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.

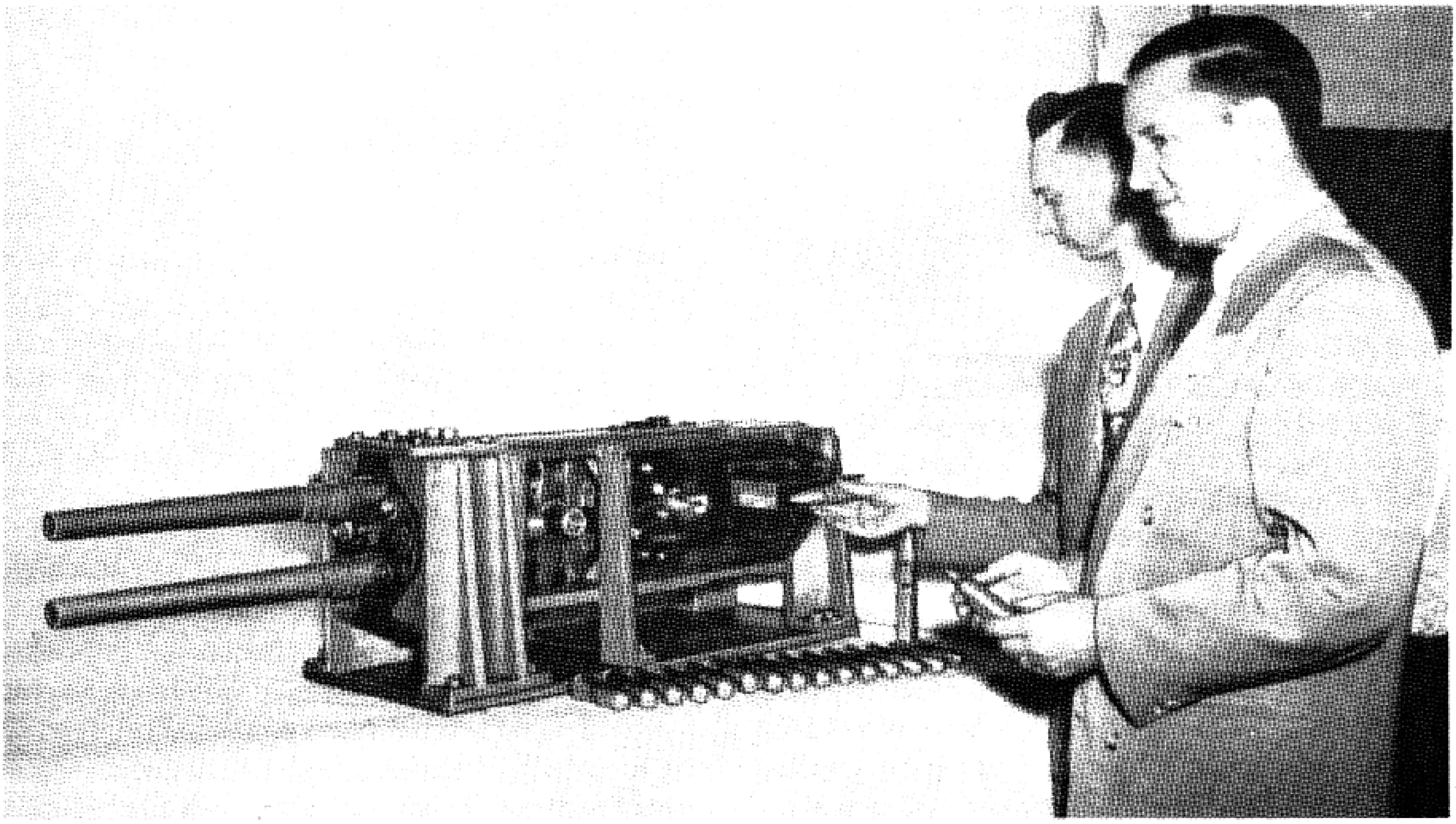

Figure 6–1. 20-mm Gun Mechanism Mk 11 Mod 0 installed in test frame. In foreground, Frank Marquardt, inventor and chief design engineer, and John J. Sauber, assistant design engineer.

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_2 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–Re8a–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_2 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.^{2}

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).

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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 alined 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

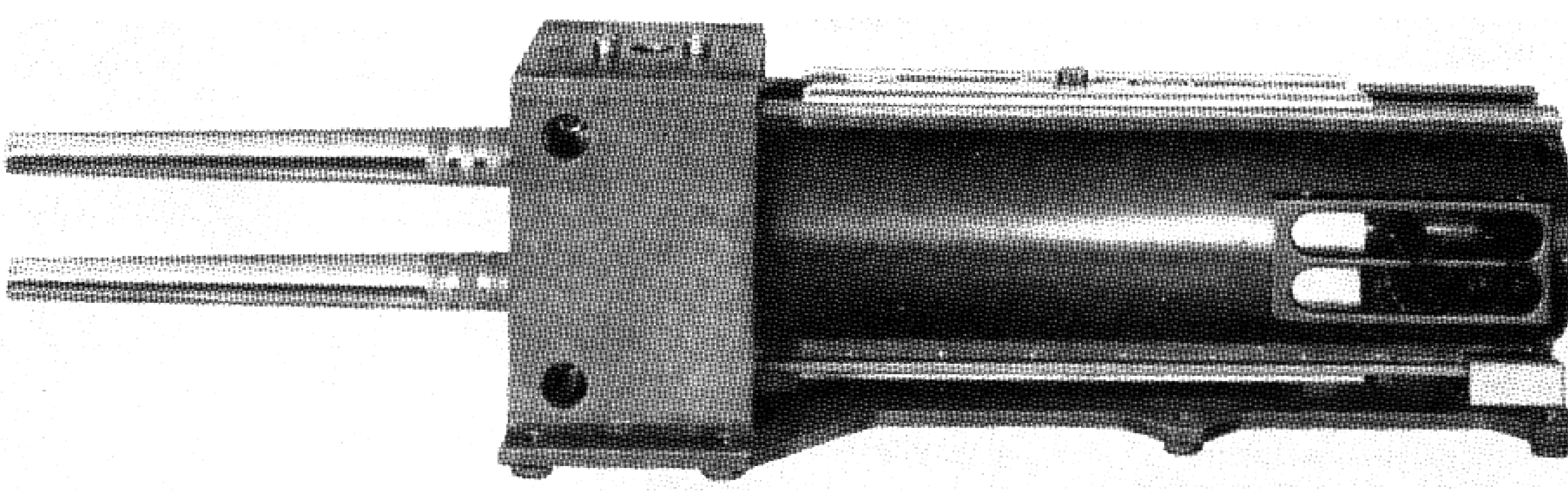

Figure 6-2. 20-mm Machine Gun Mk 11 Mod 0 mounted in test stand.

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 relocated, 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.

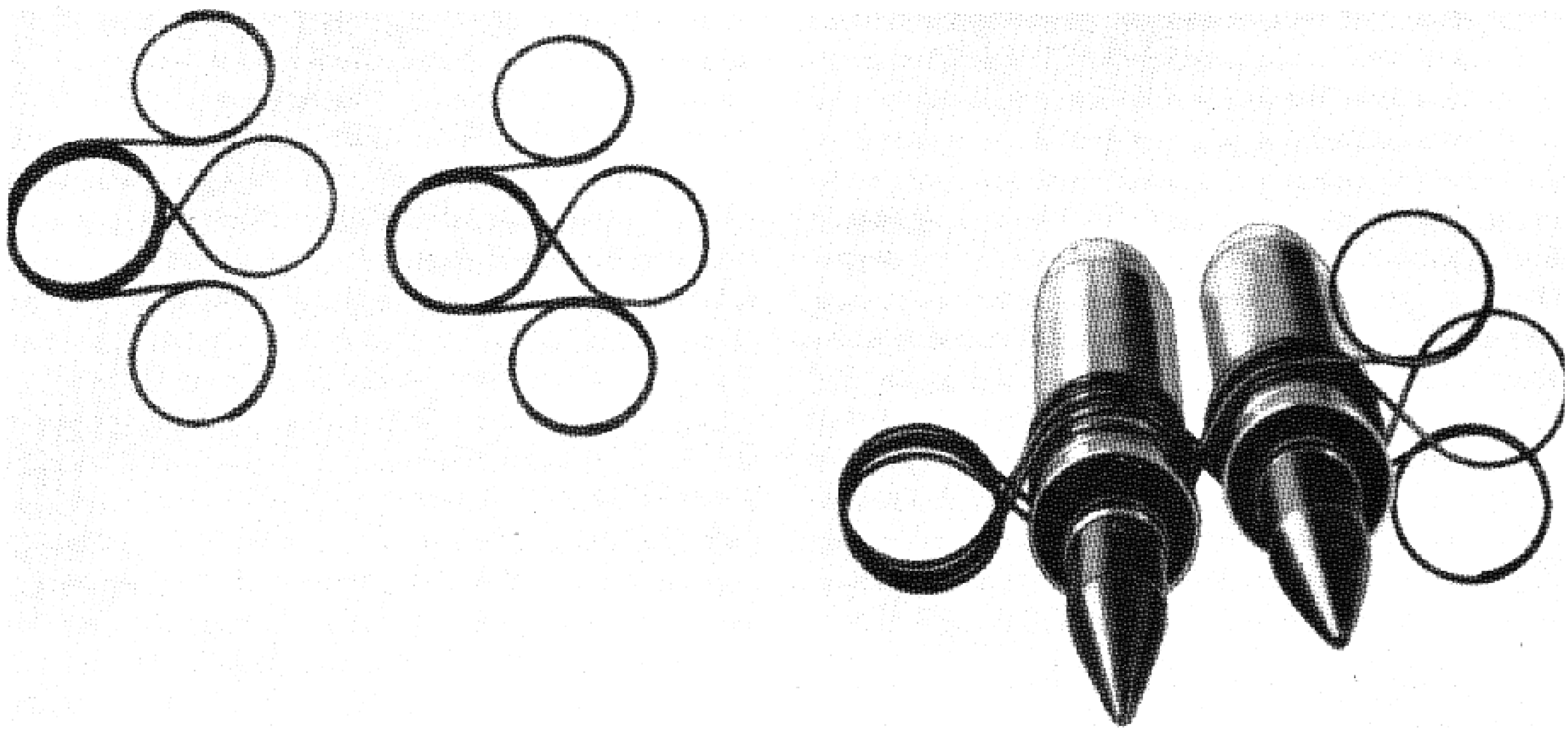

Figure 6–3. Ammunition and links for the 20-mm Machine Gun Mk 11 Mod 0. Front view.

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.

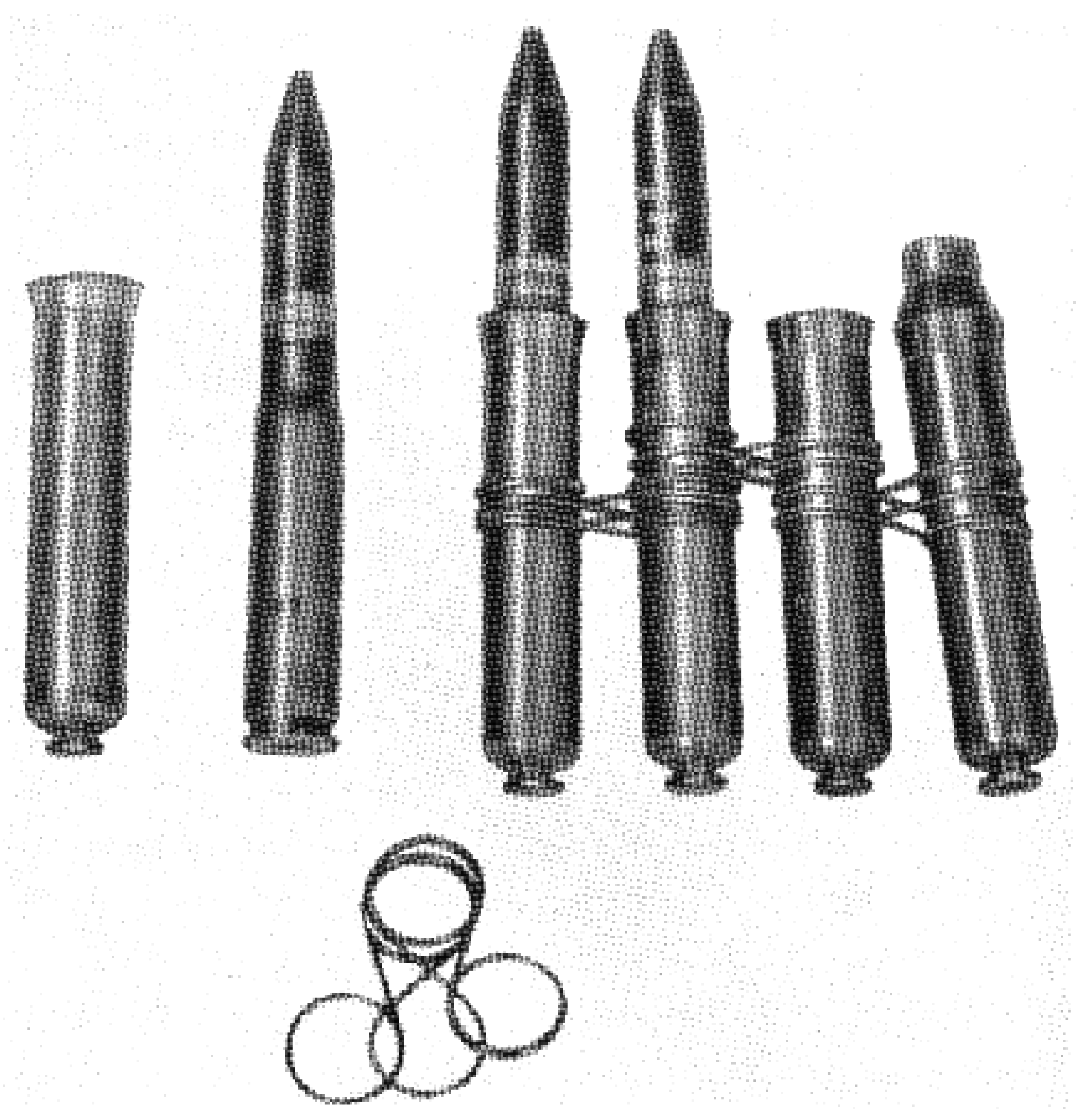

Figure 6–4. Ammunition and links for 20-mm Machine Gun Mk 11 Mod 0. Side view.

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.

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,

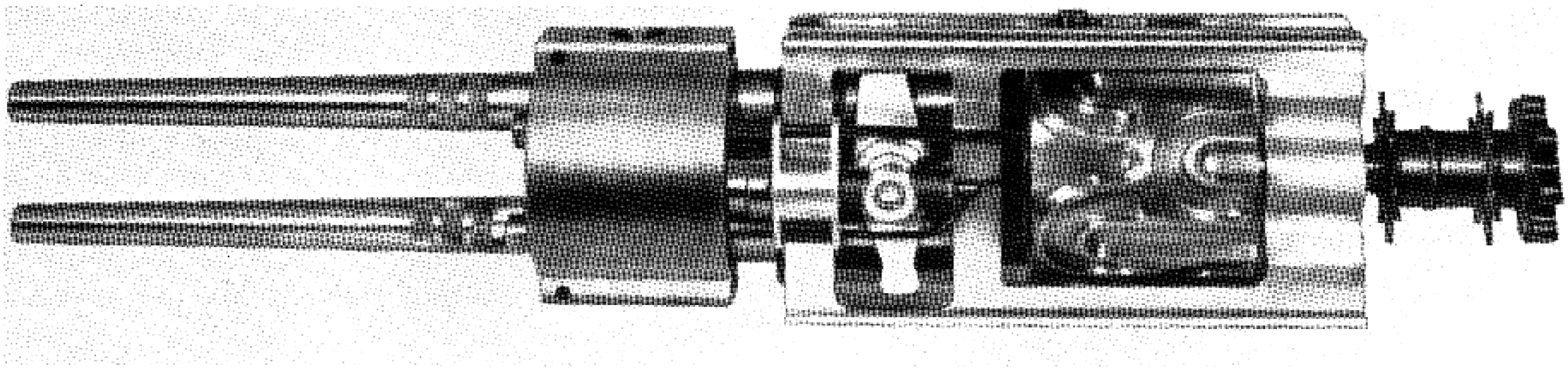

Figure 6–5. 20-mm Machine Gun Mk 11 Mod 0. Side view with receiver removed.

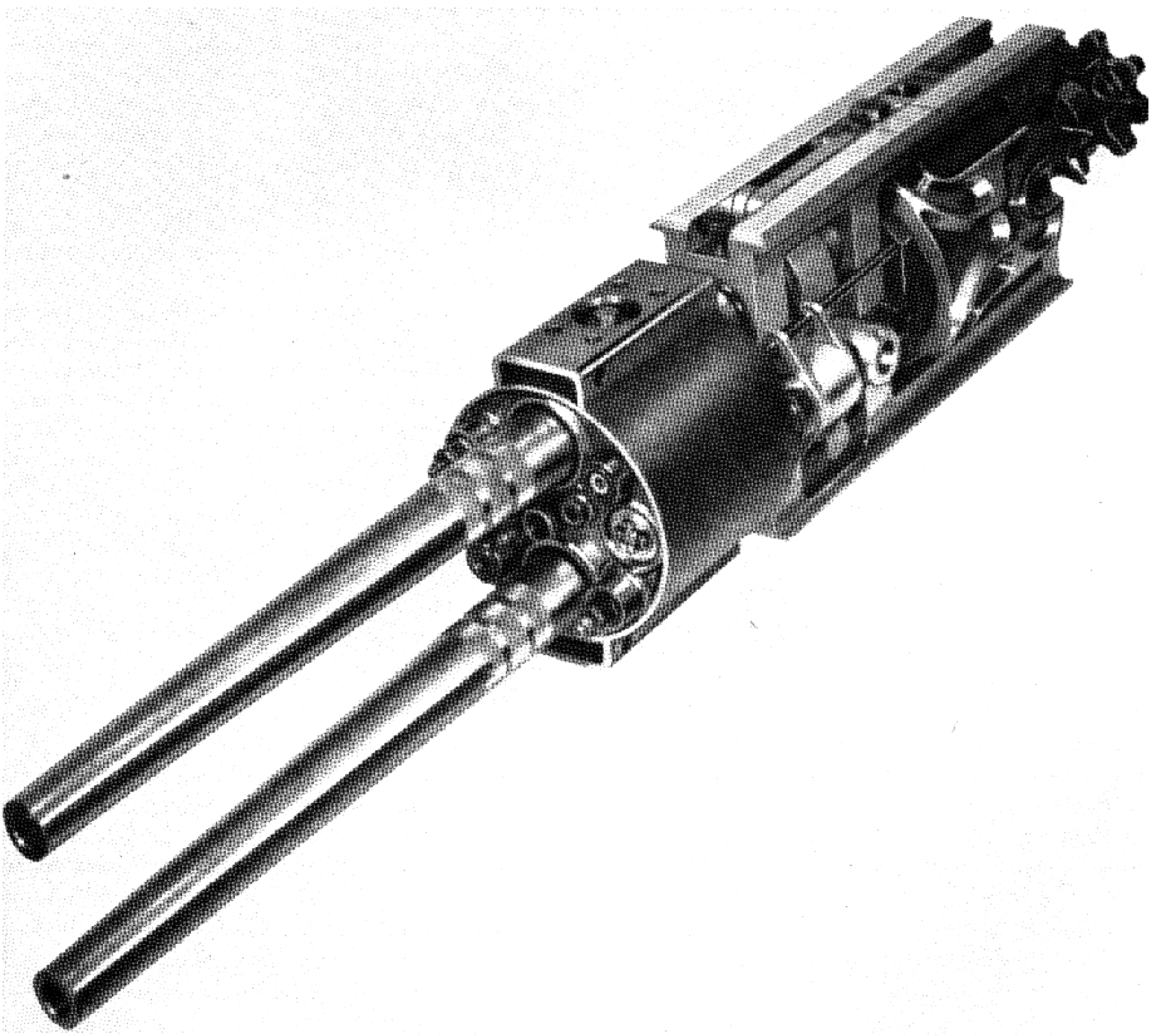

Figure 6–6. 20-mm Machine Gun Mk 11 Mod 0. Three-quarter front view with receiver removed.

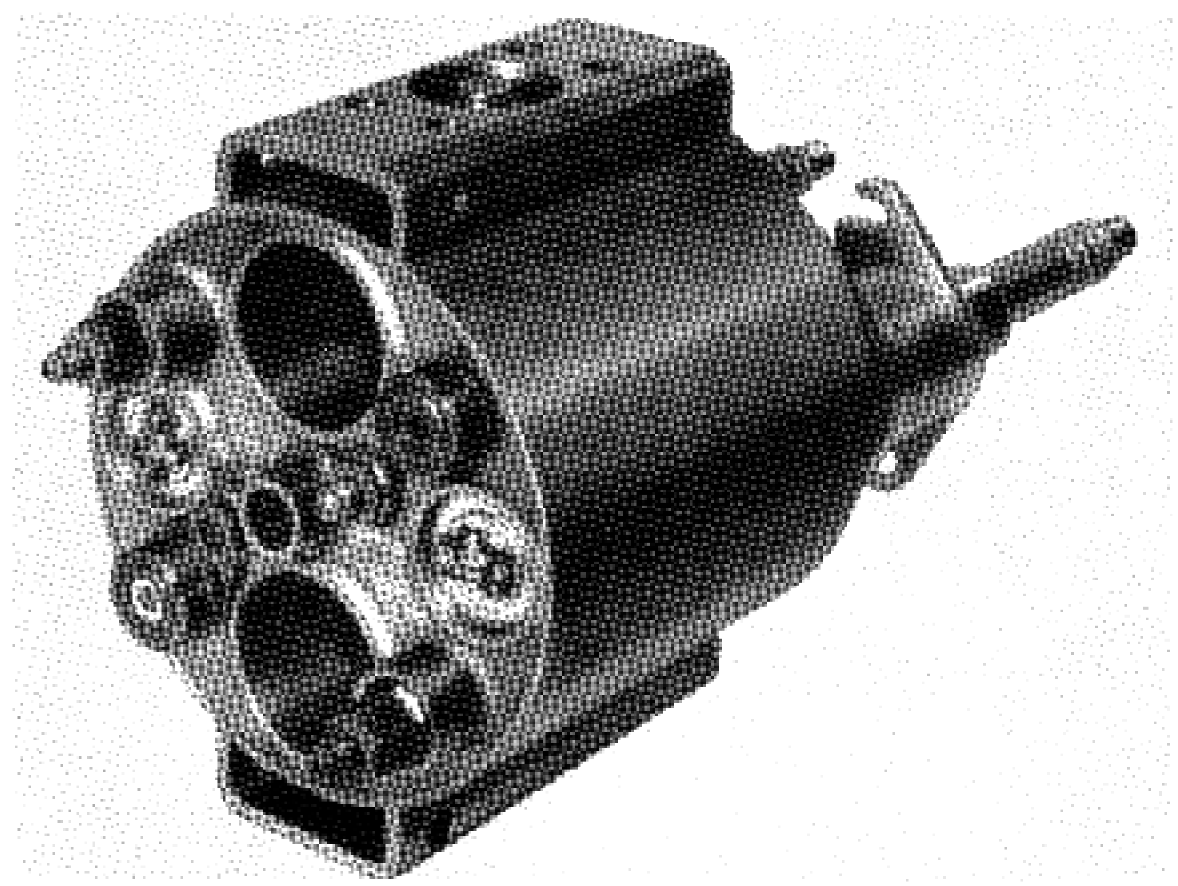

Figure 6–7. Pneumatic tank of 20-mm Machine Gun Mk 11 Mod 0.

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 2½ *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° 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

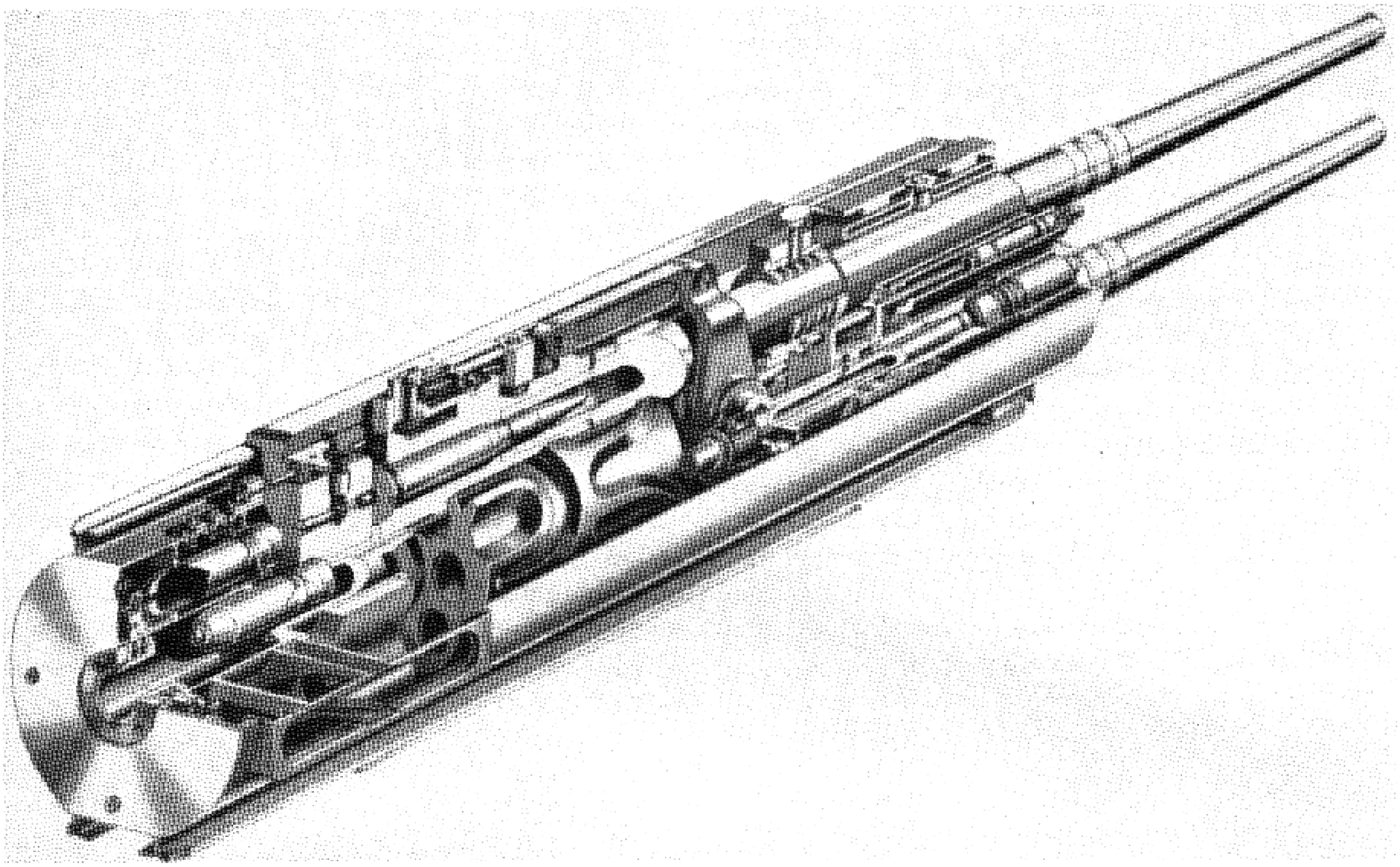

Figure 6–8. 20-mm Machine Gun Mk 11 Mod 0. Cutaway view.

are approximately 45° from alinement 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° before 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°, 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 condensors 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° 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 pullout 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°, 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°, 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

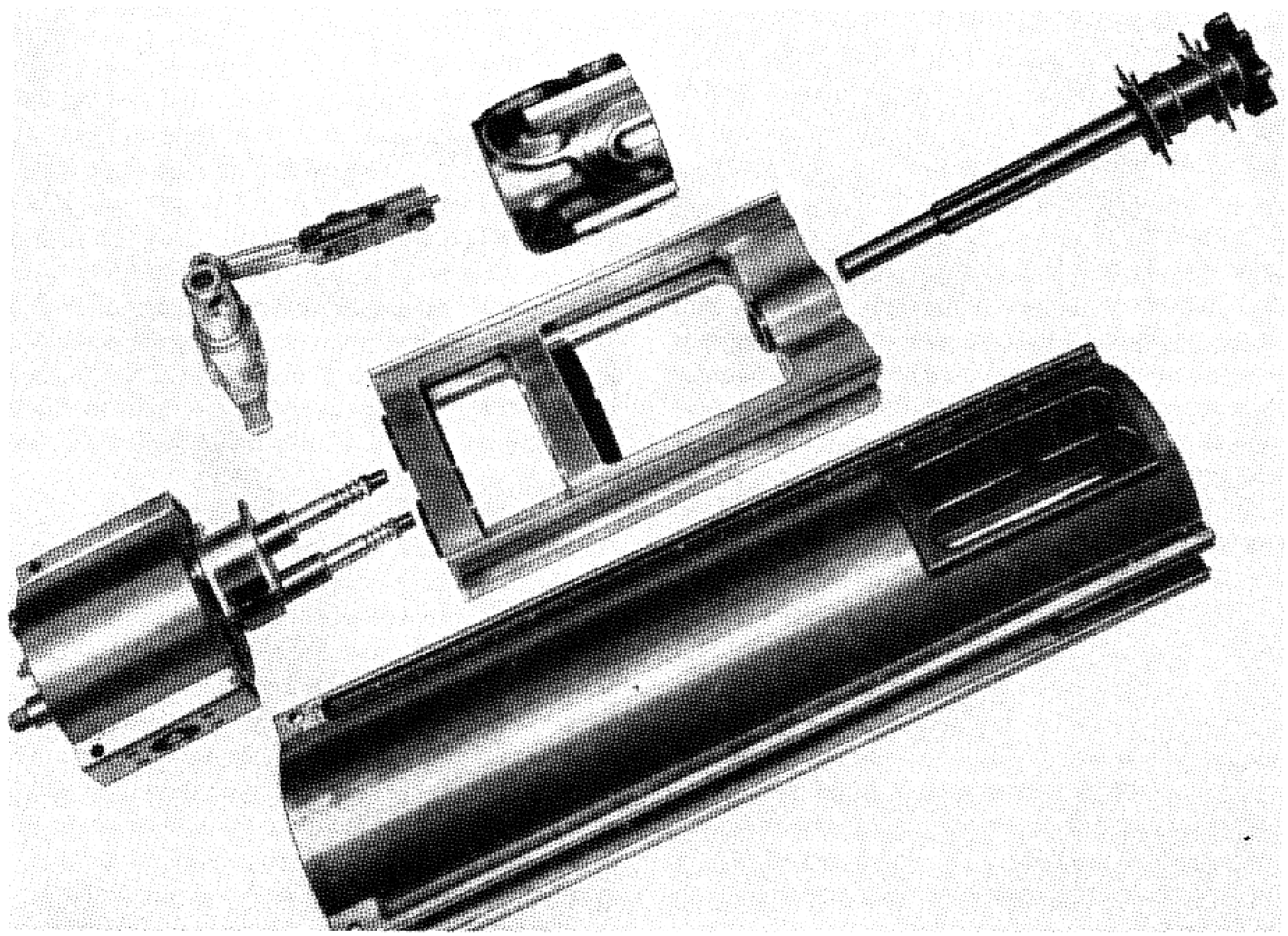

Figure 6–9. 20-mm Machine Gun Mk 11 Mod 0. Exploded view. (Barrels not shown.)

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 receiver 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.

Figure 6–10. Revolving cylinder of 20-mm Machine Gun Mk 11 Mod 0.

