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RESEARCH AND DEVELOPMENT**

Ord Project: TS2-2015

Report: SA-TR11-3100, Copy No. 8

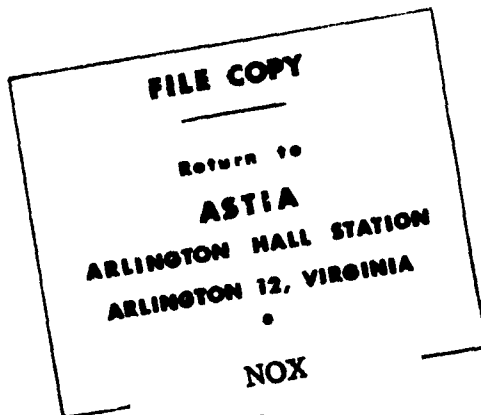
DA Project: 502-08-006

Date: 10 May 1959

Report Title: Feasibility Study of a Caliber .222, Salvo Type Shoulder Rifle (U)

Author: *D. C. Fletcher*
for **D. C. FLETCHER**
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Approved: *H. F. Hawthorne*
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Chief, Res and Dev Div



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REPORT
SA-TR11-3100

(U) SUBJECT

Feasibility Study of a Caliber .222 Infantry Salvo Type Shoulder Rifle.

(U) OBJECT

The object of this report is to present the findings of a feasibility study of a proposed design for a caliber .222 Salvo Type shoulder weapon with a rotary mechanism feeding the three barrels.

(C) SUMMARY

- (U) The proposed design has a rotating drum or rotor functioning in a cylindrical receiver to which the barrels are attached. A three-lobed bolt reciprocates in the rotor, which ejects on a clockwise stroke and feeds on the counterclockwise return stroke. The weapon is actuated by a gas-driven operating rod. Weapon action is governed by cam tracks and traverse lugs on the operating rod. Bolt movement is controlled by a chambering ring, which is seated in the bolt and interacts with the rotor and operating rod to guide the bolt in unlocking, recoil, counterrecoil, and locking.
- (C) A general analysis of the weapon and special studies of certain characteristics were made. The special studies included rate of fire, free recoil energy, and means of preventing a "ripple" firing effect. The approximate weight and center of gravity were also calculated. The proposed weapon would have a potential rate of fire of 300 salvos (900 rounds) per minute and would weigh from 9 to 10 pounds depending upon its stock and receiver materials.

(C) CONCLUSIONS

- (U) Although time and funds did not permit a thorough analysis of the overall design, certain conclusions were drawn:
- (C) 1. The rotary action appears to be an efficient and feasible means of achieving a practical, lightweight shoulder weapon capable of firing three projectiles at once.

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(C) CONCLUSIONS - Continued

- (C) 2. A firing mechanism capable of firing the three barrels simultaneously is possible.
- (U) 3. Such a weapon would have acceptable handling characteristics.
- (U) 4. The configuration of the proposed design is compact, and with the use of proper materials, would provide a lightweight weapon of acceptable silhouette.
- (U) 5. With proper muzzle brake design, such a rifle could be fired by the average person. The blast pattern caused by muzzle brakes might, however, be objectionable and contribute a fatigue factor to the weapon's use.
- (U) 6. A fairly high rate of fire would be possible with the proposed action. Volume of fire would be limited only by the practical limits of magazine capacity.
- (C) 7. While the three-barrel arrangement would place more projectiles in a given target area simultaneously, barrel alignment problems might cause difficulty in maintaining similar characteristics from weapon to weapon on a production basis.

(U) RECOMMENDATIONS

Although it is recognized that areas of the proposed design are not complete, the work accomplished indicates that:

- 1. A more thorough analysis of the proposed design should be made.
- 2. Further consideration should be given to the rotary type action for applicability to other weapons.

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SPRINGFIELD ARMORY

RESEARCH AND DEVELOPMENT DIVISION

TECHNICAL REPORT SA-TR11-3100

DCFletcher/mwp/rd/4152
10 May 1959

(C) 1. INTRODUCTION:

(C) a. This report covers the feasibility study of a proposed design for a rotary action, salvo type, infantry shoulder weapon. A salvo rifle is defined as a rifle that fires two or more projectiles simultaneously. This weapon concept was derived from initial requirements for design and development of an infantry rifle having an increased statistical probability of hitting the target with each pull of the trigger.

(U) b. The preliminary design of the salvo rifle discussed in this report was developed from a feasibility study conducted to determine the merits of using a rotary type of action in a military shoulder weapon. Springfield Armory initiated work on the salvo rifle design in September 1955. Work was continued until terminated by direction and through lack of funds.

(U) c. From the beginning of the project, it became apparent that the desired results could not be obtained by attaching three conventional receivers together. Some major objections to such an arrangement were:

- (1) The weight would be prohibitive, since three separate actions would be required.
- (2) The simultaneous control of three actions in feeding, firing, and ejecting would be extremely difficult.
- (3) The silhouette and handling qualities of such a weapon would not be desirable because of the over-all size and relatively heavy construction.

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(C) 1. INTRODUCTION: (Contd.)

(U) d. In an attempt to overcome the above objections, several proposed designs were submitted, combining such components as receivers, bolt carriers, gas cylinders, and operating rods. These designs, while reducing the weight problem, did not solve the problem of inefficient ejection or feeding, nor did they improve the silhouette of the weapon. It was evident at this point that a radical departure from the conventional concept of weapon design was necessary in order to achieve a solution. This led to the study of the three-barrel, rotary-action, salvo rifle design.

(U) 2. GENERAL DESCRIPTION AND FUNCTIONING:

a. Configuration. The proposed salvo rifle design, Figure 1, is for a percussion center fired, gas-operated, three-barreled weapon firing semiautomatically. The design incorporates a cylindrical receiver with an integral tapered stock coated with a heat-resistant material. The three barrels are threaded into a breech ring, Figure 2 (12286-SA), at the front of the receiver in a one-over-two triangular arrangement and are clamped together at the muzzle brake units. A gas cylinder operated from the upper barrel is located centrally with respect to the three barrels. The proposed design is magazine fed through the bottom of the receiver.

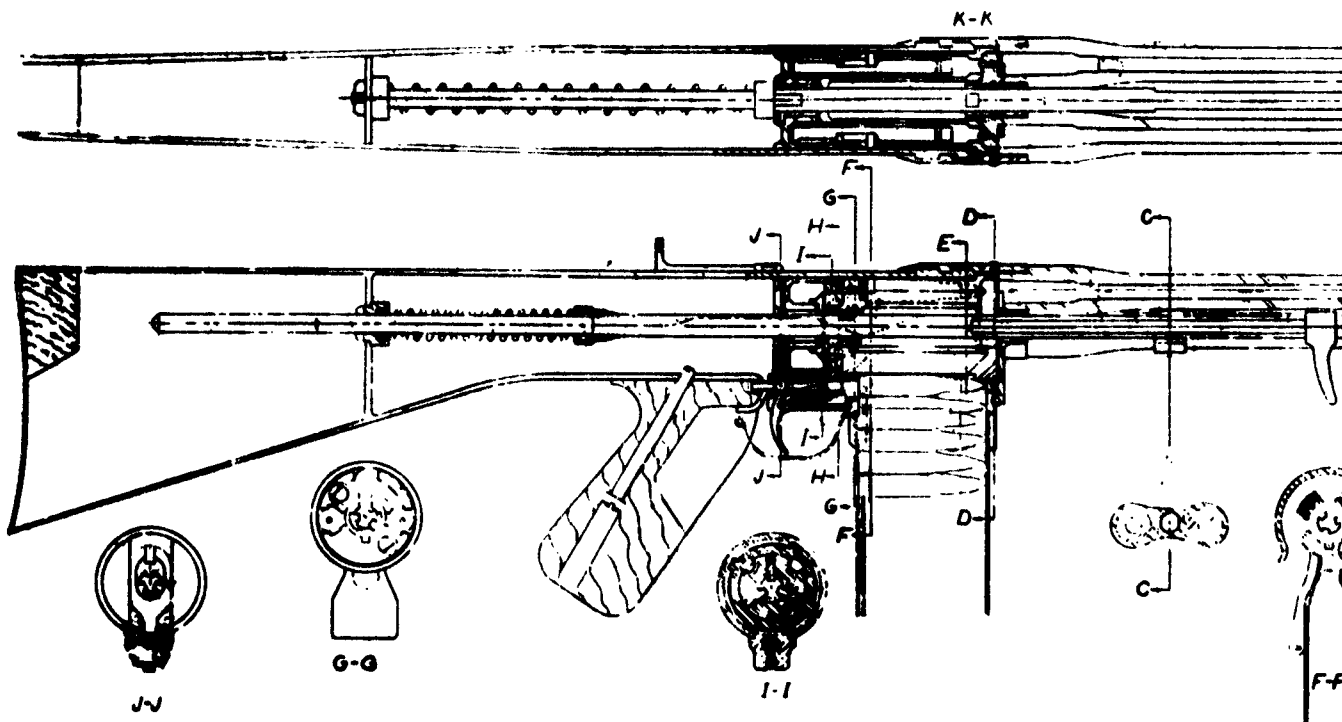
b. Action. There are three basic functioning units in the action of the proposed design: these are the rotor or bolt carrier, the bolt, and the gas-actuated operating rod.

(1) Rotor. The rotor, Figures 2 and 3 (12287-SA), is a cylindrical drum located in the front end of the receiver over the magazine opening. The front end of the rotor is supported on ball bearings in the receiver breech ring, and the rear end is supported in a journal bearing. There are seven longitudinal holes in the rotor: the largest is an axial hole passing completely through the rotor. Arranged in a trefoil pattern around the central hole are three "secondary chambers," which serve as guideways for the cartridges. The outer portions of these chambers are slots breaking

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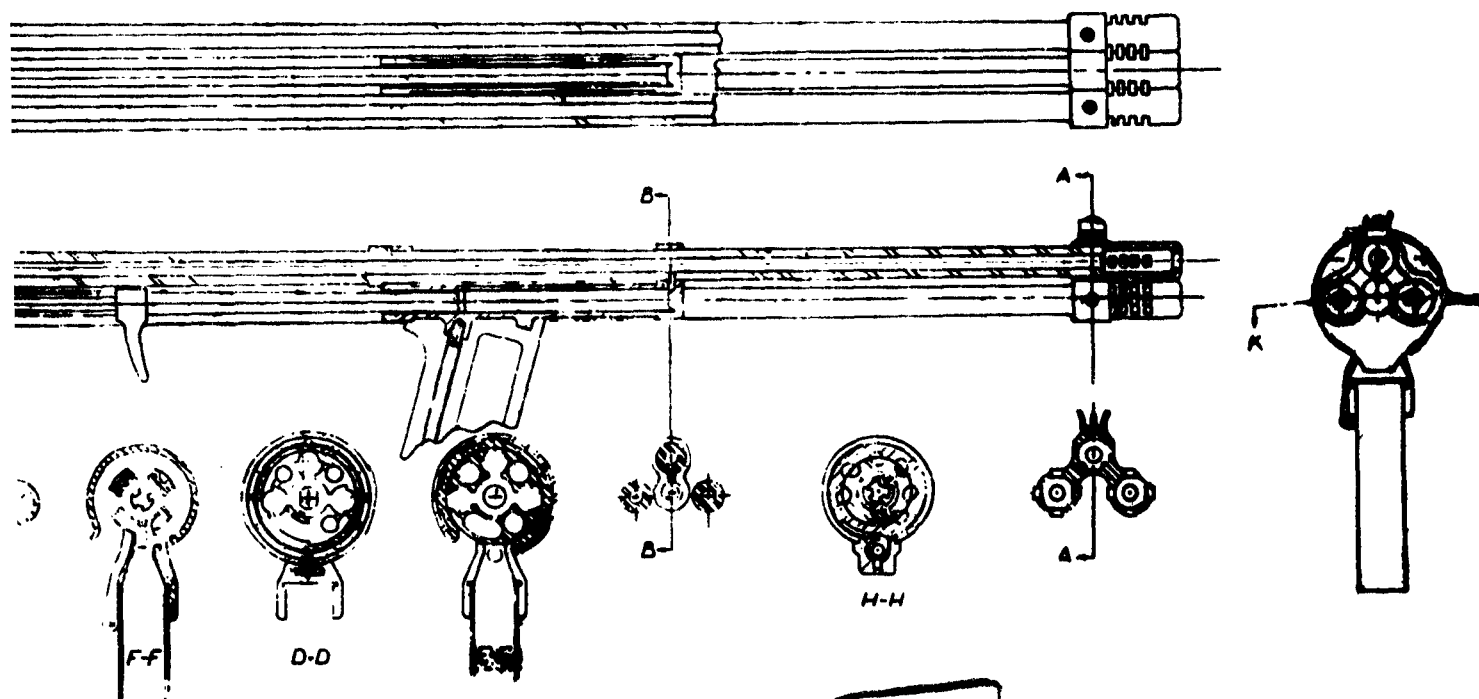
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ASSEMBLY DRAWING
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DRAWING - 3BARREL SALVO RIFLE
FIGURE 1

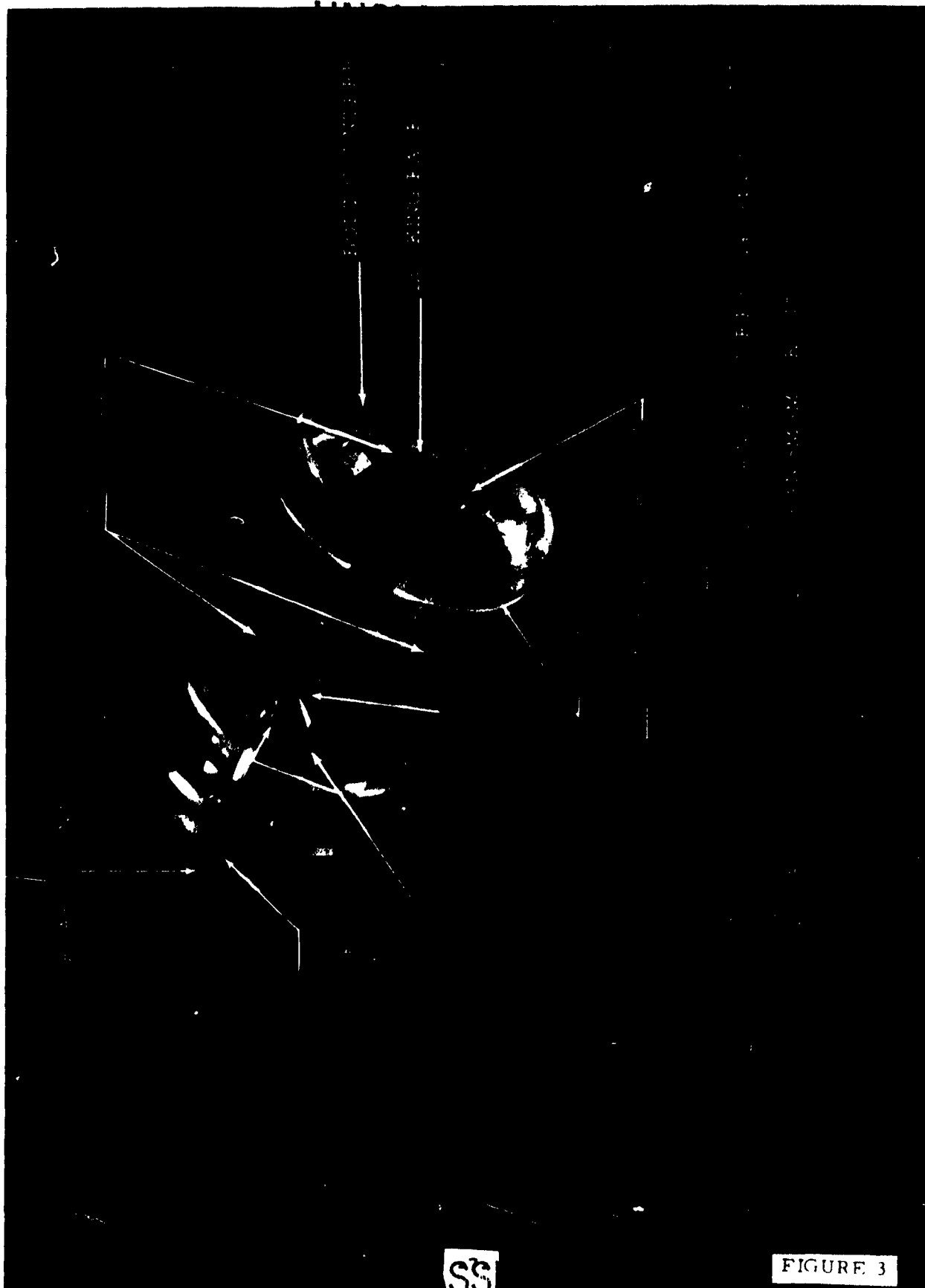
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FIGURE 2

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(U) 2. GENERAL DESCRIPTION AND FUNCTIONING: (Contd.)

b. Action. (Contd.)

