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MAY 26-54

BY Arthur E. Creech USO

June 9-54

TECHNICAL REPORT

AD 004232

TR-AE-7

EVALUATION OF
SOVIET AUTOMATIC AIRCRAFT GUNS
37MM NS AND 37MM N

SEPTEMBER 1, 1952

PROJECT NO. 30039

AIR TECHNICAL INTELLIGENCE CENTER
WRIGHT-PATTERSON AIR FORCE BASE
DAYTON, OHIO

SECRET

ARMOUR RESEARCH FOUNDATION
of
ILLINOIS INSTITUTE OF TECHNOLOGY
Technology Center
Chicago 16, Illinois

Project No. 90-1150K

EVALUATION OF SOVIET AUTOMATIC AIRCRAFT GUNS 37MM NS AND 37MM N

September 1, 1952

for

Air Technical Intelligence Center
Wright Patterson Air Force Base
Dayton, Ohio

Copy No. 280

Division of Engineering Mechanics Research

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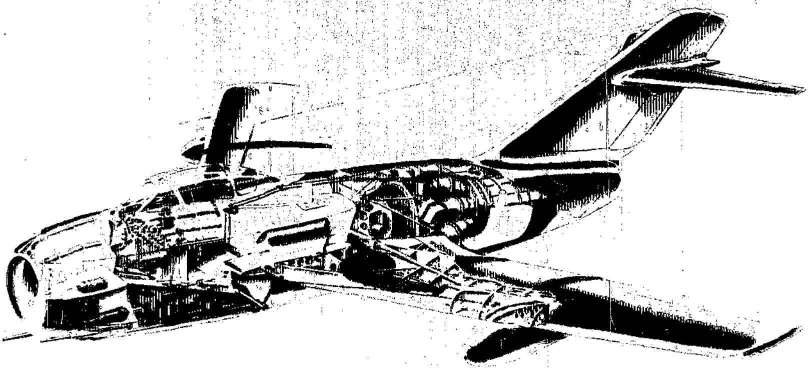
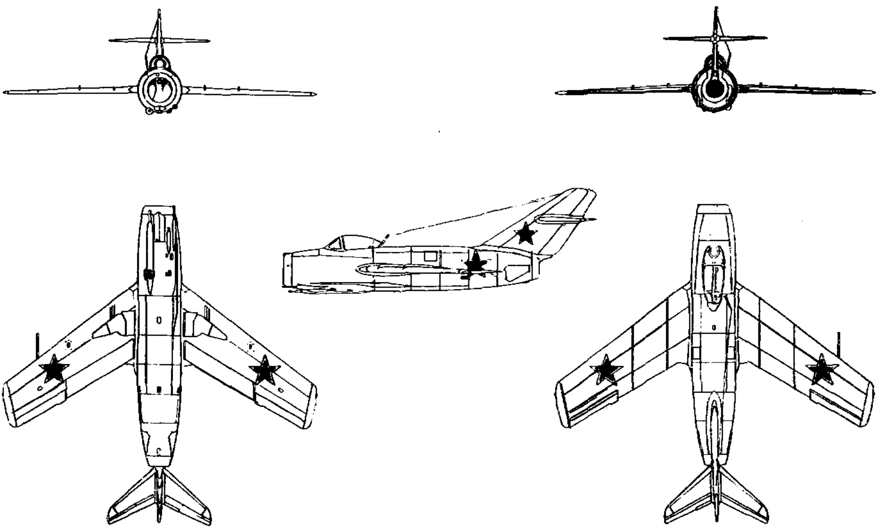
CUTAWAY VIEW OF MIG-15



SHOWING INSTALLATION OF
ONE 37 MM N AND TWO 23 MM NS SOVIET AIRCRAFT GUNS



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AUTH: CO, ATIC VHB
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Major, USAF
DATE: 1 September 1952

EVALUATION OF SOVIET
37MM AUTOMATIC AIRCRAFT GUNS

1 SEPTEMBER 1952

PROJECT NO. 30039

Prepared By

DIVISION OF ENGINEERING MECHANICS RESEARCH

ARMOUR RESEARCH FOUNDATION
OF
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CHICAGO 16, ILLINOIS

T52-12901

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SCVIET 37MM AUTOMATIC AIRCRAFT GUNS

Final Report

This report contains the data collected during the evaluation of the Soviet 37mm NS Gun and the 37mm N Gun by the Armour Research Foundation as Project 90-1150K during the period from March through May, 1952. This evaluation was performed under sub-contract from Battelle Memorial Institute for the Air Technical Intelligence Center at Wright-Patterson Air Force Base.

At Armour Research Foundation the program was managed by Mr. E. A. Kamp, Assistant Chairman of the Mechanism and Propulsion Research Department, with R. F. Windstrup as Project Engineer. Contributing personnel were: G. J. Andrews (Analysis), E. A. Kamp, M. G. Kinnavy, Dr. E. F. Lype, (Mechanism and Propulsion Research), and P. E. Stewart; H. Schwartzbart, and W. C. Troy, (Metals Research).

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION
OF ILLINOIS INSTITUTE OF TECHNOLOGY

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SUMMARY

EVALUATION OF SOVIET AUTOMATIC AIRCRAFT GUNS

37MM NS AND 37MM N

A. Purpose

The purpose of this study is to present a technical evaluation of Soviet 37mm Automatic Aircraft Guns. This evaluation will consist of determining the physical characteristics of the 37mm NS Weapon, estimating its performance, and pictorially representing its operational features. A hypothetical design for the 37mm N Gun has been prepared, and characteristics of the weapon have been computed. It is assumed by the Air Technical Intelligence Center that the 37mm N Gun is similar in operating principles to the 23mm and 37mm NS Guns.

B. Factual Data

Two 37mm NS Guns were recently received in the U. S. (without ammunition) and were available for physical examination. This type of weapon was known to be installed in Soviet fighters and attack aircraft during World War II. It was mounted either in the "V" of the engine to fire through the propeller hub or in the wing position. Information concerning the design of the 37mm N Gun was obtained by correlating physically available components such as cartridge cases, projectiles, and a link chute with the design of the 37mm NS Gun and by deducing certain design features from study of a damaged Soviet MIG-15 fighter which carried such a weapon. Further information was obtained from photographs. The MIG-15 fighter is the same aircraft which also carried the 23mm NS Gun described in Report TR-AE-2, "Evaluation of Soviet 23MM Automatic Aircraft Gun," Project No.

30033, dated February 1, 1952, issued by the Air Technical Intelligence Center at Wright Patterson Air Force Base. The 37mm N Gun was not recovered.

Physical evidence concerning the 37mm N Gun may be tabulated as follows:

1. An impression of a portion of the forward section of the gun was made in the fairing surrounding it when the above mentioned airplane crashed, Fig. 46 and 47.

2. A portion of the link chute was recovered.

3. An empty cartridge case, link, and projectile are on hand, Fig. 38.

4. The distance from the center line of the link ejection port to the muzzle was known from photographs.

5. The length of the gun bay in the MIG-15 limited the over-all length of the gun to 100 inches.

The following work was done on the evaluation program for these weapons:

37mm NS Gun

1. Detailed descriptions of the operating principles were made.

2. Schematic drawings were prepared representing the various mechanical actions.

3. A timing diagram was made in the form of a bar graph.

4. Performance of the weapon in terms of muzzle velocity, cyclic rate, and trunnion reaction were computed.

5. Photographs of the weapon and its disassembled components were taken.

6. A parts list was prepared to aid in identifying the various components.

37mm N Gun

1. A hypothetical design for a 37mm N Gun was prepared.

2. Schematic diagrams were prepared to represent the various mechanical actions.

3. A timing diagram was made.

4. Muzzle velocity, cyclic rate, and trunnion reaction were computed.

C. Digest

1. The 37mm NS Gun

A 37mm NS Gun was recovered by Intelligence sources in the Soviet zone of Germany. This weapon was turned over to the Air Technical Intelligence Center by the Office of Chief of Ordnance to support a project for the estimated physical and performance characteristics of the 37mm N Gun carried by the MIG-15. Stamping on the gun placed the time of manufacture in 1943, and Intelligence sources indicated that weapons of this type were used somewhat earlier in World War II by the Soviet Air Force.

The Soviet 37mm NS Gun is a belt fed, percussion-fired, short recoil operated aircraft gun. It has a rotating head bolt which is locked to the barrel extension during the high pressure stage of the firing cycle. The bolt is unlocked and set into motion relative to the barrel extension by the accelerator lever, actuated by the recoil of the gun. The bolt is rear seared during each cycle in automatic fire, and is released as the feeder completes its feed stroke. The feeder is powered by springs which are charged by a cam actuated by a shoulder on the barrel extension during recoil. The firing cycle in automatic fire is completed when the bolt drive spring returns the bolt to the battery position after the rear sear has been released by the feeder action. When the bolt completes locking upon its return to battery the next round is fired, and the cycle is repeated. The gun, including the pneumatic charging hose assembly (assumed to weigh 3-1/2 pounds), weighs 362 pounds. The over-all length of the gun is 134 inches, the height is 9-3/4 inches, and the width is 16-1/2 inches. Opposite hand feeding is accomplished by inverting the gun.

Components for this weapon are mainly machined from the solid, although the cylinder for the hydraulic recoil brake is a casting, and the sear release lever and feeder latch are either castings or rough forgings. The guide rod for the bolt charger return spring is made from a salvaged rifle or machine gun barrel (about Cal. .30) as evidenced by the rifling grooves in its interior. A duplicate weapon in the possession of ATIC at Wright-Patterson Air Force Base also has a rifled barrel modified for use as a bolt charger return spring guide. Since ammunition was not available for this weapon a cast was made of the chamber in the barrel, and from the outline of the casting the shape of the cartridge case was determined. It is assumed that this cartridge utilizes the same projectiles as the 37mm N Gun, samples of which are available. No powder composition data are known, but a propellant weight of 3164 grains and a muzzle velocity of 2950 ft/sec as reported by Intelligence sources are assumed as correct and are used as a basis for computations. The calculated trajectory for this ammunition is shown in Figs. 9 and 10.

Table I below lists comparative data on the 37mm NS and 37mm N Guns.

Table I

	37mm NS	37mm N
Muzzle Velocity, fps	2950	API-T 2340 HEI-T 2400
Cyclic Rate, rpm	315-345	400-450
Weight, lb	358	300
Length, in.	134	92-3/4
Height, in.	9-3/4	9-1/8
Width, in.	16-1/2	14

2. The 37mm N Gun

On the basis of information available to Intelligence on the 37mm N Gun in the MIG-15, and its assumed relationship to the 23mm NS Gun in the MIG-15, Armour Research Foundation was requested to prepare an estimate of physical and performance characteristics of this weapon. Study of the 37mm NS Gun disclosed that the 37mm N Gun in the MIG-15 did not use the same complete round of ammunition; however, the design relationship was strengthened when the similarity between the old 37mm NS and the postwar 23mm NS was observed. Intelligence sources confirmed the identity of the new gun as a 37mm N type. The earlier designation NS stood for the aircraft gun design team of Nudelman and Suranov, and the only conclusion that may be drawn from the new designation is that Suranov is not credited with the design of the new weapon. This weapon was apparently designed after the war to meet the installation requirements for jet fighters. Its first confirmed use was in the MIG-15, and it was possibly installed in earlier MIG-9's.

It is considered logical to assume that the operation of the Soviet 37mm N Gun is identical to that described for the 37mm NS Gun. The hypothetical design prepared for this weapon depicts a gun which weighs 300 pounds, is 92-3/4 inches long, 9-1/8 inches high, and 14 inches wide. This design is consistent with all known data on the weapon and ammunition, including the imprint in the airplane fairing and photographic information. Computations were based on the fact that the drop of its projectile should match the drop of the projectile for the 23mm NS Gun mounted parallel to it in the MIG-15 at a range of 1200 yards, with a forward airplane velocity of 600 mph at 30,000 feet altitude. This muzzle velocity is 2340 fps for the API-T projectile and 2400 fps for the HEI-T projectile. The calculated trajectories are shown in Figs. 42, 43, 44, and 45.

