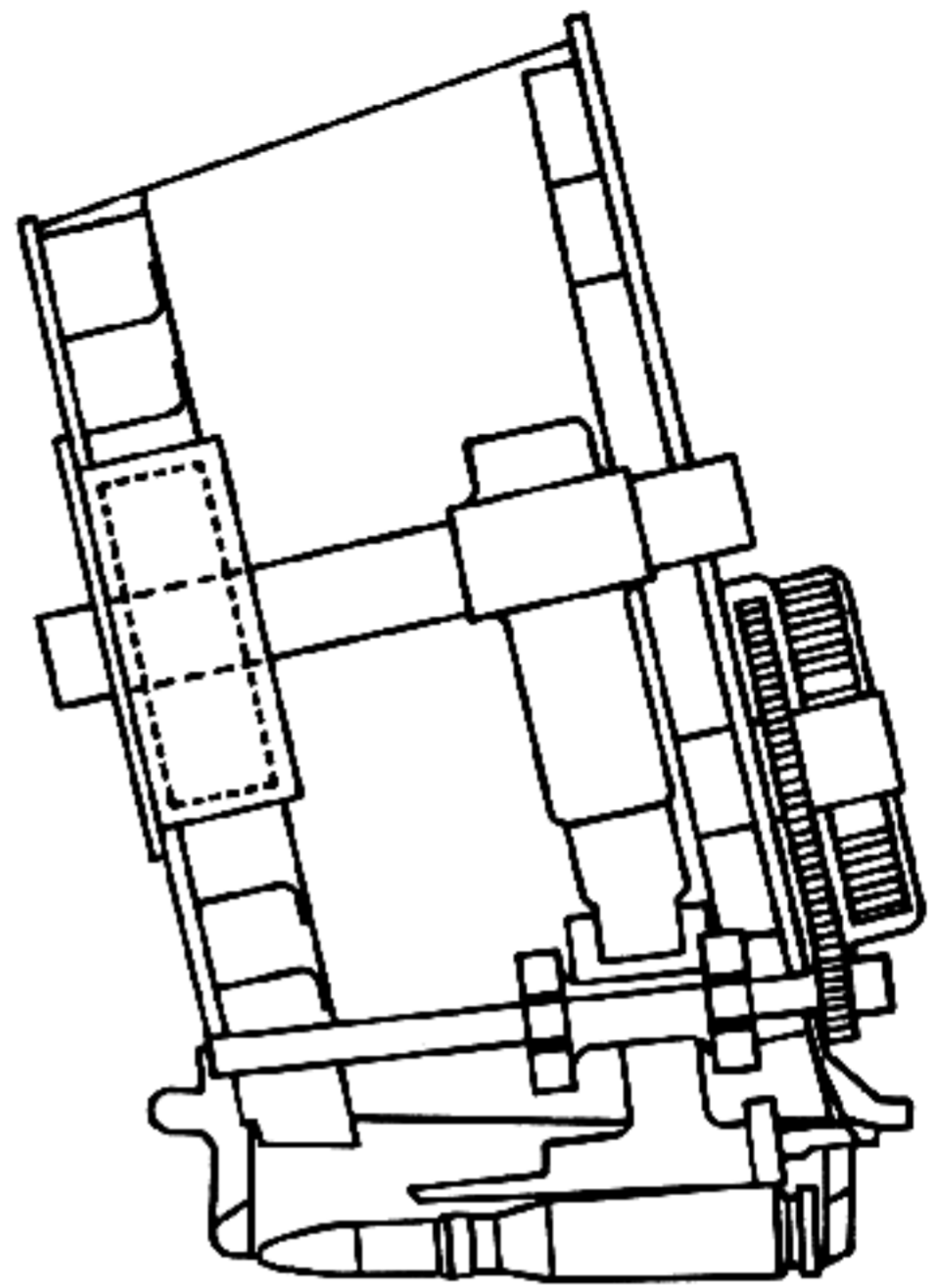
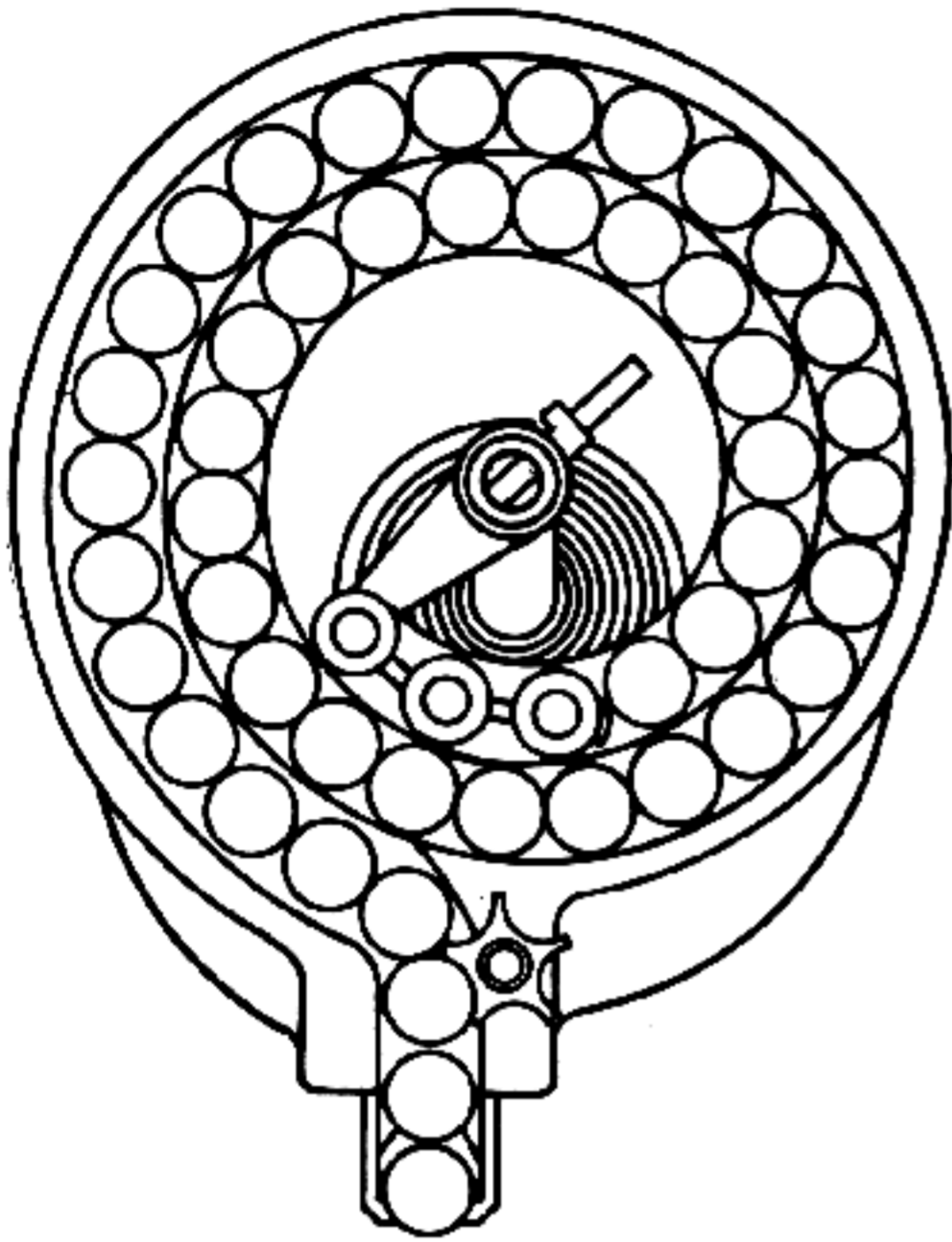


Figure 21-14. Drum magazine of 20-mm Automatic Gun Type 5TG.

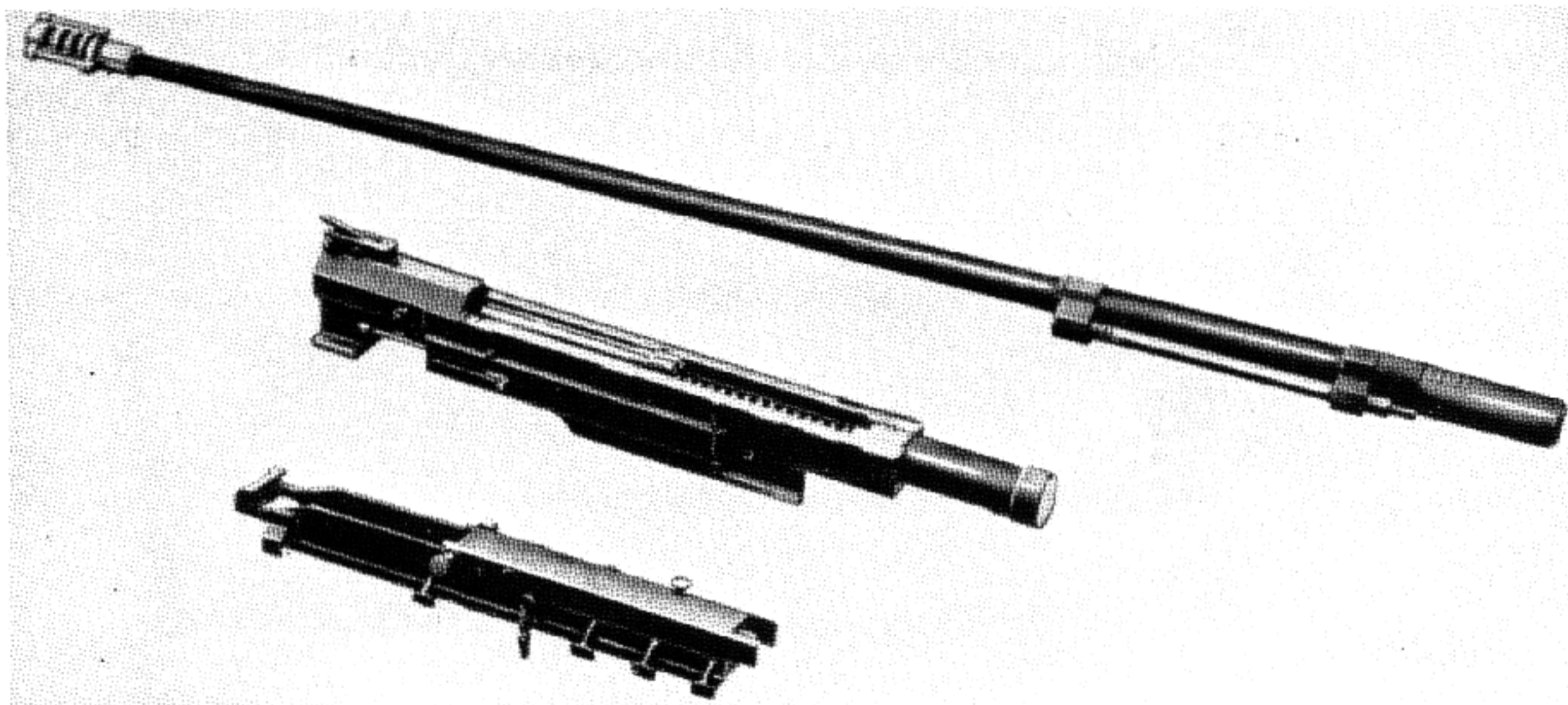


Figure 21-15. 20-mm Automatic Gun 5TG, partially disassembled.

driven forward by the recuperation spring. During its forward run, the breech seizes the lowermost cartridge in the magazine lips and pushes it into the chamber of the barrel. Shortly before reaching its foremost position, the breech's lateral noses impact upon the rebound slides, throwing them forward. Since the locking slides are still held in place by the lock, the accumulator springs are compressed by the motion of the rebound slides. On advancing, the latter release the lock which is, however, still secured in its lower position by the breech. Only when the rebound slides strike the locking slides, the lock is released by the breech. The locking slides now advance together with the breech, thereby pressing the lock upward through the locking bar.

After the breech has reached its foremost position, the locking slides continue to move forward under the action of the expanding accumulator springs. The lock is thereby brought into locking position, secured, and finally when the locking slides have arrived in their foremost position ignition is effected.

During firing the breech is connected rigidly to the breech casing by the lock. The cartridge chamber of the barrel is thus completely enclosed. The design of the breech system entirely eliminates the danger of premature opening of the breech.

As soon as the shell has passed the orifice in the barrel, the gas piston is pushed backward by the powder gases. The gas piston drives the locking

slides to the rear against the pressure of the accumulator springs. The locking bar moving backward together with the locking slides ceases to secure the bolt in its top position. Under the action of the residual gas pressure, the breech can now push the lock downward and begin its recoil motion. The rebound slides are pressed back by the accumulator springs and secure the bolt once more in its lower position. The breech now recoils unhindered, thereby compressing the recuperation spring. The empty cartridge case is pulled out of the chamber by the extractor and ejected downward when striking the nose of the ejector. After reaching its rearmost position, the breech is moved again into firing position by the recuperation spring, the process repeating itself as long as the trigger is operated and there are cartridges in the magazine.

To reduce the strain on the gun, the mount, barrel, and breech casing are movable against a recoil spring. A muzzlebrake of high efficiency reduces the recoil energy and thus the spring forces and recoil distances. The trigger casing carrying the drum magazine is connected rigidly to the cradle and therefore remains stationary during firing.

Cocking is effected by means of a cocking gear placed upon the gun and is performed by two lever movements.

For maintenance, the gun can easily be disassembled without tools. The complete disassembly

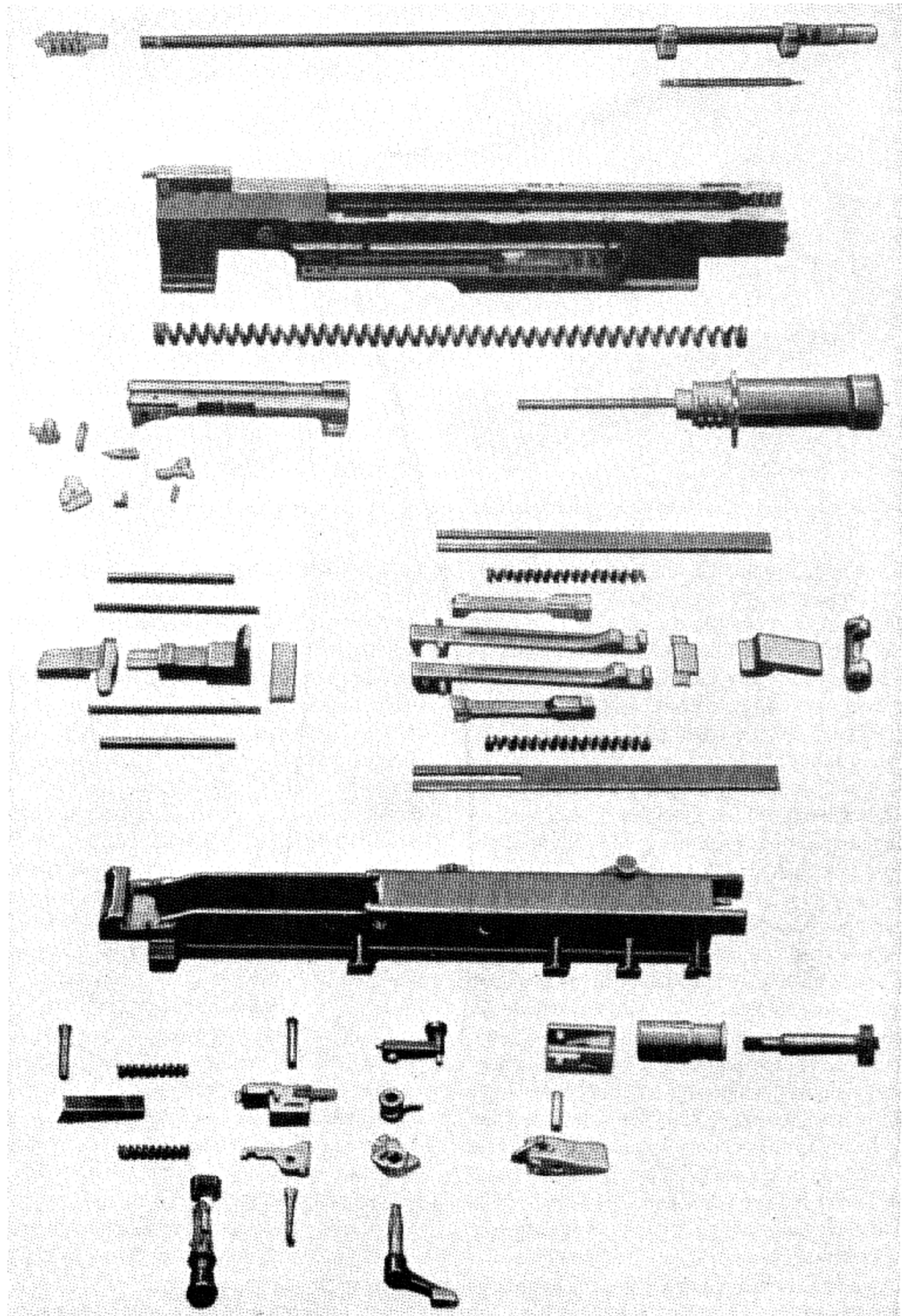


Figure 21-16. 20-mm Automatic Gun 5TG, completely disassembled (barrel not to scale).

can also be performed almost without tools. The few tools necessary for removal of a small number of parts (one lever, some wrenches and mandrels) are contained in the kit for tools and spare parts that is furnished with each gun.

Cartridge feed is effected by means of a drum magazine having a capacity of 50 rounds. A spiral spring arranged on the drum axle drives the feeder

which moves the cartridges towards the magazine exit. At the exit there is a spring-driven star wheel which accelerates the foremost few rounds independently from the rest of the cartridges. Trouble-free ammunition feed is thus assured. When the magazine runs empty, the breech is automatically held in its rear position. After changing the magazine, no recocking is therefore necessary.

### SECTION 3. 20-MM ANTI-AIRCRAFT GUN TYPE 204 GK

The Oerlikon 20-mm anti-aircraft gun type 204 GK is gas operated and features a centrally locked breechblock and belt feed. The belt can be fed

into the gun as desired from the left or the right. The cartridge cases are ejected obliquely to the rear during the forward third of the breechblock travel.

#### General Data: 20-mm Anti-aircraft Gun Type 204 GK

Gun length (without barrel): 39.4 inches. Gun length (including flame muffler): 103.4 inches. Gun weight: 154.35 pounds. Rate of fire: 1,000 rounds/minute. Muzzle velocity: 3,446 feet/second.	Barrel length: 66.92 inches. Barrel weight (with flame muffler): 52.9 pounds.
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Weight of shell: 4.23 ounces.  
 Weight of the parts recoiling in the mounting: 105.8 pounds.  
 Weight of the parts fixed with respect to the mounting (gun top with cartridge feed and trigger): 48.5 pounds.  
 Ammunition for the 204 GK gun.  
 Length of the cartridge: 8.01 inches (maximum).  
 Length of the cartridge in belt: 8.01 inches (maximum).  
 Length of cartridge case: 5.0 inches (maximum).  
 Maximum diameter:  
     Of case: 1.25 inches.  
     Of case at the belt link: 1.25 inches.  
 Length of belt link: 4.33 inches.  
 Maximum diameter of belt link: 1.32 inches.  
 Maximum diameter of belt link with cartridge: 1.35 inches.  
 Weight of belt link: 2.22 ounces.  
 Maximum diameter of guide rollers: 2.37 inches.  
 Number of cartridges required for twisting the belt through 90°: 7.  
 Inner radius of cartridge belt:  
     With case bottoms inside: 6.5 inches.  
     With shells inside: 1.97 inches.

Weights	Pointed explosive shell	Armor-piercing shell
	<i>Ounces</i>	<i>Ounces</i>
Cartridge . . . . .	11.8	13.05
Shell . . . . .	4.2	5.35
Empty case . . . . .	5.39	5.39
Propellant charge . . . . .	2.18	2.29

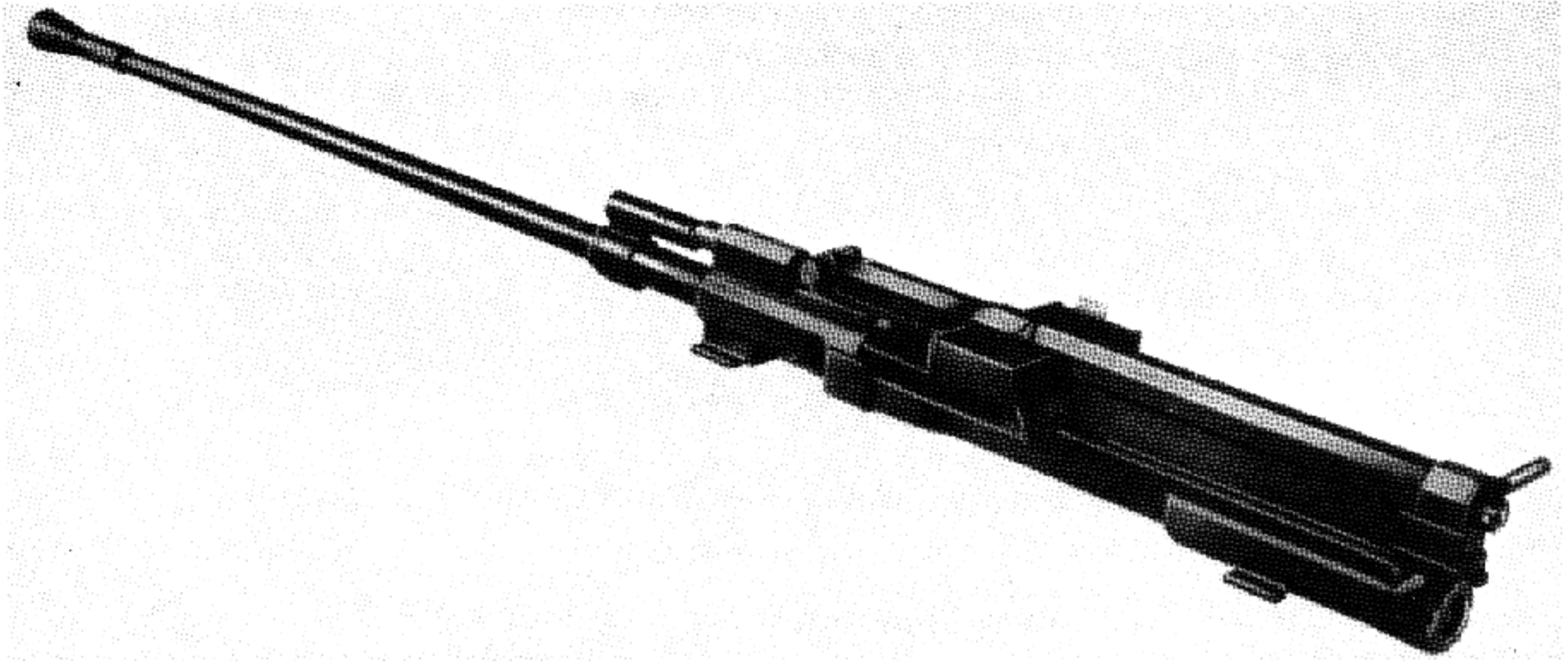


Figure 21-17. 20-mm Antiaircraft Gun Type 204 GK. Left side view.

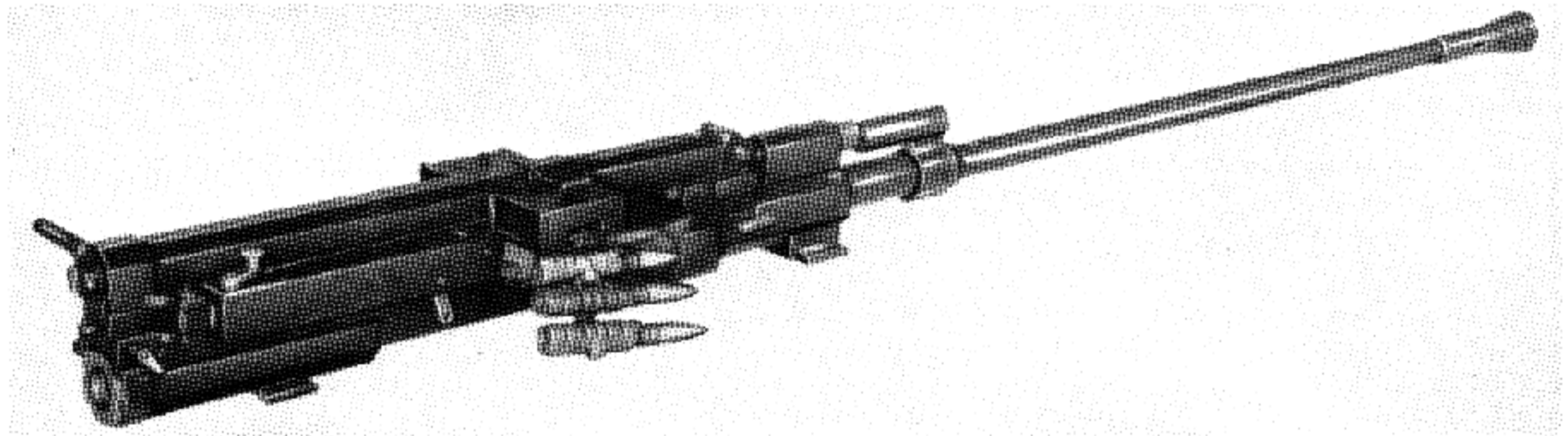


Figure 21-18. 20-mm Antiaircraft Gun Type 204 GK. Right side view.

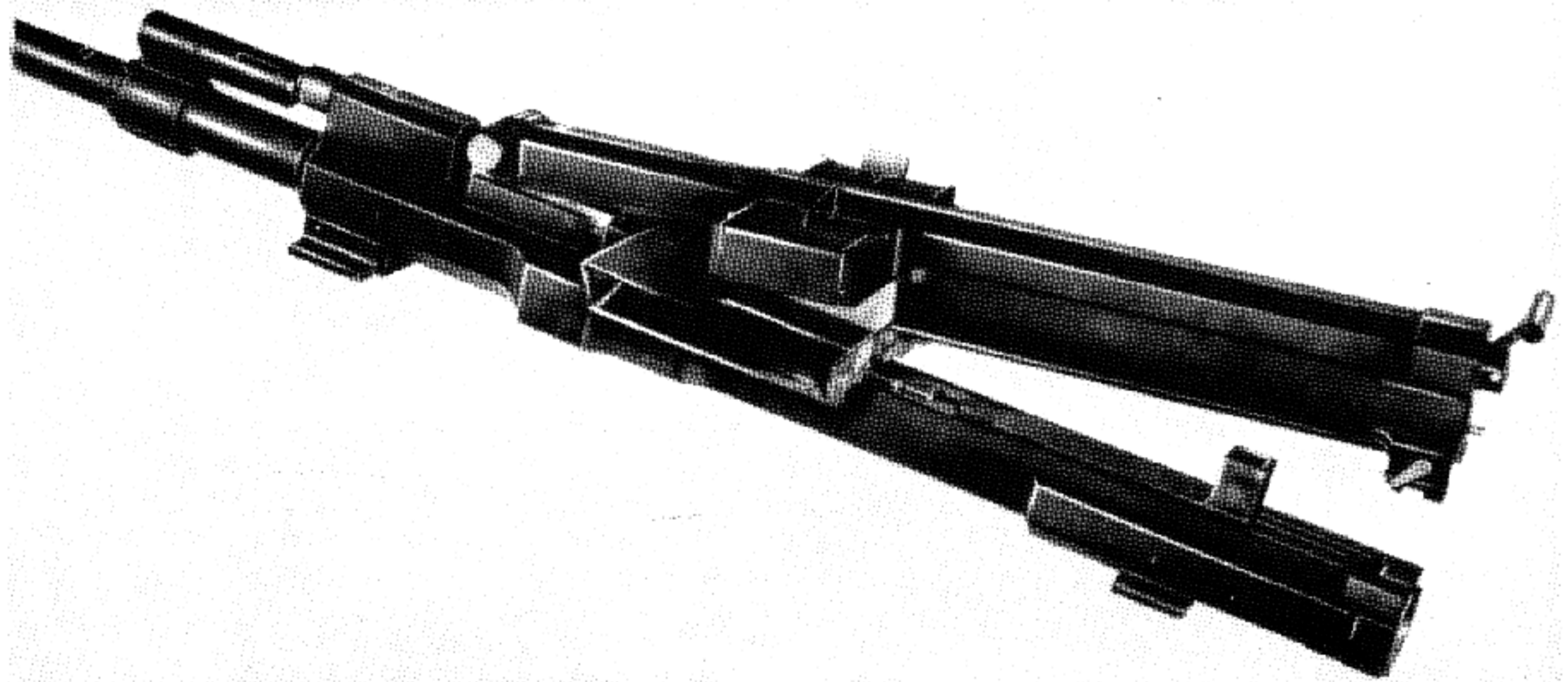


Figure 21-19. 20-mm Antiaircraft Gun Type 204 GK with cover open.

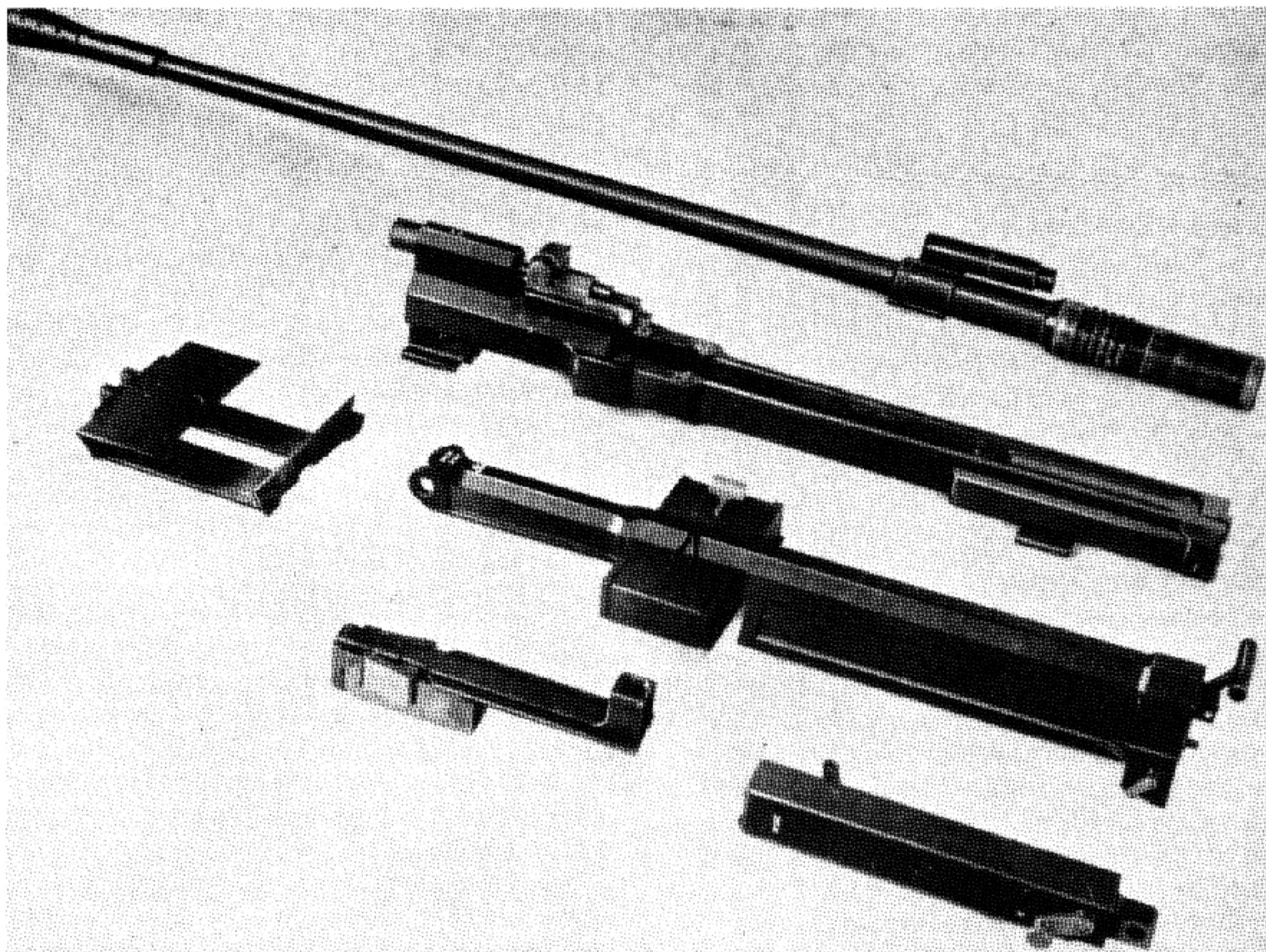


Figure 21-20. 20-mm Antiaircraft Gun Type 204 GK partially disassembled.

The belt links drop out of the feed mechanism on the side opposite the belt entry.

In the mounting there are two slide lugs which allow the gun to recoil during firing. The front slide lug is connected with the slide supported by the recoil springs. The recoil travel amounts to 20 mm. The top of the gun, which contains the cartridge feed devices, does not take part in the movement of the gun. The cartridge feed device is thus also fixed with respect to the mounting. The gun top is connected to the mounting at its rear end on the left or on the right side. The maximum trunnion thrust, acting only for a very short time, has the following values: If a flash hider is used, 4,410 pounds; if a muzzle brake is used, 2,646 pounds.

The breechblock is retracted by hand. The retracting device, which does not incorporate any gearing, is permanently built into the gun. The

force necessary for retracting ranges from 55 to 110 pounds. Over a short distance, of approximately 2 inches, an additional resistance of 22 to 33 pounds (moving the cartridge belt) must be overcome. This additional resistance is hardly noticed if the retracting device is actuated with a strong pull. A charger can be installed on the gun, but this is not yet provided. The trigger mechanism for automatic fire is arranged inside a casing on the right side of the gun top. The safety is also located in this position.

The belt can be introduced into the gun with the breechblock closed as well as when the breechblock is in its open position. After the last round has been fired from the belt, the breechblock remains to the rear. To establish firing readiness of the gun, it is unimportant whether the belt is introduced first and the breechblock cocked afterwards or vice versa.

Since the design of this weapon is largely the work of Linder, who had worked on the MG 151 in World War II, the weapon has sometimes been

described as derived from that well known German gun. There are certain external resemblances, but the locking action is completely different.

## SECTION 4. 20-MM REVOLVER GUN 206 RK

### General Description

The Oerlikon 20-mm revolver gun 206 RK is a high-performance aircraft gun, featuring a high muzzle velocity and an exceptionally high rate of fire. Ammunition is fed to the gun in belts, either from the right or from the left side. The feed direction may be changed by exchanging parts. The empty belt links are ejected laterally on the side opposite the feed side. The empty cases are ejected to the rear.

### Principle of Operation

At the rear end of the barrel is the rotatable cylinder, which contains five cartridge chambers. During firing, cartridges are fed into the chambers of the cylinder. The cylinder is rotated in steps by means of the gas-operated slide so as to successively align the chambers with the barrel. The cartridges are fired electrically when they reach the firing position behind the barrel. After the drum has been rotated by another pitch, the empty cartridge case is ejected to the rear.

Behind the drum is the star wheel, which rotates with the cylinder. The star wheel pulls the cartridge belt into the gun. From the star wheel, the cartridges are moved into the chambers of the cylinder in two steps, by means of a ram connected to the gas-operated slide. The empty belt links are ejected sideways from the star wheel. Cocking of the gun is

effected by means of two pneumatic rams. When firing is interrupted, one cartridge is left in firing position.

The gun casing is rigidly attached to the airframe. The cylinder carrier, which carries the barrel, is inside the gun casing and recoils against two springs during firing. The cartridge feed mechanism is attached to the gun casing and therefore does not move during firing. The star wheel and cylinder are connected in such a way that they can move axially relative to each other.

### Description of the Principal Components

*Casing.* The cylinder carrier slides inside the casing and is guided on the latter by means of guides at the rear, engaging guide faces of the casing, and by the cylindrical guide face, which is supported in the front wall of the casing. At its front end, the cylinder carrier is fitted with a bracket which carries two recoil springs.

The spring supports are fastened to the front wall of the casing by means of castle nuts. Two rubber buffers arranged inside the bracket coaxial with the recoil springs damp the runout of the gun. They are held in place by the spring supports. The bracket is held on the cylinder carrier by the ring.

The barrel is held in the cylinder carrier by means of bayonet lugs and secured against rotation by the spring-supported lever. For removal of the barrel, the lever must be actuated, whereupon the barrel can be rotated and withdrawn. Either a perforated flash reducer or a muzzle brake can be fitted to the barrel muzzle. On actuation of a flat spring, the flash reducer or muzzle brake can be unscrewed and removed.

The barrel is fitted with a gas port which is aligned with a bore in the bracket leading into the gas cylinder. The latter contains the spring-loaded piston. The gas cylinder with its sleeve is screwed into the bracket and secured by a plunger.

*Cylinder.* The cylinder carrier has two transverse walls, in which the cylinder is supported by means of its shaft. The shaft is held axially by the spring-

### General Data: 20-mm Revolver Gun 206 RK

Gun length; (with flash reducer): 94 inches.
Gun weight: 198 pounds.
Rate of fire: 1,650 rounds/minute.
Muzzle velocity: 3,600 feet/second.
Barrel length: 63 inches.
Length of cylinder: 7.95 inches.
Length of cartridge: 8 inches.
Weight of cartridge: 0.85 pound.
Weight of cartridge with belt link: 0.92 pound.
Weight of shell: 0.275 pound.
Mean reaction force on mounting: 3,850 pounds.
Frontal area of 1,000 belted cartridges: 2.3 square feet.

loaded plunger, which engages with a groove of the shaft. The cylinder has five cartridge chambers. Each chamber carries, in its front part, a sealing sleeve which, under the action of the gas pressure, seals the gap between the cylinder and the barrel. The cylinder is fitted with five spring-loaded rollers which engage with the cam grooves of the slide. The latter moves in the casing and slides in guides. The slide rests against the wire rope springs which are arranged on the two rods and supported in the casing by knobs with bayonet lugs.

The cam groove through which the rollers of the cylinder pass first is fitted with an insert which prevents the rollers from reentering this groove. On passing over this insert, the rollers are lifted against the action of their springs.

The upper part of the rear cylinder carrier wall carries the firing mechanism. The electric firing pin is spring-loaded. Immediately after the firing of a round, the firing pin is withdrawn to prevent its tip from scratching on the rotating cylinder. To accomplish this, two levers are rotatably mounted on the cylinder carrier by means of pins. When the gun recoils after a round has been fired, the rear arm of the first lever is lifted by the cam on the fixed feed cover and is rotated, thus pulling the firing pin back against the action of the spring. Meanwhile the cylinder has begun to rotate and the second lever which, in firing position, engages a notch in the rim of the cylinder has been lifted by the cylinder and holds the first lever in rotated position. When the next cartridge chamber is aligned with the barrel, the second lever engages another notch in the cylinder rim and thus releases the first lever, whereupon the firing pin is returned to operating position by its spring.

*Feed Mechanism.* The feed star wheel is arranged coaxial to the cylinder in the rear part of the casing. The star wheel is supported by a shaft mounted in the feed casing. The latter is seated on the casing and held in place by the shaft passing through a bore in the rear wall of the casing. The shaft is held axially by a spring-supported lockpin arranged in the rear part of the feed casing. The front end of the shaft is connected to the rear end of the cylinder shaft by means of a coupling which permits an axial movement of the two shafts with respect to each other. The feed casing is provided with a removable cover, which is held in place by

two lugs engaging notches on one side of the feed casing and by a spring-loaded pawl and the spring-loaded rod at the opposite side of the cover and engaging lugs and on the casing.

The feed casing is fitted with a cartridge belt inlet. The feed cover carries a case ejection duct and a belt link outlet.

The cartridges are moved from the star wheel into the chambers of the cylinder by means of a feed ram which moves in the lower part of the casing and is guided by ledges. The ram is connected to the slide by means of the two control rods. The rods are fastened to the slide and the ram by means of two pins. The ram is fitted with two projections which serve for pushing the cartridges into the chambers of the cylinder. From the lowermost position in the star wheel, the cartridge is moved halfway into the drum by one projection. In this intermediate position, the cartridge is prevented from moving rearwards because of the recoil by the small spring-supported pawls of the star wheel. During the next stroke of the ram, the same cartridge is pushed fully into the chamber by the other projection. It is then held in this position by the spring-loaded pawl in the rear wall of the cylinder carrier.

The axial movement of the cartridges takes place while the cylinder and the star wheel are rotating. The empty cartridge case is ejected to the rear by the ejector, which rotates about the pin on the cylinder carrier. The movement of the ejector is controlled by the cam faces on the control rod.

*Cocking Device.* The gun is fitted with an electropneumatic cocking device. It consists of a valve on the left side of the casing and two cylinders at the front end of the casing. The pistons in the cylinders act upon the slide and push it rearward for the cocking movement. The cocking gear must be supplied with compressed air.

For cocking the gun, the button of the control box must be actuated after the switch has been brought into the ON position. Compressed air is then admitted to the cocking cylinders, and the slide is pushed back to its rear position and released. The slide is then returned to its initial position by the slide springs.

During this movement of the slide, the cylinder rotates by one pitch. If the gun is to be cocked repeatedly, the button must be actuated again only after the slide has returned to its front position.



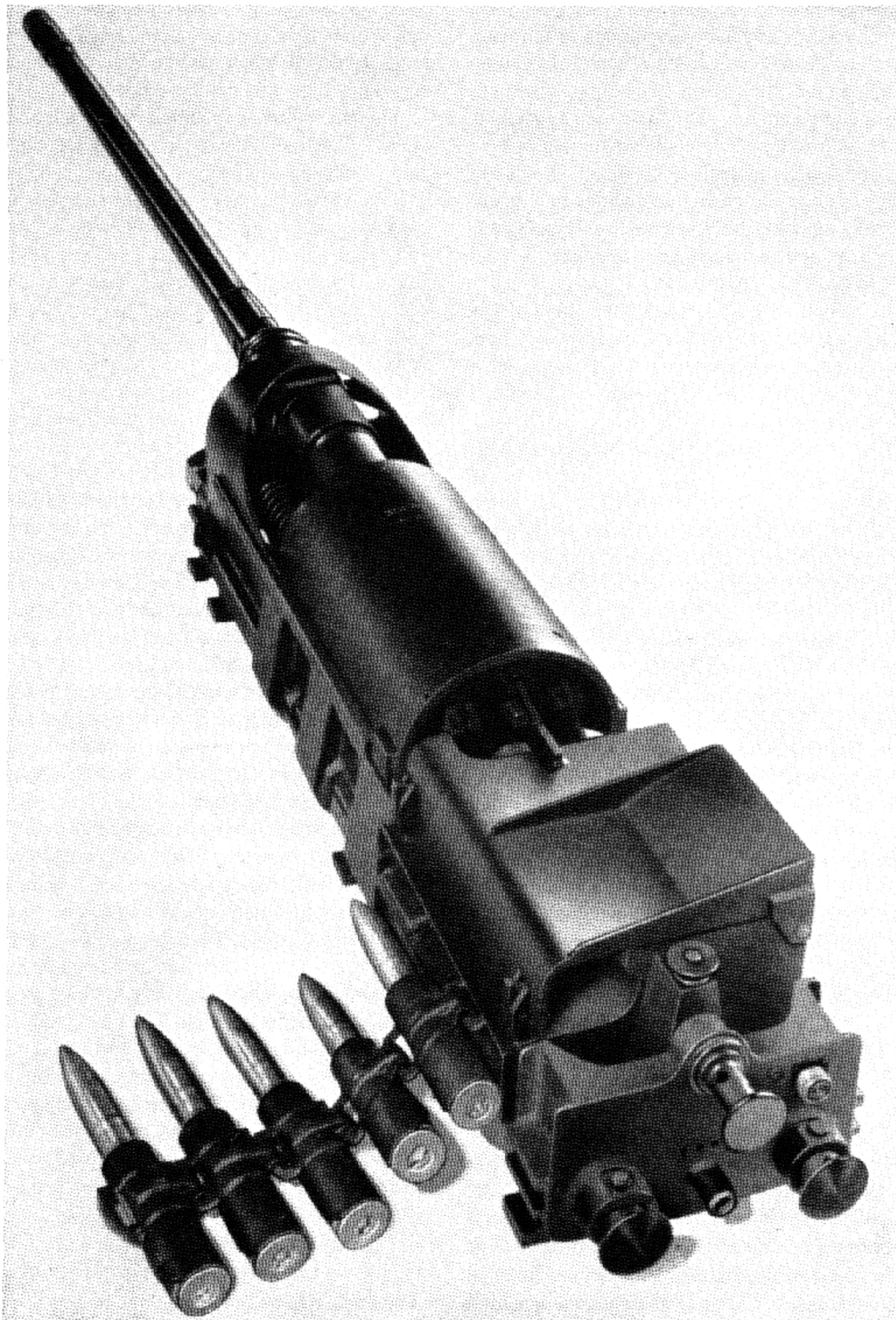


Figure 21-21. Oerlikon 30-mm Revolver Cannon 302 RK. This weapon has the same action as the 20-mm version, the 206 RK.

The gun may also be cocked by hand. For this purpose a spindle with a crank is provided, which is inserted through the bore in the rear wall of the casing and screwed into the bore of the ram. Then the nut has to be screwed into this bore over the spindle. The ram and the slide can then be moved rearward and forward again by rotating the crank. In the rear position, the shaft must be rotated in order to allow the roller to overcome the neutral

position of cam groove in the slide with which it engages. It is important to remove the cocking spindle after the cocking operation is complete.

### 30-mm Version of the Revolver Gun

The 30-mm version of this mechanism is designated 30-mm revolver cannon 302 RK. Similarities to the 20-mm 206 RK are indicated in the accompanying technical data and illustration.

## SECTION 5. JAPANESE VERSIONS OF OERLIKON MECHANISMS

### Background

In World War II, armed forces on both sides used Oerlikon automatic weapons. Most of these guns were based on the original Becker mechanism, although some details had been varied. In this group of weapons are the 14-mm Mod 14 Mark 1, the 20-mm type 99, and the 30-mm type 2. In the course of World War II, there was one notable attempt to modify the Becker action, the caseless 40-mm HO 301, which was developed by Japan for her air force.

Records indicate that beyond establishing the factory and supplying engineering know-how to the Japanese Government for the conventional Oerlikon guns, the Swiss factory was not involved in Nipponese research and development. The caseless Oerlikon gun HO 301 with its unorthodox features, is a measure of the ingenuity of Japanese ordnance engineers. These prototype weapons were fabricated under poor conditions in a nation beset by shortages of manpower and materials, and under persistent attack from the skies.

The following description of the gun HO 301, and the report on functional tests are extracted from documents originating in the Development and Proof Services, Aberdeen Proving Ground, Aberdeen, Md.

### General Description of the Japanese Caseless Gun

The Caseless 40-mm HO 301 is simple and compact, considering its caliber. The weight is 107 pounds 9 ounces, the overall length is 58.48 inches. The elements performing cartridge case extraction and ejection have been eliminated by locating the propelling charge in a rear compartment of the projectile body. This feature is combined with straight blowback operation (without locking the breechblock when firing), with searing at the rear end of the receiver, and with the locating of the recoil spring elements around the tube.

The breechblock and the elements which serve to compress the recoil springs form a rigid structure and constitute the recoiling parts. The firing pin

#### General Data: 30-mm 302 RK Gun

Gun length: 117 inches.  
 Gun weight: 400 pounds.  
 Rate of fire: 1,100-1,200 rounds/minute.  
 Muzzle velocity: 3,600 feet/second.  
 System of operation: Gas operated, revolver principle.  
 System of locking: Stationary breech with rotating cylinder.  
 System of feeding: Metallic link; feeder is powered by gas.  
 Method of headspace: Factory established.  
 Location of feed opening: Left rear side of receiver.  
 Location of ejection opening: Right upper side of receiver.  
 Method of charging: Electropneumatic.  
 Method of cooling: Air.

Barrel length: 78 inches.  
 Barrel weight: 66 pounds.  
 Rate control: Rhcostat.  
 Barrel removal: Not quick disconnect.  
 Bore:  
 Number of grooves: 16.  
 Groove depth: 0.0177 inch.  
 Groove width: 0.145 inch.  
 Pitch: 8°30'.  
 Direction of twist: Right hand.  
 Form of twist: Constant.

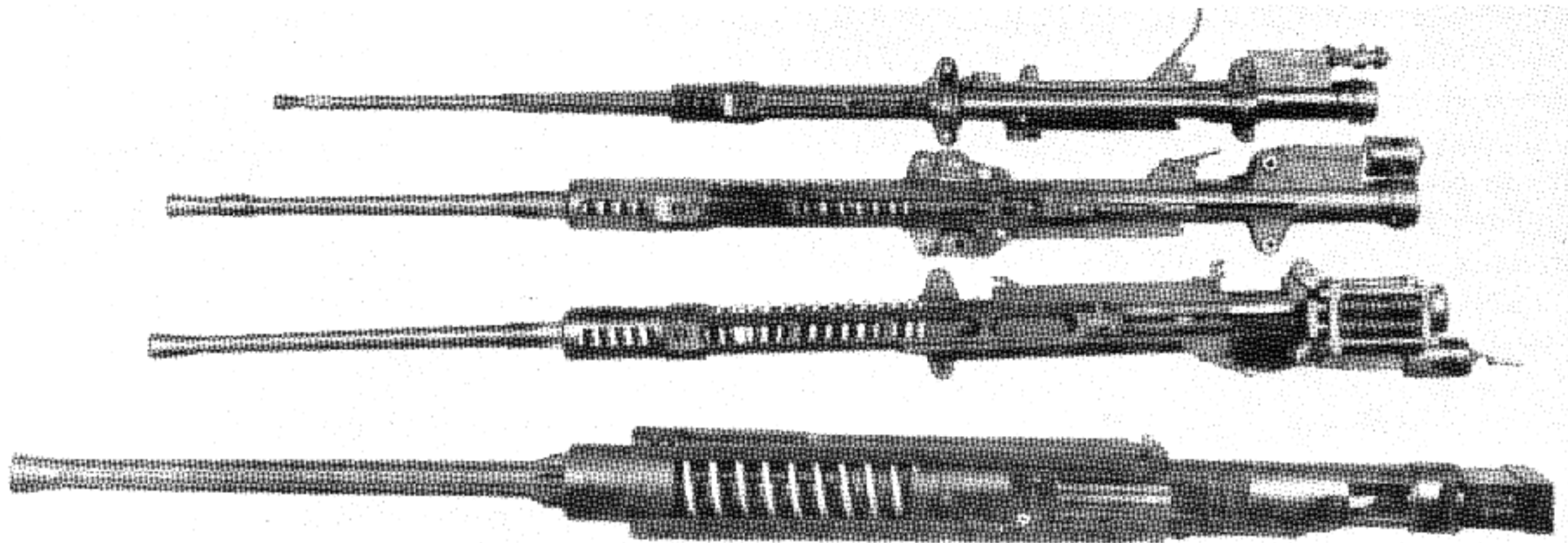


Figure 21-22. Japanese Oerlikon Type Aircraft Cannon, top to bottom: 14-mm Mod. 14 Mark 1; 20-mm Type 99; another 20-mm weapon; and 30-mm Type 2.