(1) Rotor. (Contd.)

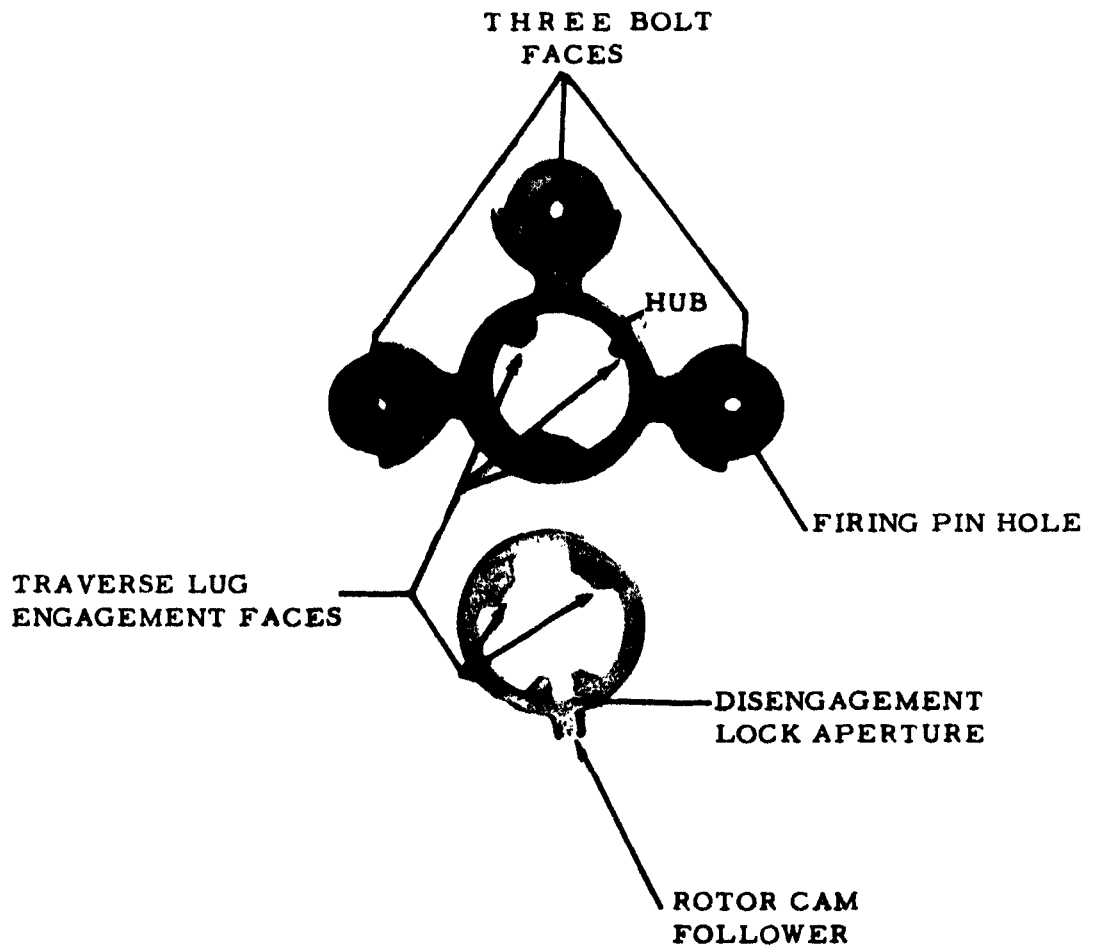
through the surface of the rotor and permitting feeding and ejection through the sides of the rotor. Adjacent and parallel to each secondary chamber is a hole which may contain either a spring-loaded striker or a firing pin. (The mock-up illustrated is provided with spring-loaded strikers.)

- (2) Bolt Assembly. The bolt assembly, Figures 4 and 5 (12320-SA) and 12288-SA), is composed of the bolt and the chambering ring. The bolt is a trefoil-shaped component with a lateral slot in its body to accommodate the chambering ring. Each of the three bolt lobes has a bolt face with a central striker or firing pin hole. A 180-degree lip on each lobe serves as an extractor. Three lugs project into the central bore of the bolt body. These lugs are engaged by the operating rod traverse lugs during the recoil stroke. The chambering ring, Figure 4, also has three inward-facing lugs. These are engaged by the operating rod traverse lugs on the counterrecoil stroke. An externally projecting cam follower on the ring rides in a cam path on the inner surface of the rotor. These relationships are covered in more detail below.

- (3) Operating Rod. The operating rod, Figure 5, is a shaft with three longitudinal cam tracks machined in its surface. These tracks are nearly identical except for a keying arrangement. The cam tracks operate on three cam followers projecting inward at the journal end of the rotor, Figure 2. Three lugs project from the operating rod near its midpoint. These lugs engage the bolt during recoil and the chambering ring during counterrecoil. The front end of the operating rod is seated in the gas cylinder, and the rear end is supported in a rear spring retainer within the stock. An operating rod spring is seated between the rear spring retainer and a front seat on the operating rod.

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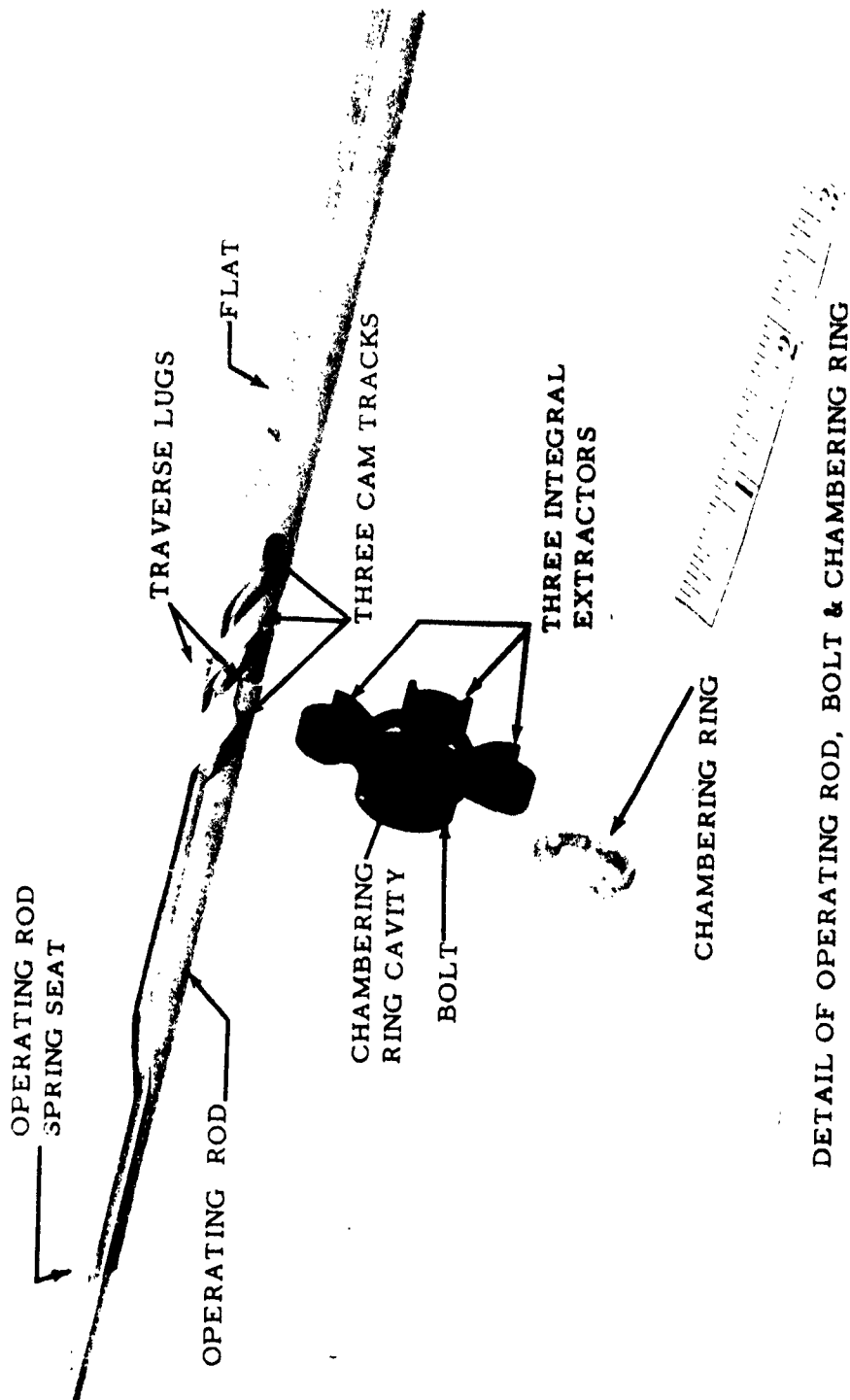


ENLARGED DETAIL OF BOLT & CHAMBERING RING

12320-SA SPRINGFIELD ARMORY - ORDNANCE CORPS 14 Oct 1956
ROTARY SALVO GUN, CAL. 22, MECHANISM (MOCK-UP)

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DETAIL OF OPERATING ROD, BOLT & CHAMBERING RING

12288-SA SPRINGFIELD ARMORY - ORDNANCE CORPS 14 Oct 1956
ROTARY SALVO GUN, CAL. 22, MECHANISM (MOCK-UP)

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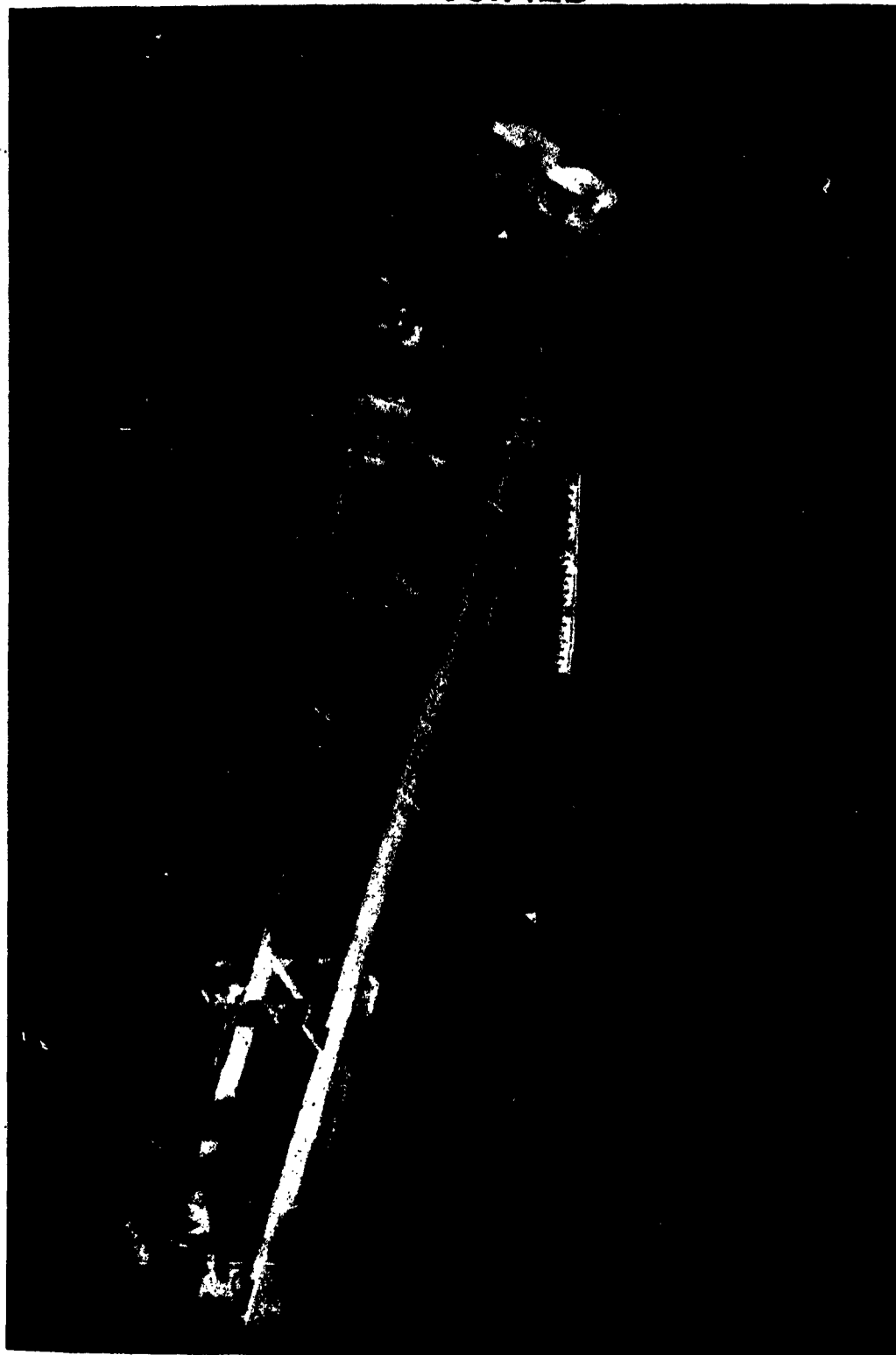
(U) 2. GENERAL DESCRIPTION AND FUNCTIONING: (Contd.)

c. Recoil. When the rifle is fired, the operating rod will move rearward approximately one-half inch before the cam tracks actuate the rotor or the traverse lugs engage the bolt. This cam dwell period insures that the bolt will remain locked until all three barrels are fired (see discussion of ripple fire, paragraph 3b (1) below). The sequence of action is then as follows (clockwise and counterclockwise directions refer to rotor movement as viewed from the rear):

- (1) As the first curved portion of the operating rod cam tracks reaches the rotor followers, the rotor turns counterclockwise approximately 47.5 degrees, Figure 6 (12284-SA). This unlocks the bolt, rotating the strikers or firing pins from behind the bolt, and aligns the three rotor chambers with the bolt lobes.
- (2) As the operating rod continues rearward, the traverse lugs on the rod pass through the chambering ring and engage the bolt lugs, forcing the bolt rearward into the rotor and extracting the empty cases from the barrel chambers, Figure 6. During this action, the rotor remains stationary.
- (3) When the empty cases clear the barrels, the rotor cam followers encounter the next curve of the operating rod cam tracks, and the rotor begins to turn clockwise, Figure 7 (12285-SA). This rotation continues as the bolt is carried to the rear of the rotor chambers.
- (4) Once the bolt begins to turn with the rotor, its lugs begin to disengage from the operating rod traverse lugs. As the bolt reaches its rearmost position in the rotor, its lugs are completely disengaged, rearward bolt movement stops, and the operating rod continues to the rear, turning the rotor.