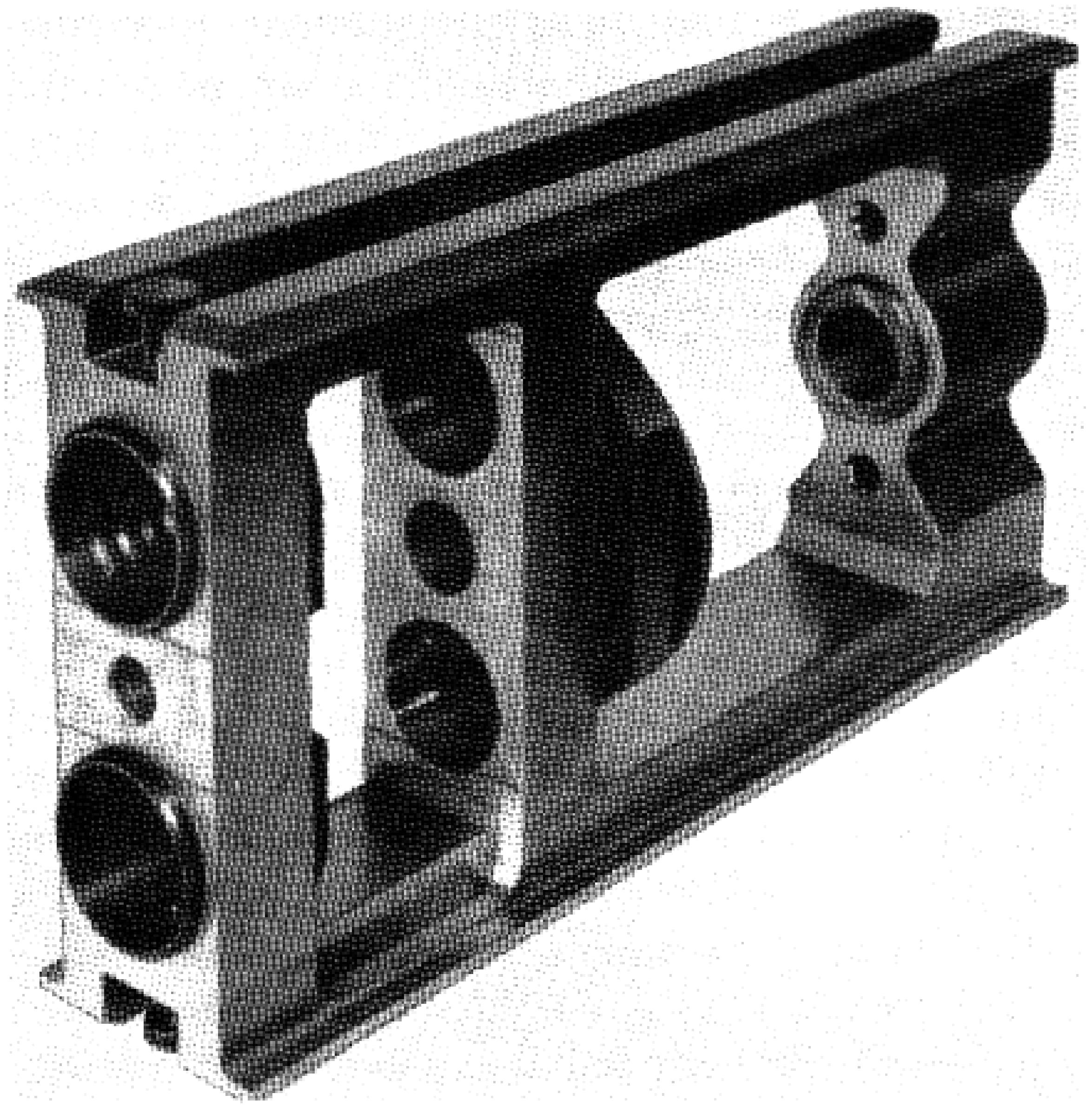

Figure 6–11. Breech of 20-mm Machine Gun Mk 11 Mod 0.

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 forward 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 alined 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 accomplish 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-

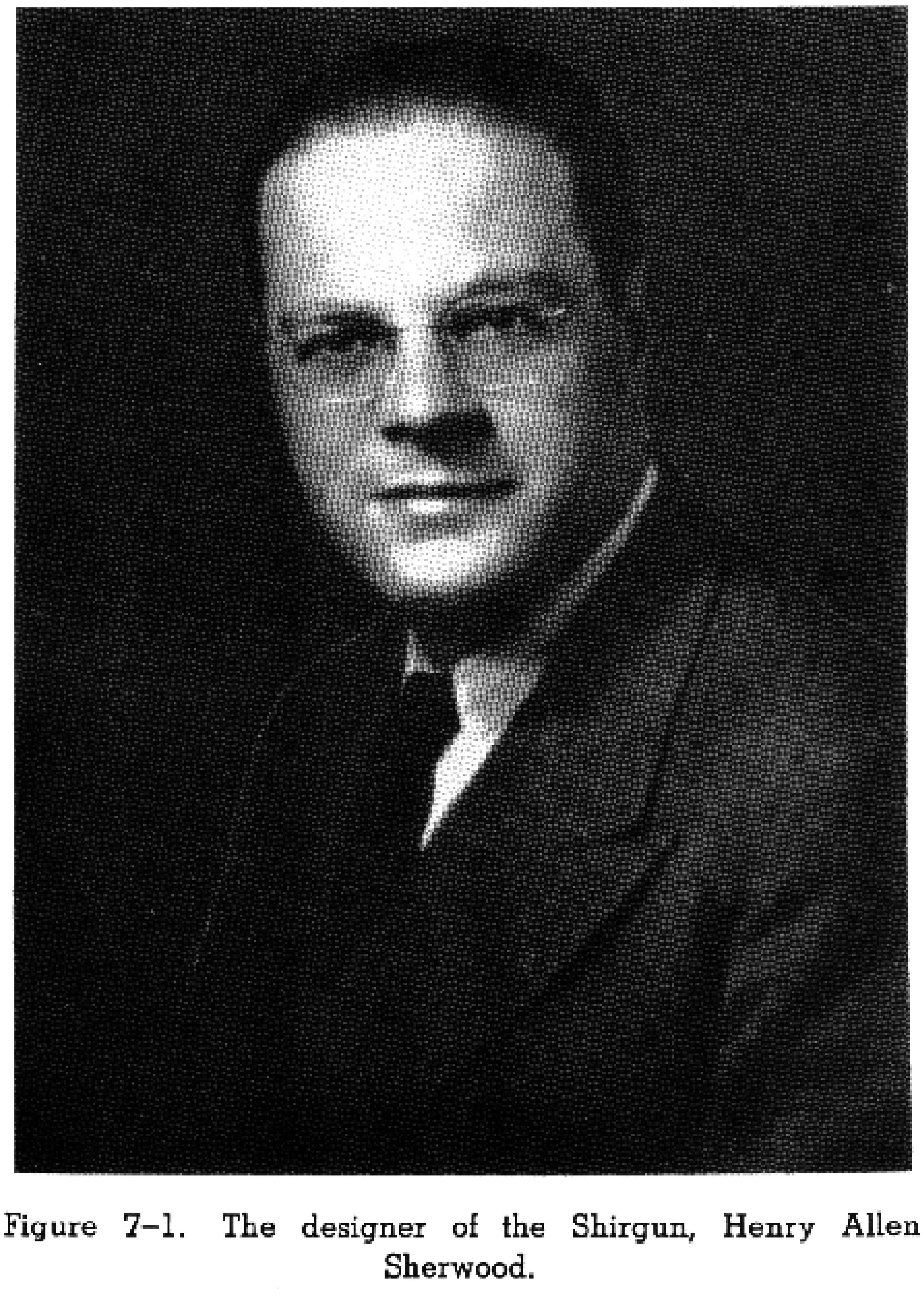

Figure 7–1. The designer of the Shirgun, Henry Allen Sherwood.

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

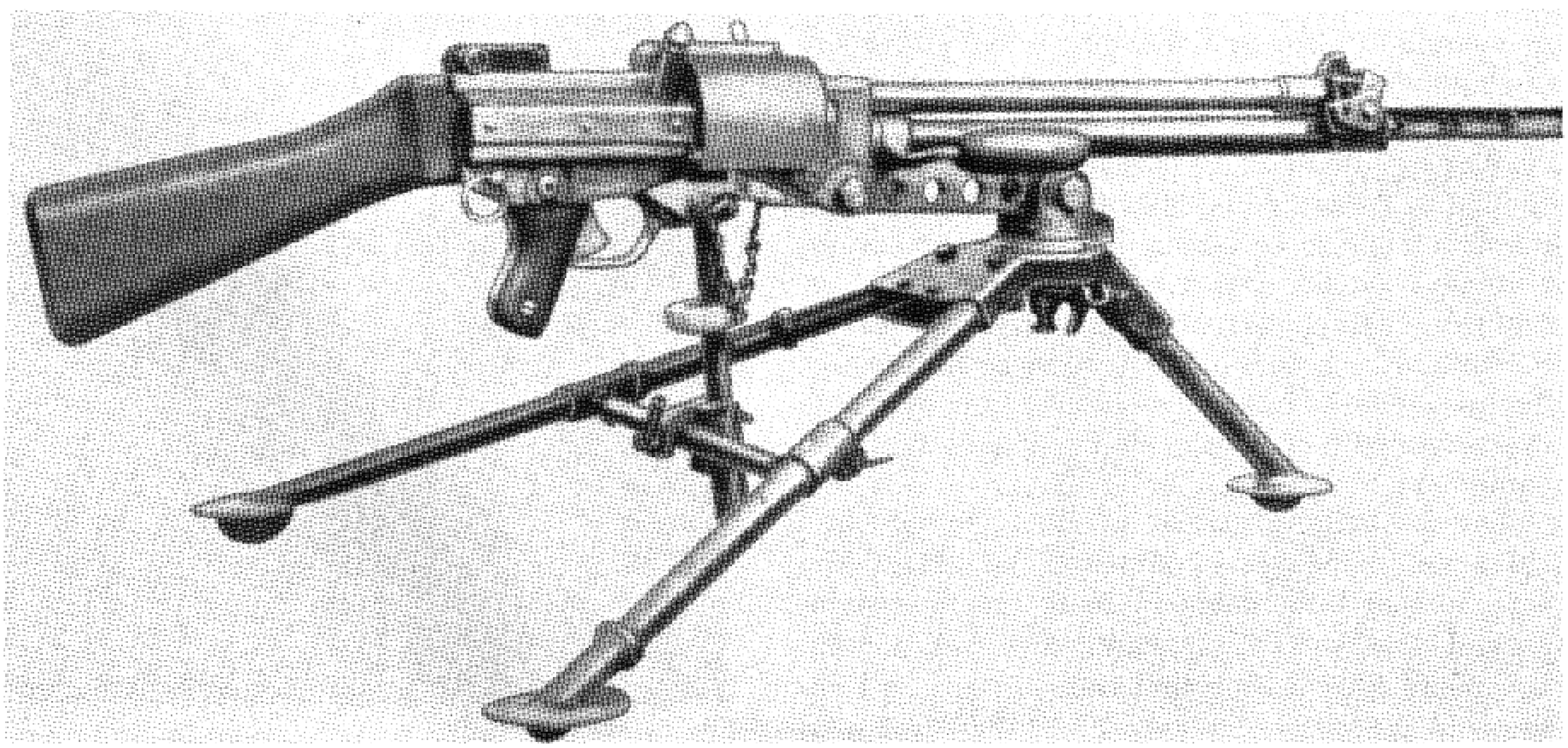

Figure 7–3. The Caliber .30 Machine Gun entered by Sherwood in the Army tests of 1941.

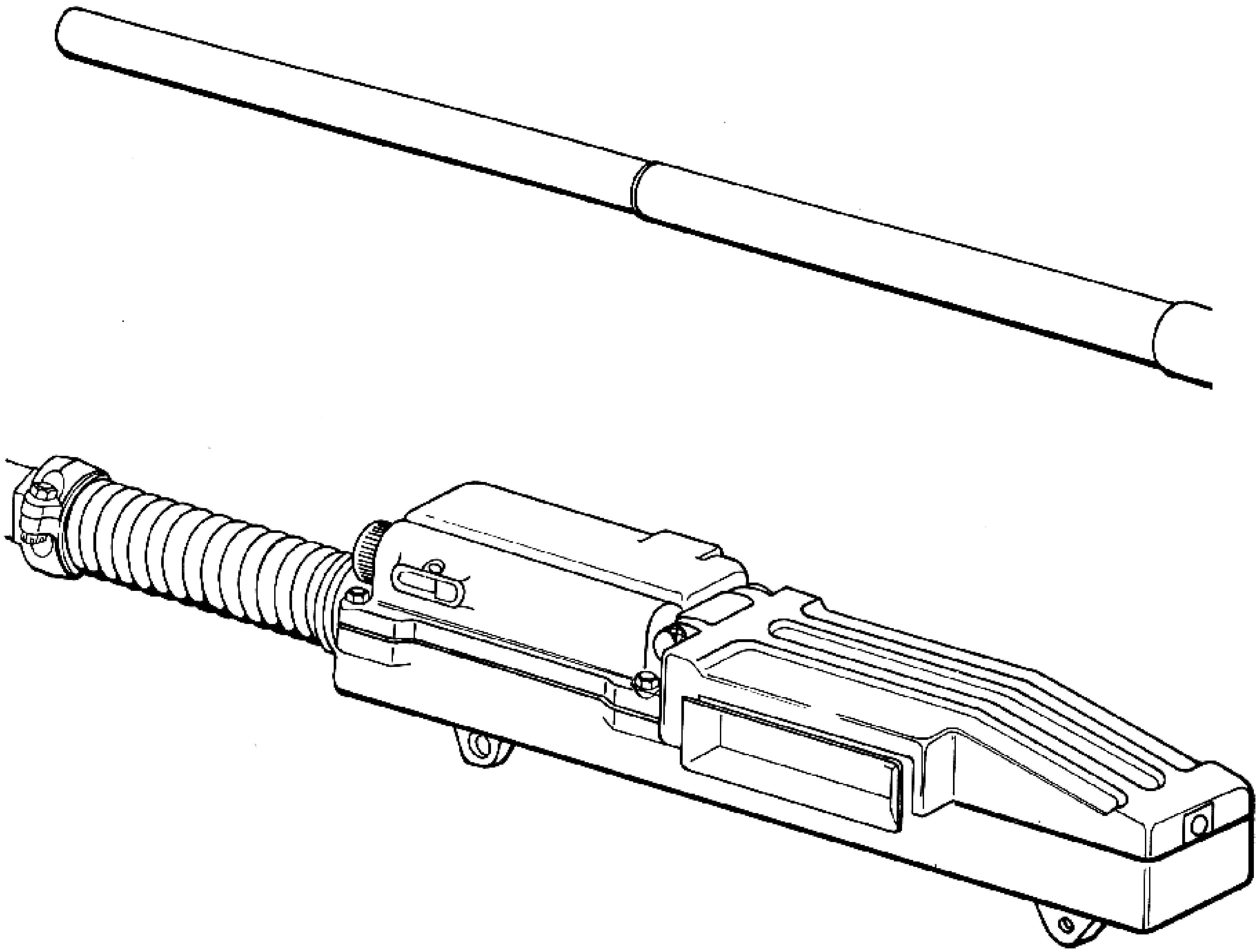

Figure 7–4. Drawing prepared by the Shirgun Corp. to show the prototype of the proposed EX 1 Type 0.

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

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COMPARISON CHART

NAME	HISPANO	SCHIRGUN SINGLE	SCHIRGUN DOUBLE	BROWNING		
CALIBER	20 MM AIRCRAFT	20 MM AIRCRAFT	20 MM AIRCRAFT	37 MM A.A.	37 MM A.A.	37 MM AIRCRAFT
MUZZLE VELOCITY 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/ROUND FT-LBS.	37,800	36,100	36,100	141,000	125,000	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	2.62	3.12	1.93
WEIGHT OF DISINTE-GRATING LINK LBS.	.14	.14	.14	.32	.32	.32
BELT RESISTING FORCE LBS.	40	450	640			
LENGTH OF COMPLETE ROUND IN.	7.23	7.23	7.23	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.	9.0+0.6+0.5+0.7=10.80	9.219+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	8×13	6.75×7.25	7.00×7.50			
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		
10.0	10.0	10.0	20.0	20.0	20.0	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	88.56		
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.

performance of its proposed designs as compared with standard weapons.

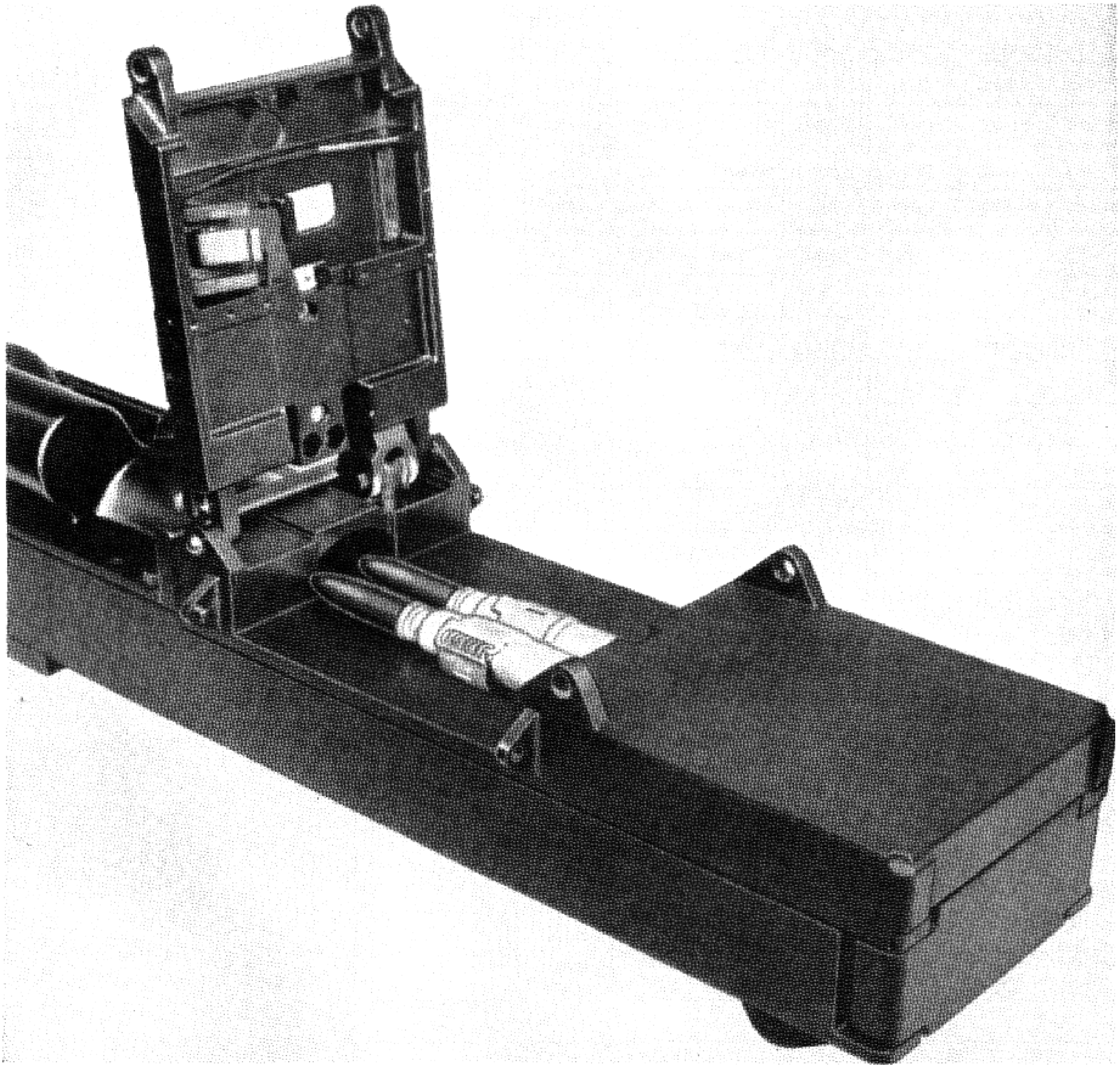

Figure 7–6. Breech of the original Shirgun. Cover open to show feedway.

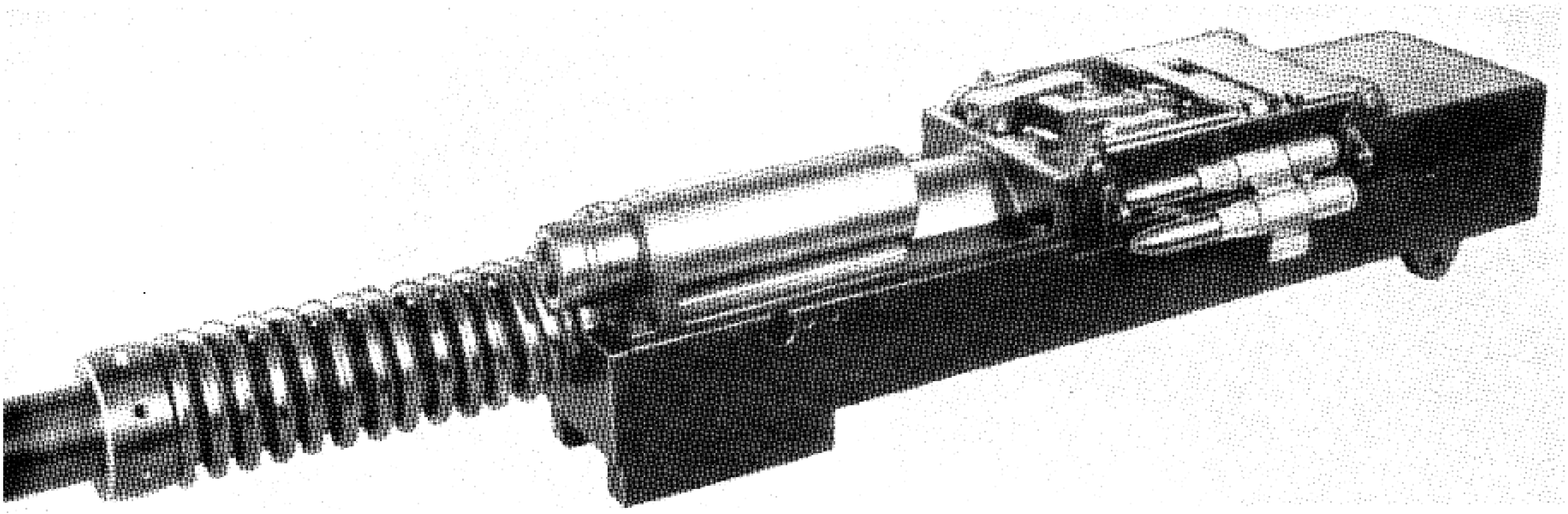

Figure 7–7. Left side of original Shirgun. Closeup view.

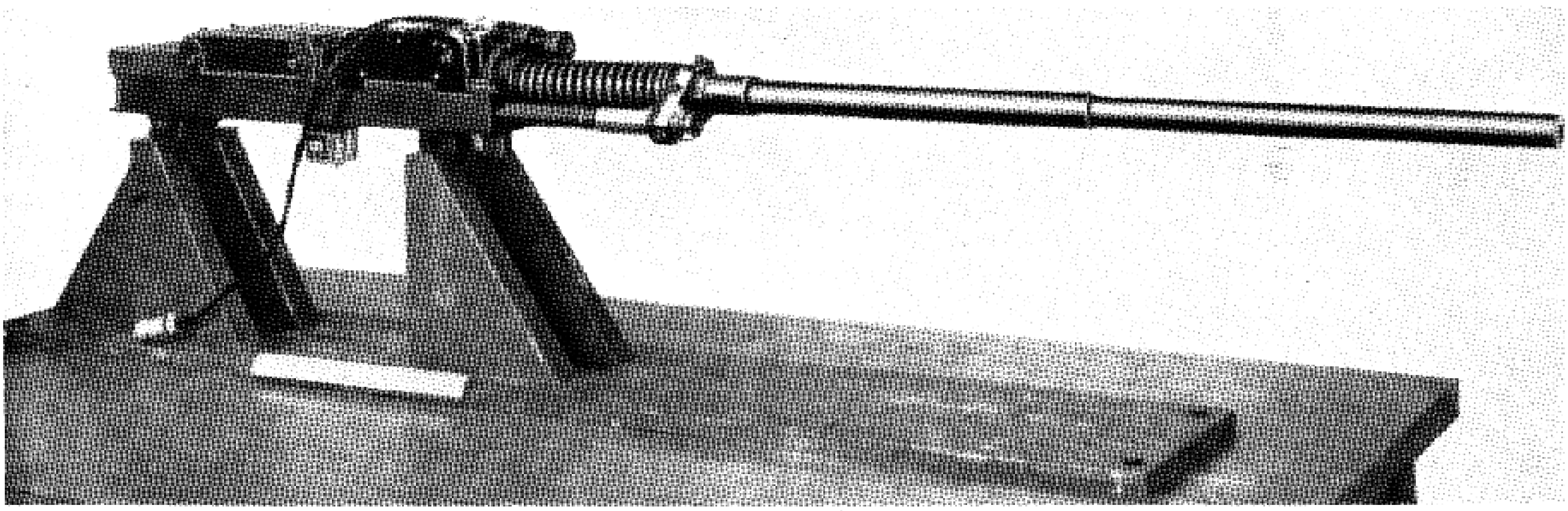

Figure 7–8. The original 20-mm Shirgun mounted on a test stand. Right side view.

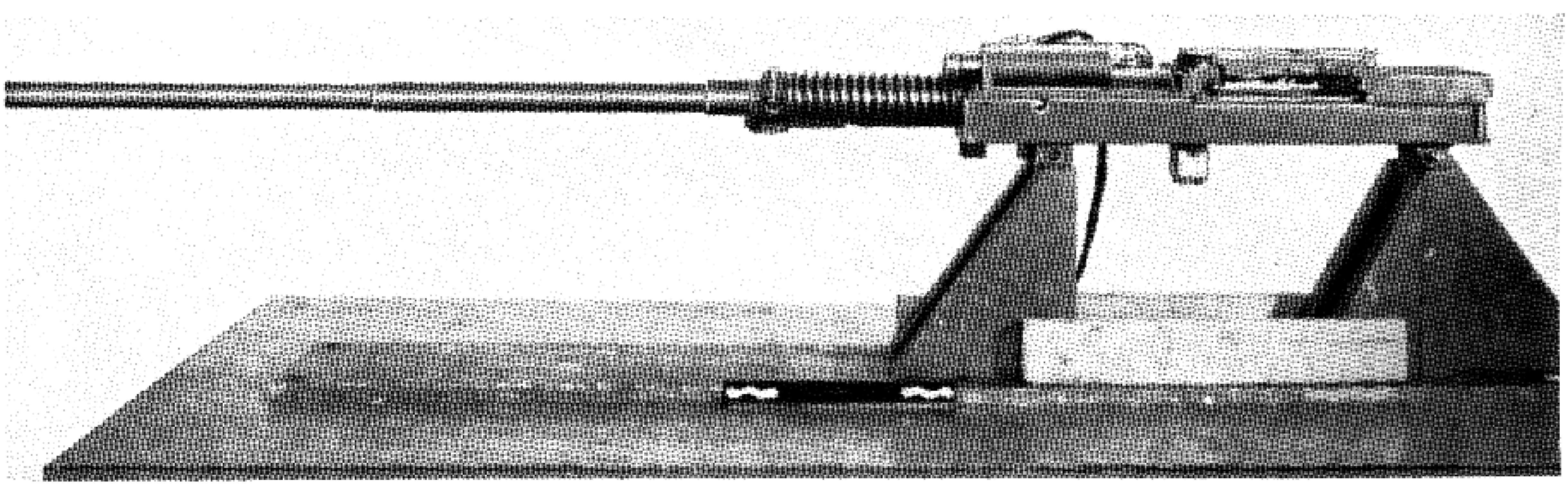

Figure 7–9. The original 20-mm Shirgun mounted on a test stand. Left side view.

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

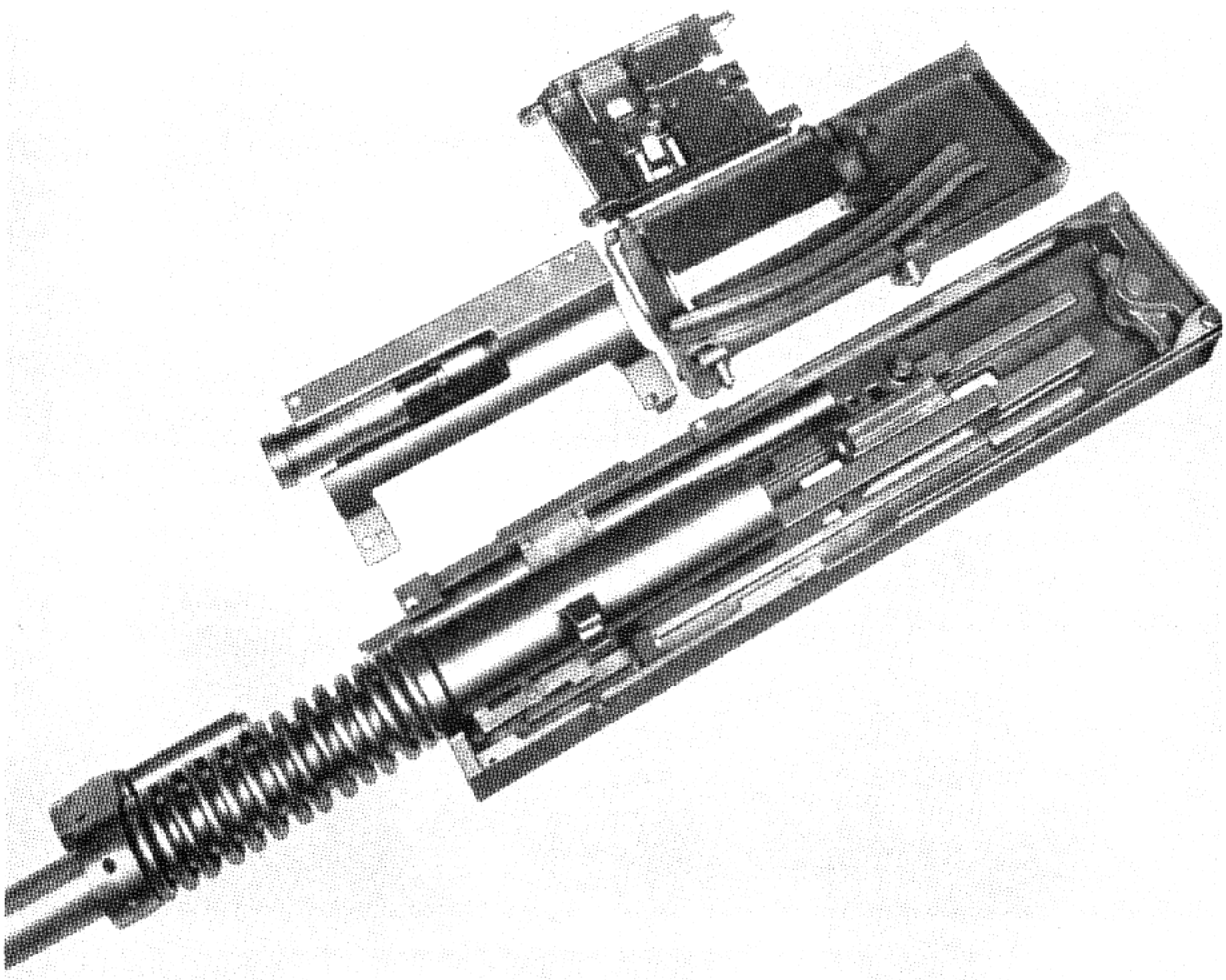

Figure 7–10. Original 20-mm Shirgun. Top of receiver removed.

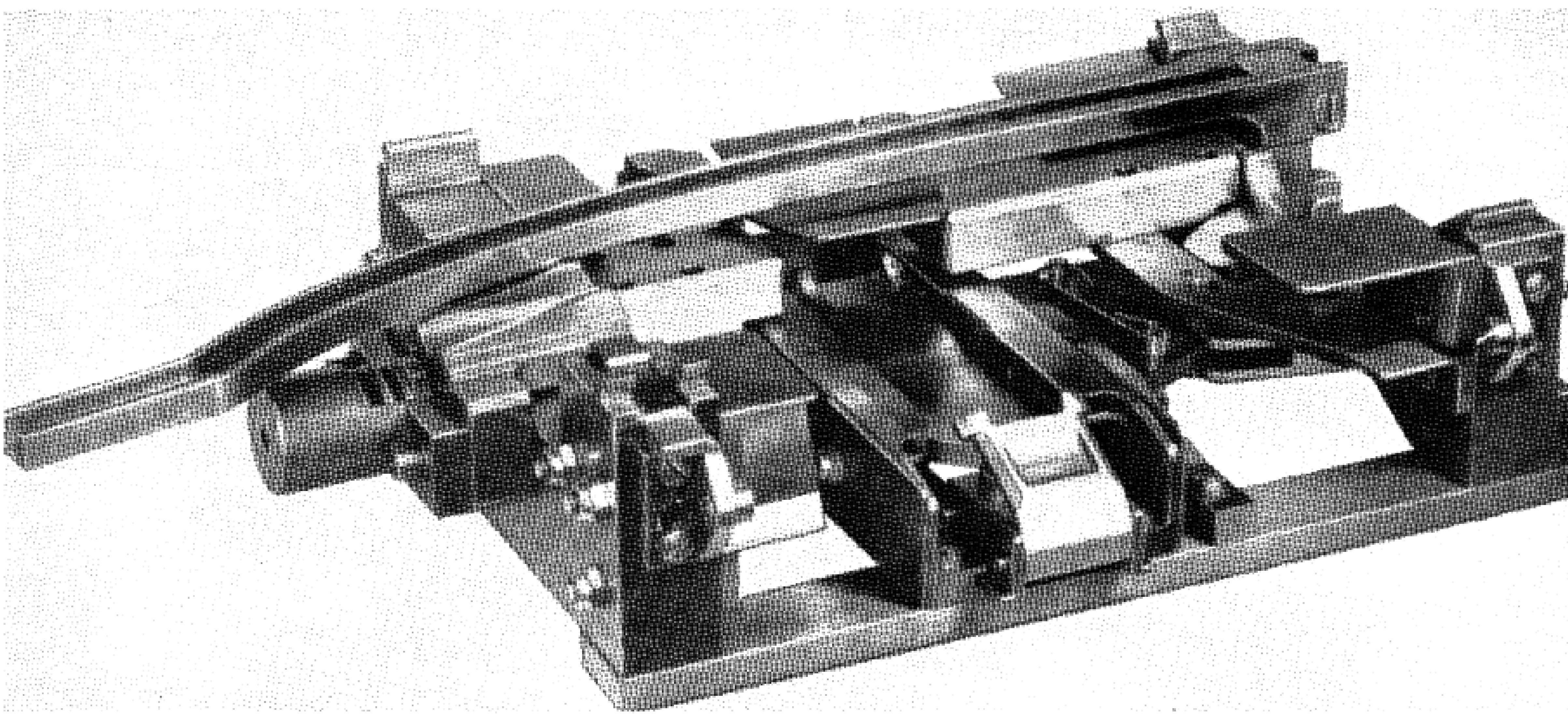

Figure 7–11. The feed of the original 20-mm Shirgun.