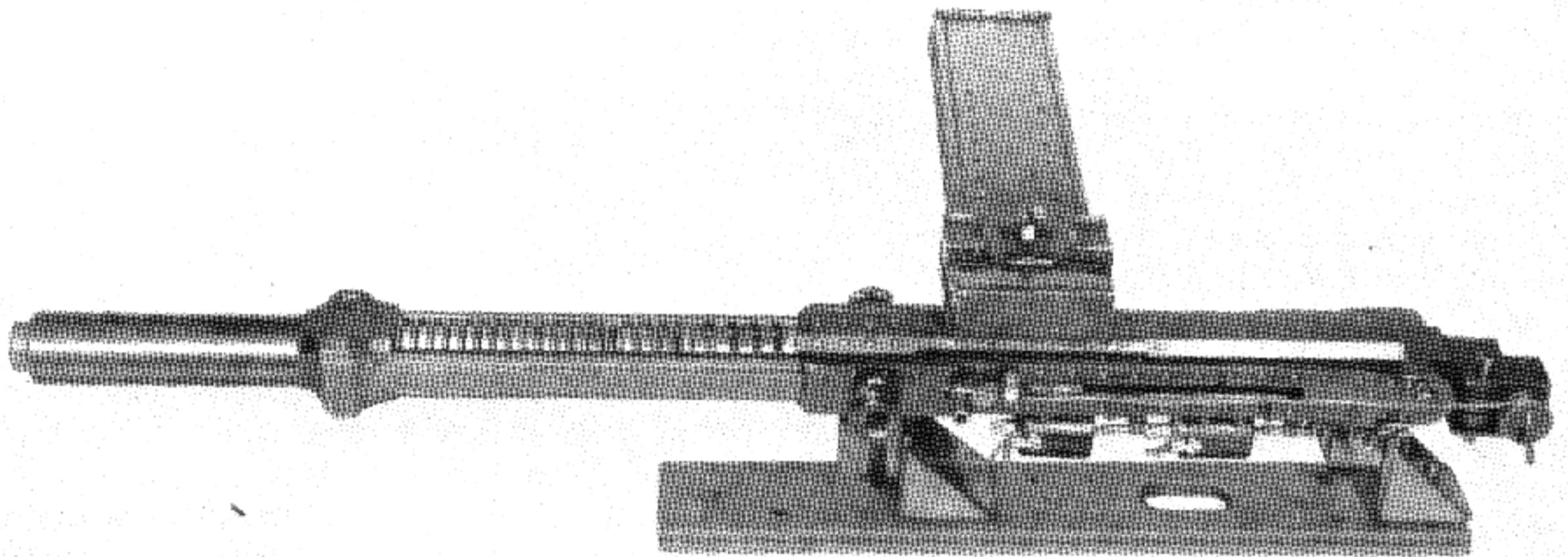


Figure 21-23. Japanese 40-mm Aircraft Cannon, HO-301, a modified Oerlikon blowback design.

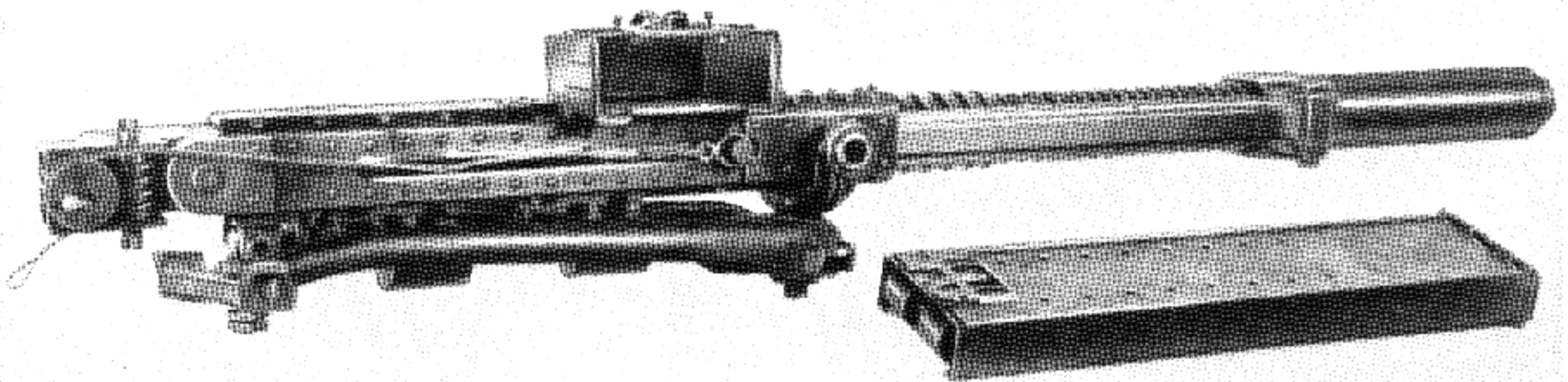


Figure 21-24. Japanese Caseless 40-mm HO-301. Right side view, with magazine removed.

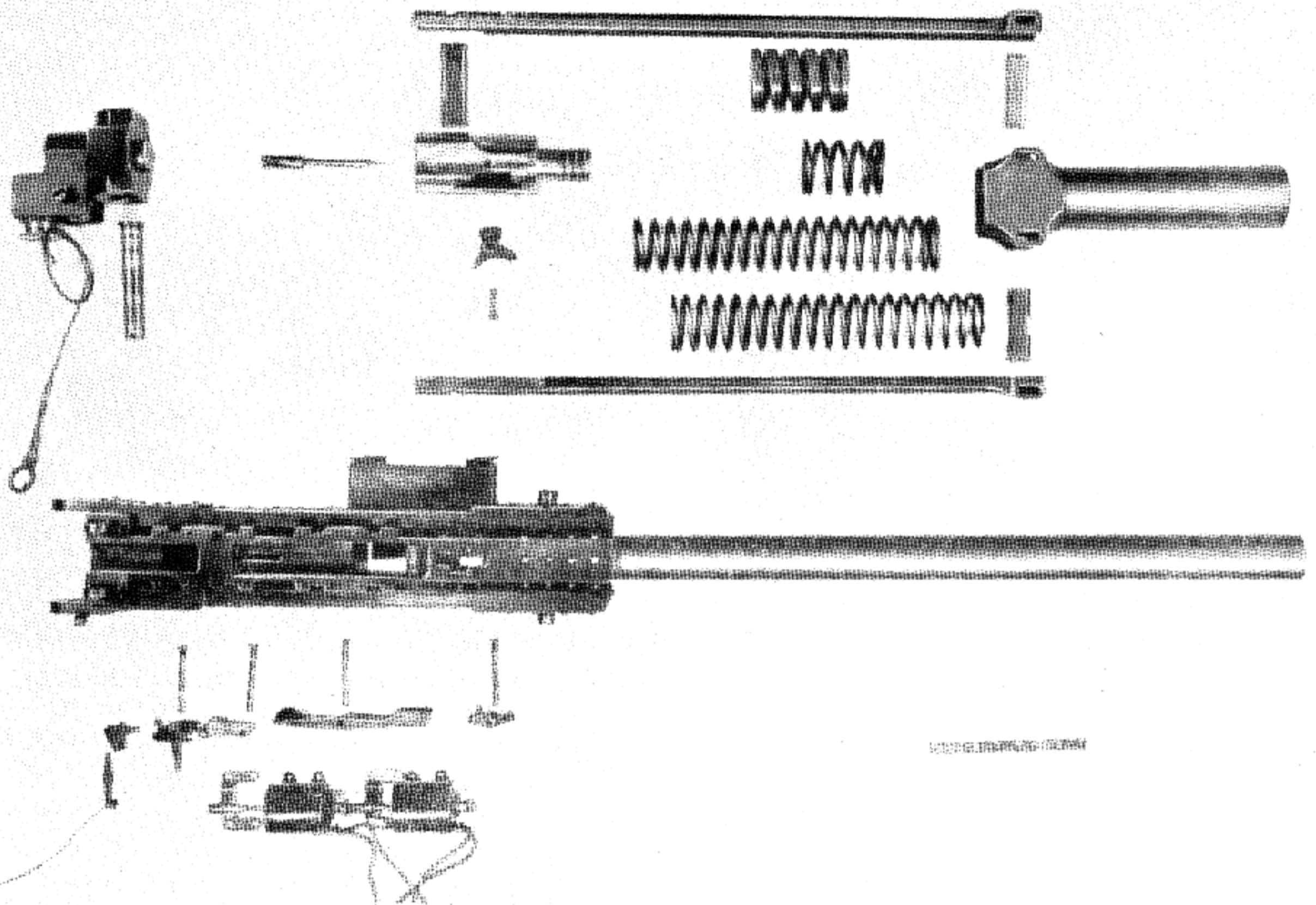


Figure 21-25. Japanese Caseless 40-mm HO-301. Disassembly of gun.

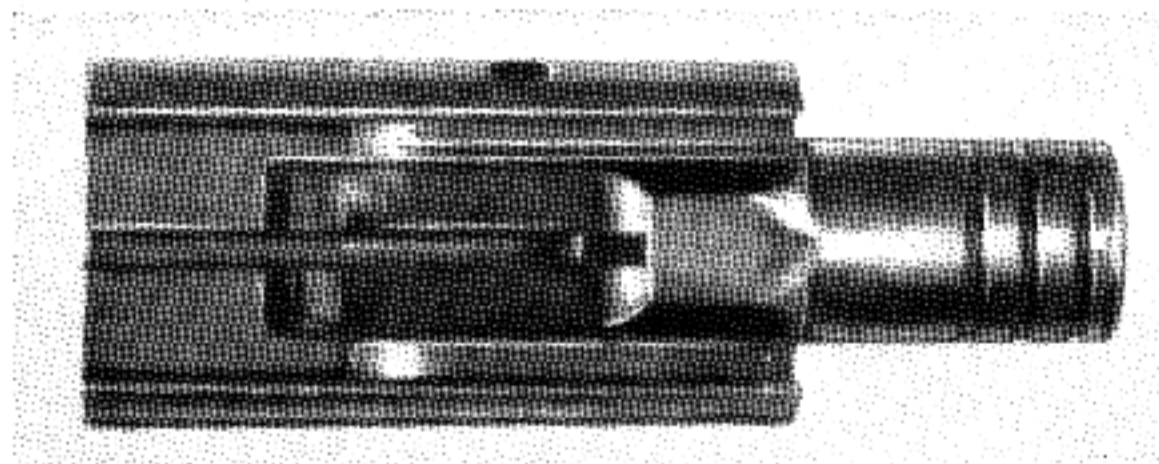


Figure 21-26. Japanese Caseless 40-mm HO-301. Bottom view of bolt.

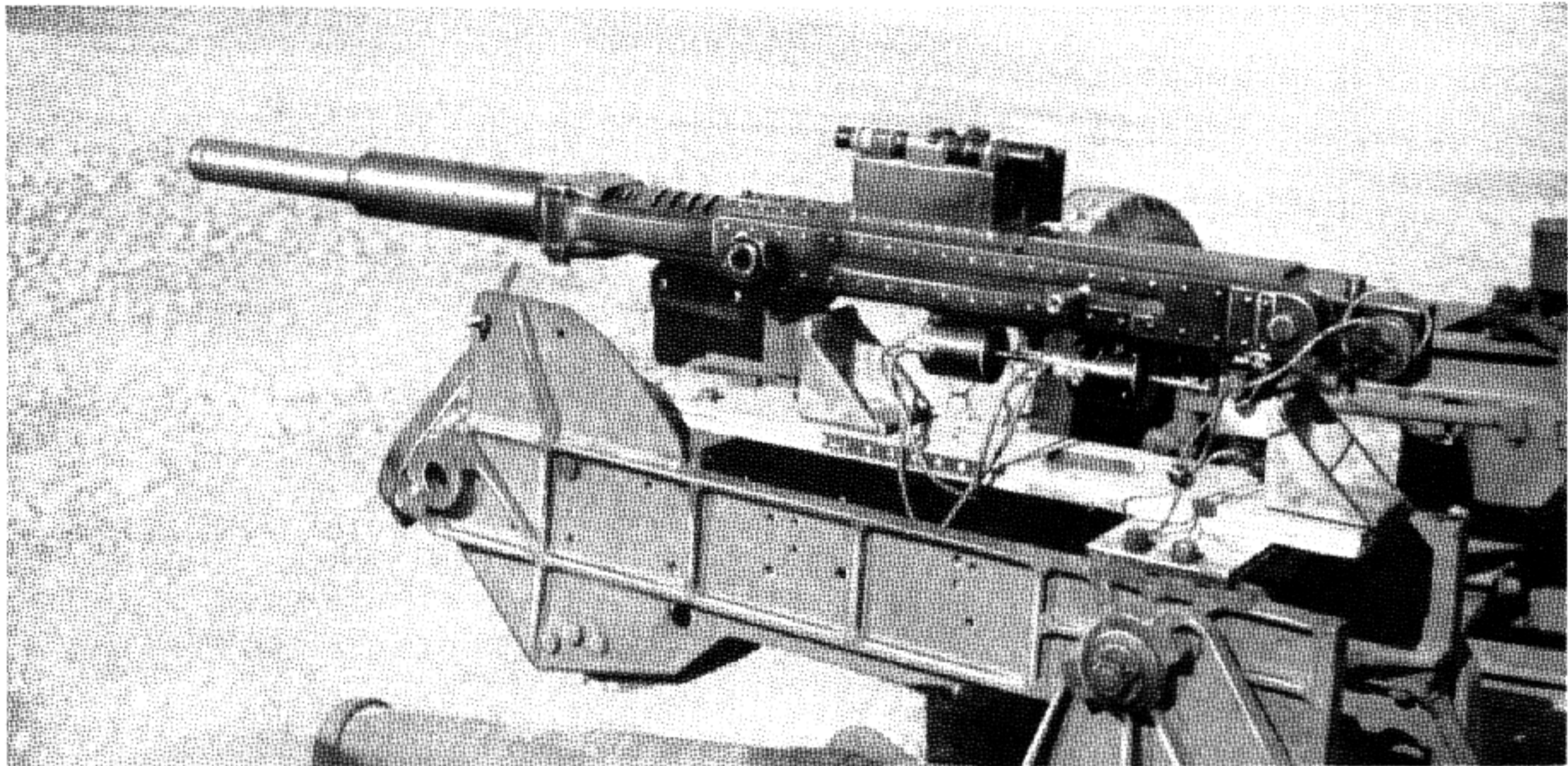


Figure 21-27. Japanese Caseless 40-mm HO-301. Left side view of the gun while undergoing test in the United States.

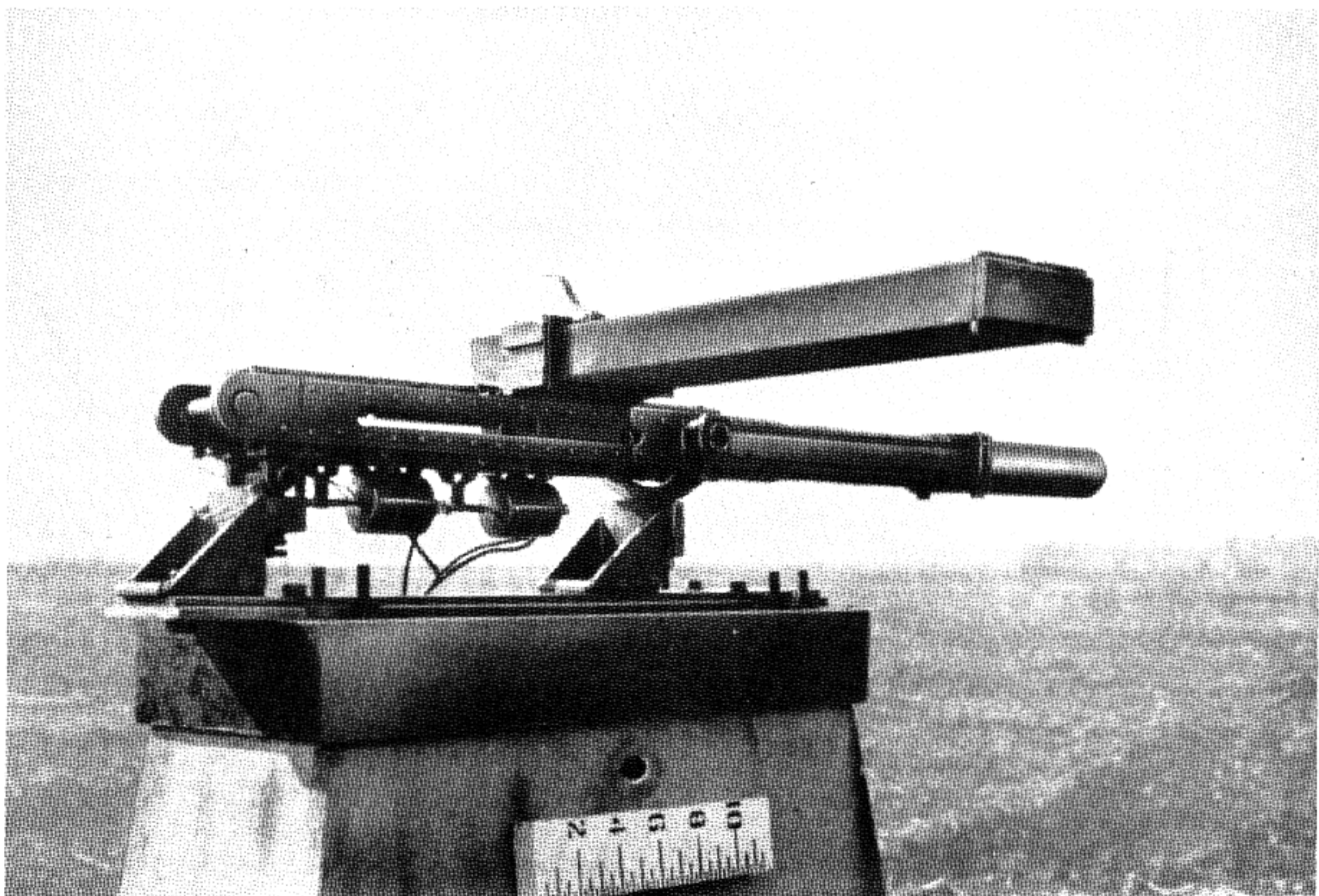


Figure 21-28. Japanese Caseless 40-mm HO-301. Right side view of the gun while undergoing test in the United States.

is actuated mechanically at the proper point of breechblock travel. In these two respects the weapon resembles the Oerlikon anti-aircraft 20-mm guns.

The principal departure from conventional gun design consists of the application of a piston breechblock face. This piston section enters the breech and acts as a partial seal when the round is fired. Three annular rings cut into the piston walls were probably intended to reduce leakage. No piston rings are used.

Another novel feature is a "loading tray" or "round positioner" which consists of two pivoted lever pieces which are located in the floor of the forward section of the receiver. The breechblock rides over these levers, depressing the rear ends in turn and raising the front ends. The loading round enters the receiver and rests on these levers, and the motions of the levers insure that the round is properly engaged by the breechblock and chambered.

The gun charger operates mechanically. The forward end of the charger cable is looped over the breechblock retracting pin. The rear end of the cable is wound around a drum located on the rear buffer plate. The drum is rotated by the worm gear, the ends of the worm gear shaft providing seats for a removable crank.

A 10-round, spring-actuated, clip-type feed magazine is utilized, which fastens to the receiver by means of spring-loaded pins. The mechanism includes a stop pawl on the gun end, which prevents more than one round from entering the receiver at a time. This construction is rigid, and, accordingly, requires an excessive amount of space in an aircraft installation, considering the capacity.

The gun sear is a spring-operated lever located in the rear floor of the receiver, pivoted at the front end. The rear end engages the breechblock. A spring is employed to hold the sear in its engaging position. Sear release is effected by two 24-volt solenoids connected in tandem. The sear mechanism contains a mechanical locking device, probably included to insure that rounds are not fired during takeoff and landing. This gun safety was necessary because no provision for charging the gun in flight was included.

The gun fires automatically when the sear is released. Firing may be interrupted by opening the

solenoid switch, which permits the sear to rise to the holding position. The breechblock retracts on each round and strikes a buffer element located in the backplate. This buffer consists of a steel block backed by two square wire springs.

The gun was originally equipped with a mounting adaptor constructed of welded tubing. The mount adaptor permitted slight adjustments in deflection and elevation after the gun was mounted, thus making possible the proper sighting of the piece.

When the gun was received at Aberdeen Proving Ground, the receiver cover plate and the breechblock retracting pin were missing. These components were improvised before tests were carried on. A mounting plate was also fabricated to provide a means of using available ground mount facilities.

### Ammunition Used for Functional Tests of the Japanese Caseless Gun

Only HE loaded ammunition was available; no other type is known to exist. The ammunition appeared to be in a satisfactory state of preservation, although some rounds were slightly rusty adjacent to the base ends. Some verdigris had formed on the primers, but not enough to interfere with the functioning. The rounds were contained in a wooden box. Each round was provided with a plastic nose and metal base protector. The fuzes were located in holes bored in a tray bore in the box. Each fuze was wrapped in wax paper.

It was observed that the metallic sealing cups for successive rounds were not identical. Some were drawn with smooth walls, some with overlapping walls, the latter apparently cut before drawing to permit the overlapping. Also, it was observed that 2 lengths of booster cavity were represented, although only 1 length of booster was present. The reason for the latter discrepancy is unknown.

The fuse depends on centrifugal force for arming. Three elements move during the arming period. Two spring-loaded safety plungers are seated in holes in the third element, a spring-loaded sliding fork. The firing pin is restrained by the tines of the fork. The firing pin moves rearward to strike the fuse primer when impact crushes the comparatively thin nose section.

The 0.35-ounce propelling charge consists of graphited flake powder contained in a silk bag.

An aluminum cup holds the charge in place. This cup contains a hole which permits admission of primer flame when the primer functions. The primer, a percussion type, is threaded into the heavy steel base plate. This base plate contains 12 holes 0.162 inch in diameter arranged in a circle around the primer. These holes serve to vent the powder gases from the rear end of the projectile. The base plate is assembled to the projectile body by threads.

The explosive charge consists of two cylindrical blocks and one hemispherical block of TNT. The cylindrical blocks are wrapped in one piece of waxed paper, the hemispherical piece in another. One of the cylindrical blocks contains the booster cavity. The explosive charge weighs 2.015 ounces. The complete projectile, fused, weighs 1.31 pounds.

### Details of the Test

*Procedure.* Preparation consisted of studying available reference material, of obtaining photographs and physical dimensions of the weapon and ammunition, and arranging for mounting the weapon. The first phase of the test consisted of 37 rounds fired both single shot and in bursts, principally to obtain records of target dispersion. During this phase, three different ground mounts were used. The first, a converted carriage, antiaircraft, 37-mm, M3, proved unstable, as did the second, a Frankford Arsenal rest on a concrete pedestal. The third was a concrete pedestal for the mount, Universal, T118, which proved satisfactory. Following this phase, nine rounds loaded with explosive were fired to observe fuze function. The final phase consisted of 10 rounds fired in darkness to observe breech and muzzle flash and, incidentally, fuze function.

During the phase concerned with target dispersion, the gun was realigned after each single shot or each burst to a sighting mark on the target. A bore sight was utilized with the elevation checked by using a clinometer. Also, this phase was fired using rounds loaded with inert material substituted for the HE charge. Since the original charge is contained in waxed paper, it may be easily removed from its compartment.

The sealing cup, which is included in the rear cavity, may occupy various positions ranging from snug against the charge to back against the inner

side of the base plate. Some difference in propellant ignition was possible, caused by the position of the cup. To discover the effect of the cup position on performance, rounds 1 to 20 were fired with the cup pressed snug against the charge, and rounds 21 to 37 with the cup against the base plate.

Recovered inert projectiles were examined to observe engraving and sealing at the band, the completeness of combustion of the powder charge, and variations in powder deposits at the vent holes in the base plate. Fuses were usually destroyed by recovery media.

Suitable safety precautions were observed with the ammunition, as directed.

The weapon and sufficient ammunition were delivered to the Ballistic Research Laboratories for a kinematic study and determination of trunnion reactions and tube pressures.

### Results

*The Gun.* The mechanical reliability of the gun was satisfactory during the 56 rounds fired. The principal mechanical deficiency was the slamming which caused difficulty in keeping the gun fastened to the mount. Evidently the recoil springs did not cushion the recoil sufficiently. The backplate buffer compression was recorded by placing paint on the exposed sides of the buffer block before firing and then observing the distance between the front of the backplate and the paint line formed when the paint was removed as the buffer was compressed. The compression was found to be complete on every round. Since the buffer compression is complete, the backplate must receive considerable impact.

When the recoil springs were calibrated and assembled in the weapon, as the breechblock was retracted each coil in turn would bind on the recoil spring housing. This caused a frictional load on this stroke which was not present during the forward stroke.

The only parts which failed were two setscrews, which sheared. One was located in the rear buffer plate; the other was a solenoid mounting screw. The only undue interference noted was the burring of the breechblock piston by the front positioning lever.

It was not found practicable to determine any reliable values for the obturation efficiency of the breechblock piston. Only an indication could be obtained by observing the frequency and intensity of breech flash. Only five occurrences of breech flash were observed. On three of these rounds, photographic records were attempted. The flash recorded with low intensity on the negatives, and did not "print over." The breech smoke was also observed. The smoke was more pronounced when single rounds were fired than when bursts were fired.

During bursts, the overall average rate of fire was 476 rounds per minute. The lowest recorded was 341 rounds per minute, the highest 573. The instrumental velocity remained within the limits of 764 and 860 feet per second, with an overall average of 807 feet per second.

Most of the dispersion was in the vertical plane, and maximum variations as high as 9 mils in this plane were recorded. Mean variations as high as 4.61 mils were recorded. All rounds tended to drift to the right from the aiming point. Dispersion was definitely increased during burst fire.

*The Ammunition.* Evidently the propelling charge is consumed while the projectile is in the tube. During night firing a blue-white "tracc" (there is no tracer element included) of very short duration was observed. Muzzle glow of low intensity was produced.

The principal deficiency appears to be the low efficiency of HE ammunition. Nineteen rounds with HE charge were fired, of which 8 exploded high order, 6 low order, and 5 failed to function. Obviously the blunt ogive presented by the fuse contributes to the deficiency. It was established by reference to "Handbook on Japanese Explosives" that the booster element is usually employed in 20-mm ammunition. If so, it is probably over-matched by this charge. Recovery and examination of dud HE ammunition was not attempted.

All recovered rounds passed through a 0.25-inch plywood screen before impacting sand or other recovery media. The recovered fuses were in such condition that it was probable that impact with the plywood would have caused function had the explo-

sive been present. The engraving on the rotating bands appeared shallow, and some evidence that gases escaped forward past the bands was found. Some paint was removed by such escaping gases. The engraving was not of uniform depth. No bands failed or slipped. There was a marked tendency for the primer cup to separate from the primer body. The sealing cups were found in various positions, usually badly battered. Only one cup was found adjacent to the nozzle plate. A gray ash was found in all base cavities and usually particles of the cloth containers, sometimes uncharred.

Two primer misfires were encountered, both of which had been struck fairly by the firing pin.

The initial position of the aluminum sealing cup did not affect performance of gun or ammunition to any noticeable extent.

### Observations on the Japanese Caseless Gun

A study of this weapon arouses speculations with reference to the practicability of muzzle disposal cartridge cases. The problem would consist in designing a cartridge case which would remain rigidly attached to the projectile during feeding, chambering, and firing, which would be released by some positive means at some safe point on the trajectory. A concurrent problem would be the designing of a fully obturated breechblock which would perform as efficiently as the conventional cartridge case in this respect.

As opposed to the thick walls and perforated base of the rear compartment of the projectile for the HO 301 (required because of the highest pressures develop in the compartment and because the rotating band is located over the walls), the cartridge case could consist of a perforated container which would tend to equalize pressures on the exterior and interior. The strength of the material could depend on the rigidity required to prevent deformation in feeding and chambering and to position the primer for firing. The volume for the charge, severely restricted in the weapon under test, could be increased to provide the velocity level desired. However, the diameter of the case would necessarily remain less than the diameter of the projectile.



The uncoupling of projectile and cartridge case along the trajectory would require precise timing and reliable functioning. An explosive separating element might be utilized, with a delay train initiated by the burning of the propelling charge.

A fully obturating breechblock for automatic operation will be required if and when chamber-con-

sumed cartridges are developed, both to prevent breech flash with its fire hazard and to increase the efficiency of propulsion. Such a breechblock should not present insurmountable difficulties to the designer, since such breechblocks have been used for many years in guns using separate-loading ammunition.

## Chapter 22

**BOFORS AUTOMATIC CANNON****SECTION 1. HISTORY AND BACKGROUND****History and Background of the Bofors Plant**

The Bofors Arms Co. is one of the oldest arms producing plants in the world. The name first appeared in the Swedish public records in November 1646, when one Paul Horsman was granted permission to erect a forge and hammermill in the mining district of Bofors, located in central Sweden. This forge was typical of many such places that were later to bring fame to the Swedish steel industry.

There was nothing outstanding about this particular establishment until the middle of the 19th century when changing world events enlarged the sphere of activity. As early as 1870, this plant was rated the largest manufacturer of roll bar stock in Sweden; in 1873, the mill was converted into a joint stock company, AB. Bofors-Gullspång. During the late 1870's, Bofors succeeded in producing a new kind of steel that was considered highly suitable for the manufacture of cannon barrels. This made the company a serious competitor to the mighty Krupp Works in Germany. In 1883 the Bofors Co. built its own workshop for the manufacture of war material and in 1888, the initial order was received from Switzerland for 28 cannon with a bore diameter of 12 centimeters.

In 1894, outright ownership of the company was acquired by the famous explosives inventor, Alfred Nobel, who immediately stressed the importance of specialization and erected the company's first research laboratory at Björkborn. The manufacture of gunpowder was started and later armor plate was added to the items produced.

In spite of keen competition, Bofors prospered and after 1900 began the manufacture of ammunition and fuses. The company made money but had no need for added factories until World War I, when huge orders made the existing facilities inadequate

and necessitated considerable enlargement of the plant.

After the defeat of Germany, the dismemberment of the Krupp plant by the victorious Allies not only removed a big competitor but also allowed Bofors to make under license many Krupp guns that could not be produced in Germany. Otto Krupp obtained a sizable portion of the stock in the Bofors Co. Personnel and equipment from the Krupp Works were eventually moved to Sweden to furnish technical aid and manufacturing know-how. Through the nineteen twenties and early thirties, the company manufactured the few weapons that were demanded by the various powers during this peaceful period in world history.

In the 1930's, when a law was passed in Sweden prohibiting foreign ownership of munitions within the borders of Sweden, control of the Bofors Co. passed to Axel Wennergren, a local financier.

**History of the Bofors 40-mm Automatic Gun**

The Bofors 40-mm antiaircraft cannon gained a reputation for efficiency during the Spanish Civil War. The development of this weapon is outside the scope of this volume, since its use is limited to shipboard installation, however, the weapon holds interest for readers of this volume for several reasons. Its design features are the basis for the design of the Bofors 57-mm aircraft cannon and the Bofors 20-mm antiaircraft cannon. The interest of both the Navy Bureau of Ordnance and the Army Ordnance Corps was attracted to the Bofors 40-mm shortly before Pearl Harbor.

The design of the Bofors 40-mm appears to have originated at the Krupp Works in Germany shortly after the end of World War I. During the 1930's, when the Krupp activities had been transplanted to



Figure 22-1. Evert Wijkander, managing director of Bofors since 1936.

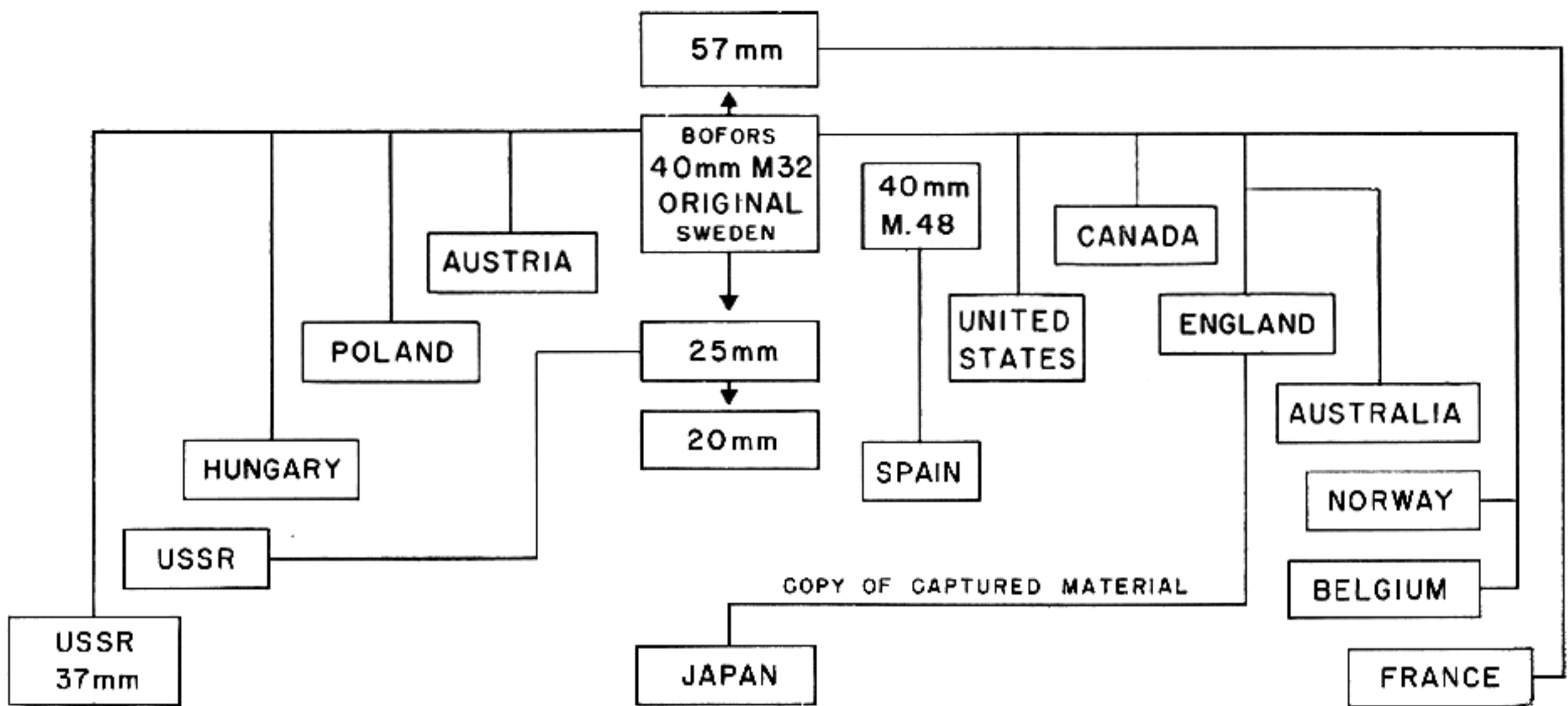


Figure 22-2. The spread of the Bofors mechanism throughout the world.

the Bofors Arms Co., the latter company became interested in the perfection of a 40-mm gun that could be used on shipboard as a defense against aircraft. The gun that was developed stemmed from the 40-mm cannon originated by the Krupp Works.

The Chief of the Bureau of Ordnance became interested in this gun through the efforts of an American businessman, Mr. Henry Howard, who had witnessed a firing demonstration in Sweden in 1939. The Bureau of Ordnance purchased one gun for test and evaluation; and when it arrived in New York along with 3,000 rounds of ammunition, it was sent to the Naval Proving Ground at Dahlgren, Va., for evaluation.

Coincidental with this transaction, the Bureau of Ordnance received a communication from the York Safe & Lock Co. of York, Pa., informing the Bureau that the York Co. was considering the possibility of obtaining a license to manufacture the gun in the United States. However, events moved too fast; before this transaction could be completed, the invasion of Norway stopped the plan.

Several years before the Navy showed interest in the 40-mm gun, the Army had sought to procure a single gun. In 1938, the Bofors Co. offered to send a pilot gun and one technician to the United States free of cost. They offered to supply 2,600 rounds of shell of several types for 6 to 12 dollars a round,

the total cost figuring \$20,200; and asked that the tests be concluded quickly and the gun returned. Evidence is now available indicating that the Bofors cable was misread and that the total amount involved was believed to be \$243,600. Lack of punctuation in the cablegram, failure to mention the word "dollars" except toward the end of message, and the belief of the recipient that "10 1000" was the sender's method of writing 10,000 caused the error. The cablegram was as follows: "Referring conference 26/4 Ordnance Department Commander Bostroem stop 40 M/M pilot gun and ammunition can be sent about 15/6 costs of freight to be paid by Bofors stop FOB price New York City 500 rounds high explosive tracer shells 10 1000 tracer drill shells 8 1000 drill shells 6 100 armour piercing tracer shells 12 100 ditto uncharged 12 dollars a piece stop please cable confirmation." Consequently, the quantities of shell were read, respectively, as 500, 10,000, 8,000, 600, and 1,200, or a total of 20,300 shells at a common cost of 12 dollars each. Actually, the pertinent portion was meant to read: "500 rounds high explosive tracer shells 10 dollars apiece, 1000 tracer drill shells 8 dollars apiece, 1000 drill shells 6 dollars apiece, 100 armor piercing tracer shells 12 dollars apiece, 100 ditto uncharged 12 dollars apiece."

Before a confirming letter from Bofors could arrive or an answer be obtained to the letter, the Office

of the Chief of Ordnance wrote to the Berlin Military Attaché asking his check on this unreasonably large quantity of ammunition for a test of one gun, the decision had been made to continue with the 37-mm Browning.

On September 1940, the Naval Proving Ground at Dahlgren completed tests which were, in every sense of the word, successful. Witnessing the trials were representatives of the Bureau of Ordnance, Army, and Naval Gun Factory. Even before this test, the Chief of the Bureau of Ordnance flew to Trinidad to witness the firing of a Swedish-made Bofors gun on a Dutch war vessel. The demonstration was so impressive that there was no longer any question of the suitability of the gun for Navy ship-board use.

From that time on, production of the gun was the only problem. Holland was now occupied, but the Navy Department was informed that a set of prints could be obtained from Java. In January 1941, additional drawings were obtained from British sources in Canada; manufacture had already commenced at Hamilton, Ontario. In November 1940, the Ordnance Department obtained a single British Army 40-mm Bofors gun, and tests were witnessed by officials of the Navy. Two months later suitable drawings were obtained and were turned over to the Chrysler Corp. for conversion to American measurements. In acquiring manufacturing rights, the Navy acted for the Army and the latter agreed to pay half the cost, which amounted to \$500,000.

On 21 June 1941, the Navy through the naval attaché at Stockholm concluded a contract permitting the manufacture of the gun in this country "for United States use". An early draft of the contract had read "for United States Forces only". Interpretation of the phrase is still the subject of litigation.

Standard Navy drawings were prepared at York, Pa., from Bofors, Dutch, and British drawings. On 19 February 1941, a letter of intent was sent to York calling for the construction of 500 guns. In April 1941, the Navy took over administration of Chrysler for both Army and Navy production.

In the early part of the program, there was little interchangeability between Army and Navy guns, one reason being that the drawings converted at York were converted in decimals and those made by Chrysler had been calculated in fractions. The 200

items originally causing trouble in interchangeability were finally reduced to 10, not including components for water cooling. Soon after the interchangeability of parts was extended, Pontiac manufacturing division of General Motors in Pontiac, Mich., became the principal producer of this weapon for Army use.

### Other Bofors Weapons Developed in the Thirties

Events leading up to World War II stimulated the arms industry greatly during the 1930's, and many countries placed large orders with Bofors. Its machinery was thoroughly modernized, and production leaned toward heavy automatic weapons development. However, aircraft armament was not overlooked, and several experimental models were produced and tested in its modern range. The Bofors Co. designed two types of 20-mm cannon, one for antiaircraft use which was nothing more than a scaled-down version of its successful 40-mm weapon.

In designing all of its automatic firing mechanisms, Bofors worked downward instead of taking a machine gun design and working up to a larger caliber as is generally the practice. The scaled-down version of the 40-mm gun was capable of both single shot or full automatic fire and employed the circular drum-type feed, as did the heavier version.

The aircraft cannon was announced for sale in 1938. It was different in design, being belt fed and using the short-recoil principle to operate the mechanism.

### Branches of AB. Bofors-Gullspång and International Adaptations

The company itself has confined its manufacturing activities to Sweden, but the internationalization of the Bofors system has proceeded rapidly since the success of the 40-mm antiaircraft gun.

The spread of this mechanism is indicated in an accompanying figure, showing those countries which at one time or another have set up facilities for making guns of the Bofors pattern. The Japanese copy was made from a British gun captured at Singapore but only six guns had been produced by the Kokura Army Arsenal before hostilities ended. In Canada, the producer in World War II was the Dominion Bridge Co. at Vancouver, British Columbia. The Australian facility was the Government Ordnance

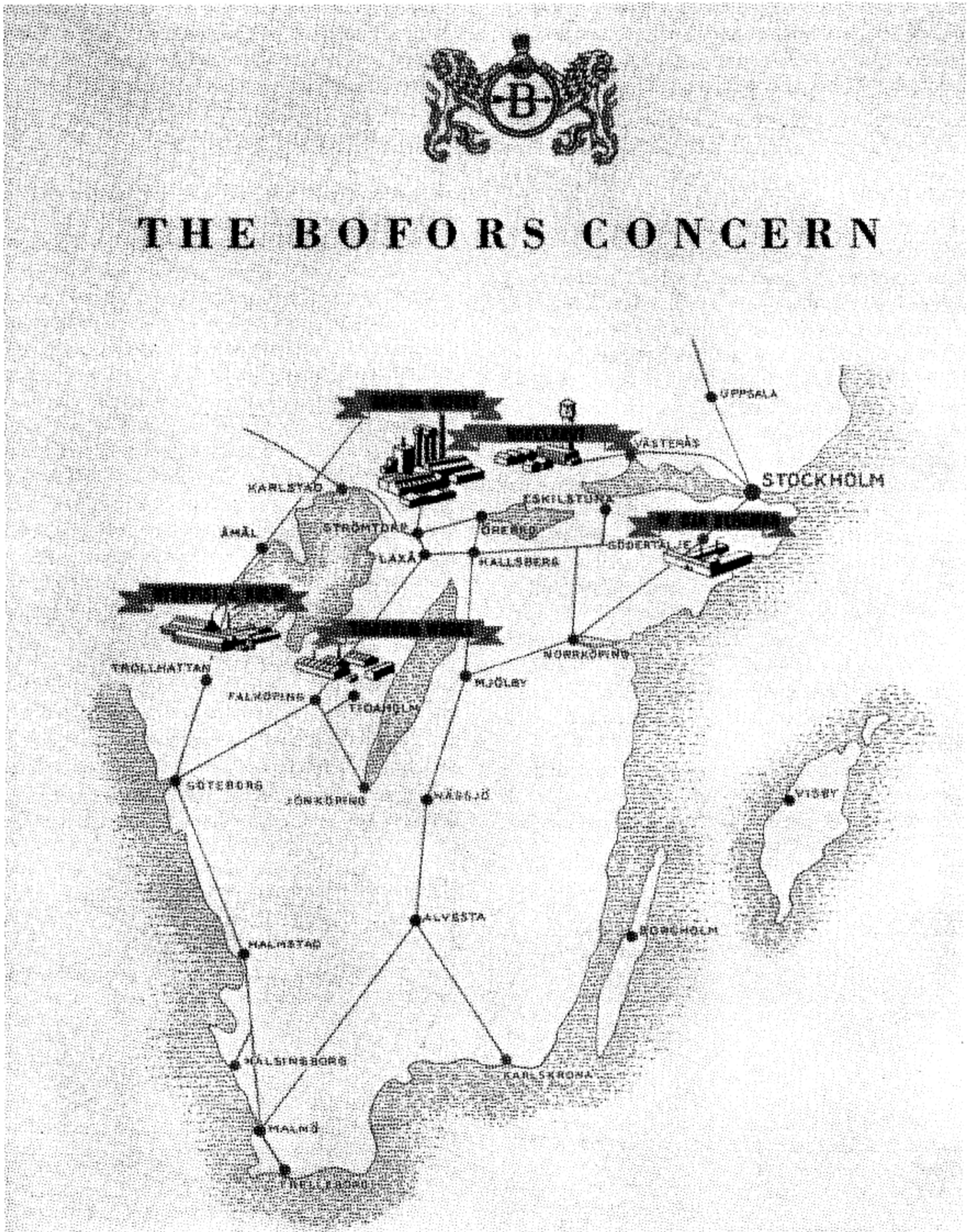


Figure 22-3. The affiliated concerns of the Bofors group.

Factory at Maribyng, Victoria. The Kongsberg Kanonfabrik, a Norwegian Government arsenal, produced for that Government. American production by York, Chrysler, and Pontiac is sum-

marized in this chapter. Another facility engaged in the production of this system is at the Puteaux Arsenal in France, which has produced the 57-mm gun for antiaircraft use in the French Fleet.

## SECTION 2. 20-MM BOFORS AIRCRAFT CANNON

### Description

The 20-mm Bofors aircraft cannon, sometimes known as the L/70, operates with short recoil, is air cooled and belt fed, and uses a metal disintegrating pushout-type link that is streamlined in design.

A muzzle booster is sometimes used to speed up the action to 700 shots per minute. A hinged cover permits inspection of components for visual check or replacement of broken parts.

An air charger located directly on top of the cover group contacts the bolt by means of a ringed member that protrudes through a slot in the center of the receiver, permitting manual operation.

A large buffer using Belleville washers is used to absorb shock and give a faster return to the recoiling parts. The barrel is quickly detachable and is housed in a slotted barrel jacket.

The feed can be made to function from right or left merely by the repositioning of parts. The sear can be released either by air or manually, air being used when the weapon is mounted for remote control firing.

The links are of thin spring steel and cover half of the cartridge case from the base to the shoulder of the cartridge. A portion of the link snaps into the

cannelure of the round. This arrangement keeps the cartridge in calibration once it is belted.

The barrel and bolt recoil securely locked together for a distance of 20 mm; at this point the bolt is unlocked from the barrel and continues to the rear, accelerated by a pivoted lever. Two projections at the point of unlocking hold the barrel and barrel extension to the rear against the barrel return spring, and the bolt continues to compress the driving spring. The fired cartridge case is extracted by a T-slot on the face of the bolt, and the empty brass travels with the bolt to the extreme rear position. It is ejected on counterrecoil by the introduction of the incoming round in the T-slot plus contact with the gradual angle that engages the empty case during this part of its forward movement. The round is chambered in its first position by a movement of a sliding bolt face similar to that of the Maxim.

When the counterrecoiling bolt is three-fourths inch from battery, it strikes the pivoting breechblock, simultaneously releasing the barrel and barrel extension, which continue toward battery as a unit. If the trigger is held back, the firing pin is automatically released just before the entire recoiling mass makes contact with the receiver. The safety feature

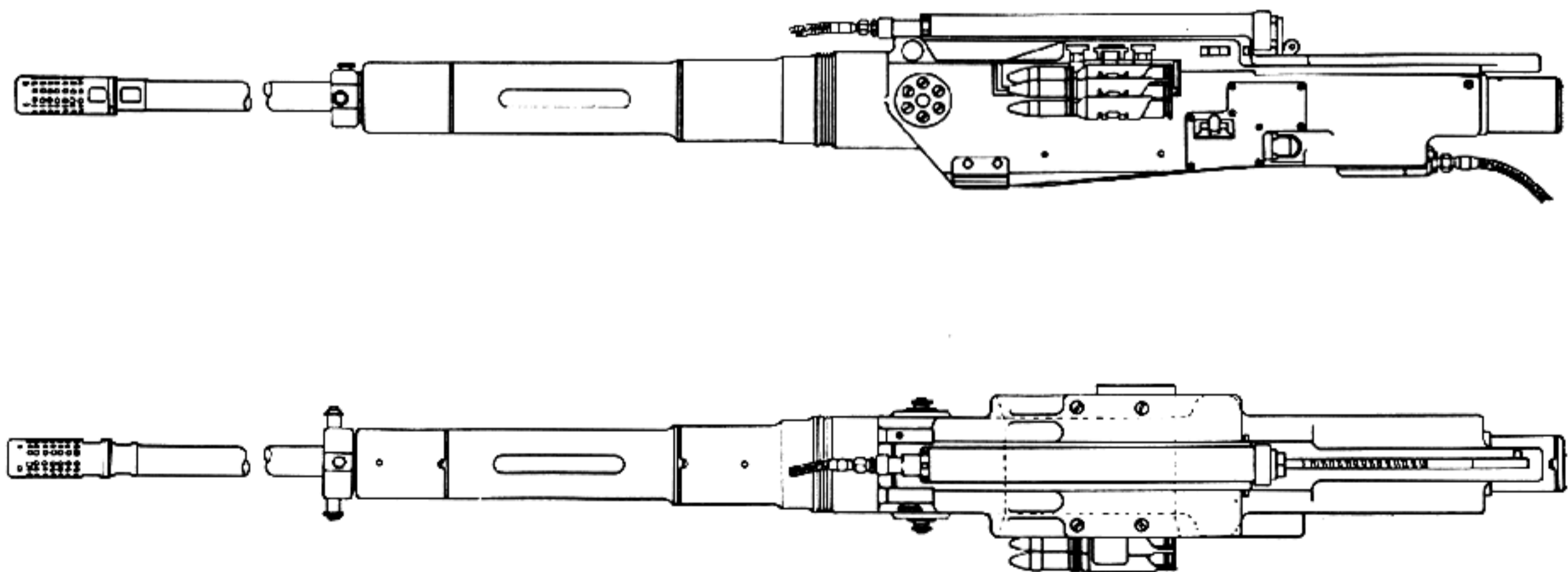


Figure 22-4. 20-mm Bofors Aircraft Cannon.

is also controlled with a breech lock, which serves as an adequate obstruction in the path of the firing pin until the firing mechanism is securely locked.

A fire regulator is located on the left side of the weapon. It permits the operator to choose automatic or single fire. Because of the gradual camming effect on the empty cartridge case while partially ejected, extraction is accomplished in a manner that prevents the empty cartridge from being thrown forcefully from the gun.

### SECTION 3. 20-MM BOFORS ANTI-AIRCRAFT CANNON

#### Description

The mechanism of the 20-mm Bofors Antiaircraft cannon is identical with that of the 57-mm Bofors aircraft cannon. The 57-mm is a scaled-up version of the battle-tested shipboard 40-mm anti-air-

The barrel is provided with a muzzle brake and booster and is screwed onto the breech mechanism in such a way that it may be readily changed. The recoil and recuperating springs encircle the barrel. The breech mechanism is entirely automatic.

This gun is considered especially suited to mounting in modern fast aircraft because of its light weight, smallness in size, and its rate of fire.

craft cannon, while the 20-mm antiaircraft cannon is a scaled-down version of the same 40-mm weapon.

#### Cycle of Operation

The 20-mm Bofors Antiaircraft cannon has the same cycle of operation as the 57-mm aircraft model.

### SECTION 4. 57-MM BOFORS AIRCRAFT CANNON

#### Description

The success of the 40-mm automatic mechanism for antiaircraft use lead to its being scaled to a 57-mm model for aircraft use. This larger bore was thought to be necessary for the specific purpose the weapon was designed, namely, antitank work in close ground support by heavily armored planes.

The gun was designed for ground attack use in the Swedish B. 18 aircraft, a type similar in appearance to the British Mosquito. The weapon's unusually large size and heavy weight limit its installation to a few types of aircraft. The components of the 57-mm model are heavier than those of the 40-mm to compensate for the greater shock of the larger round.

#### General Data: 57-mm Bofors Aircraft Cannon

Gun length, with muzzle brake attached: 16.85 feet.  
 Gun weight, with 41-shot drum feeder loaded: 1,620 pounds.  
 Rate of fire: 180 rounds/minute.  
 Muzzle velocity, with AP projectile: 2,250 feet/second.  
 System of operation: Long recoil.  
 System of locking: Vertical sliding wedge.  
 System of feeding: Drum holding 41 rounds.  
 Method of headspace: Factory established.  
 Location of feed opening: Top.  
 Location ejection opening: Bottom.  
 Method of charging: Pneumatic or hydraulic.  
 Method of cooling: Air.  
 Barrel length:  
     with muzzle brake: 130.1 inches.  
     without muzzle brake: 89.7 inches.  
 Barrel weight, complete with springs: 450 pounds.  
 Rate control: None.