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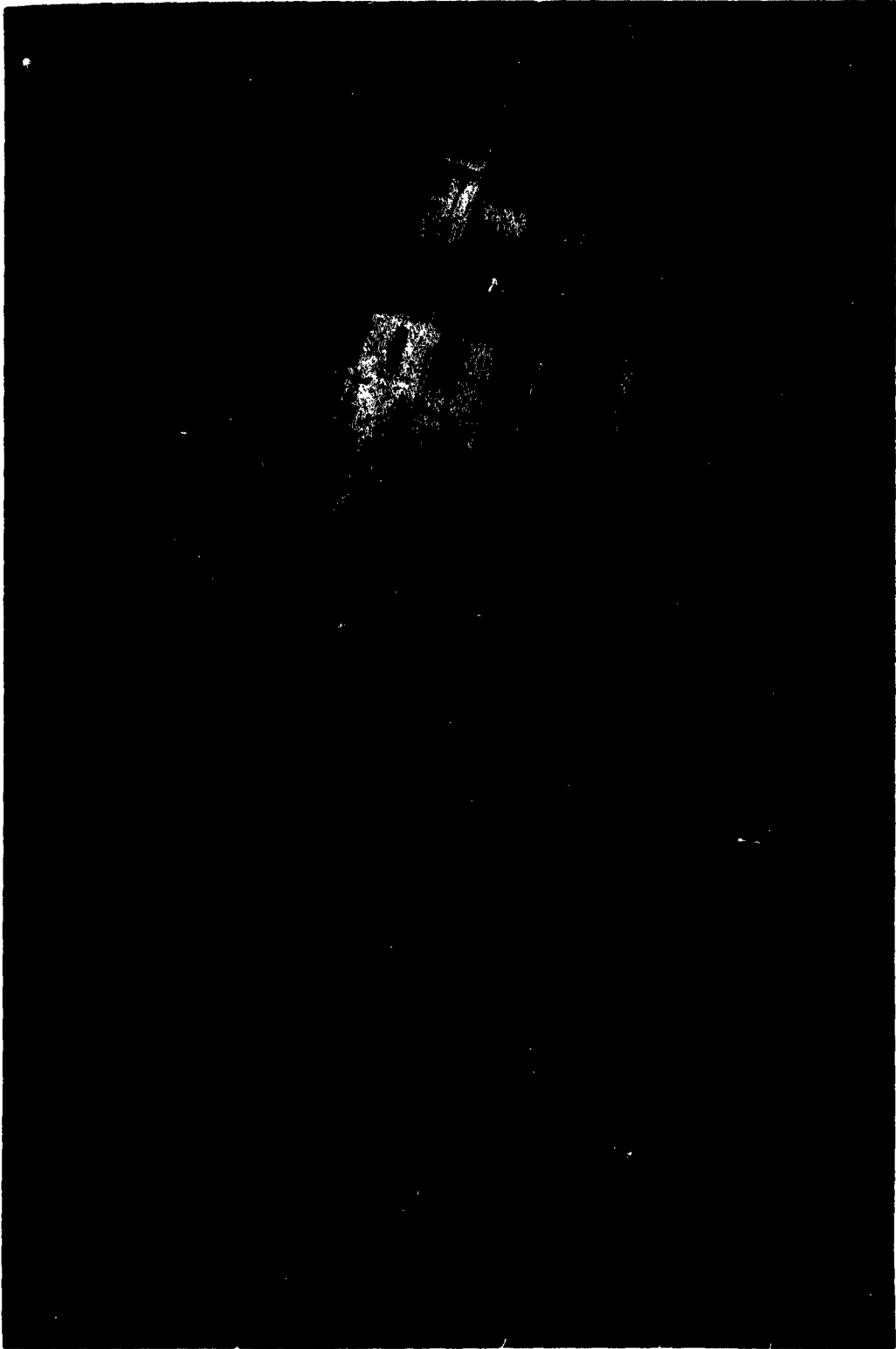


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FIGURE 6

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FIGURE 7

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(U) 2. GENERAL DESCRIPTION AND FUNCTIONING: (Contd.)

c. Recoil. (Contd.)

- (5) During the rotor rotation described above, as each cartridge reaches the five o'clock position, it is carried against the ejector and is dropped out of the lower right side of the receiver. The ejector is a pawl-like component pinned to the side of the trigger housing and projects into a clearance groove on the periphery of the rotor (Figure 2).
- (6) Once the operating rod is disengaged from the bolt, it continues to the rear until it reaches full recoil and stops against a buffer in the stock. At this point, all three cartridge cases have been ejected, and the rotor is positioned with the feed chamber for the left hand barrel in feeding position over the magazine. Total rotation of the rotor from the unlocked position is approximately 276 degrees.
- (7) The chambering ring has no function during recoil. It is carried to the rear with the bolt with its follower riding in a cam track on the inner wall of the rotor. As the bolt is disengaged from the operating rod, the rotor cam track turns the chambering ring into position to engage the operating lugs on the counterrecoil stroke.

d. Counterrecoil. Energy for the counterrecoil stroke is stored in the operating rod spring, which is compressed between the rear spring retainer in the stock and the front spring seat on the operating rod. As this spring expands, the following sequence of action occurs:

- (1) The uniformly curved portion of the operating rod cam tracks turns the rotor counterclockwise. As each rotor chamber passes over the magazine, the magazine follower and spring feed a cartridge into the rotor. In passing the ejector on the feed stroke, the cartridge presses the spring-loaded ejector aside.

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(U) 2. GENERAL DESCRIPTION AND FUNCTIONING: (Contd.)

d. Counterrecoil. (Contd.)

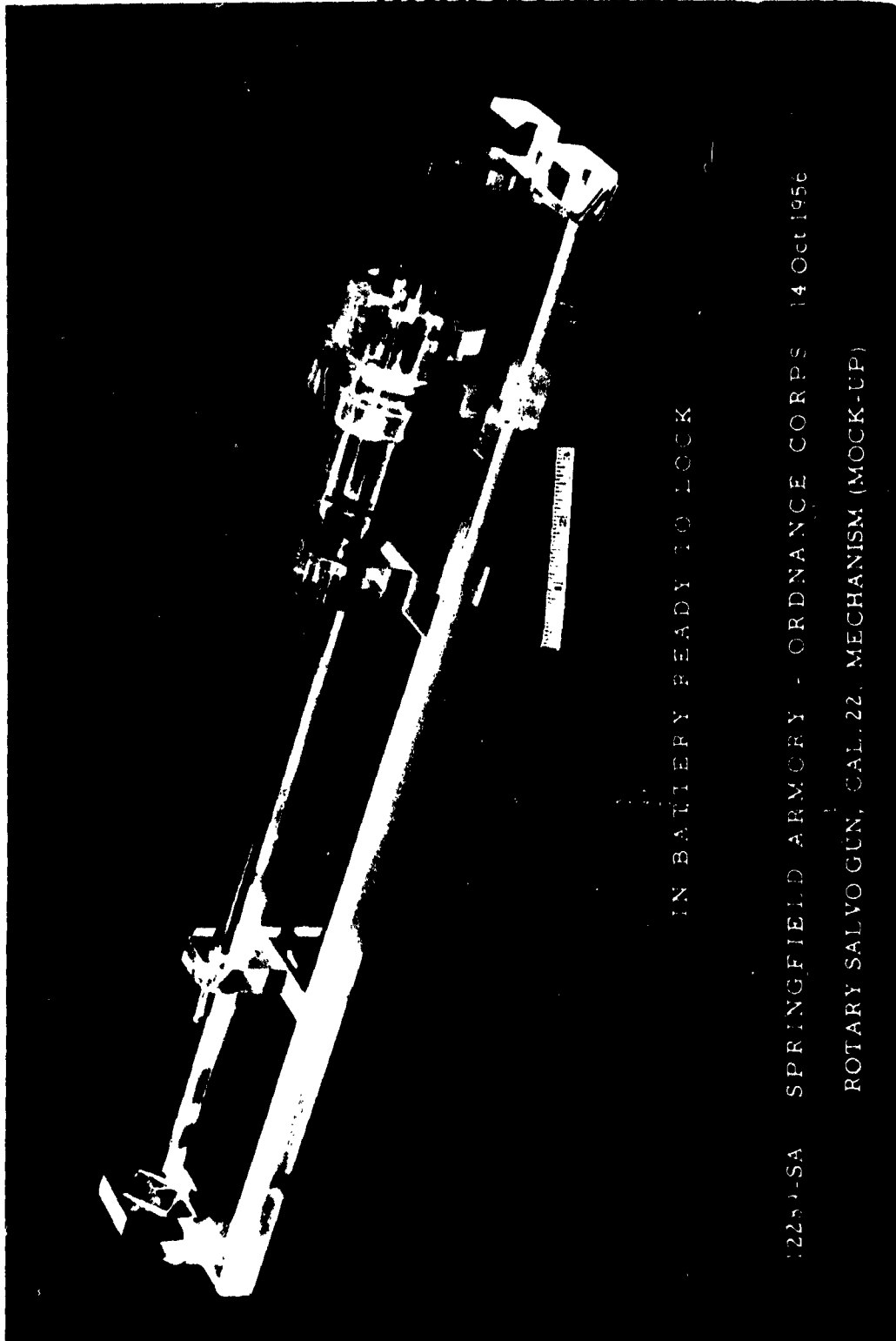
- (2) When all three rotor chambers are loaded, the operating rod traverse lugs by-pass the bolt lugs and engage the chambering ring lugs. Continued rotation of the rotor then positions the bolt lugs in pick-up position behind the traverse lugs as the bolt is carried forward.
- (3) When all three rotor chambers are aligned with their respective barrels, rotor rotation ceases, and the bolt is carried forward and chambers the rounds in the barrels.
- (4) As the cartridges enter the barrels, the cam track on the inner surface of the rotor begins to disengage the chambering ring from the operating rod traverse lugs. When the cartridges are fully chambered, the ring is completely disengaged, and the operating rod is free to continue forward.
- (5) When the cartridges are fully chambered, the bolt lobes are clear of the rotor chambers and seated against the rear face of the breech ring. The operating rod cam tracks then turn the rotor 47.5 degrees clockwise, while the bolt remains stationary, and the rotor is locked behind the bolt lobes with the strikers aligned with the striker holes in the bolt lobes. See Figures 8 and 9 (12289-SA and 12283-SA).

(U) 3. DISCUSSION AND ANALYSIS:

a. General. The study of the proposed salvo rifle design has been limited to certain areas dealing with the feasibility of the rotary-type design. Other areas have been considered and are discussed briefly. However, it should be emphasized that a detailed study would be required to provide a thorough evaluation of the over-all design.

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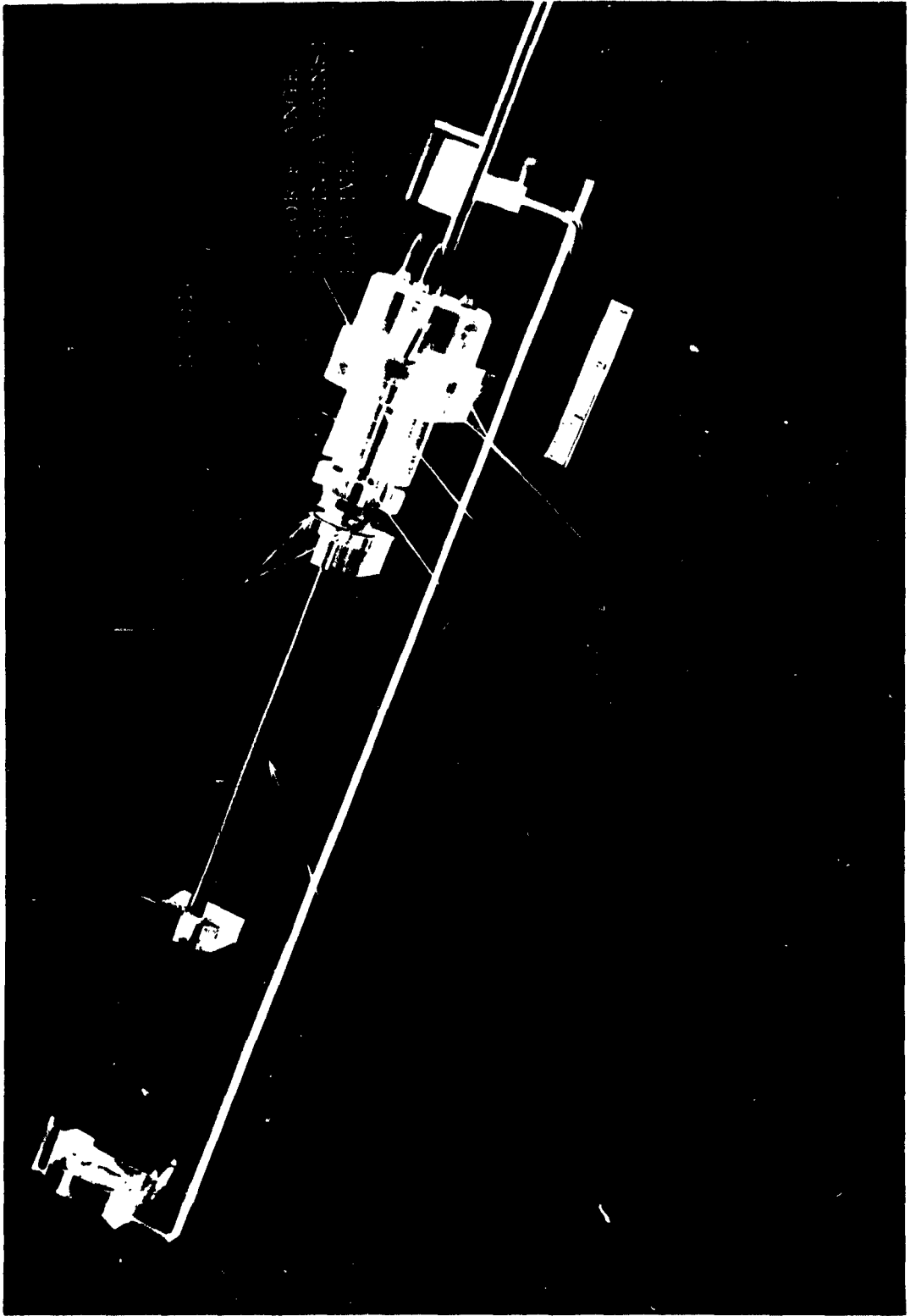
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12250-SA SPRINGFIELD ARMORY - ORDNANCE CORPS 14 Oct 1956
ROTARY SALVO GUN, CAL. 22. MECHANISM (MOCK-UP)

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FIGURE 9

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

b. Firing Mechanism. The actual firing mechanism for the salvo rifle is not detailed in the basic layout drawing, but the design provides for a system of spring-loaded strikers seated in holes parallel to the rotor chambers, Figures 2 and 3. Locking the bolt would align the strikers behind the bolt lobes in readiness for firing. In the following paragraphs, the general problem and the relative merits of hammer-firing pin and sear-striker designs are considered.