The following physical data concerning the 37mm N Gun were obtained from the imprint in the fairing and photographs:

a. Distance from end of barrel to front of fairing, in. 12.3

b. Distance from end of barrel to ℄ of case ejection port, in. 67.8

c. Outside diameter of recoil spring, in. (approximate) 4-1/4

d. Wire diameter of recoil spring, in. (approximate) 9/16

The axial distance from the end of the barrel to the center line of the case ejection port established the location of the feeder, since ejection for this weapon is directly in line with the feeder. The length of the complete round established the length of the feeder, and the length of the bolt and its travel were roughly known by both geometric limitations and the proportions of the 23mm NS and 37mm NS Guns. Consideration of these factors led to a gun length of 92-3/4 inches. The length of the gun bay in the MIG-15 was such as to limit the over all gun length to 100 inches. The gun as represented in Fig. 48 is a logical design in every respect except that more length than is necessary appears in the receiver between the front of the feeder and the front mounting point. This length is dictated by the relative location of the imprint in the fairing and the location of the feeder. It should be understood that the location of the front mounting point is arbitrary and was selected as shown to conform roughly with the 37mm NS Gun. The front mounting point could be moved 9 inches rearward without changing any mechanical or structural features or contradicting any known data.

The secondary recoil spring (Fig. 48) is not known to exist, but it increases the cyclic rate of the weapon and gives some reason for the long forward structure surrounding the barrel, which does not exist in the 23mm NS

Gun. Its function is duplicated in the 37mm NS recoil system, which has a secondary spring which also acts only near the end of recoil.

D. Conclusions

On the basis of the investigation it is concluded that the 37mm NS Gun has a muzzle velocity of 2950 fps and a cyclic rate of from 315 to 345 rpm, while the 37mm N Gun has a muzzle velocity of 2340 fps for API-T ammunition and 2400 fps for HEI-T ammunition, with a cyclic rate of from 400 to 450 rpm. Since the weapons are similar functionally and structurally (with the exception of the location of the recoil springs) the advantages for both are similar and may be listed as follows:

1. Mechanical Ruggedness

It is probable that parts breakages are rare in these weapons, since the working parts are sturdy and apparently stressed only to reasonable levels.

2. Dependability

The method of feeding is positive throughout. Since the empty case is pushed out by the incoming round which, in turn, is positioned into the T slots in the face of the bolt while the bolt is stationary, feeding jams should be rare. Extraction and ejection are gentle and positive. In-line ramming contributes to dependability.

3. Low Silhouette

This feature is of significance in aircraft gun installations where space limitations demand minimum gun profiles.

4. Relatively High Belt Pull

It is probable that belts of considerable length can be fed without ammunition boosters.

5. Reliability

Operation of these guns should be reliable under a wide range of climatic conditions.

6. Cyclic Rate

The cyclic rate of both these weapons is high considering the caliber of the ammunition fired.

7. Manufacturing Facility

These guns are adaptable to decentralized manufacturing since general purpose machine tools can be used for the construction of most of their components.

1

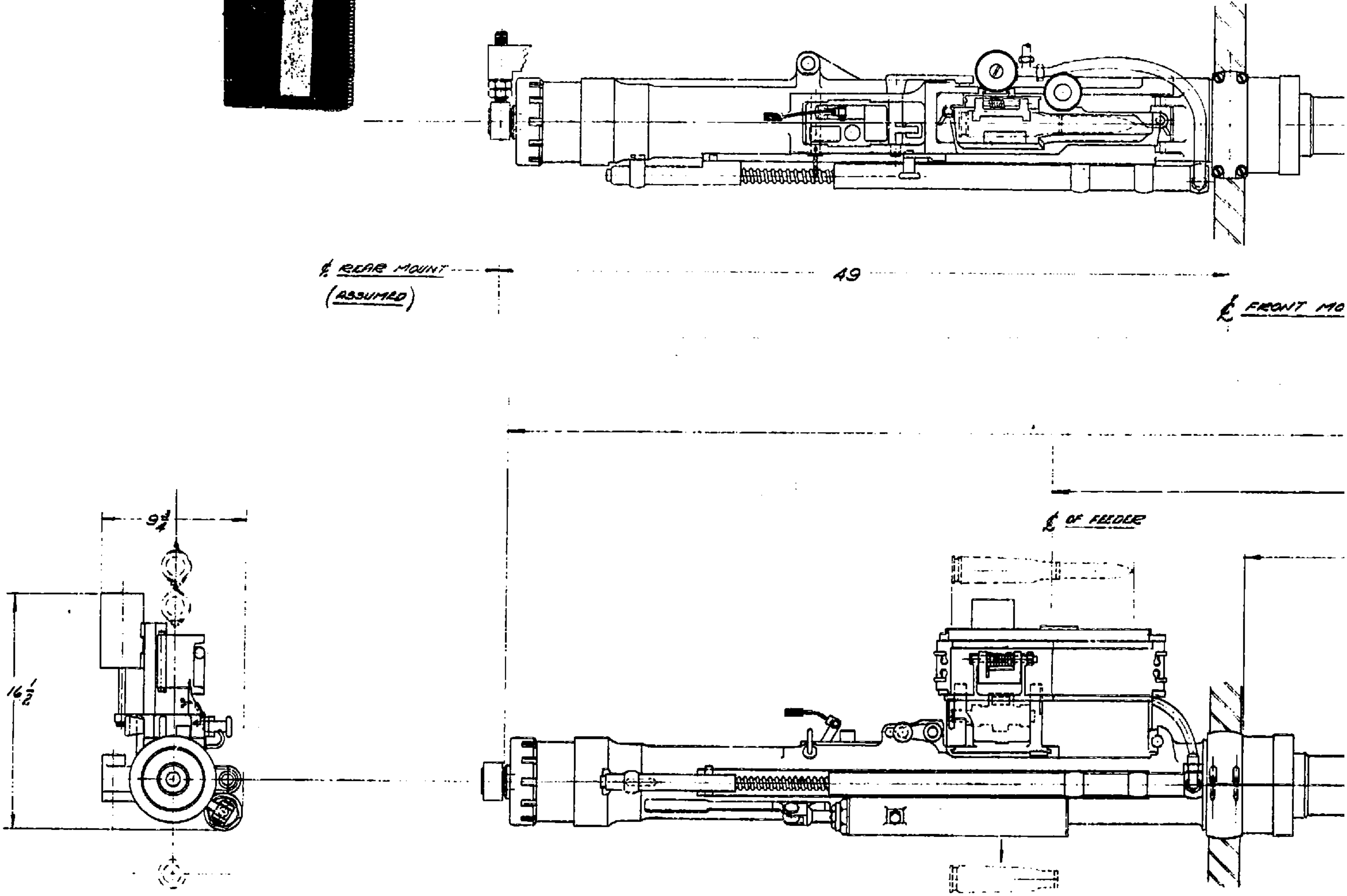

Fig. 1 OUTLINE DRAWING OF SOVIET

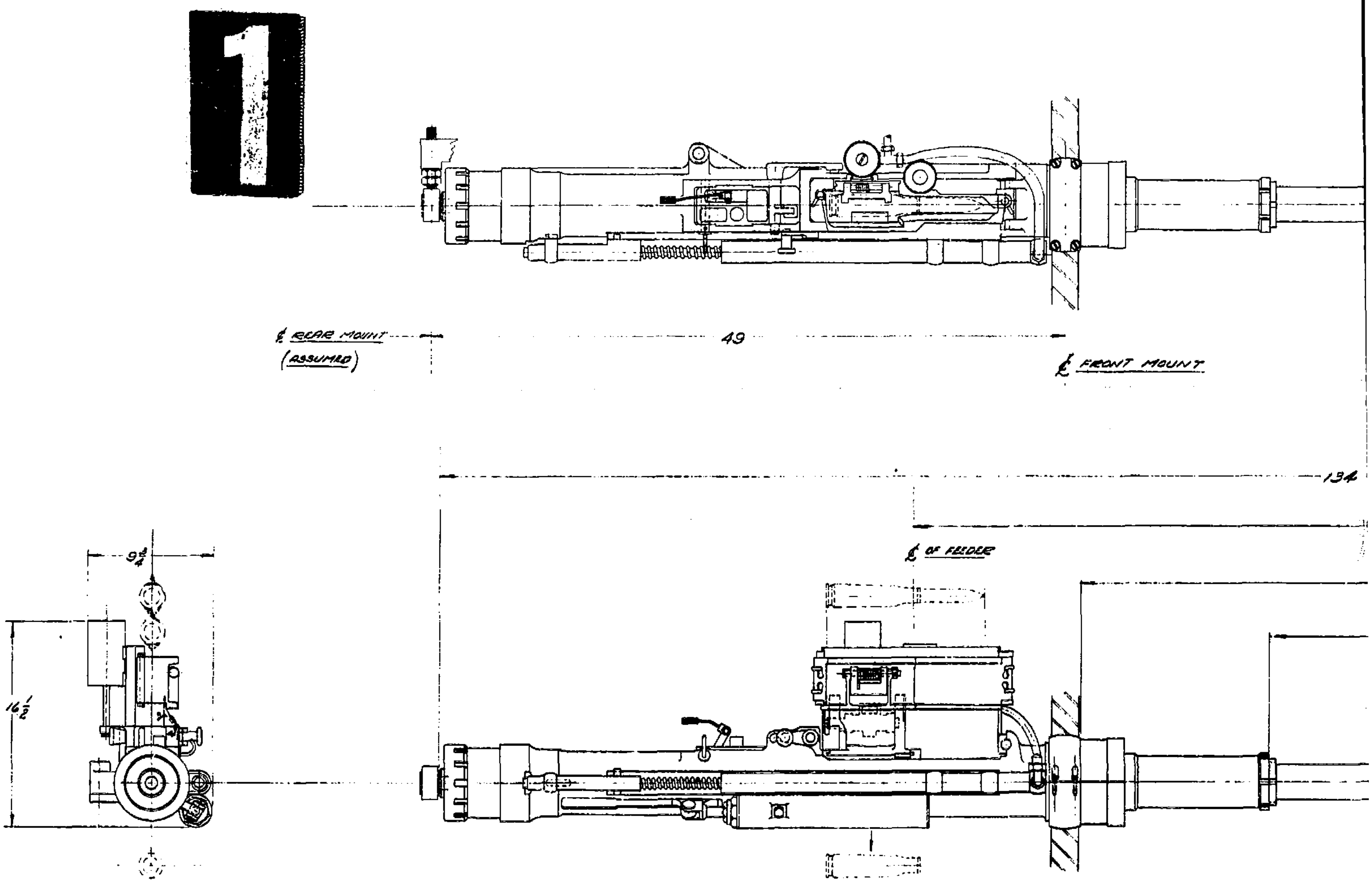

Fig. 1 OUTLINE DRAWING OF SOVIET 37 MM NS G

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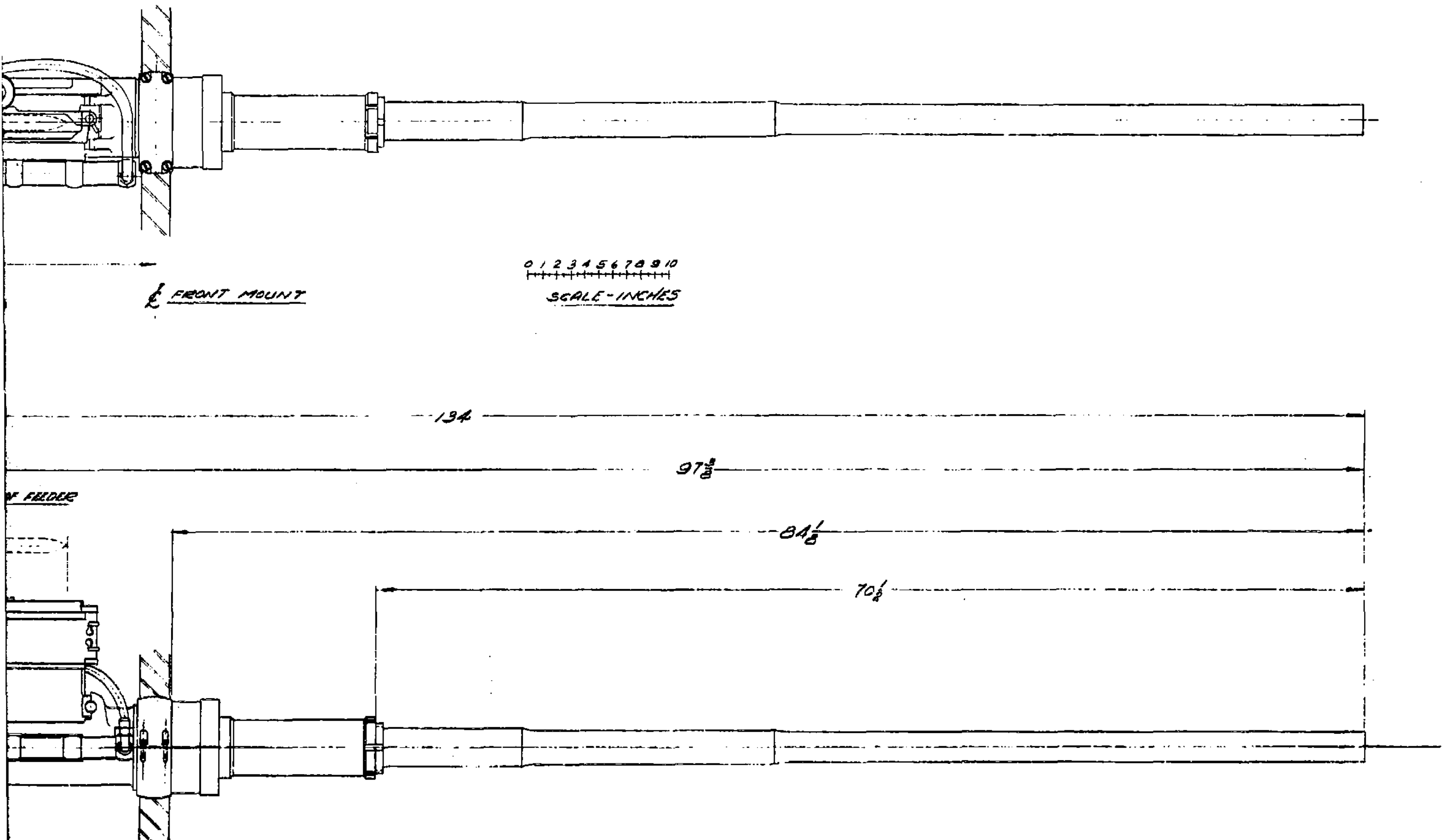