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

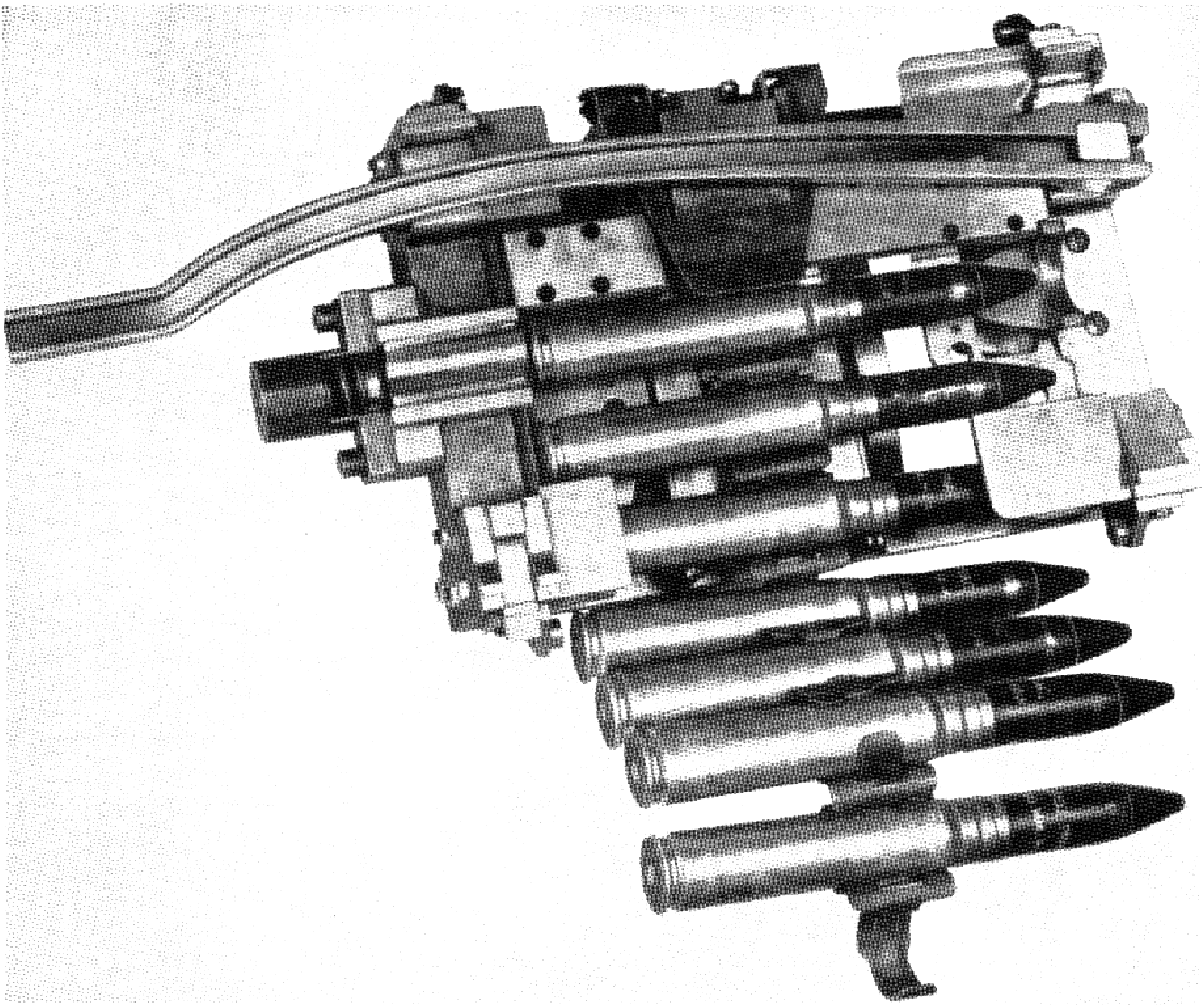

Figure 7–12. The feed of the original 20-mm Shirgun. Bottom view, showing belt of ammunition in position.

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 manufactured 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

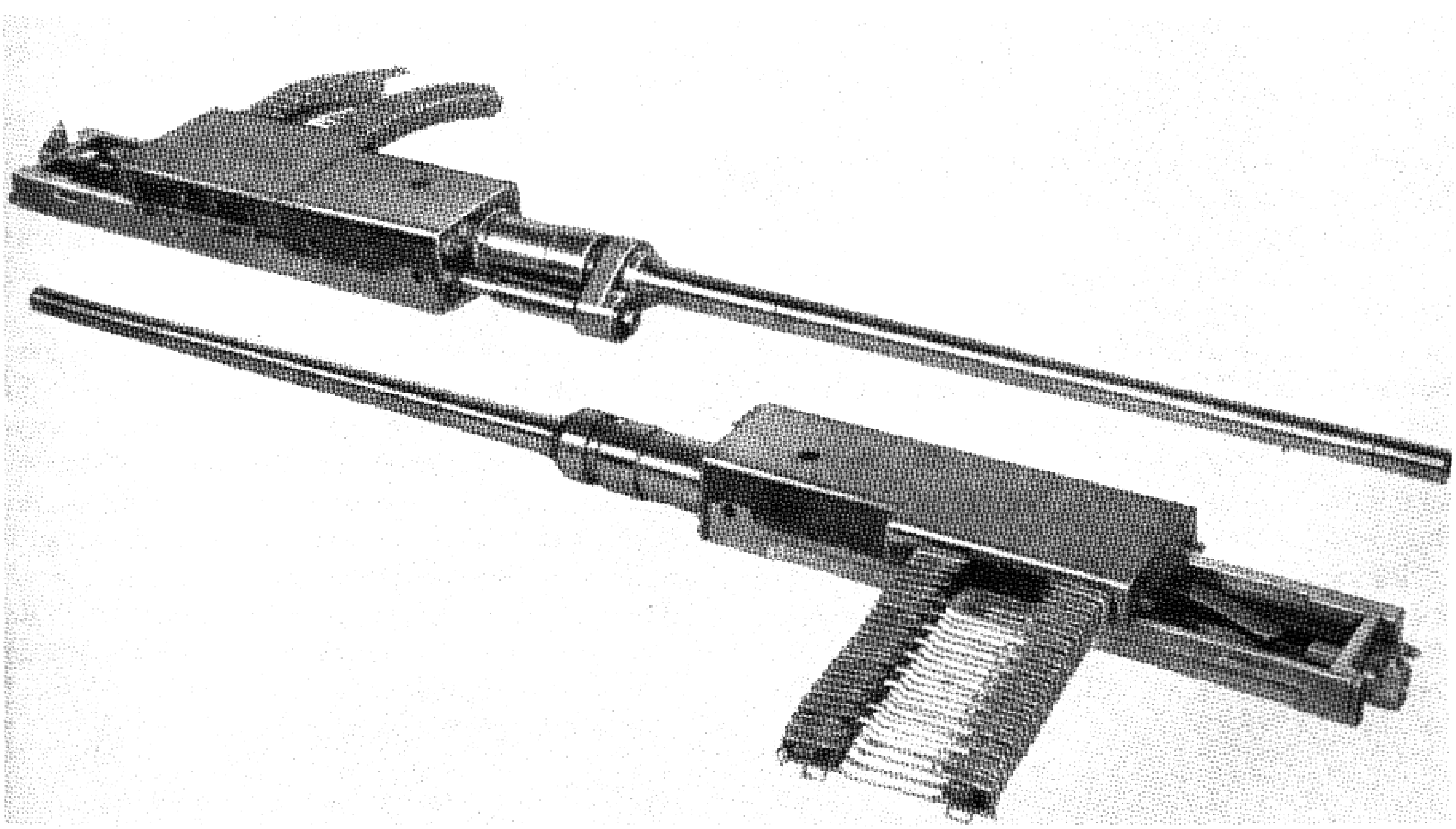

Figure 7-13. 20-mm Shirgun Mk 9 Mod 0. This model represents an intermediate stage in the development of the 20-mm Shirgun.

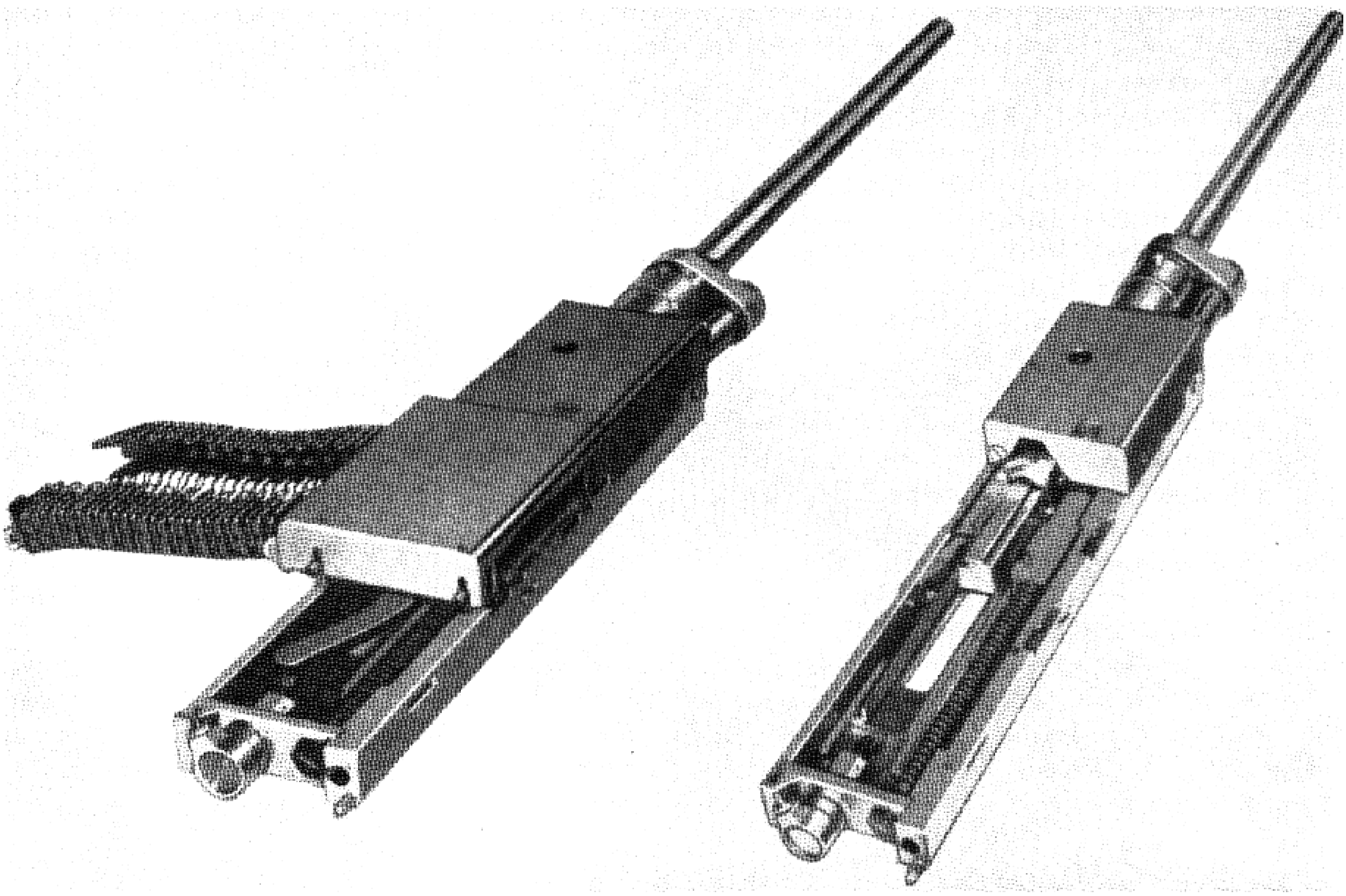

Figure 7–14. 20-mm Shirgun Mk 9 Mod 0. Two rear views showing the weapon with and without feeder.

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. Samford and Co. for this work. Only a wooden model has been made.

The Army designation for this model is T54.

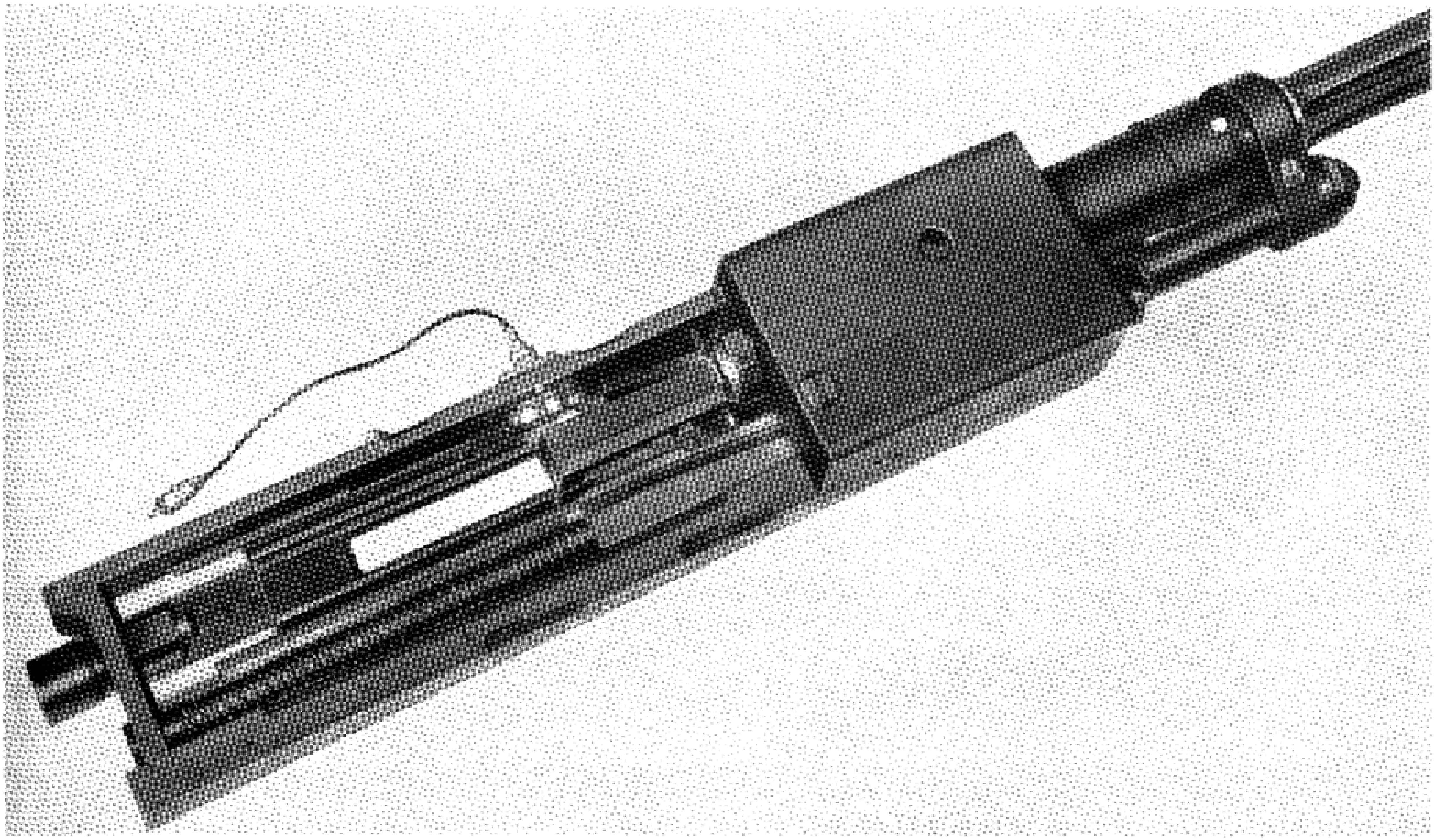

Figure 7-15. 20-mm Shirgun Mk 9 Mod 1, also known as the T128. This weapon is a conversion of the Mk 9 Mod 0 to electric ignition.

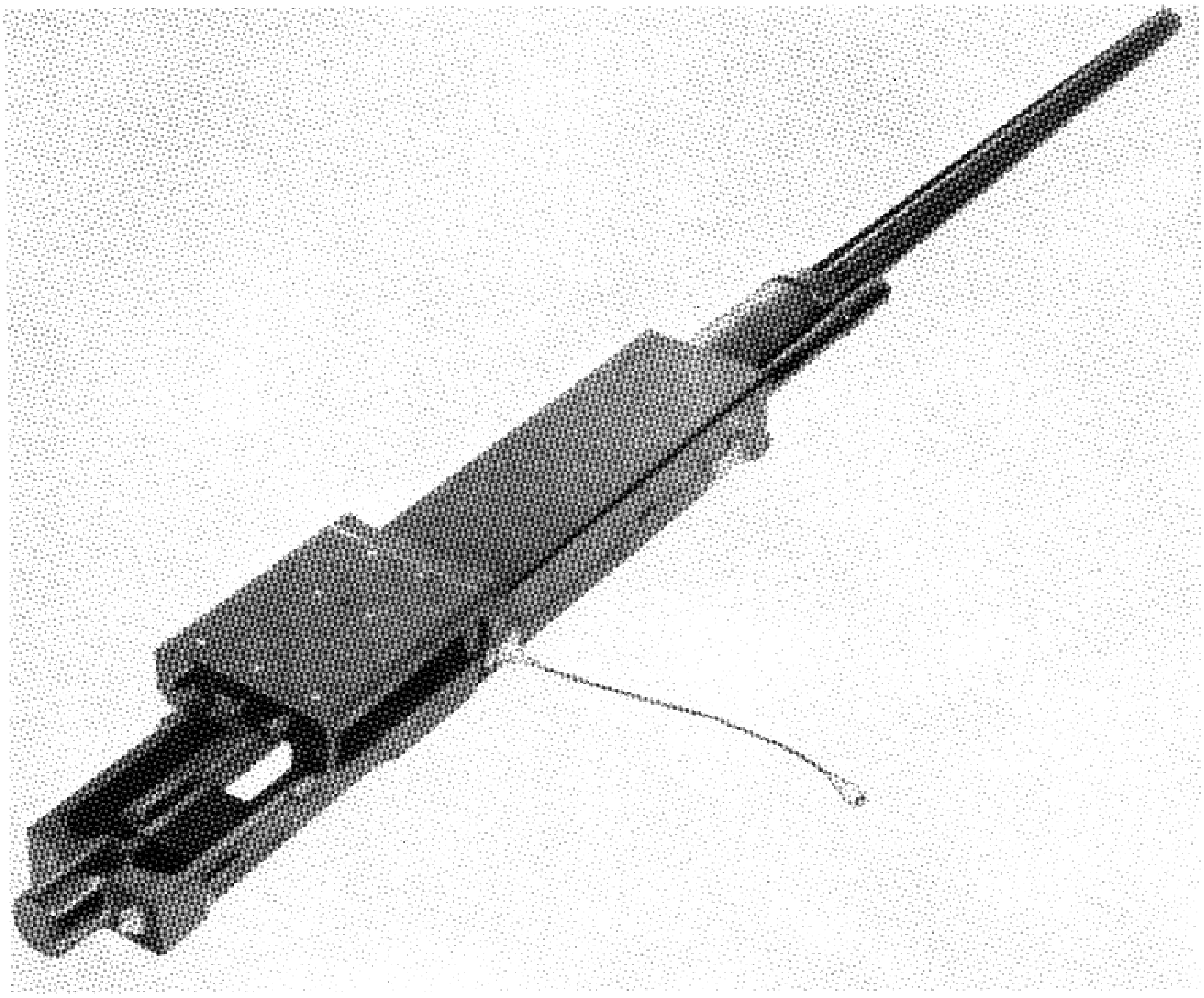

Figure 7–16. The 20-mm Shirgun as fully developed for electric ignition and high-velocity ammunition. This version is called the Mk 13 Mod 0.

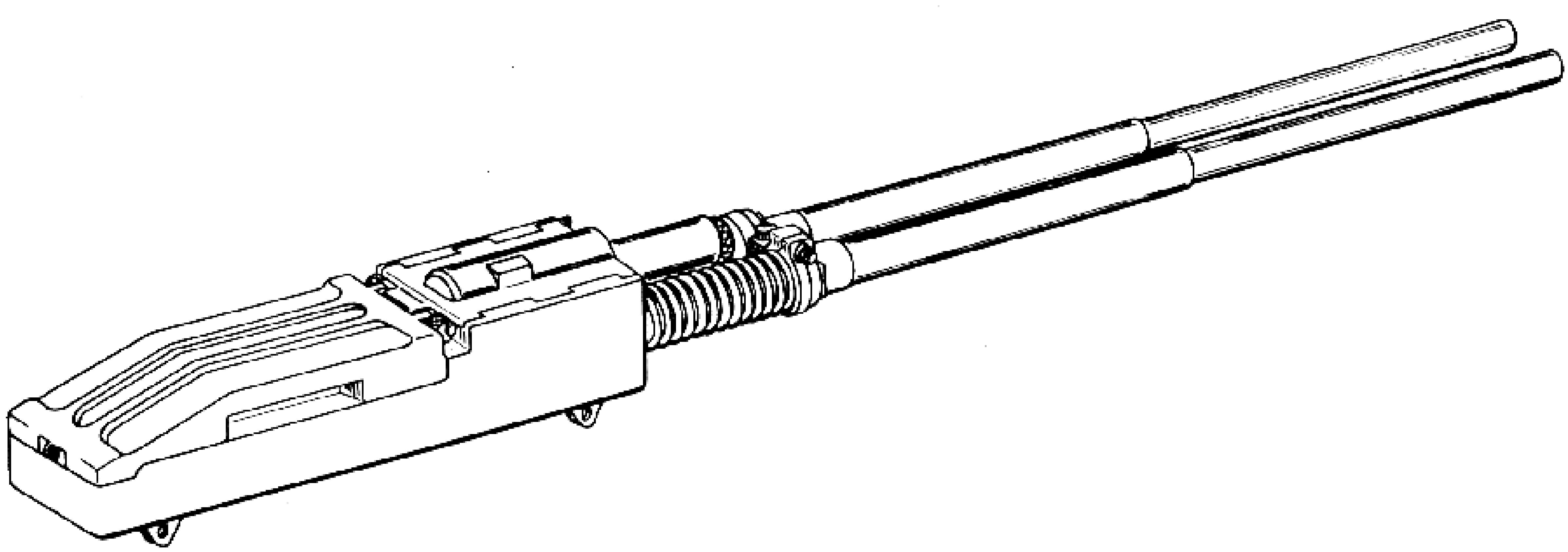

Figure 7–17. Drawing prepared by the Shirgun Corp. to show the prototype of the proposed EX 3 or Mk 10 Mod 0, double-barrel version.

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 $\frac{1}{4}$-inch deep along the entire length of the forward upper left-hand part of the bolt extension,

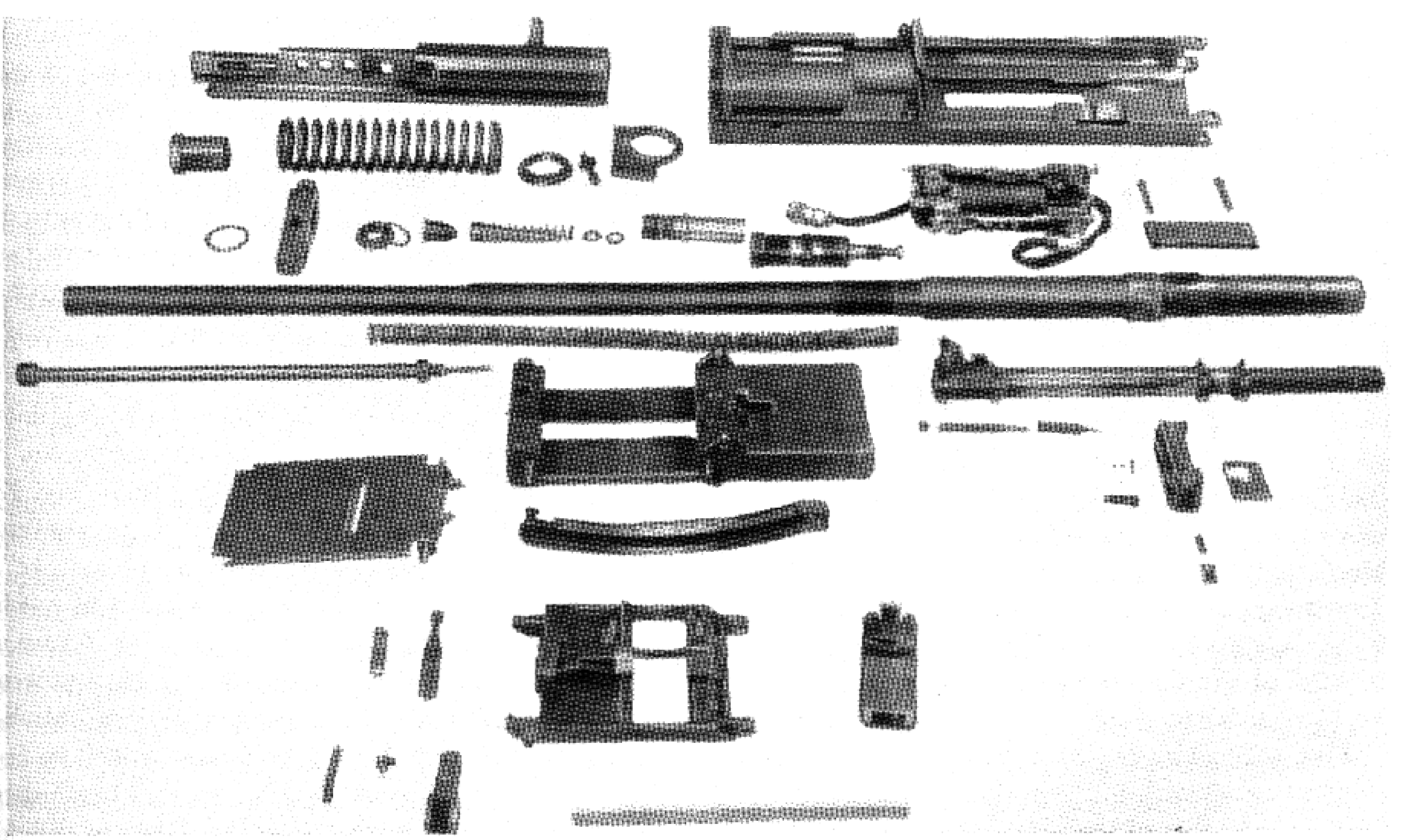

Figure 7-18. Complete disassembly of the original 20-mm Shirgun.

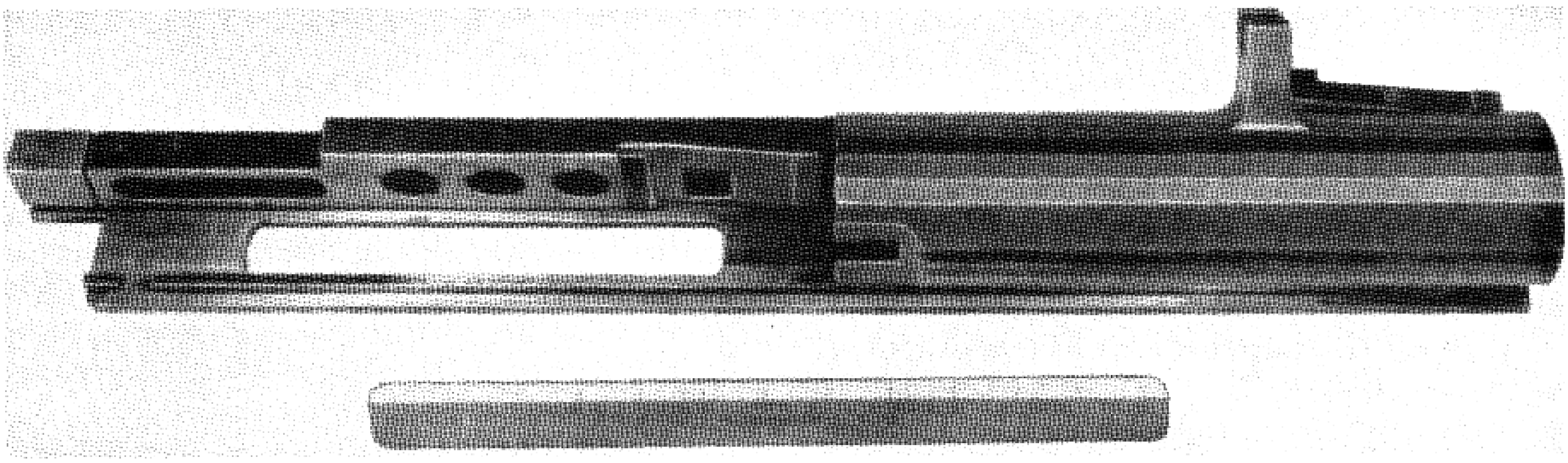

Figure 7-19. The barrel extension of the original 20-mm Shirgun.

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° 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°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°15′ angle, and released at 0.272 inch out of battery. Sear plunger No. 3 was cut at 17° and released at 0.190 inch; sear plunger No. 4 was cut at 13° and released at 0.140 inch; sear plunger No. 5 was cut at 7° and released at 0.087 inch.

2. Removing the original sear plunger with the 45° 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 2½ 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 4¼ 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 breech lock 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 Bombsight 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.

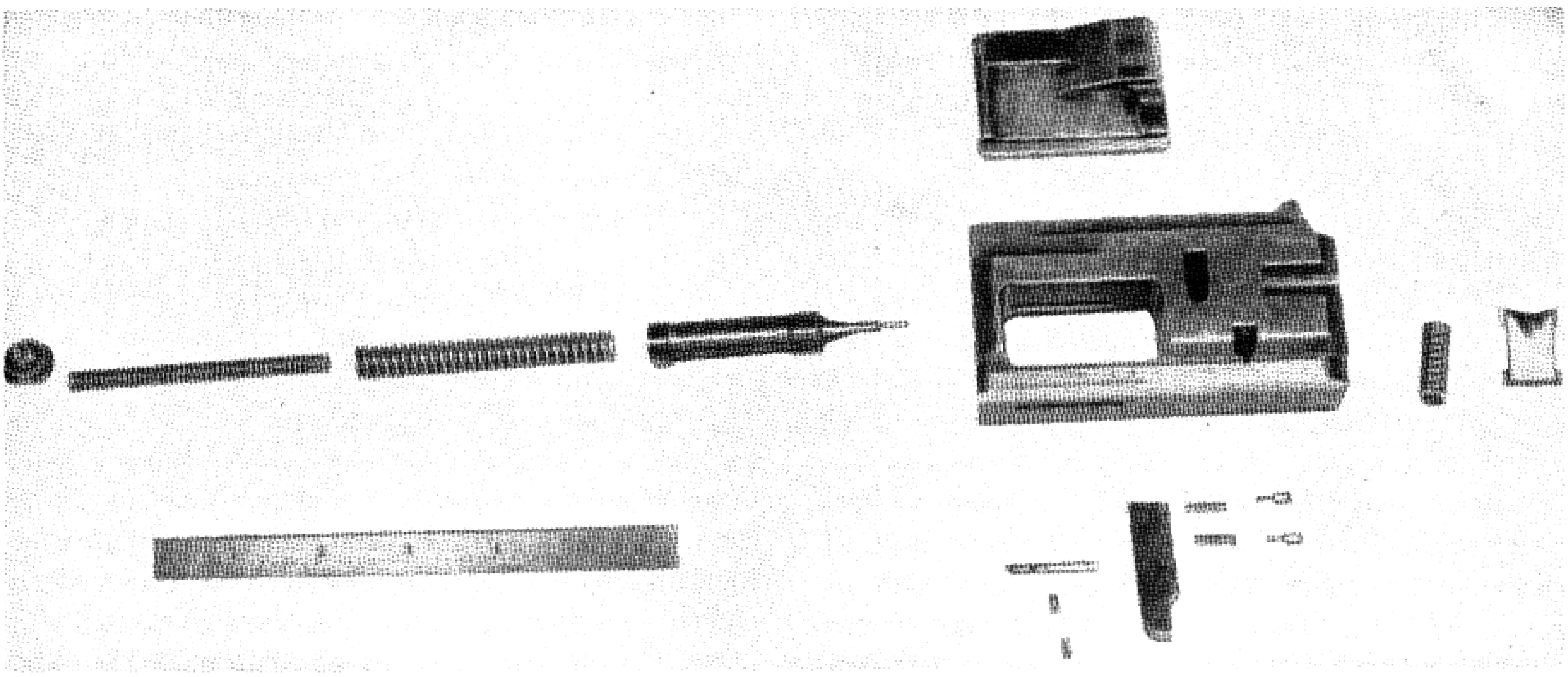

Figure 7–20. Components of the bolt of the original 20-mm Shirgun.