- (1) Simultaneous versus Ripple Fire. A basic problem of the salvo rifle concept is to obtain simultaneous firing of the three rounds. The precise simultaneity of firing will be a function of the tolerances in the firing mechanism used, and a "ripple" firing effect will be obtained if the mechanism does not compensate for the effect of the tolerances. On the basis of the analysis contained in the paragraphs below, a hammer-actuated mechanism would be preferred for the salvo rifle.
- (2) Hammer-Firing Pin Relationship. In a hammer-actuated firing mechanism, a single hammer would be used to drive the three firing pins against the cartridge primers. Simultaneity of firing would be dependent upon two variables, firing pin length and firing pin position, which may be considered in terms of time and travel. That is, the variable of position will affect both the distance the firing pin must travel and the time at which it is struck by the hammer; firing pin length will also affect travel and time of hammer impact. If the firing pins are struck in sequence, the first pin struck will have the highest velocity, the second pin will have the second highest, and the third pin will have the lowest. To offset the effect of different velocities, the travel of each firing pin must be directly proportional to its velocity. Thus, if the velocity of firing pin No. 2 is N percent of that of firing pin No. 1, its travel must also be N percent of the travel of No. 1, and correspondingly for firing pin No. 3. An additional factor to be considered is the possibility of the first firing pin striking a primer and rebounding against the hammer. If this occurred before the other firing

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

b. Firing Mechanism. (Contd.)

(2) Hammer-Firing Pin Relationship. (Contd.)

pins were struck, hammer velocity would be further reduced and affect the velocity of the other pins. To prevent this, the firing pins should be designed for sufficient overtravel to permit the hammer to strike all three pins before a rebound could occur.

- (3) Sear-Striker Relationship. The spring-loaded striker arrangement shown on the proposed basic layout drawing would require the design of a special sear mechanism to engage and release the strikers. In such an arrangement, the number of variables would tend to be greater than in a hammer-firing pin mechanism. The variable of position would be eliminated, assuming the strikers were seared in the same vertical plane. Variables affecting this mechanism would be those of length, spring constants, and engagement surface tolerances. Without selective weighing of springs, a tolerance as low as five per cent on individual spring loading could permit a velocity difference as high as ten per cent between any two strikers. Length variation would affect travel, and failure to release all three strikers simultaneously would impose a time variable. Although no calculations are presented here, it would appear that adverse combinations of variables could easily occur, and the elimination of a ripple fire effect would be more difficult on a production basis. The engagement surface tolerances of the sear and strikers would also require careful design to insure engagement and simultaneous release of all three strikers and to prevent the possibility of any striker being released individually. Such a mechanism has been considered but is proprietary information and is not discussed in this report. Because of the objectionable features discussed above further study is deemed necessary.

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

c. Operating Rod. One of the problems encountered in the design of a rotary action is the effect of torque. In driving the rotor through the approximately 276 degrees rotation required for ejection and feeding, the operating rod travels approximately two inches. To prevent the rod from turning, the rod is guided through an "anti-twist" device clamped to the two lower barrels in front of the receiver (see Figures 1 and 7). The portion of the operating rod that passes through this component is provided with flat sides which prevent it from turning. However, this cannot prevent a certain amount of twist imposed by the interaction of the rotor cam followers with the operating rod cam tracks. The potential twist has not been calculated, but would be a function of the inertia of the rotor, the distance of the point of cam action from the anti-twist mechanism, and the diameter of the operating rod. The effects of these variables could be largely offset by increasing the rod diameter and locating the anti-twist mechanism in the receiver immediately to the rear of the point of cam action.

d. Bolt and Chambering Ring. The three-lobed bolt is unique and has an excellent strength-to-weight ratio and a large locking area. The chambering ring is a major factor in the timing of bolt movement. Its interrelation with the bolt, the operating rod, and the rotor would require close control of the mating dimensions. Considering the number of dimensions concerned with proper function of the ring, the possibilities for tolerance accumulation are multiplied. However, the design does offer certain advantages in that the mechanism is extremely well protected against the entry of dirt and moisture.

e. Rotor. An analysis (paragraph 6a) of the rotor feeding action has been made to determine the potential rate of fire of the salvo rifle. The rate of fire is dependent upon the magazine feed rate, since failure to feed would occur if the rotor were rotating faster than the magazine could raise ammunition. The analysis was based on feed rate data for a 24-round magazine listed in Table I. Magazine spring and follower weights were assumed the same as those for the T44E4 rifle, and a spring constant of two pounds per inch assumed. From the magazine feed rate data, the maximum rotor angular velocity was calculated and the cyclic period determined. A value of 0.199 seconds was obtained, which corresponds to a rate of 300 salvos (900 rounds) per minute.

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

f. Gas Operation. Three gas system designs have been considered for use with the proposed rifle design. Each system is based on the principle of using the gas energy to load a spring which would then release the energy to the operating rod. A directly energized operating rod would not be feasible because of the long active stroke of the rod. Since the major portion of the energy delivered by a gas system is delivered in a short period of time, the inertia members of the weapon would not be adequate to supply the energy demands of the action. Energizing a spring would permit the energy to be stored and released over a longer period of time, making the operating rod less affected by fluctuations in gas pressure.

- (1) Design No. 1 is shown in Figure 10. In this system, the gas cylinder is clamped to and taps gas from the upper barrel. Upon initial entry into the gas cylinder, the gas exerts forward pressure on the front end of the operating rod and rearward pressure against a sleeve surrounding the operating rod. The operating rod is thus momentarily held forward, and the sleeve is thrust rearward compressing a spring against a shoulder on the operating rod. At a point shown in Section A-A of Figure 10, the sleeve is latched, and the pressure drop in the gas cylinder permits the operating rod to move rearward under the energy of the compressed spring. Upon completion of recoil, the gas cylinder sleeve is unlatched and the system as a unit (gas cylinder sleeve, operating rod, and compression spring) is returned to the original position by the driving spring of the weapon.
- (2) Design No. 2 is shown in Figure 11. In this system, a gas cylinder in the form of a sleeve surrounds the upper barrel. Gas is tapped into the sleeve, thrusting it forward to compress a spring against a shoulder on the barrel. At a given point, a spring loaded latch engages a notch in the operating rod, gas pressure drops, and the spring drives the operating rod to the rear. Upon completion of recoil, the gas cylinder latch is cammed out of the notch in the operating rod permitting the operating rod to be returned to its forward position by the weapon driving spring.

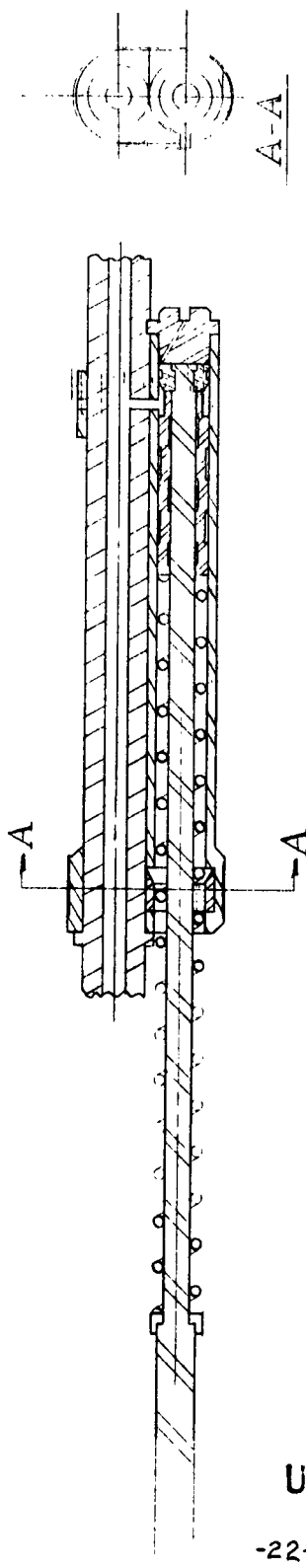
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F. C. Feltman
Sept. 25, 1956

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GAS CYLINDER DESIGN #1

FIGURE 10

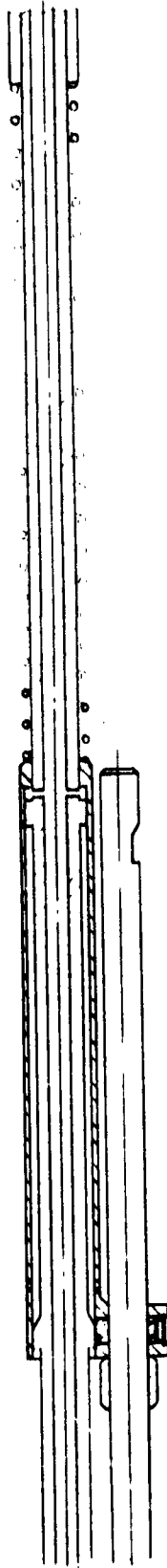
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P.C. Litchner

Oct. 3, 1956

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GAS CYLINDER DESIGN #2

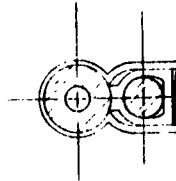


FIGURE 11

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

f. Gas Operation. (Contd.)

- (3) Design No. 3 is shown in Figure 12. This design is similar to Design No. 1 in principle, but has a greater area at the rear of the operating rod head. In addition, the spring is enclosed by a sleeve for its entire length.
- (4) Evaluation of the three systems was not completed due to termination of the project. The main problem associated with the development of any of the systems would be that of latching the spring before the commencement of operating rod recoil and of storing sufficient energy in the spring to operate the action of the weapon. Premature recoil of the operating rod in conjunction with a ripple fire effect could result in unlocking the bolt while high pressure still existed in one or more of the barrels. Further study would be required to determine the potential effectiveness of the systems.

g. Barrel Cluster. A number of problems are inherent in the clustering of barrels as proposed in the salvo rifle design. A thorough analysis has not been made due to lack of time and funds; however, certain points have been considered and are discussed below.

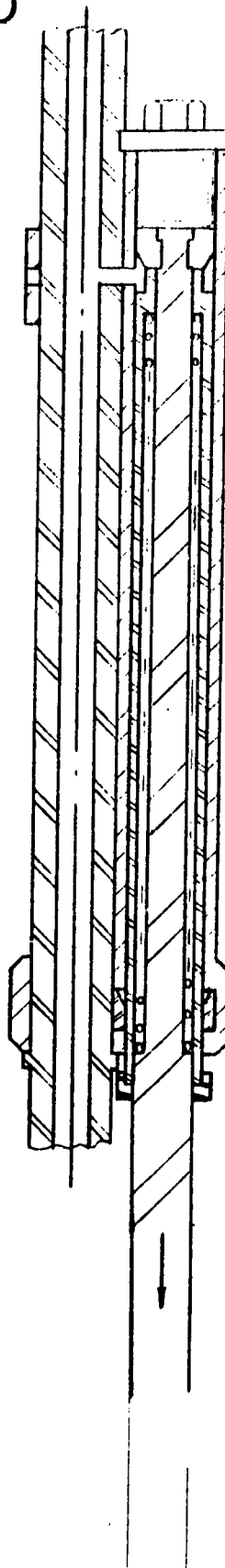
- (1) Thermodynamic Characteristics. A more thorough analysis would be required before definite conclusions could be drawn; nevertheless, certain characteristics appear evident. The heat input per barrel would not be greater than in a conventional rifle. Heat dissipation would likewise be somewhat similar to that of a conventional barrel. However, the tendency may be more severe due to three chambers radiating heat toward the center of the cylinder. This would expose the operating rod to greater temperatures than normal. The influence of positioning the three barrels in the proposed triangular arrangement, would not be expected to create any special problems.

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Oct 1, 1956



GAS CYLINDER DESIGN #3

FIGURE 12

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

g. Barrel Cluster. (Contd.)

(2) Flexural Rigidity. The flexural rigidity of the barrels as a unit would be increased by a factor of ten over that of a single barrel (see paragraph 6b). This should effect a considerable reduction in the dispersion caused by vibration in a comparable single barrel.

(3) Alignment. From a production standpoint, the cluster arrangement could create a considerable alignment problem. To the normal problem of drawing the barrels in proper alignment against the breech ring is added the further complication of clamping them at the muzzle end. The front hand grip, gas cylinder, and anti-twist mechanism are also clamped to the barrels imposing additional strains. The problem of assigning tolerances to maintain the alignment necessary to produce a consistent shot pattern from weapon to weapon may make such an arrangement extremely difficult.

h. Handling Characteristics. The silhouette of the proposed design is acceptable, although the line of action of the recoil force should preferably be lower. Certain physical characteristics of the weapon are considered below.

(1) Weight and Center of Gravity. The calculated weight of the proposed rifle with empty magazine is 9.09 pounds with an aluminum stock and receiver and 9.652 pounds with a titanium stock and receiver (see paragraph 6c). This compares favorably with the 9.7-pound weight of the M1 rifle. A comparable three-barreled weapon with conventional action would be considerably heavier (see SA-TR11-3101). The center of gravity has been calculated for both aluminum and titanium stocks and receivers. As indicated in the calculations, the center of gravity is found to be from 1.17 to 1.92 inches forward of the center of the rotor ball bearings and from 0.61 to 0.83 inch below the centerline of the

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(U) 3. DISCUSSION AND ANALYSIS: (Contd.)

h. Handling Characteristics. (Contd.)

operating rod (see Figure 13). Although the fore and aft location of the center of gravity is not in the immediate vicinity of the magazine, it is suitably located between the front and rear hand grips and is, therefore, not unfavorably located with respect to handling and firing.

- (2) Free Recoil Energy. When a rifle is fired, the rearward momentum of the rifle is equal to the sum of the momentums of the projectile and the propellant gases. The resultant kinetic energy, which must be absorbed by the person firing the weapon, is known as the free recoil energy. Obviously, excessive free recoil energy would render the weapon impractical, since the use of such a weapon could result in acute discomfort or actual injury from excessive shoulder impact. However, by deflecting a part of the propellant gases to exert a forward thrust at the muzzle of the rifle, the free recoil energy can be substantially reduced. The free recoil energy of the salvo rifle has been computed (paragraph 6d) for the rifle itself and for the rifle equipped with muzzle brakes. Without muzzle brakes, the rifle has a calculated energy of 23.65 foot-pounds. This is approximately two times the 12.9 foot-pounds experienced with the M1 rifle. When equipped with muzzle brakes, the calculated recoil energy is 10.6 foot-pounds, which is less than that of the M1 rifle. Thus, it may be concluded that the weapon would not be practical without muzzle brakes; however, when equipped with muzzle brakes, the weapon could be fired by the average person.
- (3) Noise Level. The noise level of the proposed weapon cannot be predicted. It is possible that, even when equipped with muzzle brakes, the blast pattern produced by the three barrels could be objectionable and contribute a fatigue factor to use of the weapon.

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1

C.G. - BUFFER

C.G. - COATING

C.G. - STOCK (AL.)

C.G. - RETAINER SPA REAR

C.G. - OPERATING ROD

C.G. - REAR SIGHT

C.G. - RETAINER SPG.