Barrel removal: Not quick disconnect.  
 Length of recoil: 1.1 inches.  
 Bore:  
     Number of grooves: 12.  
     Length of rifle bore: 10.26 inches.  
     Groove depth: 0.0225 inch.  
     Groove width: 0.270 inch.  
     Pitch: 1 turn in 45 calibers at breech to 1 turn in 30 calibers at muzzle.  
     Direction of twist: Right hand.  
     Form of twist: Progressive.  
 Recoil force:  
     with muzzle brake: 5,500 pounds (approximate).  
     without muzzle brake: 6,600 pounds (approximate).  
 Length of recoil:  
     minimum: 10 inches.  
     maximum: 12 inches.  
 Air pressure required to cock the gun: 425 p. s. i.



The weapon is operated by short recoil and employs a nonreciprocating bolt. It is air cooled, drum fed by a 25-round magazine, and its rate of fire is 100 rounds per minute.

A very efficient recoil system is employed to cushion the shock resulting from this unusually large round of ammunition. The recoil assembly consists of a spring and a cylinder. In counterrecoil the spring provides the force necessary to return the gun mechanism to battery position, cock the rammer, and feed a new round.

The recoil cylinder controls the length of recoil and the velocity of counterrecoil. As the piston rod is drawn to the rear in the recoil cylinder, liquid is forced from the front of the piston through eight holes in the piston head. Through the ports, the liquid passes to the rear. This effective and controlled flow sets up a fluid resistance that adequately retards recoil.

In full automatic fire, six operations make up a complete cycle. A live round is fed into the loading tray. The rammer is cocked. The round is

rammed into the chamber. The breech is closed. The round is fired. The empty case is ejected.

The large drum-type feeder indexes each round by spring pressure. While efficient and simple in operation, the system of feeding made mounting in aircraft difficult and relegated the weapon to fuselage installations only. The manufacturers of the gun have pointed out that this was no hardship since it was for a specific purpose that required a minimum number of rounds to accomplish a mission.

The magazine is fixed permanently to the gun and is charged by hand by inserting single rounds from the rear while winding the magazine with a crank and applying pressure to the spring which operates the magazine during firing. The magazine is filled by hand before takeoff.

The breech mechanism is identical with that of the 40-mm model. The vertical sliding wedge is designed in such a way that when operated automatically the rounds are fired before the recoiling parts have completely run out. The firing mechanism is

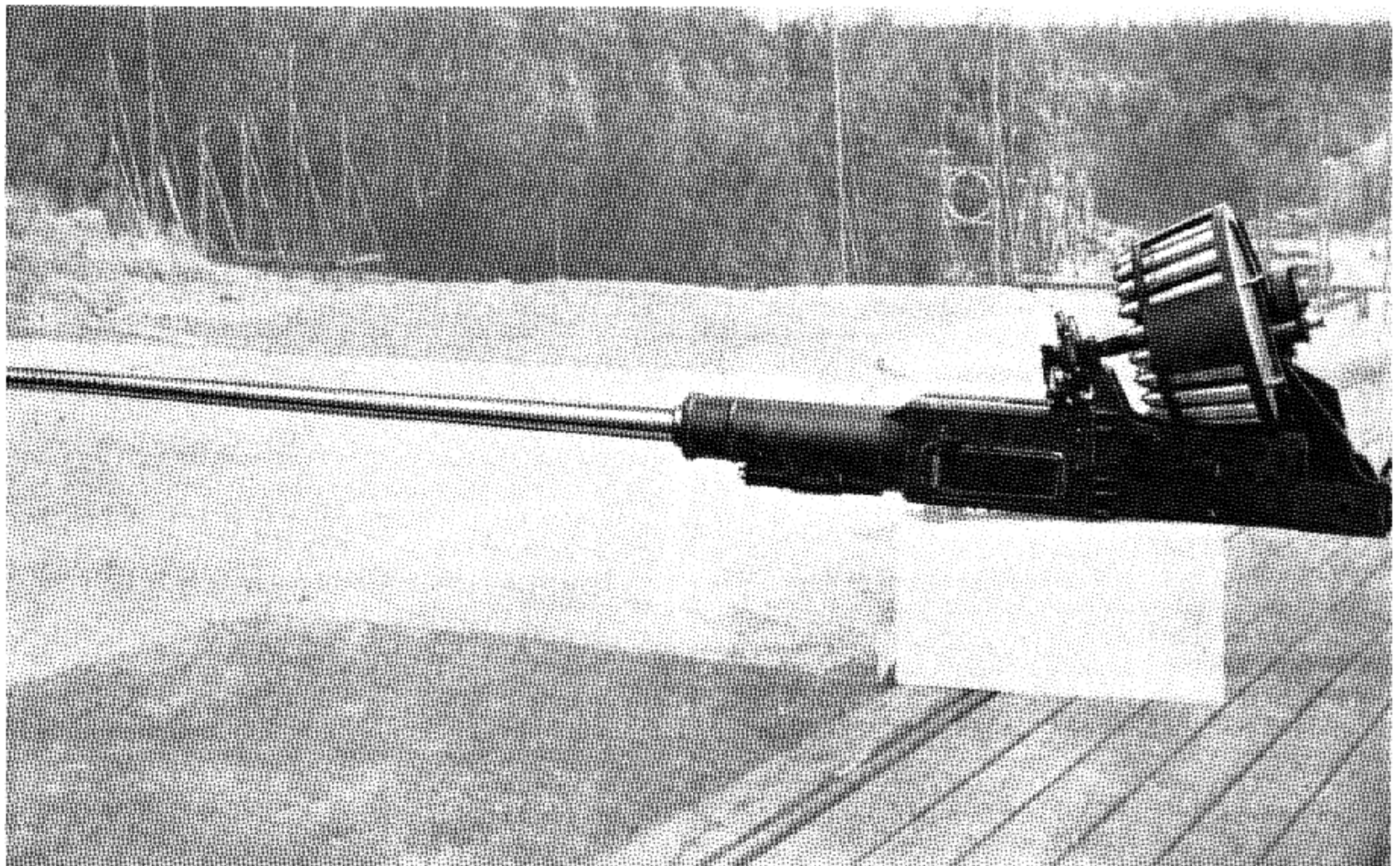


Figure 22-5. 57-mm Bofors Aircraft Cannon on the Proving Ground at the Bofors Plant.

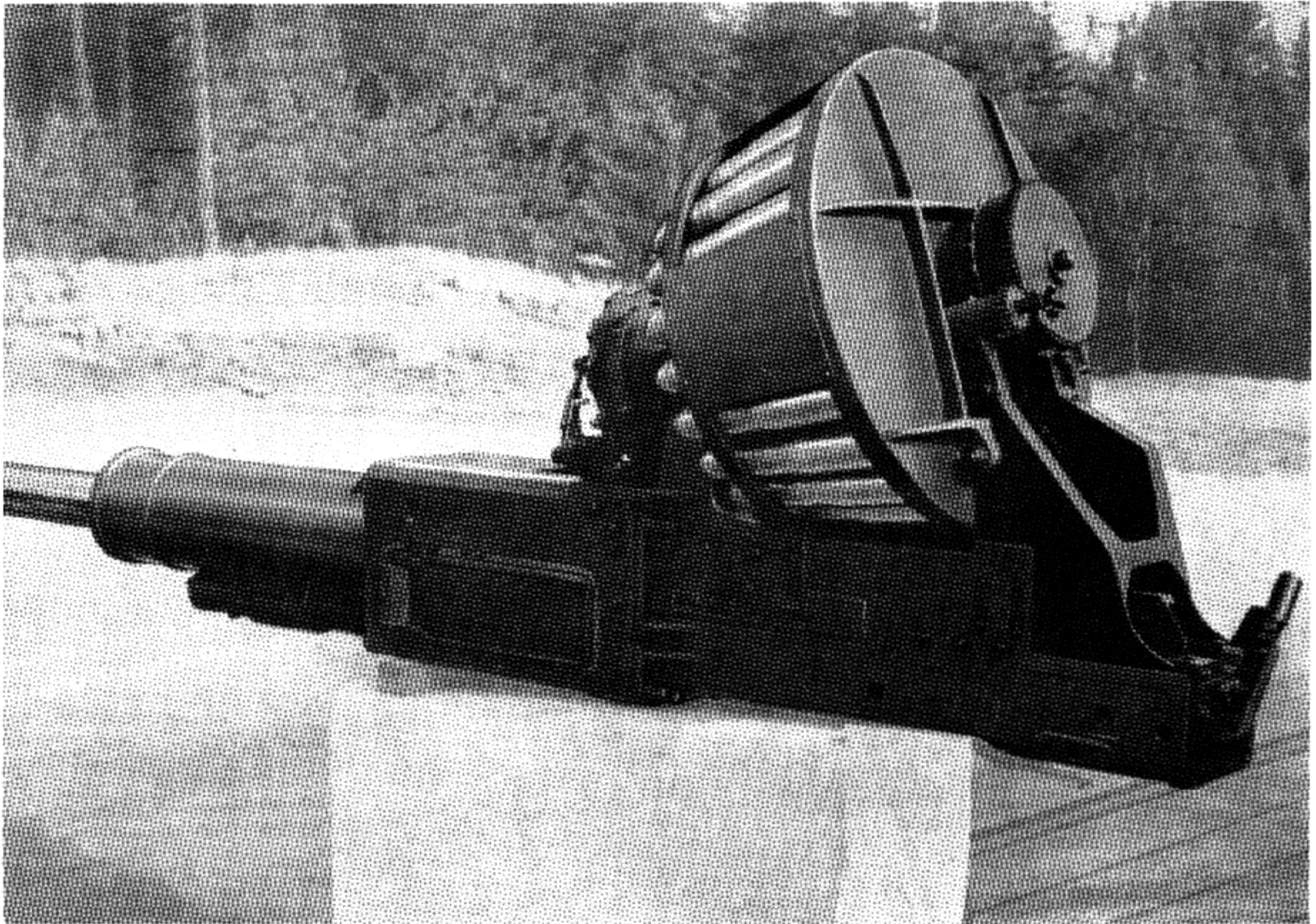


Figure 22-6. 57-mm Bofors Aircraft Cannon. Closeup view of feed.

discharged pneumatically. A pneumatic firing device can be operated electrically by means of a push button installed in the pilot's cabin or elsewhere. The weapon functions at all angles of elevation.

The recoil brake has an electric heating device allowing the gun to function at a very low temperature. The barrel is screwed into the breech ring in such a way that if it were not for its unusually heavy construction it could be readily exchanged. The recoil brake is hydraulic, and the recuperator consists of a spring which encircles the rear part of the barrel.

### Cycle of Operation

To fire the Bofors 57-mm aircraft model in flight, the operator has only to throw the selector switch from SAFE to FIRE and press the firing button. By means of a solenoid, a cam forces the sear inward

and releases the inner cocking lever and firing pin, which strikes the primer and explodes the cartridge's propellant charge.

During recoil, the cams on the side act on the outer crank to rotate the crankshaft and the inner cranks. The latter's first movement retracts the firing pin and unlocks the breechblock after  $2\frac{7}{8}$  inches of travel. At this time the projectile has safely cleared the bore, and continued rotation of the inner cranks lower the breechblock into contact with the toes of the extractors, accelerating them in their housing. The empty cartridge case is thrown down through the opening in the top of the breechblock and clear of the working mechanism of the gun, until it hits a deflector.

During the remainder of recoil, the rammer and feed pawls of the loader are raised above the incoming round, being held in position by the stop pawl. This action is brought about by movement of the

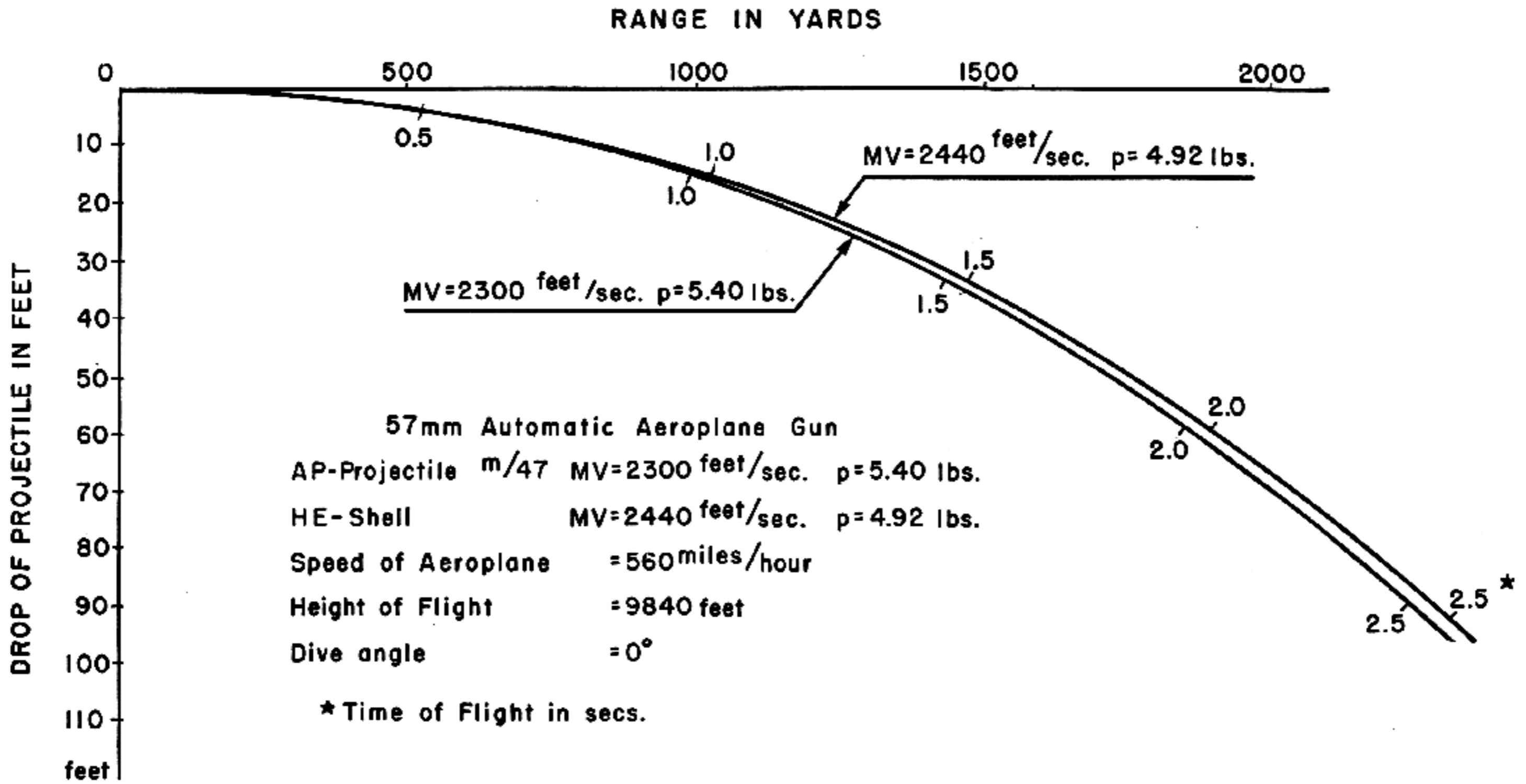


Figure 22-7. Performance of 57-mm Bofors Aircraft Cannon according to Bofors. Speed of plane has been added to muzzle velocity in computing time of flight.

roller on the feed rod by means of the guides on the sides of the tray.

Counterrecoil begins after full compression of the driving spring. The breech-locking spring acts to move the breechblock to the closed position; but this motion is stopped as the breech is latched open by the hooks on the extractor. Consequently, the outer crank is carried clear of the side cam. As the tray moves forward, the pawls on the top surface rotate the star wheel in the feeder. This action forces a loaded round on the tray up to the point where the rammer shoe is latched to the rear by the tray catch lever. When an inch from battery position, the cam on the bottom of the tray trips a

rocker arm. This in turn fires the tray catch lever, releasing the rammer to start the round into the chamber. At the end of this stroke, the ramming levers are spread by the slots in the tray. The live round, released at a high rate of speed, is literally catapulted into the chamber.

At the completion of this action, the breechblock closing spring is free to raise the breechblock to the closed position as the extractors are unhooked from the block by the rim of the cartridge in the act of chambering. While the block rises, pressure on the left inner cam is removed from the cocking lever and firing of the round is accomplished.

## Chapter 23

# 23-MM MADSEN AUTOMATIC AIRCRAFT CANNON

## SECTION 1. HISTORY AND BACKGROUND

In 1902 an 8-mm machine gun mechanism was developed by the Dansk Rekylriffel Syndikat of Copenhagen, Denmark. This automatic firing mechanism has been manufactured from that time to the present with little change in the basic design. The weapon is universally known as the Madsen, this title being derived from the name of the Danish Minister of War of that period as a tribute to his enthusiasm for the weapon at the time of its adoption by the armed services of his country.

Throughout the years, the mechanism has been

made to fit practically every rifle cartridge in existence. In 1926 the Danish company announced that they had successfully scaled up the weapon and now had a 23-mm automatic aircraft cannon suitable for both wing and flexible mounting. In 1937, the United States became interested in this type of aircraft armament and bought four guns with ammunition and accessories. By this time, the Danish company was known as Dansk Industri Syndikat.

The four guns were sent to Wright Field and to the Naval Proving Ground at Dahlgren, Va. The

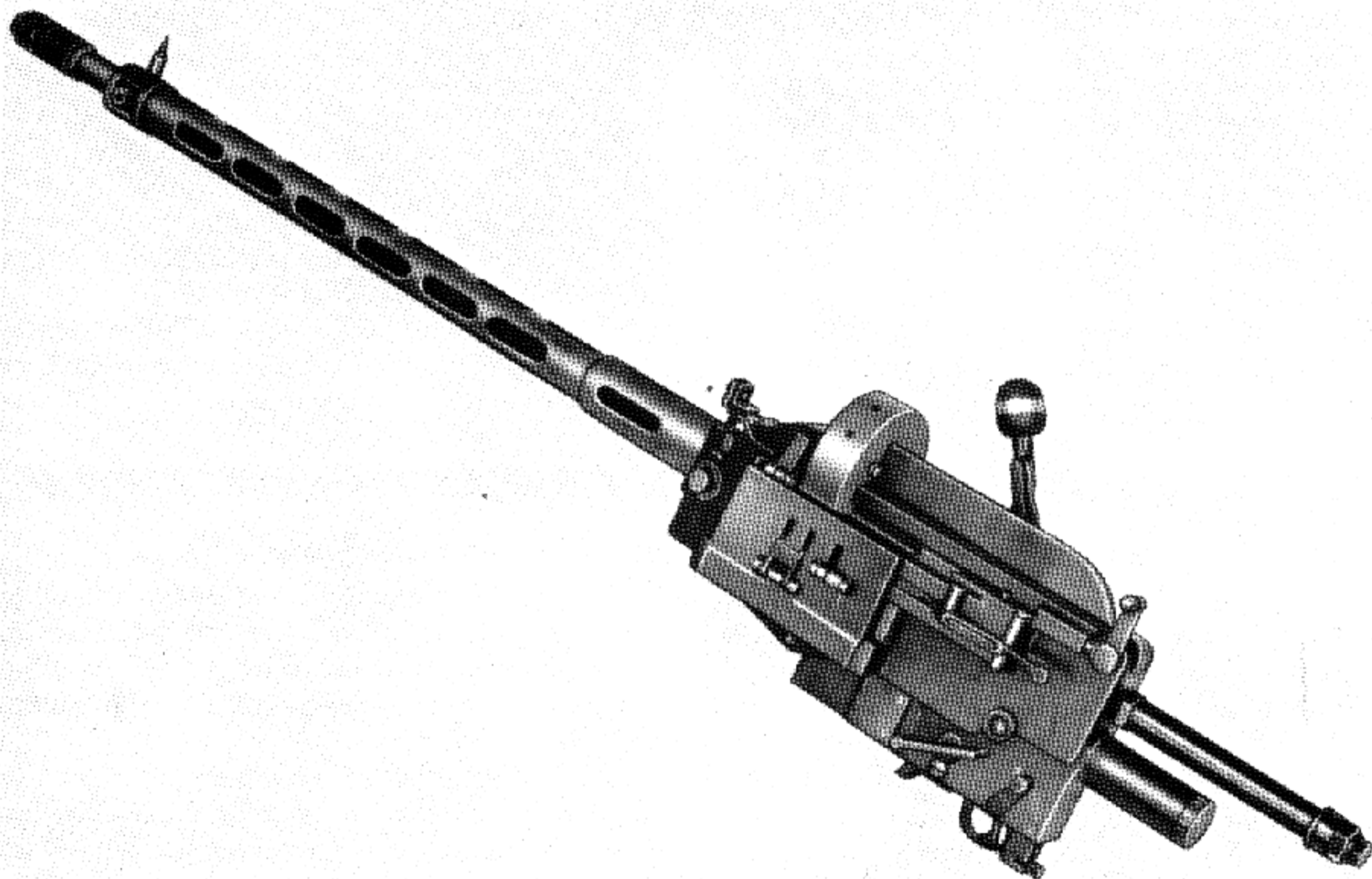


Figure 23-1. 23-mm Madsen Automatic Aircraft Cannon.

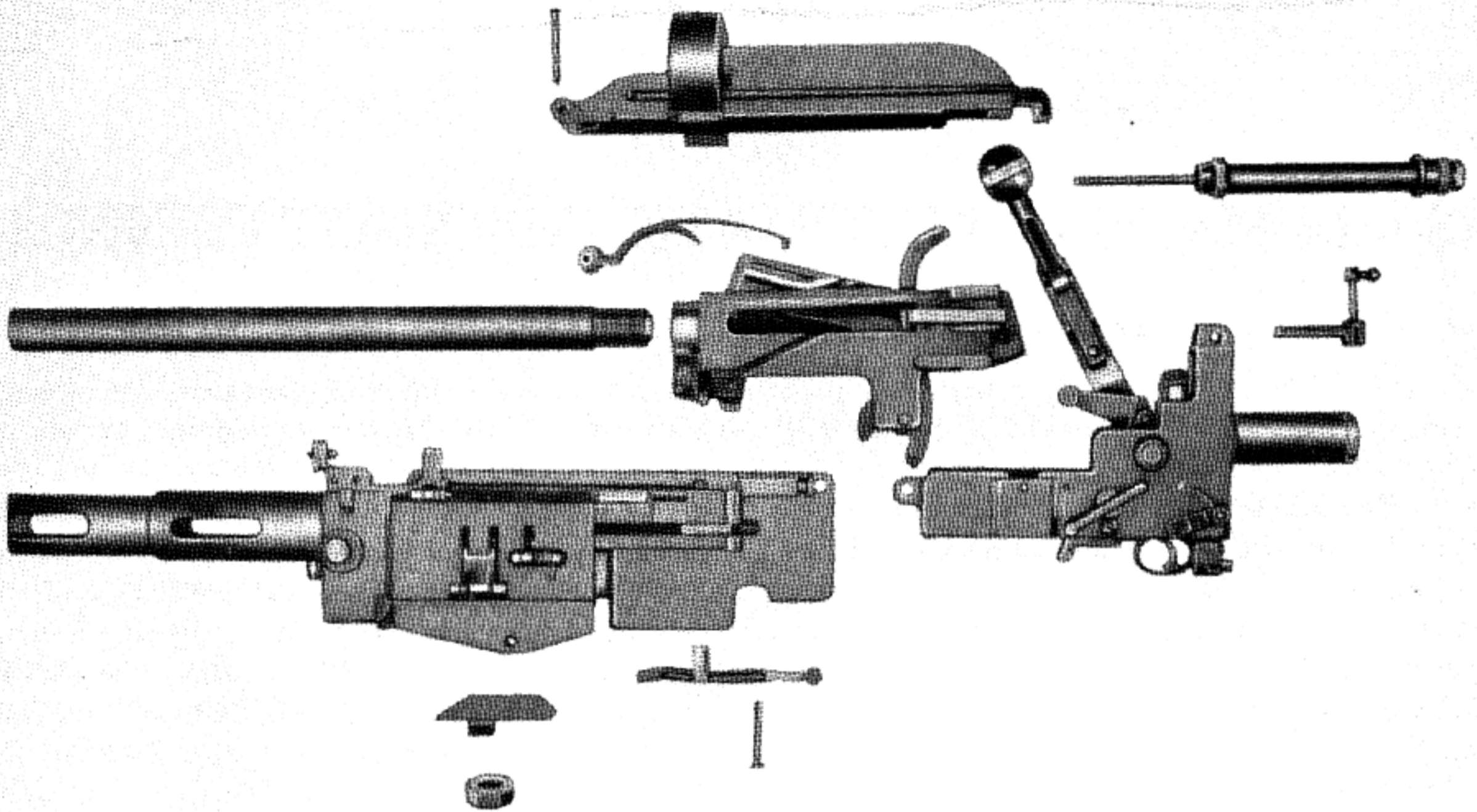


Figure 23-2. 23-mm Madsen Automatic Aircraft Cannon. Disassembled view.

tests at both places were discouraging, and the United States Government lost interest. Illustrations and discussion of developments to this date are included in *The Machine Gun*, volume 1, pages 537-541 and 570.

It is reported through official channels that after World War II this Danish company experimented with captured German weapons that had been under development at the Mauser and Rheinmetall manufacturing activities.

Unofficial reports indicate that in the post World War II period the Danish company has taken considerable interest in improvements in a 20-mm aircraft gun. Although there are many unofficial reports concerning this "new" 20-mm gun, a search of available records does not reveal that it has been exhibited in the United States.

Up to the time of going to press with this volume, photographs of the "new" 20-mm gun had not been received from the Danish company.

## SECTION 2. DESCRIPTION OF THE 23-MM AUTOMATIC AIRCRAFT CANNON

### General

The Madsen 23-mm automatic gun is air-cooled, short-recoil-operated, belt-fed, and percussion-fired. The weapon can be fired semi- or full automatic.

The distinguishing feature of this gun is its breechblock which, pivoted at its aft end, assumes three different positions for firing, ejection, and chambering.

The components are easily disassembled and assembled, but all recoiling parts must be removed from the rear before the barrel can be changed.

### The Nonrecoiling Parts

The principal components which are nonrecoiling are: The barrel casing and the frame, which are attached together; and the trigger plate assembly. The trigger plate is fastened to the frame by a screw and bolt.

The cartridge-feeding mechanism is mounted on the frame. The trigger plate accommodates the trigger mechanism and the spring housing, which contains the recoil and return spring and assists in braking the mechanism when moving backward

and in sending it forward again. The frame is closed by the frame cover.

### The Recoiling Parts

In this portion, the essential parts are: the barrel, the breech, and the breechblock.

The barrel, which is screwed onto the breech, is in the form of a long frame which accommodates the breechblock. The fore end of the breechblock can move up and down in the breech, turning on the horizontal breechblock bolt.

The fixed and movable portions are connected by means of the recoil arm, which turns on the horizontal crank bolt. The head of the recoil arm engages in a groove in the link, which is made fast to the breech.

### The Trigger Mechanism

The trigger mechanism is inside the trigger plate. The trigger guard has a seating for the trigger bolt upon which the trigger turns. The finger-grip of the trigger extends down into the trigger guard; and the trigger itself has 2 arms, 1 pointing forward, the other pointing upward. The forward-pointing arm is held up by a trigger spring, and to its extreme end is bolted a trigger rod depressor. The trigger rod moves on a bolt at its rear end between the upper ends of the trigger-guard flanges. The trigger rod points forward, and in its forward end has a notch into which the trigger rod depressor fits. On its rear end, the trigger rod depressor has a hook which engages over the trigger rod. The trigger rod spring

forms a spring connection between the trigger rod depressor and the trigger rod, pulling the upper end of the trigger rod depressor backward and the fore end of the trigger rod upward. On its upper side, the trigger rod has a lug for the notch in the percussion arm, while on the lower side of the fore end, it is cut away so that the safety catch can be turned in under it. On the right side of the trigger rod is a sliding pawl which engages downward over the up-turned arm of the trigger, so that movement of the trigger causes the pawl to move backward and forward in relation to the trigger rod.

In the trigger plate is a changeover lever, which can be turned so that the trigger cannot be moved all the way back, but only enough so that the lug of the trigger rod is withdrawn from the notch in the percussion arm, and not enough that the sliding pawl moves so far forward that the firing cam of the recoil arm can press on it.

### Recoil and Percussion Arms

The recoil of the movable portion and its return after completing the recoil are governed by means of the muzzle brake and the recoil arm in conjunction with the recoil spring, the percussion arm with the percussion spring, and the return spring.

The recoil arm is mounted on the crank bolt, which at this point is four sided, whereby the two parts conform to each other's movements. At its top, the recoil arm has a head which engages in a channel in the link, thus forming the connection between the fixed portion and the movable portion of

#### General Data: 23-mm Madsen Automatic Gun

Gun length: 87 inches.  
 Gun weight: 115 pounds.  
 Rate of fire: 500-600 rounds/minute.  
 Muzzle velocity: 2,300 feet/second.  
 System of operation: Short recoil.  
 System of locking: Pivoting bolt.  
 System of feeding: Continuous feed is an integral part of gun.  
 Method of headspace: Factory established.  
 Location of feed opening: Left side of receiver.  
 Location of ejection opening: Bottom of receiver.  
 Method of charging: Manual or mechanical.  
 Method of cooling: Air.

Barrel length: 61.5 inches.  
 Barrel weight, with muzzle brake: 42 pounds.  
 Rate control: None.  
 Barrel removal: Not quick disconnect.  
 Bore:  
 Number of grooves: 8.  
 Groove depth: 0.020 inch.  
 Groove width: 0.215 inch.  
 Pitch: 5°.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Weight of cartridge: 0.75 pound.  
 Weight of 1 belt with 100 cartridges: 83 pounds.  
 Weight of projectile: 0.37 pound.  
 Muzzle energy: 14.0 foot tons.

the gun. On the boss of the recoil arm is a firing cam as well as a face for the trigger rod depressor.

The percussion arm is also mounted on the crank bolt but can turn freely on it. It has a notch for the lug of the trigger rod and a head which, when the trigger is pressed, strikes against the hammer.

At their rear ends, both recoil arm and percussion arm have seatings for two pins, one the recoil spring pin and one the percussion spring pin on which the recoil spring and the percussion spring work. The springs are compressed between a spring base in the trigger plate and a collar on the spring pins.

The return spring is placed in the return spring housing. By means of the return spring plunger, the fore end of which rests against a seating on the back of the link, the return spring helps the recoil spring to brake the recoil of the movable portion after each round and to send the mechanism forward again.

### The Safety Device

The safety catch consists of a transverse bolt and catch. On the bolt, opposite the end of the trigger rod, is a radial collar which, when the catch is set at "S", engages under the end of the trigger rod and prevents it from being depressed, thus stopping the gun from firing.

### The Breechblock

On its lower right-hand side, the breechblock has a guide pin, and above at the rear it is drilled for the breechblock bolt on which the fore end of the block can swing up and down.

The breechblock track is in the right-hand side of the frame, and on its inner side has four cams which altogether form a track serving to guide the movements of the breechblock during the recoil and return action.

The guide pin rests between the two foremost cams of the breechblock track. When the round is fired, recoil begins. The barrel and the breechblock retain their mutual positions (that is, the chamber remains closed) until the guide pin strikes against the middle cam of the track. The ejector prevents the breechblock guide pin from running under the middle cam. The guide pin moves along a runway and the fore end of the breechblock is raised, whereby the chamber is opened. As the recoil proceeds the guide pin moves along another runway,

which keeps the breechblock raised and permits the empty case to be ejected.

When the guide pin has passed, the breechblock spring inserted in the frame cover will press the breechblock down, and as the recoil is simultaneously at an end and the return movement begins, the guide pin will slide along so that the chamber is open during the forward movement. In the course of the latter movement, the cartridge is fed into the chamber, which is closed by the movement of the breechblock. During the final part of the forward movement, the guide pin is carried back to the starting point between the two foremost cams.

The breechblock is drilled longitudinally for the firing pin; when the chamber is closed by the breechblock, the whole is in alinement with the percussion cap.

On its fore end the hammer has a face which rests against the firing pin, which projects a little way out of the rear end of the breechblock; the rear part of the hammer serves as an anvil for the percussion arm. When the latter is released by a pressure on the trigger, it strikes the hammer which transmits the blow to the firing pin and through it to the percussion cap.

### The Feeding Mechanism

The cartridge feeding mechanism consists of the feeder house, which is comprised of the feed funnel cab with its dividing pawl and stop pawl, feed funnel and slide with spring driving pawl and right and left stop pawls, cartridge distributor, cartridge-hook stop block, cartridge hook, and cartridge feeder.

A cartridge belt can be fixed to the feed funnel on the frame in such a manner that the stop pawls engage under the first cartridge and prevent it from sliding downward. The slide with its spring driving pawl has on its inner side a pin which moves in an oblique track on the left side of the breech, so that during the recoil movement it moves downward, moving upward again during the return movement. This draws the cartridge belt upward, and the stop pawls prevent it from sliding down again, in order that the driving pawl of the slide can reach the next cartridge in the belt when the slide moves down. The dividing pawl directs the cartridge while it is being drawn from the belt and during its introduction to the chamber. The cartridge distributor



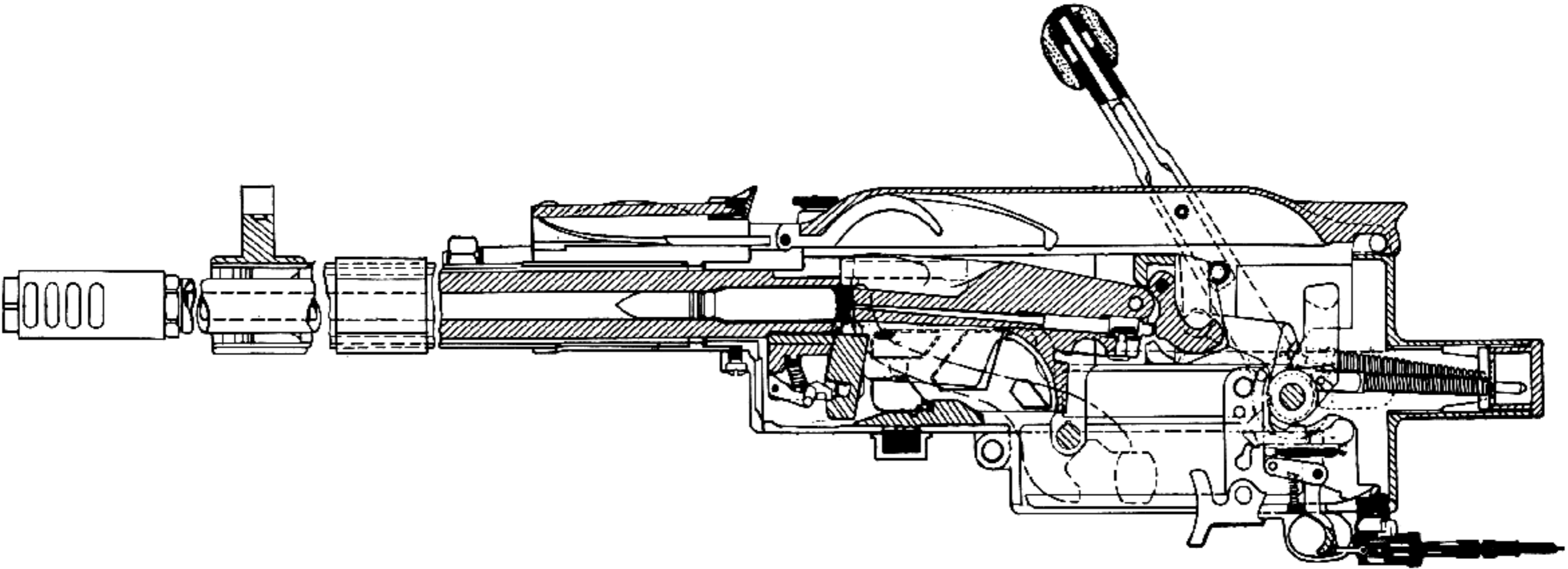


Figure 23-3. 20-mm Madsen Cannon. Longitudinal sectional view.

presses the cartridge into the breech with its forward-pointing arm.

The cartridge hook, which works on the left side of the breech, engages the flange of the cartridge and draws it back during the recoil movement. At the moment the cartridge hook strikes against the stop block the cartridge is released, the cartridge hook being pressed into the breech by the stop block, thus disengaging it from the cartridge flange, and the spring pawl on the stop block throws the cartridge forward into the cartridge seating in the breechblock.

The cartridge feeder is a three-armed lever working on the cartridge feeder bolt placed between the two lower flanges of the breech, so that it works between the left side of the breechblock and the wall of the breech, which is cut away to receive the cartridge.

The cartridge feeder is actuated by the passing of the two short arms over the cartridge feeder block, which is placed in the trigger plate, whereby its long arm moves forward during the return action and pushes the cartridge into the chamber. During the recoil, the long arm of the cartridge feeder is turned back so far that it comes behind the next cartridge placed into the breech by the cartridge distributor and, under the pressure of the cartridge feeder and the spring pawl of the cartridge stop block. This positions the incoming cartridge and seats it first in the breechblock and then in the chamber.

The cartridge opening in the left side of the breech is so placed that only when the breech is in

its rearmost position does it give access to the cartridge released from the cartridge hook.

### Ejector Mechanism

The ejector mechanism consists of the ejector, ejector pawl, and ejector pawl spring which is placed in the forward lower part of the breech, and the ejector block on the bottom of the frame.

When the movable portion moves backward, the ejector is raised, gliding up the forward ramp of the ejector block. It is retained in the vertical position by the ejector pawl, the nose of which engages in the notch in the ejector; when the ejector has moved up the ramp, its claw moves up in front of the cartridge flanges. Simultaneously, the breechblock is raised as already described, and by means of a ramp on the ejector block, the ejector pawl is so lifted that the ejector is released.

While the breechblock is up, the rear lower corner of the ejector trips against an upright edge on the ejector block so that it is thrown backward and lies flat. By this movement the claw of the ejector extracts the cartridge case, which follows the ejection-way of the breechblock and is thrown out through a hole in the bottom of the trigger plate. During the return action of the movable portion, the breechblock, which is then in its lowest position, will keep the ejector in its recumbent position; but when the breechblock moves up into the firing position, the ejector is released; the ejector pawl, actuated by the ejector pawl spring, will then move the ejector into its vertical position again.

## SECTION 3. CYCLE OF OPERATION OF THE 23-MM AUTOMATIC AIRCRAFT CANNON

### Loading

To load, the gunner inserts the cartridge belt into the feedway until the stop pawls engage under the first cartridge, then loads the gun by performing two loading movements.

During the first movement, when the gunner draws the crank back, the slide with its withdrawing pawl moves down and catches the first cartridge. When the crank moves forward, the slide moves up again and moves the cartridge belt over with it; the stop pawls engage under the second cartridge in the belt; the dividing pawl is pressed up and out by the

first cartridge; the cartridge hook comes forward and seizes the rim of the first round.

During the second loading movement, when the gunner draws the crank back, the cartridge hook draws the first cartridge back (that is, out of the cartridge link and in behind the cartridge distributor, which presses it in toward the cartridge way in the left side of the breech); the dividing pawl, which is now free, springs forward; the slide moves down again, and the driving pawl moves in under the second cartridge; the cartridge hook, just before the movement comes to an end, is pressed back by the

stop block on the side of the frame, whereby the first cartridge is set free; the cartridge distributor presses the cartridge in toward the middle of the gun, in front of the cartridge feeder which is then in its rearmost position; the spring pawl of the stop block at the same time throws the cartridge forward a little.

When the crank moves forward, the cartridge feeder pushes the cartridge into the chamber, while the dividing pawl insures that the point of the bullet is in the right direction; the slide moves the cartridge belt up, and another cartridge is thus ready to be drawn back by the cartridge hook, which then engages its flange.

## Firing

*Single-Shot Firing.* Set the change-over switch at "E."

Every round is fired by a separate pressure on the trigger. A pressure on the trigger forces the trigger back so far that it strikes against the changeover switch, whereby the forward-pointing arm of the trigger draws the trigger rod depressor down by means of its hook. The trigger rod depressor draws down the trigger rod, disengaging the trigger rod lug from the notch of the percussion arm. The percussion arm, under the influence of the percussion spring, strikes against the hammer, which transmits the stroke to the firing pin, thus firing the round.

The recoil takes the movable portion back. During this movement, the breechblock guide pin glides in the breechblock track, whereby the breechblock is raised, the firing pin being withdrawn prior to this movement. Furthermore, the empty case is ejected and the cartridge feeder is turned to its rearmost position, while the cartridge hook releases the cartridge which has been placed in front of the cartridge feeder by the cartridge distributor. At the same

time, the slide moves down and catches the next cartridge.

The recoil arm and percussion arm are pressed back by the movable portion, which at the same time compresses the return spring, recoil spring, and percussion spring. During the final part of the movement of the recoil arm, the firing cam points forward, whereby the trigger rod depressor is pressed forward and its hook is disengaged from the trigger rod, which is then forced by its spring so that its lug engages in the notch of the percussion arm, which is then prevented from striking.

When the movable portion has gone right back, the recoil spring and return spring press it forward again. During the forward movement, the breechblock moves down, and when it reaches its lowest position, the cartridge feeder will feed a cartridge into the chamber; this completed, the breechblock moves up and closes the chamber. The ejector, which during the final part of the recoil and the first part of the return movement has laid flat, will be raised by the ejector pawl during the last part of the return movement. The slide lifts the cartridge belt up and the cartridge hook seizes the flange of the next cartridge.

*Automatic Firing.* For automatic firing, the gunner will turn the changeover switch to "A," which means that it is so turned that the trigger is not restricted in its action.

When the trigger is forced back, its upward-pointing arm moves farther forward than in single-round firing. The upward-pointing arm is accompanied by the sliding pawl which is carried farther forward, the result being that the firing cam of the recoil arm presses on the sliding pawl during the end of the movement. The sliding pawl, and with it the trigger rod, are pressed down, and the round is fired.

## Chapter 24

## KRIEGHOFF EXPERIMENTAL CANNON

## SECTION 1. HISTORY AND BACKGROUND

During World War II, the Krieghoff Waffenfabrik, of Suhl, Germany, devoted its time mainly to the production of the Parabellum (Luger) pistol. (See volume 1, pp. 310-311.) This company turned out large quantities of the famous weapon and the management took great pride in stating that the workmanship was of better construction than the well-known Oberndorf product.

## 7.92-mm FG-42

Early in World War II, the Krieghoff establishment was given the job of designing and producing a weapon to arm airborne infantry, a method of warfare that had never been attempted before this time. The specifications laid down demanded an extremely light-weight weapon employing the standard 7.92-mm cartridge and having a high rate of

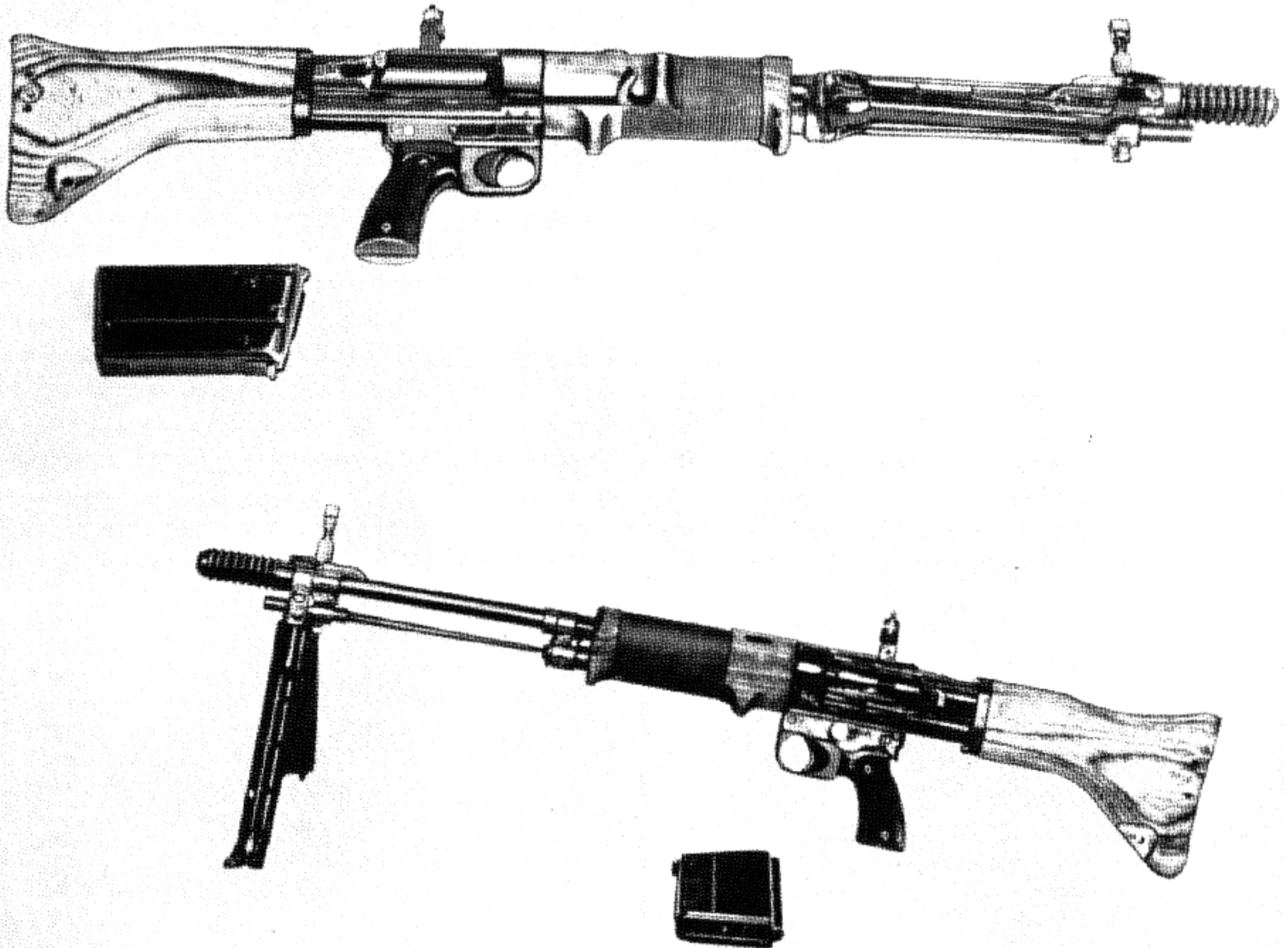


Figure 24-1. Machine Gun, 7.92-mm Model FG-42.

fire if needed but, if the occasion demanded, capable of firing single shot with the accuracy of an infantry rifle. The result of this order turned out to be one of the outstanding ordnance accomplishments of the Germans in World War II, and the finished product was given the official designation of 7.92-mm FG-42. The letters represent the initials of the Fallschirm Jaeger Gewehr (paratroop machine gun), and the numerals indicate the year of adoption. Shortly after the gun had been issued, the Germans used it in the invasion of Crete. This

was the first time a military objective had been taken by soldiers parachuted from troop-carrying planes and the FG-42 played no small part in the success of the campaign. The FG 42 was a gas-operated, rotating form of lock, air-cooled, bipod-supported weapon that had an unusually large ventilated forearm grip. The overall weight of the gun was only 14 pounds with bipod and loaded clip that held 20 rounds. (See volume 1, pp. 489-491.)

For an American light machine gun developed from the FG-42, see this volume, chapter 14, pp. 423-433.

## SECTION 2. DEVELOPMENT OF A UNIQUE LOCKING SYSTEM IN VARIOUS CALIBERS

### General Description

Before World War II the Krieghoff company had in the development stage a gun design with a unique feature of locking by means of cams cut in the receiver sides to raise and lower the lock. This feature was incorporated into guns of various calibers ranging from 7.92-mm to 30-mm.

These weapons are all gas-operated, cam-locked, air-cooled, belt-fed aircraft machine guns and cannon. The receivers are fabricated by welding. The top of the receiver is open to accommodate the feed tray, which is held in the receiver by the feed assembly. The rear of the receiver has vertical slots cut to mate with the projection on the sides of the backplate. In the inner front sides of the receiver are two rollers that engage the cam track and support the slide assembly.

The first of this series was a 20-mm experimental aircraft cannon, and it is believed by many ordnance technicians that it was designed as early as 1938 and that all other experimental models of similar

design are direct outgrowths of this 20-mm 1938 version. The translation of a German report which follows describes the action of these weapons regardless of the caliber.

### Description of Components

*Receiver Housing.* The receiver is of fabricated welded construction and houses the barrel, barrel-recoil springs, slide assembly, drive spring, guide rod and rear buffer, and scar assembly. The barrel charging assembly is fixed on the left side of the receiver. The slide charging assembly is at the bottom front of the housing. The feed assembly and the tube lock assembly are hinged to the receiver. The top of the receiver is open to accommodate the feed tray, which is held in the receiver by the feed assembly. The inner sides of the receiver have longitudinal slides cut to mate with the projections on the rear of the slide assembly. The rear of the receiver has vertical slots cut to mate with the projections, or lands, on the sides of the backplate. In

#### General Data: 20-mm Krieghoff Experimental Aircraft Cannon

Gun length, with muzzle brake in barrel: 126 inches.  
 Gun weight: 114 pounds.  
 Rate of fire: 600-700 rounds/minute.  
 Muzzle velocity: 2,850 feet/second.  
 System of operation: Gas piston actuated.  
 System of locking: Pivoting lock.  
 System of feeding: Actuated by bolt extension.  
 Method of headspace: Factory established.  
 Location of feed opening: Top right side of receiver.  
 Location ejection opening: Bottom.  
 Method of charging: Electropneumatic.  
 Method of cooling: Air.

Barrel length: 89 inches.  
 Barrel weight: 47 pounds.  
 Rate control: None.  
 Barrel removal: Quick disconnect.  
 Bore:  
 Number of grooves: 9.  
 Groove depth: 0.015+0.002 inch.  
 Groove width: 0.205+0.010 inch.  
 Pitch: 7° (equals 1 turn in 25.587 calibers and 1 turn in 20.137 inches).  
 Direction of twist: Right hand.  
 Form of twist: Constant.

the inner front sides of the receiver are two rollers which engage the cam track and support the slide assembly.

*Barrel, Breech Ring and Breechblock.* The barrel has to be assembled to the receiver from the rear. The barrel is held to the breech ring by interrupted threads. The barrel is prevented from rotating from the locked position by a retaining lug in the breech ring. This retaining lug is engaged by the receiver tube retainer which, when pulled out, allows the tube to be unlocked, leaving it free to rotate for disassembly. The barrel and breech ring are held in the receiver by a retaining sleeve, which is threaded onto the barrel after assembly in the receiver. The retaining sleeve bears against the upper section of the gas cylinder which, in turn, bears through another sleeve against the barrel recoil spring housed in the receiver. The breech ring bears against a collar in the receiver, preventing the barrel from escaping in the forward direction. The rear of the recoil spring bears against the front of the same collar. The barrel has a port through which gases escape to the gas cylinder to operate the slide assembly. The barrel is equipped with a muzzle brake.

The breechblock, which is of the vertical sliding type, does not cover the entire base of the cartridge case. The breech is open when the block is in the "up" position and closed when the block is in the "down" position. There are two rollers on the inside of the block, which ride in the cam track of the slide assembly to raise and lower the block. The firing pin is spring-loaded in the retracted position. It is actuated by the pin in the block, which in turn is operated by the pin in the ring. The gun fires

on counterrecoil. As it is driven forward, the firing pin cam in the receiver is struck by the pin in the ring which operates the pin in the block; thus the firing pin is driven forward. During recoil, the receiver firing pin cam overrides the breech pin.

*Slide Assembly.* The slide assembly has at its forward end a gas-operated piston which drives the slide rearward during the firing cycle. The sides of the slide have cam tracks in which ride two sets of rollers. One set is secured to the breechblock and functions to close and open the breech. The other set is secured to the receiver and acts as a guide to support the front of the slide in its movements. At the rear of the slide assembly are 2 projections, 1 on each side, which ride in the slides of the receiver, supporting and guiding the rear of the slide. At the top rear of the slide is the feed operating cam, which engages the feed cam to operate the feed assembly on recoil of the slide assembly.