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 hacksaw cut was made 0.087 inch to the right and angled in 15° as it came aft. This allowed only one point of contact with the belt feed lever slot, thereby reducing 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 alined, 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

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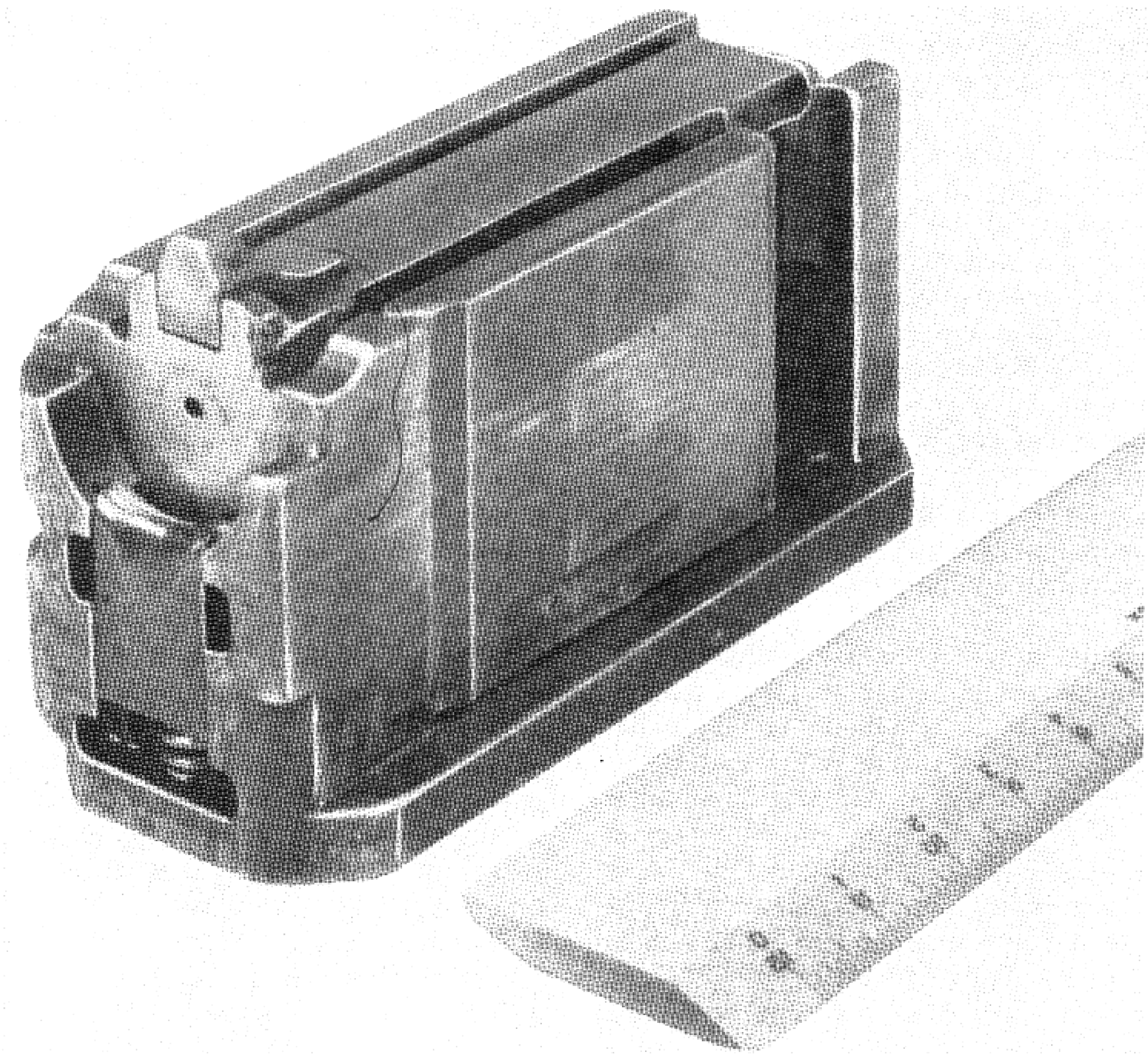

Figure 7–21. The bolt of the original 20-mm Shirgun.

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 required 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 aline 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 1⅞ 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
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: Orignal 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°) instead of 45° 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:

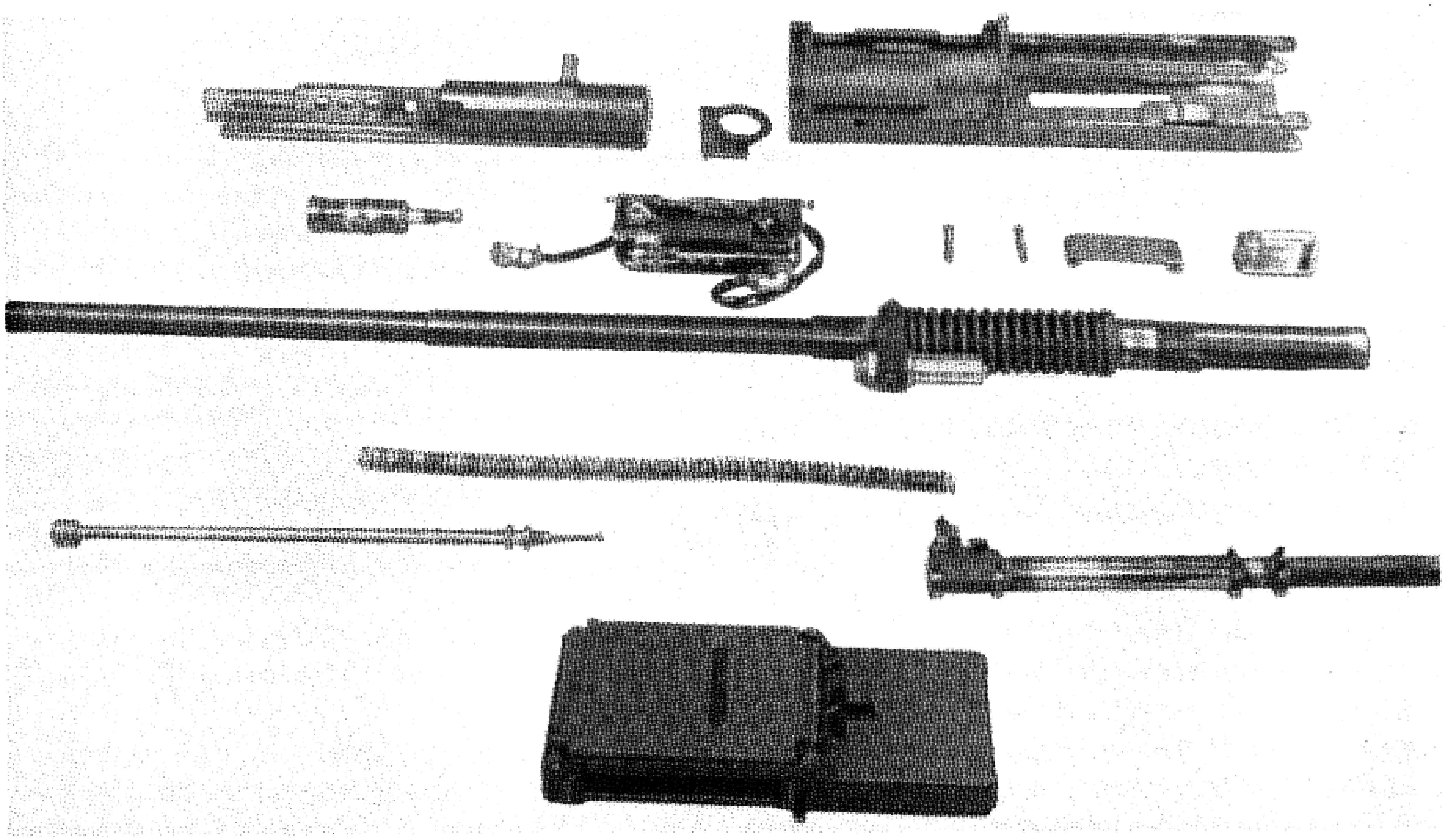

Figure 7–22. Partial disassembly of the original 20-mm Shirgun.

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 (¼ 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	77⅜
Length of barrel (inches)	67½	52½
Maximum height with feeder (inches)	7¼	[1] 11⅝
Maximum width (inches)	6⅞	5⅝
Maximum width with firing mechanism (inches)	8	....

[1] 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°) instead of 45° 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.

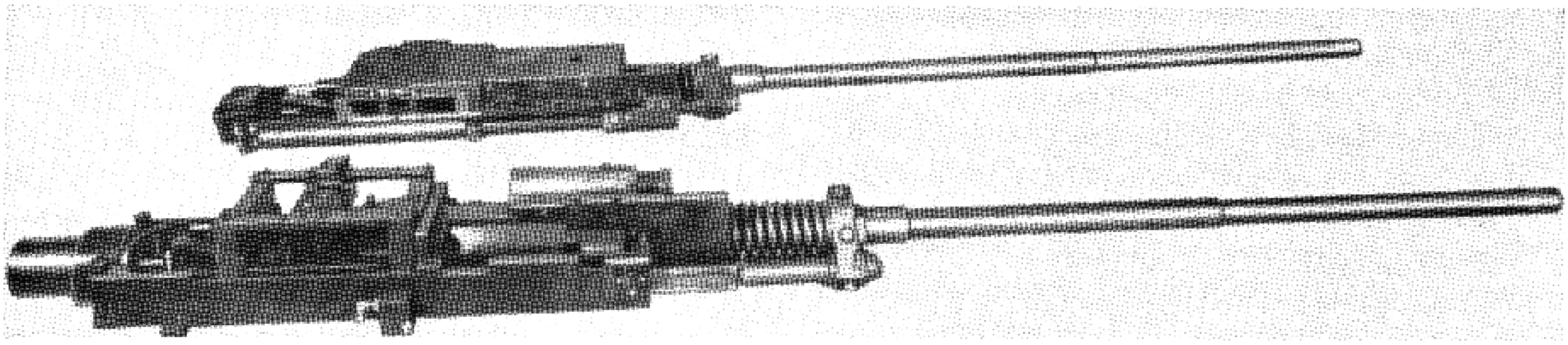

Figure 7–23. Early versions of the 20-mm Shirgun. In the foreground: EX 1 Type 1. In the rear: EX 1 Type 2, which is also known as the T55.

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 1⅛ 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 ½-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 1½ 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 alinement, 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

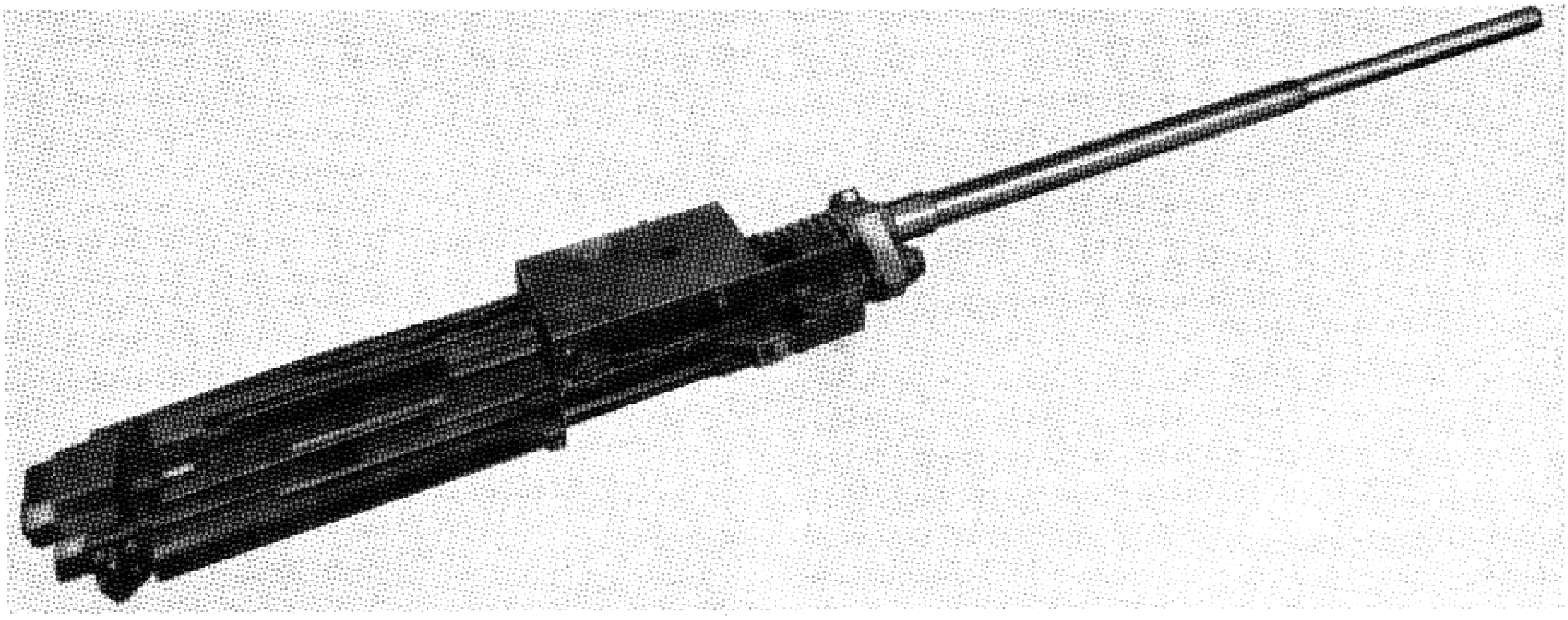

Figure 7–24. Closeup view of the T55 (EX 1 Type 2) Gun with its feed mechanism removed.

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 9¾ 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.

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(*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 following 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 10⅛ to 9$\frac{1}{16}$ 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 accerelations 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 cannelure 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 pressures 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 installation 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-

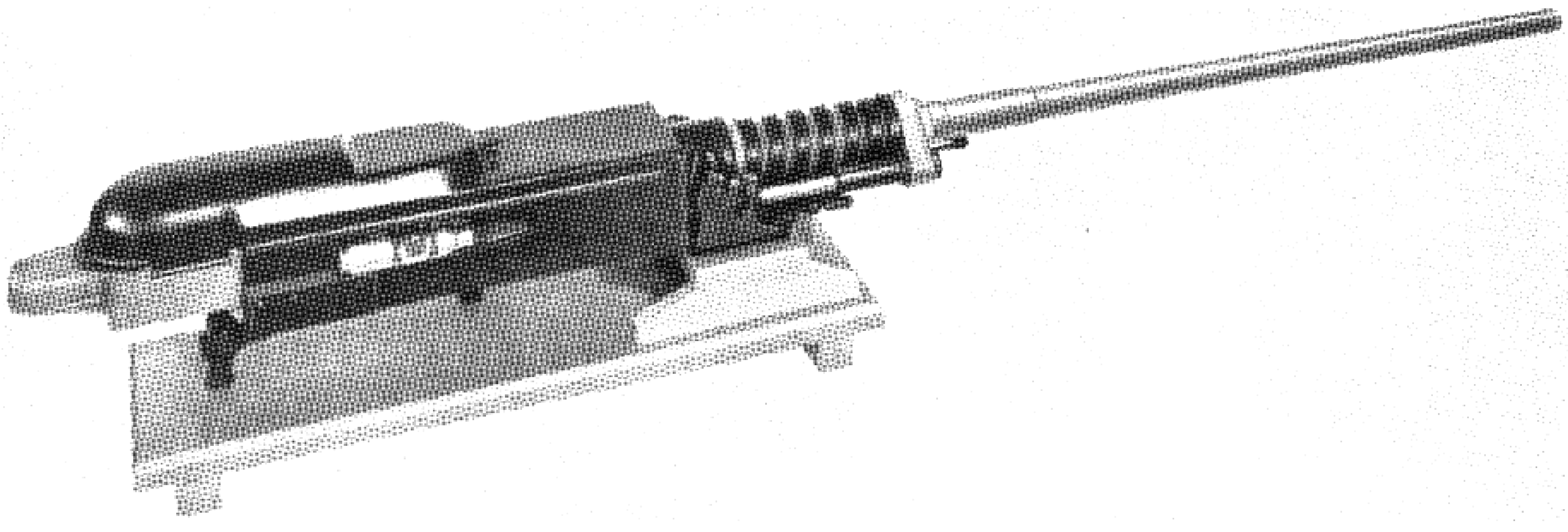

Figure 8–1. 20-mm Automatic Gun T33. Wooden mockup.

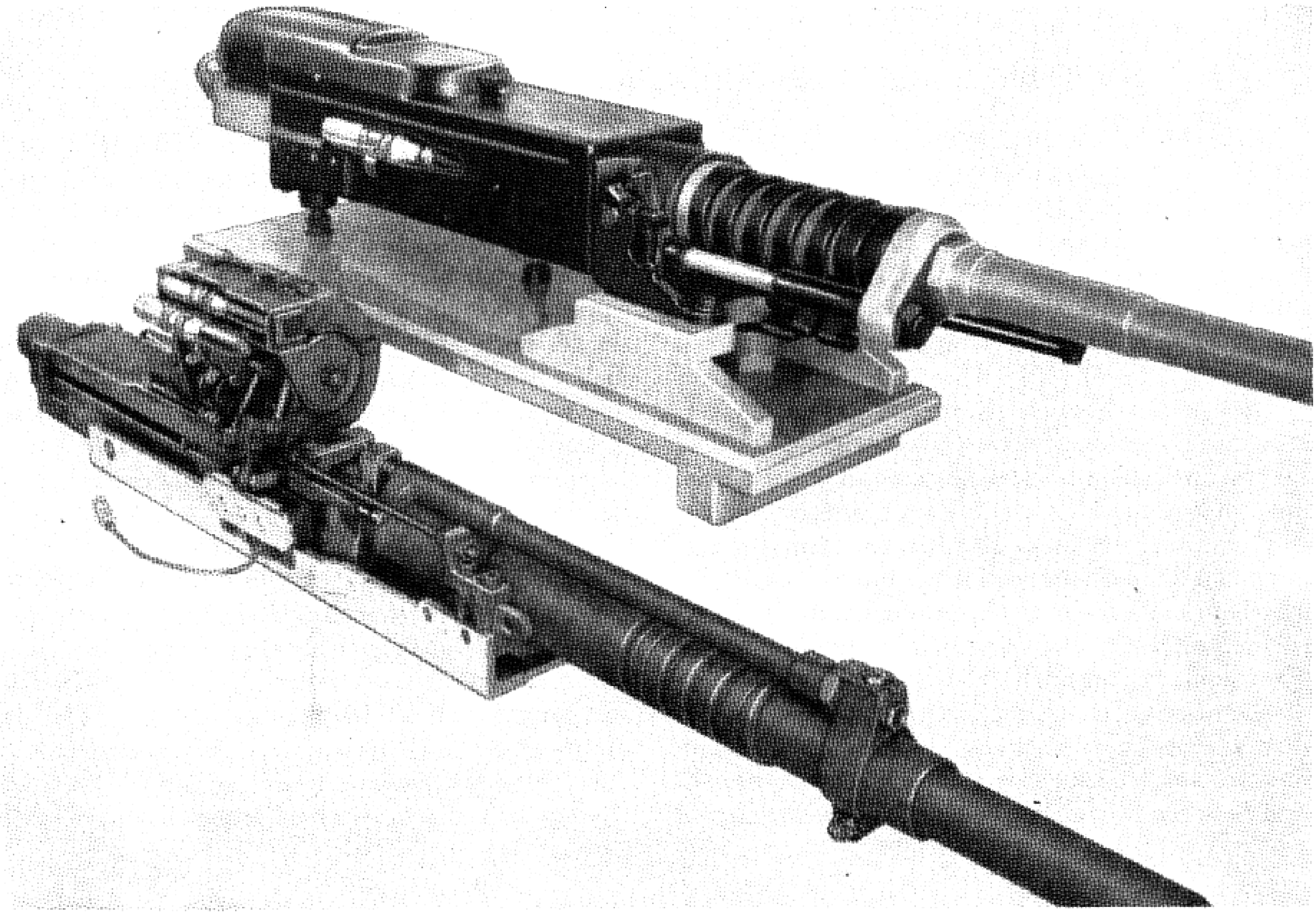

Figure 8–2. Comparison of 20-mm guns. On left, T31; on right, mockup of T33.

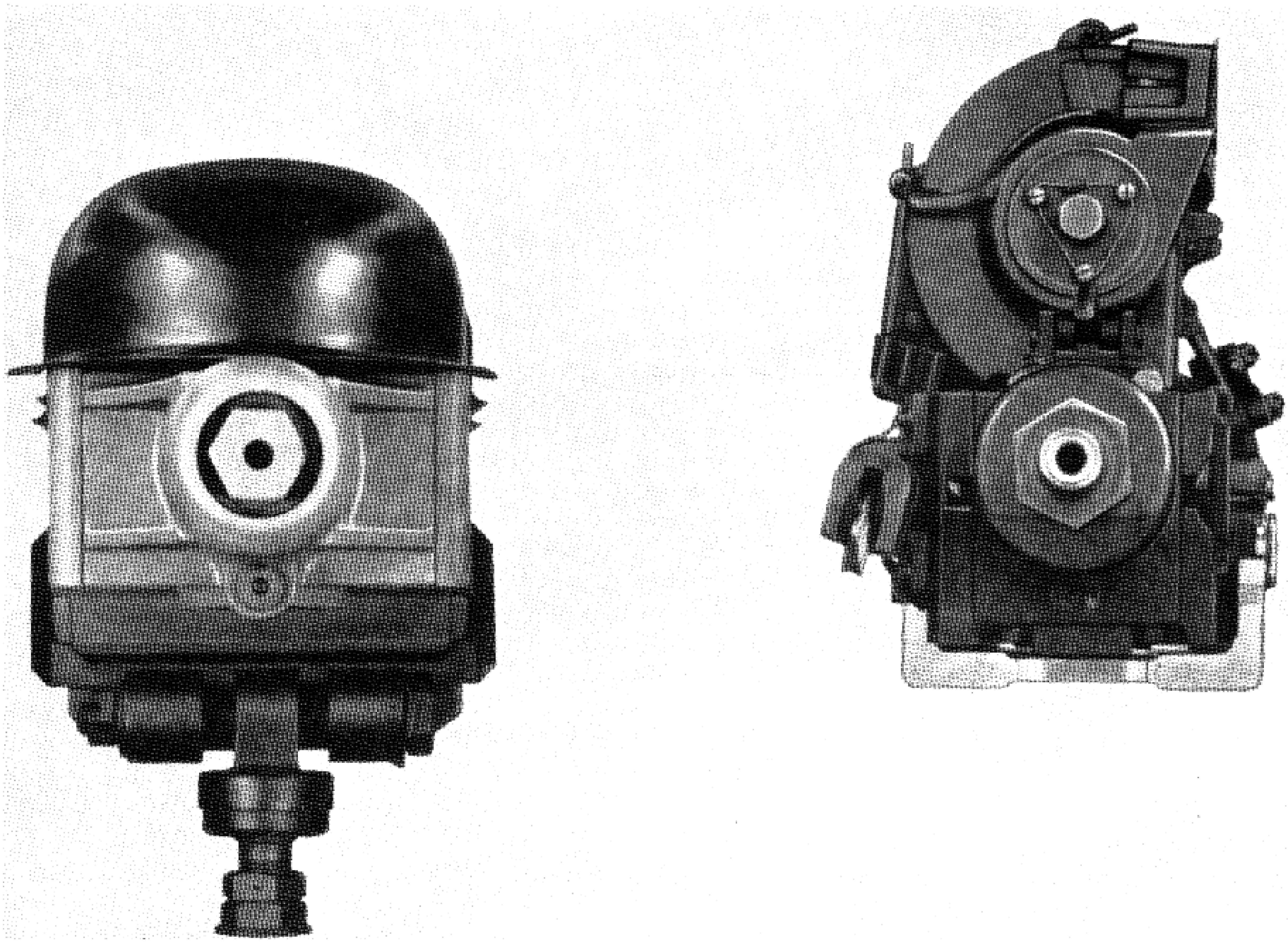

Figure 8–3. Comparison of 20-mm guns from the rear. On left, T33; on right, T31.

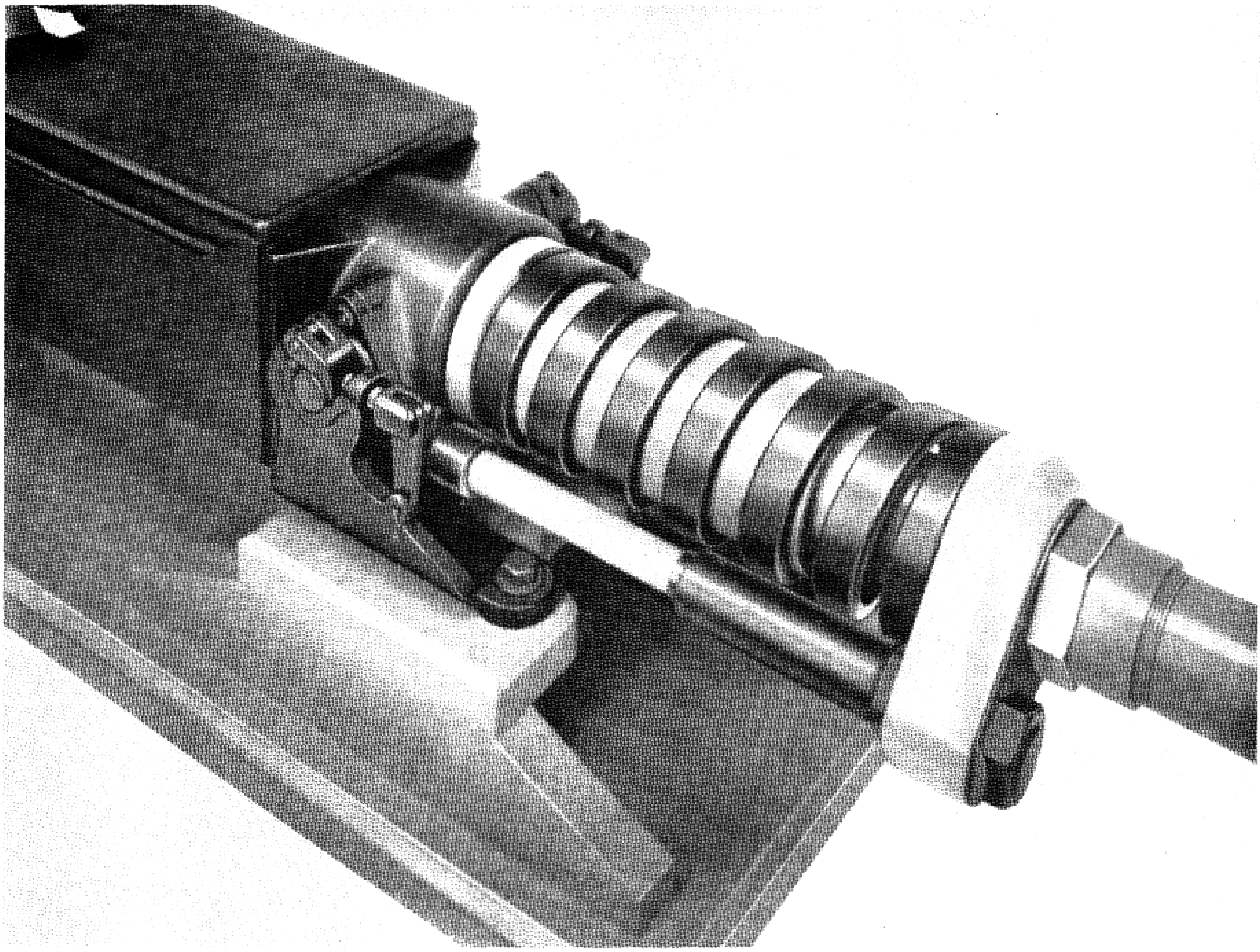

Figure 8–4. 20-mm Gun T33. Closeup view of front mounting.

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.

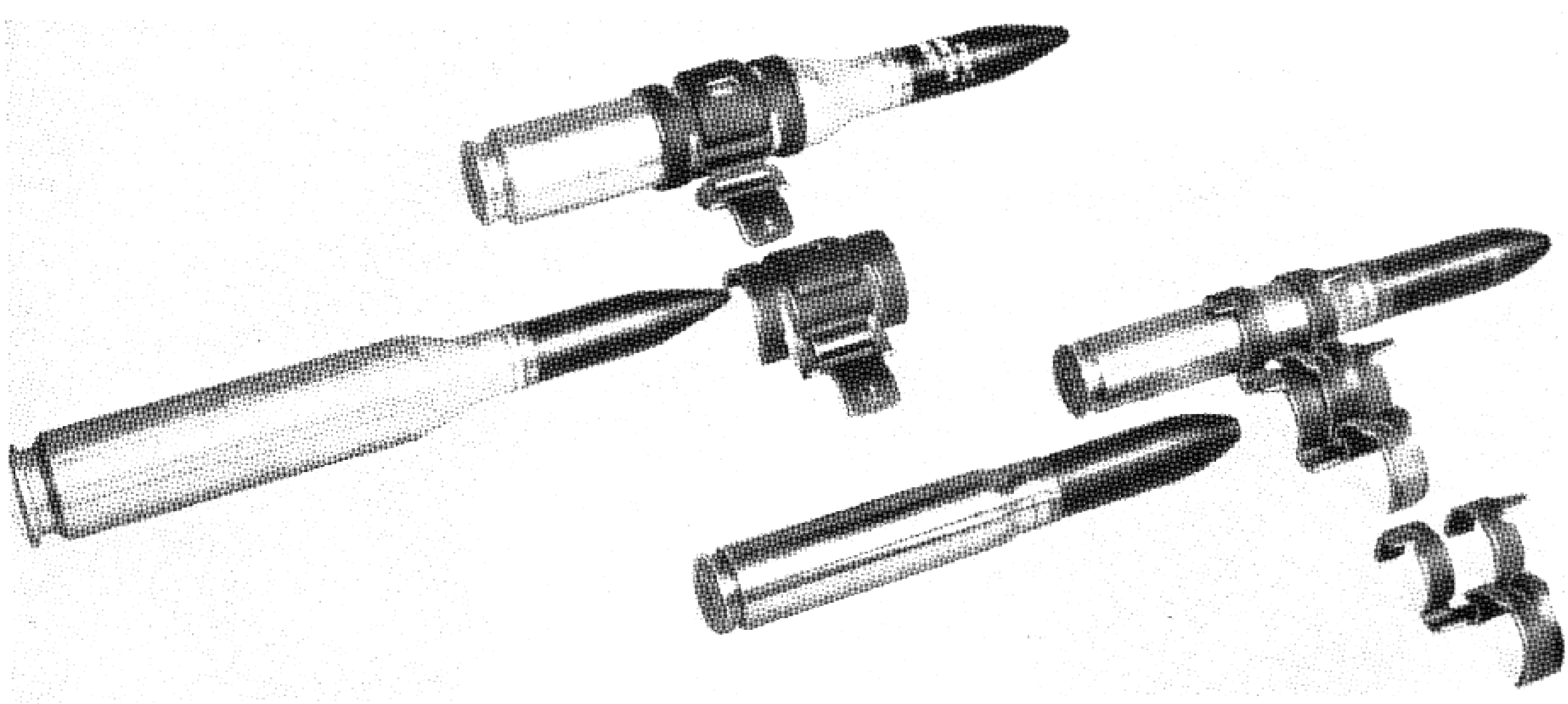

Figure 8–5. Large ammunition and links for 20-mm Gun T33 compared with normal-sized Hispano-Suiza ammunition.

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.

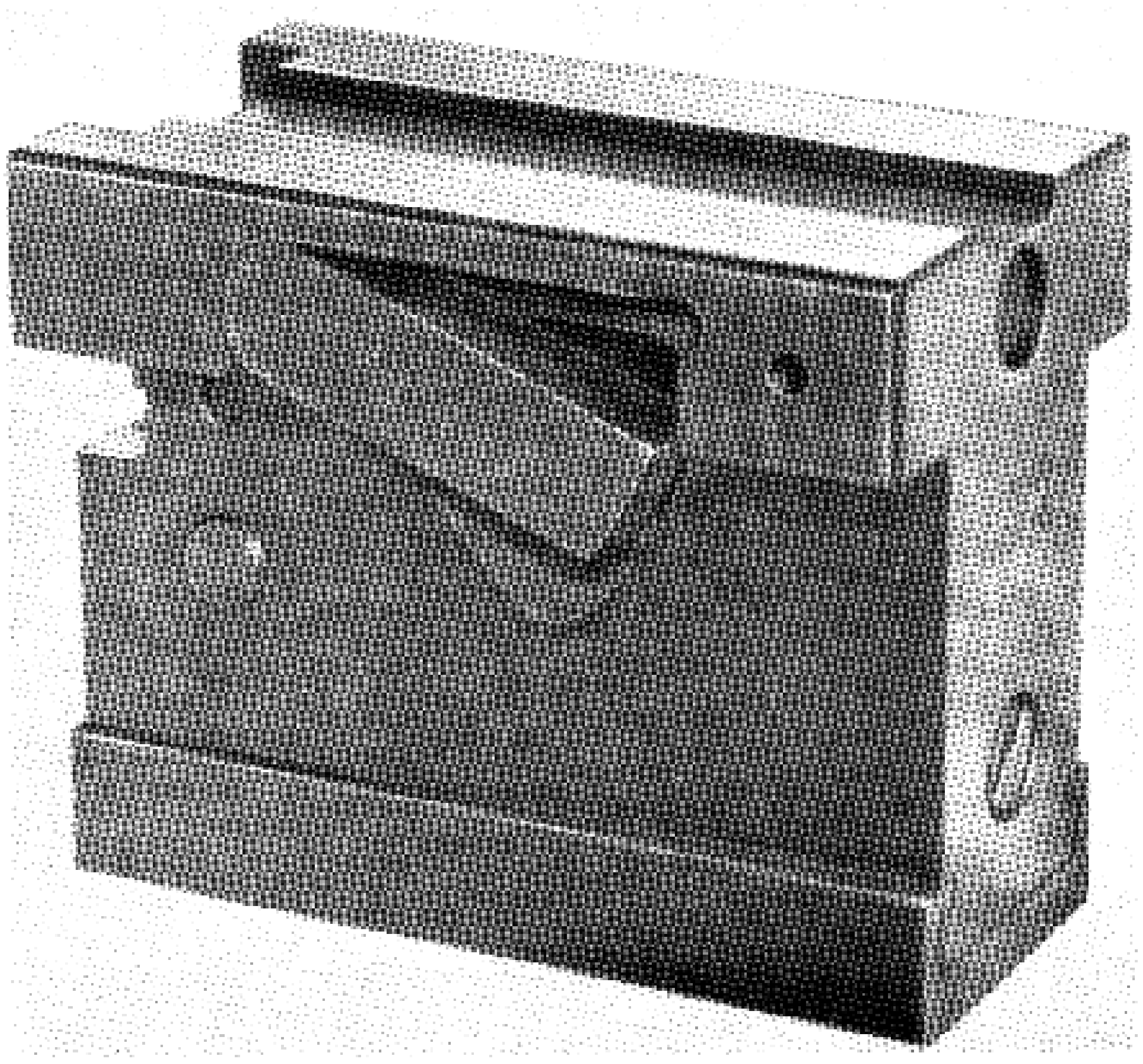

Figure 8–6. Bolt of the 20-mm Gun T33E3, showing parts in the locked position. This bolt is the pivot-locking type.