C.G. - GRIP R



2

U.G. ROTOR & STRIKERS

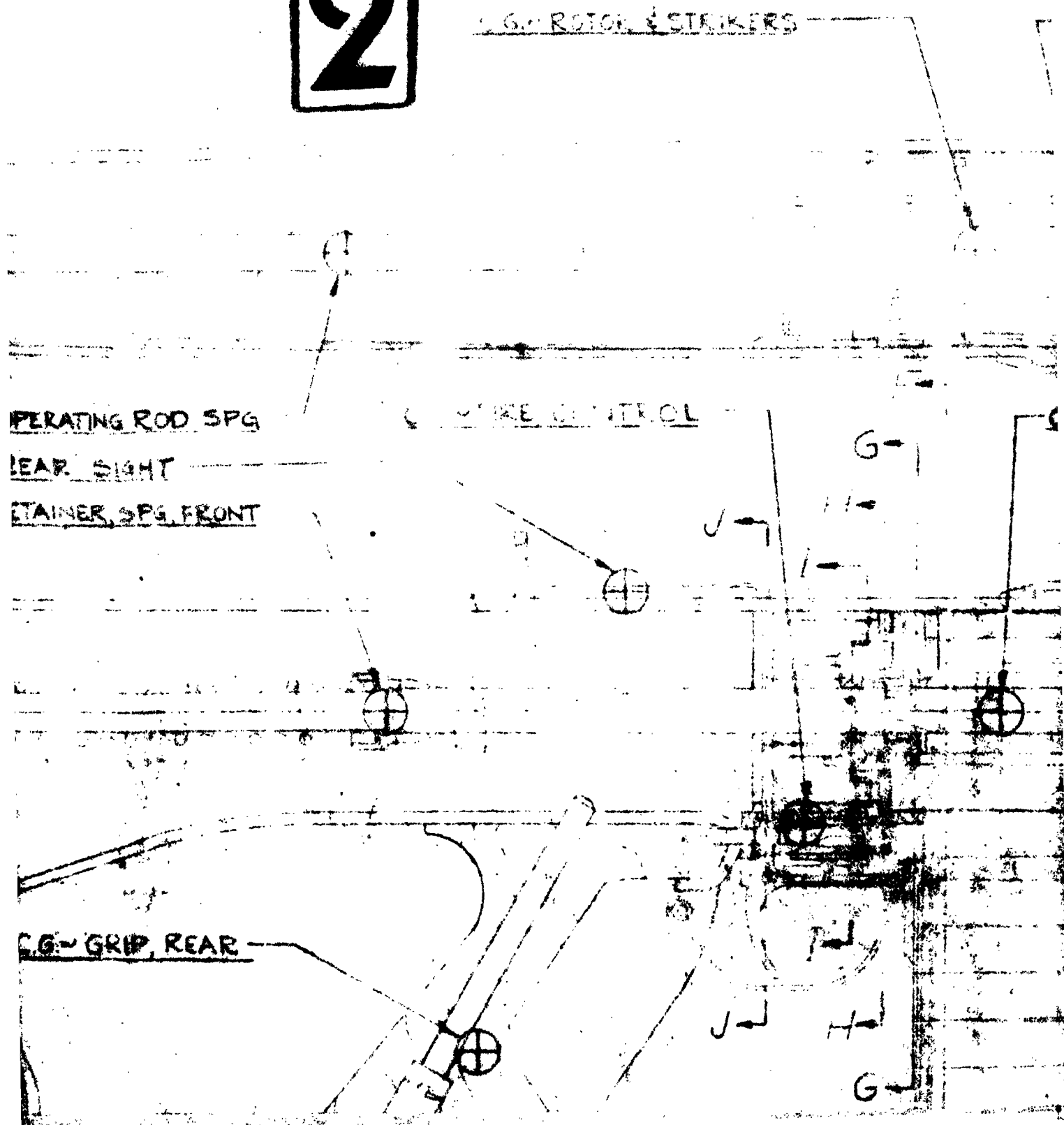
OPERATING ROD SPG

REAR SIGHT

RETAINER, SPG, FRONT

WIRE CONTROL

U.G. GRIP, REAR



3

C.G. - BOLT & CHAMBERING LINE

C.G. - OPERATING ROD

C.G. - RECEIVER

C.G. - BREECH RING

C.G. - (3) ROUNDS (CHAMBERED)

C.G. - WEAPON - AL.
STOCK & REC'R

C.G. - WEAPON - TI. STOCK & REC'R

12.0

1.17
1.27

1.72
1.31

4

C.G. ~ GAS CYLINDER

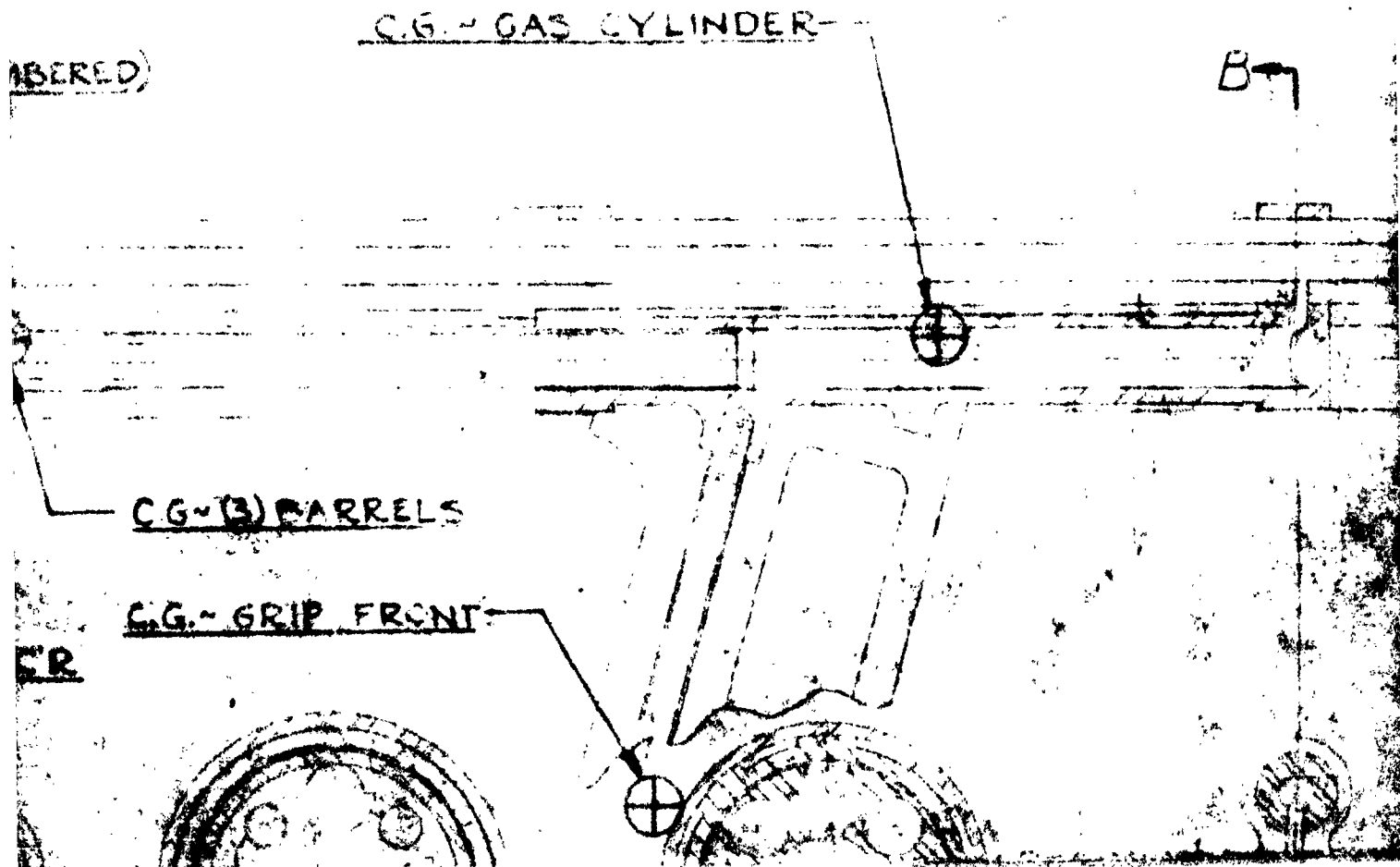
B-7

BERED)

C.G. ~ (3) BARRELS

C.G. ~ GRIP FRONT

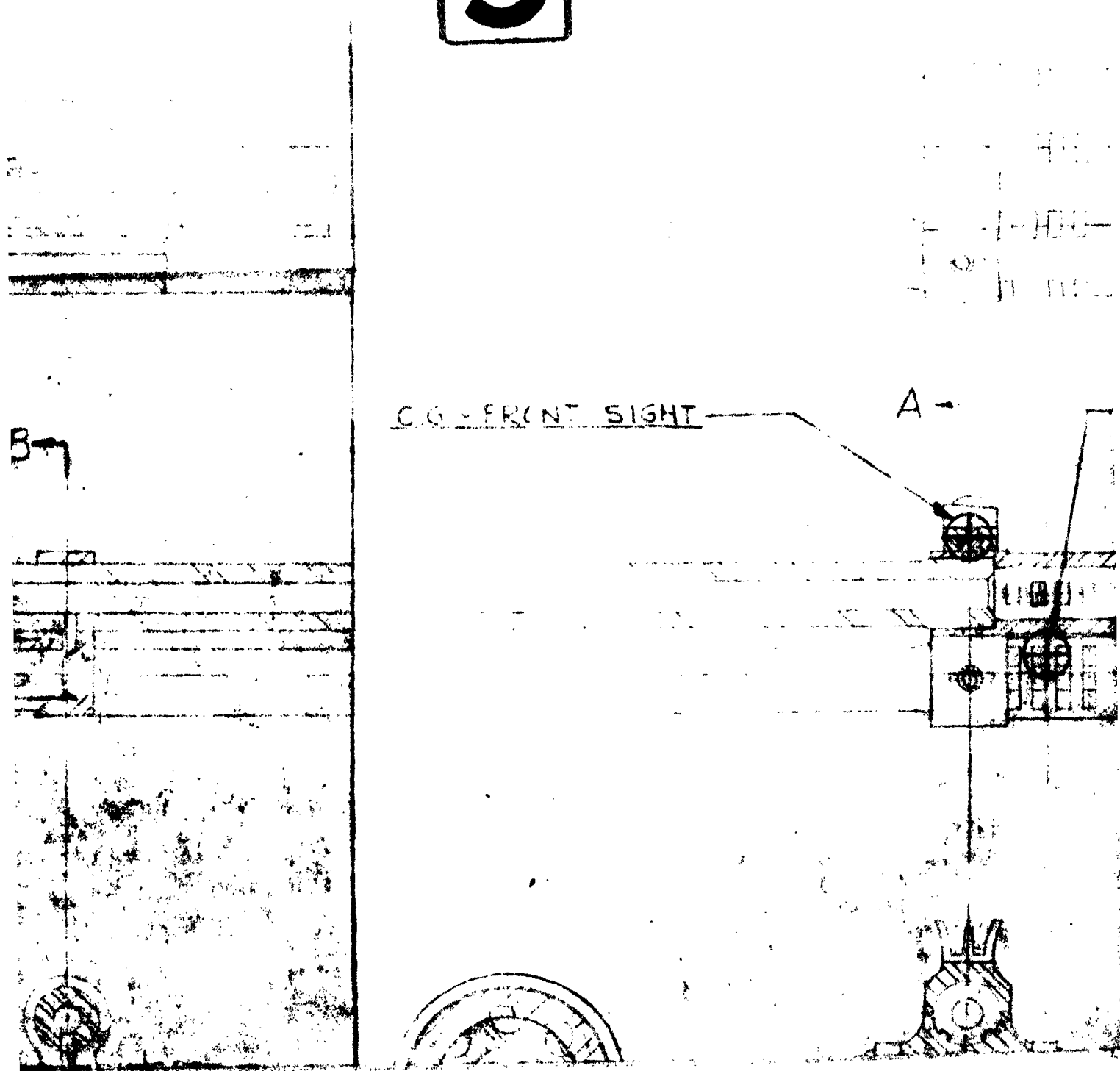
ER



5

C.G. - FRONT SIGHT

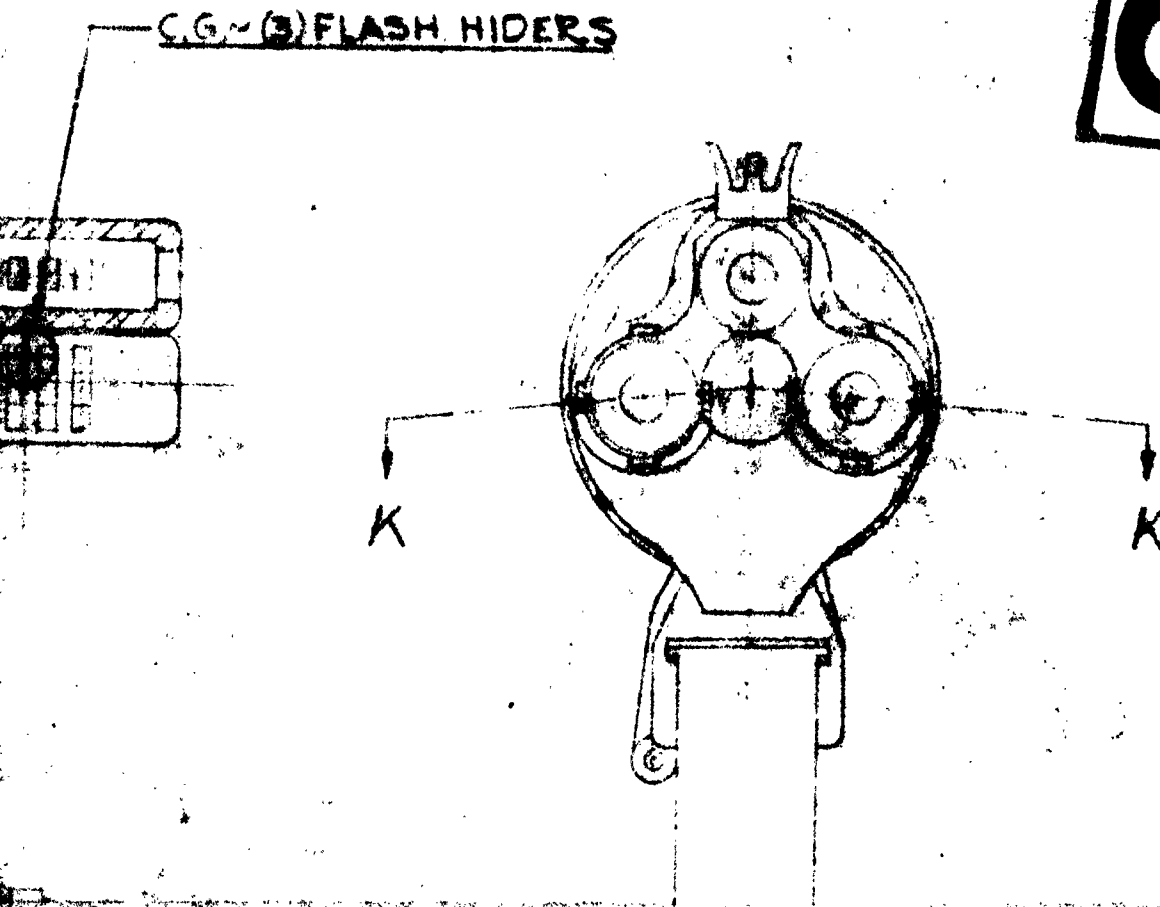
A -



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6

C.G. (3) FLASH HIDERS



C.G. - BUFFER

C.G. - COATING

C.G. - STOCK (AL)