The rammer block is held in its forward position by the rammer-block spring and is locked in that position by the rammer-block lock. The lock is depressed by the breech ring when the round is rammed; this releases the rammer block so that the slide continues forward, compressing the rammer block spring. The rammer head is fixed to the rammer block. The extractor is pivoted at the rear of the rammer block and is spring loaded to hold it in the "up" position. The extractor has two cam surfaces which bear against the extractor operating cams on the feed tray, forcing the extractor down when the empty case is being reinserted into the link. The rammer block is buffered front and rear by banks of flat springs.

#### General Data: 30-mm Krieghoff Experimental Aircraft Cannon

<p>Gun length: 116 inches.            Gun weight: 390 pounds.            Rate of fire: 400-600 rounds/minute.            Muzzle velocity: 2,850 feet/second.            System of operation: Gas piston actuated.            System of locking: Sliding block.            System of feeding: Metallic link.            Method of headspace: Factory established.            Location of feed opening: Top left.            Location ejection opening: Top right; expended case is placed back into link.            Method of charging: Electropneumatic.            Method of cooling: Air.</p>	<p>Barrel length: 57 inches.            Barrel weight: 88 pounds.            Rate control: None.            Barrel removal: Not quick disconnect.            Bore:              Number of grooves: 20.              Groove depth: 0.02945 inch.              Groove width: 0.01692 inch.              Pitch: 2°30'.              Direction of twist: Right hand.              Form of twist: Constant.</p>
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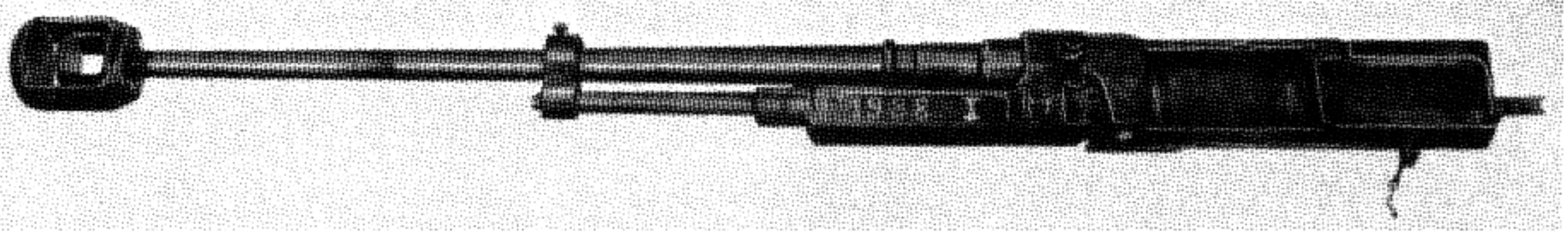


Figure 24-2. Early version of Krieghoff Experimental 20-mm Aircraft Cannon. Assembled view.

*Feed Assembly.* The feed assembly is hinged to the receiver and contains the mechanism for feeding and disintegrating the linked belt after the empty case is reinserted into the links. The feed cam is pivoted by means of a pin secured to the cover and is spring-loaded by a leaf spring. The feed pawl is spring-loaded so that the links will depress it on the return stroke. It slides in ways and is driven by the other end of the feed cam, which lies in a longitudinal slot of the feed pawl support. A lever which actuates the holding pawls projects from the face of this longitudinal slot.

As the feed cam arm is operated, the arm contacts the lever and the holding pawls are drawn down to permit the feed pawl to place the next link and

round in line for ramming. Belleville springs absorb some of the feed shock. A holding pawl keeps the links stationary on the return stroke of the feed pawl. The feed body has transverse grooves machined in it to guide and support the links as they are fed through. A link disintegrating cam is set in the rear grooves to drive the link disintegrating pin. This pin in turn drives the other two connecting pins, so that the connecting hinges are no longer pinned together, and the links part.

*Barrel Lock and Buffer Assembly.* The barrel lock and buffer assembly is hinged to the receiver. The barrel lock is pinned at one end and spring loaded to hold it in the "down" position when assembled. The barrel lock buffer absorbs the force

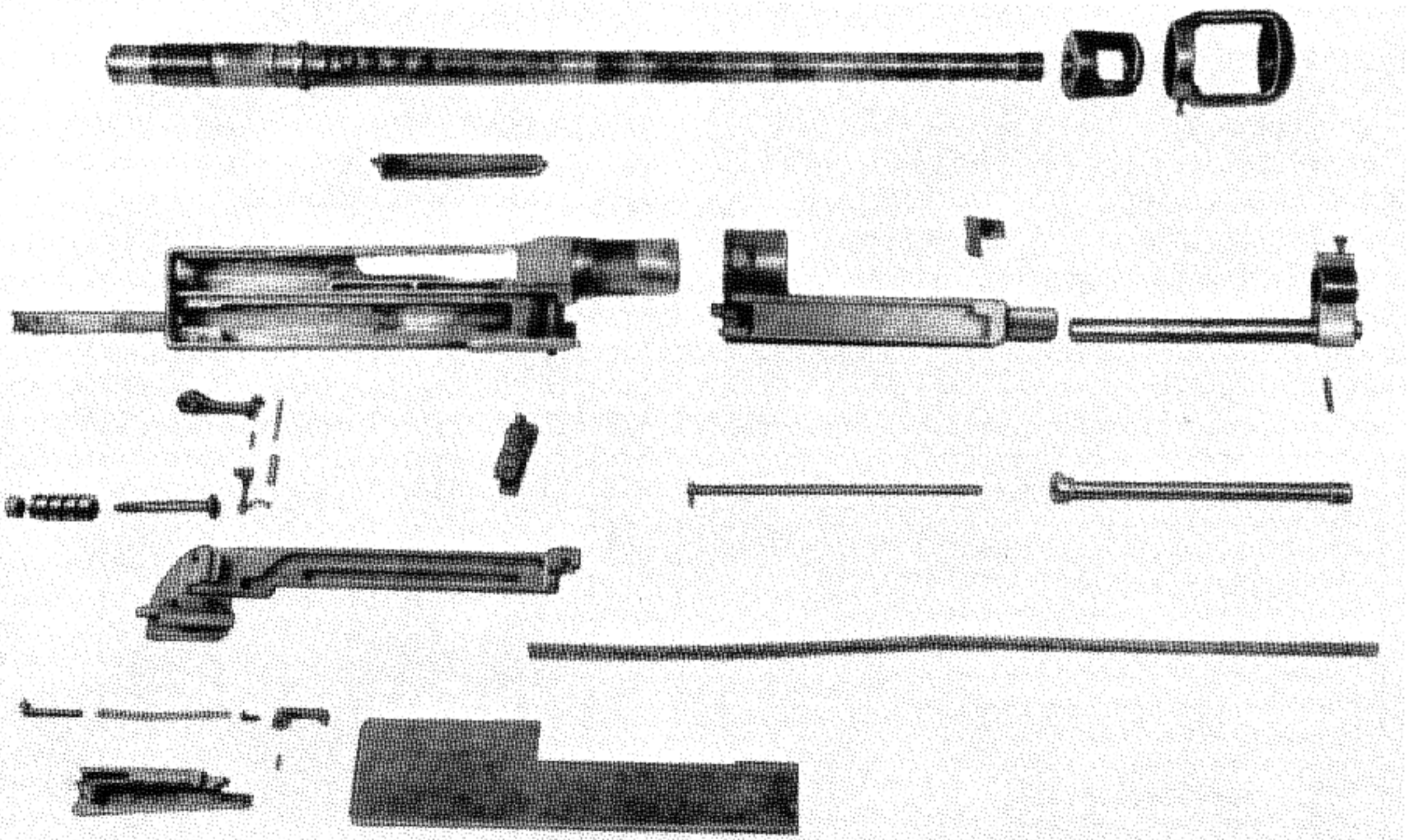


Figure 24-3. Early version of Krieghoff Experimental 20-mm Aircraft Cannon, completely disassembled.

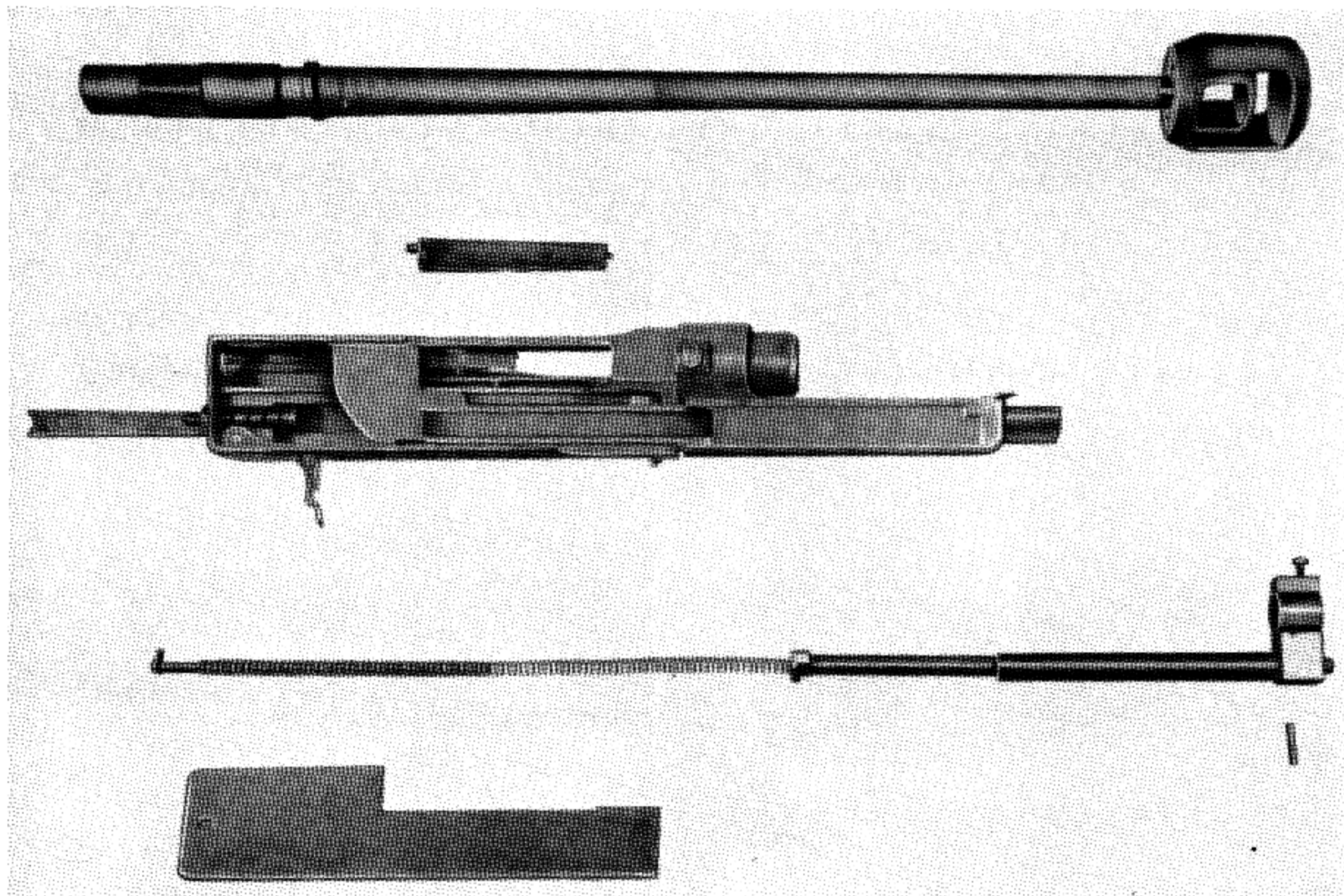


Figure 24-4. Early version of Krieghoff Experimental 20-mm Aircraft Cannon, partially disassembled.

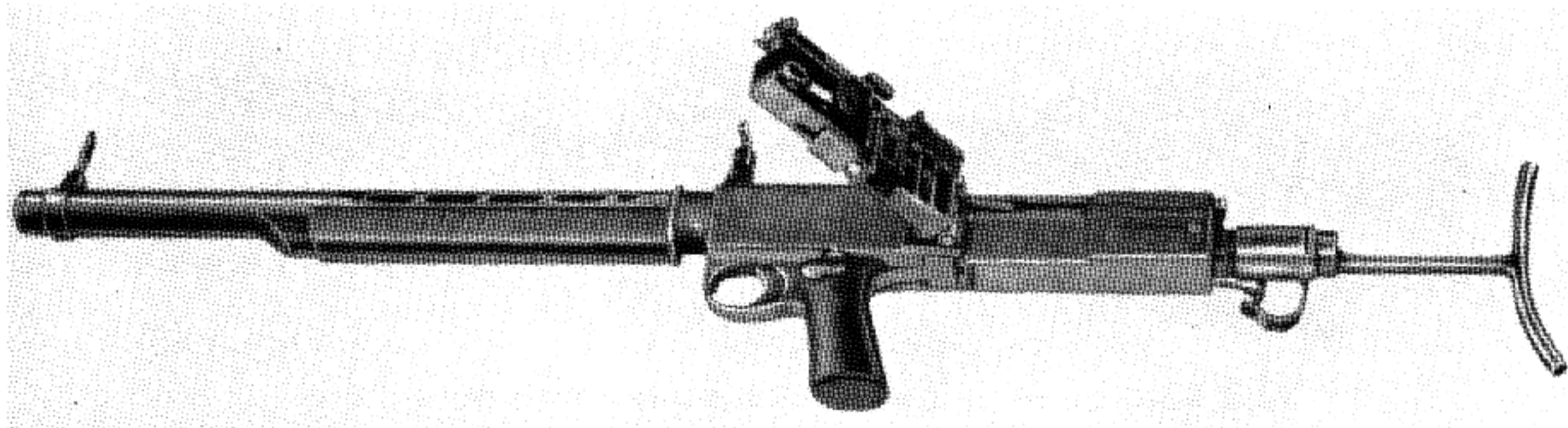


Figure 24-5. Krieghoff Experimental Aircraft Machine Gun, 7.92-mm Model 1940, with feed open.



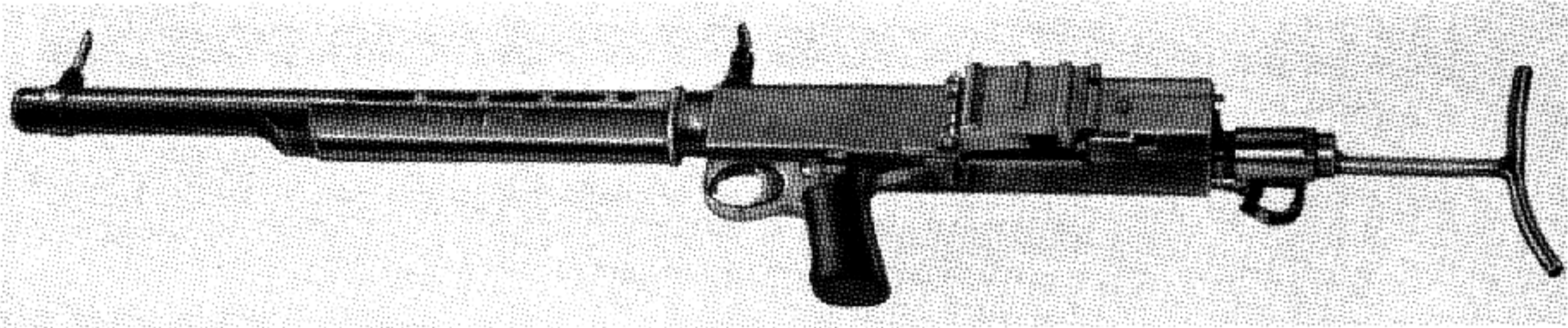


Figure 24-6. Krieghoff Experimental Aircraft Machine Gun, 7.92-mm Model 1940. Right side view.

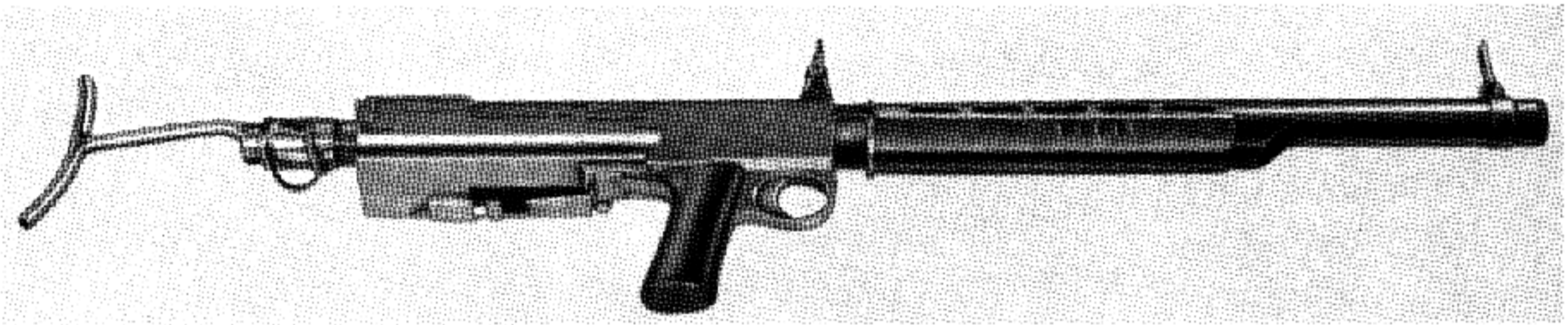


Figure 24-7. Krieghoff Experimental Aircraft Machine Gun, 7.92-mm Model 1940. Left side view.

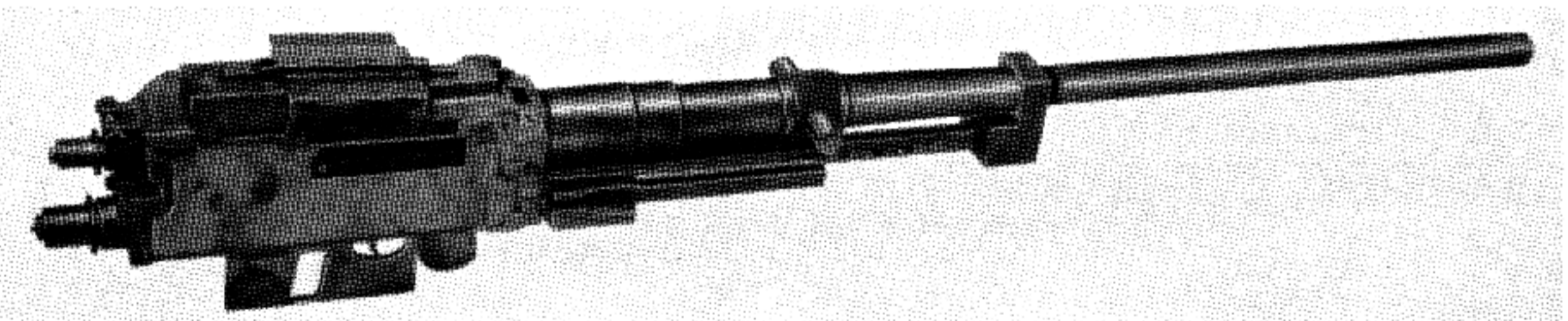


Figure 24-8. Second version of Krieghoff Experimental 20-mm Aircraft Cannon.

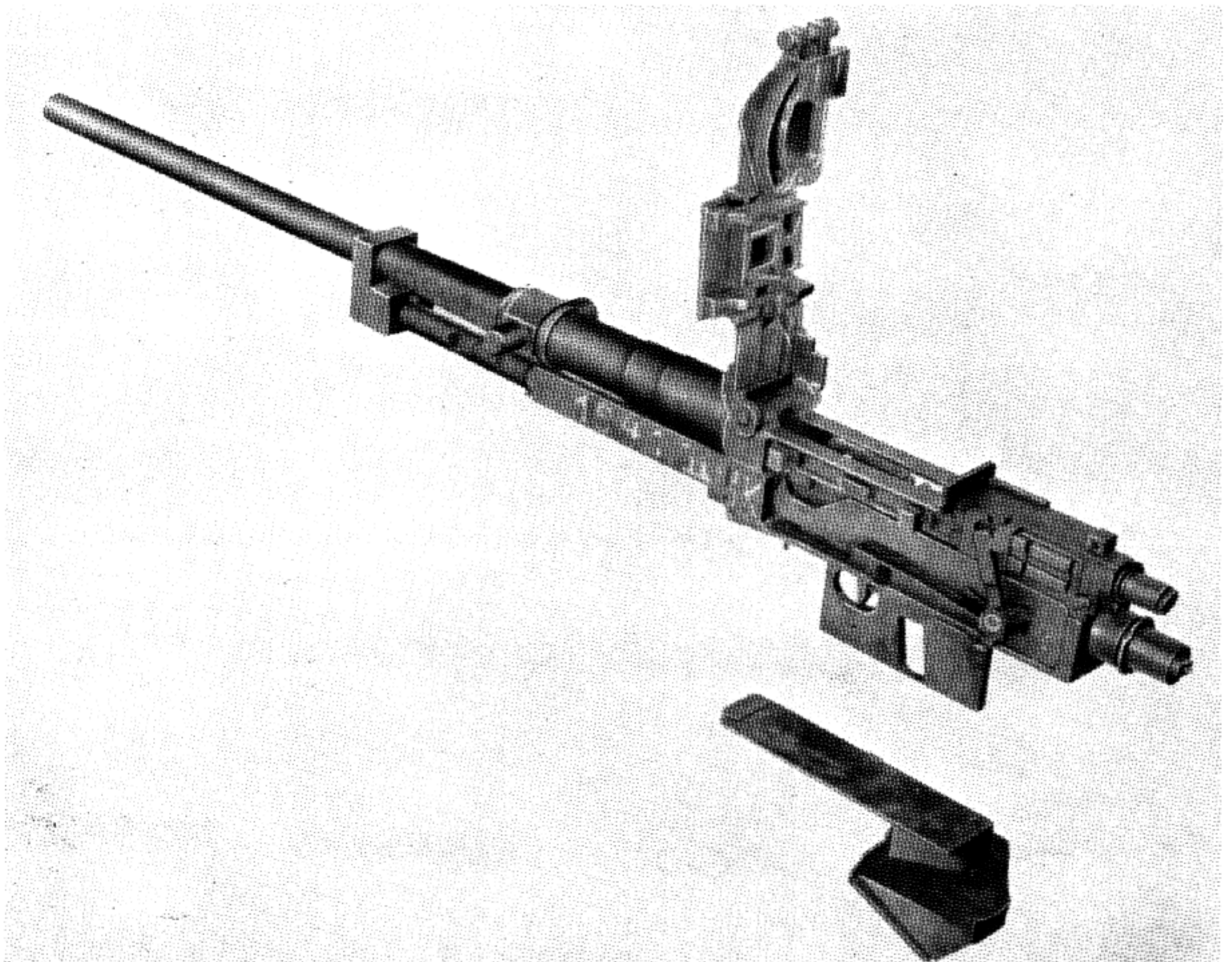


Figure 24-9. Second version of Krieghoff Experimental 20-mm Aircraft Cannon, with feed open.

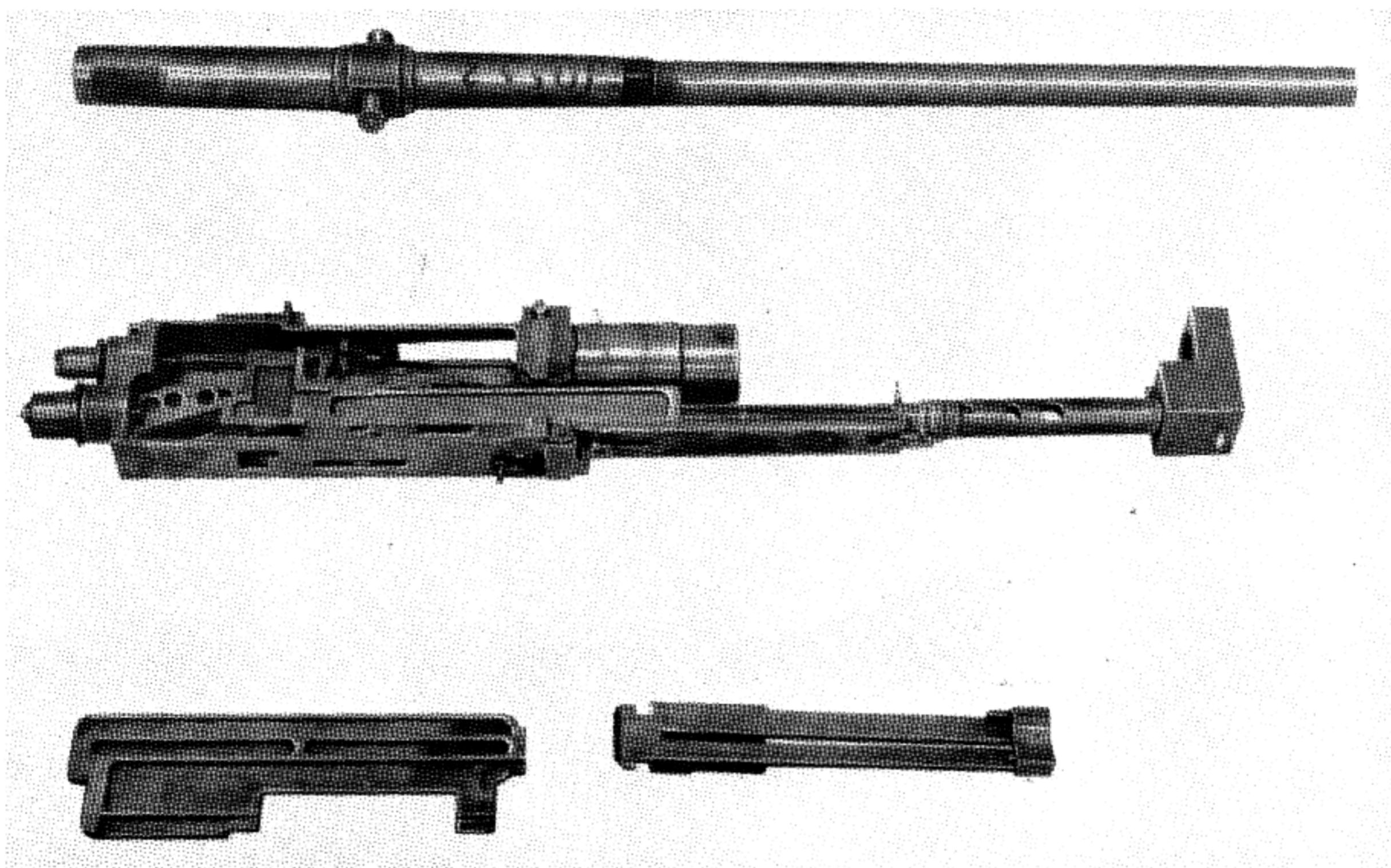


Figure 24-10. Second version of Krieghoff Experimental 20-mm Aircraft Cannon, partially disassembled.

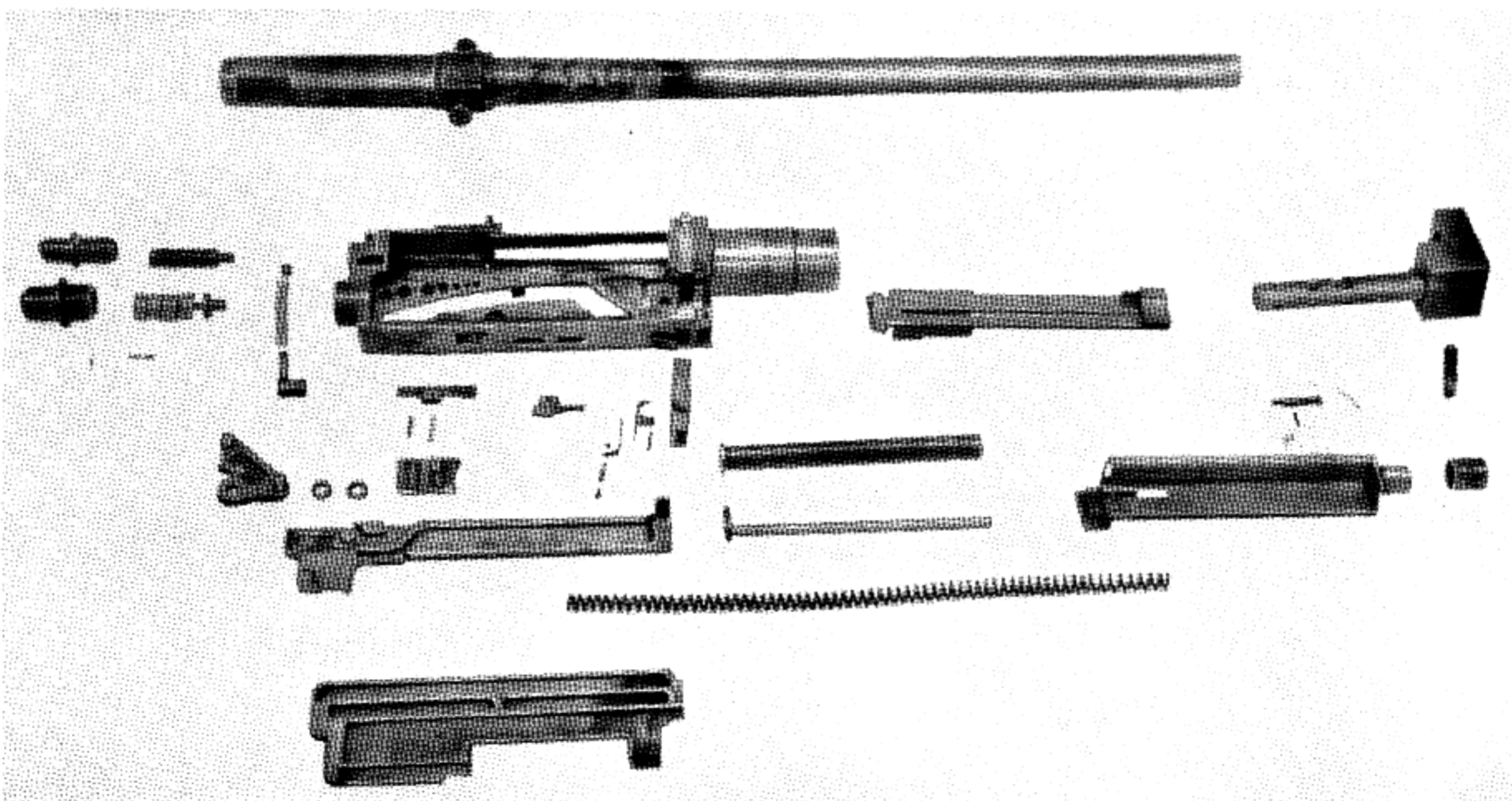


Figure 24-11. Second version of Krieghoff Experimental 20-mm Aircraft Cannon, completely disassembled.

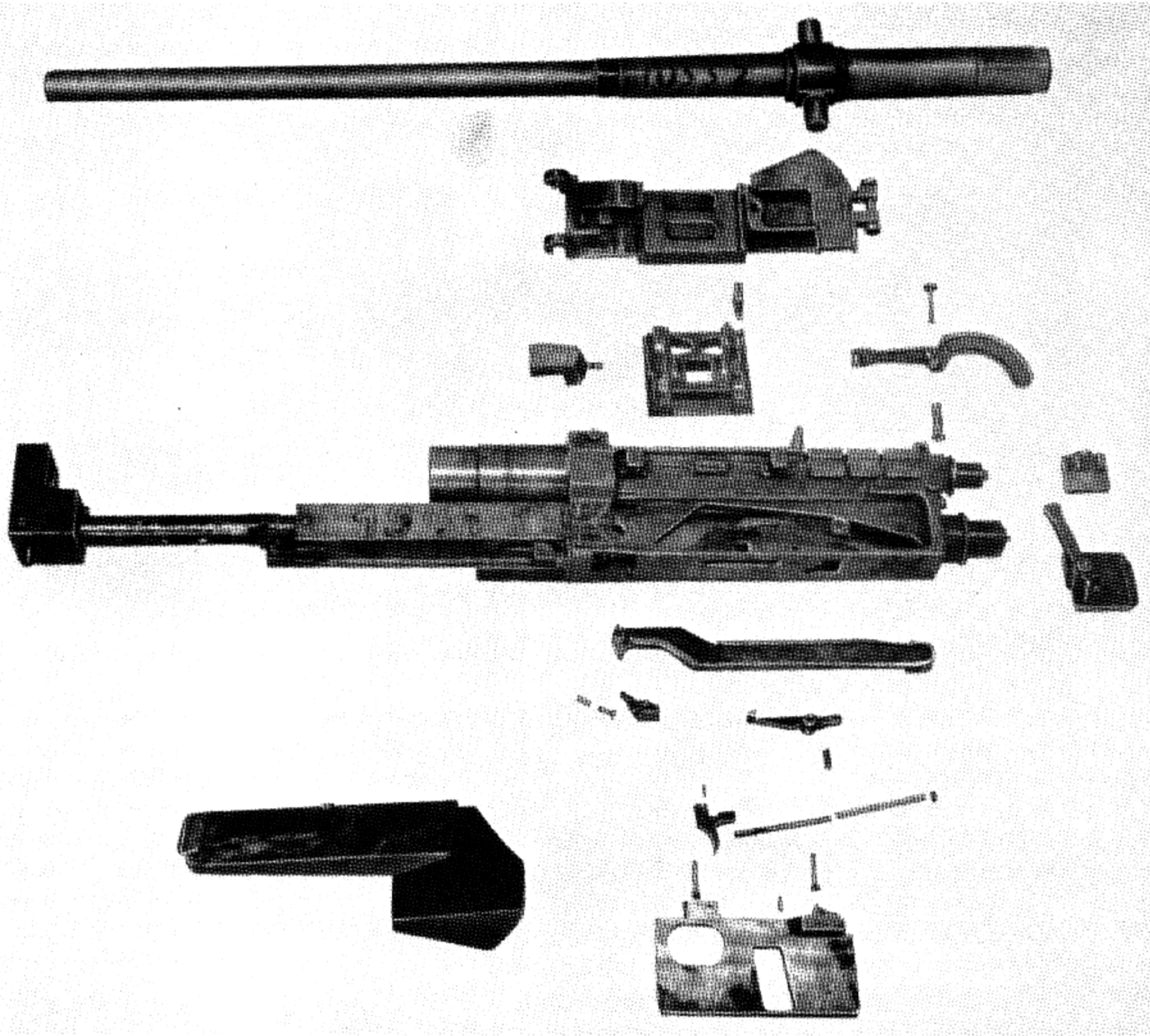


Figure 24-12. Second version of Krieghoff Experimental 20-mm Aircraft Cannon. Exploded view of feed elements.

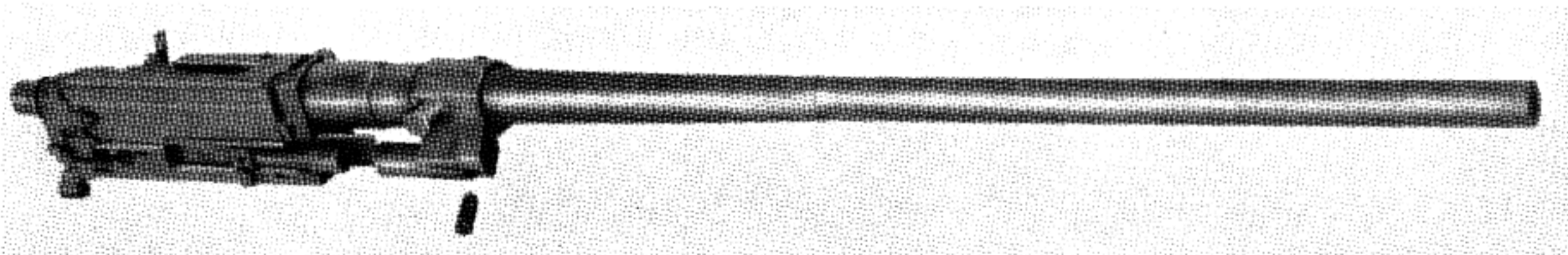


Figure 24-13. Third version of Krieghoff Experimental 20-mm Aircraft Cannon.

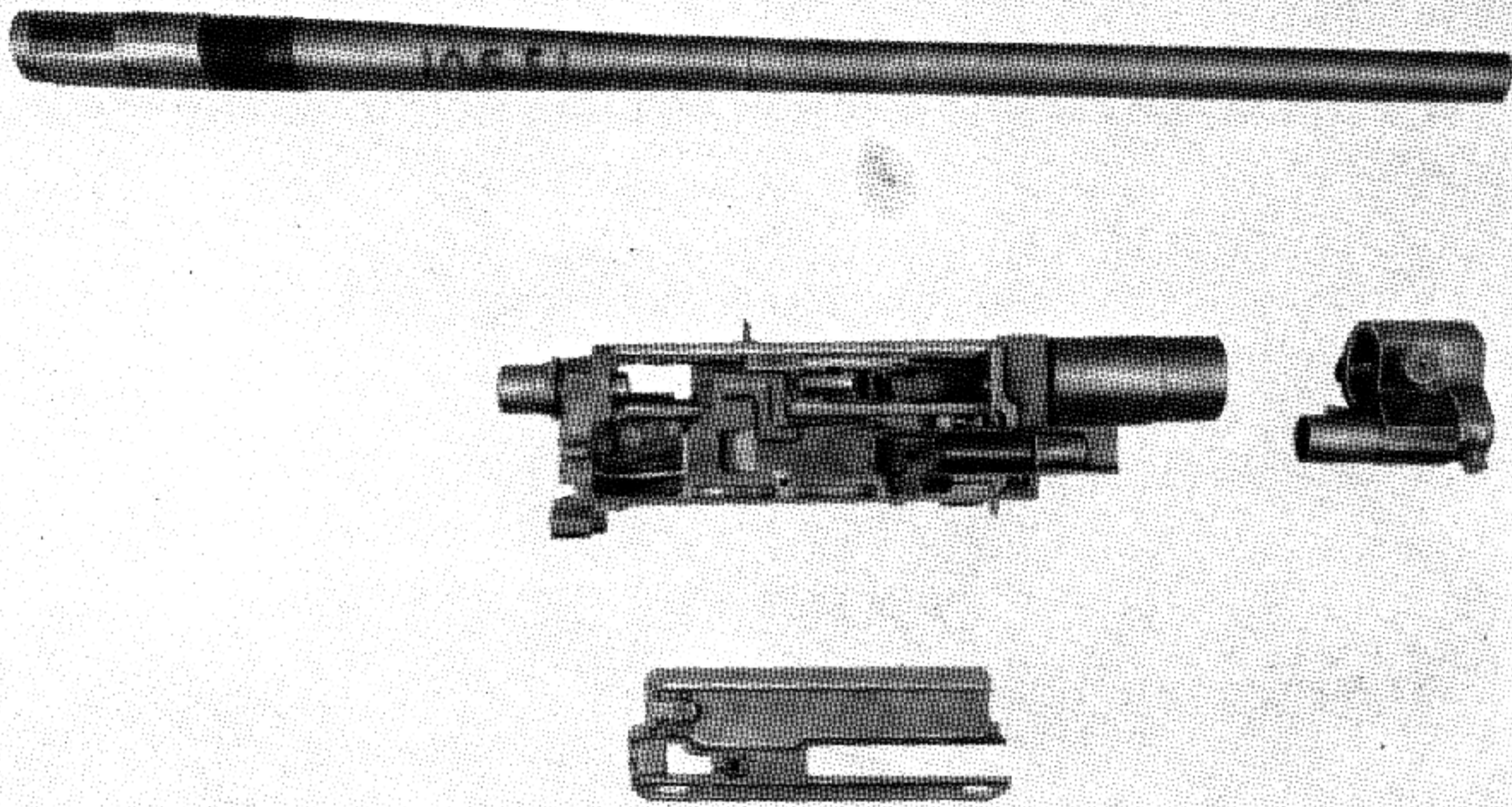


Figure 24-14. Third version of Krieghoff Experimental 20-mm Aircraft Cannon, partially disassembled. Right side view.

of the recoil springs as they attempt to return the barrel to firing position, and the open breechblock is engaged by the barrel lock.

*Feed Tray.* The feed tray, which guides the linked ammunition belt, has a longitudinal slot to permit the rammer to project up to contact the rounds. At the rear of the tray are two extractor cams which engage the extractor and lower it to enable the extractor to release the empty case after reinserting it into the link.

## Operation

*Charging.* After the feed belt has been inserted into the feedway, compressed air is admitted to the front of the slide charging cylinder and the piston is driven rearward. The rod engages the slide assembly and it is forced rearward, compressing the drive spring until the sear engages the slide assembly. Compressed air is also admitted to the barrel charging cylinders. These cylinders (two in number) have a catch which engages a depression in the breech ring through a slot in the left side of the receiver. As the air is allowed to enter the charger, the breech ring and barrel are driven rearward by the catch, and the raised breechblock engages and raises the barrel lock. Further rearward movement

allows the breechblock to clear the lock, and the lock snaps down and engages the front face of the raised breechblock, which holds the barrel rearward against the force of the compressed barrel recoil springs.

*Cycle of Operation.* After the feed belt has been inserted into the feedway and the gun charged it is ready for automatic firing. The trigger mechanism is operated; and by means of a lever system in the backplate, the sear is depressed, allowing the slide assembly to be driven forward by the compressed drive spring. The feed cam and feed pawl are returned by force of the leaf spring to their original position. The holding pawl prevents the links from being retracted from the feedway by the returning feed pawl. As the rammer head approaches the feed tray, the extractor is lowered by its cam and contacts the extractor cams on the feed tray. The rammer head contacts the base of the round and strips it from the link. The extractor, no longer held down by the extractor cams, is forced up by its spring and the lip of the extractor engages the rim of the cartridge case. The round is rammed into the chamber.

During the final movement of the round entering the chamber, the rammer-block lock is depressed by

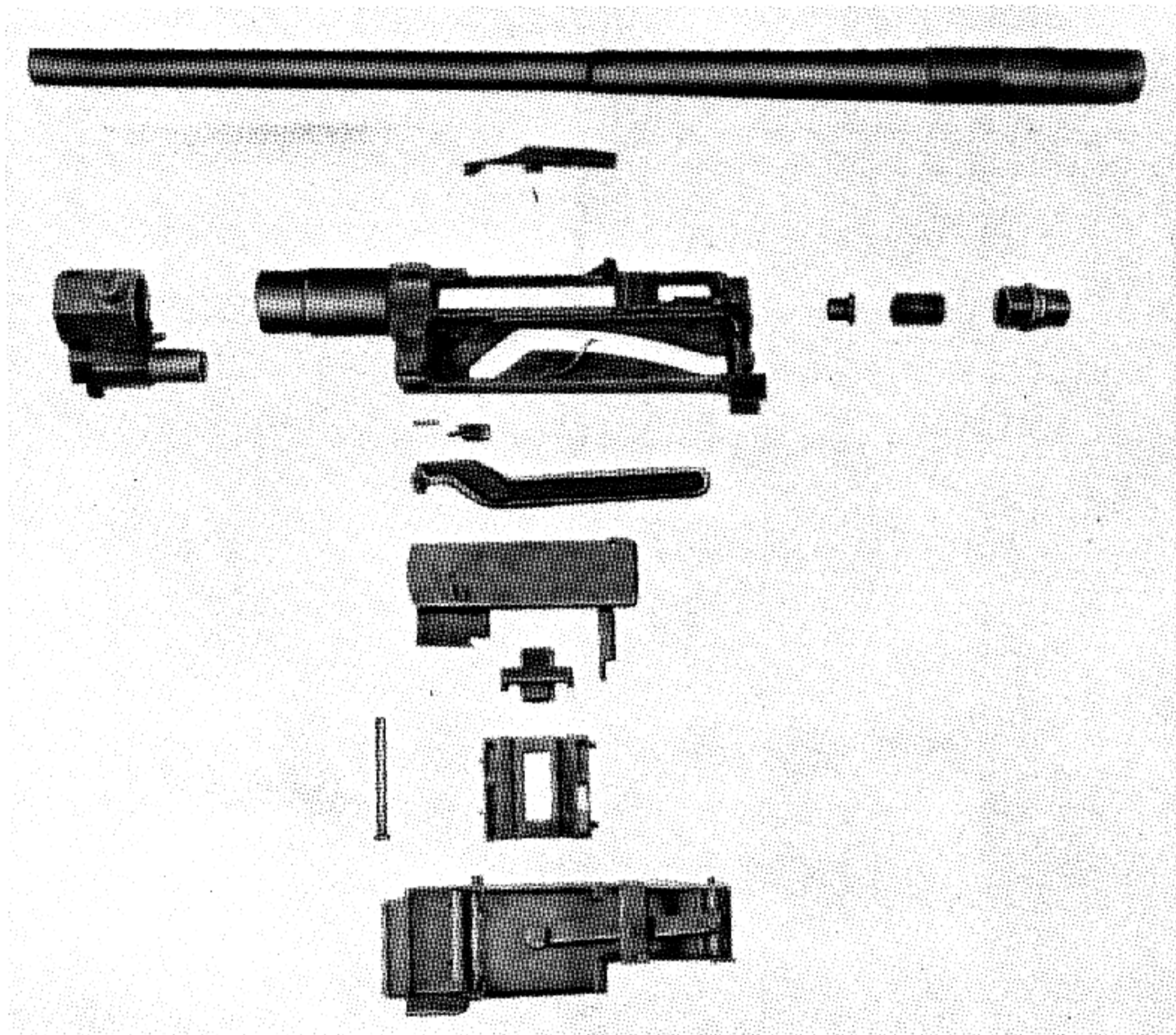


Figure 24-15. Third version of Krieghoff Experimental 20-mm Aircraft Cannon, completely disassembled. Left side view.

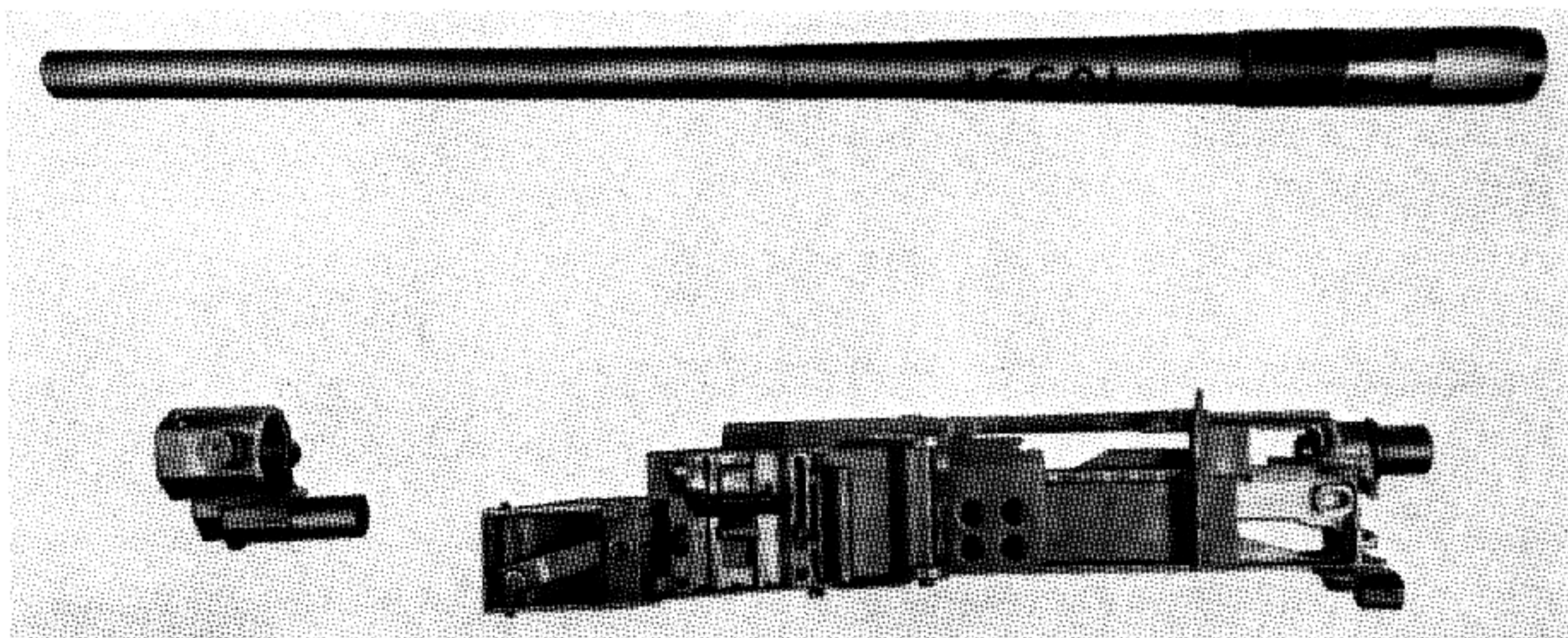


Figure 24-16. Third version of Krieghoff Experimental 20-mm Aircraft Cannon, partially disassembled.

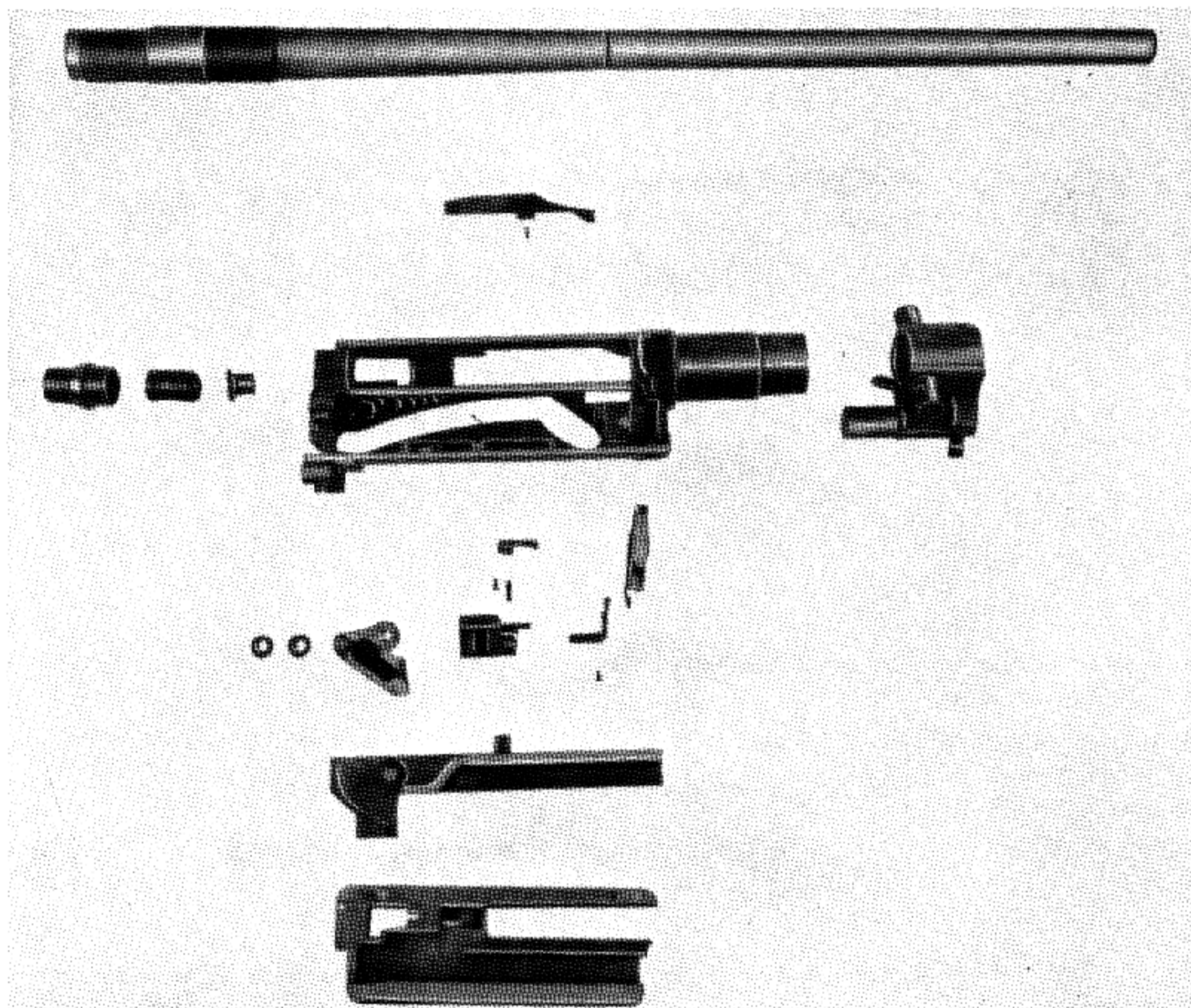


Figure 24-17. Third version of Krieghoff Experimental 20-mm Aircraft Cannon, completely disassembled. Right side view.