VING OF SOVIET 37 MM NS GUN

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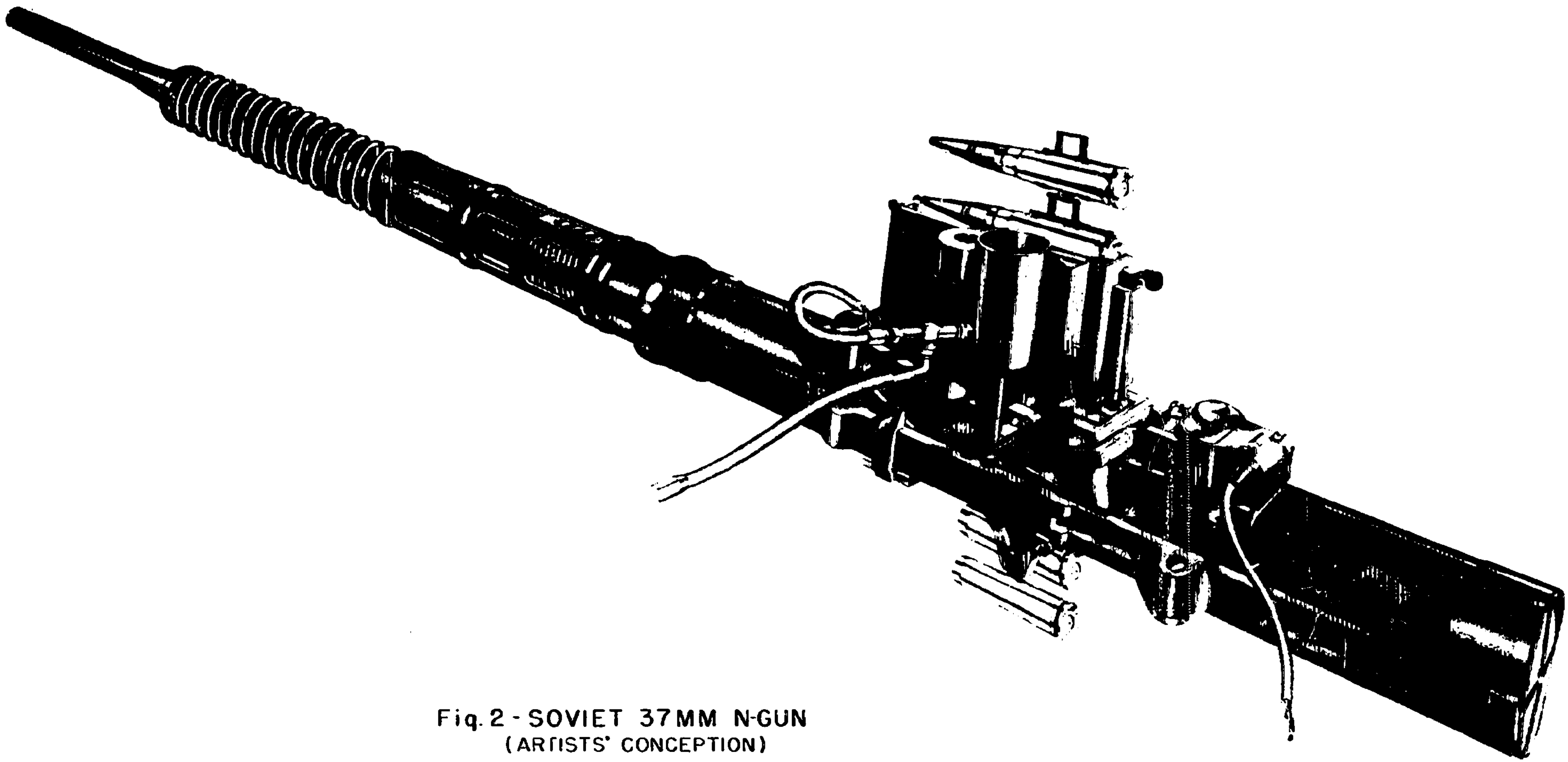

Fig. 2 - SOVIET 37MM N-GUN
(ARTISTS' CONCEPTION)

ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY

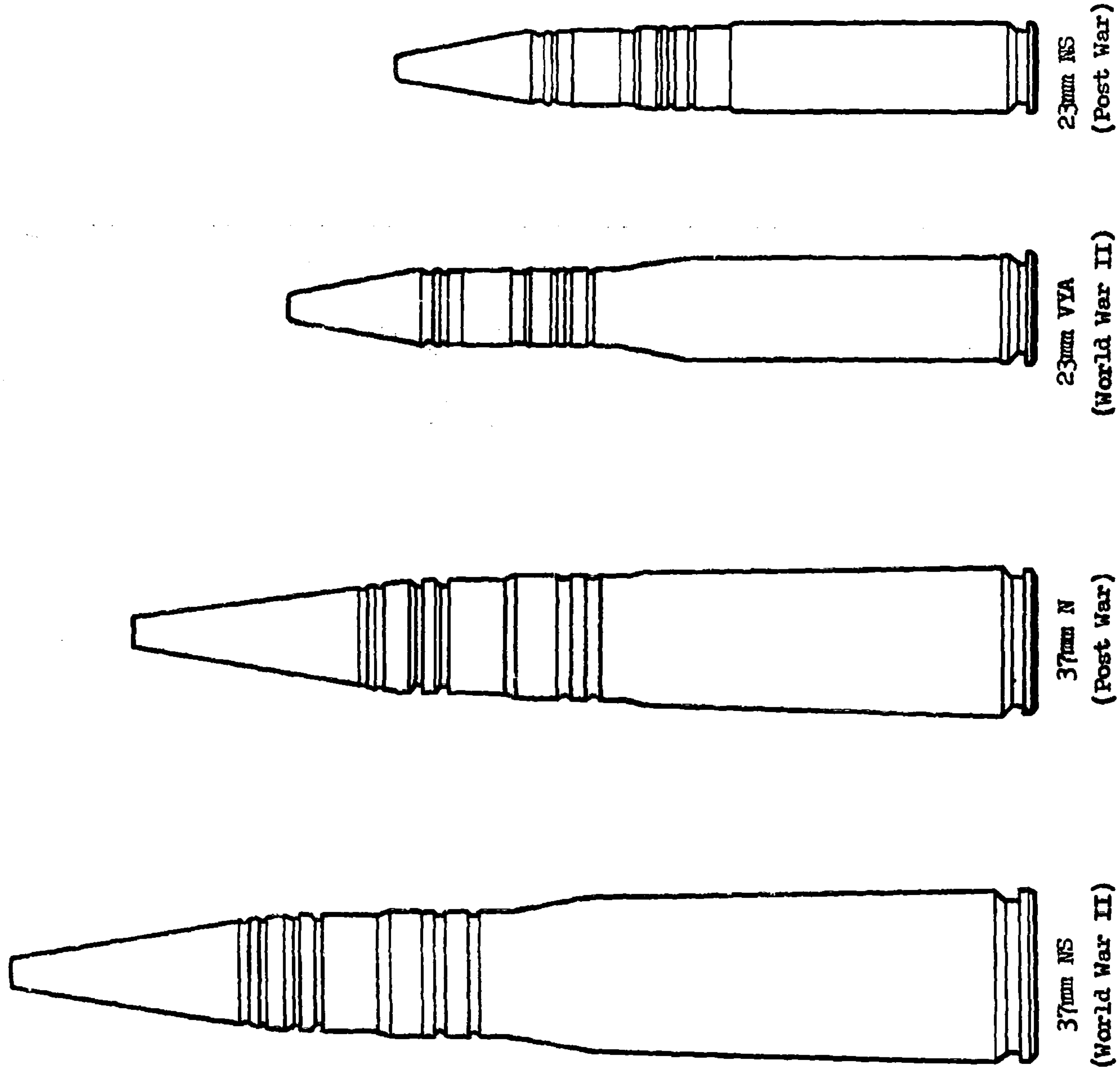

Fig. 3 COMPARISON OF SOVIET 37MM AND 23MM AMMUNITION

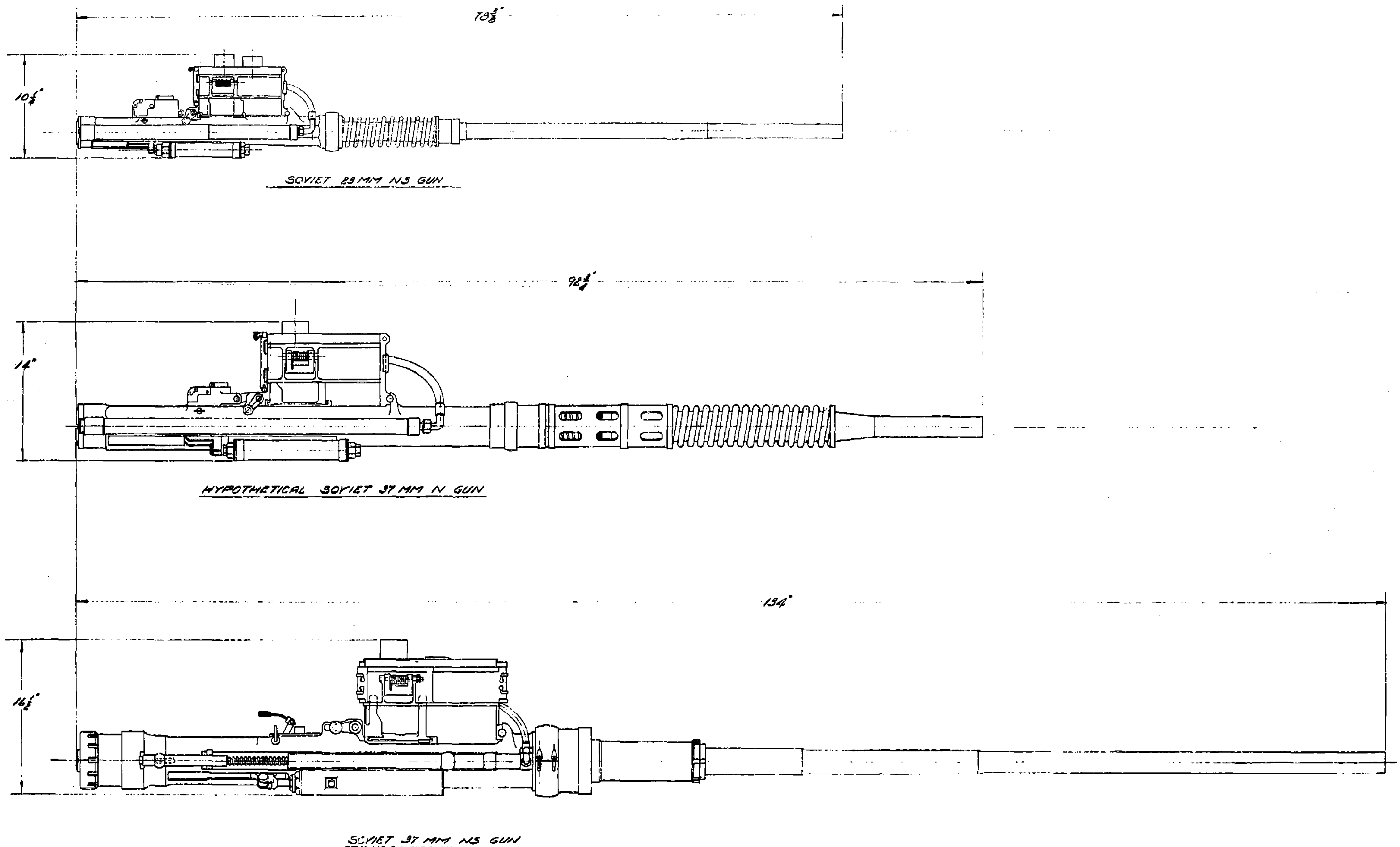

Fig. 4 COMPARATIVE STUDY OF SOVIET 23 MM NS, 37 MM NS, AND 37 MM N GUNS

PART I

REPORT ON THE SOVIET 37MM NS AUTOMATIC AIRCRAFT GUN

I. PHYSICAL CHARACTERISTICS OF THE 37MM NS GUN

A. General

The weapon is a belt-fed, percussion-fired, short-recoil operated aircraft gun. It has a rotating head bolt which is locked to the barrel extension during the high-pressure stage of the cycle. The bolt is unlocked and set into motion relative to the barrel extension by an accelerator lever which is actuated by the recoil of the gun. The bolt is seared rearward during every cycle in automatic fire, and is released as the feeder completes its feed stroke. The spring-operated feeder is charged through the actuation of a cam by a shoulder on the barrel extension in recoil. The gun cycle is initiated when the bolt is released by a rear sear, allowing the drive spring to return the bolt to the battery position and fire the round.