C.G. - RETAINER, S&A REAR

C.G. - OPERATING ROD

C.G. - REAR SIGHT

C.G. - RETAINER, SFG F

C.G. - GRIP RE

7

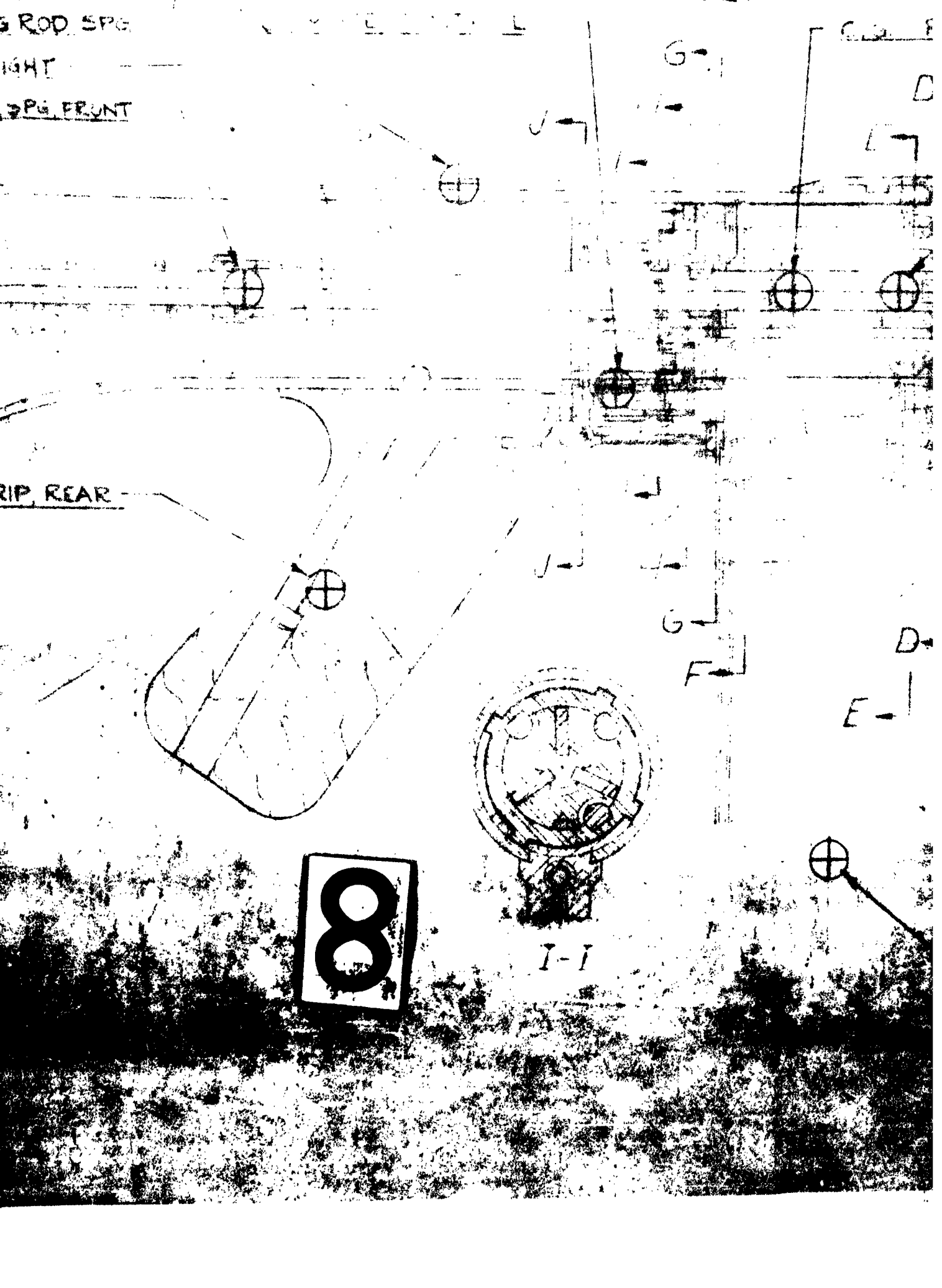
G-G

ROD SPG

RIGHT

SPG FRONT

WIP, REAR



C.G. - BREACH FING

C.G. - BREACH FING

C.G. - 3 ROUNDS (CHAMBERED)

C.G. - WEAPON - AL.
STOCK & REC'R

C.G. - WEAPON - T1 STOCK & REC'R

C.G.

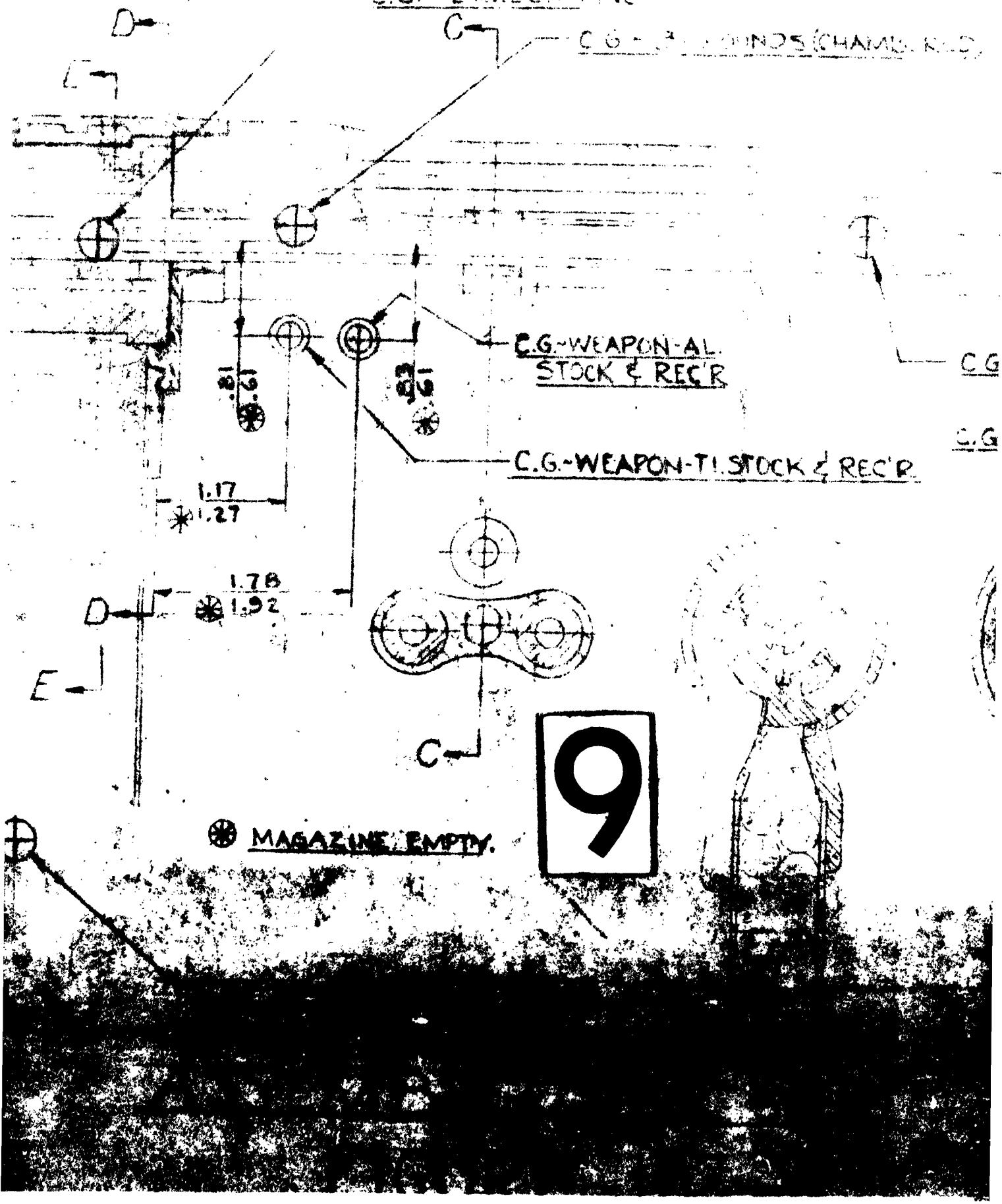
C.G.

1.17
1.27

1.78
1.92

MAGAZINE EMPTY.

9



HAMBERED

C.G. - GAS CYLINDER

B

C.G. - (3) BARRELS

C.G. - GRIP FRONT

REC'R

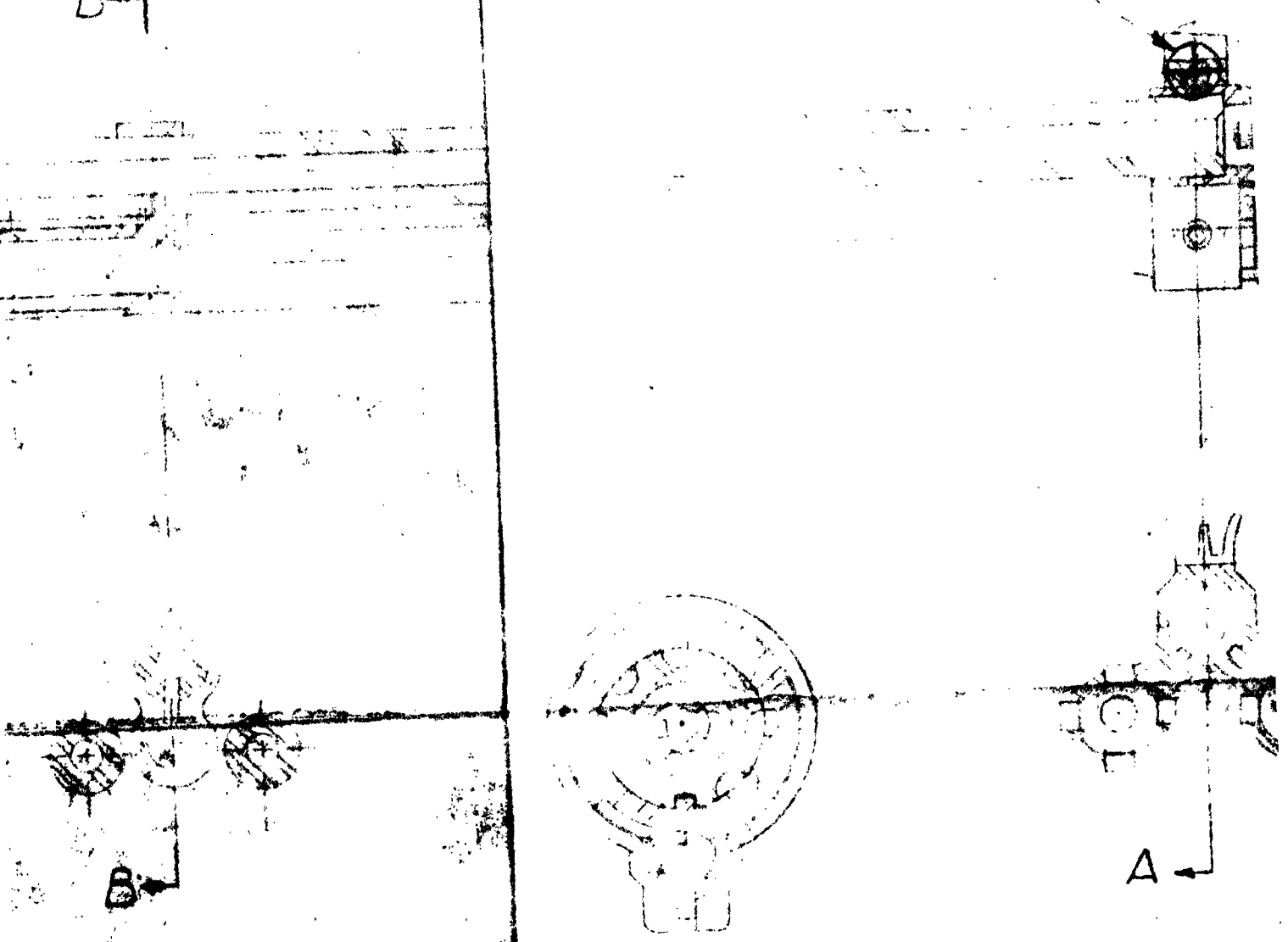
B

10

CALIBRENT SIGHT -

A -

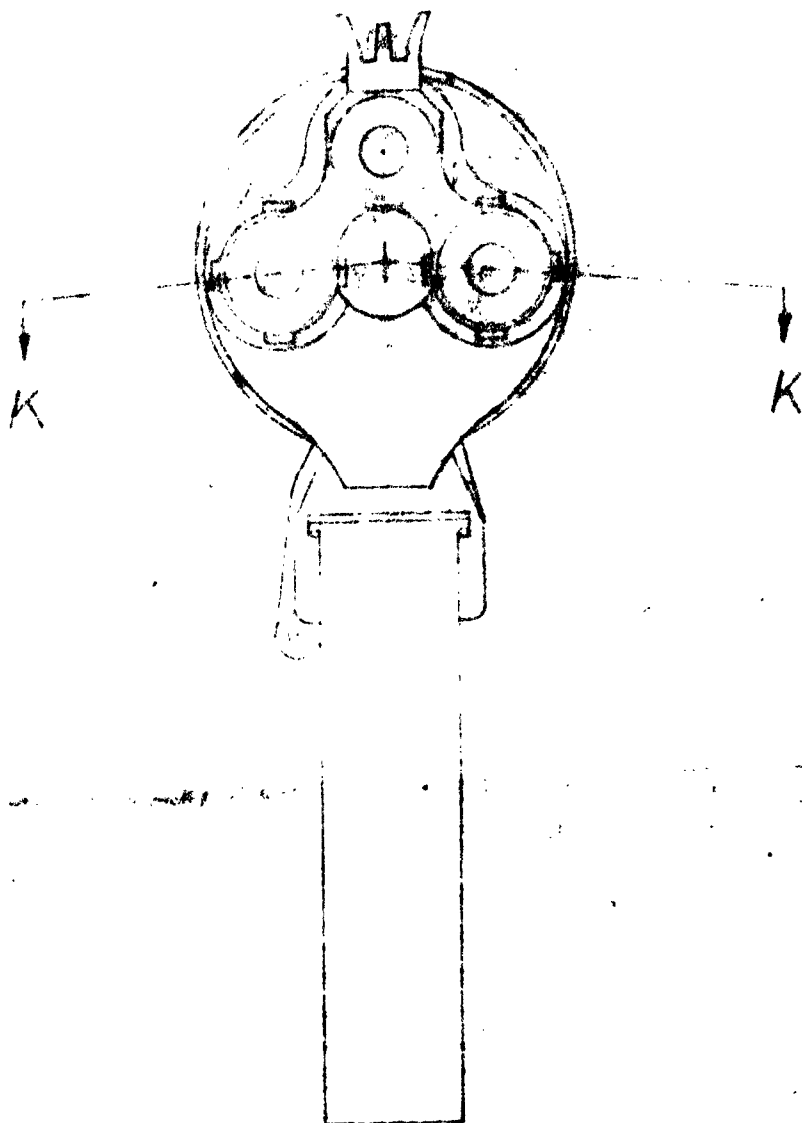
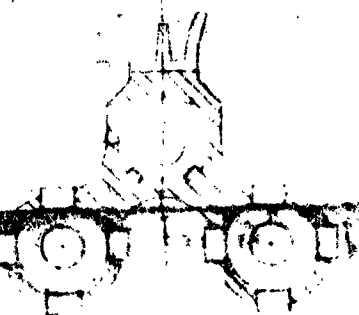
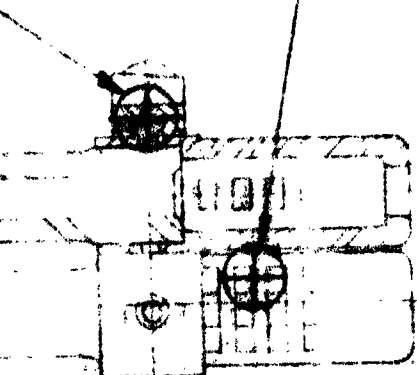
B -



11

A -

CGM (3) FLASH HIDERS



12

Clair C. Fisher
Nov 1, 1955

Witnessed and understood
Signed & Corbett 18.6.1956
Witnessed and understood
Signed W. Scholtz 1 Feb. 1956

13

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(U) 4. EVALUATION OF THE WEAPON:

a. A weapon of the proposed design would have an acceptable military silhouette and handling qualities. As a production weapon, alignment problems might make it difficult to obtain reproducible accuracy characteristics from weapon to weapon.

b. A hammer-actuated firing mechanism would be preferable to the sear-striker system of the proposed design, since the variables contributing to a ripple-fire effect would be reduced and greater simplicity of design could be obtained.

c. The rotary feeding and ejection system appears feasible and would permit a weight reduction greater than is possible with conventional mechanisms. There may be structural weaknesses not apparent without a thorough stress analysis.

d. The absence of sliding or bearing contact of parts with the receiver would make it possible to fabricate this component from materials other than steel.

e. The recoil energy of such a weapon would require the use of muzzle brakes. This could result in an objectionable blast pattern.