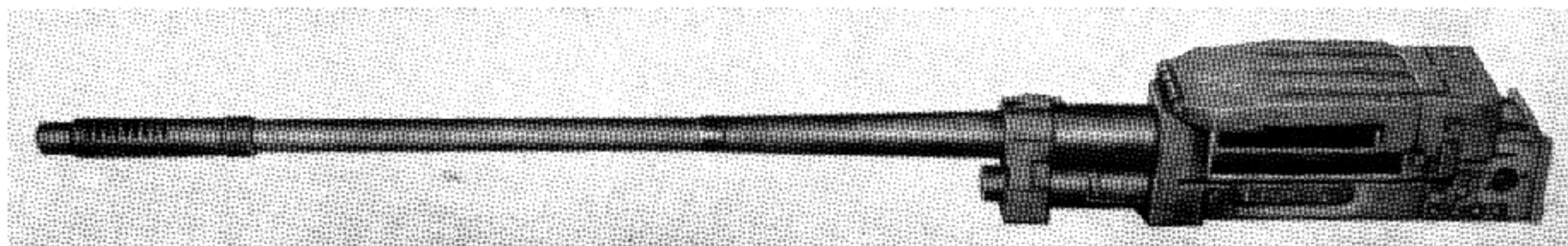


Figure 24-18. The final version of Krieghoff Experimental 20-mm Aircraft Cannon. This design was later scaled up to 30-mm.

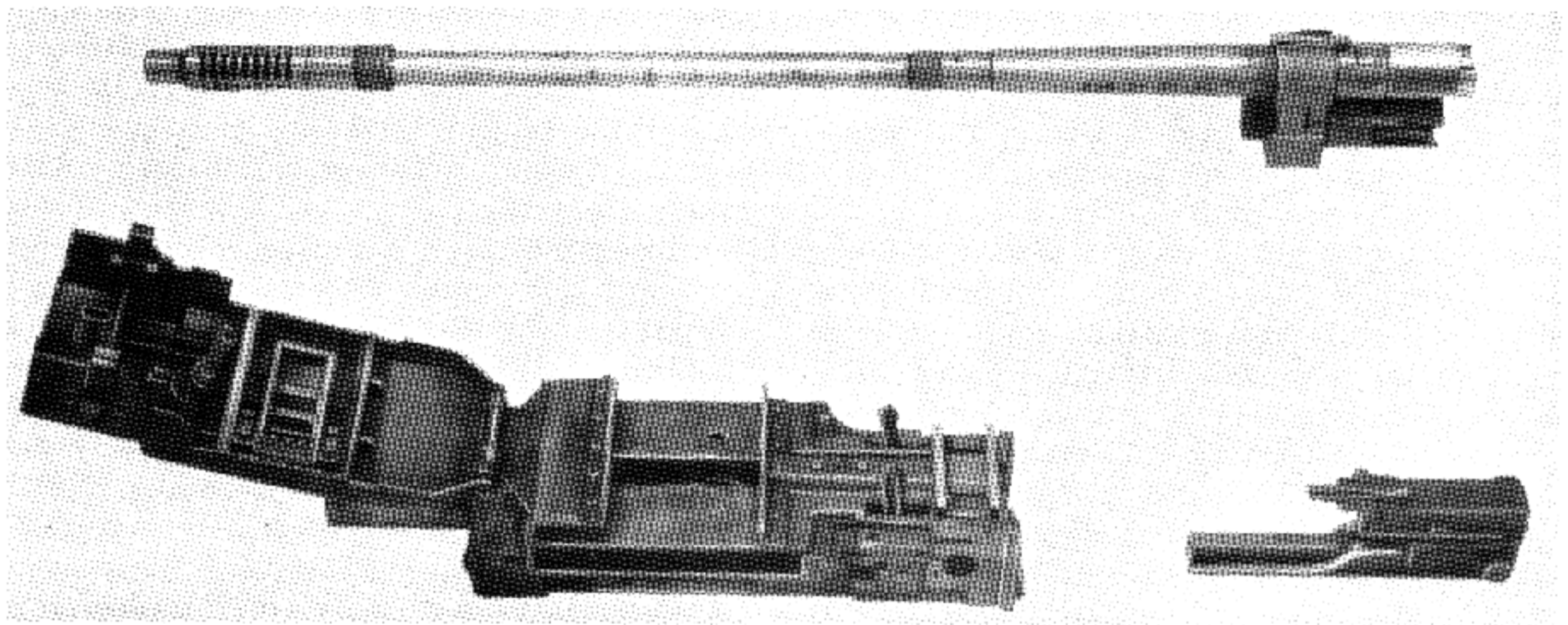


Figure 24-19. Final version of Krieghoff Experimental 20-mm Aircraft Cannon, partially disassembled.

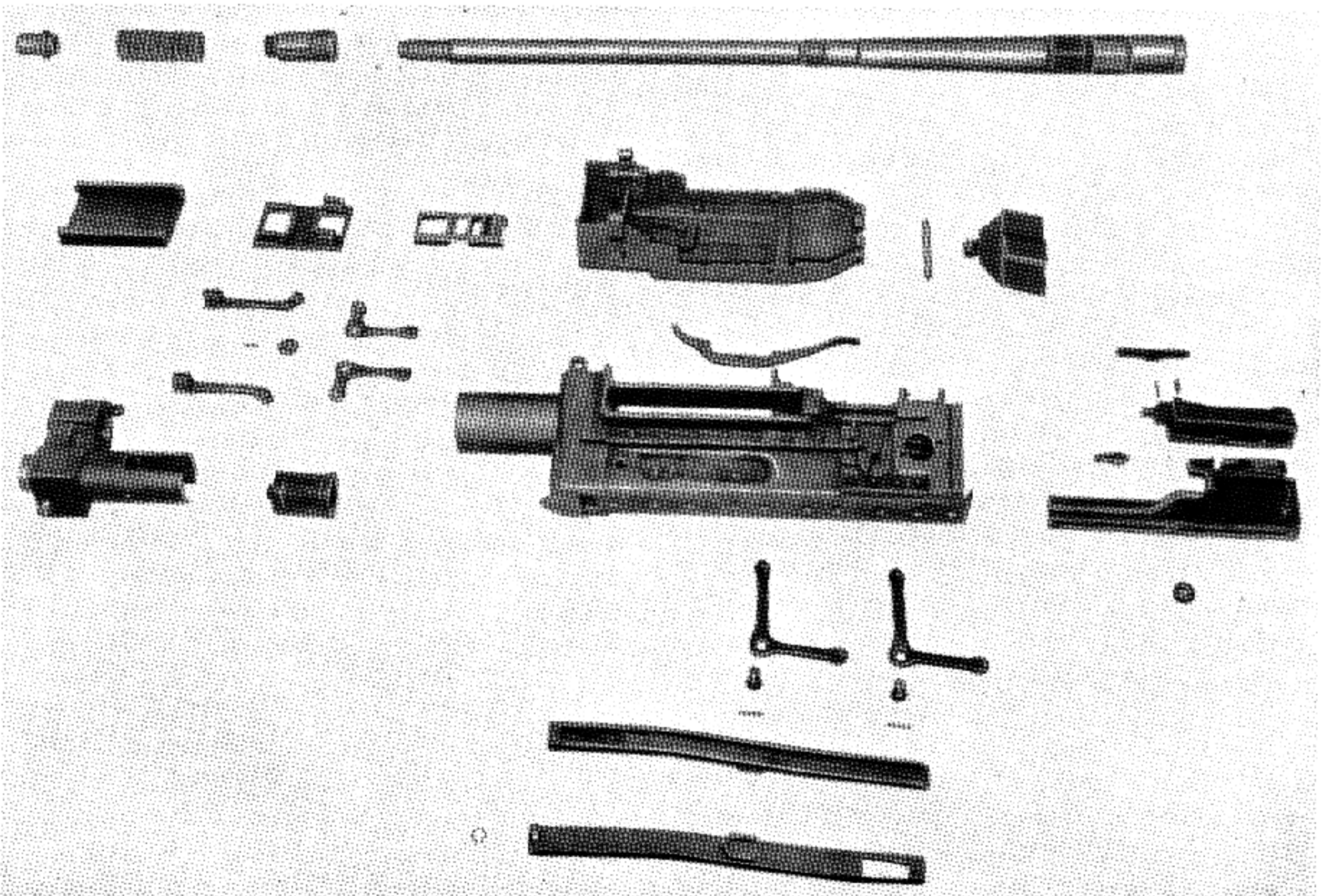


Figure 24-20. Final version of Krieghoff Experimental 20-mm Aircraft Cannon, completely disassembled.



the breech ring and relative movement between the slide assembly and rammer block results. The slide assembly continues to be driven forward by the drive spring. The rammer block is held by the face of the breech ring; thus, the rammer block spring is compressed by the continued forward run of the slide. The breechblock rollers engage the downward portion of the cam track in the sides of the slide, and the breechblock is drawn down. The gas piston of the slide enters the gas cylinder. The downward movement of the breechblock disengages the block from the barrel lock, and the gun is allowed to run forward under the combined force of the drive spring and the compressed recoil springs. As the gun runs forward, the receiver firing pin cam engages the ring firing pin actuator and depresses it. This in turn depresses the block firing pin actuator, the spring-loaded firing pin is driven into the primer, and the round is fired.

The barrel starts to recoil. Powder gases are led through a port in the barrel to the gas cylinder. The gases drive the slide assembly rearward and the cam

track raises the breechblock; this action enables it to engage the barrel lock to hold the barrel in the recoil position. Further rearward movement of the slide results in the extractor's withdrawing the empty case from the chamber and reinserting it into the link. As the case is reinserted into the link, the extractor cam depresses the extractor to disengage the lip from the empty case and to allow continued rearward movement of the slide. After the empty case has been reinserted into the link, the feed operating cam is engaged by the feed cam. The cam is rotated about its pivot point, engages the holding pawl operator, and the pawls are depressed. Further movement of the feed cam results in the feed pawl's driving the links across the feedway and positioning a new round for ramming. As the links are forced across, the link disintegrating cam surface engages the link disintegrating pin and drives it inward. This pin in turn drives the other pins in the link connecting hinge, and the links part. The slide assembly strikes the rear buffer, and, if the sear is still held depressed, the cycle is repeated.

## Chapter 25

## CAPTURED RHEINMETALL AIRCRAFT WEAPONS

## SECTION 1. HISTORY AND BACKGROUND

## Early History

The history of Rheinmetall-Borsig A. G. may be traced back to the establishment of a modest company named Rheinische Metallwaren und Maschinenfabrik A. G., which began making bullets in 1889. Early in the history of the company it began to be spoken of as "Rheinmetall." At the outbreak of World War I, Rheinmetall was second only to the firm of Friedrich Krupp A. G. in the manufacture of German munitions.

After Germany lost World War I, Rheinmetall was placed under the control of the occupying forces through a group called the Inter-Allied Control Commission, which governed the manufacture of all arms producing plants in Germany.

## Curtailement Following World War I

The commission laid down the activities that were permitted in the field of armaments. The curtailment imposed caused a lean time for the firm even though it turned to the manufacture of agricultural machinery. Some of the personnel went to Switzerland to firms such as Oerlikon and Solothurn.

In 1929, Rheinmetall established a subsidiary company in neutral Holland under the name of Hollandische Industrie and Handels Mattschaps (HIH). This venture turned out to be unsatisfactory; however, in the same year the firm acquired ownership of the Waffenfabrik Solothurn A. G. in Solothurn, Switzerland. This venture was the second attempt to activate Rheinmetall in a neutral country.

The Solothurn plant was originally developed for watchmaking, but the German owners obviously had other ideas. As soon as the company's presence was accepted by Switzerland, financial support was forthcoming from Germany, by loans and by the purchase of shares in the company. In the early

1930's, this support had become so unwieldy that the Reichskredit Bank was formed to administer the aid to industry. In addition, money was continuously forthcoming from the Reich Luftfahrt Bank.

## Design Procedure

Among the engineers in the newly acquired factory were some of Germany's most talented automatic cannon specialists.

The genius of Fritz Herlach and Theodor Rakula is shown in a unique approach to the design of weapons as well as in their own professional skill in developing actual working principles. Herlach's excellent work in designing automatic arms won him the presidency of the company; he succeeded the world-famous Heinrich Ehrhardt, designer of artillery and other types of military ordnance. Others occupying prominent places in the design and development branch were the internationally known Dr. Walter F. Grasse and Dr. Richard H. Braun.

The need for a design was originated by a military request or by the firm. The design of the new weapon to meet the need was developed through conferences of the gun and ammunition designers.

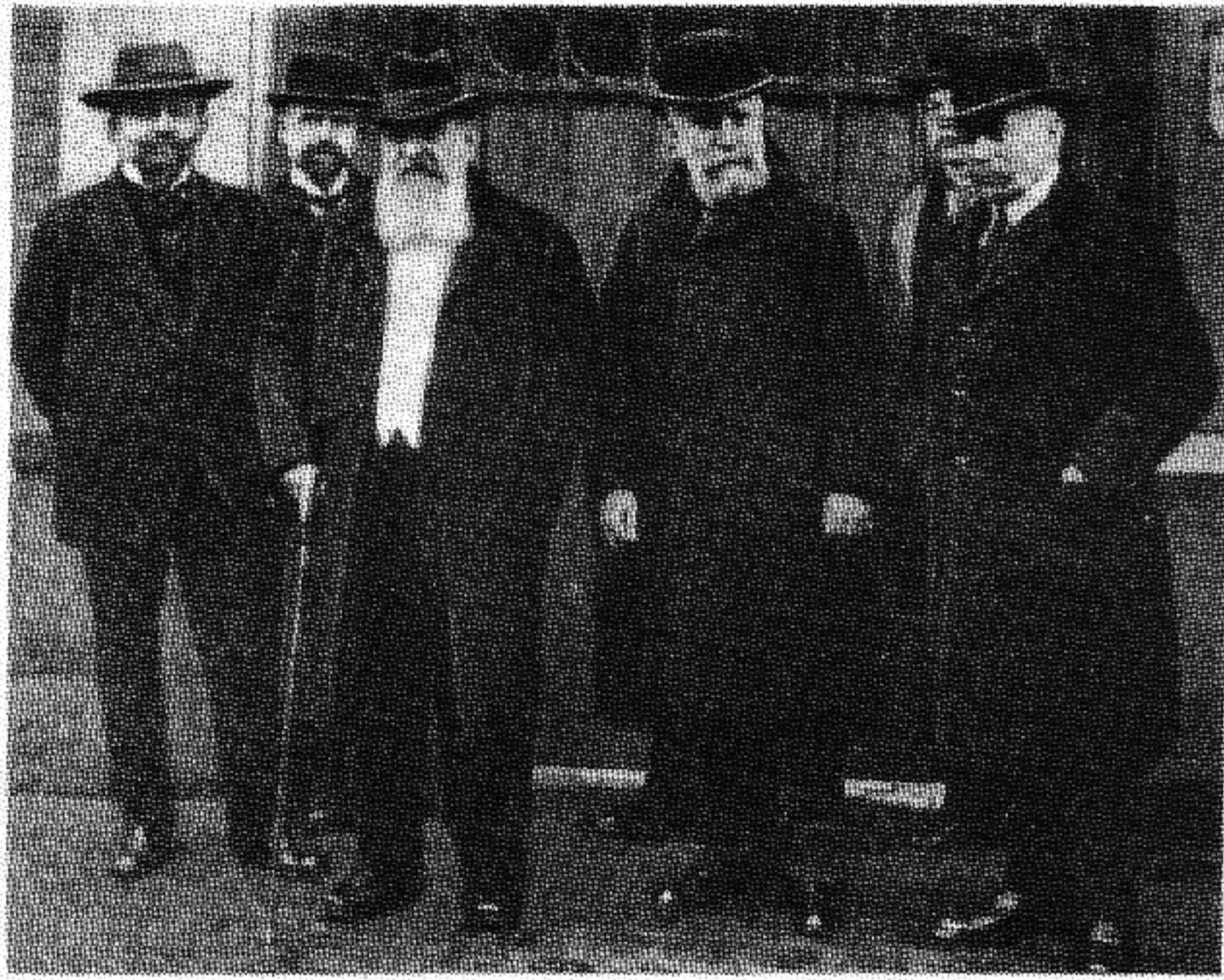
Once the design had been approved, it was first ascertained if normal methods were to be used or whether metal stampings would be employed in the manufacture of the receiver and other components.

The specification was reviewed, and tentative ideas were suggested for meeting the various requirements such as caliber, muzzle velocity, rate of fire, and weight of gun.

The ammunition branch was called in and asked to design the round. In consultation with the ballistics branch, the ammunition branch settled upon the length of the projectile, its weight, and the chamber pressure. The latter group were also responsible for the design of the cartridge case.

SCIENTIFIC AMERICAN

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Figure 25-1. The page from "Scientific American" reproduced here indicates the more than local interest in the Rheinmetall Co. early in the 1900's. Third from the left of the photograph is Heinrich Ehrhardt, the proprietor. In 1889, when the company started operations in Dusseldorf, Ehrhardt became its technical adviser and vice chairman of the board of directors.

At this stage, the gun designer could voice an objection, such as to the shape of the base of the case in an instance where it would not suit his various components. This procedure was allowed to continue for as much as three or four months; during this period, the gun designer had time to think out the design in its entirety and solve his side of the problem.

For the setting up of the various systems, designers with comprehensive experience were always sought for the prototype of basic design. Production experts were responsible for the best production procedure dependent upon available raw material and for suggesting ways to simplify a system so as to

obtain the most plausible manufacture with the least effort.

The hardening and surface technicians had not only to harden the unit produced but also to discover the particular use of various materials or metals. Pattern-shop men produced various wooden mock-ups of different systems mounting, so that a first test could be made from these models for clearance, serviceability, and visual inspections for details that could have been overlooked in the drafting stages.

Preliminary calculations were made to ascertain the time required for manufacture and to work out the quantity and quality of materials available for

mass production. By these methods the time required was reduced to a minimum from the day of development to the day of mass production.

It was, of course, important that the finished experimental unit should resemble in every respect the future mass produced article. It was on this account necessary that the experimental plant should have at its disposal first class machines by means of which various kinds of production could be realized. Rheinmetall was well equipped with physical,

chemical, metallographical, and X-ray laboratories, and equipment for testing durability. Benches for hot and cold weather testing were at the disposal of the scientists. For aircraft armament testing, there was available a special aviation section at the Tarnowitz Proving Ground. The sections were assisted by expert engineers in examination of drawings, measurements, and material. Special engineers furnished the technical descriptions and servicing instructions.



Figure 25-2. Dr. Walter F. Grasse, Dr. Richard H. Braun, and Mr. Theodor Rakula (from left to right). These men held positions of responsibility in the Rheinmetall-Borsig company during World War II, and deserve credit for the designs of much of the aircraft armament used by the Luftwaffe.

The experience obtained from the experimental laboratories and field tests were made known at certain times so that they could be applied to other developments. The originators of the prototype, who were known in the department as creative designers, were sometimes engineers and sometimes not. In most instances, they were men with considerable background in weapon design or firing.

A special department was established by the company in which designers continuously scrutinized foreign patents and foreign mechanisms; by this method, the management had a general survey of the degree of efficiency not only of their own designs but of any potential enemies.

As soon as a complete prototype was ready, range trials were arranged. Usually mass production was anticipated within 3 to 4 years. Questions of fitting of components in air frames or engines were handled at the levels that dealt with construction of fighter aircraft; decisions were in turn relayed direct to the manufacturers of the various components as well as of the plane itself. Liaison for questions dealing with the weapon's construction and installation in aircraft was established among the various design and production departments.

In order to aid the factory in shortening the time to get into full production, an arrangement existed whereby the design section detached a certain number of its personnel to work at the factory in a supervisory capacity during the early stages of production planning and production.

In the 20 years between World War I and World War II, specialists in various fields had been developed through the design procedure just described. These men felt that it was only through the close cooperation of design, science, and production that the highest performance could be expected. The field of automatic cannon placed the highest demands on material and was recognized as one of the most difficult fields of weapon development.

### Expansion Preceding World War II

By 1935, the Rheinmetall firm was again expanding its activities. Negotiations had been started with the bankrupt Borsig works, which had a well-equipped heavy steel fabrication plant at Tegal, a suburb of Berlin. In January 1936, the two firms were merged and Rheinmetall-Borsig A. G. came into existence.

The Rheinmetall plant at Unterl us was enlarged from a group of ranges to include a fairly large machine shop for developing machine guns, a filling factory for loading, a number of laboratories, and auxiliary buildings for administration.

About 1937, a research group was set up. Later on, as a direct result of World War II, the headquarters of the development organization was evacuated to Unterl us and the moving of various kinds of equipment and documents from other sections followed.

The workers at Rheinmetall-Borsig had a slogan to which much of their superior work was attributable: "We do not know that this will not work; let us try it," rather than the stultifying converse, "We do not think this will work; we will not try it." Examples of this attitude, among many, are the Munchausen 56-centimeter recoilless gun, made on the Davis principle and designed to be carried on aircraft, and the work on bent barrels designed to shoot around corners. The quality of the workmanship on weapons is what mattered the most, and at no time during World War II did the organization allow quality to become debased by wartime conditions. On the other hand, no effort was wasted in applying an unnecessary degree of finish in places where it did not matter.

The firm was willing to expend considerable sums of money for power machinery, tools and fixtures, especially press tools for making the prototype. The idea behind this plan was that the effectiveness of the design could not be determined unless the prototype was carefully constructed with suitable tools. If the weapon should be acceptable, these tools would be of use for the initial production. If the weapon was not acceptable and there was no further use for the tools, the firm was prepared to write off their cost as a necessary development expenditure.

The development of all types of automatic cannon intended for installation in aircraft was undertaken from the point of view of the effectiveness of the weapon against its intended target. It was recognized that the most effective result could be obtained by the detonation of a high-explosive charge inside the enemy plane. With this requirement, it was also recognized that the employment of thin case projectiles holding a maximum of explosive would be the most suitable for use in firing from air to air.

The quantity of high explosive required for effective destruction depended upon the area of surface to be destroyed. In the earliest period of development, a quantity of 75 grams of explosive was considered to be quite sufficient. This quantity could be housed in a projectile having a minimum diameter of 3 centimeters. This knowledge was soon confirmed by experience gained in combat, and the poor effect of 20-mm ammunition upon 4-engine bombers was proved at the same time. The 3-centimeter high explosive projectile weighing 330 grams and holding 72 grams of high explosive was considered the optimum caliber. In order to put an opponent out of combat, it was estimated that 1 hit against a fighter plane and 4 hits against a 4-engine bomber could be reckoned upon as sufficient. The 3-centimeter high-explosive shell was accordingly designed for two weapons that were under construction, namely the MK-103 and the MK-108.

The Rheinmetall engineers came to the conclusion that the gunner's aim was influenced by the instability of the plane in relation to the horizontal and vertical axes, making accurate pinpoint fire next to impossible. The rigid firing method gave a raking fire. In this form, it was not dependent on ballistics but governed by the directional properties of the plane.

The effectiveness of raking fire becomes greater the denser the cone of fire; in other words, with a higher firing rate and a larger number of guns, combat action with rigidly armed fighters against bombers remained limited to medium distances of approximately 3,300 feet. At longer distances, the dispersion became so large that a sufficiently high density of fire could not be obtained, at least not with the gun weights of existing weapons. With these facts in mind, the Rheinmetall experts designed the MK-108. Its origin dates back to the Becker automatic cannon of World War I; however, it was revived in 1941 and put into production in 1944. The slowness in getting into production is accounted for not by inability to start production but by the fact that the German Air Force suddenly realized that it was on the defensive. To combat the heavy bombing raids that were then being carried out by both British and American forces, the automatic cannon offered by Rheinmetall was de-

signed for one purpose only—air-to-air combat against big bombers.

### Designation System for Weapons

When World War II began, so much automatic cannon development work was under way in Germany by different plants that the designations given to prototype and already adopted weapons became highly confusing. By the end of 1942, a system was instituted of identifying each of the four plants which were handling 90 percent of all experimental and development work. Rheinmetall-Borsig was allotted the number 1; Mauser, 2; Kreighoff, 3; and Krupp, 4.

To identify a weapon, a three digit number was assigned, the first digit representing the plant that developed it, and the last two standing for the order or sequence in which it was developed. As several firms were given the same problem in design, the company credited with the solution had its number assigned to the project. This number was carried all the way through to adoption. For instance, if Rheinmetall developed a prototype for the thirteenth type of weapon specified by the military authorities, the official designation of the finished product would be MK-113. If Mauser were first to succeed in this development, the nomenclature would be MK-213.

### Unterlüs Plant

At the end of World War II, the Rheinmetall-Borsig organization at Unterlüs comprised a large range area with seven main firing points and the factory area, which included work shops, laboratory, and other buildings. The organization was one of the leading firms in research, design, and development of weapons for modern warfare in Germany. Many weapons were under development and in manufacture; among them were the models identified in the following paragraphs and described in later sections of this chapter.

### Aircraft Machine Gun 13-mm MG-131

In 1938, when Germany was on the threshold of war, the 13-mm MG-131 made its debut. The gun was developed by the Rheinmetall-Borsig firm as a result of a directive from Herman Goering to produce a weapon to fill the need of the German Air Force for a high-speed light machine gun cham-

bered for a caliber larger than the standard rifle cartridge. (See volume I, pp. 457-460.)

### **Automatic Aircraft Cannon 30-mm MK-101**

This weapon was made by the Rheinmetall-Borsig firm about 1942. It was the first weapon to be designed under the new system of designation devised to identify each of four plants developing automatic cannon for Germany. The weapon was used by the German Luftwaffe, mostly on the Russian front, in the Heinkel 129, a heavily armored plane especially designed for ground attack. The weapon was also used for tank-destroying purposes. (See volume I, pp. 555-556.)

### **Automatic Aircraft Cannon 30-mm MK-103**

The 30-mm MK-103 was designed to meet a need of the German Air Force for a gun effective against tanks and heavily armored vehicles. Although some work had been done on the design of such a weapon as early as 1940, it was the Russian front reverses that pointed out to the German high command the need for development of a higher rate of fire and higher velocity 30-mm aircraft cannon. This requirement eliminated some of the successful but lower velocity and slower firing 30-mm cannon already in operation. Production of the 30-mm MK-103 was begun early in 1943. Although it was reasonably satisfactory as a gun, the MK-103 was not used extensively in airplanes. Operational tactics had been altered to meet the attacks of the Allied heavy bombers, and fighter aircraft were required to attack at short range inside the defending

fighter screen. This use required a lighter gun with a lower pressure, higher capacity, high explosive shell, and higher rate of fire. The answer to this need was the MK-108, and the MK-103 was relegated to antiaircraft use on the ground.

### **365-mm Recoilless Cannon G-104**

This weapon was designed on order from the German Air Ministry for a recoilless gun similar to the MK-113 but capable of firing a 1,400-pound projectile from an airplane. Three guns in all were to have been built, but only one was completed and partially tested before the order for the weapon was withdrawn.

### **Automatic Aircraft Cannon 30-mm MK-108**

Design work on the MK-108 was commenced in August 1941, but the gun was not given a high priority in production until 1944 when the German high command realized that they were on the defensive. The MK-108 was designed for one purpose only, air-to-air combat against big bombers. One direct hit from its unusually large projectile was expected to bring down any plane.

### **Aircraft Cannon 5.5-cm MK-112**

As a result of the satisfactory performance of the 30-mm MK-108, a larger caliber weapon of the same type was requested by the German Air Force. The new gun was to be constructed of plain carbon steel, and sheet metal used wherever possible to facilitate manufacture and lower the cost of production.

The engineers of the Rheinmetall-Borsig firm decided that it was feasible to manufacture the weapon with available material, and undertook the work.

## **SECTION 2. 30-MM MK-101**

### **Description and Principles of Operation**

The MK-101 is a 30-mm automatic aircraft gun, scaled up from the 20-mm semiautomatic antitank gun designated MK S 18 1000. (See volume I, pp. 554-556.) The MK-101 has a very long chamber and an extremely high velocity cartridge for this type of gun.

The barrel, which is fitted with a muzzle brake, recoils and counterrecoils within the recuperator housing. A stepped piston is rigidly attached over the front guide surface of the barrel. When the

barrel recoils, the piston moves within the piston sleeve, which is fitted in the front end of the recuperator housing. Both ends of the stepped piston are fitted with piston rings. The front end of the piston slides inside the piston cylinder, while the rear end slides inside the recuperator housing.

In the recuperator housing, in the top of its front end, is an air inlet for admitting air between the rear end of the piston sleeve and the step in the piston. Air admitted here forces the barrel rearward during charging.

Between the rear end of the step piston and the shoulder inside the recuperating housing are the recuperating springs and the buffer spring, which are compressed by recoil of the barrel. The recuperator housing is assembled to the front end of the main housing by means of interrupted threads on the outside of the cam sleeve, which is rigidly attached to the rear end of the recuperator housing by wedges.

Inside the cam sleeve is a locking sleeve with rollers which ride in cam slots in the cam sleeve. The locking sleeve has interrupted threads in the front end for receiving the barrel and in the rear end for receiving the bolt. A coupling sleeve fits over the rear end of the locking sleeve and is held by interrupted threads after completing 60° of rotation. The barrel is held by the interrupted threads in the front end of the locking sleeve and is prevented from rotating during firing of the barrel lock, which rides in a groove in the barrel during recoil.

When the barrel is forced rearward either by compressed air acting on the stepped piston or by recoil, the cam slots in the cam sleeve—acting on the rollers attached to the locking sleeve—cause the locking sleeve to rotate and disengage the interrupted threads on the bolthead from those in the locking sleeve.

The rotation of the locking sleeve is insufficient to disengage the interrupted threads on the barrel in the coupling sleeve from their mating threads on the locking sleeve. The coupling sleeve is prevented from rotating during recoil by a lug extending from the rear of the sleeve at the right side. This lug carries the coupling slide, which is actuated by the spring loaded coupling lever.

The lever is spring loaded in such a way that the coupling slide is normally being forced outward; thus, when the gun recoils, the coupling slide is forced behind the catch plate (which is mounted in the extractor plate on the right side of the receiver) and holds the barrel in recoil position. Forward thrust of the coupling slide against the catch plate is absorbed by ring springs.

When the bolt moves forward into the locking sleeve and against the face of the chamber, a cam surface on the right side of the bolt engages the rear end of the coupling lever and cams the coupling slide out of engagement with the catch plate.

The barrel locking sleeve and coupling sleeve move forward under the force of the recuperator spring, and the bolt moves forward with them under the force of the driving spring. As the bolt and barrel move forward together, the rollers on the locking sleeve follow the cam slots in the cam sleeve and rotate the locking sleeve. This action locks the bolt in firing position.

The bolthead is flat on the top and bottom and is provided with locking lugs on both sides, which engage mating lugs or interrupted threads in the locking sleeve. A spring-loaded extractor is located in the under side of the bolt, and the spring-loaded rammer is located in the top of the bolt.

The firing pin is cocked against the spring by a cocking lever, which is actuated by contact with the cam in the left side of the receiver. The firing pin is held in the cocked position by a sear, which is actuated by a spring-loaded lever.

Pressure on the firing plunger located in the left side of the receiver actuates the sear lever against the spring and disengages the sear from the grooves

#### General Data: 30-mm Automatic Aircraft Cannon MK-101

<p>Gun length: 116 inches.            Gun weight: 396.9 pounds.            Rate of fire: 260 rounds/minute.            Muzzle velocity: 2,734 feet/second.            System of operation: Reciprocating (short recoil).            System of locking: Locking ring.            System of feeding: Magazine, 6 rounds; drum, 30 rounds.            Method of headspace: Factory established.            Location of feed opening: Top of receiver.            Location ejection opening: Bottom of receiver.            Method of charging: Electropneumatic.            Method of cooling: Air.</p>	<p>Barrel length: 53.1 inches.            Barrel weight: 88.2 pounds.            Rate control: None.            Barrel removal: Quick disconnect.            Bore:              Number of grooves: 16.              Groove depth: 0.0177 inch.              Groove width: 0.205 inch.              Pitch: 8° 30'.              Direction of twist: Right hand.              Form of twist: Constant.            Muzzle energy: 49.2 foot-tons.</p>
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in the firing pin. This action allows the firing pin to move forward.

A firing safety lock can be positioned to prevent depressing the firing plunger. The bolt moves on guideways in the receiver. It recoils with the barrel until unlocking occurs, then it is thrown back by the accelerator.

The accelerator, located in the bottom of the receiver, is rotated to the rear about its pivot pin by recoil of the coupling sleeve against it. When the accelerator rotates rearward, it compresses a return spring which returns the accelerator to its forward position after the barrel moves forward.

In a tubular housing in the bottom of the receiver is a bolt drive spring. The rear end of the spring bears against the receiver backplate; the front end enters a sleeve. The top of this sleeve is recessed to engage a lug on the bottom of the bolt. When the bolt recoils, it forces the sleeve rearward and compresses the drive spring.

The guide rod extends from the backplate into the spring. In the receiver backplate is a ring spring buffer which is struck by the bolt during recoil.

*Magazines.* Two removable magazines are provided for the weapon. One is the flat type; the other is a drum. In both magazines, the ammunition is fed by spring pressure. The magazine is held in the magazine holder by a pin at the front and by a spring-loaded latch at the rear. In the rear end of the magazine holder, the spring-loaded bolt sear which extends through the top of the receiver engages an abutment in the top of the bolt when the bolt is in the cocked position.

The pressing lever lifts the sear out of engagement with the bolt. The lever is held in the depressed position by a spring-loaded latch as long as ammunition is in the magazine. When the last round leaves the magazine, the ammunition feeder in the magazine strikes the latch, disengaging it from the sear lever and allowing the sear to drop into position to engage the bolt. Thus the bolt is held in the cocked position after the last round is fired from the magazine.

In the top of the receiver and on the rear end of the magazine holder, is a spring-loaded ejector. When the bolt recoils with the empty case held against the bolt face, the base of the case strikes the end of the ejector, is pivoted downward over the extractor, and is ejected through the ejector opening

in the bottom of the receiver. This opening is uncovered by the bolt drive spring during recoil when the spring is compressed by the bolt.

*Bolt Charger.* The bolt can be charged manually or pneumatically by the charger, which is located on the bottom of the recuperator housing. The charger consists of a pneumatic cylinder, a piston, and a piston rod which has racked teeth cut on the bottom.

A retractable, hand-cocking pin engages the teeth on the piston rod. The piston rod extends through the rear end of the cylinder and contacts the sleeve which connects the bolt and driving spring. Cranking the cocked pinion shaft runs the piston rod rearward and cocks the bolt.

When cocking is accomplished pneumatically, air is admitted through an air line in the cylinder head, and the piston and rod are forced rearward to cock the bolt. The piston and rod are returned to their forward position by the bolt when the bolt is released. Release of the bolt is caused by the sear being disengaged.

The charging piston and rod are held in their forward position by a locking piston and plunger which engages a recess in the charging piston rod. The locking piston is located in the hand cocking pinion housing and is disengaged by air pressure when charging is accomplished pneumatically.

When the bolt is cocked manually, the hand-cocking pinion forces the locking piston out of engagement with the charger piston rod as the pinion is manually pressed into engagement with the rack teeth on the piston rod.

*Firing System.* On the left side of the gun near the firing plunger there is a firing solenoid. When the solenoid is energized, it actuates a lever which strikes the firing plunger, causing the gun to fire. Firing continues automatically as long as the solenoid is energized. Firing is interrupted by opening the solenoid circuit, which leaves the bolt forward with a round in the chamber. The firing circuit is arranged to permit single automatic fire.

*Cocking.* Air from an air cylinder is admitted to the charging mechanism through an electric solenoid valve. The compressed air which flows through the elbow connector into the pinion housing forces the charging locking piston against the spring to the right until the plunger in the locking piston disengages the recess in the charging rack.

The compressed air flows through the air lines against the charging piston of the compressed air cylinder and forces it and the rack to the rear. The rack, whose end is pressed against the sleeve, forces the bolt mechanism, which is coupled with the sleeve, back until the bolt sear engages the bolt mechanism. Simultaneously, compressed air passes through a compressed-air line attached to the line fitting of the recuperator housing into the space between the piston sleeve and step piston of the recuperator.

Pressure exerted by the air against the piston forces the gun barrel to the rear against the recuperator spring and the buffer spring to a point where the coupling slide of the coupling sleeve is engaged by the catch plate of the striking plate. After the contact button of the charger has been released, the air imprisoned in its cylinder escapes through the release opening in the piston housing. After the bolt sear is released by pressure on the release lever, the bolt moves forward and brings the cocking rack forward again.

Under the effect of the driving spring, the plunger of the charging rack locking piston engages the depression in the charging rack and locks it forward. In order to cock the weapon by hand, the cocking crank is placed on the hand-cocking pinion shaft and the hand cocking pinion is pressed in toward the right with the cocking crank. The teeth of the hand-cocking pinion engage those of the charging rack, and the catch on the hand-cocking pinion forces the rack-locking piston against its spring until the piston plunger is disengaged from the charging rack.

When the cocking pinion is rotated, the rack moves back and pushes the sleeve back until the bolt, which is coupled to the sleeve, is engaged by the sear. Simultaneously, the barrel, which is locked with the bolt by means of the locking sleeve, is forced back with the coupling sleeve by mechanical means until the coupling slide engages its mating part in the striking plate. The recuperator spring and the buffer spring are now compressed.

*Release of the Bolt Mechanism.* The bolt mechanism, which has been brought back into its cocked position by means of the rack in the compressed air cylinder, is released after a loaded magazine has been inserted. The bolt moves forward under the pressure exerted by the driving spring, feeding the cartridge into the chamber of the barrel.

*Chambering of the Round and Locking of the Bolt.* As the bolt moves forward, a cartridge which projects into the path of the bolt mechanism is struck by the rammer, stripped from the magazine, and rammed into the chamber. The claw of the extractor engages the rim of the cartridge.

Shortly before the bolt mechanism strikes the locking jacket, the coupling lever is lifted by a cam surface of the bolt. The coupling lever disengages a coupling slide from the catch plate and the striking plate.

The coupling jacket is released, and the compressed recuperator spring and buffer spring bring the barrel, the locking jacket, and the coupling jacket forward together. The rollers of the locking jacket, which follow the cam grooves in the cam sleeve, rotate the locking sleeve, causing the interrupted threads in the locking sleeve to engage those of the bolt, the barrel, and the locking jacket. The coupling jacket and the bolt mechanism move to their most forward position. The weapon is now loaded and ready for firing.

*Firing.* Firing is accomplished by depressing the firing button, which energizes the electric solenoid. The lever of the solenoid presses against the trigger plunger, which moves the firing lever against its spring. The firing lever moves the firing pin sear out of engagement with the groove of the firing pin.

Under the action of the cocked firing-pin spring, the firing pin moves forward and strikes the primer, exploding the powder charge.

*Unlocking, Recoil of Bolt Mechanism, Ejection of Cartridge Case.* The barrel and the bolt mechanism are firmly locked together until after the projectile has cleared the muzzle. The barrel, the locking jacket, the coupling jacket, and the bolt mechanism, all rigidly locked together, recoil approximately 32-mm.

In the meantime, the cocking lever of the bolt mechanism strikes the cocking cam, causing the firing pin to be retracted by means of a lever. This lug engages a slot in the body of the firing pin until the sear is placed under spring pressure. The sear then engages the groove in the firing pin, holding it to the rear. In the course of further recoil in the barrel, the locking sleeve, whose rollers are guided in the cam slots to the cam sleeve, is now rotated. This action unlocks the bolt from the locking sleeve.

After unlocking, the bolt mechanism is accelerated rearward by the accelerator lever, which is motivated by the coupling sleeve. The accelerator lever is returned to its forward position by its return spring.

During recoil of the barrel, which amounts to a maximum of 150 mm, the recuperator spring and the buffer springs are compressed. These springs absorb the excess recoil force. Both springs move the barrel, the locking sleeve, and the coupling sleeve forward.

After a short counterrecoil, the coupling slide, which is pressed outward by spring force of the coupling lever, is engaged by the catch plate in the striker plate. The barrel, the locking sleeve, and the coupling sleeve are held stationary while the recuperator spring is still somewhat compressed. The impact of the coupling slide on the catch plate is absorbed by the friction ring spring in the striker plate.

While the barrel is still in counterrecoil, the bolt mechanism moves farther back with the cartridge case, which has been caught by the extractor. The ejector strikes the face of the cartridge case, tips the cartridge case about the extractor, and throws it out below. During recoil, the bolt compresses the drive spring and strikes the bolt buffer.

*Counterrecoil Movement.* After the bolt mechanism strikes the bolt buffer, the bolt moves in counterrecoil under force of the driving spring and puts the bolt in reverse motion. After the magazine has been emptied, the bolt is automatically engaged by the bolt sear. At the same time, a device in the magazine presses the sear release lever latch out of engagement with the sear release lever, allowing the lever to move into the path of the bolt and stopping it on counterrecoil. The bolt is held in its rearmost position. After a filled magazine has been inserted, the bolt is again released by pressure of the release lever and the weapon is ready for firing again. At this time, charging is not necessary.

### Cycle of Operation

To fire the MK-101, a loaded drum is attached in its fastening latches on top of the receiver. Air from a cylinder is admitted to the charging mechanism through an electric solenoid valve. Compressed air enters the piston housing against the charging piston, forcing it back with the bolt assem-

bly until it engages a rear-searing device. The release of air depresses the sear and allows the bolt assembly to be driven forward under the energy of the compressed driving springs.

The bolt face picks up a round from the mouth of the feed and chambers it, at the same time the rotating sleeve locks the piece in battery. Firing is accomplished by depressing the button that engages the solenoid; this action moves a lever that in turn disengages the front sear from the firing pin grooves. At this time, a heavy spring drives the firing pin into the primer to fire the chambered round. The barrel, bolt, and locking sleeve are all firmly joined while the projectile is traveling through the bore; they remain joined until an inch and a half of recoil takes place.

During the first movement rearward the cocking lever is pivoted, at first withdrawing the firing pin within the bolt face and then compressing the firing pin spring tightly until it is seared back fully cocked.

The locking sleeve, the roller of which is guided in the cam slots, is now rotated, unlocking the bolt. At this point, the accelerator speeds the bolt rearward. The barrel and locking sleeve are held in a retracted position while the bolt starts into recoil. At this instant, the empty cartridge case is held firmly against the bolt face by means of the extractor claws. The claws continue to grip the expended round until the ejector makes contact with the rim of the case and kicks it out through the ejection slot in the bottom of the receiver.

Further recoil compresses the driving spring, and the bolt hits the buffer. This action causes an opposite movement to begin. As the bolt moves forward, the first round in the magazine is started toward the chamber. At the same time, the extractor claw is cammed over the rim of the cartridge.

Shortly before the bolt strikes the locking ring, the coupling lever is lifted by an inclined ram on the bolt body. This action releases the retracted barrel and locking ring at the exact instant the bolt lugs are opposite their mating threads in the ring.

The rollers in the locking ring follow the camming grooves which rotate the sleeve, quickly locking the entire assembly. If the solenoid is still actuated, the firing lever moves the sear out of engagement with the button on the firing pin. The latter flies forward to fire the propellant charge in the cartridge.

## SECTION 3. 30-MM MK-103

## Description of the Weapon

The MK-103 is a 30-mm automatic aircraft cannon that is gas operated and air cooled. A steel cartridge belt feeds the weapon from the top. A metal disintegrating link is employed. The locking action is practically identical with that of the experimental American automatic cannon that never advanced beyond the limited-service use, namely, the Navy's 1.1.

The weapon was made in two different types. One is an engine-mounted gun with a shrunk-on inner liner, which is assembled from the rear; the other is a flexible gun with a monobloc barrel which is assembled from the front. With the exception of the barrel mounting, the two types are identical. The first weapons made were fitted with a magnetic trigger, and the latest type was equipped with an electropneumatic trigger. For the engine-mounted installation, a reinforced friction brake and barrel-recuperator spring were used because the engine-mounted gun was fired without the muzzle brake.

While the official rate of fire was between 420 and 450 rounds per minute, numerous attempts were made to increase the rate of fire of this weapon to 600 rounds per minute. However, all such attempts resulted in poor performance of several parts.

The weapon housing, feed, and several other parts were stamped out of sheet metal.

The barrel brake and barrel extension constitute the recoiling parts. The barrel extension is so constructed that it helps restrain the barrel during recoil. The feed mechanism is powered by means of the lug engaging the top of the barrel lock during recoil.

The breech bolt mechanism is unlocked by the gas-operated piston. Gas is admitted from a barrel port, which is located just to the rear of the shoulder. The gases are trapped in the space between the outer wall of the gun barrel and the inside of the forward portion of the receiver extension. A cylinder houses and guides the operating parts of the plunger assembly. The plunger thus is forced to strike the breech bolt slide, which is located on the bottom of the breech bolt assembly; the slide is forced rearward by gas pressure on the piston, causing the locks to move inward and to release the breech bolt.

The breech bolt assembly is now free to move rearward in full recoil. The rear end of the firing pin loses contact with the post on the slide as the bolt unlocks. This action restrains the current from reaching the primer until the breech bolt is locked.

The slide is provided with slots by which the charger lug on the left side and the driver spring lug on the right side are fastened to the breech bolt assembly. The driving spring and charger with the sear are assembled into the one unit at the bottom of the receiver. The charger lug is equipped with a

## General Data: 30-mm Automatic Aircraft Cannon MK-103

## Gun length:

With muzzle brake: 91 inches.

Without muzzle brake: 80 inches.

Gun weight: 319.7 pounds.

Rate of fire: 420 rounds/minute.

Muzzle velocity: 2,822 feet/second.

System of operation: Gas-operated reciprocating system.

System of locking: Two swinging locks.

System of feeding: Barrel-recoil-operated; metallic link belt.

Method of headspace: Factory established.

Location of feed opening: Top portion of receiver, either left- or right-hand side.

Location of ejection opening: Bottom of receiver.

Method of charging: Electropneumatic.

Method of cooling: Air.

Barrel length: 52.3 inches.

Barrel weight: 57.3 pounds.

Rate of control: None.

Barrel removal: Quick disconnect.

## Bore:

Number of grooves: 16.

Groove depth: 0.002 inch.

Groove width: 0.146 inch.

Pitch: 8° 30'.

Direction of twist: Right hand.

Form of twist: Constant.

Muzzle energy: 45.5 foot-tons.

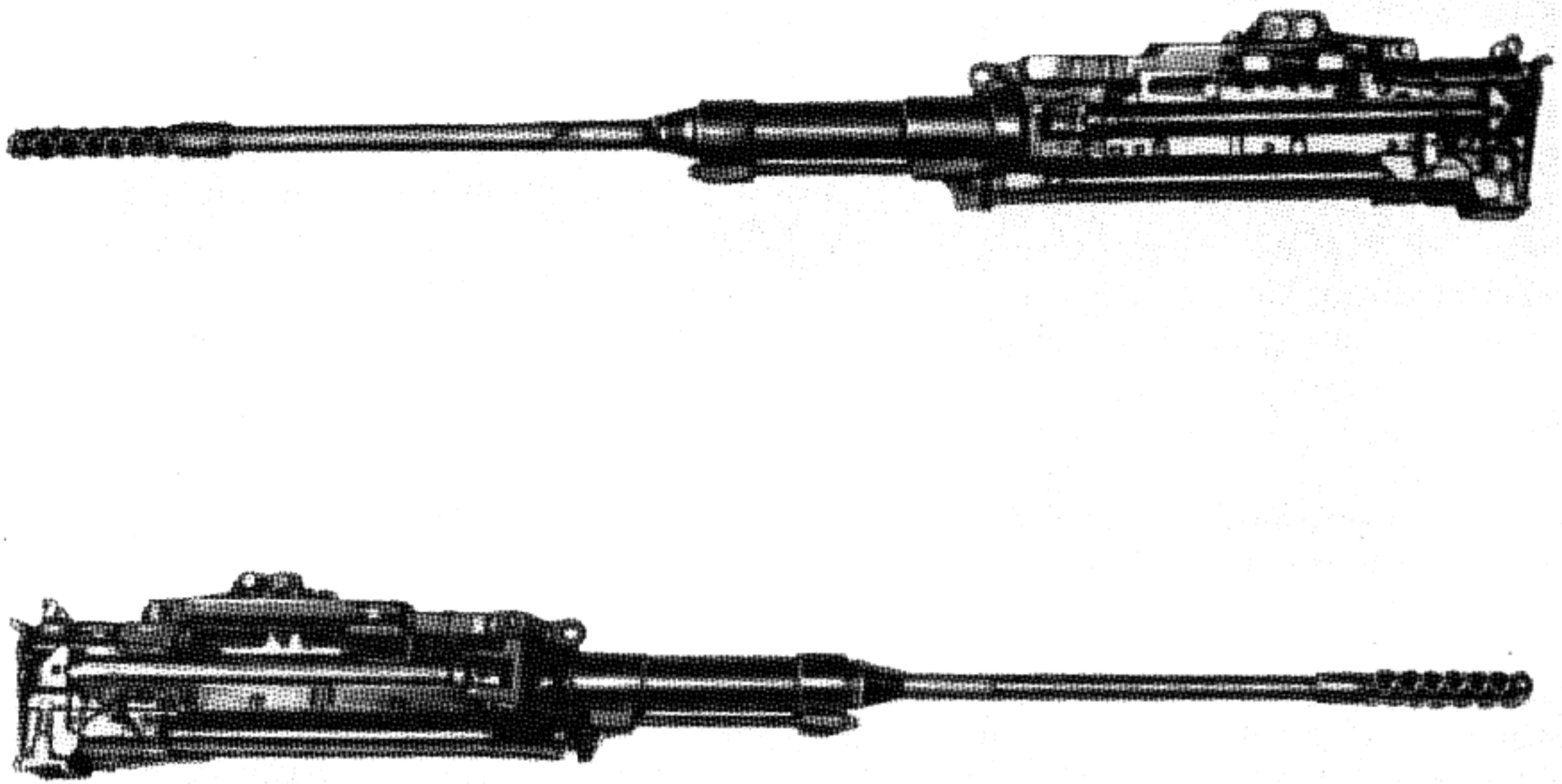


Figure 25-3. Automatic Aircraft Cannon 30-mm MK-103. Right- and left-side views.