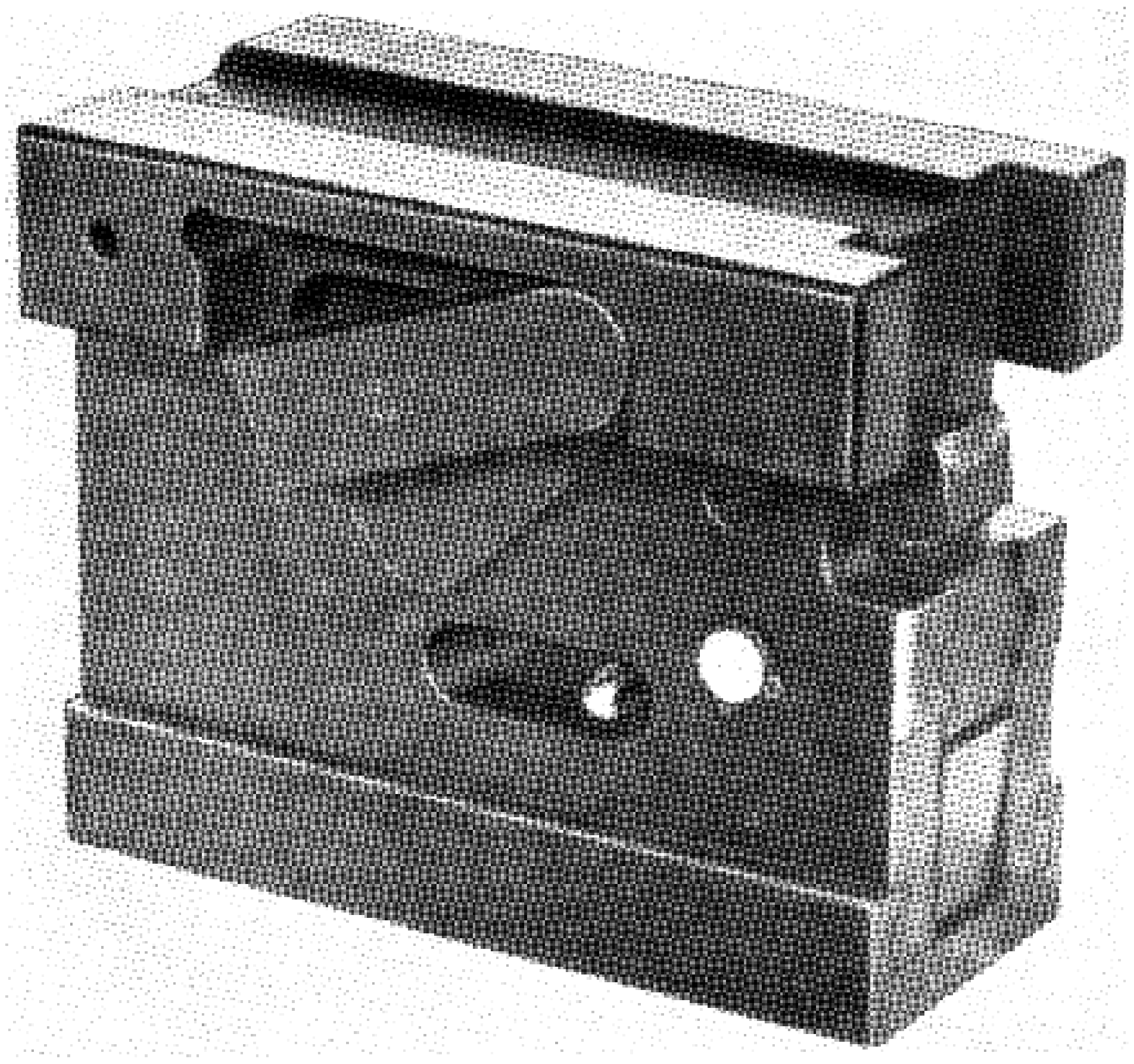

Figure 8–7. Bolt of 20-mm Gun T33E3, showing extractor.

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	...	

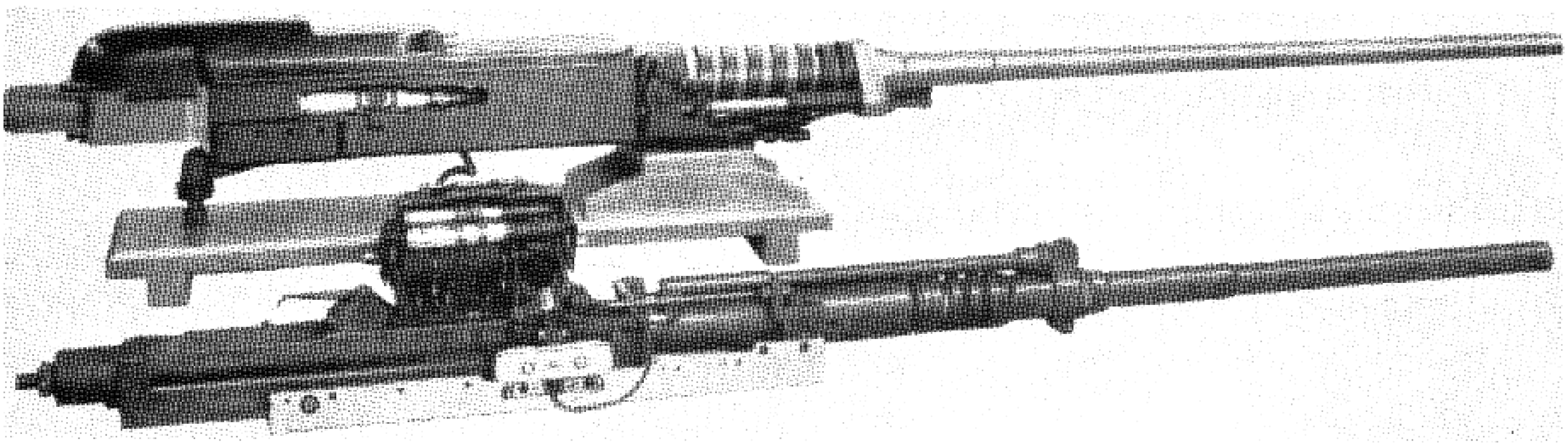

Figure 8–8. 20-mm Automatic Guns, T33 (above) and T31 (below). Right side views.

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 alinement 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

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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			
		Model A	Model B	Modified model B	Estimated potential characteristics
Gun length . . . . inches	81 17/32	81 17/32	80½	93⅛ [1]	83½.
Gun weight . . . pounds	177	177	130	158 [1]	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		

[1] 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			
		Model A	Model B	Modified model B	Estimated potential characteristics
Bore:					
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 5/16	14 7/16	14 7/16	14 7/16.
Gun height, overall (inches).		4 3/4	4 7/16	4 7/16	4 7/16.
Distance from muzzle to face of chamber (inches).		63	63	63	63.
Distance of gas orifice from breech (inches).		11 31/32	19 1/2	19 1/2	

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 29/32	7 29/32	7 29/32	
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.

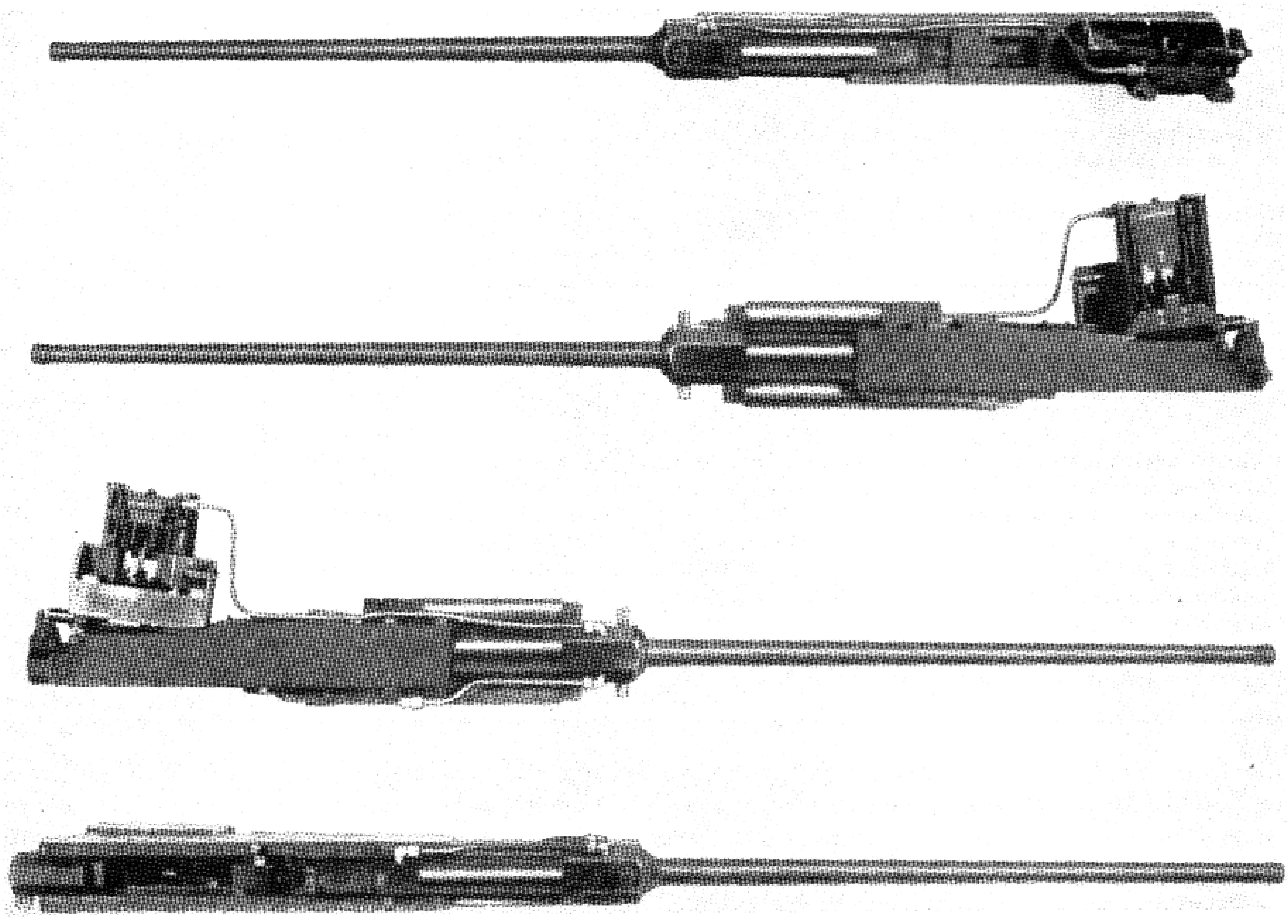

Figure 8–9. 20-mm Automatic Gun T33E3. Four views showing left side, bottom, top, and right side.

The T33E3 model A weapon was designed for mounting flat on its side to keep the height within 4¾ 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 1¾ inches minimum deflection to 3⁷⁄₁₆ 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 ¾-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 4¾ 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° 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 considered. 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 alinement 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....	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.

1 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 conjunction 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 modification 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	93⅛	84
Height . . . . . do	4¾	4 7/16	4 7/16
Width . . . . . do	Minimum	14 7/16	14 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 4¾ 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 extend 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 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 1½ inches of breech face.
2	5, 885	20	....	Bolt returned to within ¼ inch of breech face, gas piston tight in cylinder.
3	21, 000	34	64	Bolt returned to within ¼ 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 alinement 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 reproportioned. 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-

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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 interference 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 11⅛-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 1⅞-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 29½ 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 10⅝ 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 1½-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 Fabreeka pads which stop the feeder slide were badly frayed.
2. Both Fabreeka 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 11⅛-inch bolt travel and with a ramming velocity of 29½ feet per second, the bolt did not overtake the rammed round until the round was fully chambered. With the buffer adjusted for a 10⅝-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: 11⅛ inches.
- Approximate ramming velocity: 29½ feet per second.

STAGE 2:
- Weight of propellant: 840 grains.
- Battery to buffer bolt travel: 10⅝ 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 58½ 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 reduced 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.	Barrel length: 63 inches.
Gun weight: 135 pounds.	Barrel weight: 58 pounds.
Rate of fire: 750–800 rounds/minute (estimated).	Rate control: None.
Muzzle velocity: 1900 feet/second.	Barrel removal: Quick disconnect.
System of operation: Gas unlocking, blowback.	Bore:
System of locking: Swinging locks.	Number of grooves: 16.
System of feeding: Buffer actuated.	Groove depth: 0.020 inch.
Method of headspace: Factory established.	Groove width: 0.250 inch.
Location of feed opening: Right- or left-hand side of receiver.	Pitch: 9° 30′.
Location of ejection opening: Bottom of receiver.	Direction of twist: Right hand.
Method of charging: None.	Form of twist: Constant.
Method of cooling: Air.	Cartridge: Same type as German MK 108.

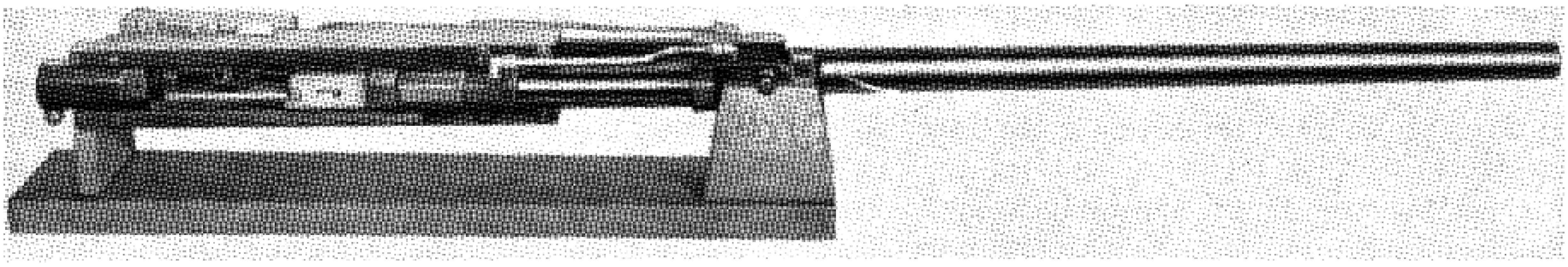

Figure 8–10. 30-mm Gun Mk 5 Mod 0. Right side view.

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 breechblock, 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 centerline 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-

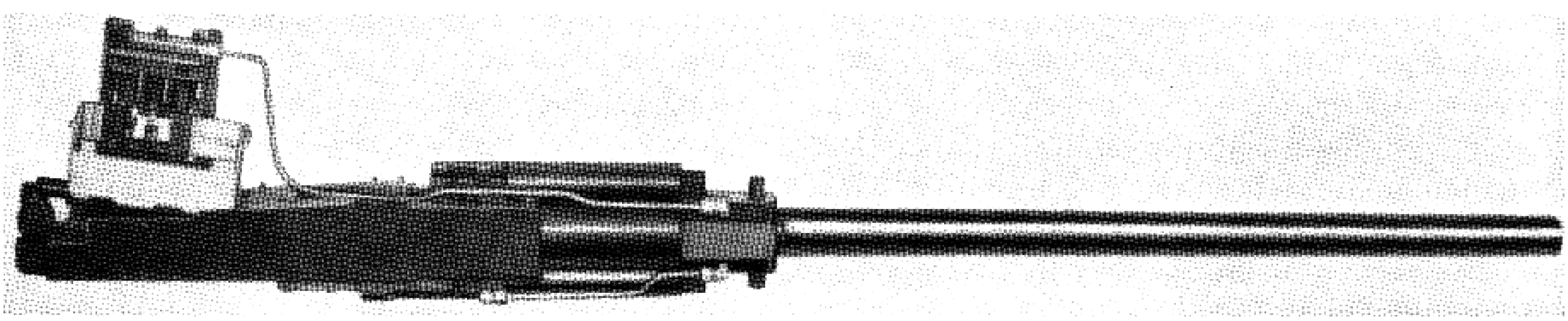

Figure 8–11. 30-mm Gun Mk 5 Mod 0. Top view.

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 nonseared 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° 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 blowback 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 1⅛ inches, the Army Air Force requested that the projectile be able to penetrate 1½ 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 2½ 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 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 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.

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: 1¼ 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 1⅛ inches of tube travel: 100 pounds.
Sear release: 35 to 40 pounds.

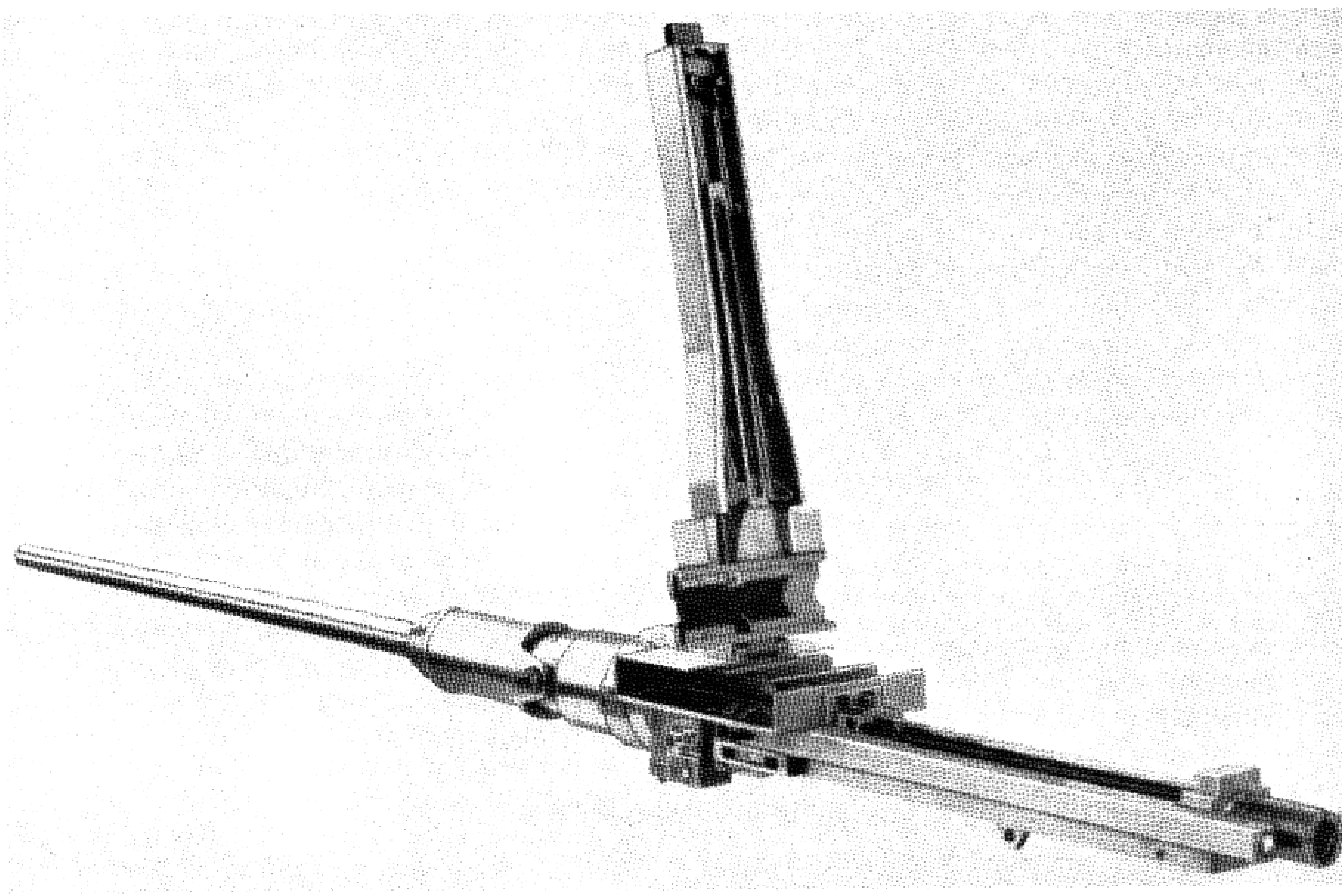

Figure 9–1. 20-mm Gun T24. Left side view with cover open.

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, bolthead, 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.

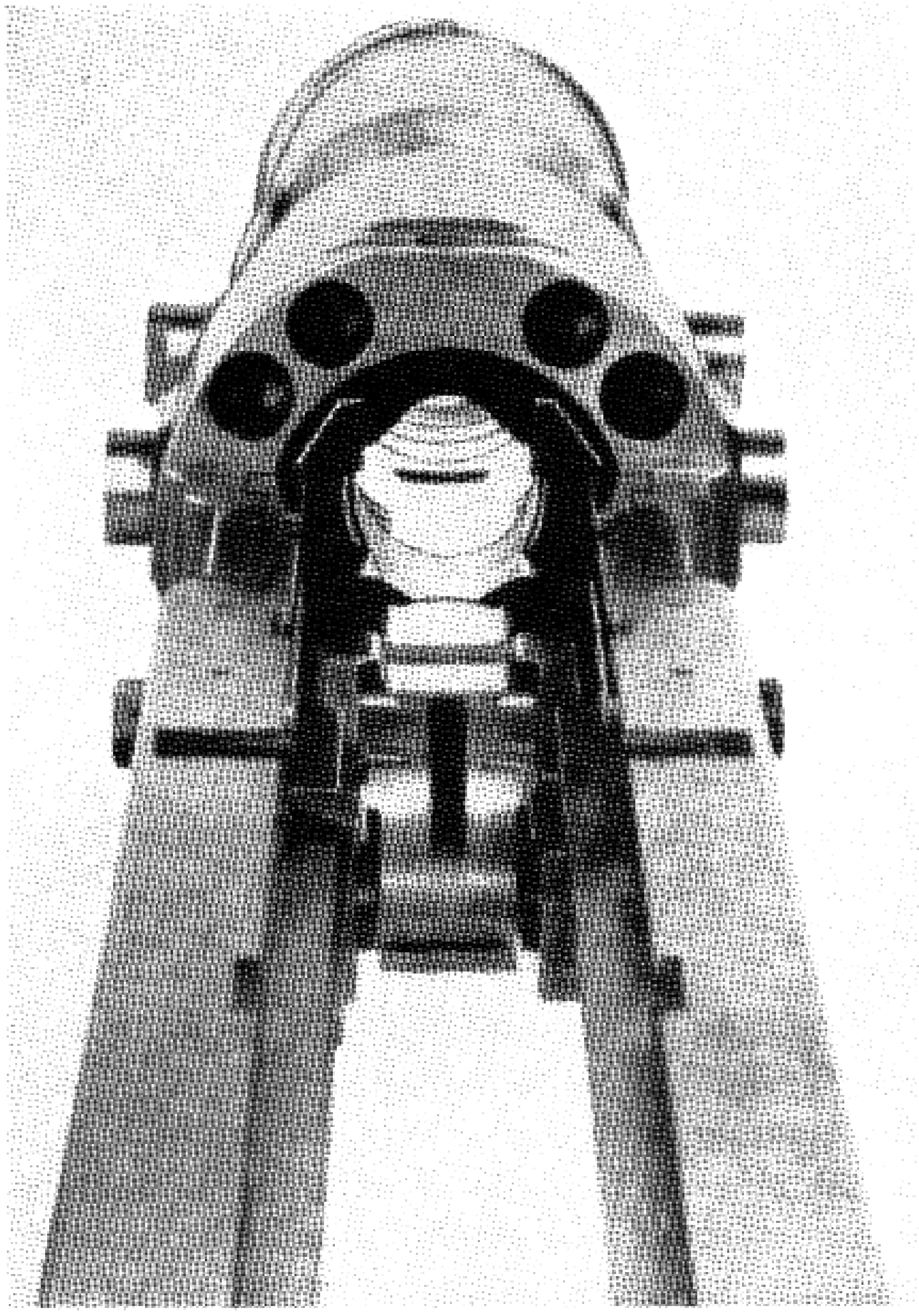

Figure 9–2. 20-mm Gun T24. Rear view with feed, cover, and tube removed.

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 recesses 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 alinement.

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-

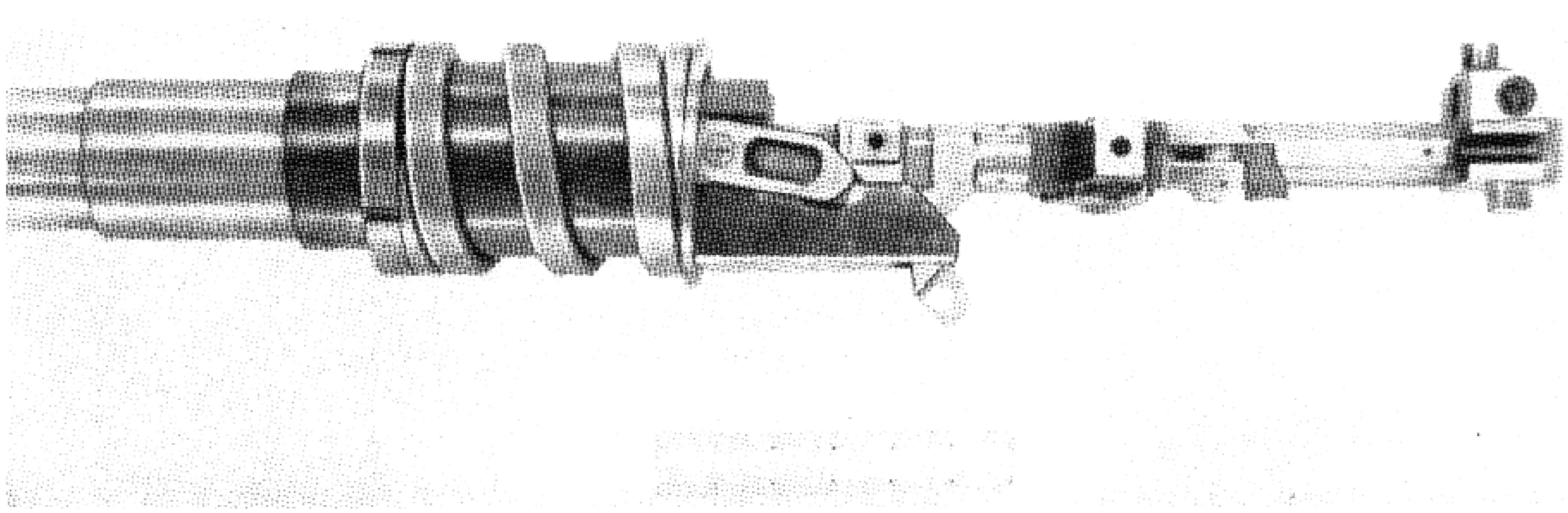

Figure 9–3. 20-mm Gun T24. View showing bolt engaging lock cut in tube extension.

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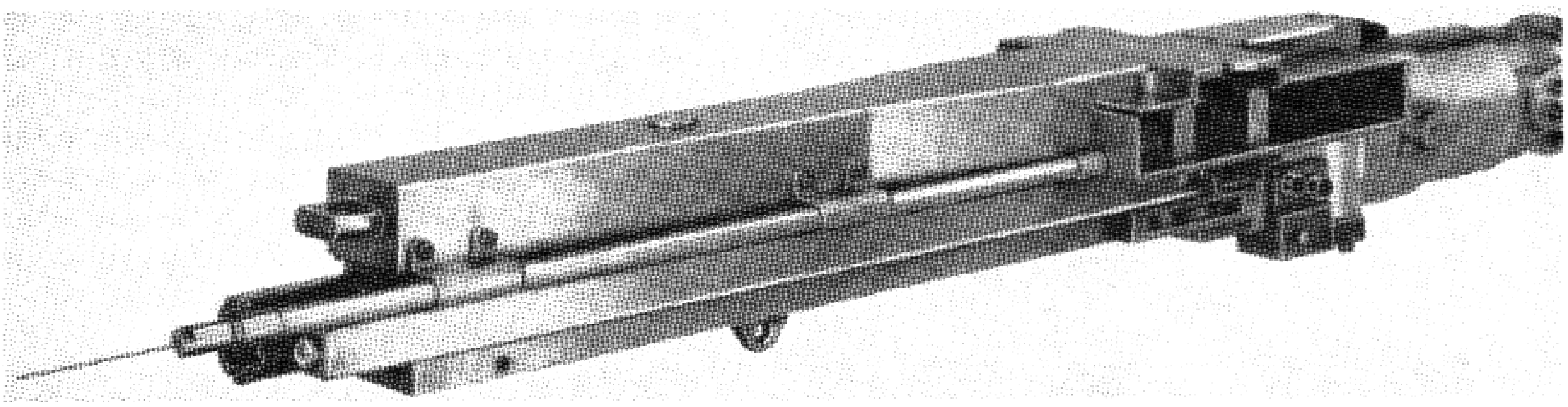

Figure 9–4. 20-mm Gun T24. View showing manual charger.

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.

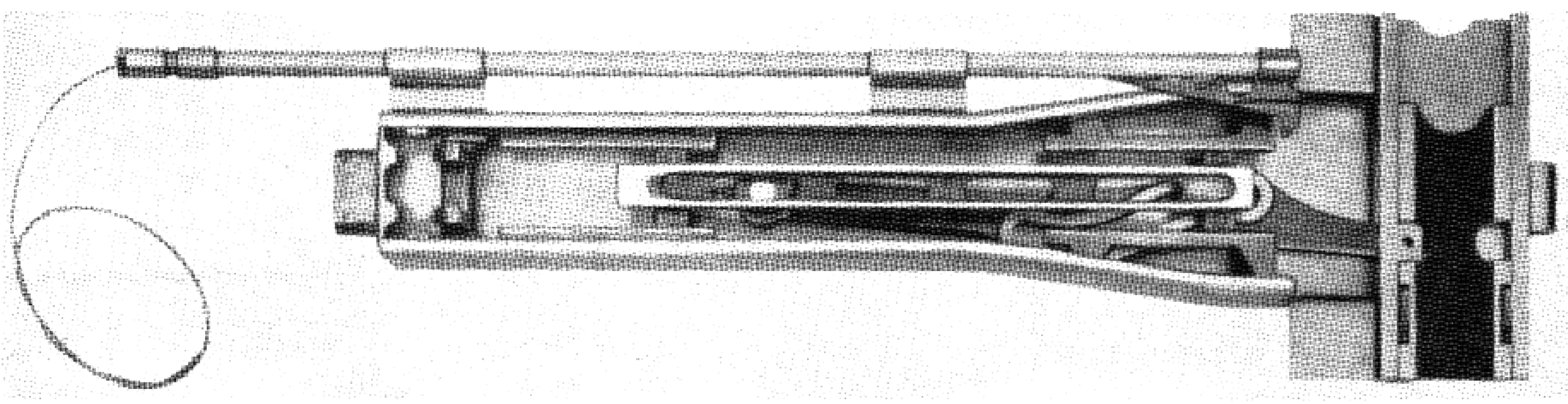

Figure 9–5. 20-mm Gun T24. View of cover from below showing mounting of charger.