(U) 5. PROJECTED DEVELOPMENT:

Upon termination of this project, a number of areas of the proposed design were felt to require further effort. These areas are listed below:

a. Redesign of the fire-control system.

b. Analysis and determination of the use of materials.

c. Adoption of three magazines or a magazine of greater capacity for increasing firepower.

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(U) 5. PROJECTED DEVELOPMENT: (Contd.)

d. Analysis to decrease the rotary action of the rotor from 275 degrees to 180 degrees or less.

e. Replacement of the three spring-loaded strikers with a single cylindrical hammer and three firing pins.

f. Replacement of the 3/8-inch operating rod with a 1/2-inch rod, if required.

g. Repositioning of the operating rod anti-twist mechanism to a location closer to the rotor cam followers, or redesign to provide an offset in the operating rod.

h. Redesign and simplification of the bolt and rotor.

i. Study and evaluation of the proposed gas systems.

(C) 6. CALCULATIONS:

(C) a. Rotor Feed Analysis.

(C) (1) Magazine Feed Rate. Figure 14 is a sketch of a cross section of the magazine used in this analysis. On the basis of the dimensions shown, the magazine feed rate data were calculated; these data are listed in Table I. The following dimensions, weights, and formulae were of especial use in the calculations:

(U) (a) Cartridge Elevations During Feeding.

| | |
|-----------------------|-----------------|
| Top round (being fed) | Elevated 0.378" |
| Next round (No. 23) | Elevated 0.372" |
| Next round (No. 22) | Elevated 0.330" |
| Next round (No. 21) | Elevated 0.274" |
| Remaining rounds | Elevated 0.258" |

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- (C) 6, CALCULATIONS: (Contd.)
 (C) a. Rotor Feed Analysis. (Contd.)
 (C) (1) Magazine Feed Rate. (Contd.)
 (U) (a) Cartridge Elevations During Feeding. (Contd.)

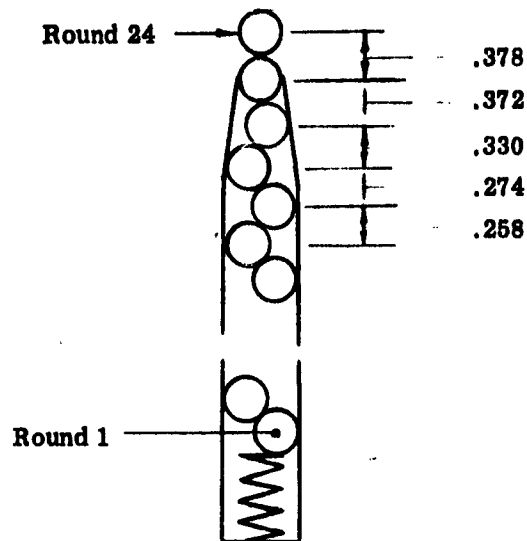


FIGURE 14

(C) (b) Weights.

- W_1 = Weight of one round of ammunition = 0.021 lb.
 W_2 = Weight of magazine follower* = 0.044 lb.
 W_s = One-half weight of magazine spring* = $1/2$ (0.035)
 = 0.0175 lb.
 nW_1 = Total weight of ammunition in magazine where
 n = no. of cartridges in magazine.

* Note: Weights of magazine follower and magazine spring assumed approximately same as those of T44E4 Rifle.

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(C) 6. CALCULATIONS: (Contd.)

(c) a. Rotor Feed Analysis. (Contd.)

(c) (1) Magazine Feed Rate. (Contd.)

(c) (c) Formulae.

$$f = M_t a = \frac{W_t}{g} a \quad (1)$$

where

f = magazine spring force at specified spring extension from full load compressed height
 M_t = total mass accelerated by magazine spring
 a = acceleration of cartridge from magazine into rotor cavities
 g = acceleration due to force of gravity = 32.2 ft/sec²
 $W_t = nW_1 + W_2 + W_3$
 $= nW_1 + 0.044 \text{ lb.} + 0.0175 \text{ lb.}$

$$\begin{aligned} a &= \frac{fg}{W_t} \quad (2) \\ &= \frac{fg}{nW_1 + W_2 + W_3} \\ &= \frac{32.2f}{0.021n + 0.0615} \end{aligned}$$

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(c) 6. CALCULATIONS: (Contd.)

(c) a. Rotor Feed Analysis. (Contd.)

(c) (1) Magazine Feed Rate. (Contd.)

(c) (c) Formulae. (Contd.)

$$f = F - k\Delta \quad (3)$$

where

f = magazine spring force at specified spring extension from full load compressed height
 F = magazine spring force with full magazine = 15 lb.
 k = magazine spring index (assumed 2 lbs./in.)
 Δ = magazine spring extension from full load compressed height.

$$t^2 = \frac{2(s - v_0 t)}{a} \quad (4)$$

$$t = \sqrt{\frac{2(s - v_0 t)}{a}}$$

where

t = time in seconds required for cartridge elevation
 v_0 = initial velocity of cartridge
 a = uniform acceleration of cartridge
 s = distance from magazine to center of cartridge rotor cavity.

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(C) TABLE I. MAGAZINE FEED RATE

| <u>n</u> | <u>nW₁</u> (lbs.) | <u>W_t</u> (lbs.) | <u>f</u> (lbs.) | <u>a</u> (ft/sec ²) | <u>t</u> (Seconds) |
|----------|---------------------------------|--------------------------------|--------------------|------------------------------------|-----------------------|
| 24 | 0.504 | 0.5655 | 15.0 | 854 | 0.00859 |
| 23 | 0.483 | 0.5445 | 14.484 | 857 | 0.00857 |
| 22 | 0.462 | 0.5234 | 13.968 | 859 | 0.00856 |
| 21 | 0.441 | 0.5025 | 13.452 | 862 | 0.00855 |
| 20 | 0.420 | 0.4815 | 12.936 | 865 | 0.00853 |
| 19 | 0.399 | 0.4605 | 12.420 | 868 | 0.00852 |
| 18 | 0.378 | 0.4395 | 11.904 | 872 | 0.00850 |
| 17 | 0.357 | 0.4185 | 11.388 | 876 | 0.00848 |
| 16 | 0.336 | 0.3975 | 10.872 | 881 | 0.00846 |
| 15 | 0.315 | 0.3765 | 10.356 | 886 | 0.00843 |
| 14 | 0.294 | 0.3555 | 9.840 | 891 | 0.00841 |
| 13 | 0.273 | 0.3345 | 9.324 | 897 | 0.00838 |
| 12 | 0.252 | 0.3135 | 8.808 | 905 | 0.00834 |
| 11 | 0.231 | 0.2925 | 8.292 | 913 | 0.00831 |
| 10 | 0.210 | 0.2715 | 7.776 | 922 | 0.00827 |
| 9 | 0.189 | 0.2505 | 7.260 | 933 | 0.00822 |
| 8 | 0.168 | 0.2295 | 6.744 | 946 | 0.00816 |
| 7 | 0.147 | 0.2085 | 6.228 | 962 | 0.00809 |
| 6 | 0.126 | 0.1875 | 5.712 | 981 | 0.00801 |
| 5 | 0.105 | 0.1665 | 5.196 | 1005 | 0.00792 |
| 4 | 0.084 | 0.1455 | 4.680 | 1036 | 0.00780 |
| 3 | 0.063 | 0.1245 | 4.132 | 1069 | 0.00768 |
| 2 | 0.042 | 0.1035 | 3.472 | 1080 | 0.00764 |
| 1 | 0.021 | 0.0825 | 2.728 | 1065 | 0.00769 |

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(c) 6. CALCULATIONS: (Contd.)

(c) a. Rotor Feed Analysis. (Contd.)

- (c) (2) Rate of Fire. The calculated rate of fire was based on round No. 21 (first round of the second salvo). As the first salvo is hand charged, calculations were based on the slowest round of the first automatic salvo. From Table No. 1, it is noted that the time which must be allowed to lift Cartridge No. 21 from the magazine to its proper seating in the three-lobed face bolt and rotor cavity is 0.00855 seconds; and, from the Salvo Gun Layout, the rotor must rotate 84 degrees during the feeding of Cartridge No. 21. Therefore the rate of rotation of the rotor is calculated as follows:

Maximum rotation of rotor during feeding of Cartridge

$$\text{No. 21} = \frac{84}{360} \times \frac{1}{0.00855} = 27.3 \text{ rps.} = 1640 \text{ rpm.}$$

The maximum possible rotation of the rotor from the Salvo Gun Layout is 276 degrees or 0.767 revolutions. With the maximum rate of rotation of the rotor at 1640 revolutions per minute, the average rate of rotation is assumed to be $\frac{2}{3} \times 1640$ revolutions per minute or 1093 revolutions per minute. Therefore, the time consumed during 0.767 revolutions is 0.042 seconds.

The time required to rotate 276 degrees clockwise for ejection of the three cartridge cases and 276 degrees counterclockwise for feeding of three cartridges will be $2 \times 0.042 = 0.084$ seconds. The rotary action for the ejection of the three cartridge cases and the feeding of the successive three cartridges consumes 42.3 per cent of the cyclic time as shown by the calculations following:

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(C) 6. CALCULATIONS: (Contd.)

(C) a. Rotor Feed Analysis. (Contd.)

(C) (2) Rate of Fire. (Contd.)

Total length of action rod travel = 4.705 inches
Rod travel required to rotate rotor 276 degrees = 2.00 inches
Percentage of stroke for 276 degrees rotation = $2.00/4.705$
(100%) = 42.3%

From this analysis, it is indicated that the cyclic period is
 $0.084/0.423 = 1.99$ seconds, which is equivalent to 5 salvos
per second or 300 salvos per minute or 900 rounds per minute.

- (U) b. Flexural Rigidity of Barrels. The flexural rigidity of the three barrels as a unit in the salvo weapon will be increased by a factor of ten over that of a single barrel weapon. Generally, considering the barrel deflection as that of a cantilever beam carrying a uniformly distributed load, the maximum deflection would be:

$$d = \frac{WL^4}{8EI}$$

where: d = maximum deflection, inches
W = uniformly distributed load, lbs.
L = barrel length, inches
E = Modulus of Elasticity, lb/in²
I = Moment of Inertia of section, inches⁴

For the three barrel configuration, the I is thirty times greater while the W is increased only three times; therefore the deflection for the three barrel weapon is 1/10 of the deflection for a single barrel weapon.

Single Barrel

$$d = \frac{WL^4}{8EI}$$

Three Barrel

$$d_{3 \text{ bbl.}} = \frac{3WL^4}{8E \cdot 30I} = \frac{WL^4}{80EI}$$

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(c) 6. CALCULATIONS: (Contd.) ,

- (c) c. Weight and Center of Gravity. The weight and center of gravity of the proposed design were calculated for four sets of conditions. Center of gravity calculations were made with reference to the centerline of the operating rod and the rotor ball bearings in the breech ring. The results are tabulated in Tables II-V and are summarized below.

Aluminum Stock and Receiver

| <u>Full Magazine</u> | | <u>Empty Magazine</u> | |
|----------------------|---------------------------|-----------------------|-------------------------|
| C. G. | * \bar{x} = 1.78 inches | C. G. | \bar{x} = 1.92 inches |
| | ** \bar{y} = -0.83 inch | | \bar{y} = -0.61 inch |
| Weight: | 9.540 pounds | Weight: | 9.099 pounds |

Titanium Stock and Receiver

| <u>Full Magazine</u> | | <u>Empty Magazine</u> | |
|----------------------|-------------------------|-----------------------|-------------------------|
| C. G. | \bar{x} = 1.17 inches | C. G. | \bar{x} = 1.27 inches |
| | \bar{y} = -0.81 inch | | \bar{y} = -0.61 inch |
| Weight: | 10.093 pounds | Weight: | 9.652 pounds |

* \bar{x} plus toward muzzle, minus toward stock

** \bar{y} plus above operating rod, minus below

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(C) TABLE II. CALCULATION OF CENTER OF GRAVITY ASSUMING
ALUMINUM STOCK AND RECEIVER AND FULL MAGAZINE

| <u>Component</u> | <u>Material</u> | <u>W</u> <u>Weight</u> <u>(lbs)</u> | <u>x-</u> <u>Distance</u> <u>(inches)</u> | <u>Wx</u> <u>(#")</u> | <u>y-</u> <u>Distance</u> <u>(inches)</u> | <u>Wy</u> <u>(#")</u> |
|------------------------|-----------------|---|---|--|---|--------------------------|
| Rotor & Strikers | (Steel) | 0.454 | - 1.84 | - 0.84 | 0. | 0. |
| Bolt & Chambering Ring | (Steel) | 0.114 | - 0.90 | - 0.10 | 0. | 0. |
| Three Barrels | (Steel) | 3.000 | + 6.30 | +18.90 | +0.14 | + .42 |
| Three Flash Hiders | (Steel) | 0.309 | +22.38 | + 6.92 | +0.14 | + .04 |
| Front Sight | (Steel) | 0.218 | +21.78 | + 4.75 | +1.04 | + .23 |
| Rear Sight | (Steel) | 0.056 | - 4.79 | - 0.27 | +0.98 | + .05 |
| Grip (Rear) | (Wood) | 0.169 | - 6.00 | - 1.01 | -2.77 | - .47 |
| Grip (Front) | (Wood) | 0.169 | +10.50 | + 1.78 | -2.77 | - .47 |
| Operating Rod Spring | (Steel) | 0.107 | - 7.14 | - 0.76 | 0. | 0. |
| Receiver | (Alum) | 0.240 | - 1.60 | - 0.38 | 0. | 0. |
| Operating Rod | (Steel) | 0.904 | + 0.89 | + 0.80 | 0. | 0. |
| Gas Cylinder | (Steel) | 0.370 | +12.35 | + 4.57 | +0.14 | + .05 |
| Fire Control | (Steel) | 0.100 | - 3.22 | - 0.32 | -0.92 | - .09 |
| Breech Ring | (Steel) | 0.782 | - 0.60 | - 0.47 | 0. | 0. |
| Magazine & 21 Rounds | (Steel) | 1.313 | - 1.21 | - 1.59 | -5.30 | -6.96 |
| 3 Rounds in Chamber | | 0.063 | + 1.18 | + 0.07 | +0.14 | + .01 |
| Coating | (Rubber) | 0.300 | -14.75 | - 4.43 | -1.07 | - .32 |
| Stock | (Alum) | 0.570 | -12.75 | - 7.27 | -0.71 | - .40 |
| Buffer | (Rubber) | 0.102 | -16.05 | - 1.64 | 0. | 0. |
| Spring Retainer; Rear | (Steel) | 0.100 | -10.50 | - 1.05 | 0. | 0. |
| Spring Retainer; Front | (Steel) | 0.100 | - 6.80 | - 0.68 | 0. | 0. |
| Totals | | 9.540 | | +16.98 | | -7.91 |
| | | $\bar{x} = \frac{+16.98}{9.54} = 1.78"$ | | $\bar{y} = \frac{7.91}{9.54} = -0.83"$ | | |