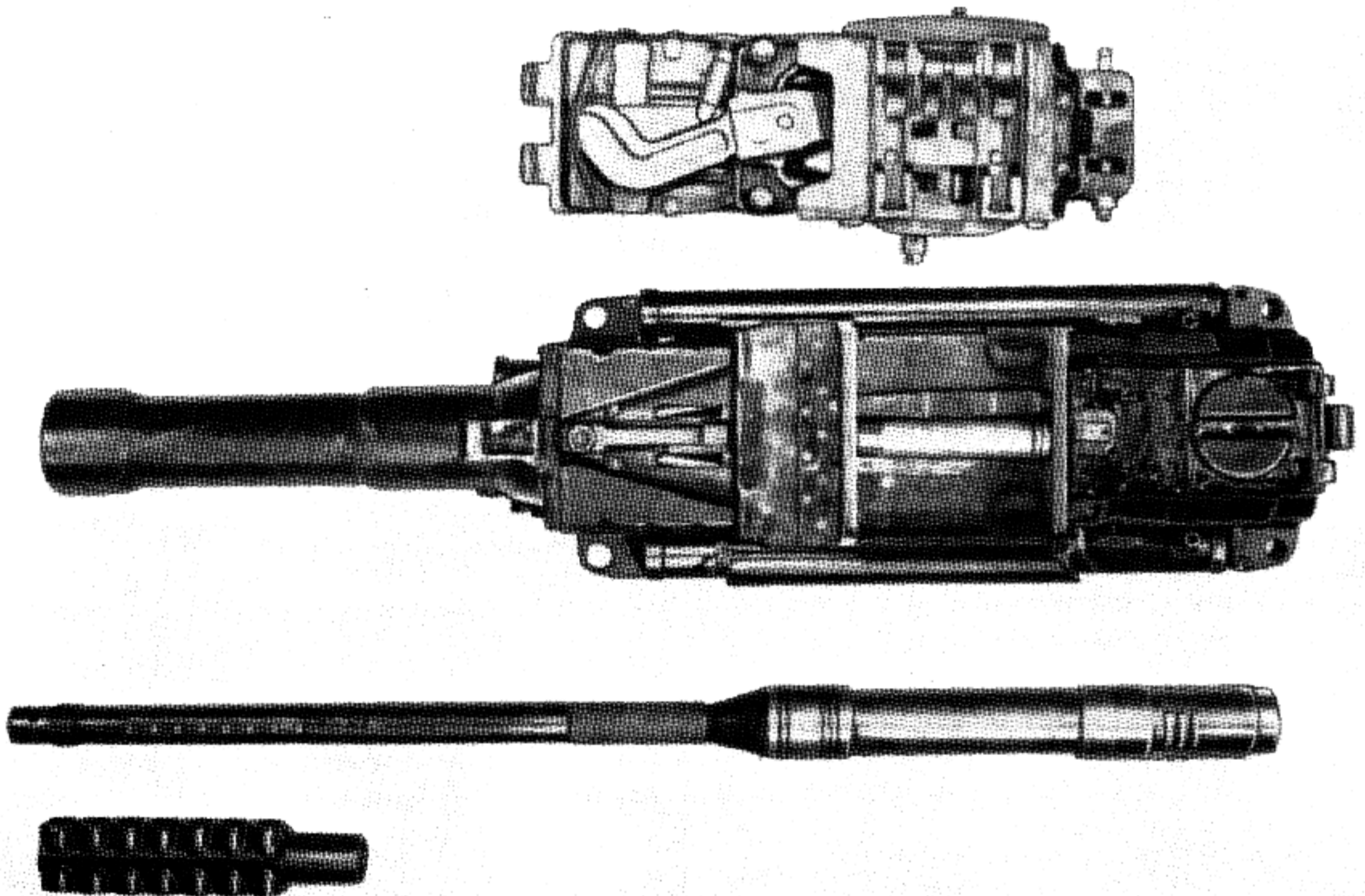


Figure 25-4. Automatic Aircraft Cannon 30-mm MK-103. Major assemblies.

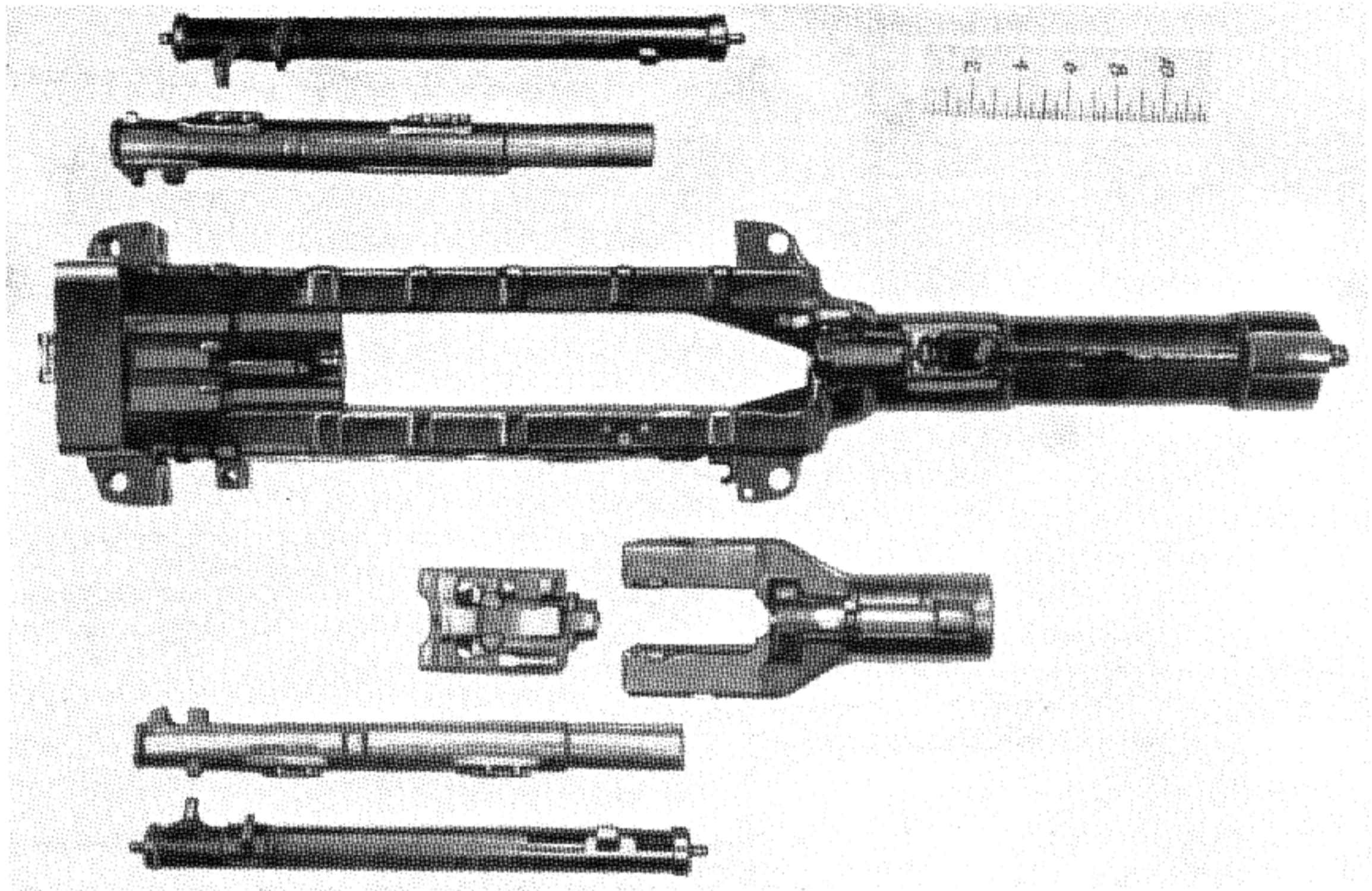


Figure 25-5. Breech mechanism of Automatic Aircraft Cannon 30-mm MK-103. Disassembled view.

spring latch, which must be released before the lug can engage the breech bolt. The rear end of the latch must be pushed inward for release.

The construction and location of these parts indicate that in the original installation a solenoid might have been utilized for the unlatching.

The sear consists of a blade arrangement which projects upward and rearward into the receiver.

The exterior electric connections are brought into the container mounted on the left side of the receiver. Two indicating circuits are included, one of which is completed when the breech bolt is seared, the other when the breech bolt is closed and locked. A third circuit provides the firing current.

### Cycle of Operation

The operator places a loaded belt in the feedway with the first cartridge behind the belt holding pawl. Compressed air is released into the charging mechanism. The center feed pawls then index the incoming round.

The air entering the connection at the front of the driving spring and charging assembly drives the charging piston rearward. The charging piston has a lug which engages the slide of the breech bolt and drives the bolt assembly rearward, compressing the driving spring.

The sear engages the breech bolt assembly and holds it in the rearward position until the solenoid operating the pneumatic piston is energized and the sear is released. Upon release of the sear, the drive spring sends the bolt assembly forward. As the bolt is driven forward, the rammer, which projects up through the slot in the feed box, engages the rim of the positioned round and strips it from the link.

As the round is rammed forward, the nose is forced down toward the line of bore by a guide in the forward top of the feed box, while the rim is held from rotating up by the link in the roof of the feed box. The gradual widening of the slot in the bottom of the feed box assists in aligning the round with the chamber.

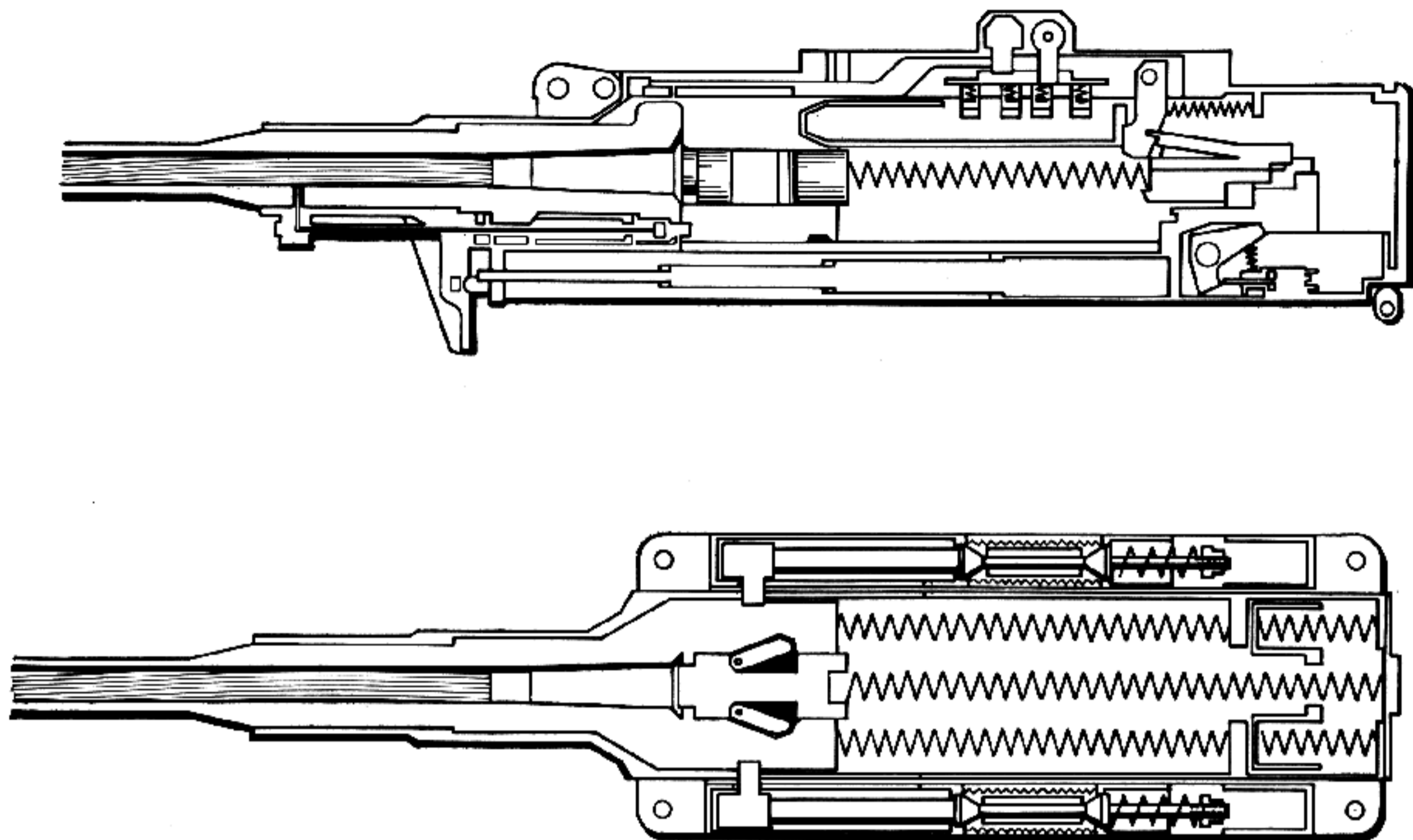


Figure 25-6. Automatic Aircraft Cannon 30-mm MK-103. Sectional view.

As the round enters the chamber, the claw extractor engages the rim of the case. The upper part of the bolt assembly is abruptly stopped as it strikes the face of the breech, while the slide continues in its path. This relative movement causes the locking plates, which are pivoted in the upper block, to be swung outward by the camming surfaces in the slide. The locking plates seat in two lock abutments in the tube extension. Further forward movement of the slide causes the electric contact to be made which fires the round.

On recoil of the tube extension, the feed cam roller engages the feed crank-cam, rotates the feed cam about its pivot, and compresses the feed cam return plunger spring. Upon rotation of the feed crank, the feed pawls are moved. They engage the cartridge links and place another round in position for stripping and ramming.

On counterrecoil, the feed crank is rotated to its original position by the feed cam roller, assisted by the feed return plunger spring. The spring-loaded feed pawls are depressed by the following round as the feed slide is drawn back to its original position.

Two stop pawls prevent movement of the cartridge belt during return of the feed pawl slide.

After the projectile has passed the gas port, pressure is led to the gas cylinder assembly by the gas tube. The gas piston is forced rearward by the gas pressure and strikes the slide, driving it rearward. The movement of the slide cams the lock plates inward; the bolt assembly is driven rearward, assisted by the remaining pressure in the tube.

The claw extractor extracts the empty case from the chamber, and the bolt assembly carries it rearward. The projector at the rear of the feed box strikes the top of the case, and the cartridge is pivoted down and out of the receiver. The driving springs are compressed on recoil of the bolt assembly.

Continued recoil fully compresses the driving springs, and the movement ends with the bolt striking the buffer. The first phase of counterrecoil places the cartridge-holding pawl in the feeder over the next round. The rest of the forward travel is used to strip and chamber the new round and to lock the action into battery. The cycle is repeated if the electric circuit is still energized.

## SECTION 4. 365-MM RECOILLESS CANNON G-104

## Description of the Weapon

Design requirements for the G-104 (*Gerat-104* or *Device-104*), which were set up by the German Air Ministry, specified that it be a recoilless gun somewhat similar to the MK-113 but capable of firing a 1,400-pound projectile from an airplane. The principle of this recoilless system involves making the weight of the cartridge case equivalent to the projectile and discharging the heavy case from the rear of the gun.

The tube is rifled its entire length with a right-hand twist, and the projectile and cartridge case are preengraved. The effect of the gas exhaust is minimized by muzzle brakes which direct the gas sideways away from the aircraft parts.

## General Data: 365-mm Recoilless Cannon G-104

## Muzzle velocity:

Projectile: 1,034 feet/second.

Case: 1,050 feet/second.

Pressure: 1,700 to 2,000 p. s. i.

Recoil: 0.3937 inch.

## Bore:

Form of twist: Right hand.

The weapon was designed to be mounted beneath the aircraft and to be hydraulically lowered into the firing position.

*Tube With Muzzle Brake and Reinforcements.* The tube is rifled its entire length with a uniform, right-hand twist. The electric firing mechanism is located in the center of the tube on a reinforced area. Muzzle brakes are assembled on both ends of the tube and are so designed that the gases are guided and distributed as far as possible away from the aircraft.

*Electric Firing System.* The firing system consists of two main parts: The housing and the stop pin. The housing is assembled to the reinforcement on the tube and takes the gas pressure. The stop pin presses against the housing and has a spring which touches the contact rings through the current that flows to the primer. The stop pin holds the round in place by its position in the groove between the shell and the case.

*Projectile.* The projectile is a base-fused, armor-piercing shell with a soft iron preengraved rotating band. The rear of the base plate contains a contact ring in its circumference, through which the

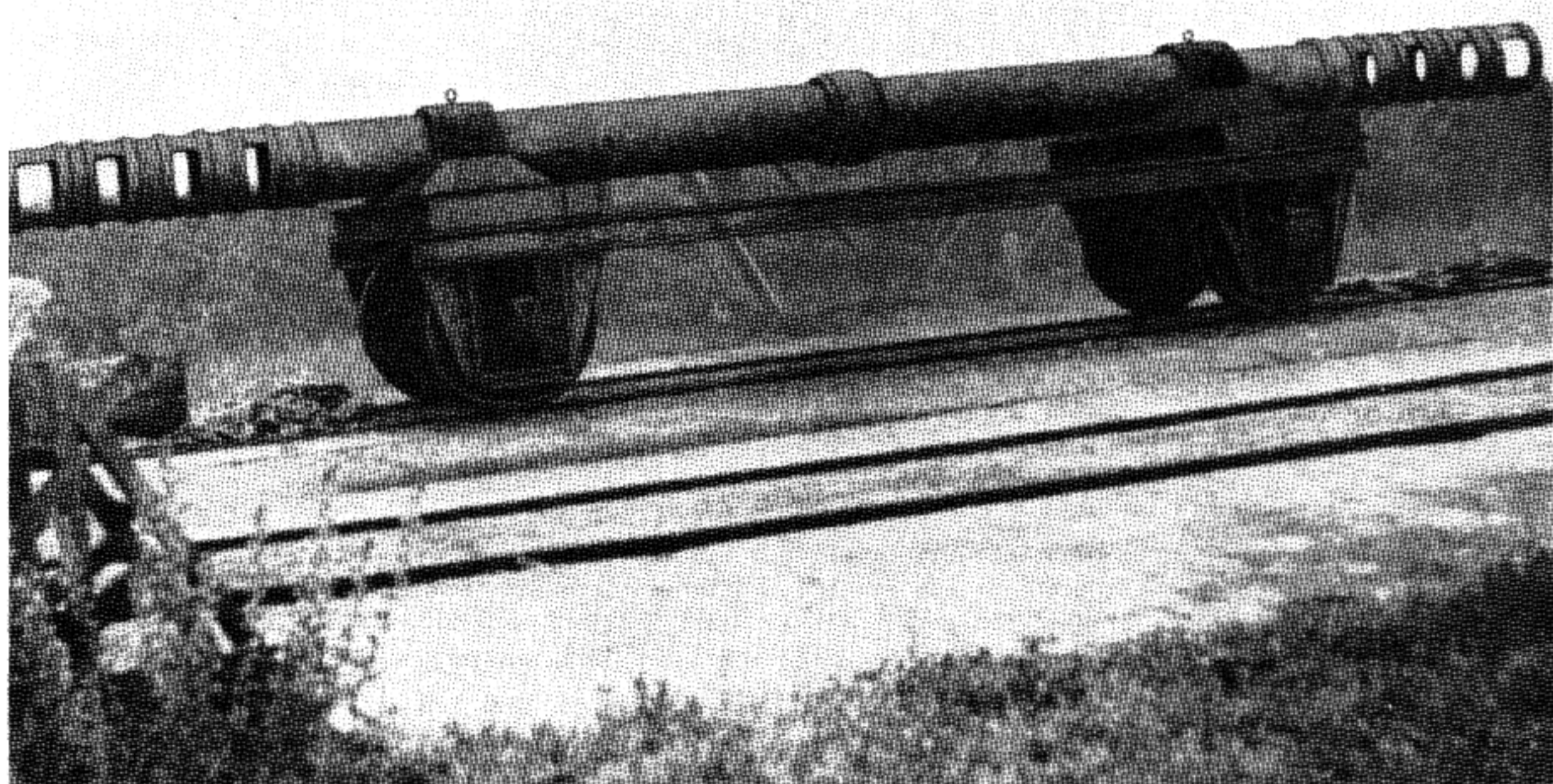


Figure 25-7. 365-mm Recoilless Cannon, G-104.



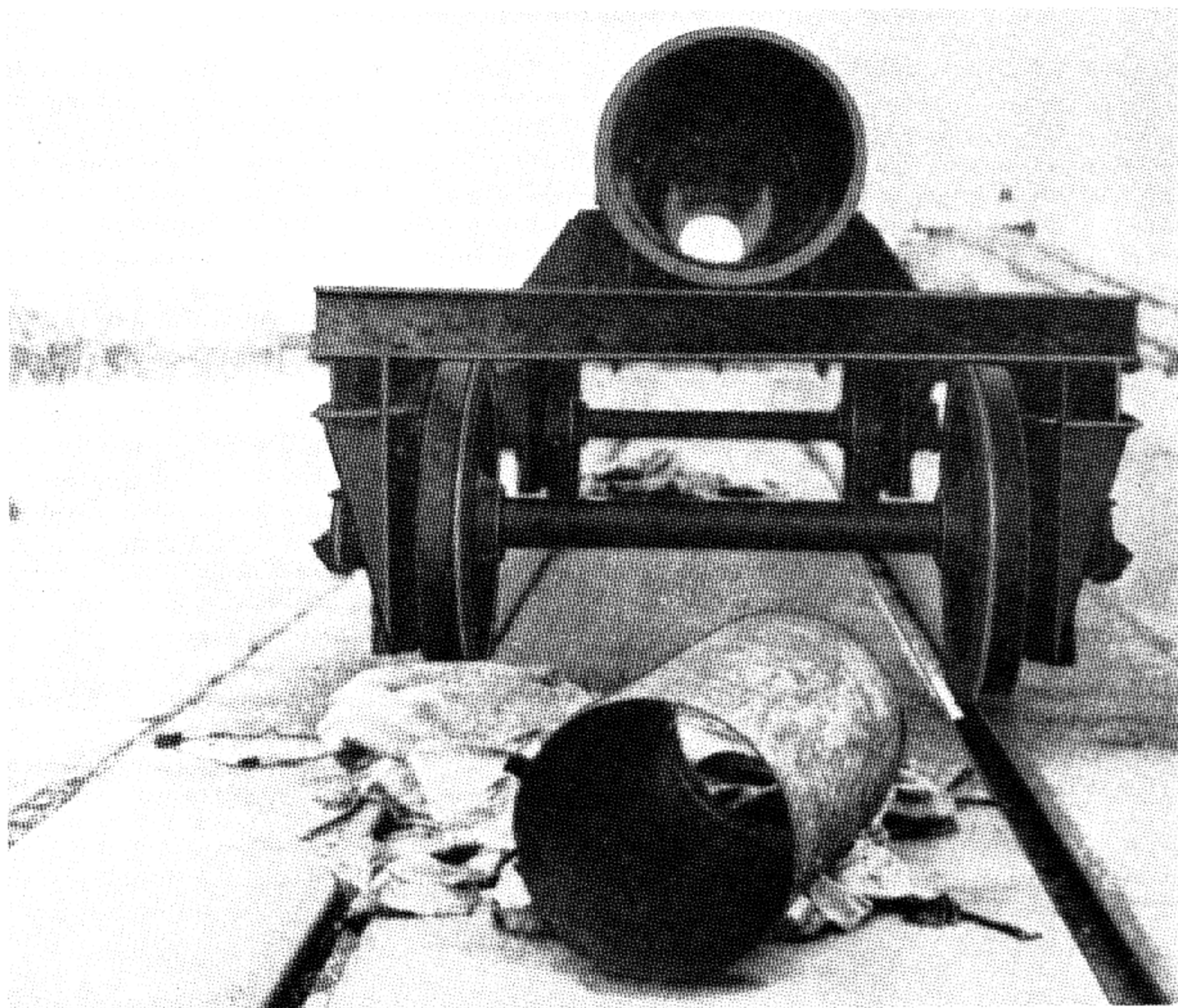


Figure 25-8. 365-mm Recoilless Cannon, G-104. View through bore.

ignition circuit is transmitted to the electric igniter located in the center of the base plate.

*Cartridge Case and Propelling Charge.* The cartridge case contains a propelling charge which is ignited by two igniter pads. At the front end of the cartridge case is a preengraved rotating band by means of which compensation can be made for variations in weight due to manufacturers' tolerances. This is done by replacing the balance plate at the rear of the cartridge case.

The shell and cartridge case are assembled and fired as a fixed round. They are held together by means of three shear pins in the cartridge case which

catch in a groove in the shell and are held in place by means of screws. The complete round is held in a tube by the firing system.

### Functional Tests

Tests were made to determine whether the weapon was recoilless. In these tests, the weapon was mounted on a moveable mounting. Forward and backward movement of about 10 mm was obtained. The results varied significantly. Upon mounting under an aircraft, slight damage to the aircraft occurred in the vicinity of the muzzle brake. The steering mechanism was also slightly damaged.

These defects were eliminated by strengthening the aircraft. The strengthening was not completed, as

the order for the weapon was withdrawn by the Air Ministry. Only 15 rounds were fired altogether.

## SECTION 5. 30-MM MK-108

### Description of the Weapon

The MK-108 is blow-back operated, rear-seared, and belt fed. It uses electric ignition and is charged and triggered by compressed air. The most unusual feature of this weapon is the extremely short barrel with its resulting low muzzle velocity. The term "headspace" in its ordinary sense is not applicable to this gun.

American ordnancemen nicknamed the weapon "the paving buster" because of its appearance and its steady rate of slow fire, which sounds very much like the common pneumatic paving tool.

Another unusual feature of this efficient weapon is its construction. More than 80 percent of the parts are stampings; accordingly, the manufacture is both easy and cheap.

When installed in aircraft, no method of adjustment for harmonization was incorporated in the mount.

On the ME-109 plane, the gun is mounted on its side and fired through the hub of the propeller. Sixty rounds of ammunition can be fed by means of a metal disintegrating link belt from an ammunition can located directly above the gun. The system of operation employed in the MK-108 closely resembles the original Becker Oerlikon method. It has been brought up to date and uses a larger cartridge with a steel case.

The receiver is a metal stamping to which certain fixtures are joined by welding, for example, locking lugs for securing the backplate hinges to accommo-

### General Data: 30-mm Automatic Aircraft Cannon MK-108

Gun length (overall): 45 inches.  
 Gun weight: 135 pounds.  
 Rate of fire: 450 rounds/minute (maximum).  
 Muzzle velocity:  
     1,600 feet/second.  
     1,640 feet/second.  
 System of operation: Blowback.  
 System of locking: Inertia.  
 System of feeding: Belt fed.  
 Method of headspace: Fixed.  
 Location of feed opening: Top side.  
 Location of ejection opening: Top side.  
 Method of charging: Air.  
 Method of cooling: Air.  
 Barrel length: 23 inches.  
 Barrel removal: Permanently fastened.  
 Bore:  
     Direction of twist: Right hand.  
 Muzzle energy: 15.2 foot-tons.  
 Receiver:  
     Length: 26½ inches.  
     Width: 8 inches (approximate).  
     Depth: 8 inches (approximate).

NOTE. This weapon can be fired only from the rear seared position, since it utilizes the forces of inertia for locking.

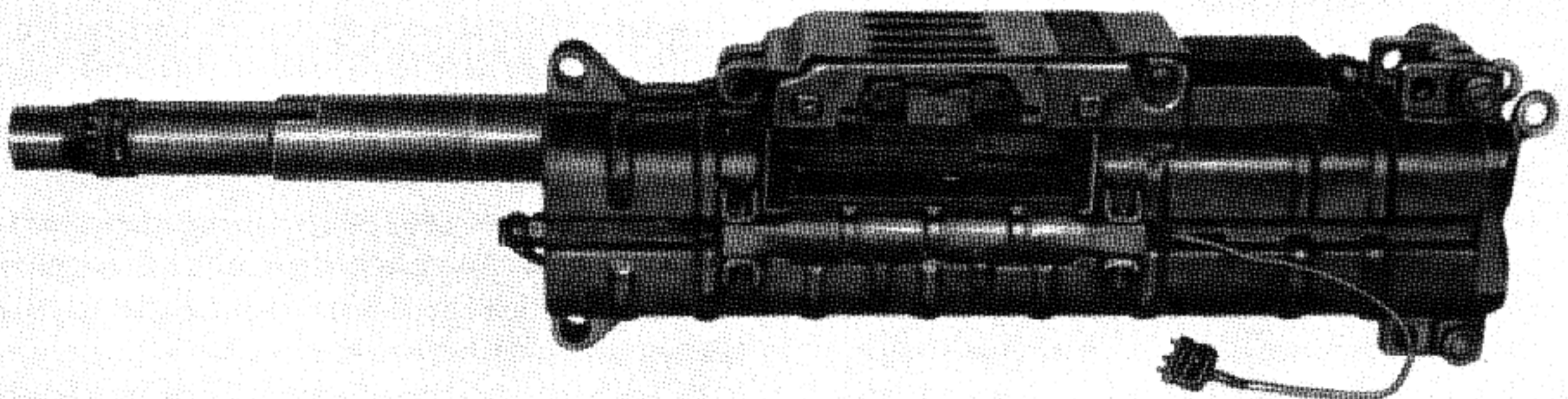


Figure 25-9. Automatic Aircraft Cannon 30-mm MK-108. Left side view.

date the sear housing, cover pin mounting lugs by which the cannon is bolted to the aircraft, and the guides for the ammunition of the feedway. Although the belt feed slides appear to have been forged, the feed mechanism is welded to a stamped cover. The bolt, sear mechanism, and backplate can be either forged or cast. The bolt and the charging cylinder seem to have considerable machine work on them and are well finished. However, the feed mechanism, the sear mechanism, and the backplate except for the bearing surfaces are roughly constructed.

The principal assemblies consist of the receiver, the cover which contains the entire feed mechanism, the sear assembly, an electrical firing device located on the left side of the receiver, the bolt assembly, driving spring assembly, a compressed air operating assembly built into the forward part of the receiver directly below the barrel, and the barrel proper.

The receiver is roughly 26½ inches in length and slightly over 8 inches in depth and width. The sides of the receiver are stamped so as to provide guides for the belt. Viewed from the rear, the receiver assumes a slightly oval shape.

The feedway is built into the receiver starting approximately 11 inches from the rear of the receiver. It is approximately 1¾ inches in depth and extends for nearly 8¼ inches. When viewed from the side, the receiver has a flat appearance.

Because the operational power is straight blow-back and the system of feeding also requires slow movement, the weapon was expected to have a rate of fire of 600 rounds per minute maximum.

Its construction makes it adaptable for use in fuselage, wings, and engine. It has been experimentally mounted in a rotating mount.

The barrel is affixed to the receiver by threading and locked in place by means of a split pin driven vertically through a round opening in the top of the receiver so as to engage a locking groove in the barrel. The headspace on this weapon is fixed. The cover is attached to the receiver by means of a bolt nine-sixteenths of an inch in diameter and 3⅛ inches long, which is held in place by a spring. The cover is hinged just forward of the feedway in the center of the top of receiver, so that, when it is in a closed position, it supports the feed mechanism in its proper relation to the feedway.

The sear mechanism is affixed to the top of the receiver in a housing 1¾ inches to the rear of the feedway. The bolt is machined so as to fit the guides in the receiver, and it is bored through its entire length 3 times. The central and largest opening accommodates a charging cylinder, while the other small openings accommodate the driving spring assemblies. The top of the bolt is affixed to the housing which contains the firing electrode and the extractor. Two grooves milled into the top of the bolt operate the belt feed levers of the feed mechanism.

These groups or assemblies are easily removed from the receiver without the use of special tools. The only assemblies which present difficulties in assembly and disassembly are the driving springs; this difficulty is due to the pressure required to compress the springs upon their guides.

The cannon is initially charged by compressed air through the medium of a charging cylinder, or piston. The air is metered to the piston from a supply consisting of two interconnected air bottles. Initial charging simply forces the bolt to the rear of the receiver, compressing the driving springs. It is held to the rear by two dogs which extend downward through the top of the rear of the receiver from the sear mechanism. Alining of the round with the chamber is accomplished on the first few inches of forward motion of the bolt.

Ejection of the used cartridge case and link is also accomplished during the forward motion of the bolt. When the bolt reaches full battery position, electrical contact is made and the round is fired.

Since there is no breech-locking device other than the weight of the spring-loaded bolt, the recoil of the cartridge case forces the bolt to the rear. As long as air pressure is maintained in the sear mechanism the weapon will continue to fire automatically. The valves of the air metering system are apparently electrically operated by means of solenoids incorporated in the valve housing.

### Cycle of Operation

To prepare the MK 108 for firing, the operator places a loaded belt of cartridges in the ammunition container and inserts the first round under the belt-holding pawl with the bolt forward.

When readying the weapon for combat, the pilot gunner pushes in on the charger button. The electric-powered solenoid opens an air valve on the

charging device, and the belt is thrown rearward until it engages the sear and holds the assembly in a cocked position.

The valve now releases the air, permitting the charger to return home from its own spring tension. On this recoil stroke of the bolt, the belt feed lever, which is actuated by lugs riding in grooves in the bolt body, moves a cartridge over to the edge of the feed mouth. The gun is now cocked and the cartridge positioned for the next phase of operation.

When the sear is released, the heavy bolt starts home under compression of the driving spring. Its first forward movement causes the incoming round to be moved over the necessary distance to be indexed. The bolt face, which is narrower than the cartridge width, contacts the base of the cartridge, pushing it through the link into the chamber. Before final movement is halted by complete chambering, an electric contact is made that energizes the firing pin. This action detonates the electric primer, but the time delay is enough to allow the bolt to go still farther into battery.

Actual explosion of the propellant takes place while the bolt is still traveling at full speed forward, allowing the projectile to clear the bore of the weapon before the heavy bolt can begin counter-recoil movement.

The lubricated cartridge case is free to exert full blowback pressure on the face of the bolt, which starts recoiling immediately after the projectile clears. The cartridge case is supported by the extractor until the bolt face clears the rear end of the link. At this time, the dog rises to stop travel of the empty case, leaving it in its link. Continued movement of the bolt to the rear causes the feed arms to move the belt over halfway, shoving the empty case and link outside the receiver. This principle is known as two-stage feeding. The feed may be operated from left to right or vice versa by repositioning parts.

The bolt recoil is stopped by compression of the two strong driving springs, which then drives the assembly into counterrecoil to repeat the cycle if the solenoid remains actuated.

## SECTION 6. 5.5-CM MK-112

### Description of the Weapon

This gun was built at the suggestion of the German Air Force.

The new weapon was to have the following characteristics: Caliber, 5.5 cm; blowback operated having a muzzle velocity of 1,950 feet per second; total weight, not to exceed 600 pounds; overall length, 80 inches; muzzle energy, 97.5 foot-tons; rate of fire, a minimum of 300 rounds per minute. The projectile was to weigh 3.3 pounds, have an overall length of 8.8 inches, and contain an explosive charge of 14.8 ounces.

In the earlier stages of development and testing, a total of 10 weapons were fabricated for trial. Five more weapons were held back for improvement on the basis of test results. Seven of the completed weapons representing the original design, weighed 660 pounds, and three improved models weighed 605 pounds. Records indicate that reducing the weight was a critical problem because of the shortage of metals in Germany at that time.

In order to test individual parts for duration of functioning, extended firing tests were performed

with the prototype design. One weapon was tested with approximately 1,300 rounds. The firing tests were made at a temperature range from 15° F. to 185° F. Smooth operation of the weapon was not

### General Data: 5.5-cm Aircraft Cannon MK-112

Gun length (overall): 80 inches.
Gun weight:
600 pounds (maximum).
660 pounds (for original design).
605 pounds (for improved model).
Rate of fire: 300 rounds/minute.
Muzzle velocity: 1,950 feet/second.
System of operation: Blowback.
System of locking: Inertia.
System of feeding: Belt fed.
Method of headspace: Fixed.
Location of feed opening: Top side.
Location of ejection opening: Top side.
Method of charging: Air.
Method of cooling: Air.
Barrel removal: Permanently fastened.
Bore:
Direction of twist: Right hand.
Muzzle energy: 97.5 foot-tons.

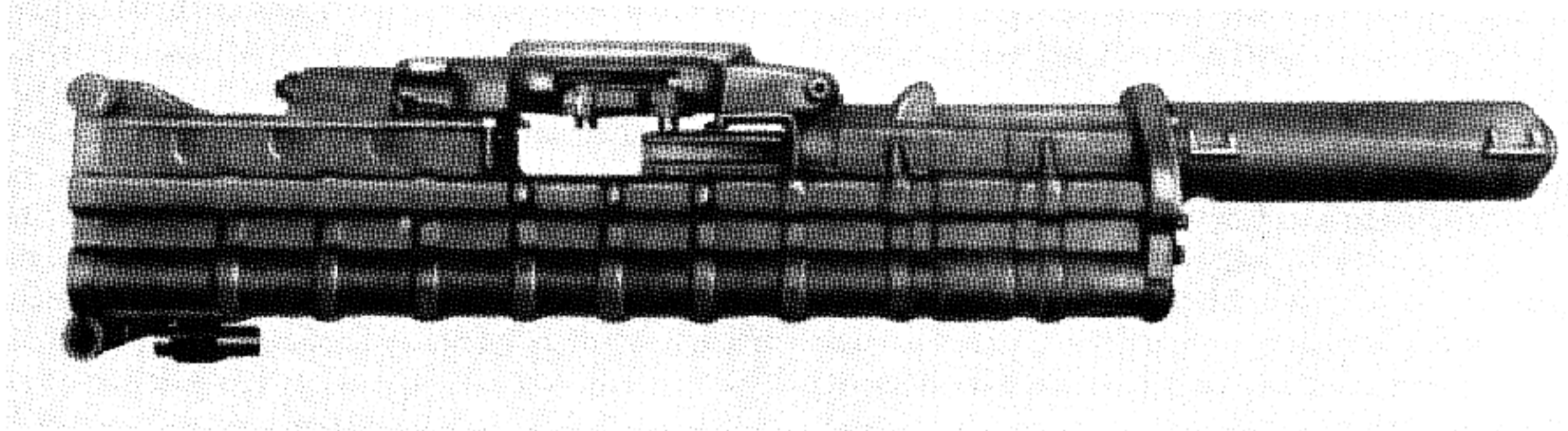


Figure 25-10. Aircraft Cannon 5.5-cm MK-112. Right side view.

achieved at high temperatures. The performance of the ammunition belt was not satisfactory in the early design. Further experimental tests were performed and the required firing rate of 300 rounds a minute was achieved. Also a belt lift of 2 meters was obtained. Bursts of fire to 20 rounds were fired in the initial firing.

Increasing the rate to 360 rounds per minute brought on further complications with the cartridge

belt, hence the rate of fire was finally standardized at 300 rounds per minute.

Cold weather tests performed at  $-58^{\circ}$  F. demonstrated the weakness of plain carbon steels, and it was necessary to redesign many of the parts for use in these low temperatures.

Difficulties with the electric ignition system and the connections between the firing lever and the ignition bolt were experienced in practically all early

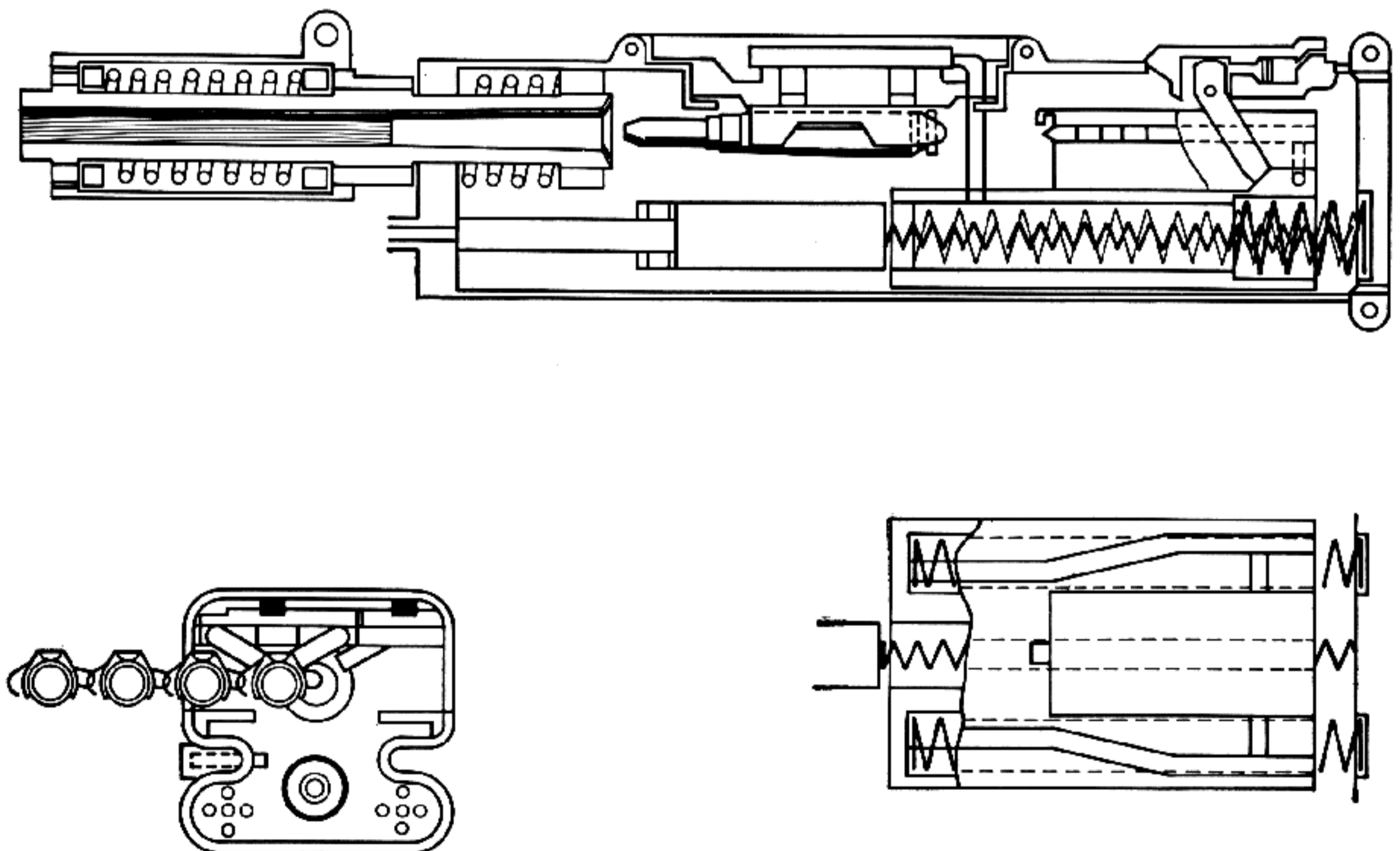


Figure 25-11. Aircraft Cannon 5.5-cm MK-112. Longitudinal and transverse sections.

firing. A hydraulic cocking mechanism was designed to replace the original pneumatic cocking mechanism.

## Description of Principal Components

*Tube, Electric Firing System, and Recoil Mechanism.* In the forward part of the cradle is the tube, which is held in place with a set of buffer springs. A recoil mechanism, comprised of ring springs, is located around the front part of the tube, housed in a steel tubing and provided with a trunnion hole for installation in an aircraft mount.

*Weapon Cradle.* The cradle of the MK-112 is formed out of sheet metal, as are the slides for the breechblock. Two holes are located on the upper part of the cradle for the installation of the feed mechanism, and two other holes are provided for the electropneumatic trigger mechanism. Two holes are located in the rear section of the cradle for the mounting of the rear plate. The cocking mechanism is mounted on the front plate, and a filling plug is provided for connection with the pneumatic system. On the left side of the cradle and below the breechblock, the electric switch lever is mounted.

*Breechblock Mechanism, Buffer, and Electric Firing Mechanism.* The breechblock is a forged monobloc, the front section of which is provided with a removable hardened steel bushing, held in position with a bayonet joint and secured with a pin. The extractors are also located in the breechblock and operated with springs. The electric firing pin is placed in a horizontal groove, and the electric wiring is mounted on the left side of the breechblock. On the bottom part of the breechblock are holes provided for the buffer springs. On the upper part of the breechblock, a catch plate is provided for the pneumatic trigger. Feed cam grooves are located on both sides of the plate.

*The Counterrecoil Springs and the Breechblock.* The counterrecoil mechanism consists of 2 sets of 4 springs, left- and right-hand turns, assembled in telescopic manner.

*Feed Mechanism.* The housing for the feed mechanism is fabricated from sheet metal and contains two transport slides which move in opposite direction to the feed fingers and the safety pawls. The transport slides are connected with two transport levers which are encased in the feed housing and mesh with the breechblock. The controlling

grooves which regulate the transport catches are also located in the feed mechanism. The feed mechanism is connected to the cradle by means of a bolt which may be quickly disengaged by hand.

*Electropneumatic Cocking Mechanism.* A cocking bolt is mounted on the front wall of the cradle cover over which a cocking piston slides horizontally. A horizontal helical spring, located in the bottom of the cradle, returns the cocking piston to battery.

*Electropneumatic Trigger.* The electropneumatic trigger is located in the top rear section of the cradle and rests against two ring springs, which act as a buffer to absorb forces developed by the breechblock. The trigger housing retains a trigger latch which locks the breechblock in the recoiled position. The trigger latch is controlled by an air-operated piston.

*Rear Plate.* The rear plate is connected to the cradle by means of a bayonet-type bolt. The rear plate limits the maximum recoil travel of the breechblock and acts as a retainer for the springs and the cocking mechanism.

*Electric Firing Lever.* The firing lever is formed out of sheet metal and is connected to the cradle by means of a bolt. An electric contact, located within the cradle, energizes the firing system when the breechblock passes over its surface. In case of a misfire, a lever in the rear section of the firing lever initiates firing mechanically through the breechblock.

*Ammunition Feed Belt.* The cartridge belt is punched out of sheet metal. It is provided with slots and hooks. The rounds hold the links together to form a belt assembly, and the links disintegrate into parts when the rounds are rammed into the gun.

## Cycle of Operation

This weapon is operated on the blowback principle. When the electropneumatic trigger is released, the breechblock is rammed into battery by the action of the counterrecoil springs. The breechblock indexes the feed mechanism by cam action between the grooves located in the breechblock and transport levers in the feed system. The belt is indexed by half a pitch, and the round is aligned with the center of the tube when the breechblock rams the cartridge into the gun. At the same time, the extractor engages the rim of the case.

Electric ignition takes place before the breechblock reaches the forward dead end of travel. Gas pressure pushes the breechblock beyond the length of the case and extraction occurs. The surplus energy of the breechblock is absorbed by a buffer mechanism, which is located in the breechblock and rests against the cradle.

When the electropneumatic trigger is not operated, the breechblock is locked in recoil position. In case of a misfire, the counterrecoil forces are

absorbed by a spring buffer. The electropneumatic cocking mechanism pushes the breechblock beyond the locking trigger, and the cocking mechanism is returned by a helical spring. The ammunition may be fed from either right or left side of the weapon.

In order to keep the recoil forces within certain limits for the installation in aircraft, the weapon is equipped with a mechanism to absorb surplus forces developed in firing.

## SECTION 7. SG SERIES OF RECOILLESS AIRCRAFT CANNON (113A, 116, 117, AND 118)

### Description of the Weapons

Known officially as the SG series (*Sonder Gerat* or special purpose equipment), these weapons were developed at the Herman Goering Werke at Brunswick. They never advanced beyond the developmental stage.

These weapons were designed in various calibers on the principle of the Davis gun and were recoilless. The most popular version was the 7.5-cm sabot type projectile having a 4.5-cm AP core that was fired out of one end, and an equal weight that was shot out of the other. The two elements were fastened together by a rod with the weakened section arranged so that the two halves would part at a predetermined chamber pressure.

The SG-113A was mounted vertically, muzzle downward, and fired by some echo impulse from tanks on the ground as the aircraft passed over them. Radar was the means of obtaining the echo. Other types were mounted to fire straight up for use against heavy bombers, while still others were designed for forward firing.

#### General Data: 7.7/4.5-cm Gun SG-113A

<p>Gun length: 62.2 feet. Gun weight: 105.6 pounds. Muzzle velocity: 2,112 feet/second. System of operation: Recoilless, single loader. Barrel length: 62.2 feet. Barrel weight: 105.6 pounds.</p>
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#### General Data: 30-mm Cannon SG-116

<p>Gun length: 63 inches. Gun weight: 70.56 pounds. Rate of fire: Single shot. Muzzle velocity: 2,822 feet/second. System of operation: Recoilless, loaded from muzzle with self-consuming cartridge case; propellant force kicks counterweight to rear. System of locking: None. System of feeding: Manual. Method of headspace: Factory established. Location of feed opening: None. Location ejection opening: None. Method of charging: None. Method of cooling: Air.</p>	<p>Barrel length: 52.68 inches. Barrel weight: 46.53 pounds. Rate control: None. Barrel removal: Not quick disconnect. Bore: Number of grooves: 16. Groove depth: 0.0177 inch. Groove width: 0.1456 inch. Pitch: 8° 30'. Direction of twist: Right hand. Form of twist: Uniform.</p>
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General Data: 30-mm SG-117 and 30-mm SG-118<sup>1</sup>

<p>Gun length: 63 inches. Gun weight: 61.74 pounds. Rate of fire: 10,000 rounds/minute. Muzzle velocity: 1,641 feet/second. System of operation: 7 barrels grouped together, fired electrically. System of locking: Rigid. Whole unit glides back and fires by contacts along rail that is mounted perpendicular. System of feeding: Manual. Method of headspace: Factory established. Location of feed opening: Rear. Location of ejection opening: None. Method of charging: None. Method of cooling: Air.</p>	<p>Barrel length: 21.46 inches. Barrel weight: 4.85 pounds each. Rate control: None. Barrel removal: Not quick disconnect. Bore:     Number of grooves: 16.     Groove depth: 0.0177 inch.     Groove width: 0.138 inch.     Pitch: 4° 30' up to 8° 30'.     Direction of twist: Right hand.     Form of twist: Progressive.</p>
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<sup>1</sup> These two weapons differ only in the method of mounting. Data tabulated are identical for both guns.





Figure 25-12. Experimental installation of SG-116 in German fighter plane.



Figure 25-13. SG-116 installation as seen from wing tip.

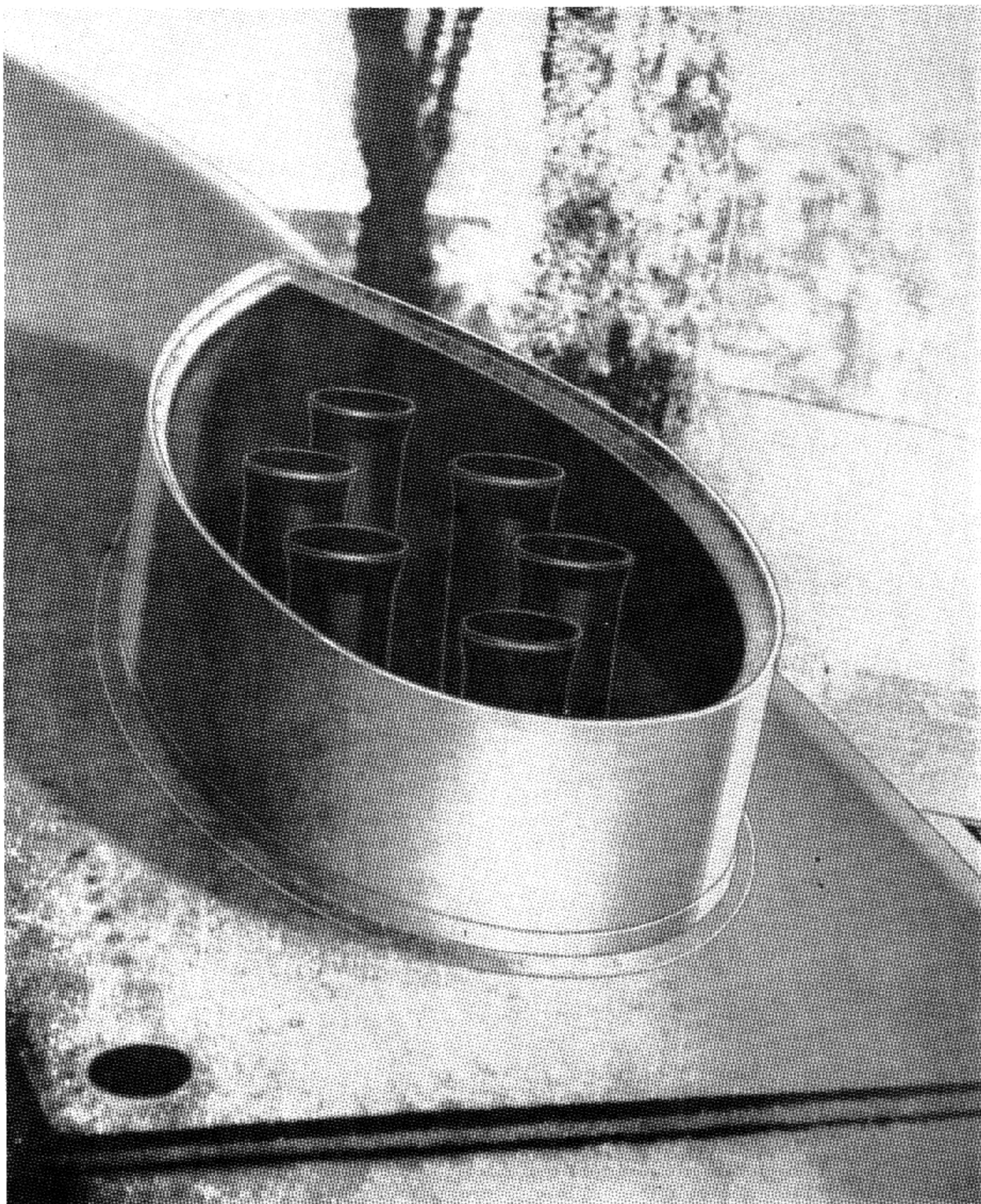


Figure 25-14. SG-116 installation from front, showing shape of fairing around muzzles.