The gun fires API-T or HEI-T ammunition (Fig. 11 and 12) and design features indicate a metallic, open-link, disintegrating belt which is similar to that used in the 37mm N and 23mm NS Guns. See Fig. 37 for a photograph of the link for the 37mm N Gun.

The gun is mounted near the front of the receiver in a spherical bearing, which allows universal motion for harmonization. The mount for this gun is not available, but it is probable that the front portion is similar to that used on the 23mm NS Gun, consisting of a hinged outer bearing race which can be opened for installing the gun. The rear mount can be either a pin protruding into the recoil spring housing or a clamp around the outside of this housing. Either method can easily incorporate provisions for vertical and horizontal adjustment.

B. Basic Gun Data

Physical data of the gun as measured or calculated are as follows*

Weight of gun (including pneumatic line assembly, solenoid, and valve), lb		362
Weight of pneumatic line assembly, solenoid and valve (assumed), lb		3-1/2
Over-all length of gun, in.		134
Over-all height of gun, in.		9.75
Over-all width of gun, in.		16.5
Length of barrel, in.		90.75
Weight of barrel, including sleeves, lb		90.6
Weight of recoiling parts (including bolt) lb		165.64
Weight of bolt assembly, lb		14.78
Weight of feeder assembly, lb		42.82
Weight of sear mechanism, lb		4.42
Muzzle velocity (HEI-T), fps Muzzle velocity (API-T) fps	Based on intelligence data	2950
*Rate of fire (fixed gun, free firing), rpm		315-345
*Maximum trunnion reaction, lb (see Section VII)		4600+

Rifling

Number of grooves	16
Depth of grooves, in.	0.018
Width of grooves, in.	0.191
Width of lands, in.	0.097

*Calculated data are designated by asterisks.

Rifling (Contd.)

Twist (uniform, RH)	Approx. 1 turn in 30-1/2 calibers (6°)
Length, in.	82.9

Bore of Barrel

Across rifling lands, in.	1.460
Across rifling grooves, in.	1.496
Travel of projectile in barrel, in.	83.4

Springs (Only main operating springs are included)

Drive Spring (four strands)

Outside diameter, in.	1-1/8
Free length, in.	40.0
Number of coils	66
Diameter of wire (four strands)	approx. 0.240
Rate, variable, lb/in.	See Fig. 33

Feeder Spring (Outer)

Outside diameter, in.	1-15/16
Free length, in.	8-7/8
No. of coils	14
Diameter of wire, in.	0.355
Rate, lb/in.	426

Feeder Spring (Inner)

Outside diameter, in.	1-3/16
Free length, in.	10-1/4
No. of coils	28

Feeder Spring (Inner, contd.)

Diameter of wire, in.	0.175
Rate, lb/in.	48-1/2

Recoil Spring (Outer)

Outside diameter, in.	4-1/2
Free length, in.	18-3/4
Number of coils	12
Diameter of wire, in.	0.568
Rate, lb/in.	209

Recoil Spring (Inner)

Outside diameter, in.	3
Free length, in.	13-1/2
Number of coils	14-1/2
Diameter of wire, in.	0.470
Rate, lb/in.	362
Diameter of charging piston (bolt, in.)	1-9/16
Diameter of charging piston (feeder, in.)	2-9/16

C. Ammunition Data

	API-T	HEI-T
Over-all length of cartridge, in.	12.78	13.0
Length of projectile, in.	6.49	7.0
Length of cartridge case, in.	7.66	7.66
Diameter of projectile over rotating band, in.	1.469	1.469
Diameter of projectile over Bourrelet, in.	1.457	1.457
Weight of complete round, lb	3.75	3.66
Weight of projectile, lb	1.694	1.61

*Weight of cartridge case, lb	1.60	1.60
Weight of propellant, grains	3164	3164
*Capacity of cartridge case (to base of projectile), cc	260	260
Density of loading - volume basis	unknown	
Density of loading, weight basis, grams/cc approx.	0.789	0.789
Weight of belt link, lb (assumed similar to 37mm N)	0.3	0.3

The barrel is not adaptable for quick replacement without tools, although with very few exceptions all components of the gun are readily detachable, and it can be rapidly stripped for servicing. This weapon creates a general impression of reliability.

The major structural parts are the receiver and barrel extension. Both are relatively complex, and are apparently machined from the solid. The maximum feeder pull, based on the force exerted by the cocked springs, is 1100 pounds. The feeder is a well-integrated component and its constituent parts are sturdy. Heat-treated steel is used on the major working parts, and chrome facing appears on the feeder slide, link stripper, recoil buffer lug, and feeder spring cap. Welding appears only on the charger cylinder, and no sheet metal stampings are used.

D. <u>Parts List</u>

A parts list has been prepared, assigning to the major components or assemblies an item number, title, and a corresponding reference number for figures in Section II of this report.

*Calculated data are designated by asterisks.

Item No. (See Fig. 4)	Title	Additional Fig.
1.	Barrel	13, 17
2.	Barrel Support	17
3.	Receiver Assembly	14, 15
4.	Recoil Spring Sleeve	18
5.	Recoil Spring Housing	18
6.	Recoil Spring Stud	18
7.	Recoil Spring, Outer	18
8.	Recoil Spring, Inner	18
9.	Bolt Charger Piston Assembly	23
10.	Bolt Charger Mount	23
11.	Bolt Charger Cylinder	14
12.	Bolt Charger Mount Key	14
13.	Bolt Charger Spring Guide	23
14.	Bolt Charger Return Spring	23
15.	Bolt Charger Lug	23
16.	Barrel Support Lock	13
17.	Accelerator	
18.	Barrel Extension Assembly	18
19.	Sear Assembly	27, 28
20.	Sear Mounting Pin	
21.	Bolt Head	21
22.	Bolt Body	21
23.	Bolt Pawl Components	21
24.	Bolt Gate	21
25.	Firing Pin Components	21

26.	Barrel Lock	
27.	Link Stripper Assembly	16
28.	Feeder Charger Piston Assembly	16
29.	Feeder Charger Cylinder	16
30.	Feeder Slide Lug	16
31.	Feeder Cover Plate	16
32.	Feeder Assembly	14, 15
33.	Drive Spring	
34.	Feeder Spring Cap	16
35.	Feeder Springs (Inner and Outer)	16
36.	Feeder Spring Housing	16
37.	Feeder Cam Plate	16
38.	Recoil Brake Mounting Wedge	
39.	Recoil Brake Housing	24
40.	Recoil Brake Throttling Rod	24
41.	Recoil Brake Cap	24
42.	Recoil Brake Piston Assembly	24
43.	Recoil Brake Mounting Lug Components	24

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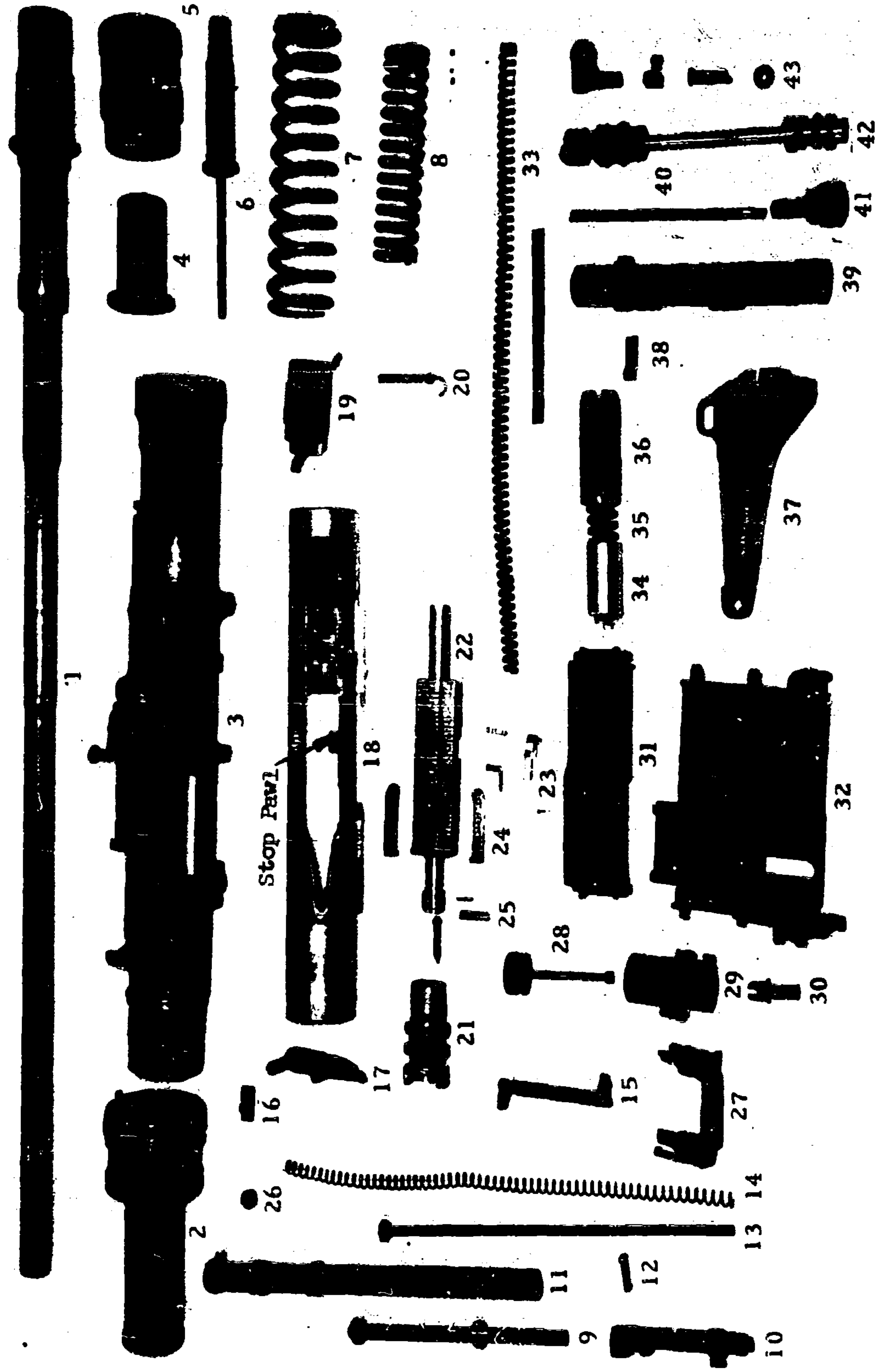

Fig. 5 COMPONENTS OF 37MM NS GUN

II. DESCRIPTION OF THE GUN ACTION

A. Firing Cycle

See Fig. 6 for schematic operating diagrams. When the gun is ready to fire, the bolt is held in the rear position by the trigger sear. The feeder springs are expanded, and a cartridge is positioned in the T-slot in the face of the bolt.