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(C) TABLE III. CALCULATION OF CENTER OF GRAVITY ASSUMING
ALUMINUM STOCK AND RECEIVER AND EMPTY MAGAZINE

| <u>Component</u> | <u>Material</u> | <u>W</u> <u>Weight</u> (lbs) | <u>x-</u> <u>Distance</u> (inches) | <u>Wx</u> (#") | <u>y-</u> <u>Distance</u> (inches) | <u>Wy</u> (#") |
|-------------------------|-----------------|------------------------------------|--|-------------------|--|-------------------|
| Rotor & Strikers | (Steel) | 0.454 | - 1.84 | - 0.84 | 0. | 0. |
| Bolt & Chambering Ring | (Steel) | 0.114 | - 0.90 | - 0.10 | 0. | 0. |
| Three Barrels | (Steel) | 3.000 | + 6.30 | +18.90 | +0.14 | +0.42 |
| Three Flash Hiders | (Steel) | 0.309 | +22.38 | + 6.92 | +0.14 | +0.04 |
| Front Sight | (Steel) | 0.218 | +21.78 | + 4.75 | +1.04 | +0.23 |
| Rear Sight | (Steel) | 0.056 | - 4.79 | - 0.27 | +0.98 | +0.05 |
| Grip (Rear) | (Wood) | 0.169 | - 6.00 | - 1.01 | -2.77 | -0.47 |
| Grip (Front) | (Wood) | 0.169 | +10.50 | + 1.78 | -2.77 | -0.47 |
| Operating Rod Spring | (Steel) | 0.107 | - 7.14 | - 0.76 | 0. | 0. |
| Receiver | (Alum.) | 0.240 | - 1.60 | - 0.38 | 0. | 0. |
| Operating Rod | (Steel) | 0.904 | + 0.89 | + 0.80 | 0. | 0. |
| Gas Cylinder | (Steel) | 0.370 | +12.35 | + 4.57 | +0.14 | +0.05 |
| Fire Control | (Steel) | 0.100 | - 3.22 | - 0.32 | -0.92 | -0.09 |
| Breech Ring | (Steel) | 0.782 | - 0.60 | - 0.47 | 0. | 0. |
| Magazine (Empty) | (Steel) | 0.872 | - 1.21 | - 1.06 | -5.30 | -4.62 |
| 3 Rounds in Chamber | | 0.063 | + 1.18 | + 0.07 | +0.14 | +0.01 |
| Coating | (Rubber) | 0.300 | -14.75 | - 4.43 | -1.07 | -0.32 |
| Stock | (Alum.) | 0.570 | -12.75 | - 7.27 | -0.71 | -0.40 |
| Buffer | (Rubber) | 0.102 | -16.05 | - 1.64 | 0. | 0. |
| Spring Retainer (Rear) | (Steel) | 0.100 | -10.50 | - 1.05 | 0. | 0. |
| Spring Retainer (Front) | (Steel) | 0.100 | - 6.80 | - 0.68 | 0. | 0. |
| Totals | | 9.099 | | +17.51 | | -5.57 |

$$x = \frac{+17.51}{9.099} = +1.92''$$

$$y = \frac{-5.57}{9.099} = -0.61''$$

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(C) TABLE IV. CALCULATION OF CENTER OF GRAVITY ASSUMING
TITANIUM STOCK AND RECEIVER AND FULL MAGAZINE

| <u>Component</u> | <u>Material</u> | <u>W</u> <u>Weight</u> <u>(lbs)</u> | <u>x-</u> <u>Distance</u> <u>(inches)</u> | <u>Wx</u> <u>(#")</u> | <u>y-</u> <u>Distance</u> <u>(inches)</u> | <u>Wy</u> <u>(#")</u> |
|--|-----------------|---|---|---|---|--------------------------|
| Rotor & Strikers | (Steel) | 0.454 | - 1.84 | - 0.84 | 0. | 0. |
| Bolt & Chambering Ring | (Steel) | 0.114 | - 0.90 | - 0.10 | 0. | 0. |
| Three Barrels | (Steel) | 3.000 | + 6.30 | +18.90 | +0.14 | +0.42 |
| Three Flash Hiders | (Steel) | 0.309 | +22.38 | + 6.92 | +0.14 | +0.04 |
| Front Sight | (Steel) | 0.218 | +21.78 | + 4.75 | +1.04 | +0.23 |
| Rear Sight | (Steel) | 0.056 | - 4.79 | - 0.27 | +0.98 | +0.05 |
| Grip (Rear) | (Wood) | 0.169 | - 6.00 | - 1.01 | -2.77 | -0.47 |
| Grip (Front) | (Wood) | 0.169 | +10.50 | + 1.78 | -2.77 | -0.47 |
| Operating Rod Spring | (Steel) | 0.107 | - 7.14 | - 0.76 | 0. | 0. |
| Receiver | (Titanium) | 0.404 | - 1.60 | - 0.64 | 0. | 0. |
| Operating Rod | (Steel) | 0.904 | + 0.89 | + 0.80 | 0. | 0. |
| Gas Cylinder | (Steel) | 0.370 | +12.35 | + 4.57 | +0.14 | +0.05 |
| Fire Control | (Steel) | 0.100 | - 3.22 | - 0.32 | -0.92 | -0.09 |
| Breech Ring | (Steel) | 0.782 | - 0.60 | - 0.47 | 0. | 0. |
| Magazine & 21 Rounds | (Steel) | 1.313 | - 1.21 | - 1.59 | -5.30 | -6.96 |
| 3 Rounds in Chamber | | 0.063 | + 1.18 | + 0.07 | +0.14 | +0.01 |
| Coating | (Rubber) | 0.300 | -14.75 | - 4.43 | -1.07 | -0.32 |
| Stock | (Titanium) | 0.959 | -12.75 | -12.23 | -0.71 | -0.68 |
| Buffer | (Rubber) | 0.102 | -16.05 | - 1.64 | 0. | 0. |
| Spring Retainer (Rear) | (Steel) | 0.100 | -10.50 | - 1.05 | 0. | 0. |
| Spring Retainer (Front) | (Steel) | 0.100 | - 6.80 | - 0.68 | 0. | 0. |
| Totals | | 10.093 | | +11.76 | | -8.19 |
| $\bar{x} = \frac{+11.76}{10.093} = +1.17"$ | | | | $\bar{y} = \frac{-8.19}{10.093} = -0.81"$ | | |

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(C) TABLE V. CALCULATION OF CENTER OF GRAVITY ASSUMING
TITANIUM STOCK AND RECEIVER AND EMPTY MAGAZINE

| <u>Component</u> | <u>Material</u> | <u>W</u> <u>Weight</u> <u>(lbs)</u> | <u>x-</u> <u>Distance</u> <u>(inches)</u> | <u>Wx</u> <u>(#")</u> | <u>y-</u> <u>Distance</u> <u>(inches)</u> | <u>Wy</u> <u>(#")</u> |
|-------------------------|-----------------|---|---|--------------------------|---|--------------------------|
| Rotor & Strikers | (Steel) | 0.454 | - 1.84 | - 0.84 | 0. | 0. |
| Bolt & Chambering Ring | (Steel) | 0.114 | - 0.90 | - 0.10 | 0. | 0. |
| Three Barrels | (Steel) | 3.000 | + 6.30 | +18.90 | +0.14 | +0.42 |
| Three Flash Hiders | (Steel) | 0.309 | +22.38 | + 6.92 | +0.14 | +0.04 |
| Front Sight | (Steel) | 0.218 | +21.78 | + 4.72 | +1.04 | +0.23 |
| Rear Sight | (Steel) | 0.056 | - 4.79 | - 0.27 | +0.98 | +0.05 |
| Grip (Rear) | (Wood) | 0.169 | - 6.00 | - 1.01 | -2.77 | -0.47 |
| Grip (Front) | (Wood) | 0.169 | +10.50 | + 1.78 | -2.77 | -0.47 |
| Operating Rod Spring | (Steel) | 0.107 | - 7.14 | - 0.76 | 0. | 0. |
| Receiver | (Titanium) | 0.404 | - 1.60 | - 0.64 | 0. | 0. |
| Operating Rod | (Steel) | 0.904 | + 0.89 | + 0.80 | 0. | 0. |
| Gas Cylinder | (Steel) | 0.370 | +12.35 | + 4.57 | +0.14 | +0.05 |
| Fire Control | (Steel) | 0.100 | - 3.22 | - 0.32 | -0.92 | -0.09 |
| Breech Ring | (Steel) | 0.782 | - 0.60 | - 0.47 | 0. | 0. |
| Magazine (Empty) | (Steel) | 0.872 | - 1.21 | - 1.06 | -5.30 | -4.62 |
| 3 Rounds in Chamber | | 0.063 | + 1.18 | + 0.07 | +0.14 | +0.01 |
| Coating | (Rubber) | 0.300 | -14.75 | - 4.43 | -1.07 | -0.32 |
| Stock | (Titanium) | 0.959 | -12.75 | -12.23 | -0.71 | -0.68 |
| Buffer | (Rubber) | 0.102 | -16.05 | - 1.64 | 0. | 0. |
| Spring Retainer (Rear) | (Steel) | 0.100 | -10.50 | - 1.05 | 0. | 0. |
| Spring Retainer (Front) | (Steel) | 0.100 | - 6.80 | - 0.68 | 0. | 0. |
| Totals | | 9.652 | | +12.26 | | -5.85 |

$$\bar{x} = \frac{+12.26}{9.652} = +1.27''$$

$$\bar{y} = \frac{-5.85}{9.652} = -0.61''$$

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(c) 6. CALCULATIONS: (Contd.)

(c) d. Free Recoil Energy.

- (c) W_r = Rifle weight - 9.1 lbs (from TABLE III)
 W_b = Bullet weight - 55/7000 lbs
 W_p = Propellant weight - 21 grains
 V_r = Free recoil velocity of rifle
 V_b = Muzzle velocity of bullet - 3200 fps
 V_e = Effective escape velocity of powder gases
- 4,700 fps (Tschappet, Macfarland)

(C) Bullet Energy Rate (3 Shot Salvo)

$$\begin{aligned} M_b &= W_b V_b \\ M_b &= 3(55/7000) 3200 \\ M_b &= 75.43 \text{ lb-ft/sec} \end{aligned}$$

(c) Gas Energy Rate

$$\begin{aligned} M_g &= W_p V_e \\ M_g &= 3 (21/7000) 4700 \\ M_g &= 42.29 \text{ lb-ft/sec} \end{aligned}$$

(U) Total Energy Rate (Without Muzzle Brake)

$$\begin{aligned} M_t &= M_b + M_g \\ M_t &= (75.43 + 42.29) \text{ lb-ft/sec} \\ M_t &= 117.72 \text{ lb-ft/sec} \end{aligned}$$

(U) Free Recoil Velocity of Rifle (Without Muzzle Brake)

$$\begin{aligned} M_t &= W_r V_r \\ V_r &= M_t / W_r \\ V_r &= 117.72 \text{ lb-ft/sec} / 9.099 \text{ lb} \\ V_r &= 12.94 \text{ ft/sec} \quad (\text{M1 Rifle} = 9.21 \text{ ft/sec with Ball Ammunition}) \end{aligned}$$

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(C) 6. CALCULATIONS: (Contd.)

(C) d. Free Recoil Energy. (Contd.)

(U) Free Kinetic Energy of Rifle (Without Muzzle Brake)

$$KE_f = 1/2 (W_r V_r^2 / g)$$

$$KE_f = 1/2 (9.099 \text{ lbs} / 32.2 \text{ ft/sec}^2) 12.9 \text{ ft/sec}^2$$

$$KE_f = 23.65 \text{ ft lb} \quad (\text{M1 Rifle} = 12.9 \text{ ft-lb with Ball Ammunition})$$

(U) Free Recoil (With Muzzle Brake)

The total "Free Theoretical Momentum" (free recoil) can be reduced by the factor F_2 when a Springfield Armory No. 2B design muzzle brake is used. Factor F_2 is the theoretical value calculated for the Springfield Armory muzzle brake No. 2B.

$$F_2 = \frac{.76 A_e + \sum av \cos \theta}{A_e + A_v'}$$

where: A_v' = Total effective area of gas escape vent
= .3104 in²

A_e = Bore Area
= .038 in²

av = Area of deflection plate - .462 in²

θ = Effective angle of gas deflection, 90°

$$F_2 = \frac{.76 (.038) + 0}{.038 + .3104}$$

$$F_2 = .08289$$

Therefore: $M_{gb} = .08289 M_g$
 $M_{gb} = .08289 (42.29)$
 $M_{gb} = 3.51 \text{ lb-ft/sec}$

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(C) 6. CALCULATIONS: (Contd.)

(C) 4. Free Recoil Energy. (Contd.)

(U) Total Momentum (With Muzzle Brake)

$$\begin{aligned}M_{tb} &= M_b + M_{g_b} \\M_{tb} &= (75.43 + 3.51) \text{ lb-ft/sec} \\M_{tb} &= 78.94 \text{ lb-ft/sec}\end{aligned}$$

(U) Free Recoil Velocity of Rifle (With Muzzle Brake)

$$\begin{aligned}V_{rb} &= M_{tb} / W_r \\V_{rb} &= 78.94 \text{ lb-ft/sec} / 9.099 \text{ lbs} \\V_{rb} &= 8.67 \text{ ft/sec} \quad (\text{M1 Rifle} = 9.21 \text{ ft/sec with Ball Ammunition})\end{aligned}$$

(U) Free Recoil Energy of Rifle (With Muzzle Brake)

$$\begin{aligned}KE_{tb} &= 1/2 (W_r V_{rb}^2 / g) \\KE_{tb} &= 1/2 (9.099 \text{ lb} / 32.2 \text{ ft/sec}^2) 8.67 \text{ ft/sec}^2 \\KE_{tb} &= 10.62 \text{ lb-ft} \quad (\text{M1 Rifle} = 12.9 \text{ ft-lb with Ball Ammunition})\end{aligned}$$

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