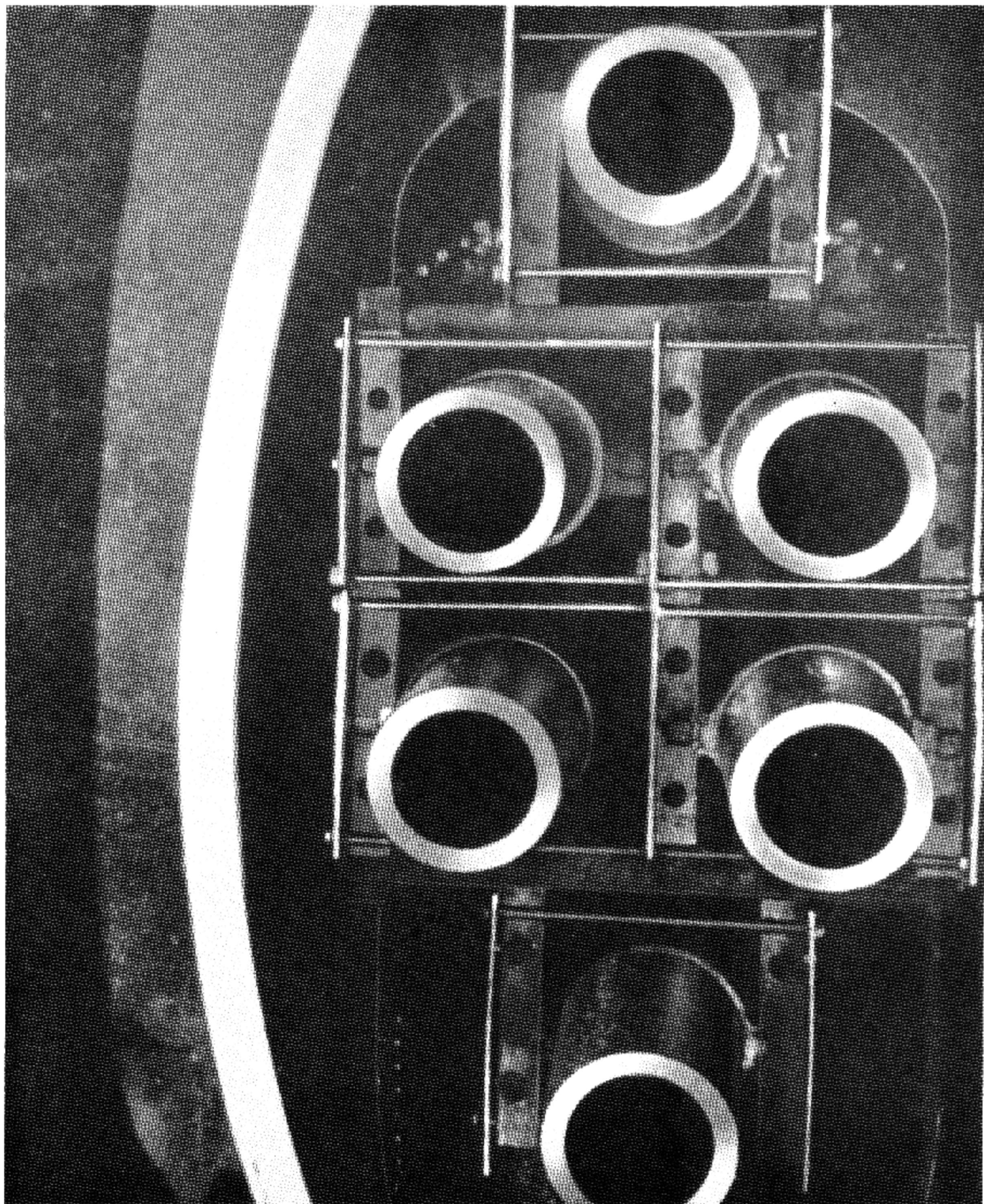


Figure 25-15. SG-116 installation. Top view.

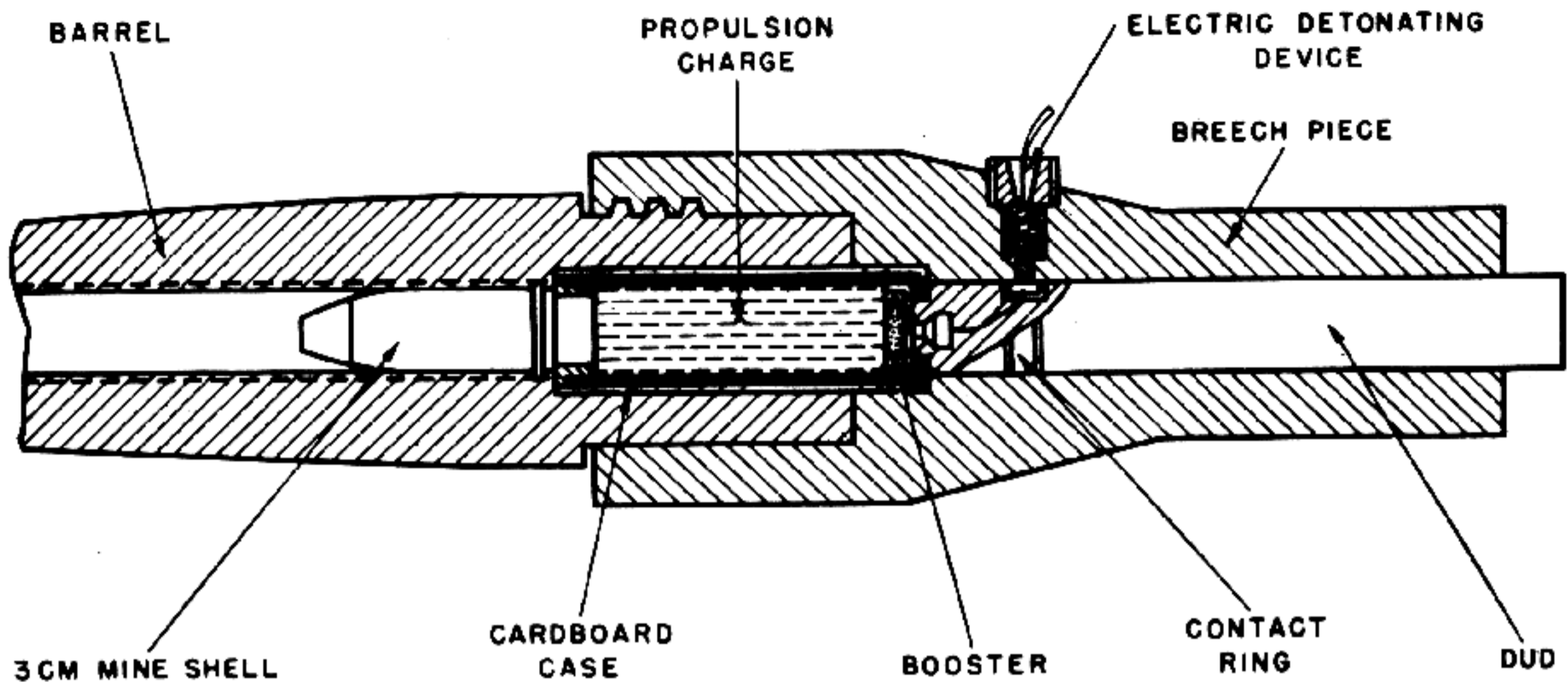


Figure 25-16. Section through one of the barrels of an SG-116.

## SECTION 8. 5.5-CM AUTOMATIC CANNON MK-114

### Description of the Weapon

The Ordnance Bureau of the Air Ministry set up the following requirements for the development of this automatic cannon: caliber, 5.5 cm; muzzle velocity, 3,250 feet per second; shell weight, 4.4 pounds; explosive, at least 0.88 pound; cyclic rate, at least 150 r. p. m.; weight to be not over 2,200 pounds; no alloy steels to be used; simple construction; electric firing; remote control; for use either as fuselage or engine-mounted gun. In order to keep the recoil force down, a recoil mechanism with a brake was to be provided.

The ammunition for the 5.5-cm flak device 58 was to be used. The gas-pressure loading system with fixed bolts was to be used.

The Rheinmetall-Borsig firm undertook the design of the gun, which was quite difficult. The specified total weight of not over 2,200 pounds allowed a gun weight of about 1,540 pounds. The use of nonalloyed steel seriously compromised the design. The various models that were completed came close to the requirements in their general structure but never met the main requirements fully.

Development work was stopped in the fall of 1944 by order of the Air Ministry.

### General Data: 5.5-cm Automatic Cannon MK-114

Gun length: 137 inches.	Method of cooling: Air.
Gun weight: 1,543.5 pounds.	Barrel length: 165.7 inches.
Rate of fire: 150 rounds/minute.	Barrel weight: 551.25 pounds.
Muzzle velocity: 3,446 feet/second.	Rate control: None.
System of operation: Gas operated.	Barrel removal: Not quick disconnect.
System of locking: Sliding vertical wedge.	Bore:
System of feeding: Gas-operated feeder.	Number of grooves: 20.
Method of headspace: Factory established.	Groove depth: 0.0295 inch.
Location of feed opening: Top portion of receiver; may be fed from left or right.	Groove width: 0.197 inch.
Location of ejection opening: Bottom.	Pitch: 8° 30'.
Method of charging: Electropneumatic.	Direction of twist: Right hand.
	Form of twist: Uniform.

## SECTION 9. 5.5-CM AUTOMATIC RECOILLESS CANNON MK-115

## Description of the Weapon

The German High Command ordered the Rheinmetall engineers to explore the possibilities of developing a belt-fed automatic aircraft cannon based on the recoilless principle. At the end of hostilities,

allied engineers found a device well along in the development stage. Officially called the MK-115, this unique weapon employed a locked breech; but by means of diverting gases through an orifice, the recoil forces were cut to practically zero. A combustible cartridge case was used by this weapon.

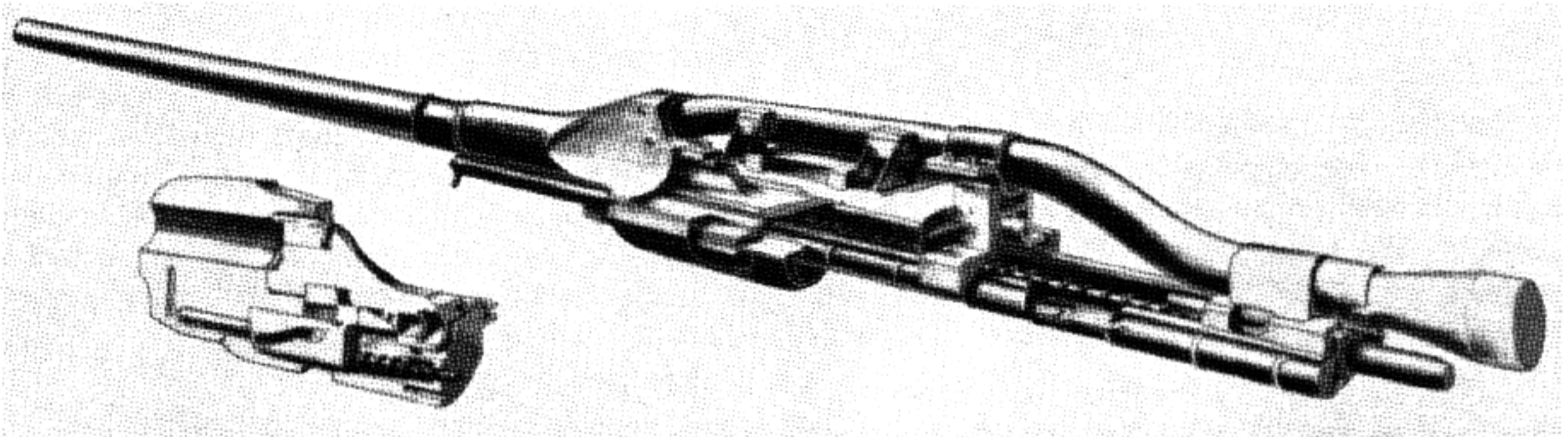


Figure 25-17. Artist's conception of 5.5-cm Automatic Recoilless Cannon MK-115.

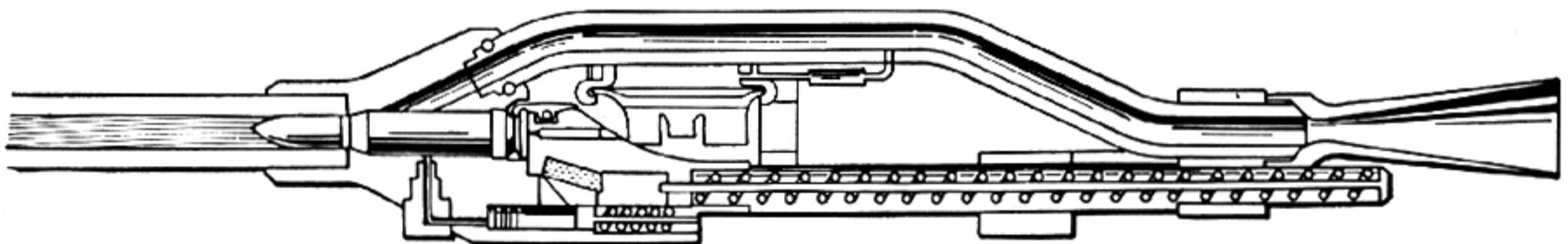


Figure 25-18. 5.5-cm Automatic Recoilless Cannon MK-115. Longitudinal section.

## General Data: 5.5-cm Automatic Recoilless Cannon MK-115

Gun length: 129.9 inches.  
 Gun weight: 396.9 pounds.  
 Rate of fire: 300 rounds/minute.  
 Muzzle velocity: 1,969 feet/second.  
 System of locking: Swinging lock.  
 System of feeding: Gas-operated belt.  
 Method of headspace: Factory established.  
 Location of feed opening: Top of receiver, either left- or right-hand side.  
 Location of ejection opening: Rear portion of case is pulled back into link and ejected from the side opposite to that from which it is fed.  
 Method of charging: Electropneumatic.  
 Method of cooling: Air.

Barrel length: 51.97 inches.  
 Barrel weight: 83.9 pounds.  
 Rate of control: None.  
 Barrel removal: Not quick disconnect.  
 Bore:  
 Number of grooves: 20.  
 Groove depth: 0.0295 inch.  
 Groove width: 0.197 inch.  
 Pitch: 8° 30'.  
 Direction of twist: Right hand.  
 Form of twist: Uniform.

NOTE: This weapon used a combustible cartridge case, leaving only the base to dispose of.

## SECTION 10. 5-CM BK AUTOMATIC AIRCRAFT GUN

## Description

The 5-cm BK automatic aircraft gun is a recoil-operated mechanism having an electrical firing system. The gun is fed and rammed by a series of air-operated pistons. The system is interlocked by electrical switches which, through solenoid-operated valves, control the compressed air supply to the pistons. The ring-shaped magazine has a capacity of 22 rounds. The recoil system is of the hydro-pneumatic type.

The tube and breech ring are housed and ride in the cradle. The recoil mechanism and counter-recoil mechanism are mounted on the cradle and secured to the breech ring. The ring magazine encircles the cradle and contains an endless belt of links with a capacity of 22 rounds. The links

ride on a strip fastened to the inside of the outside shell of the magazine. The rounds are loaded in the belt through an opening in the magazine at the left rear. The endless belt is moved by the feed mechanism which is mounted on top of the drum magazine.

The feed mechanism is operated by the compressed air supply. At the proper time during the cycle, the air enters the cylinder and drives the piston which carries the cross piece and feed pawls. The holding pawls are cammed downward and return to the holding position on the return stroke of the feed piston. The return of the piston is caused by the feed springs, which are compressed on feeding. The positioning of the round by the feed system is indicated for the continuing of the cycle by operation of a switch.

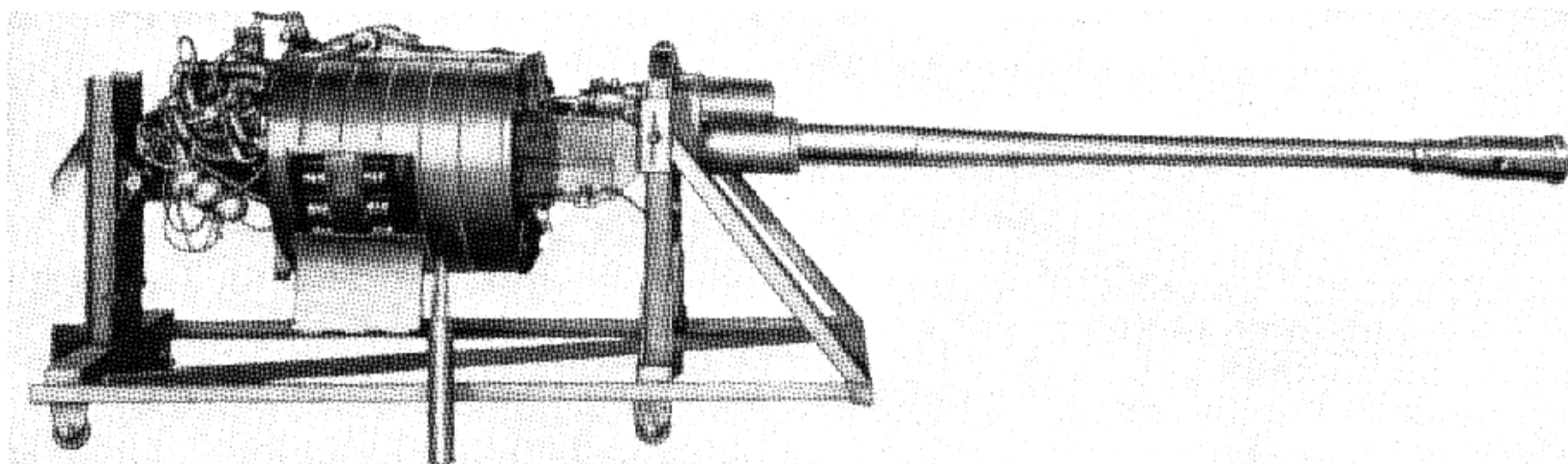


Figure 25-19. 5-cm BK Automatic Aircraft Gun, mounted in test stand. Right side view.

## General Data: 5-cm BK Automatic Aircraft Gun

Gun length: 149 inches.  
 Gun weight: 1,170 pounds.  
 Rate of fire: 45-50 rounds/minute.  
 Muzzle velocity: 3,010 feet/second.  
 System of operation: Long recoil.  
 System of locking: Sliding vertical block.  
 System of feeding: Circular automatic feeder holding 22 rounds.  
 Method of headspace: Sliding block constructed with sloping face so as to insure perfect headspacing.  
 Location of feed opening: Rear of breech.  
 Location ejection opening: Rear of breech.  
 Method of charging: Electropneumatic.  
 Method of cooling: Air.

Barrel length, without muzzle brake: 94 inches.  
 Barrel weight: 480 pounds.  
 Rate of control: None.  
 Chamber pressure: 40,000 p. s. i.  
 Bore:  
 Number of grooves: 20.  
 Groove depth: 0.75 mm.  
 Groove width: 5.0 mm.  
 Pitch: 8° 30'.  
 Direction of twist: Right hand.  
 Form of twist: Constant.  
 Muzzle energy: 238 foot-tons.  
 Capacity of ring magazine: 22 rounds.

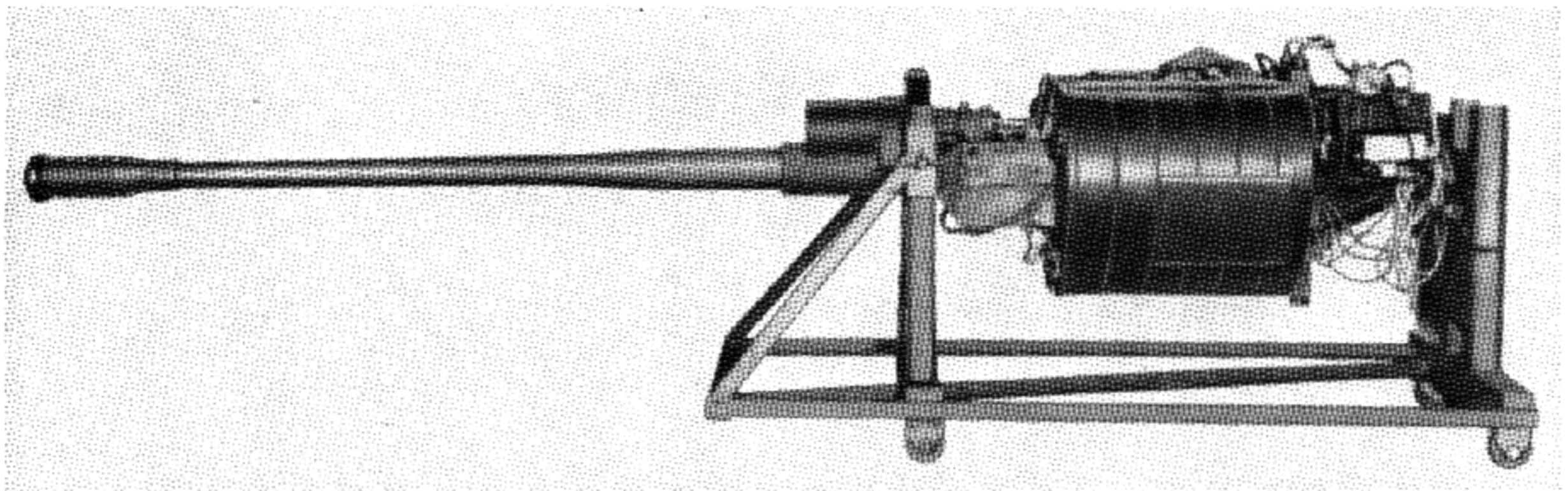


Figure 25-20. 5-cm BK Automatic Aircraft Gun, mounted in test stand. Left side view.

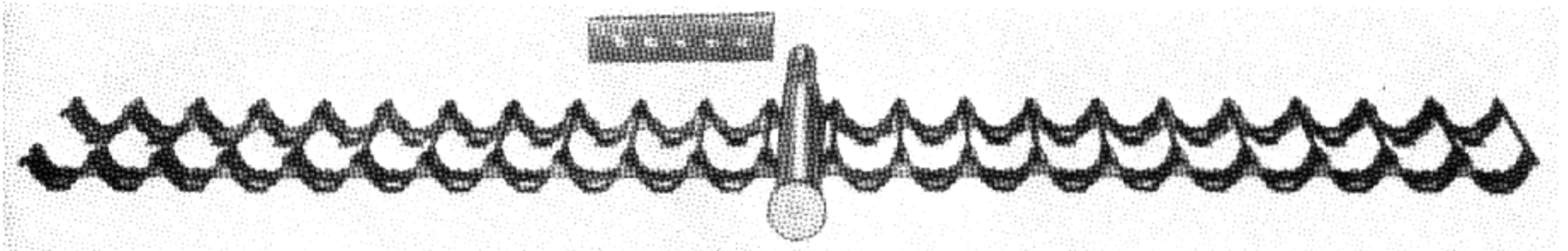


Figure 25-21. Feed belt of 5-cm BK Automatic Aircraft Gun.

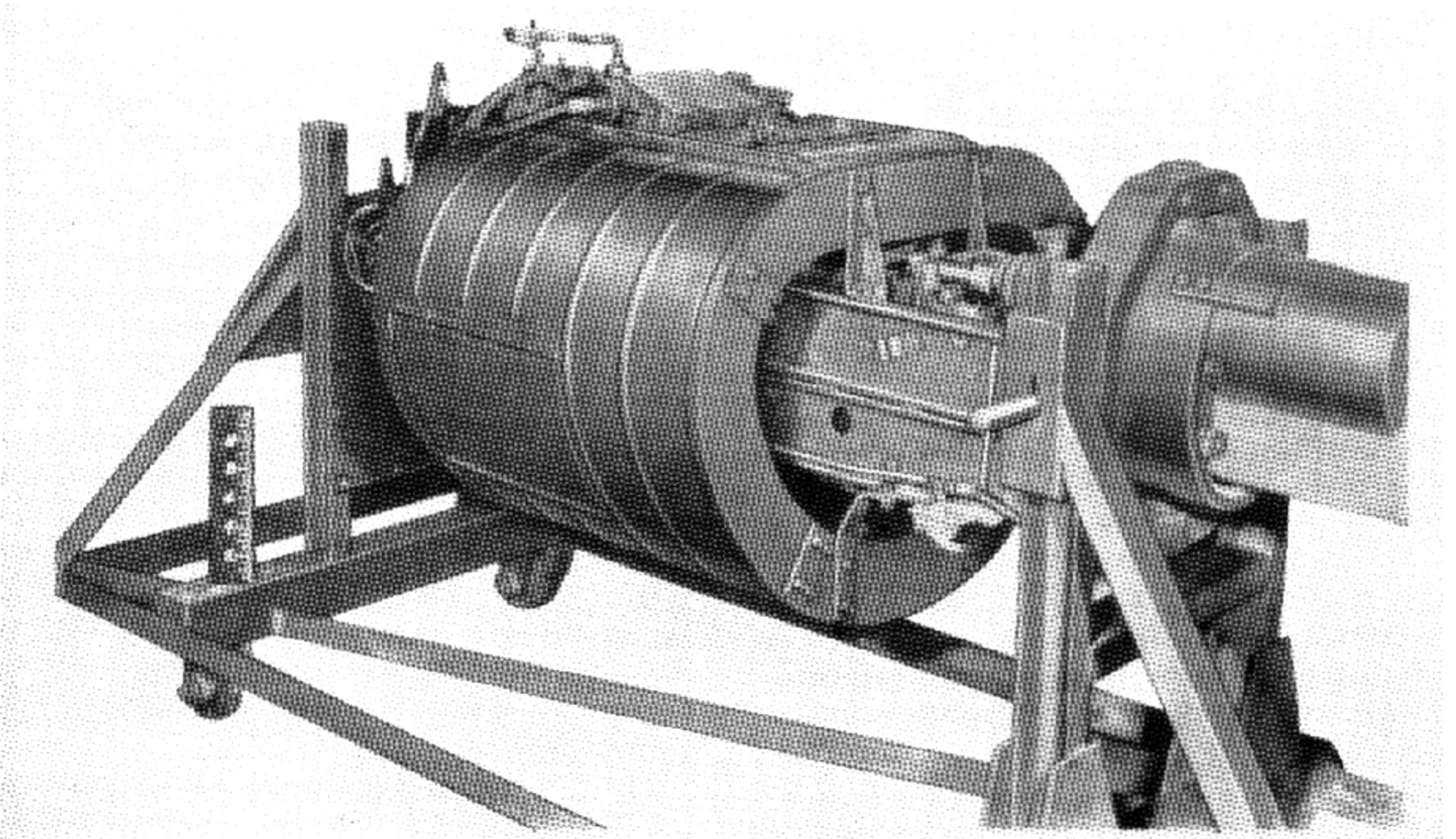


Figure 25-22. Receiver of 5-cm BK Automatic Aircraft Gun. Closeup view.



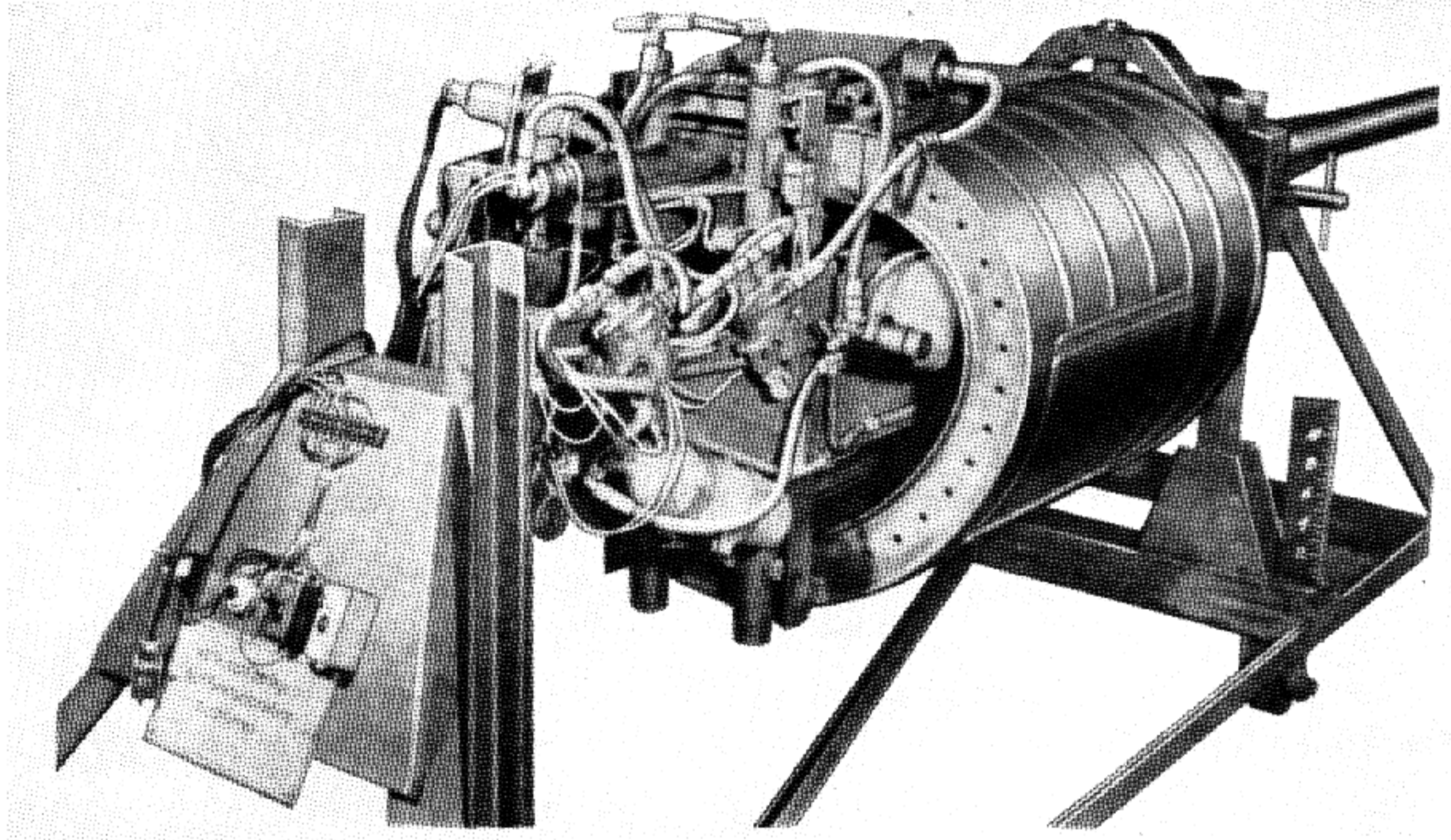


Figure 25-23. 5-cm BK Automatic Aircraft Gun. Right rear view.

On each side of the cradle and beneath the magazine, there are air bottles which contain the compressed air supply to operate the gun. The air is metered to the proper piston through one of three electrically-operated valves. There are six electric switches which complete the circuits to operate the valves at the proper time.

The main switch is operated by a lever in the rear of the loading tray. The lever is depressed by the round as it is positioned on the tray. This lever is operated by the rammer head moving forward and rearward. A switch is operated when the breechblock is in the down, or open, position, to prevent ramming of the round on a closed breech.

The loading tray is secured to two spring-loaded, air-operated pistons riding in cylinders. At the proper time in the cycle, the air is applied to the cylinders to drive the pistons down, compressing the springs so that the tray may return to its upward position on release of the air pressure. At the front of the tray is a spring-loaded holding pawl. When the round is pushed on the tray from the right side by the feed mechanism, the holding pawl is rotated

upward and then snaps down, holding the front of the round under the bridge. As the round is rammed forward, the holding pawl accommodates the larger diameter of the case by rotating upward. As the rear end of the round enters the tray, it depresses a spring-loaded retaining catch which snaps out again after the round is in its seat. This action prevents the rear end of the round from escaping. A small vertical plate engages the front of the rim, thus preventing it from being driven forward by the face of the holding catch as the round is moved into position on the tray. The ramming head is secured to the air-operated piston in the ramming cylinder. The rammer piston, when being driven forward, compresses a spring to return the rammer upon release of the air pressure. The rammer head has an extension on the top and left side to hold the round when the tray is moving down, and to stop the round when it is being put on the tray by the feed mechanism.

The breechblock is practically the same as that used in the MK-214. The operating shaft rotated by the operating cam fits into the operating crank.

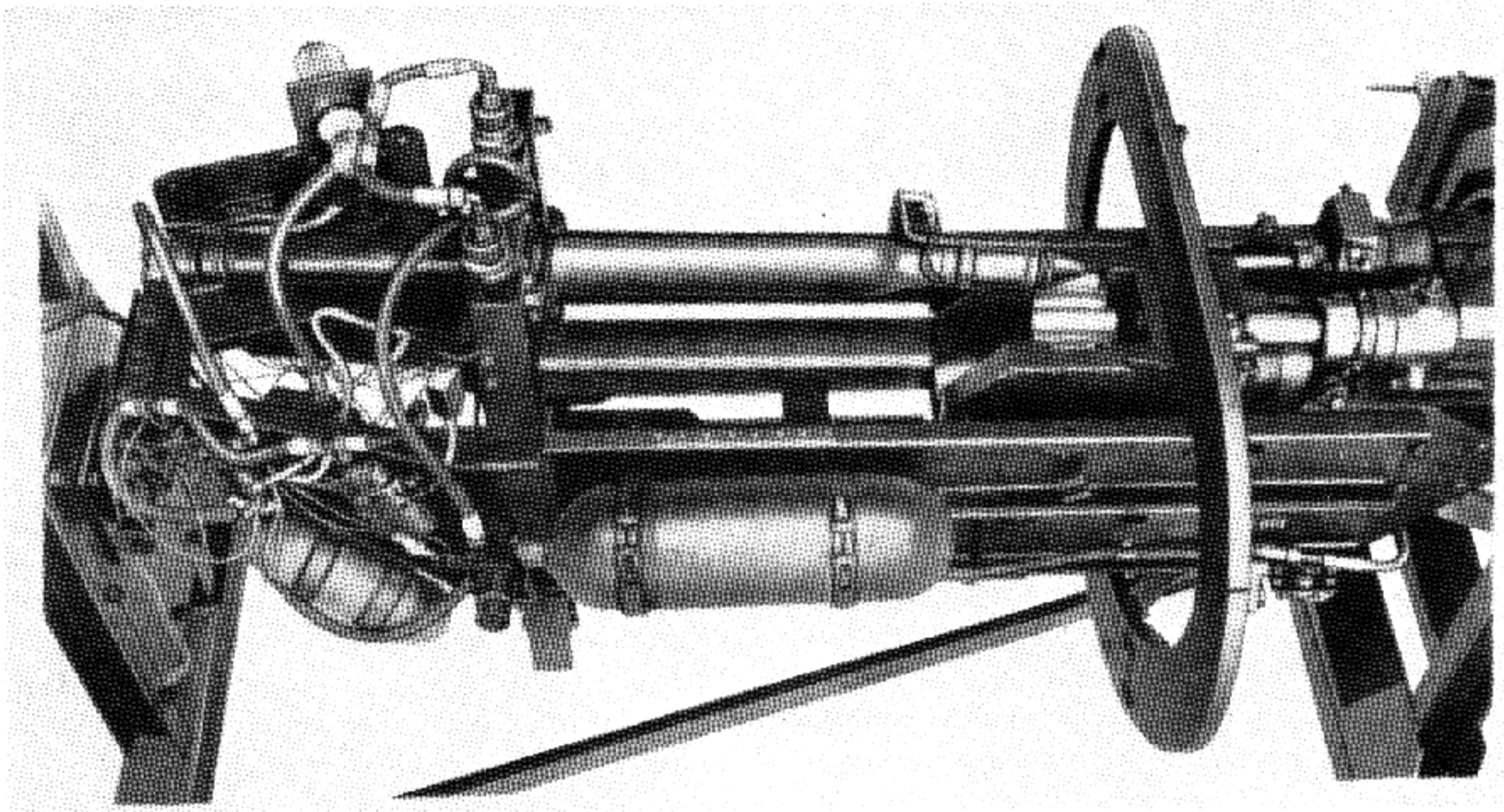


Figure 25-24. Receiver of 5-cm BK Automatic Aircraft Gun, with cover removed. A round is about to descend for ramming.

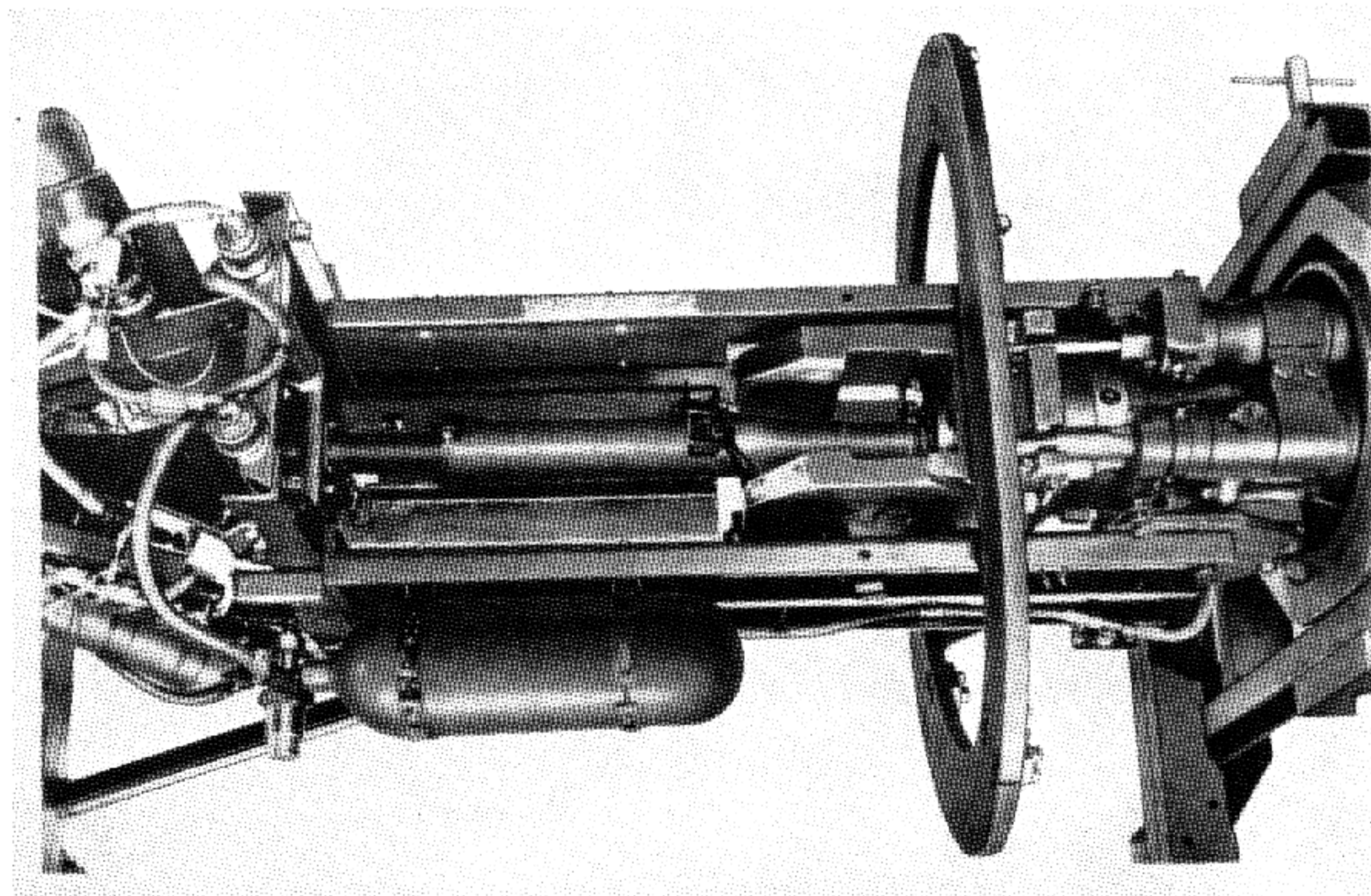


Figure 25-25. Receiver of 5-cm BK Automatic Aircraft Gun, with cover removed. A round is being rammed.

The cam is straight, but it is pivoted and spring-loaded in such a way that the roller on the crank of the operating shaft strikes the back of it on recoil and the cam rotates out of the path of the roller. However, in counterrecoil when the roller strikes the cam, the cam will not rotate. Instead, the operating shaft and crank rotate and the breechblock is opened. The extractors strike the extractor cam on the block and extract the empty case; then they catch on the holding lips of the block to keep it open until the next round trips the extractors. When the lips are open, the closing spring is compressed. On closing the block, the last travel of the operating crank engages the firing pin actuator and rotates it to allow the firing pin to ride forward and make contact with the chambered round. The insulated conductor contacts the insulated firing pin. When the block has closed, the firing circuit is completed by the conductor's making contact with the source of electricity, provided the rest of the circuit is completed by the operator and the tray is in the up posi-

tion. When the block begins to lower, the firing pin is retracted.

The recoil system is of the hydropneumatic type, the same as that used on the MK-214. The counterrecoil cylinder consists of a steel cylinder and piston rod. The counterrecoil cylinder contains 0.9 liter of recoil oil under 882 p. s. i. of nitrogen pressure. The recoil cylinder consists of a steel cylinder, a hollow piston rod, and a throttling rod. The cylinder is completely filled with recoil oil. When firing takes place the tube and breech ring are forced to the rear, taking the recoil and counterrecoil pistons with them. The nitrogen in the counterrecoil cylinder is compressed and at the same time the oil in the recoil cylinder is forced through the orifices in the head of the recoil piston, through the main throttling orifice, and past the stationary throttling rod. In this way, the fluid resistance necessary to retard and stop recoil is set up. Then recoil ceases, since the throttling rod has almost blocked off the orifice, and the compressed nitrogen forces the tube and breech ring back into battery. The tapered section at the

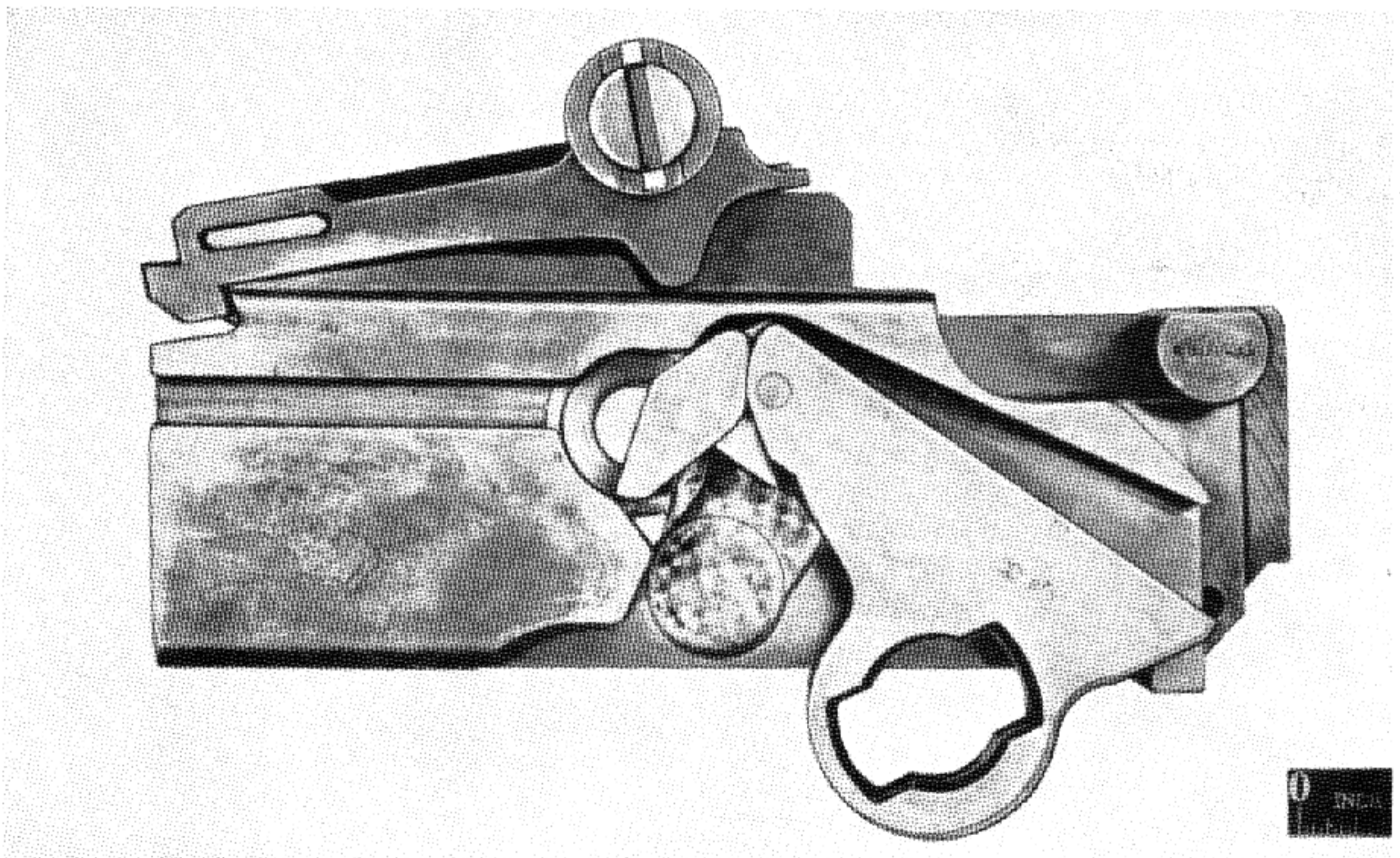


Figure 25-26. Breechlock of 5-cm BK Automatic Aircraft Gun. Assembled view.

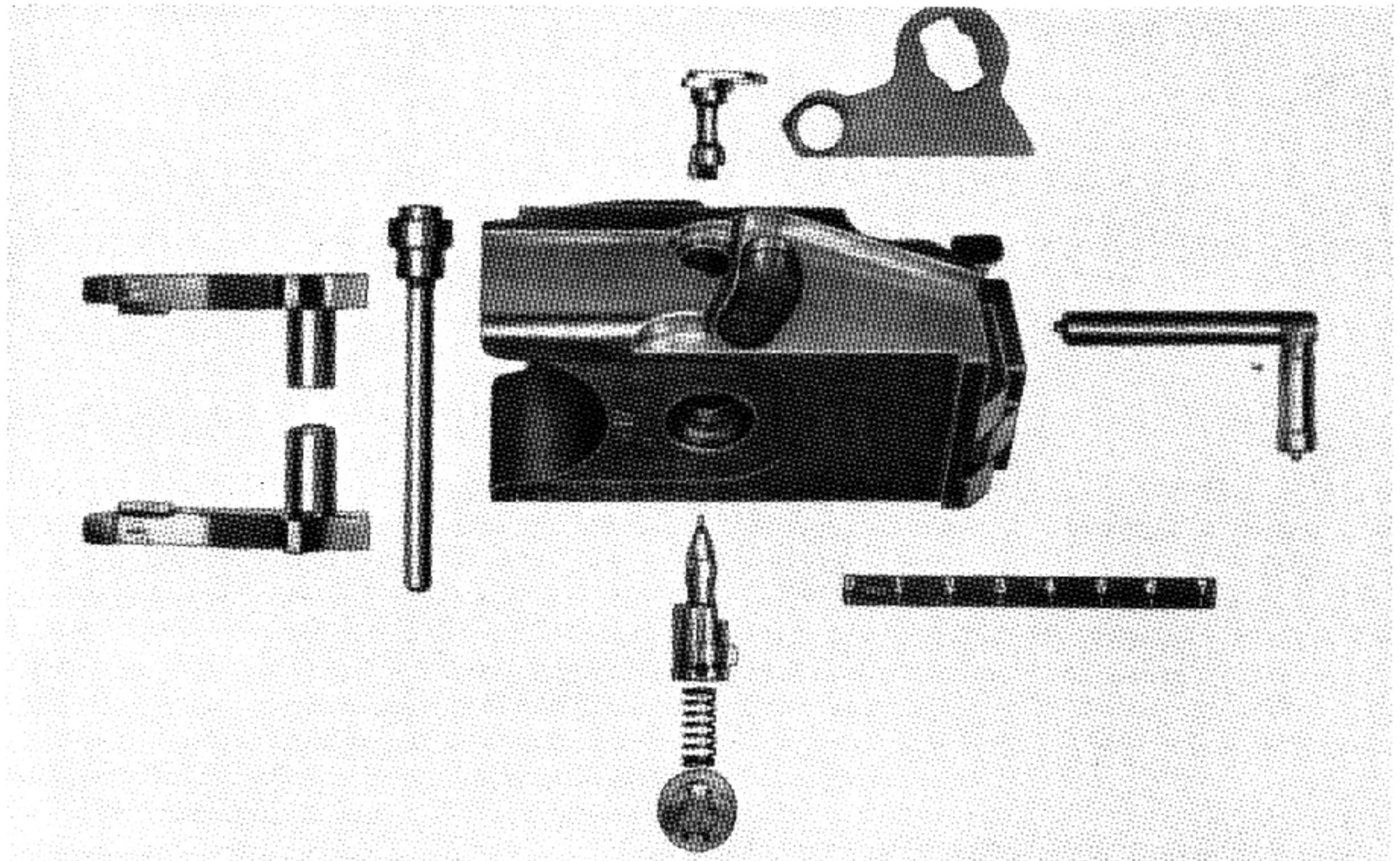


Figure 25-27. Breechlock of 5-cm BK Automatic Aircraft Gun. Disassembled view.

back of the throttling rod offers resistance to fluid flow and acts as a counterrecoil buffer.

### Operation

When there is a round in the chamber, the operator can complete the electric firing circuit and thus fire the gun. The tube and breech ring recoil rearward, the force of recoil being absorbed by the recoil cylinder. As the gun recoils, the roller on the crank of the operating shaft overrides the breech opening cam. The recuperator then draws the barrel back into battery through the force of the compressed nitrogen.