When the trigger sear is actuated, the sear (Item 19) releases the bolt and the drive spring sends it home against the barrel, chambering the round. The head of the bolt (Item 21) strikes the base of the barrel and stops. The body of the bolt, (Item 22) continues forward, and a pin in the bolt body extension follows a cam groove in the bolt head, causing the head of the bolt to be rotated so that the locking lugs on the bolt head engage recesses in the barrel extension (Item 18), locking the bolt head to the barrel extension. Rebound of the bolt body is prevented by a spring-loaded pawl (Item 23) which snaps into a recess in the barrel extension.

As the bolt body nears the end of its forward travel, 5/16 inch after the bolt head is locked, the firing pin (Item 25) fixed to the bolt body, is brought into contact with the primer, firing the round.

When the round fires, reaction against the bolt head causes the bolt assembly, barrel extension, and barrel to move rearward, because the bolt head is locked to the barrel extension. After about 4.5 inches of recoil travel, the accelerator (Item 17) pivoted in the receiver, starts to move the bolt body rearward at an increased velocity, causing it to cam the bolt head locking lugs out of engagement with the recesses in the barrel extension. This is possible because the pawl which prevents the bolt body from rebounding is disengaged from the barrel extension during recoil by the camming action of an intermediate lever between the receiver and the

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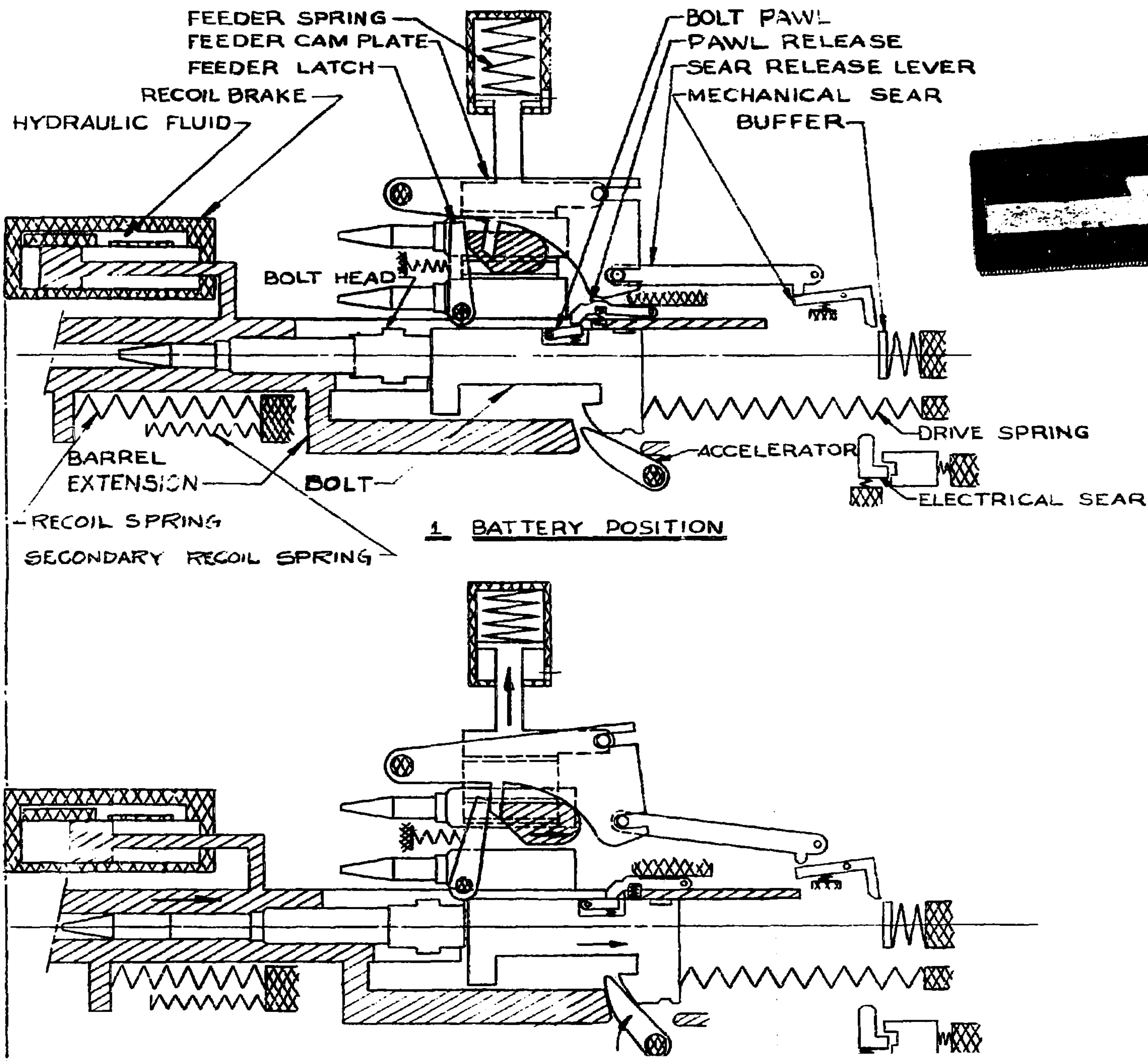
STATIONARY PARTS



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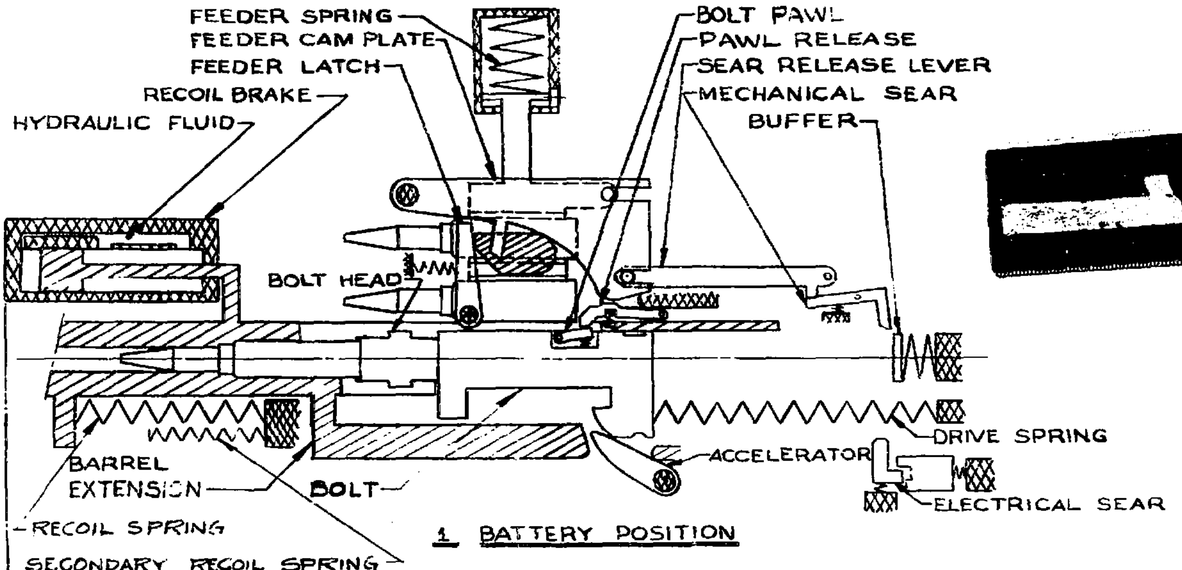
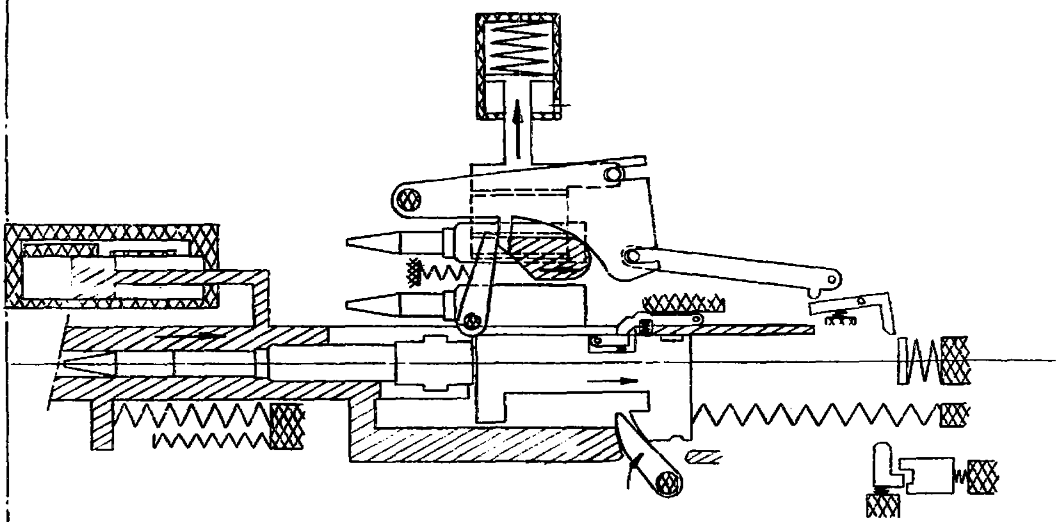
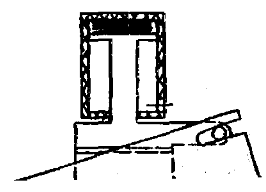


1 BATTERY POSITION



2 START OF UNLOCKING



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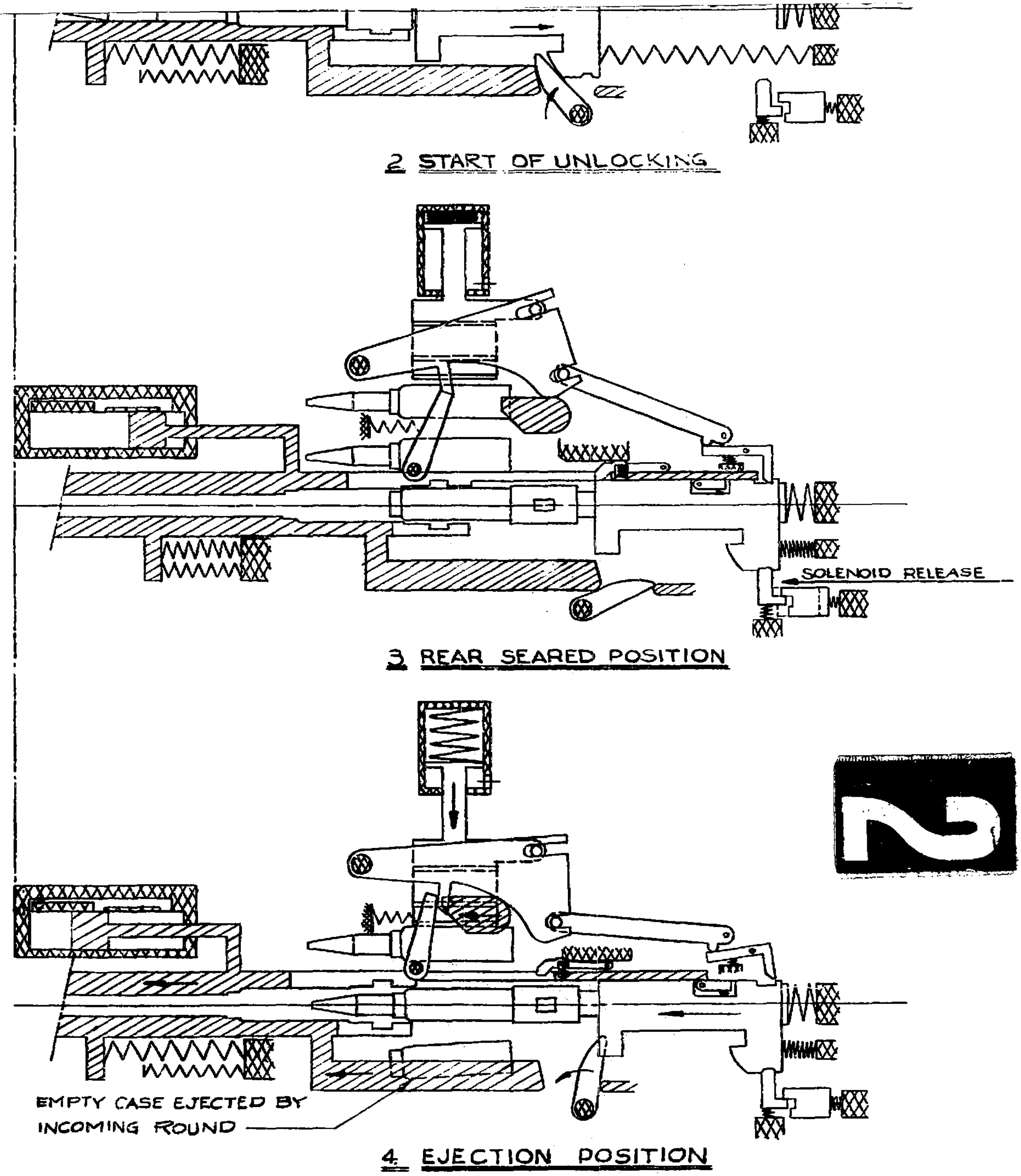