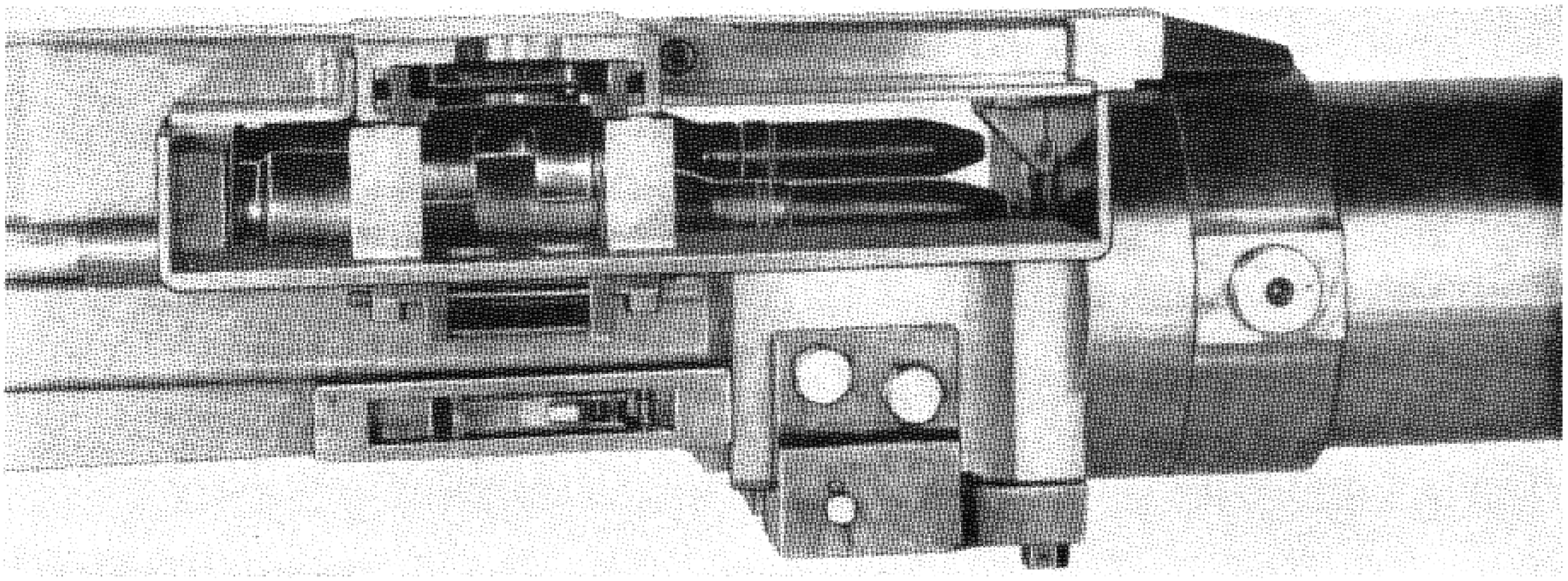

Figure 9–6. 20-mm Gun T24. Closeup view of cartridges in feedway.

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 ears 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 the cartridge case ejector. The action of closing the cover holds the feedway securely in position.

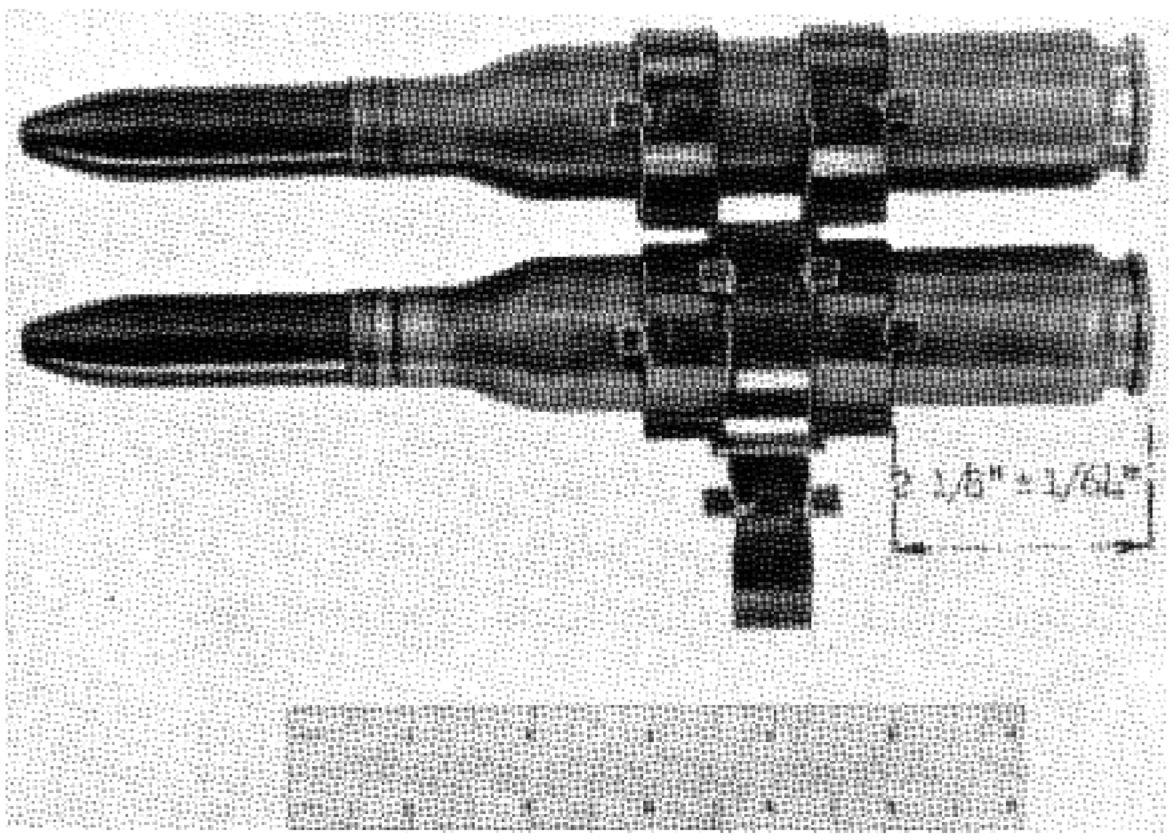

Figure 9–7. 20-mm Gun T24. Cartridges and links.

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.

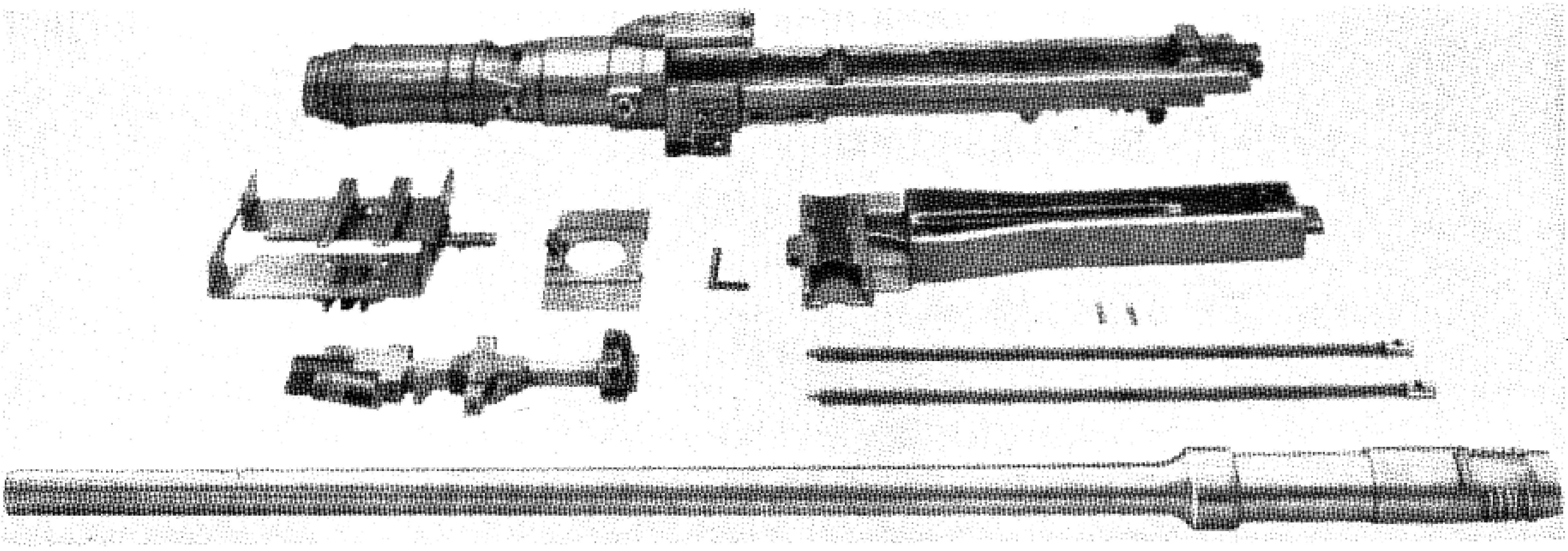

Figure 9–8. 20-mm Gun T24. Subassemblies.

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

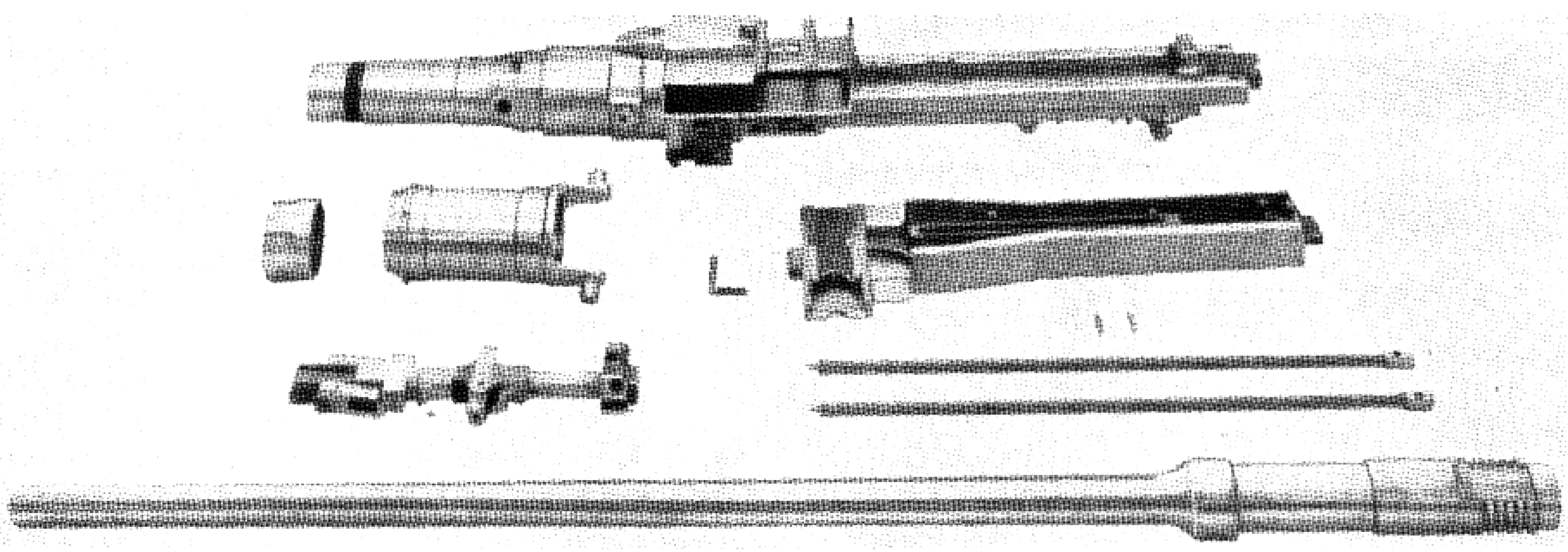

Figure 9–9. 20-mm Gun T24. Subassemblies showing adaptor removed.

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°, 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.

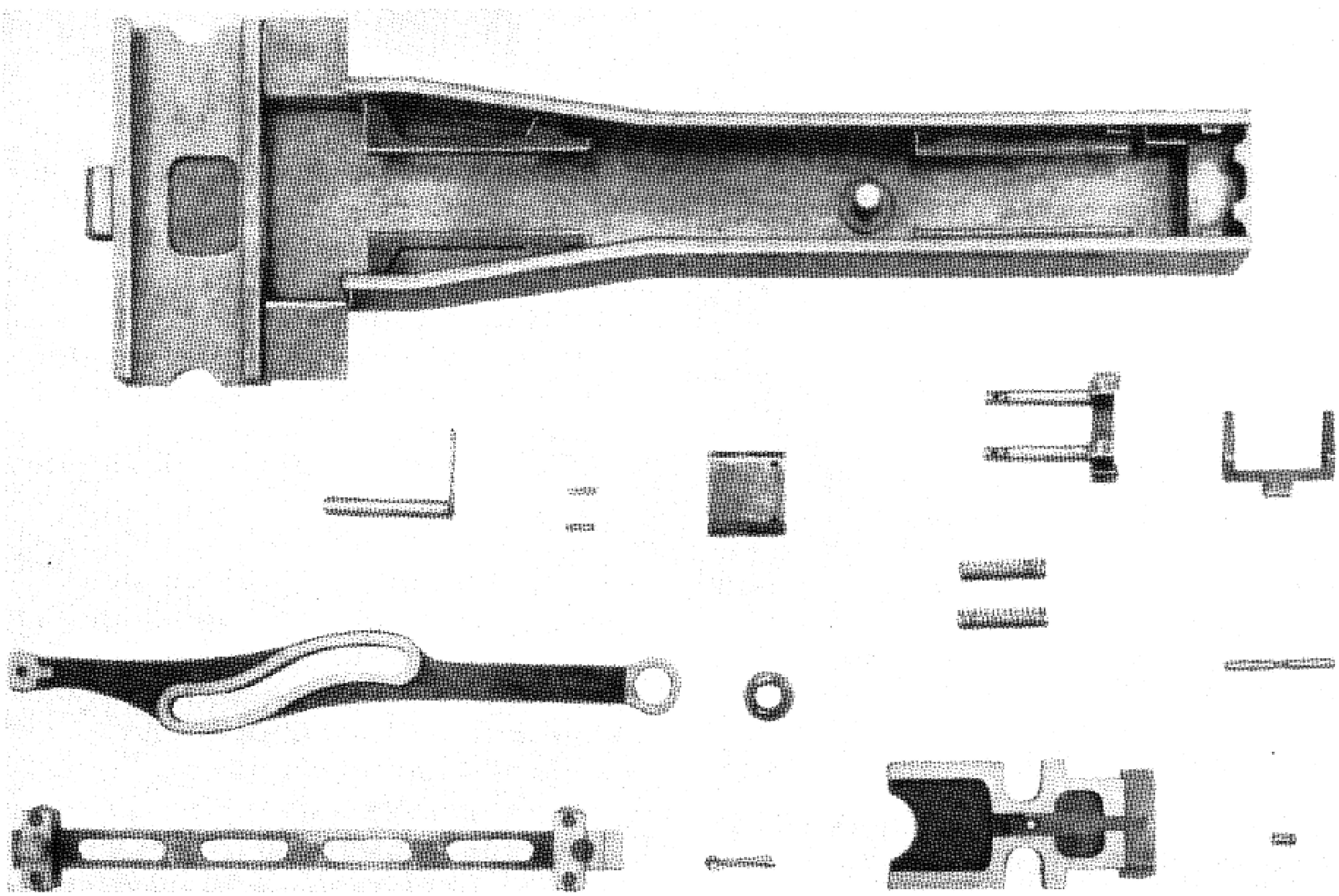

Figure 9–10. 20-mm Gun T24. Components of cover group.

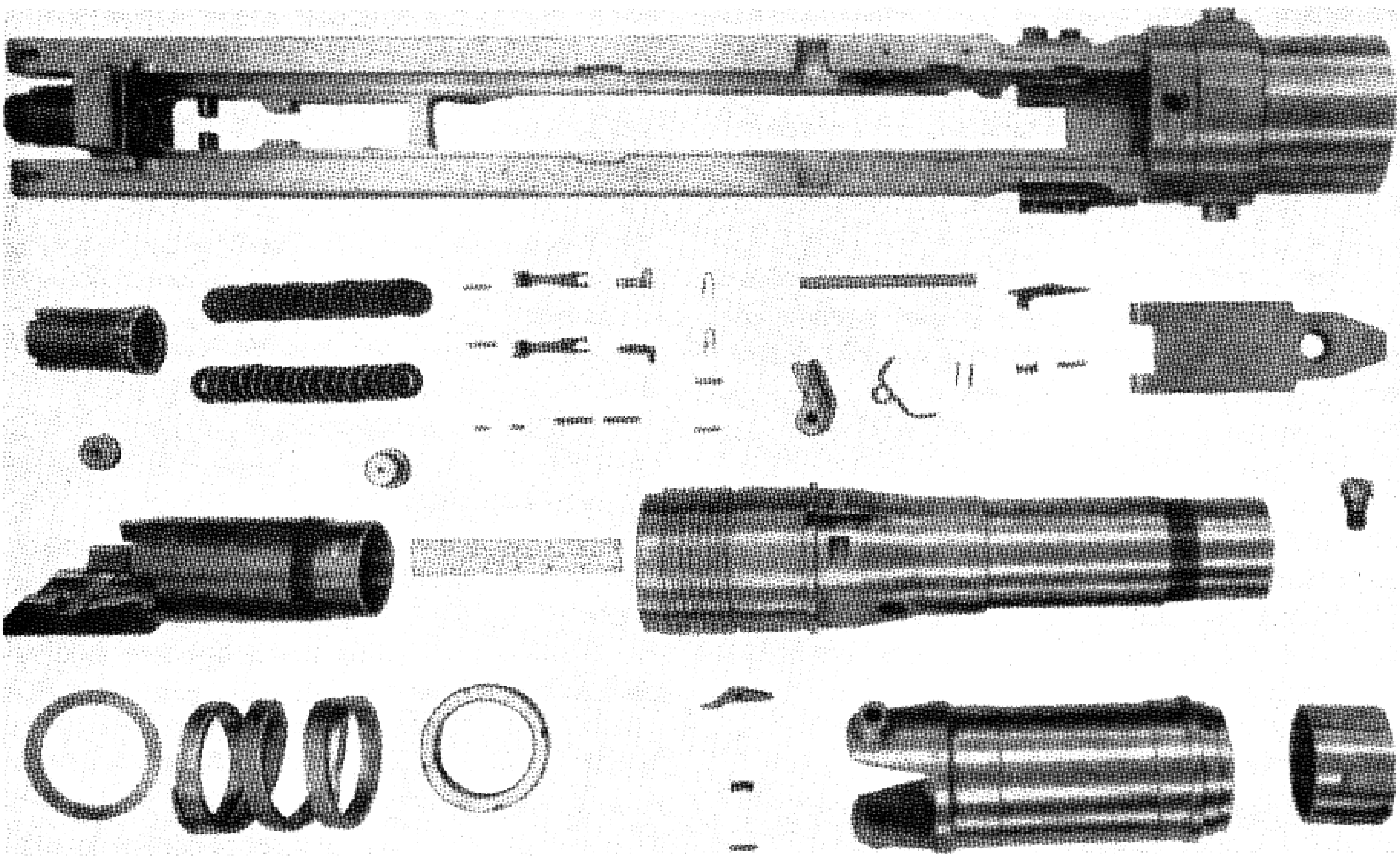

Figure 9–11. 20-mm Gun T24. Components of receiver group.

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

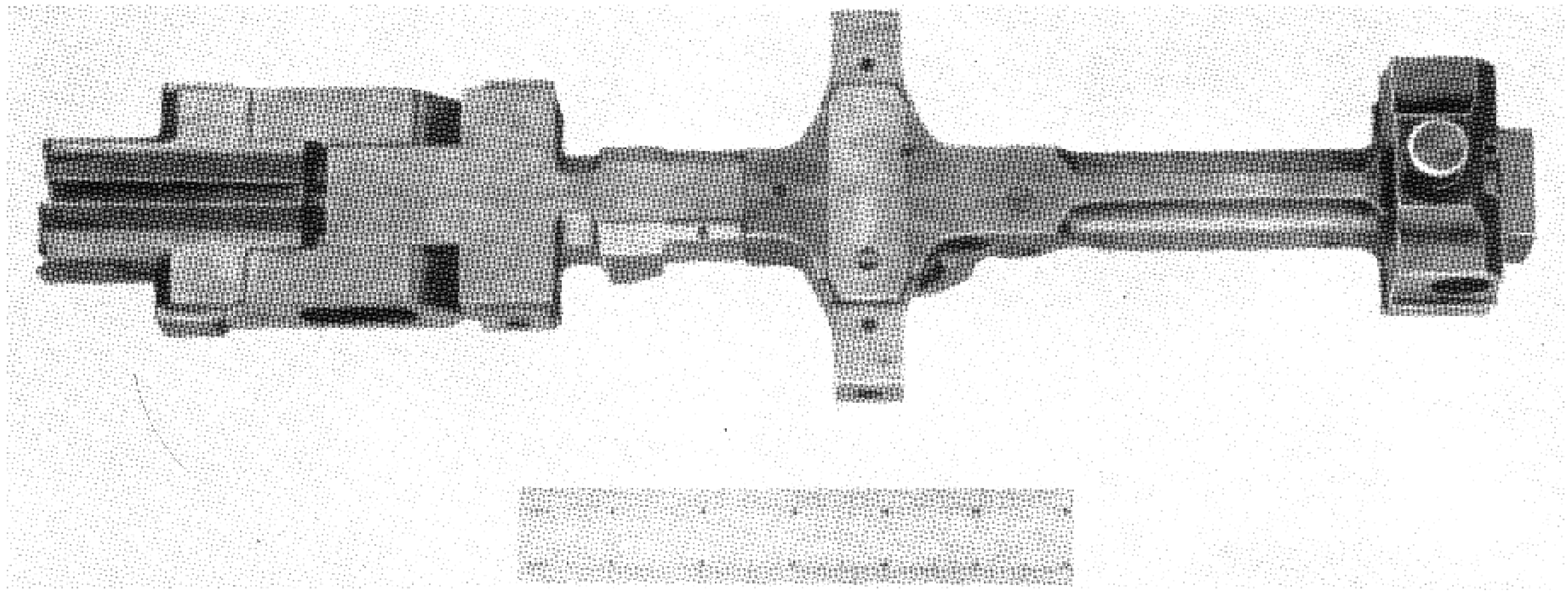

Figure 9–12. 20-mm Gun T24. Top view of bolt.

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.

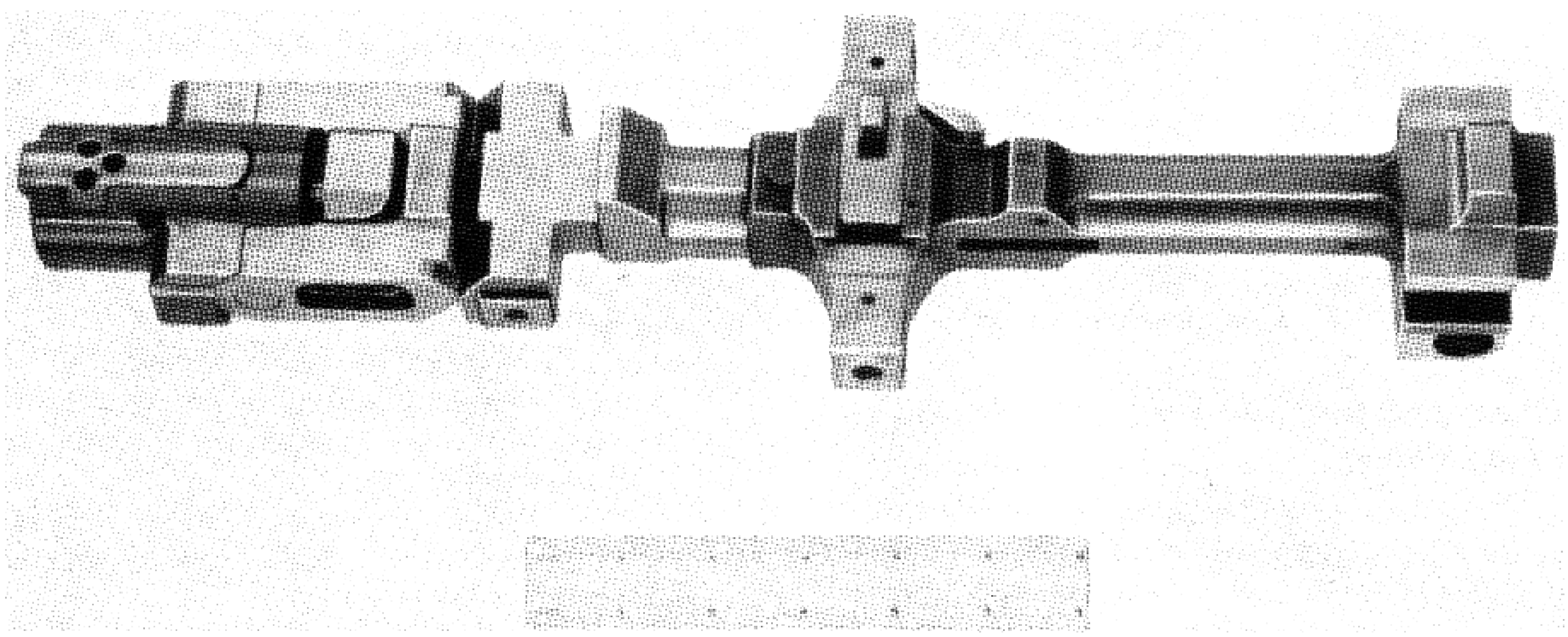

Figure 9–13. 20-mm Gun T24. Bottom view of bolt.

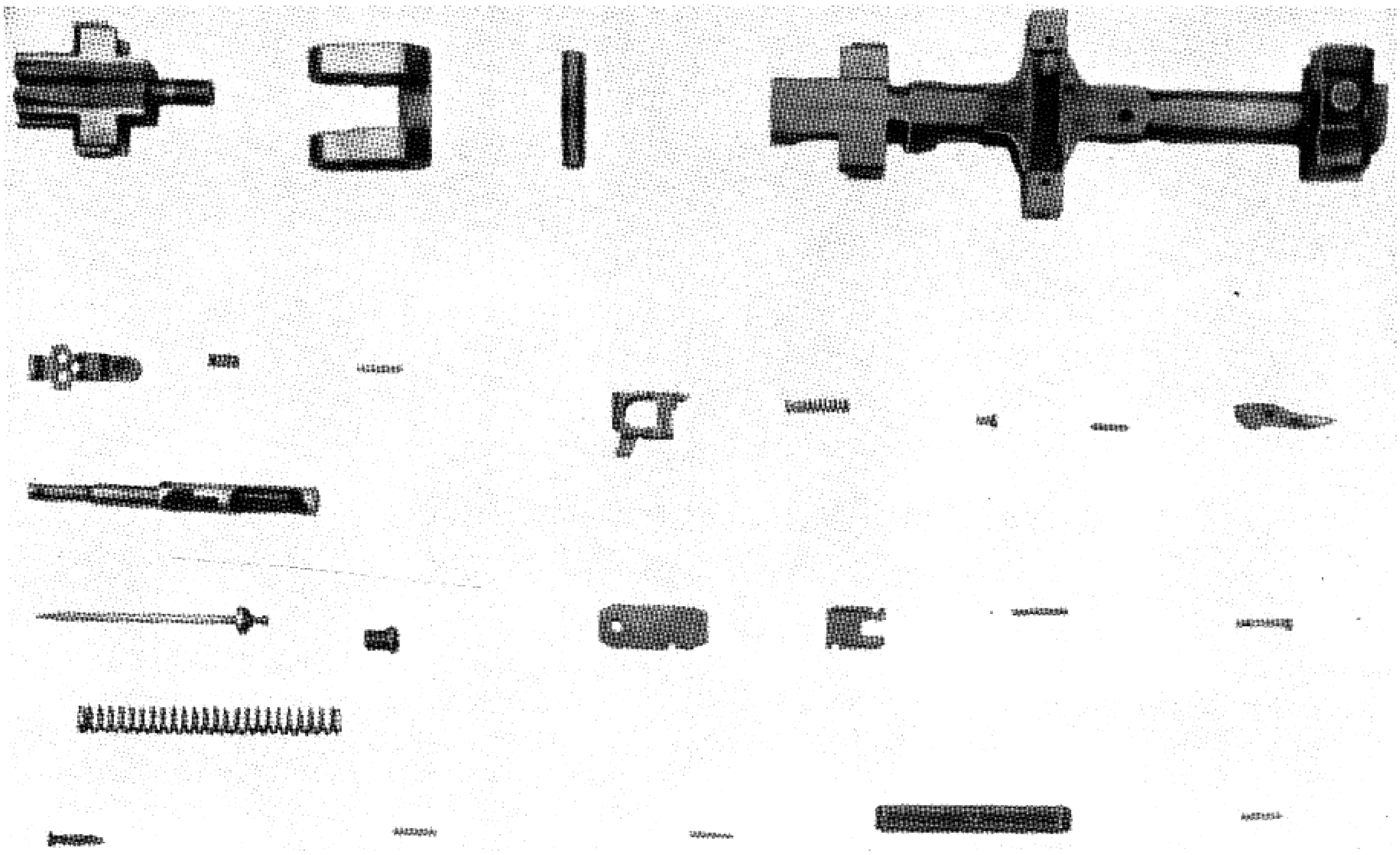

Figure 9–14. 20-mm Gun T24. Components of bolt.

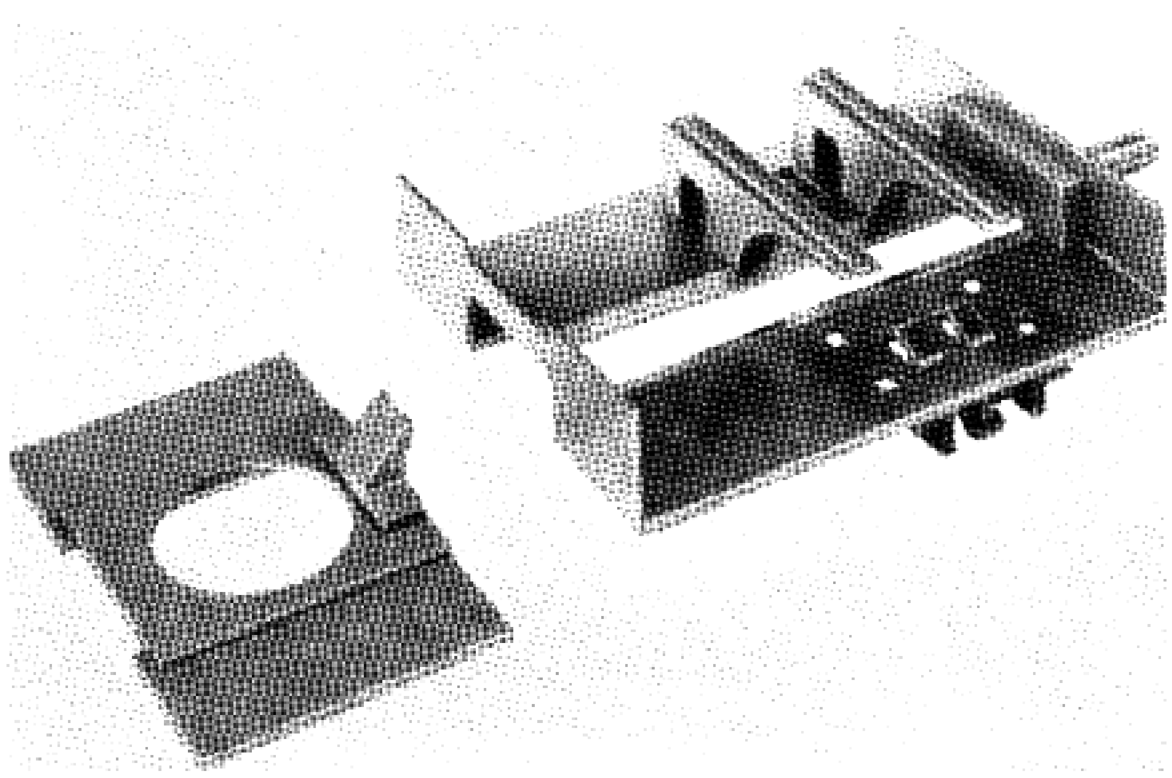

Figure 9–15. 20-mm Gun T24. Feedway.

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.

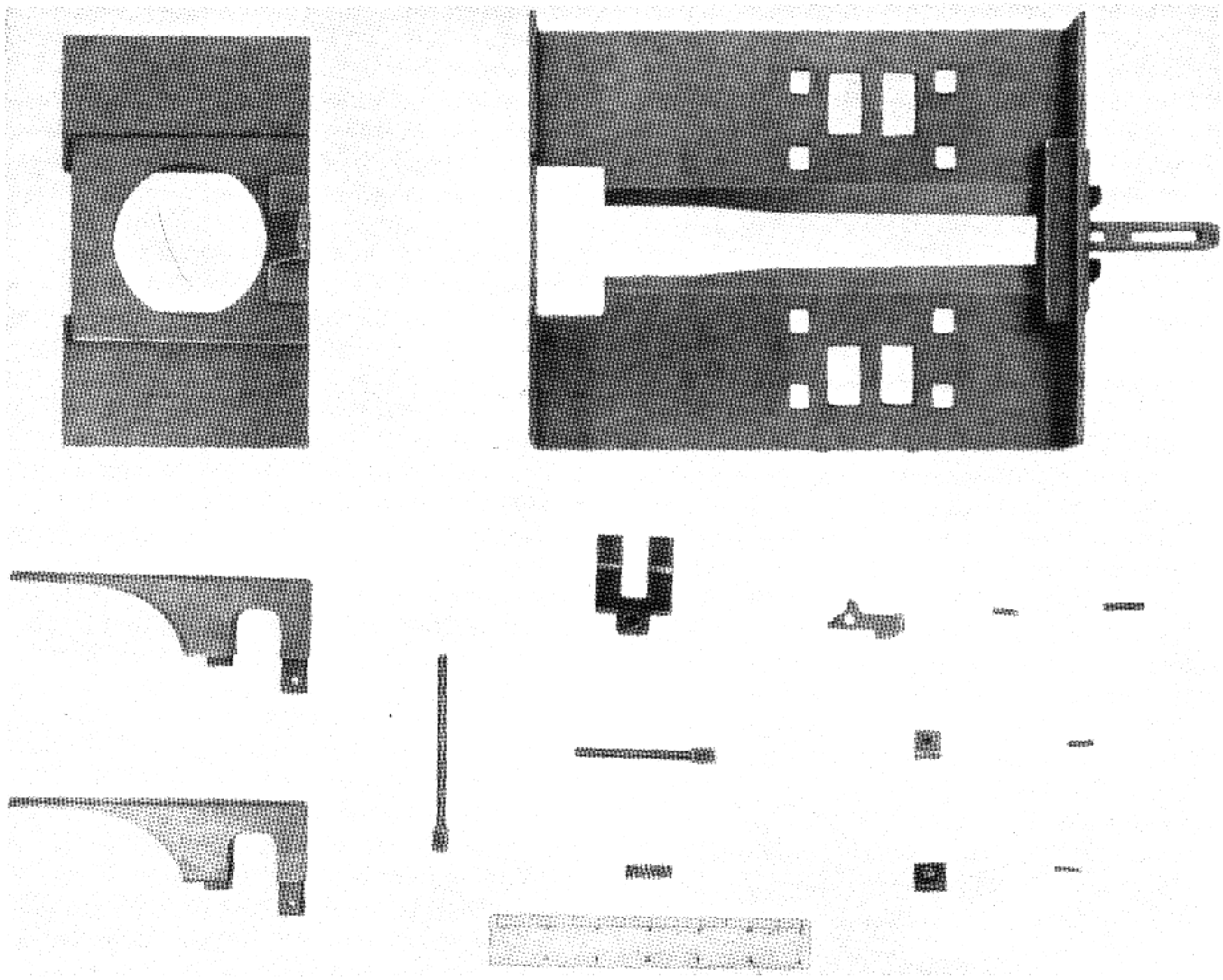

Figure 9–16. 20-mm Gun T24. Components of feedway.