As the gun goes into battery, the roller on the crank of the operating shaft strikes the breechblock opening cam and the shaft is rotated, drawing the breechblock down and compressing the breechblock closing spring. When the block reaches the end of its travel, the extractors strike the extractor cam on the block and the extractors pivot. The empty case is extracted by this action. When the gun is in battery, air pressure is allowed to enter the tray

cylinders, forcing the tray down and compressing the tray springs. The rammer head and the yoke at the front of the tray strip the round from the linked belt. When the tray carrying the round is at the bottom of its travel, air pressure is allowed to enter the rammer cylinder and the rammer head is driven forward, compressing its spring and driving the round into the breech.

The extractors are tripped by the rim of the case and the block is closed by action of the compressed breechblock spring. The rammer head is allowed to return to its position by action of its compressed spring, and the tray is allowed to return to its upward position by the force of the compressed tray springs. The firing circuit is completed as the block rises, the tray being in the up position. When the tray is in this position, the feed mechanism moves the linked belt to the left, putting a new round on the tray. The round is held by the rammer head and the front holding pawl, ready to be moved into the line of the bore.

## Chapter 26

# EXPERIMENTAL 47-MM AIRCRAFT MACHINE GUN (ITALIAN)

## SECTION 1. HISTORY AND BACKGROUND

In World War II, the collapse of Italy brought to Allied hands a 47-mm experimental aircraft machine gun that proved interesting mainly because of its similarity to the not-too-successful United States Baldwin 37-mm aircraft automatic cannon model 1917. (See *The Machine Gun*, volume 1, pp. 526-530.) The main difference between the Italian experimental cannon and the Baldwin gun is the placing of the recuperator spring housing beneath the barrel, instead of on top as was the case with the Baldwin.

The Italian engineers designed their weapon with a bore diameter of 47 mm for reasons of economy. Barrels and ammunition could be made with machinery and dies that had previously been used in the manufacture of the universally used Hotchkiss revolving cannon of the same caliber.

The operation of the experimental Italian gun is novel; however the weapon contributes little toward the advancement of aviation ordnance. The

method of firing, locking and unlocking the breech mechanism is not new. The feed mechanism and method of empty case ejection is interesting, as a directly vertical feed when using clips or metallic strip is advantageous. A point may be gained as concerns the ejection spring loaded lug on the face of the breechblock. The trigger and sear mechanisms are almost identical with the type used on the 40-mm Bofors gun.

The arrangement of the recoil springs is somewhat unusual; however, similar variations have been made on other guns. The counterrecoil cylinder is conventional and is very similar to the counterrecoil cylinder used on several 37-mm guns. The method of returning the breechblock carrier to the sear levers is conventional. The carrier is moved from its extreme forward position at firing to its extreme rearward position when cocked. This is accomplished by both recoil and counterrecoil of the gun barrel.

## SECTION 2. DESCRIPTION OF THE WEAPON

### General

The Italian 47-mm aircraft machine gun C. 102 is a long-recoil operated, metallic strip fed type of automatic gun.

### Breech Locking Mechanism

This gun has a positive locking rotating breechblock. The external circumference of the breechblock has a three-section French interrupted screw that locks in the gun barrel when rotated. When a complete round of ammunition is placed in the gun chamber, the breechblock has completed its forward movement. However, the firing pin which is at-

tached rigidly to the breechblock carrier, continues to move forward for a short distance and stops when the forward end of the firing pin protrudes from the face of the breechblock about 0.110 inch. The firing pin has a "speed thread" on its external circumference that rotates the breechblock when the breechblock has seated in the gun. Firing of the gun occurs when the firing pin protrudes from the face of the breechblock. After about 5 inches of recoil, the breechblock is unlocked by a cam guide secured to the bottom of the slide. The breechblock has secured to it an arm and roller. The roller runs in the cam guide on the bottom of the slide.

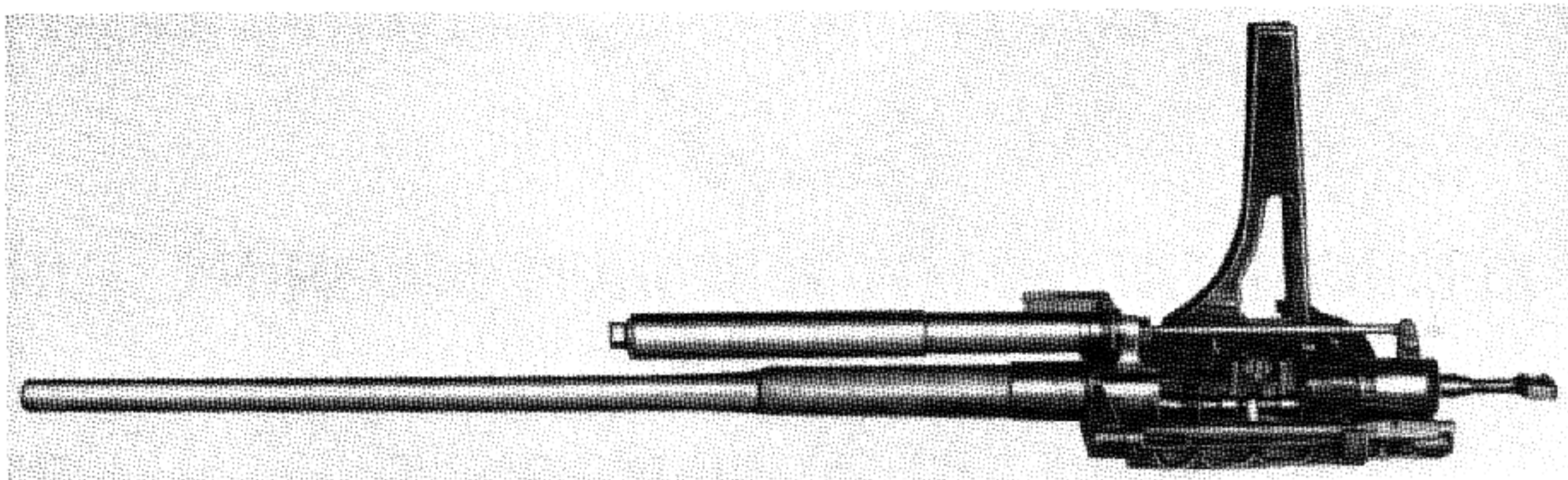


Figure 26-1. The American Baldwin 37-mm Aircraft Cannon.

### Feed Mechanism

Automatic operation of the feed mechanism is accomplished by a long rod, sliding block, and safety buffer connected to a bracket on the right underside of the gun barrel. When the gun barrel recoils, it pushes to the rear the rod, sliding block, and buffer. Attached to the sliding block, which is at the rear of the assembly, is a lever arm that operates vertically over about  $30^\circ$ . On the aft end of this arm is a heart-shaped cam that rides under and over a lug about one-fourth inch in width and located on the inside of the gun slide. The metallic feeding strip is pulled down in its guide by the forward end of the

lever operated by the heart-shaped cam when the gun is in recoil. The buffer is a safety device in the event of overtravel of the gun in recoil.

Ejection of an empty case is coincident with feeding. A small spring-loaded lug on the bottom of the breechblock face holds the empty case to the face of the breechblock. When a new round is fed to the breechblock face by the vertical action of the feed mechanism lever arm, the new round pushes down the empty case thereby retracting the spring-loaded lug. The empty case is then released from the breechblock face and continues down through an opening in the bottom of the gun slide.

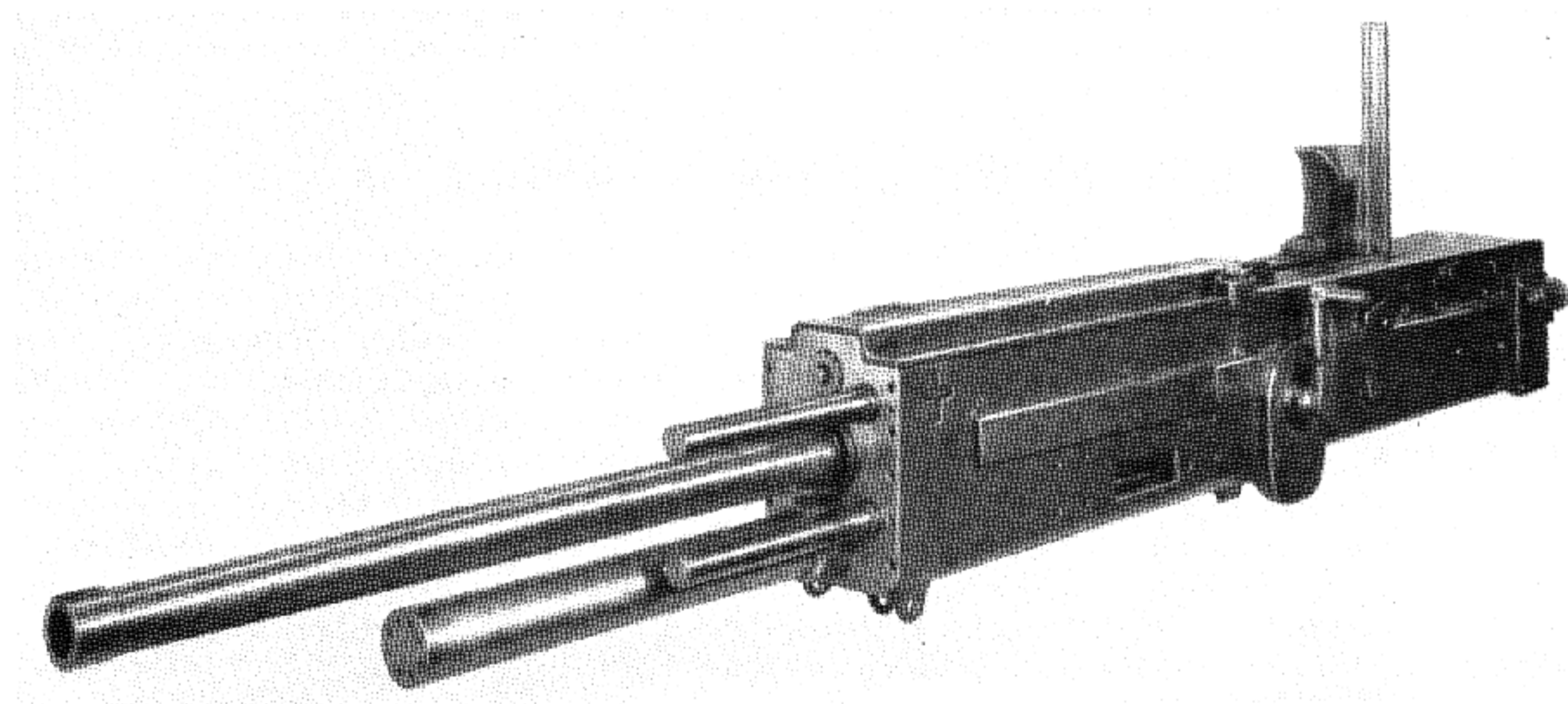


Figure 26-2. Experimental Italian 47-mm Aircraft Machine Gun. Left front view.

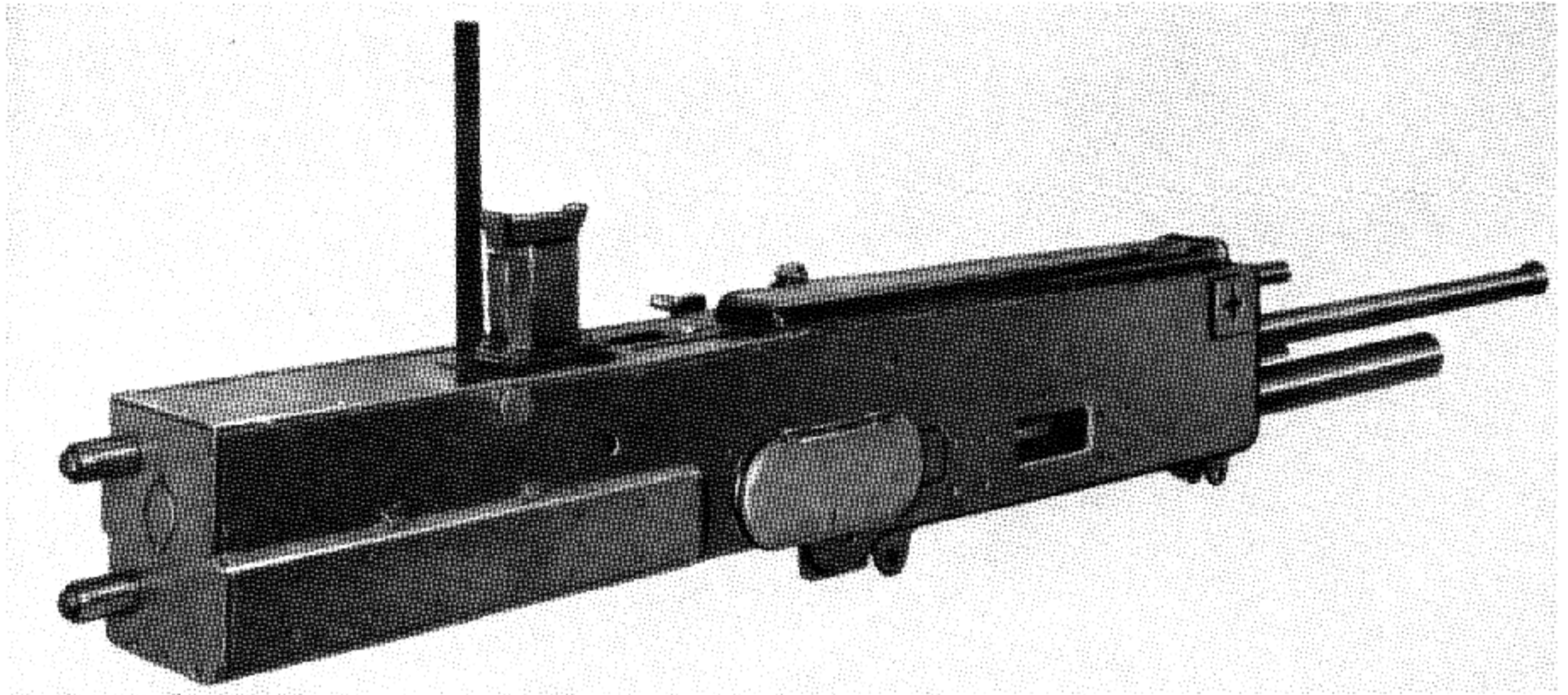


Figure 26-3. Experimental Italian 47-mm Aircraft Machine Gun. Right rear view.

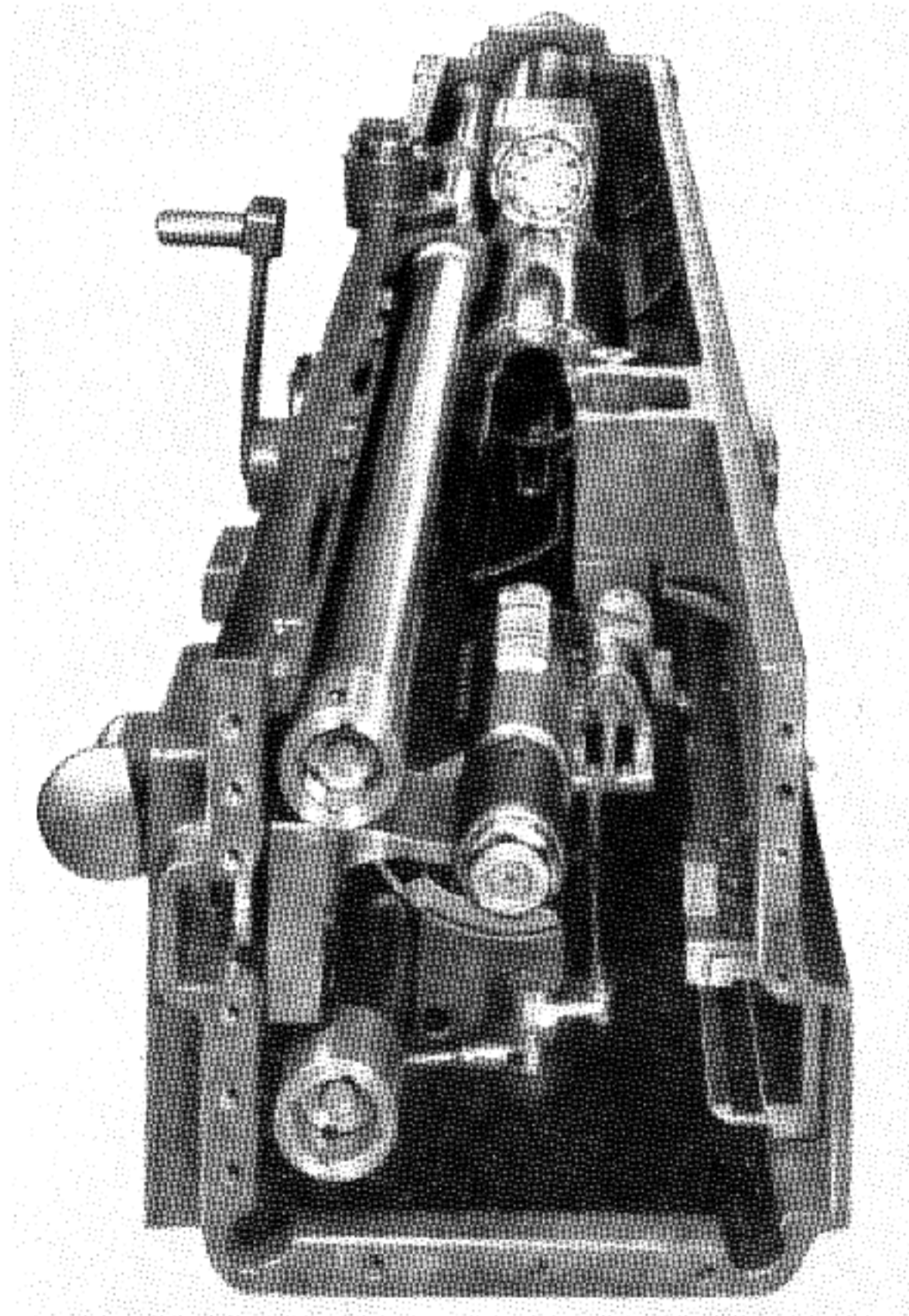


Figure 26-4. Experimental Italian 47-mm Aircraft Machine Gun. Rear view of operating mechanism.

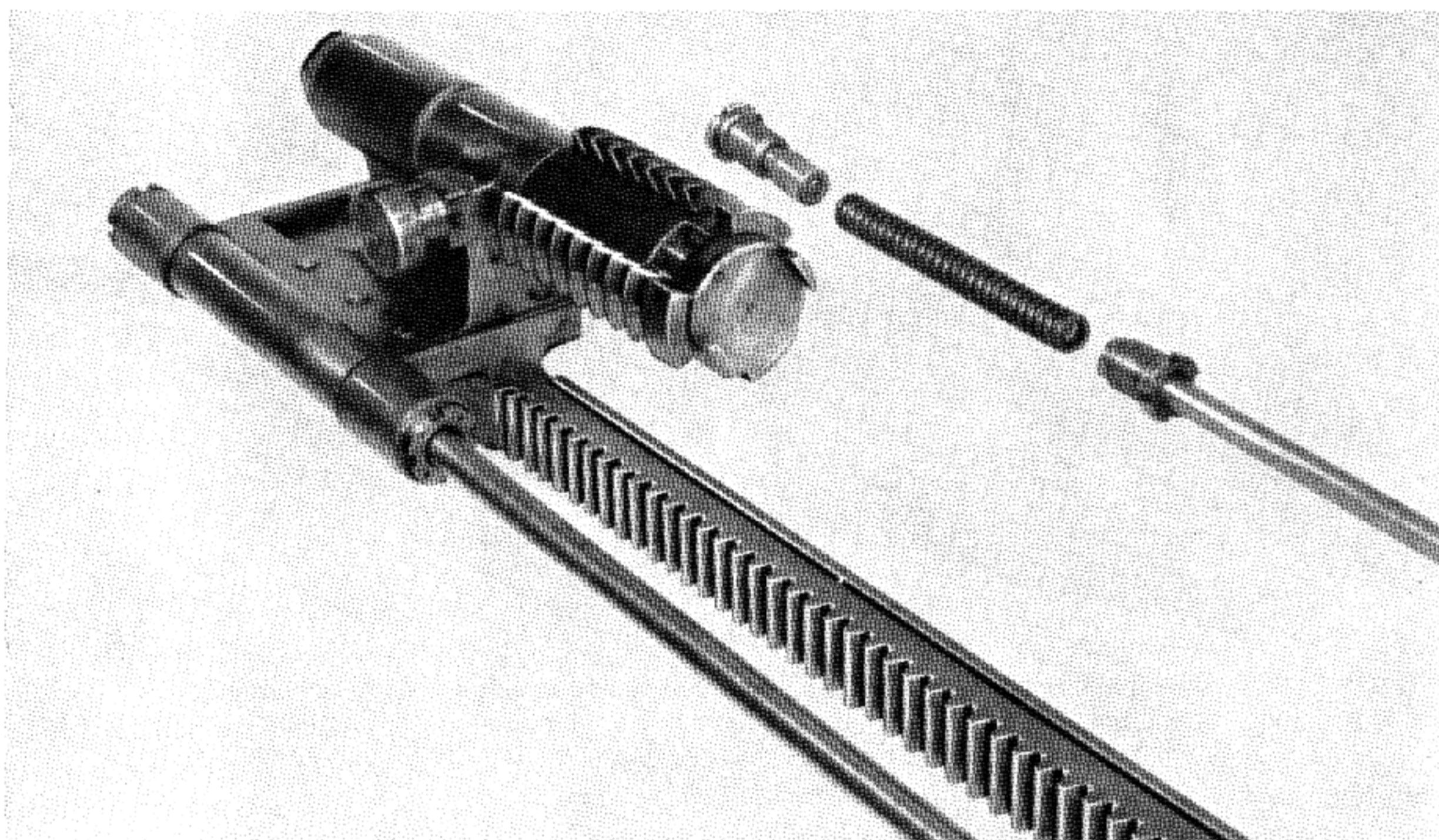


Figure 26-5. Experimental Italian 47-mm Aircraft Machine Gun, showing breechblock carrier with breechblock affixed.

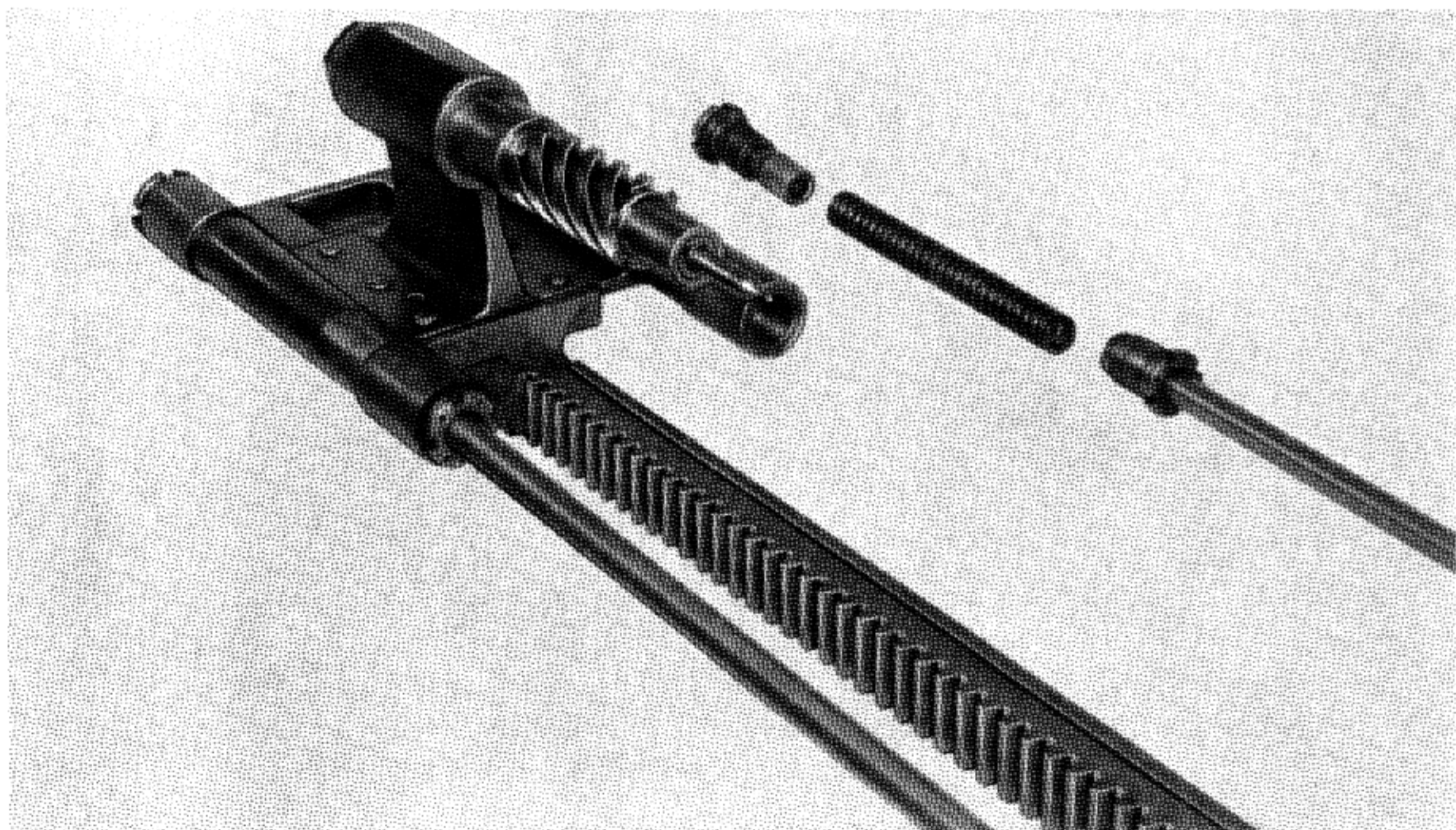


Figure 26-6. Experimental Italian 47-mm Aircraft Machine Gun, showing breechblock carrier.



## Trigger and Sear Mechanism

The trigger and sear mechanism consists basically of a spring-loaded hand-operated plunger on the outside of the slide and three sear levers on the inside of the slide. All three sear levers may together or singly hold back the breechblock carrier in the cocked position. The first sear lever is actuated by the feed mechanism; when the last round passes a plunger in the feed guide, the feed mechanism sear lever is raised up and catches the breechblock carrier at the end of the firing cycle. The second sear lever is operated by a rod that runs along the inside bottom of the slide. This rod is connected to a lever that is depressed by a cam bracket on the left underside of the gun. When the gun barrel returns to battery position, the sear lever is depressed thereby allowing automatic firing. Therefore, in this case, the breechblock carrier will not be held in the cocked

position. The third sear lever is operated manually. When the trigger plunger is depressed by hand, the sear lever is also depressed, allowing the breechblock carrier to go forward. Full automatic firing results only when ammunition is being continually fed to the mechanism and at the same time the trigger plunger is kept depressed.

## Recoil and Counterrecoil Mechanism

The recoil cylinder contains four springs. There are two sets of springs, one set placed behind the other, with a separator collar in between. Each set of springs consists of one small-diameter spring within a large-diameter spring.

The counterrecoil cylinder is of the self-contained hydraulic type, of conventional design. However, there are no means of adjustment to regulate the return of the gun to battery position. The fluid contained therein is a mixture of water and glycerine.

## SECTION 3. CYCLE OF OPERATION

Assuming that the breechblock is locked in the gun and the chamber is empty, the breechblock carrier must be brought to the rear and cocked. This is done manually by turning the hand operating crank in a clockwise direction. A pinion gear on the hand operating crank shaft meshes with a long rack in the upper left side of the slide. To this rack is connected the breechblock carrier which is supported by the driving spring tubes. When the carrier is brought to the rear of the slide, it is held there by the feed mechanism and manual trigger sear levers. With the carrier in this position, the upper and lower driving springs are compressed. When feeding the initial rounds of ammunition into the mechanism, the feed mechanism sear lever is disengaged from the carrier. A cycle of operation may now begin.

When the manual trigger plunger is depressed, the manual sear lever disengages from the carrier. Due to the action of the driving springs, the carrier and breechblock with the first round are driven forward. Upon seating of the round and breechblock in the gun, the carrier and firing pin continue to move forward, thereby locking the breechblock in the gun and firing the round.

When the gun barrel recoils to about 5 inches, the breechblock is unlocked since its arm and roller follow the cam guide on the bottom of the slide. The maximum recoil of the gun barrel is about 12 inches. At this point, the feed mechanism is pulling another round down. Although the gun barrel has reached its maximum recoil, the breechblock and carrier have yet to travel rearward about an additional 12 inches. As the gun barrel returns to battery position, a spring-loaded pawl attached to a bracket on the right underside of the gun barrel engages a sliding rack on the bottom of the slide. This rack meshes with a pinion gear that is on a shaft which has a gear on its opposite end (left side of slide) that meshes with the pinion gear on the hand operating crank shaft. This gear then meshes with the rack that is connected to the breechblock carrier to the rear where it is caught and held by the manual trigger sear lever.

It is not possible for the carrier to go into counterrecoil if the gun barrel is out of battery because of a ratchet and pawl on the bottom of the gun-operated rack. This pawl will keep the rack from moving rearward until the gun barrel is in battery position. The gun-operated rack on the bottom of the slide moves in the direction opposite to that of the driving-spring-operated carrier rack.

## Chapter 27

# JAPANESE AUTOMATIC AIRCRAFT CANNON DEVELOPMENT

## Post World War II Study of Japanese Weapons

When the United States Army occupied Japan after World War II, a study was made of automatic guns which the Japanese had under development at the close of hostilities. Unfortunately, many of the actual model guns had been destroyed, either during bombing raids or by the Japanese themselves to prevent capture. However, evidence that was gathered indicated that virtually all known gun systems had been copied by the Japanese. In addition to the designs borrowed from other countries, the Japanese had several unconventional designs in the developmental stage. In the latter category is a group of so-called "recoilless" guns, produced

by the foremost Japanese designer of automatic guns, Mr. Shiro Kayaba. The inventor had retained photographs which enabled the United States ordnance team to reach certain conclusions concerning the various models.

### 13-mm, 20-mm, and 37-mm Models

The two 13-mm guns, the 20-mm model and the 37-mm design operate on an improved Maxim principle, wherein the single major spring acts as barrel return, bolt return, and buffer. This action is accomplished by forming the accelerator as an extension of the rear arm of the toggle joint, which is pivoted on the rear of the barrel extension. An anchor, pivoted in the receiver is linked to the accelerator. An important advantage of this design



Figure 27-1. Japanese 13-mm Drum-Fed Machine Gun.

is the complete mechanical timing of the bolt and barrel extension which is incorporated in the toggles and linkages.

### 40-mm "Recoilless" Machine Gun

The 40-mm gun appears to be designed to discharge a blast of gas to the rear when fired, in order to counteract the recoil force. This action, in conjunction with the action of a cradle having recoil and counterrecoil springs, would permit a high de-

grees of recoil-damping. In all probability the 40-mm gun was designed around the caseless round of ammunition for the Japanese HO-301 gun.

### 80-mm Recoilless Gun

The 80-mm gun is nonautomatic and, like the 40-mm design, discharges gas to the rear. It is a simple affair and apparently was intended for some type of free suspension. This gun incorporated no radically new ideas.

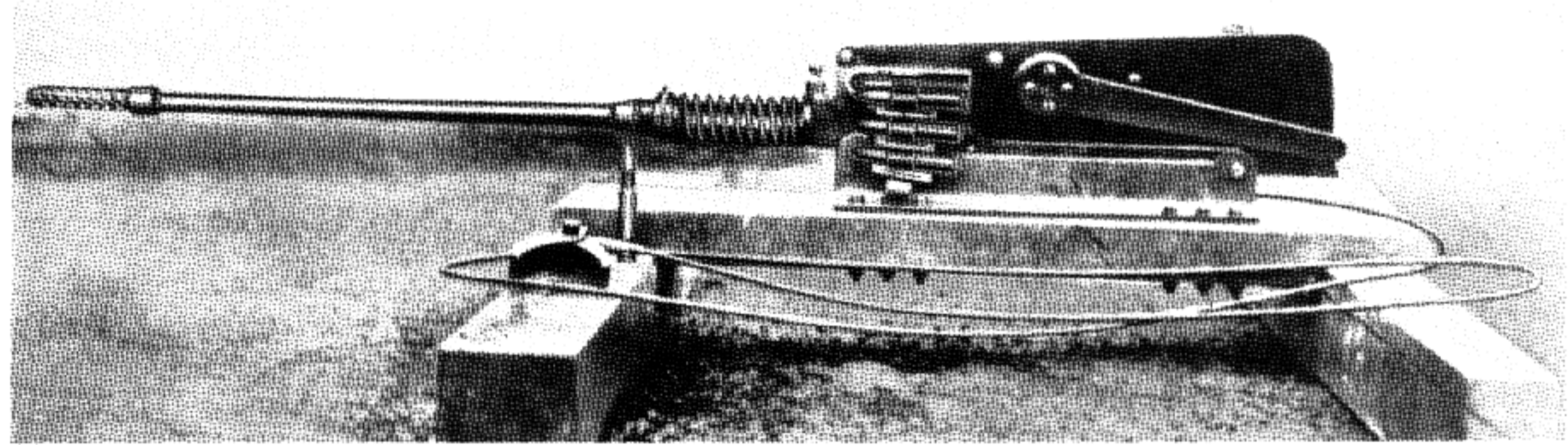


Figure 27-2. Japanese 13-mm Belt-Fed Machine Gun.

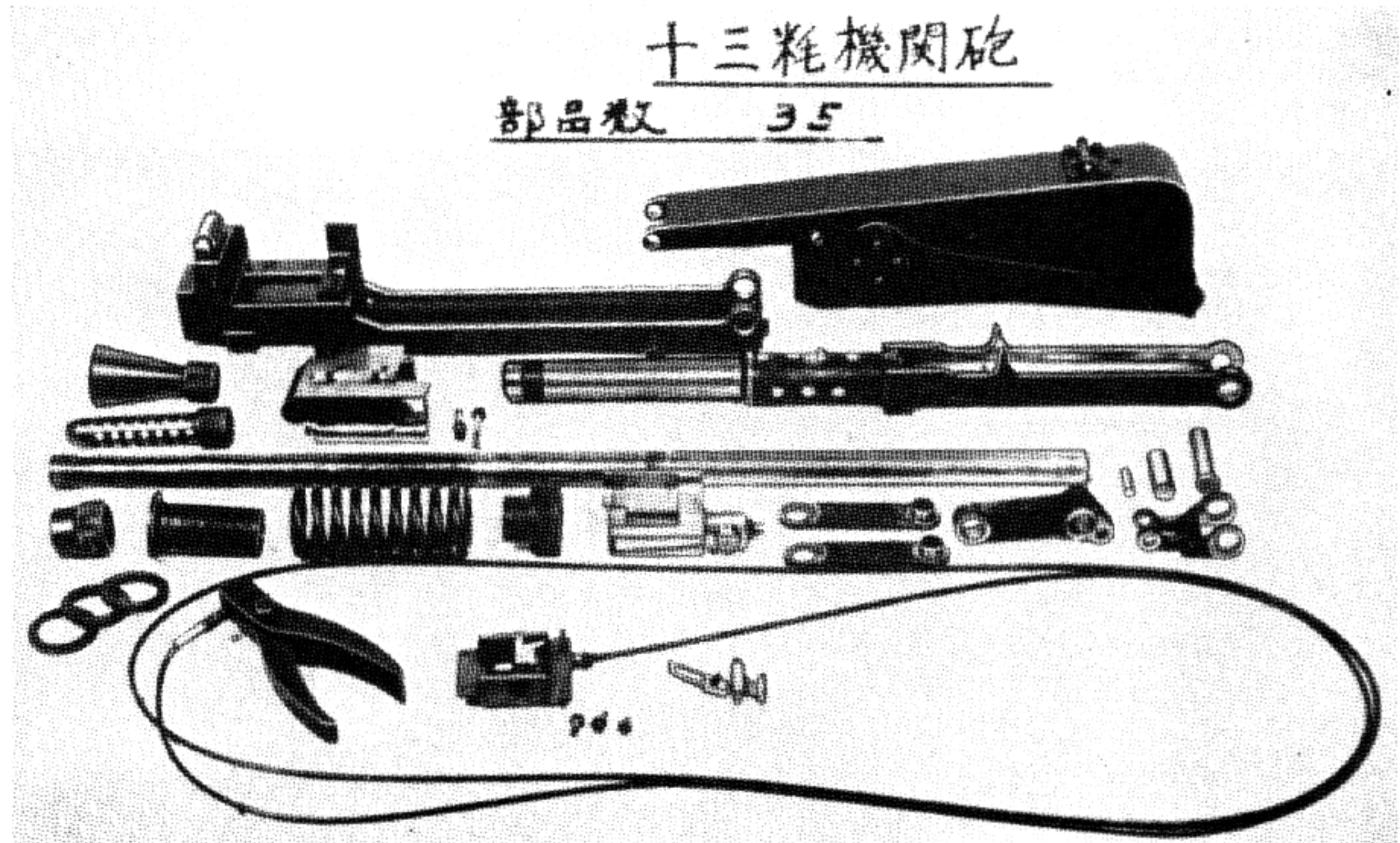


Figure 27-3. Japanese 13-mm Belt-Fed Machine Gun, stripped.

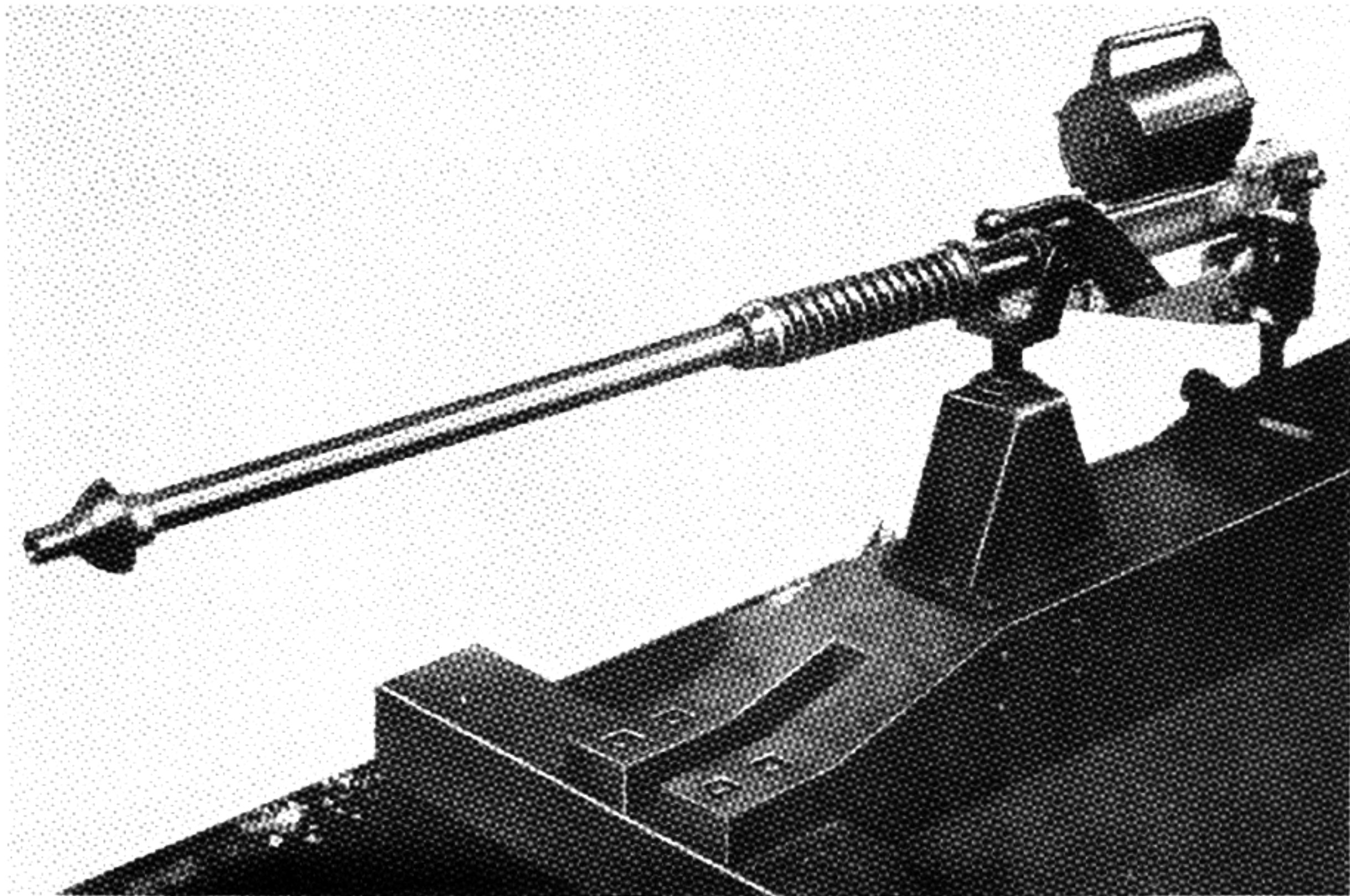


Figure 27-4. Japanese 20-mm Drum-Fed Machine Gun.

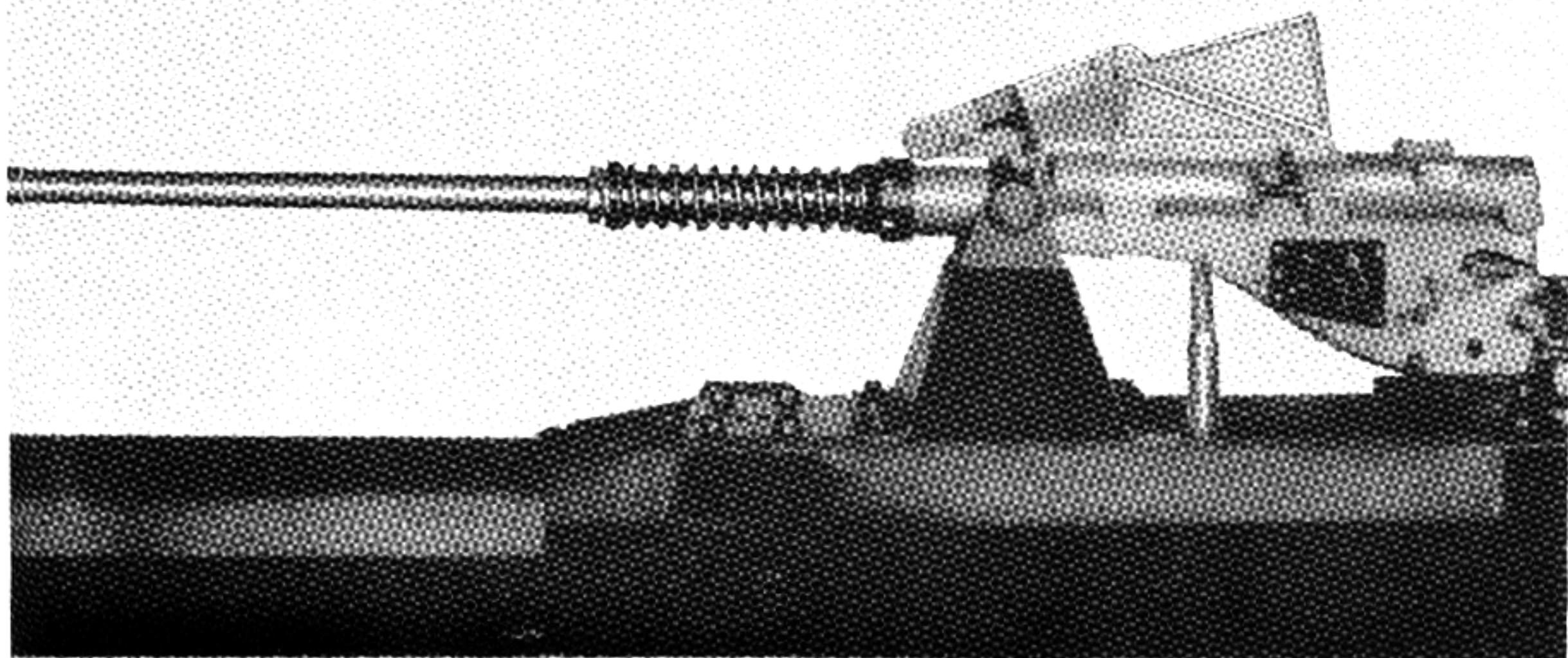


Figure 27-5. Japanese 37-mm Magazine-Fed Machine Gun.

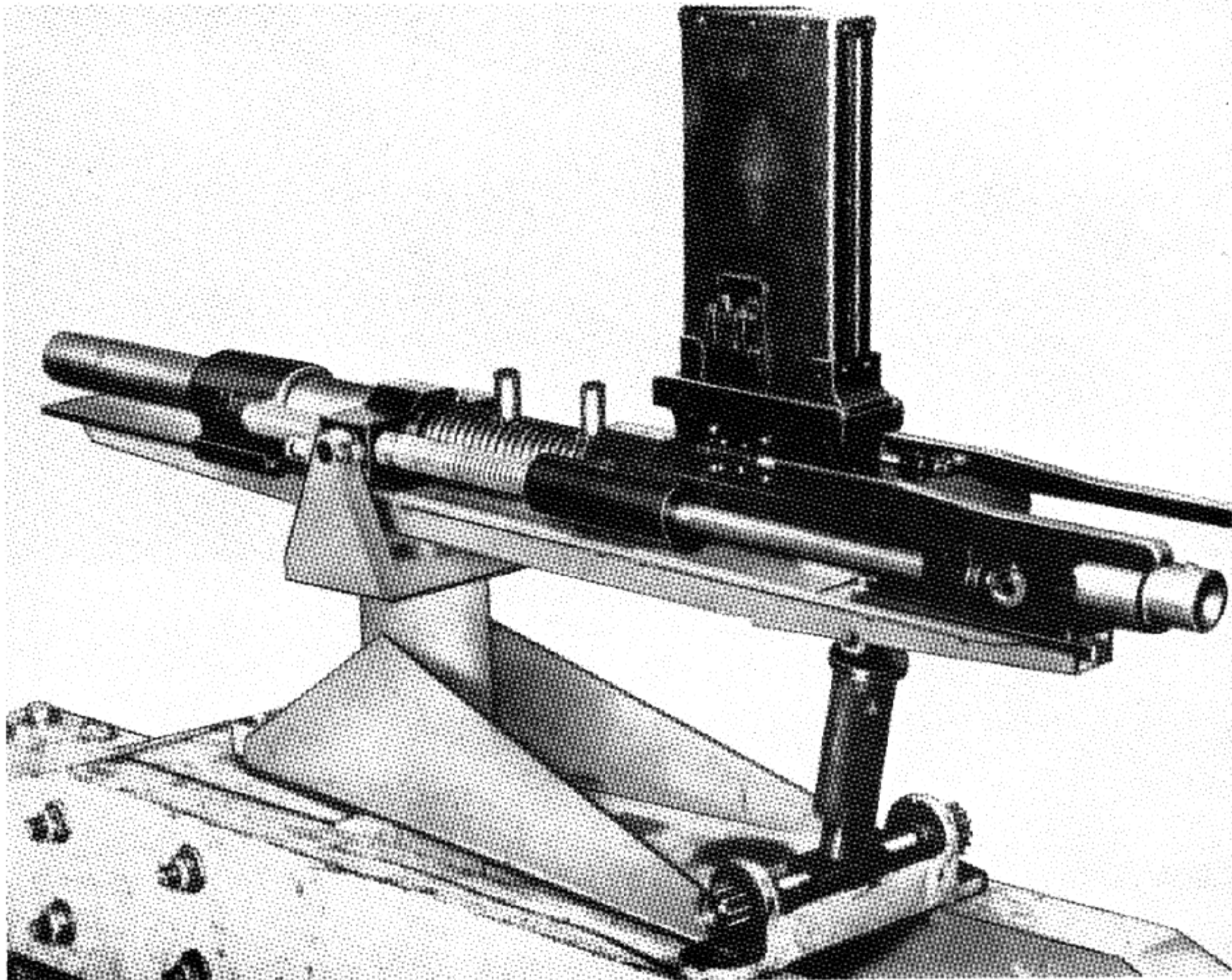


Figure 27-6. Japanese 40-mm "Recoilless" Machine Gun.

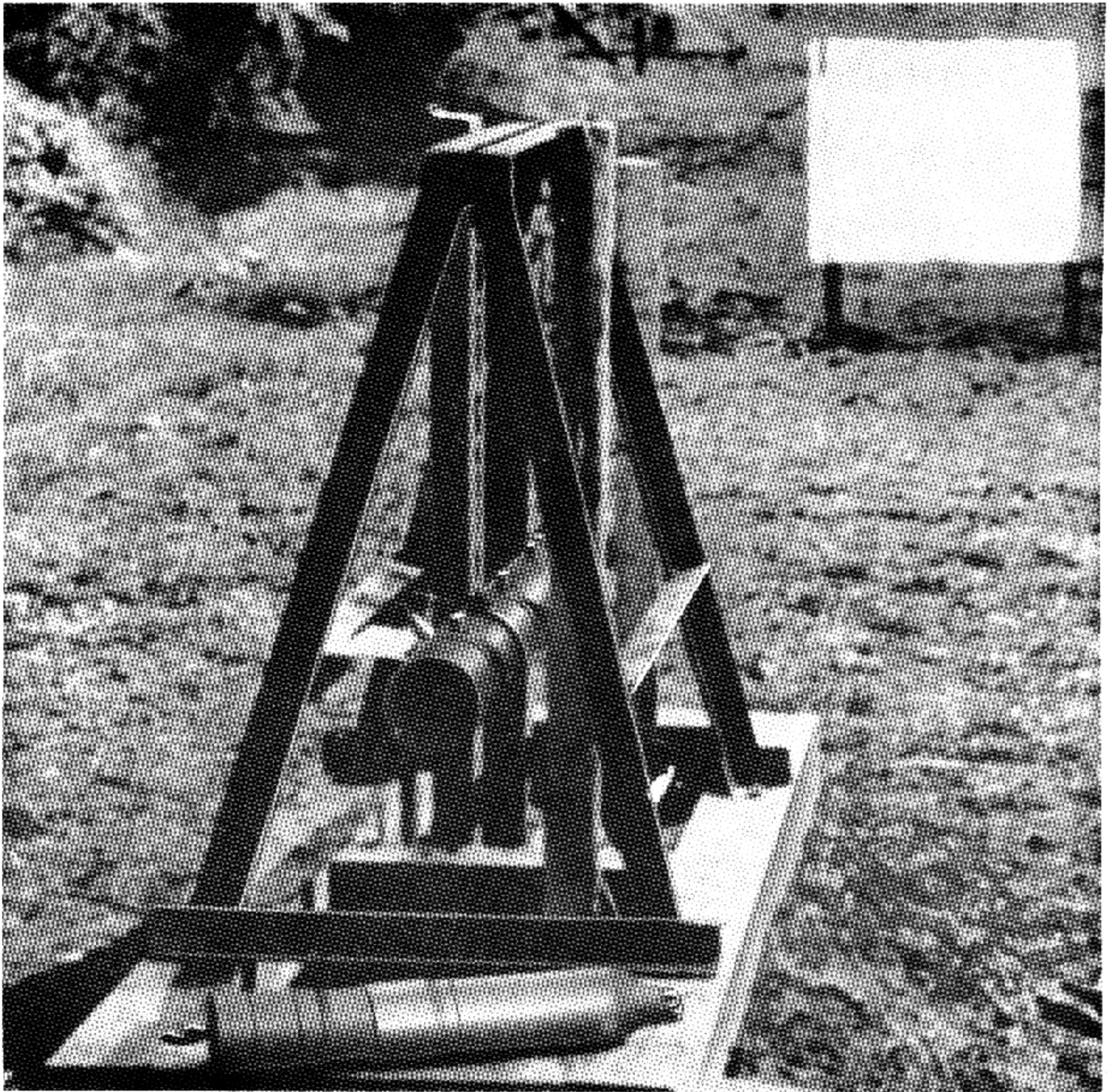


Figure 27-7. Japanese 80-mm Recoilless Gun on test stand.

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