Fig. 6 SCHEMATIC FIRING CYCLE FOR 37 MM N GUN

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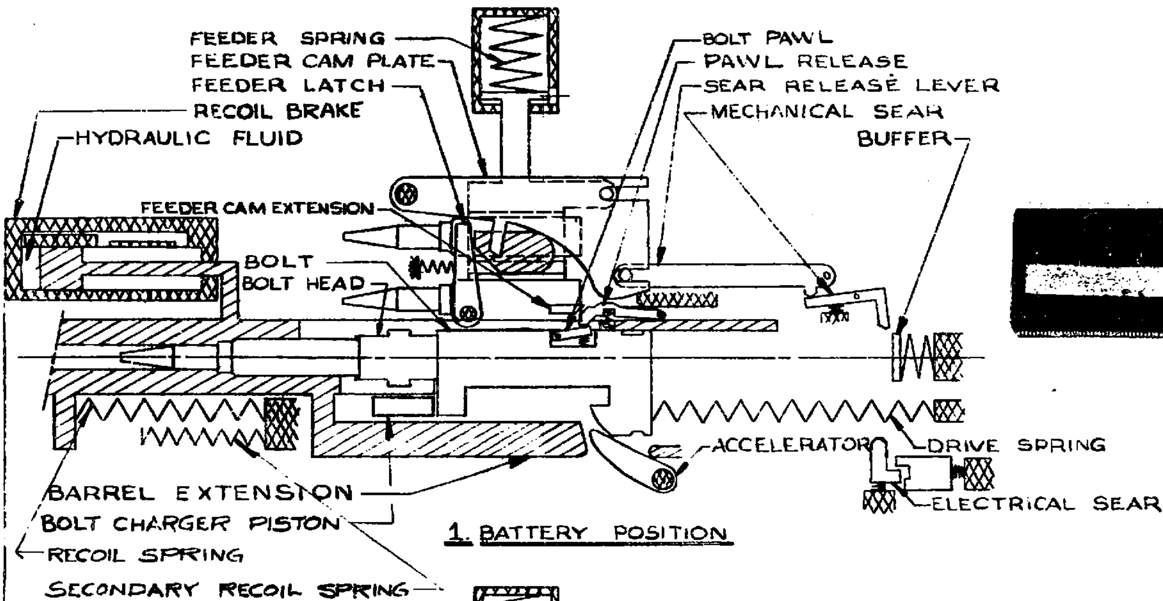
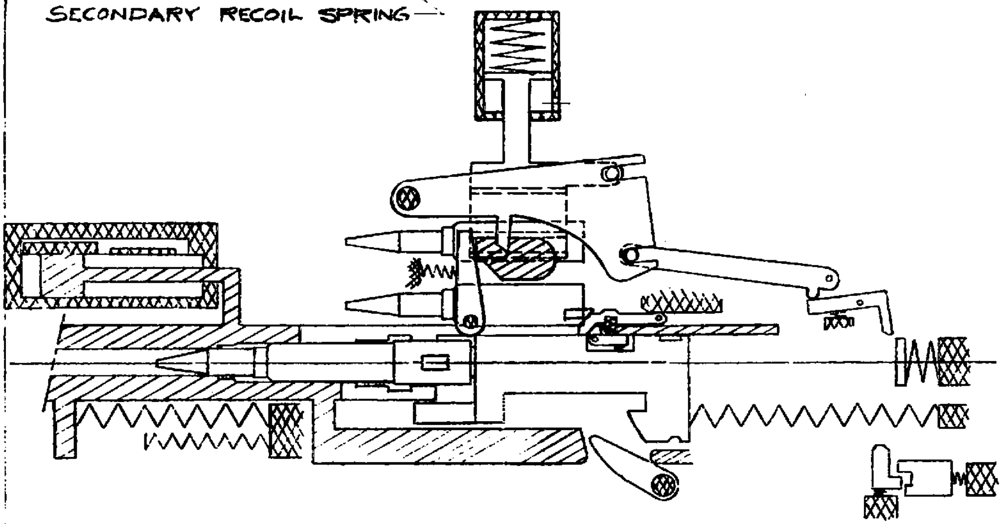
1

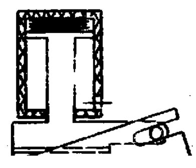
CODES: RECOILING PARTS
STATIONARY PARTS



1. BATTERY POSITION



2. EXTRACTION



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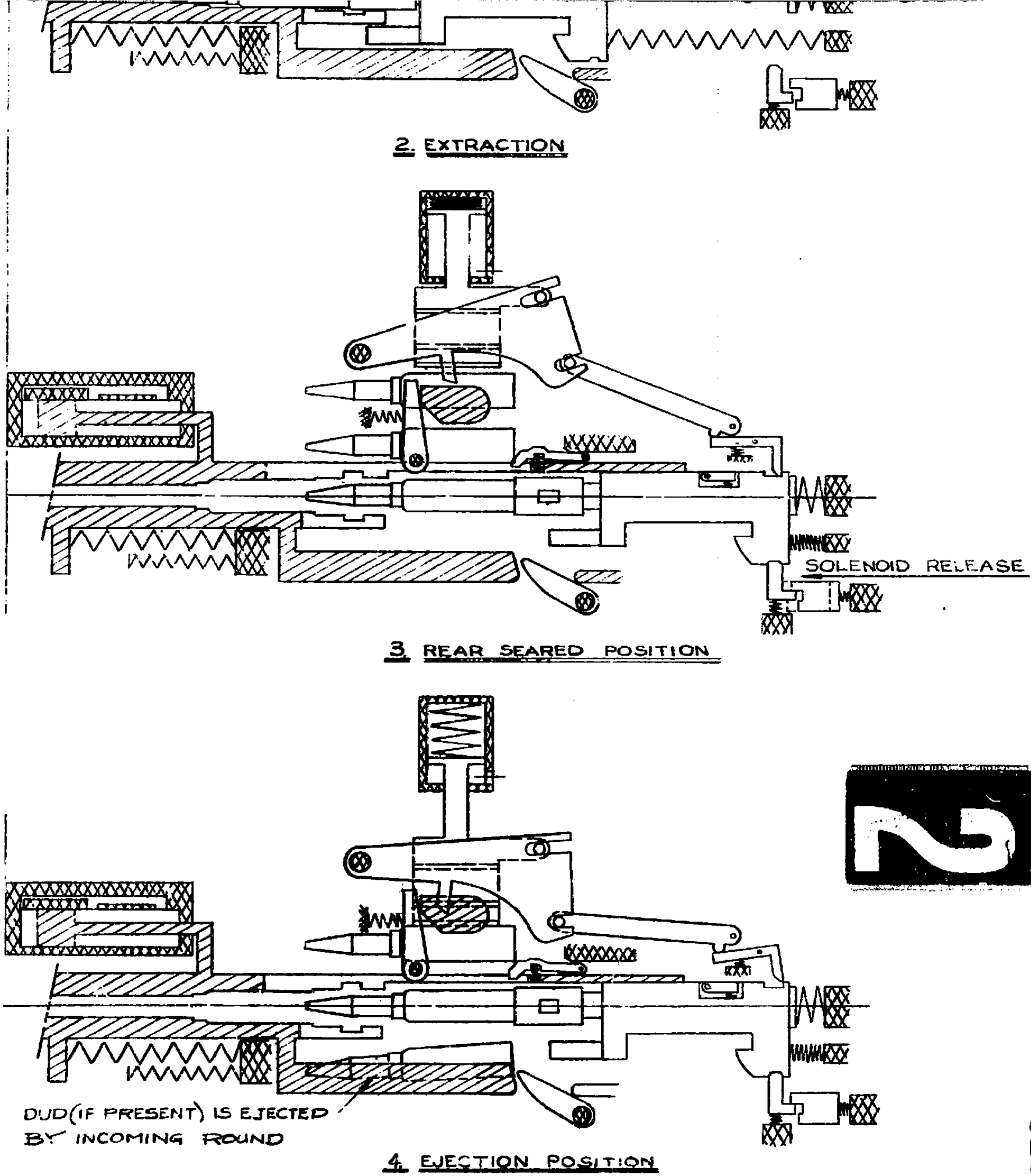

Fig. 7 SCHEMATIC CHARGING CYCLE, 37 MM N GUN

travel of the barrel extension is about 7.7 inches. When recoil is completed, the energy stored in the recoil springs acts to return the barrel and barrel extension to battery. During the recoil stroke the hydraulic recoil brake (Fig. 24) exerts a varying resistance to recoil in order to dissipate excess recoil energy in the form of fluid friction. The heaviest resistance to recoil is offered during the first three inches of travel. This brake also acts to slow the moving parts in counterrecoil, offering its greatest resistance during the last three inches of counterrecoil. This effect reduces the impact of the counterrecoiling parts as they reach battery, since the recoil springs are not arranged to provide a resilient overrun in counterrecoil.

When the barrel extension is 0.8 inches from battery on its counterrecoil stroke, a cam on its side releases the latch holding the feeder cam plate, which allows the feeder springs to expand. The expansion of the feeder springs operates the feeder slide (Fig. 16), which forces a new round against the empty case held in the T-slot on the face of the bolt head (which is held in alignment with the round being fed by the feeder-operated sear) and pulls in the ammunition belt. The links are stripped from the rounds in the feeder by the link stripper assembly (Item 27) and discharged through the bottom of the gun. When the feeder cam plate is 0.5 inch from completing its feed stroke, it actuates a pin in the receiver (Fig. 15) which causes a stop pawl in the barrel extension (Item 18) to be moved out into the path of the round being fed, causing it to stop in the proper position on the face of the bolt. A spring-loaded pin (Fig. 20) in the face of the bolt acts to retain the cartridges on the face of the bolt during ramming.

As the feeder cam completes its stroke, it releases the sear holding the bolt rearward and allows the drive spring to return the bolt to battery, initiating another cycle.

B. Charging Cycle

See Fig. 7 for schematic operating diagrams.

Charging is accomplished pneumatically through a system involving two cylinders, one (Item 11) to move the bolt rearward against its drive spring and one (Item 29) to charge the feeder springs. Both cylinders receive air under pressure simultaneously through a common valve.

During charging, air under pressure acts on the bolt charger piston assembly (Item 9) in the charger housing (Item 11). Under this force the piston moves rearward, causing the charging lug (Item 15) to move the bolt rearward and compress the drive spring (Item 33) and the bolt charger return spring (Item 14). Simultaneous motion of the feeder cam plate (Item 37) depresses the bolt pawl, (Item 23), allowing the bolt body to continue rearward under the force of the air acting on the bolt charger piston assembly (Item 9). The rearward motion of the bolt body rotates the bolt head lugs (Item 21) out of engagement with the recesses in the barrel extension (Item 18) thus unlocking the bolt and allowing the air pressure to move the bolt completely rearward to the seared position.

Meanwhile, air under pressure enters the charger cylinder for the feeder (Item 29), exerting force on the charger piston assembly for the feeder. This force causes the feeder cam plate (Item 37) to be lifted, thus compressing the feeder springs (Item 35) and moving the feeder slide (Fig. 16) outward. The feeder pawls (Fig 16) are forced upward against their springs by the rounds in the ammunition belt during this motion. The rounds in the ammunition belt are held stationary during the outward motion of the feeder slide by the action of the holding pawl in the feeder cover plate (Item 31). After the feeder slide and the bolt have completed their travel under air pressure the valve reverses, venting the air on the high pressure side of each piston. This allows the drive spring (Item 33) to move the bolt forward until it is caught by the sear (Item 19), and causes the feeder springs (Item 35) to move the feeder slide in. The feeder pawls (Fig. 16) which in the outward position of the feeder slide moved down behind the rounds in the belt under the force of their springs, pull the belt into the gun and position a round in the T-slot in the face of the bolt. The feeder cam plate releases the sear near the end of its stroke, causing the bolt to be held rearward only by the trigger sear.