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" dimension 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. (⅛-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 ¼-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 1⅜ 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 forming 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 occuring 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

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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 cone. 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 experimental 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 considerable 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 progress. 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

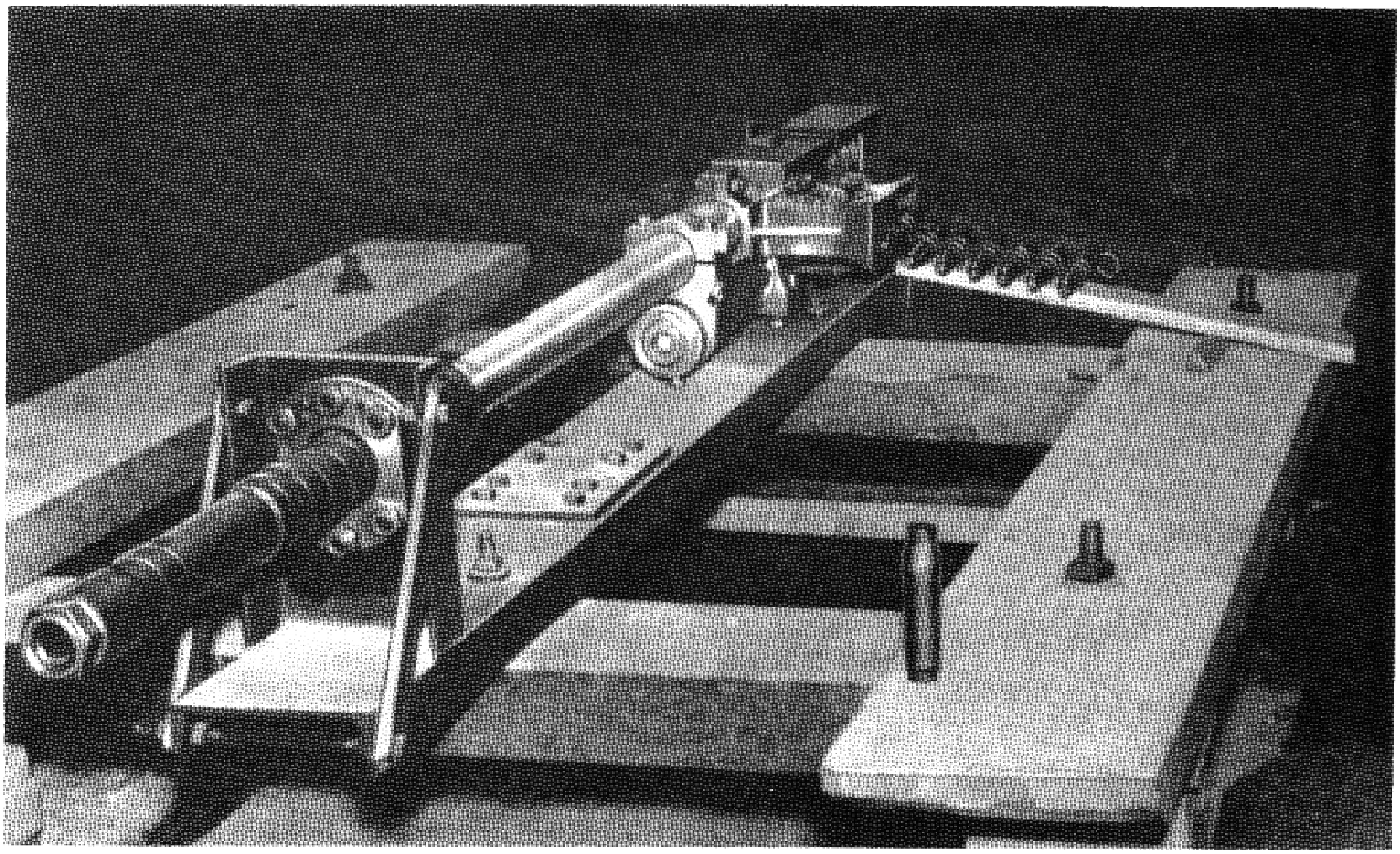

Figure 10–3. The 20-mm Johnson Automatic Cannon mounted on a test stand firing Oerlikon ammunition.

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-

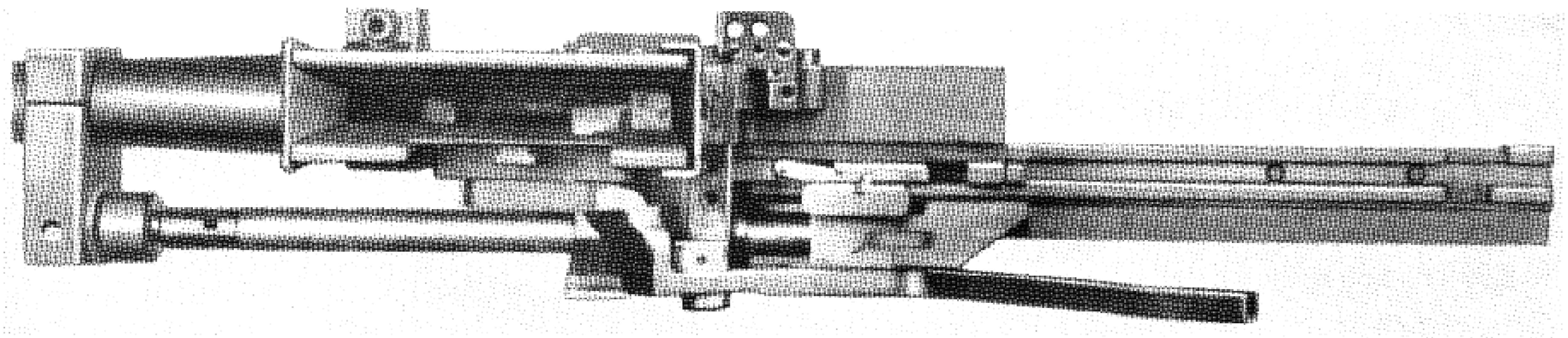

Figure 10–4. Mechanism of the 20-mm Johnson gun in its developmental stage. Left side view.

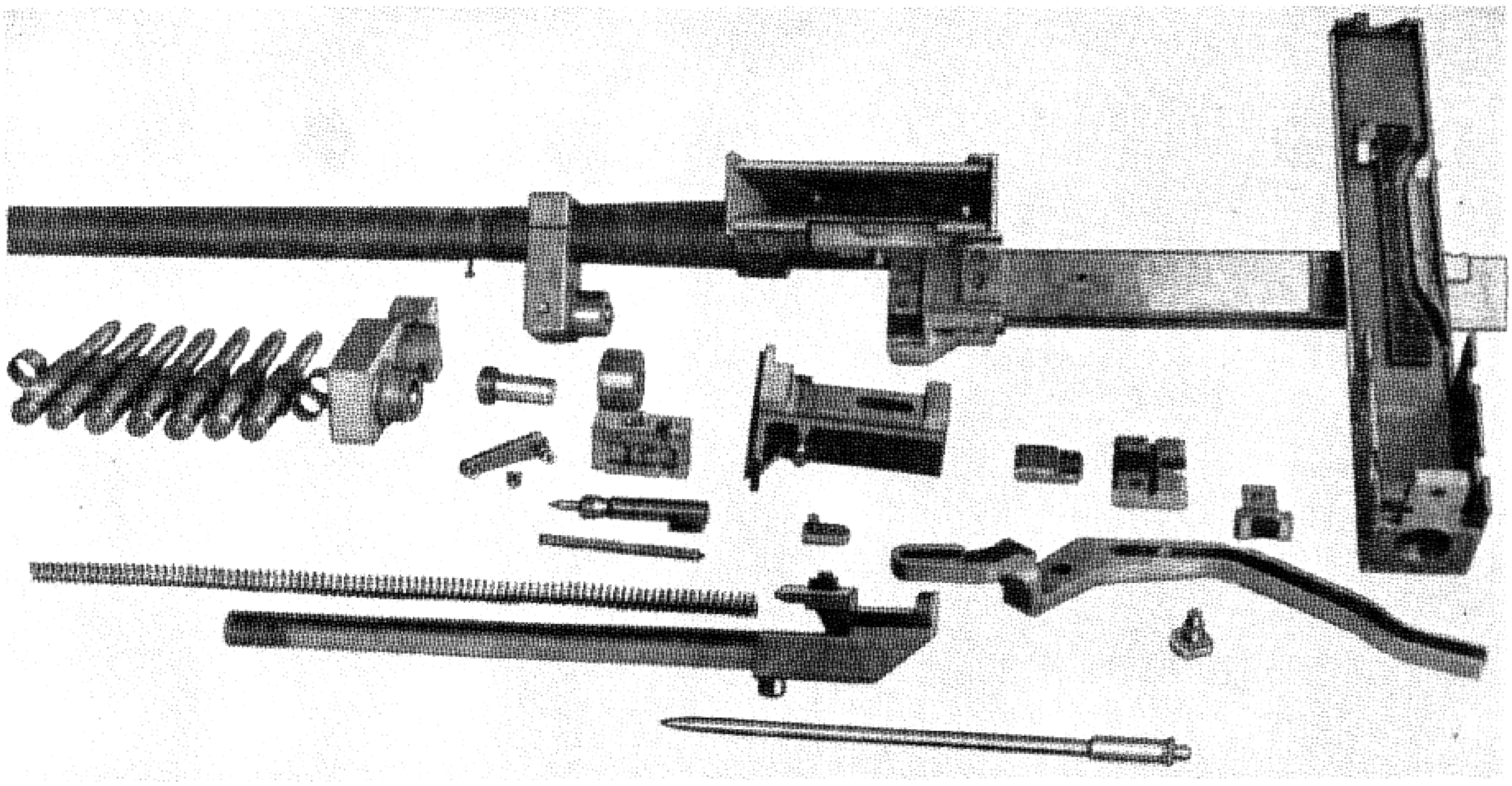

Figure 10–5. An early version of the 20-mm Johnson gun, disassembled.

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.

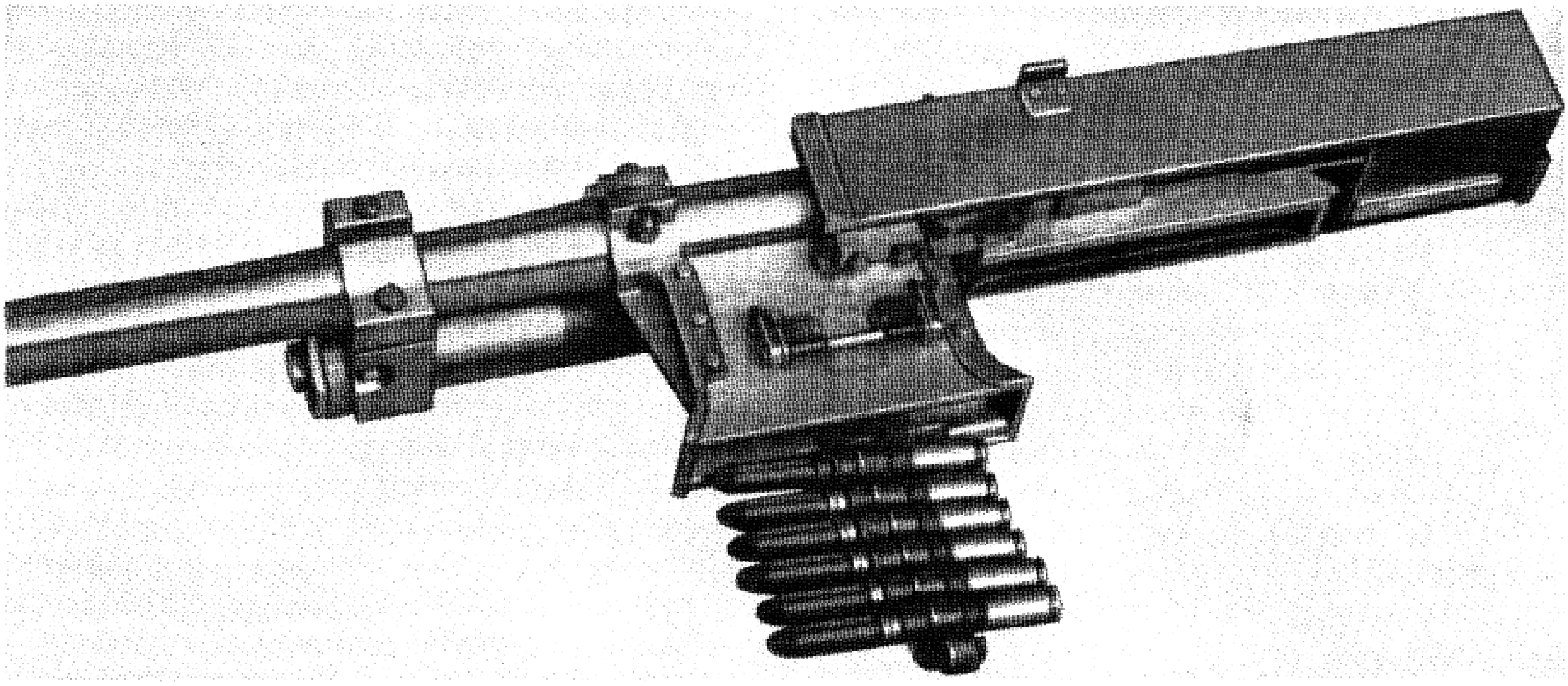

Figure 10–6. Later version of the Johnson gun EX 2. Left view from above.

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 breechblock assembly through a lateral dovetailed slot in the front face of the breechblock, alines 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° 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° 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 bleechblock. 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 cammed 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 toolroom 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)

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.	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).

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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 porthole 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 alined 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

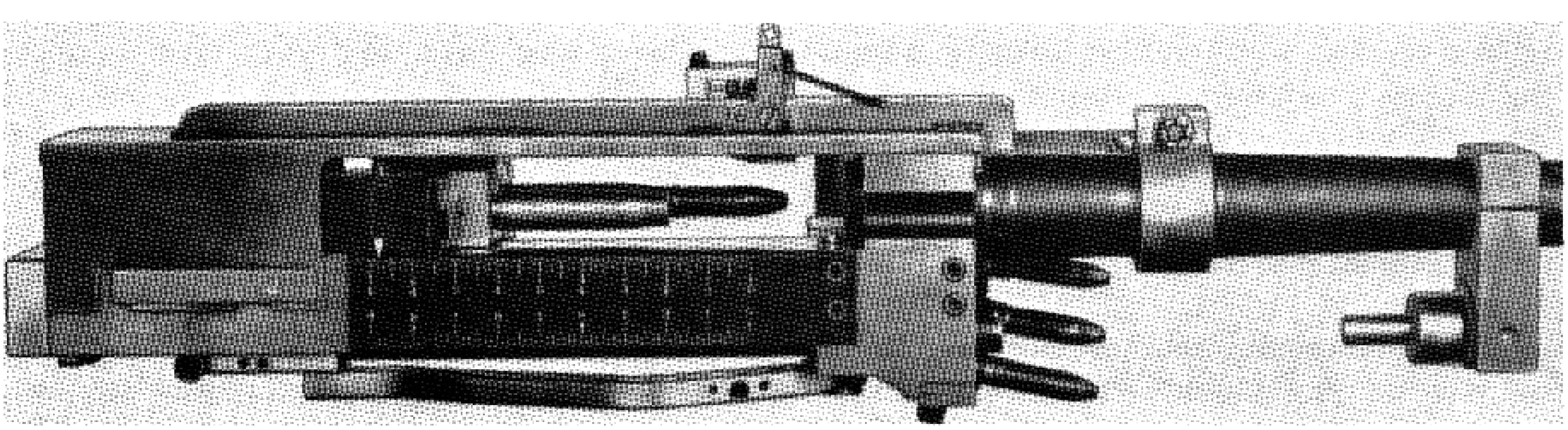


Figure 10–7. Development of the Johnson gun. Bolt recoil measured.

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°, 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 eases 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° 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.

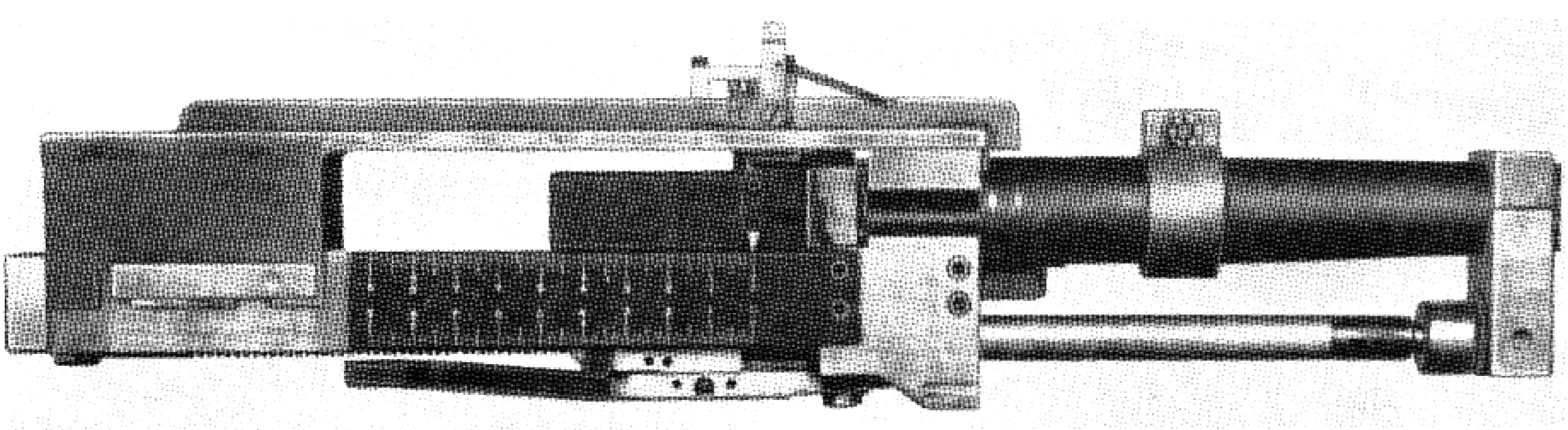


Figure 10–8. Test set to measure bolt recoil. The 20-mm Johnson gun is under test.

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.

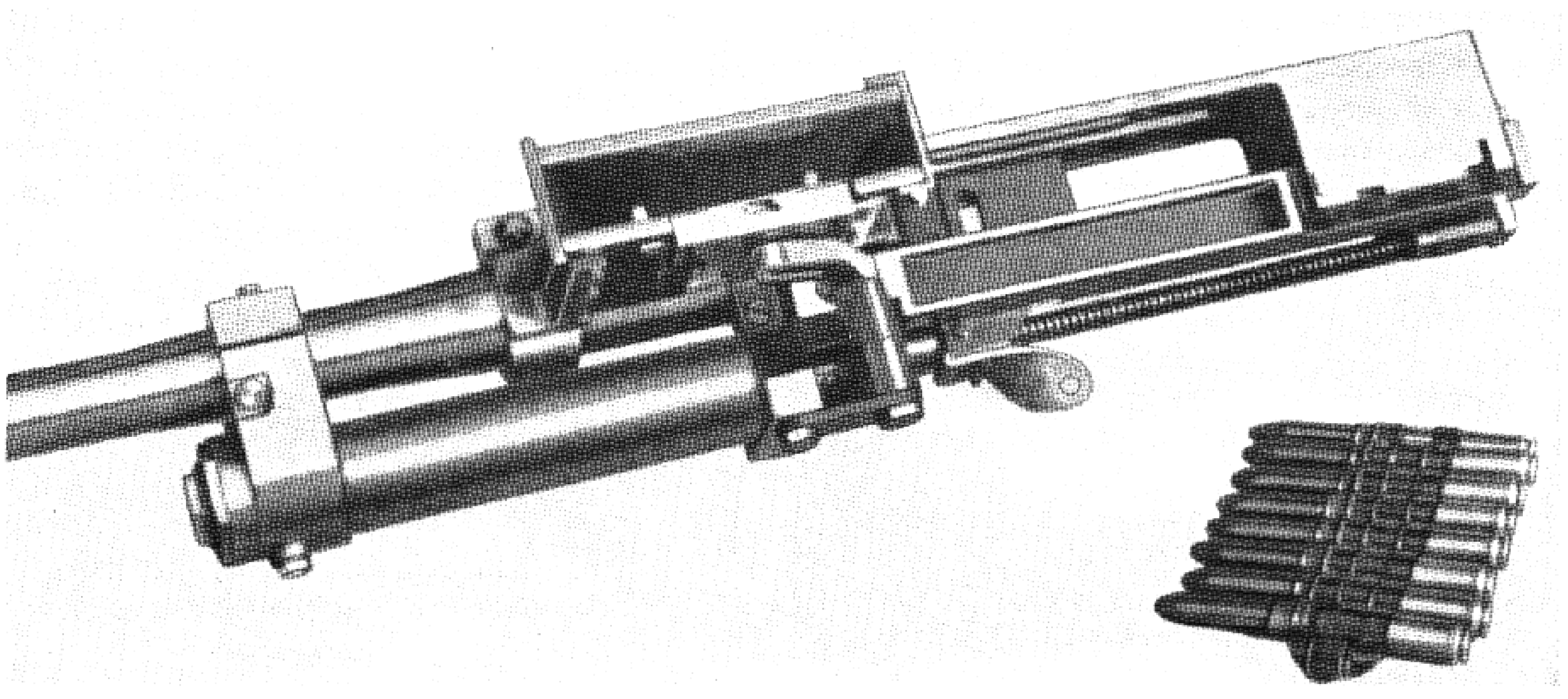


Figure 10–9. Johnson gun EX 2. Left view from below.

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 blowback.

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.

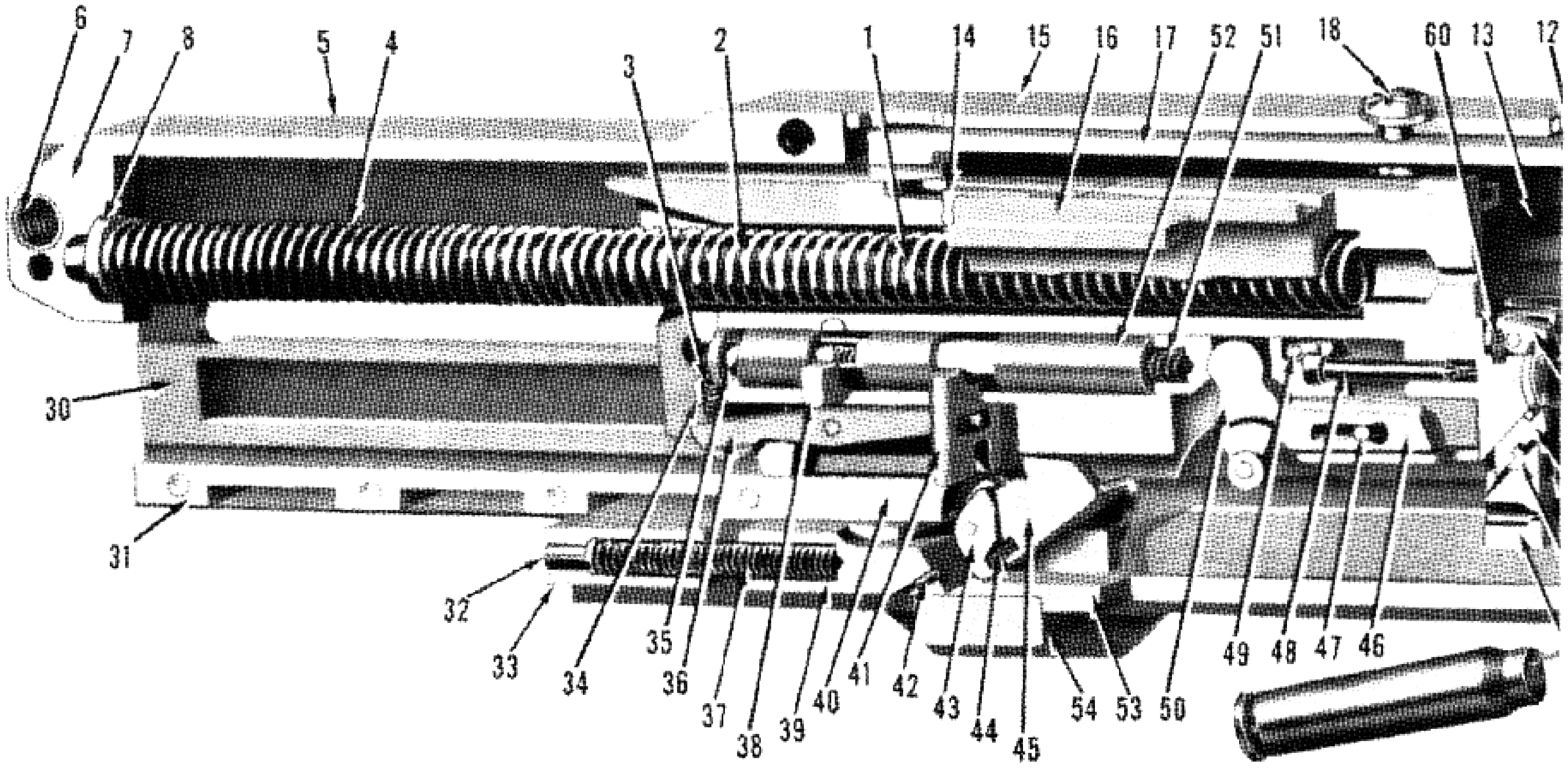
Locking. As the breechblock closes, a spur on the breechblock contacts the forward end of the lock, disengaging the lock from the detent in the platform and thus releasing the platform so that it can move forward under the impulse of the platform spring, thereby exerting a strong locking or lifting pressure 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

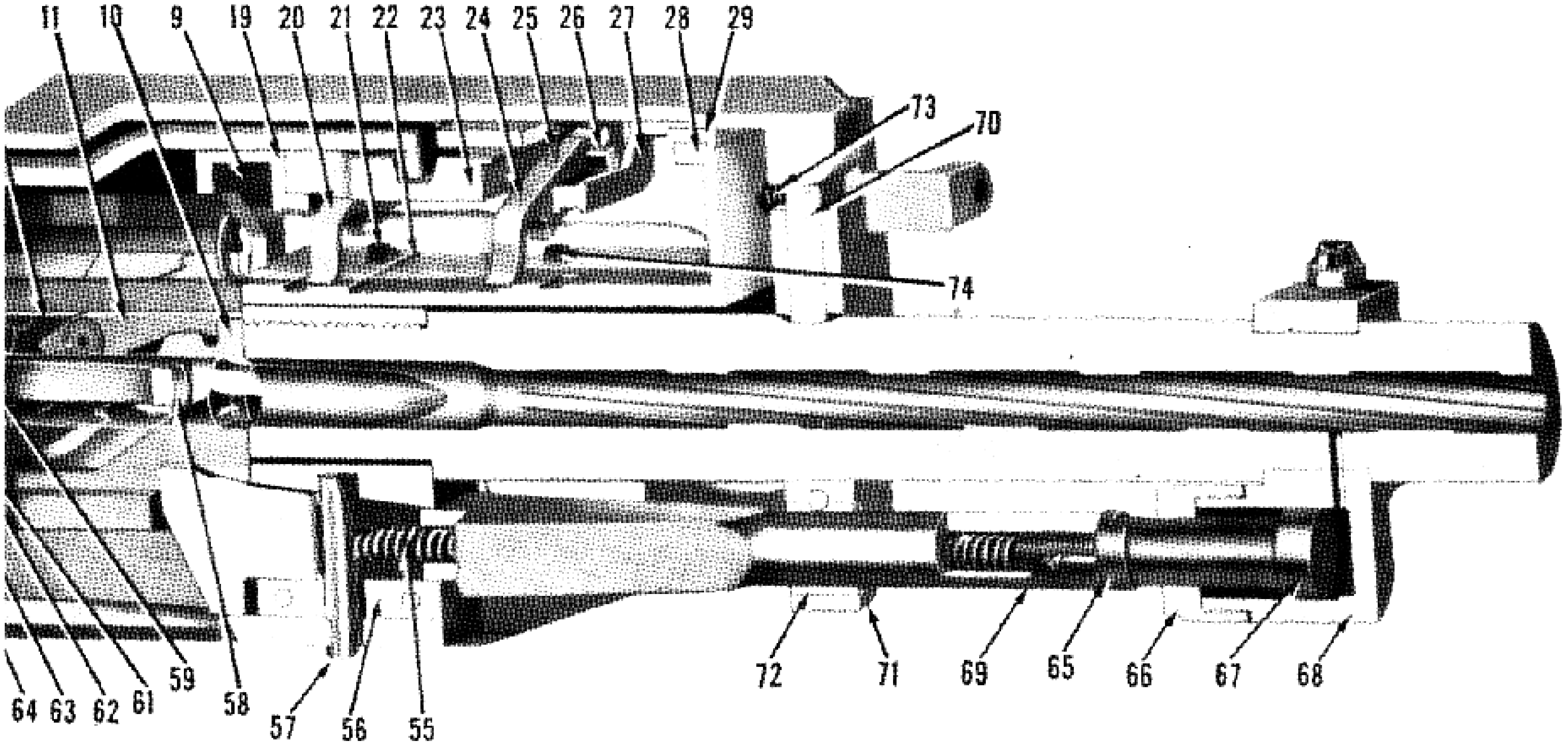
During the summer of 1945 the Johnson organization commenced to design the fourth model, in which the weights of the parts were radically reduced. The fourth model was designed with the same fundamental mechanism as previous models, but full advantage was taken from all the lessons learned in the previous two firing models. It was



1 MAIN SPRING PILOT NOSE
2 MAIN DRIVE SPRING PILOT
3 AUTOMATIC SEAR LEVER SPRING
4 MAIN DRIVE SPRING
5 TOP COVER PLATE
6 REAR RETAINER PLATE SPRING
7 REAR RETAINER PLATE
8 PILOT GUIDE PLUG
9 BACK PLATE
10 CAM TRACK, LOWER
11 CAM FOLLOWER, SWITCH, FRONT
12 CAM TRACK, MIDDLE
13 CAM TRACK, UPPER
14 FEED CAM SWITCH BLOCK
15 COVER
16 BREECH BLOCK
17 FEED LEVER
18 FEED LEVER PIVOT PIN
19 REAR GIB
20 REAR PAWL
21 BACK STOP, KEFT REAR
22 BOTTOM PLATE
23 SLIDE
24 FRONT PAWL
25 PAWL SPRING
26 PAWL SHAFT
27 FRONT GIB
28 FRONT PLATE
29 TOP PLATE
30 RECEIVER PLATE, L.H.
31 REAR BOTTOM PLATE
32 PLATFORM SPRING GUIDE
33 PLATFORM STOP BLOCK
34 FIRING PIN SPRING LOCK PLATE
35 FIRING PIN SPRING GUIDE
36 AUTOMATIC SEAR LEVER
37 PLATFORM SPRING
38 MANUAL SEAR

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 German 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
40 LOCK THRUST KEY
41 AUTOMATIC SEAR
42 LOCK STOP PIN
43 RELEASE LEVER
44 RELEASE LEVER SPRING
45 LOCK
46 COCKING SLIDE
47 COCKING SLIDE SPRING
48 FIRING PIN
49 FIRING PIN LATCH
50 COCKING LEVER
51 FIRING PIN SPRING
52 FIRING PIN BODY
53 FRONT BOTTOM PLATE
54 LOCK SUPPORT KEY
55 GAS ROD SPRING
56 BARREL BLOCK
57 GAS ROD SPRING PIN
58 GRIPPER ARM, L.H.
59 EXTRACTOR
60 EXTRACTOR SPRING
61 ANGULAR ROUND CONTROL PIN
62 EJECTOR
63 VERTICAL CONTROL PIN
64 BREECH SLIDE
65 GAS ROD PLUG
66 GAS CYLINDER CAP
67 GAS PISTON
68 GAS CYLINDER
69 GAS ROD
70 BARREL LOCK
71 FRONT SUPPORT
72 BUSHING
73 TRAY POSITIONING SPRING
74 BACK STOP, LEFT FRONT

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 ¾-inch armorplate 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 backplate.)
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	...	(1)	...
Mar. 18, 1943	T22E2	3,700	1,219	43	7
Aug. 3, 1943	T22E4	5,000	1,108	36	2
Oct. 11, 1943	T22E5	...	(2)	...	...