C. Loading the Weapon

To load the gun the feeder cover plate (Item 31) is opened and the link of the leading round in the belt is engaged with the link stripper. The feeder cover plate is then closed. After charging twice, the gun will fire upon release of the trigger sear.

D. Timing Diagram

The cyclic time of the gun consists of the following time intervals:

1. The time from firing to the full recoil travel of the barrel extension, at which time the feeder springs are fully compressed.

2. The time of the barrel extension travel in counterrecoil to the point at which the feeder is unlatched.

3. The time for feeding.

4. The time for the bolt travel from seared position to locked position. A graphic representation of the timing of the motions of the various components appears in Fig. 8.

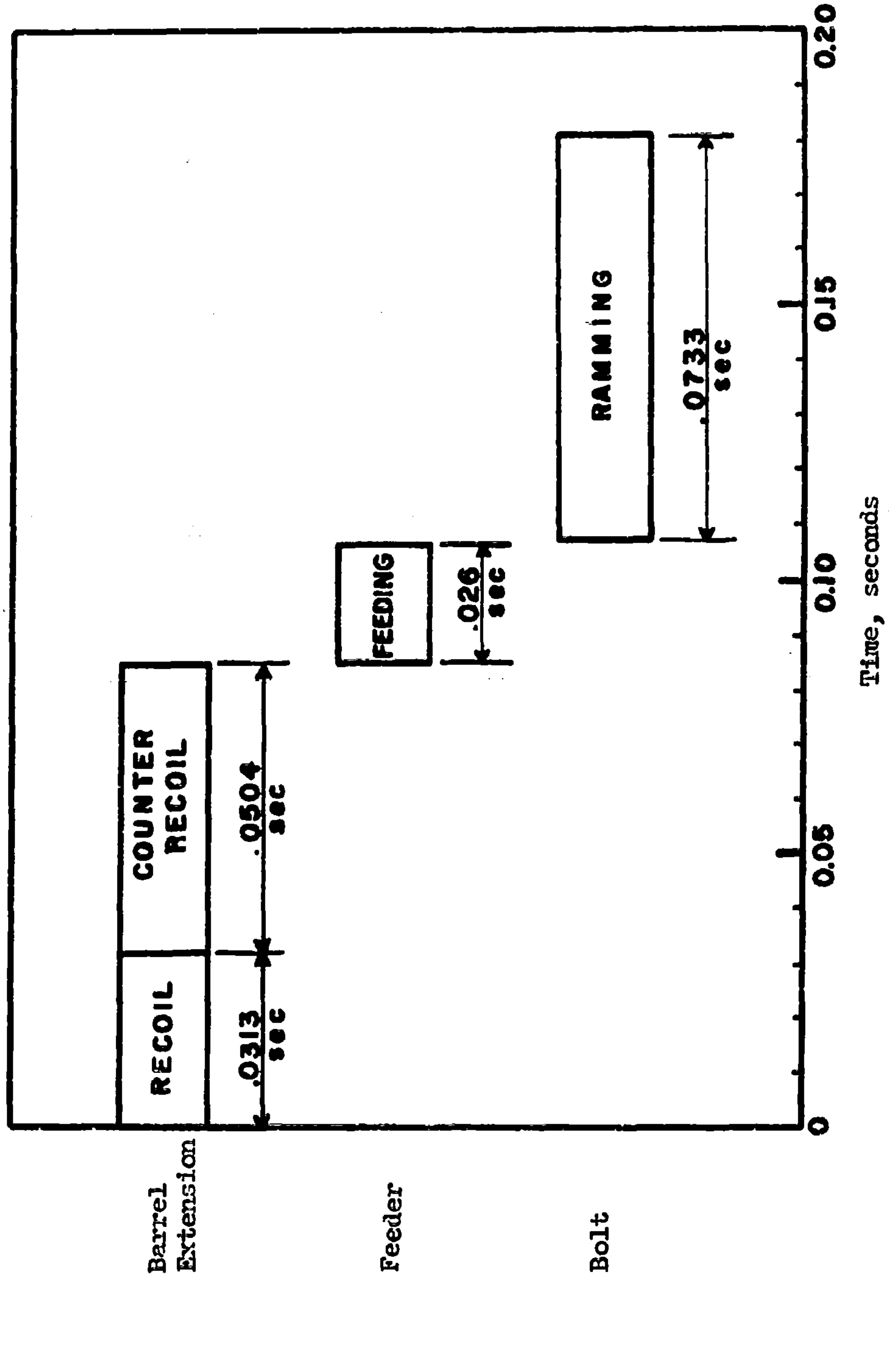

Fig. 8 TIMING DIAGRAM FOR 37MM NS GUN

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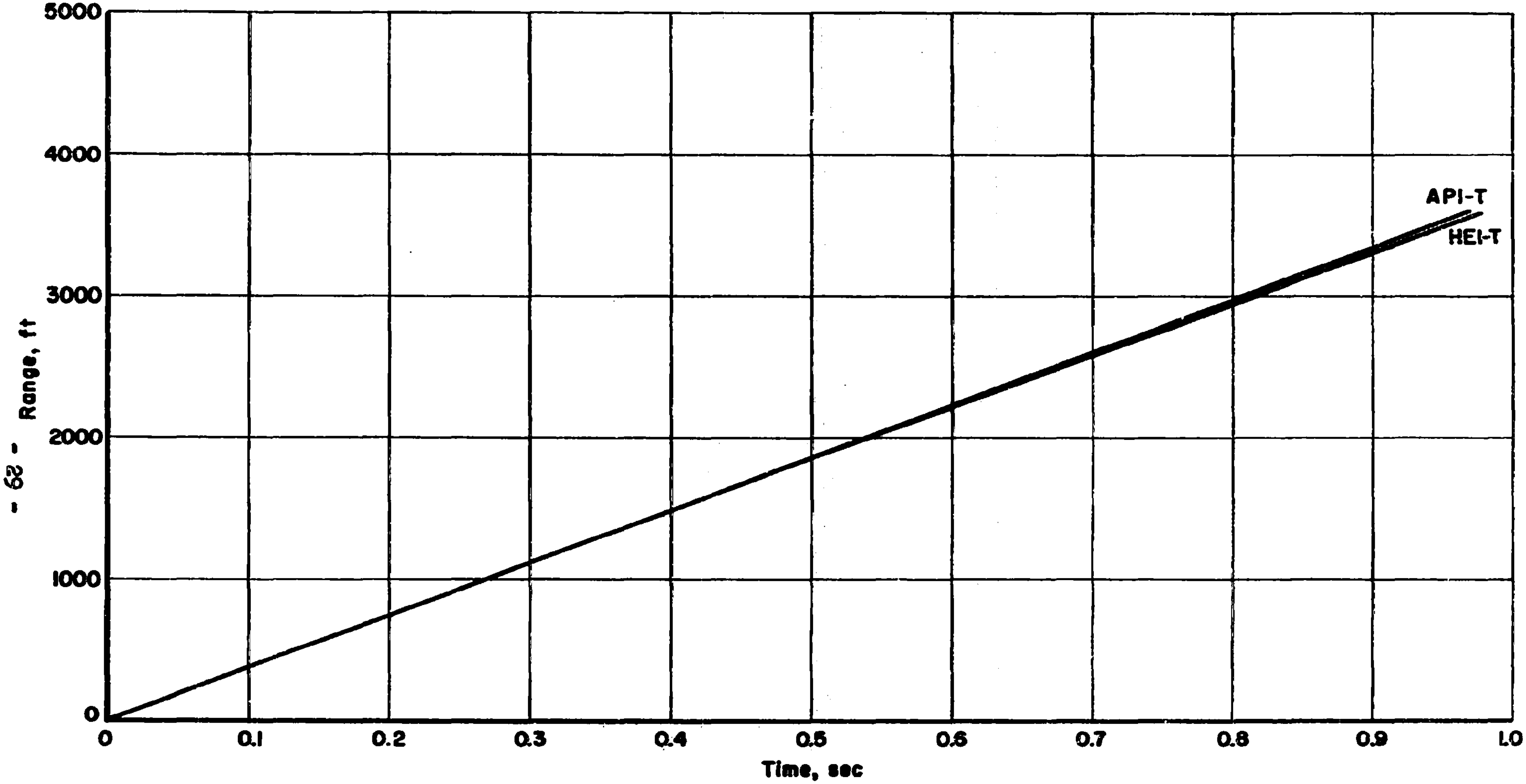

Fig. 9 HORIZONTAL COMPONENT OF TRAJECTORY FOR 37MM NS GUN, API-T AMMUNITION

T52-12901

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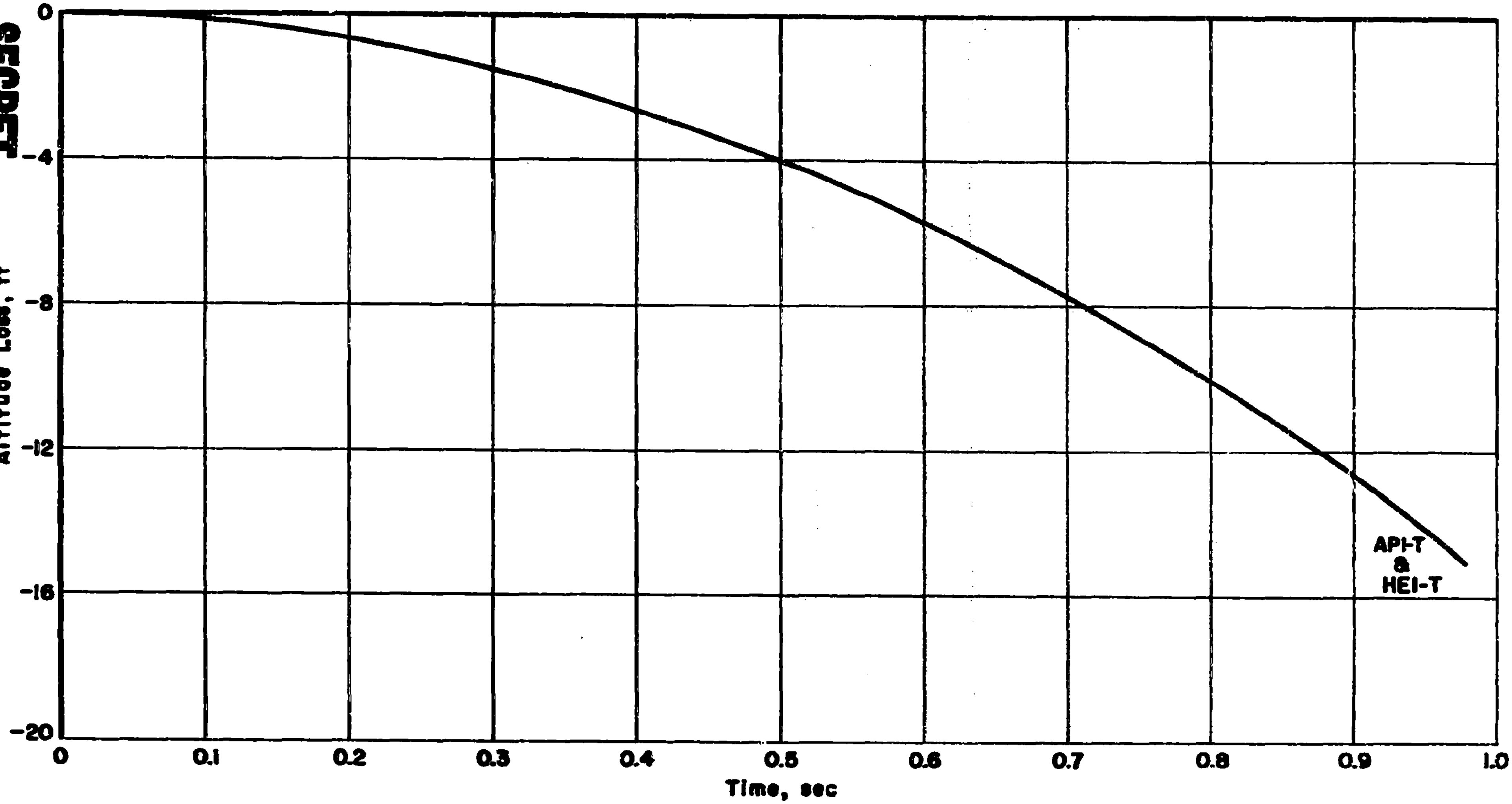