[1] Broken sear ruined bolt.
[2] 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 9/16-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 1½ 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.

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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.

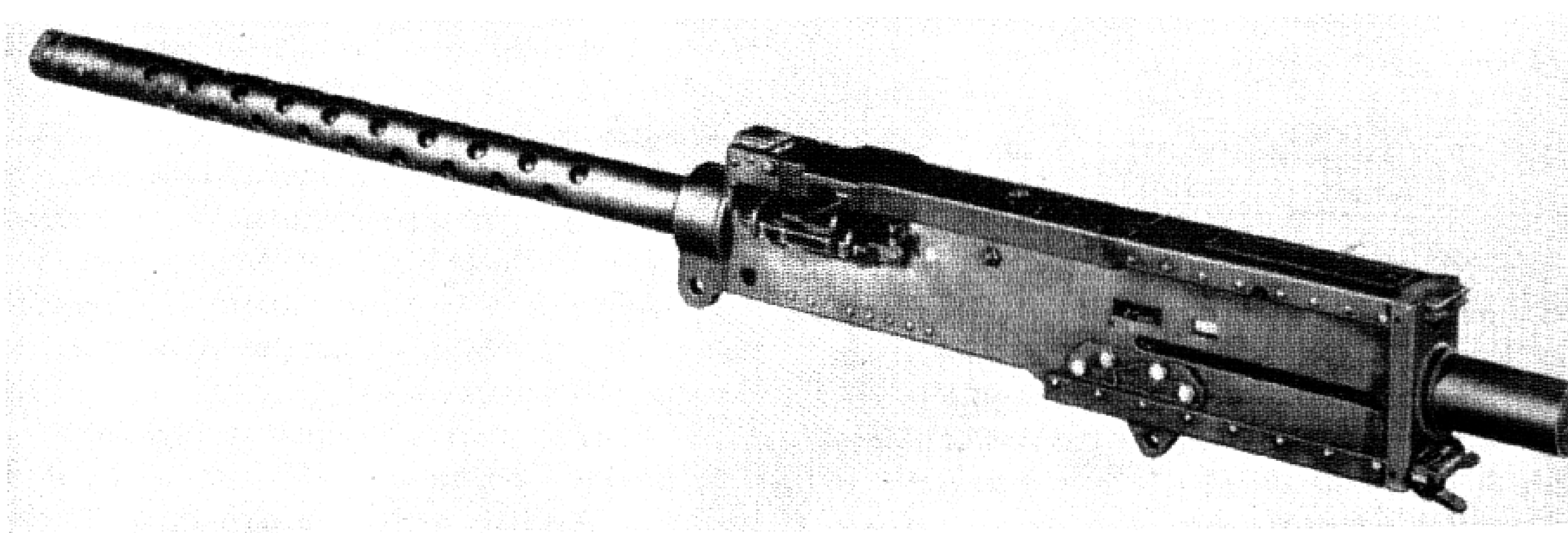

Figure 11–1. Browning Machine Gun, Caliber .50, T25. Left side view.

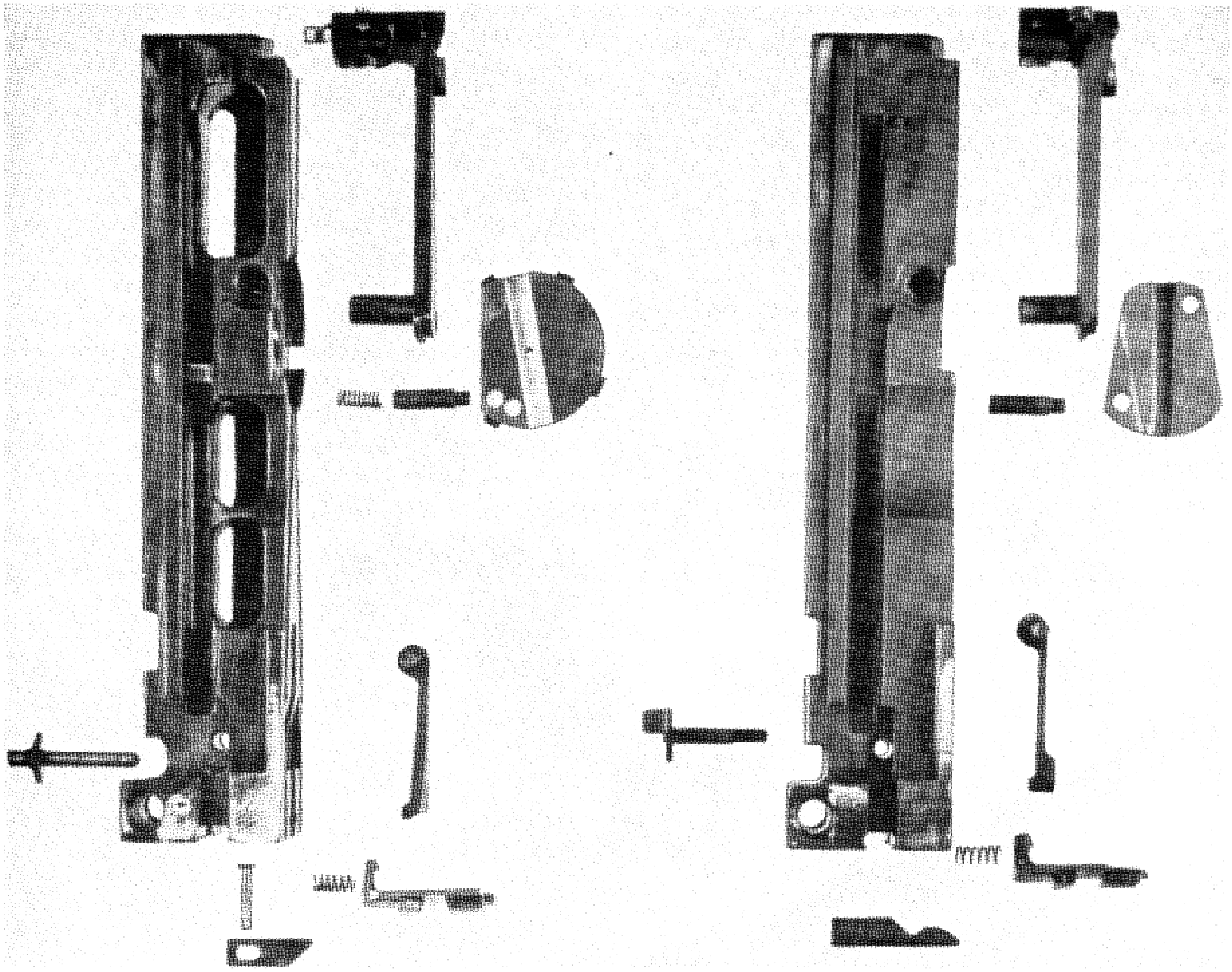

Figure 11–2. Comparison of bolt components for Browning Caliber .50 machine guns. Parts for the M2 bolt assembly are shown at right, and corresponding parts for T25E1, at left.

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	Breakages
T25E3......	5, 000	1, 250	2	2
T25E3......	5, 000	1, 285	8	0
T25E3......	5, 000	[1] 1, 195	5	1

[1] 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.

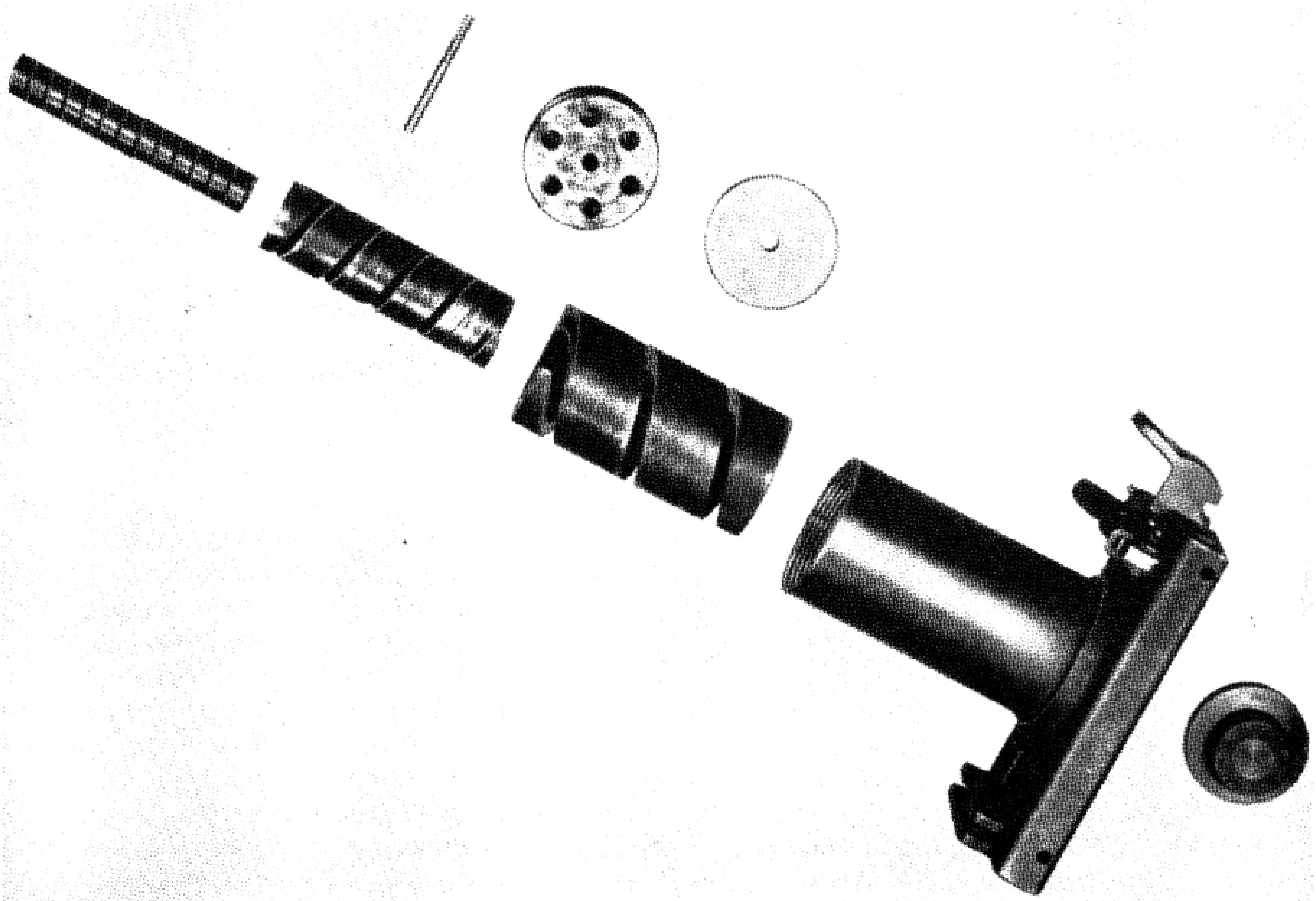

Figure 11-3. Backplate of T25 high-speed machine gun. View showing three nesting buffer springs.

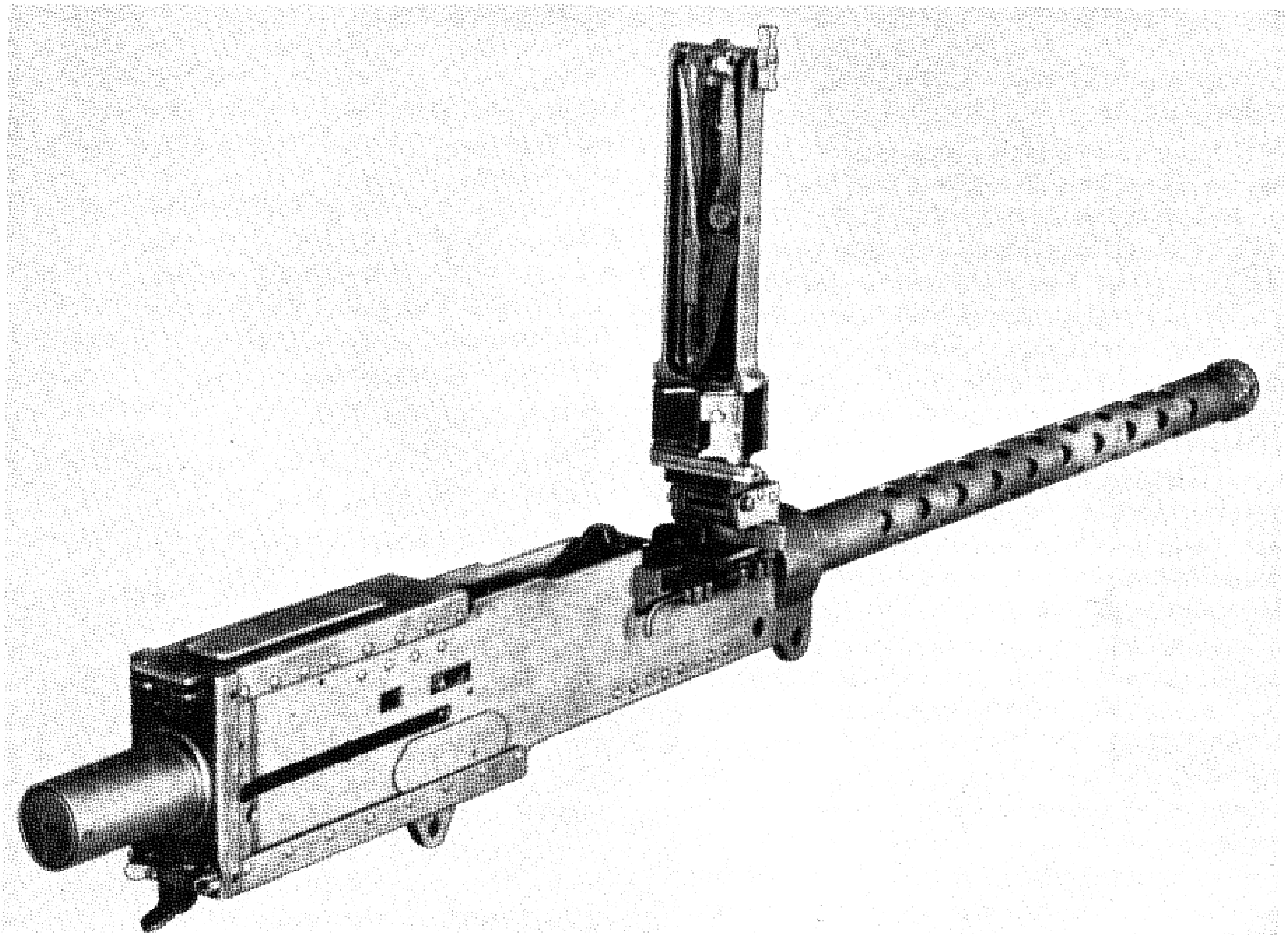

Figure 11-4. Browning Machine Gun, Caliber .50 T25E3. Right rear view.

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° F. to +140° 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. Redesigned 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

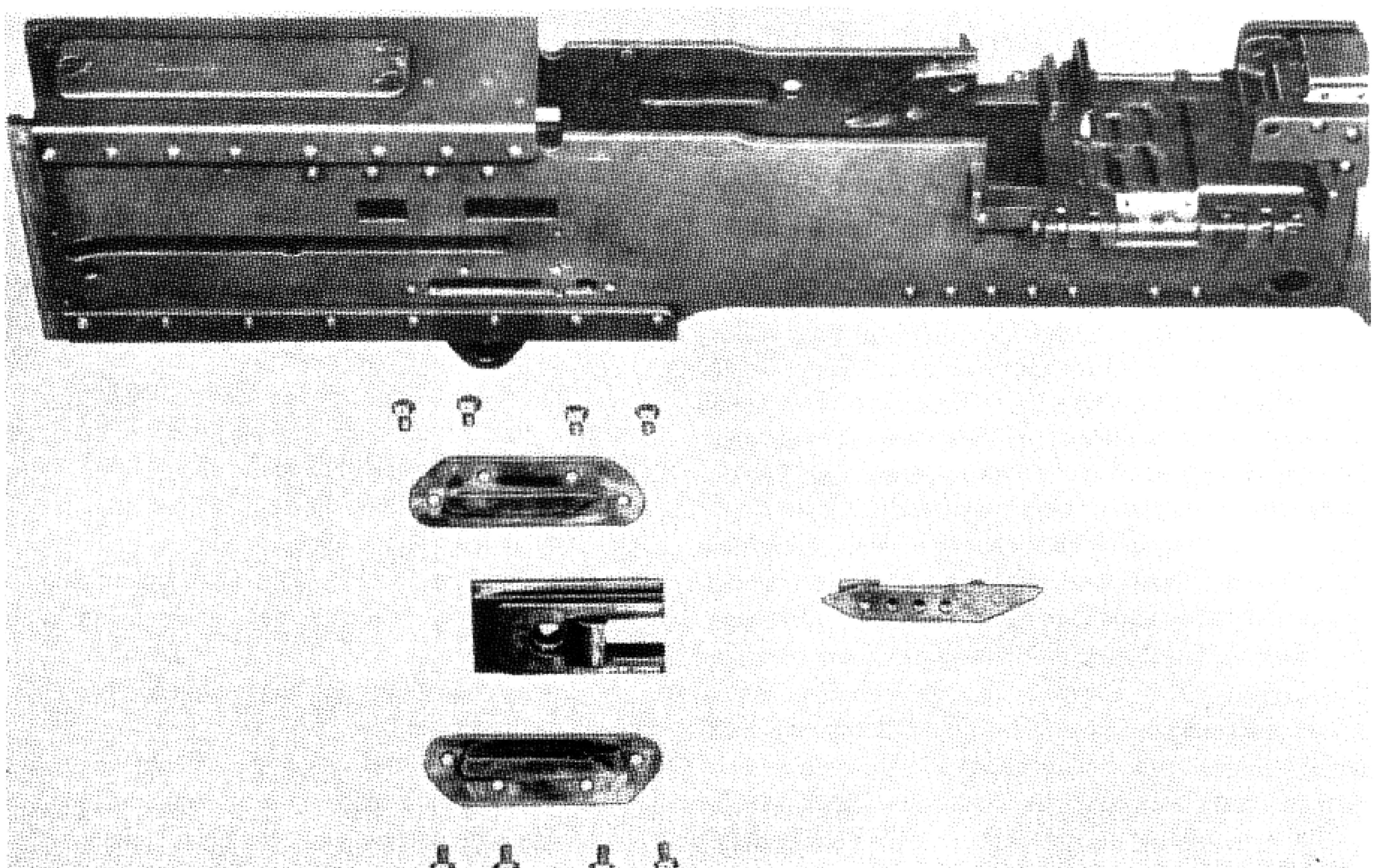

Figure 11-5. Modified parts of T25 gun. The rear of this receiver is fitted for a special backplate.

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-

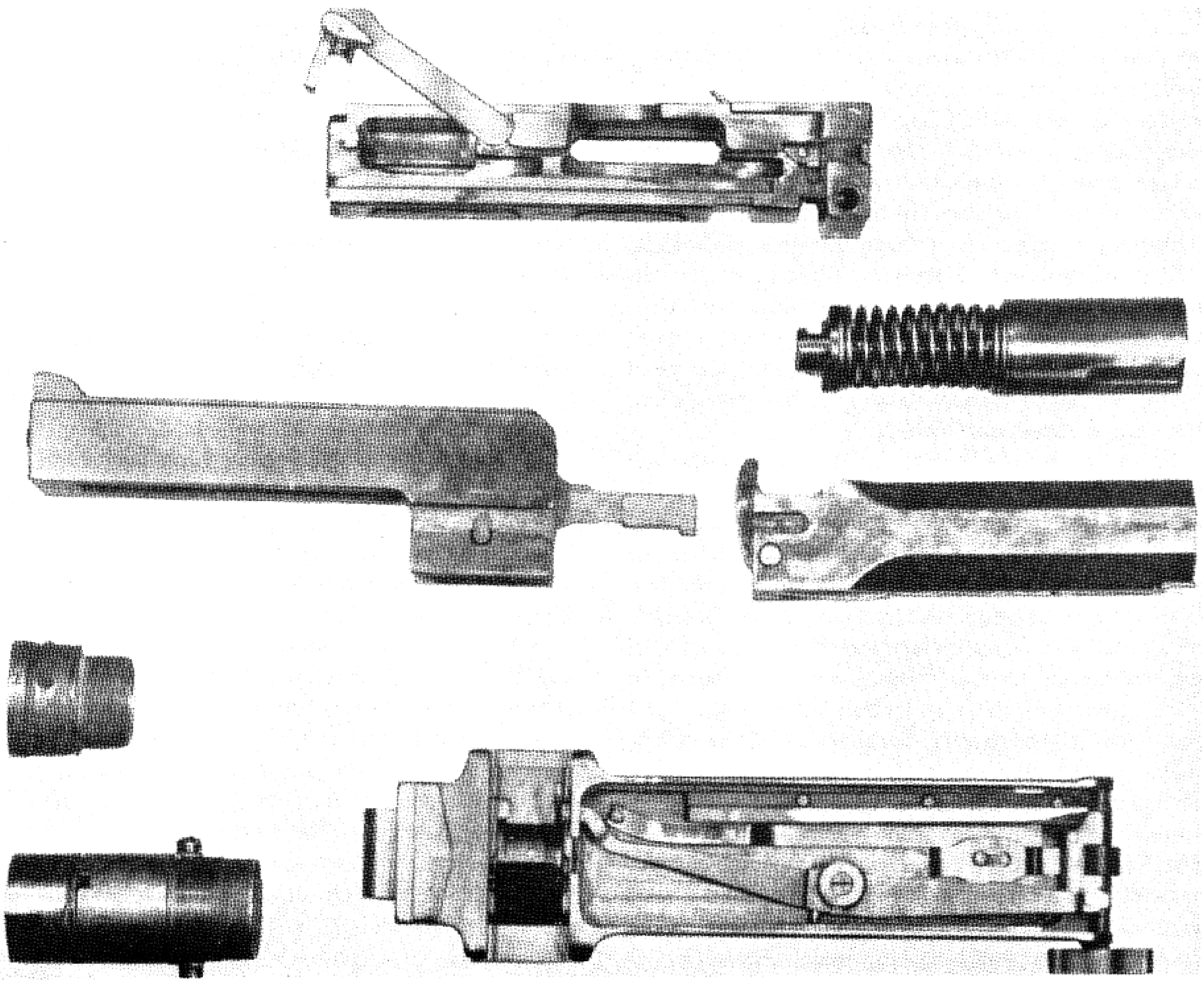

Figure 11–6. Modified parts of T25 gun. Lightened bolt at top. Air buffer immediately below. Barrel extension with wide depressor grooves. Buffer body. Booster and barrel bearing. Cover with heavier belt feed lever and curved cover extractor spring.

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

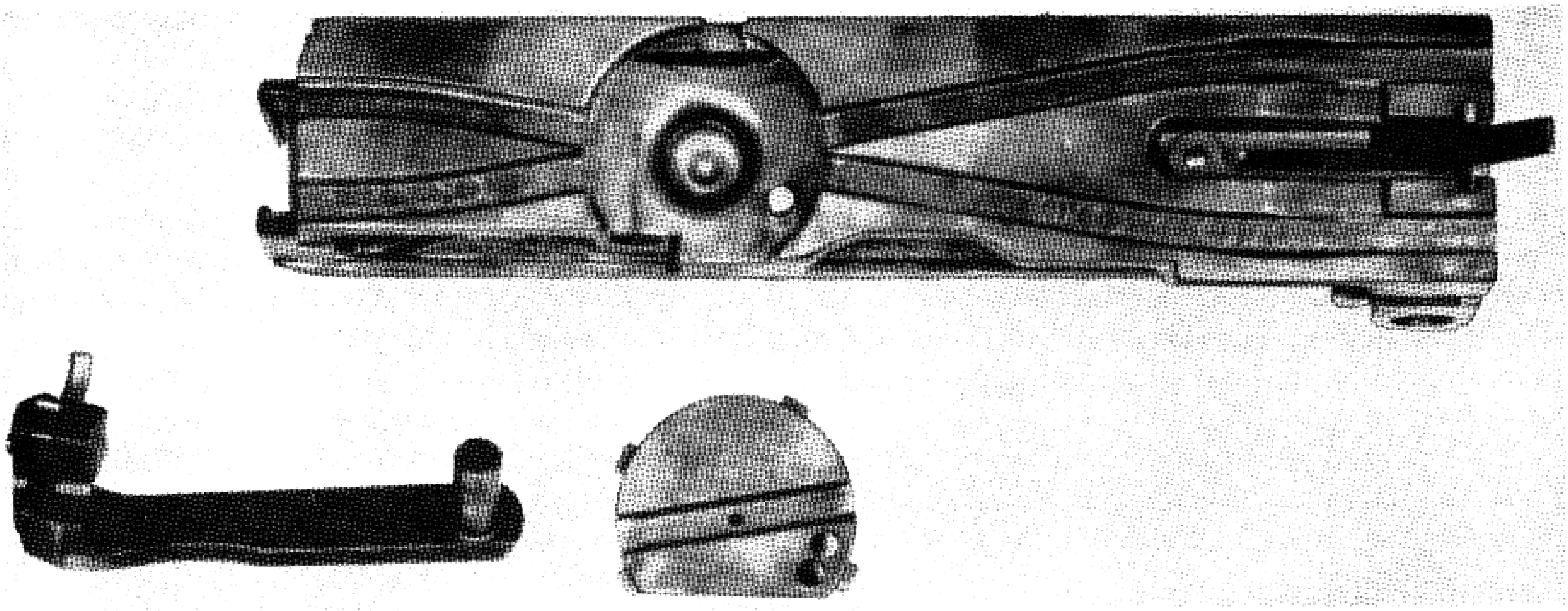

Figure 11–7. Modified parts of Browning Machine Gun, Caliber .50 T25. Lightened bolt and modified bolt switch and extractor.

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 assembly, 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 boster. 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 rearmost 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 1⅛ inches, at which time they are completely stopped by the barrel buffer body.

During this recoil of 1⅛ 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 5¾ 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 cartridge 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–M3. 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 4½ 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.

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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 counterrecoil 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 protects 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 tunnion 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 1⅛ inches, at which time they are completely stopped by the oil buffer body assembly.

During this recoil of 1⅛ 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 1⅛ 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 7⅛ 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 for 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 upward. 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 extractor 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	[1] 6	...
T27E1	15 Feb 44	2,400	1,150	6	11
T27E1	do	1,200	...	[2]	...
T27E3	6 Mar 44	5,000	1,150	10	8
T27E3	do	5,000	...	[3]	14
T27E4	5 Apr 44	3,600	1,330	9	10
T27E5	27 Jun 44	2,100	1,100	[4]	...
T27E5	do	400	1,030	[4]	...
T27E5	do	1,600	1,057	[2]	...
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

[1] Test stopped.
[2] Gun blew up.
[3] Numerous.
[4] 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 failure 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 aircraft 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 hiders 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 hiders 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 alinement, 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.

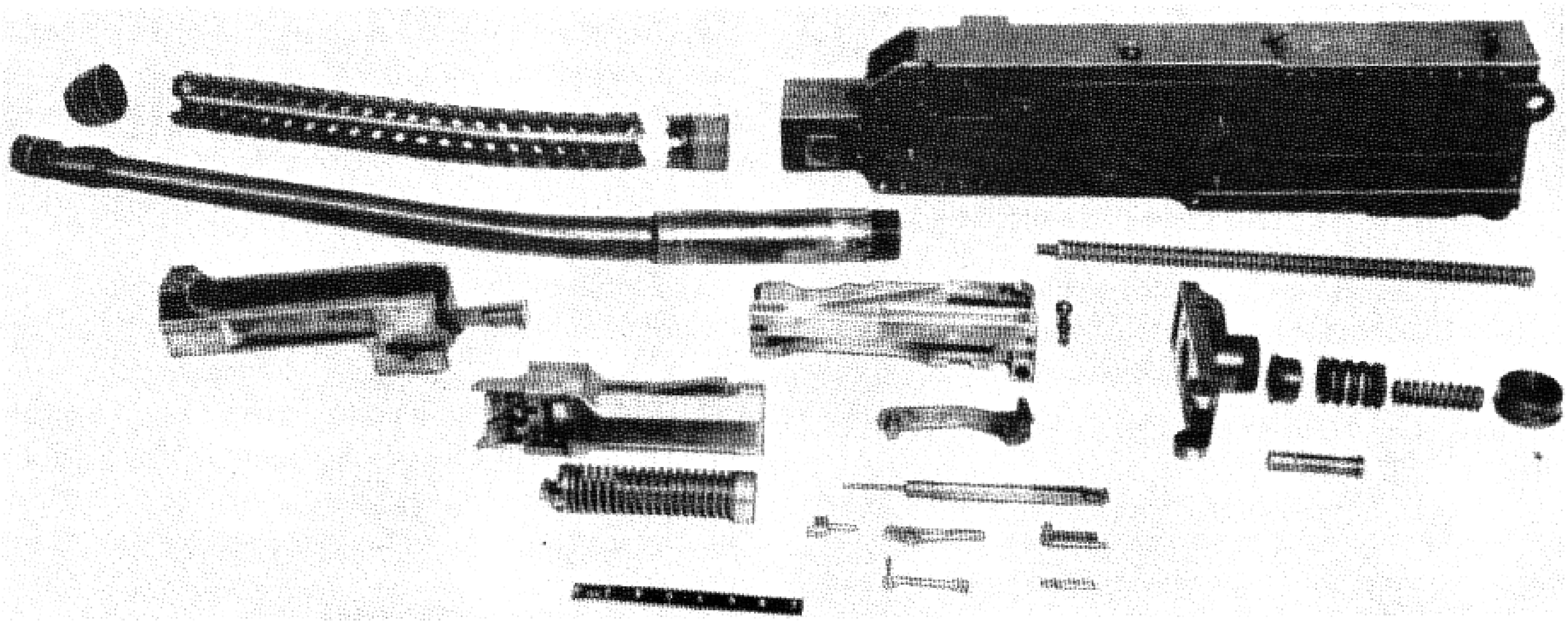

Figure 11–8. Japanese 20-mm Browning Aircraft Cannon HO–5B.

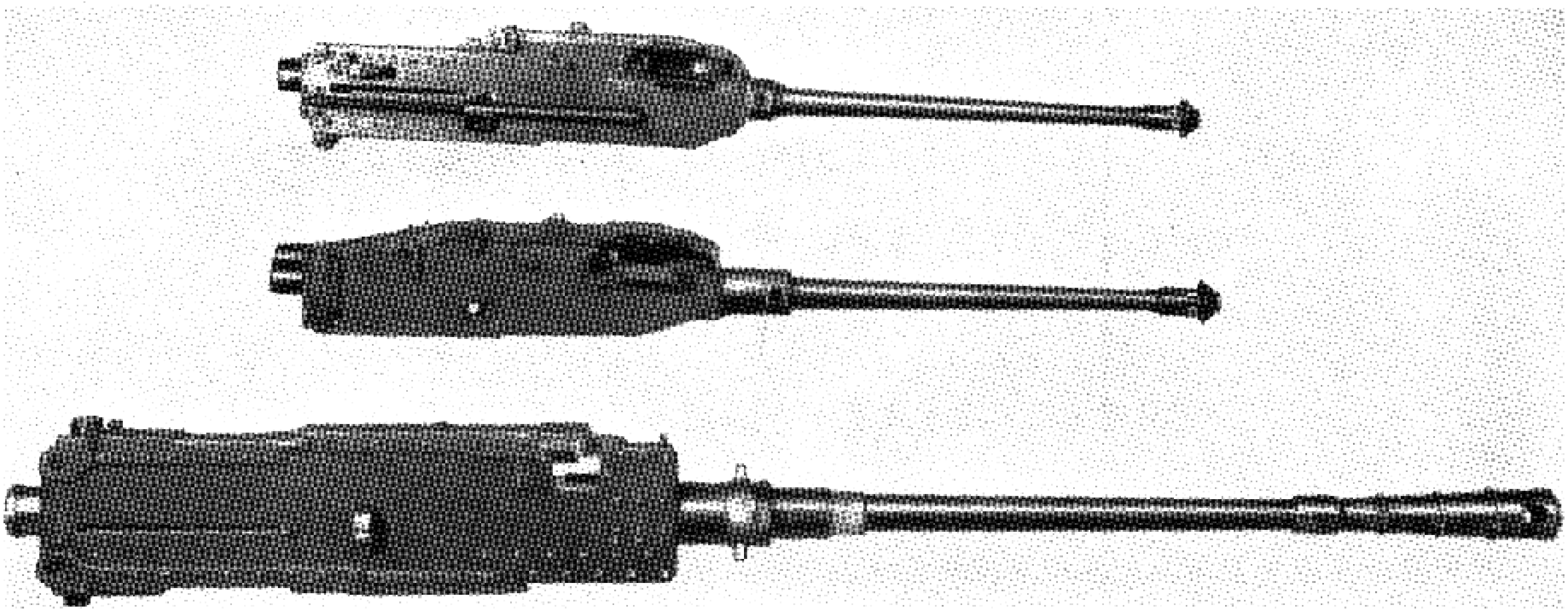

Figure 11–9. Japanese Browning Aircraft Cannon. Top, HO–155 Type 1, 30-mm; center, HO–155 Type 2, 30-mm; bottom, HO–204, 37-mm.

258070°—54——25