Fig. 10 VERTICAL COMPONENT OF TRAJECTORY FOR 37MM NS GUN, API-T AMMUNITION

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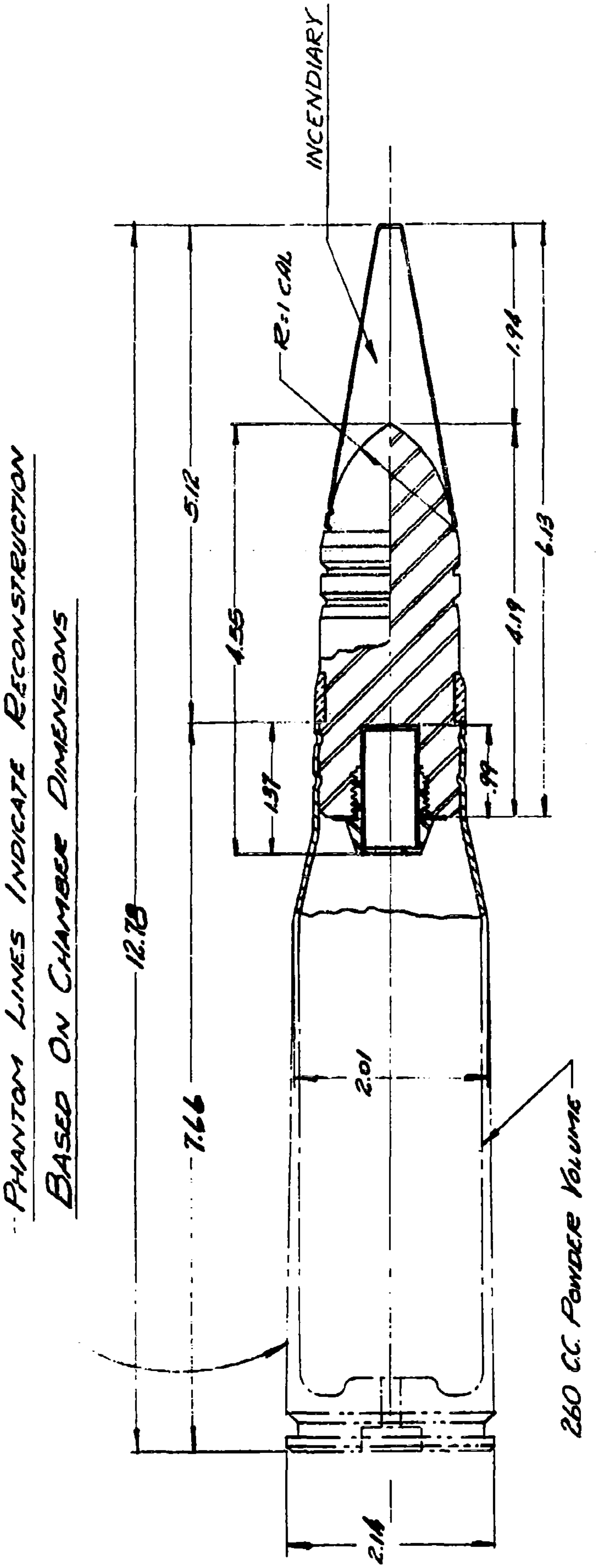

Fig. 11 CARTRIDGE, API-T, 37 MM FOR SOVIET 37 MM NS GUN

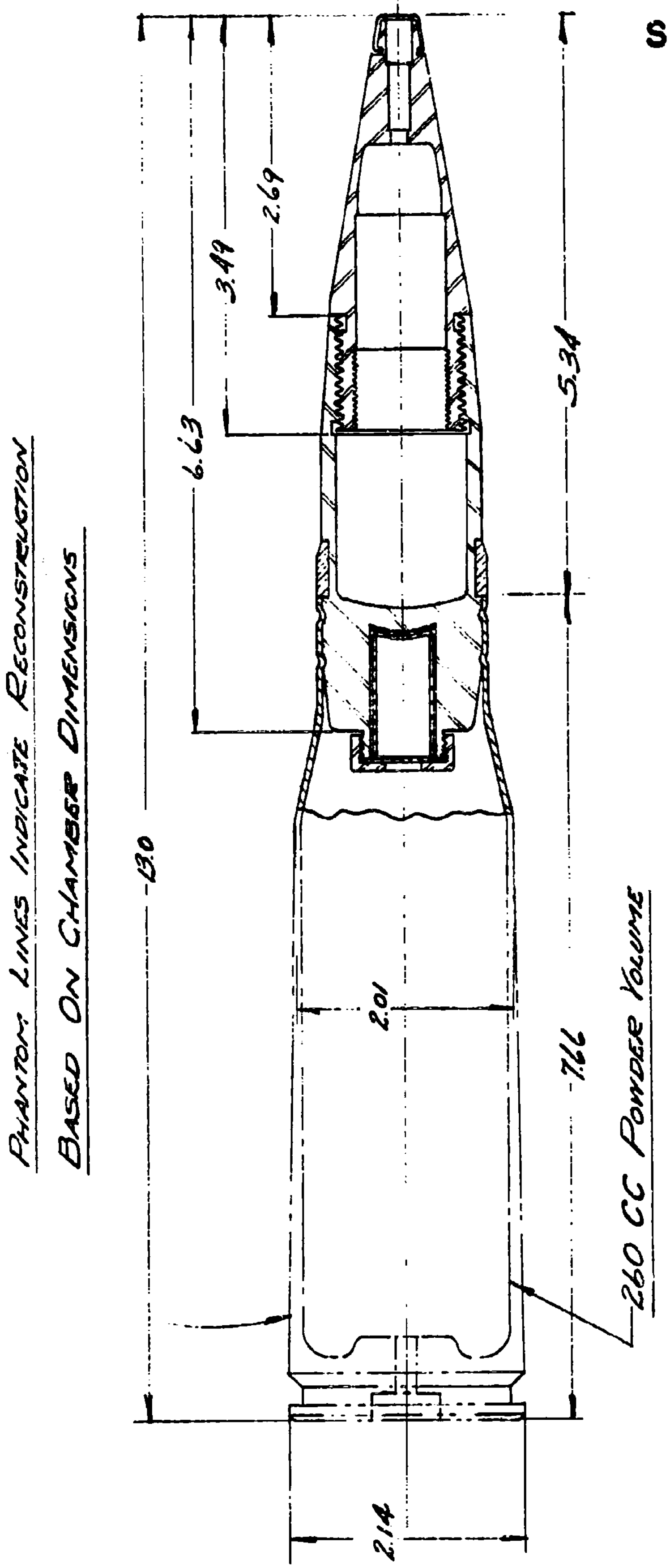

Fig.12 CARTRIDGE, HEI-T, 37 MM, FOR SOVIET 37 MM NS GUN

Fig. 13 37MM NS GUN, TOP VIEW

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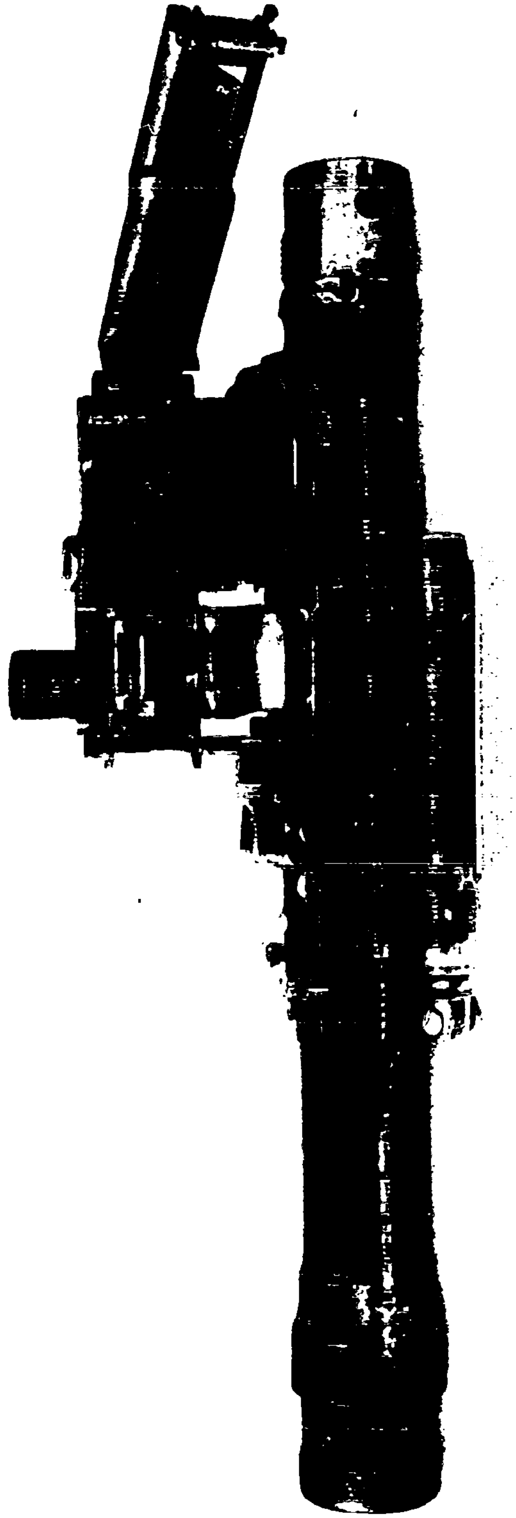

Fig. 14 RECEIVER FOR 37MM NS GUN, FEEDER COVER PLATE OPEN

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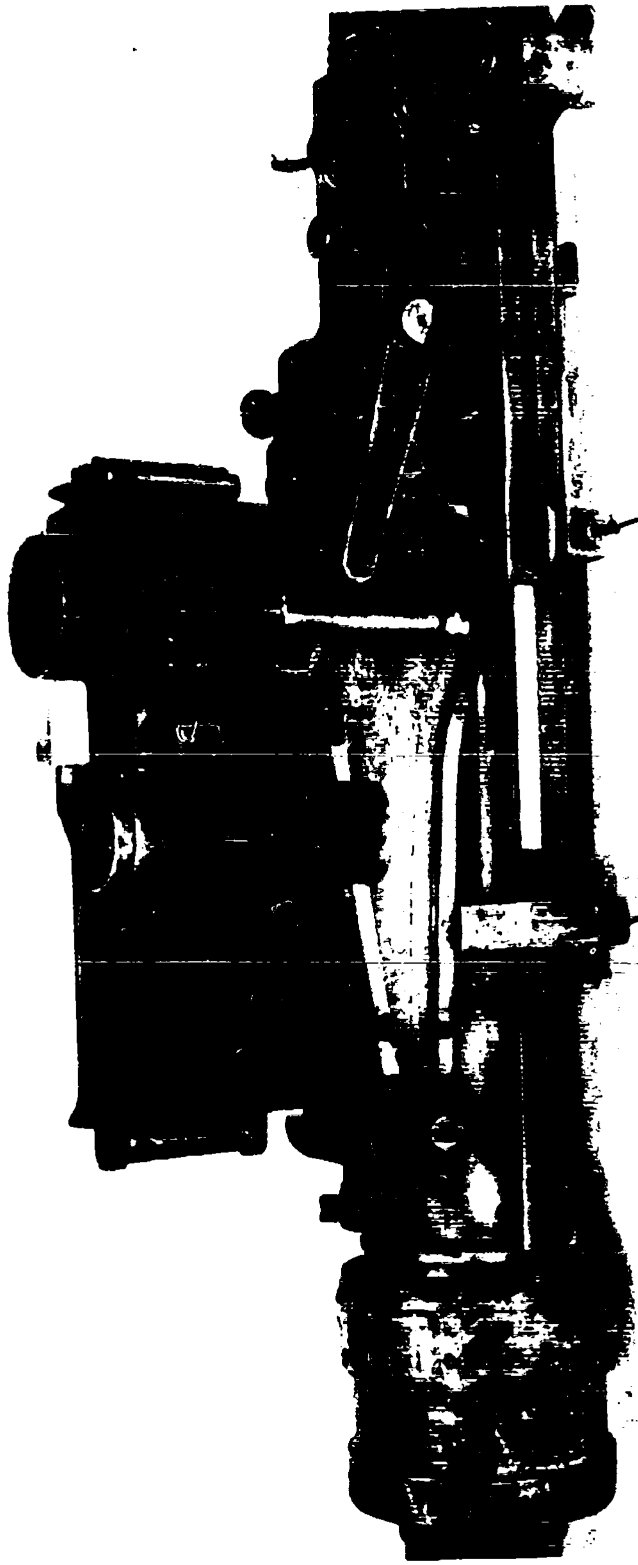

Fig. 15 RECEIVER FOR 37MM M5 GUN, TOP VIEW

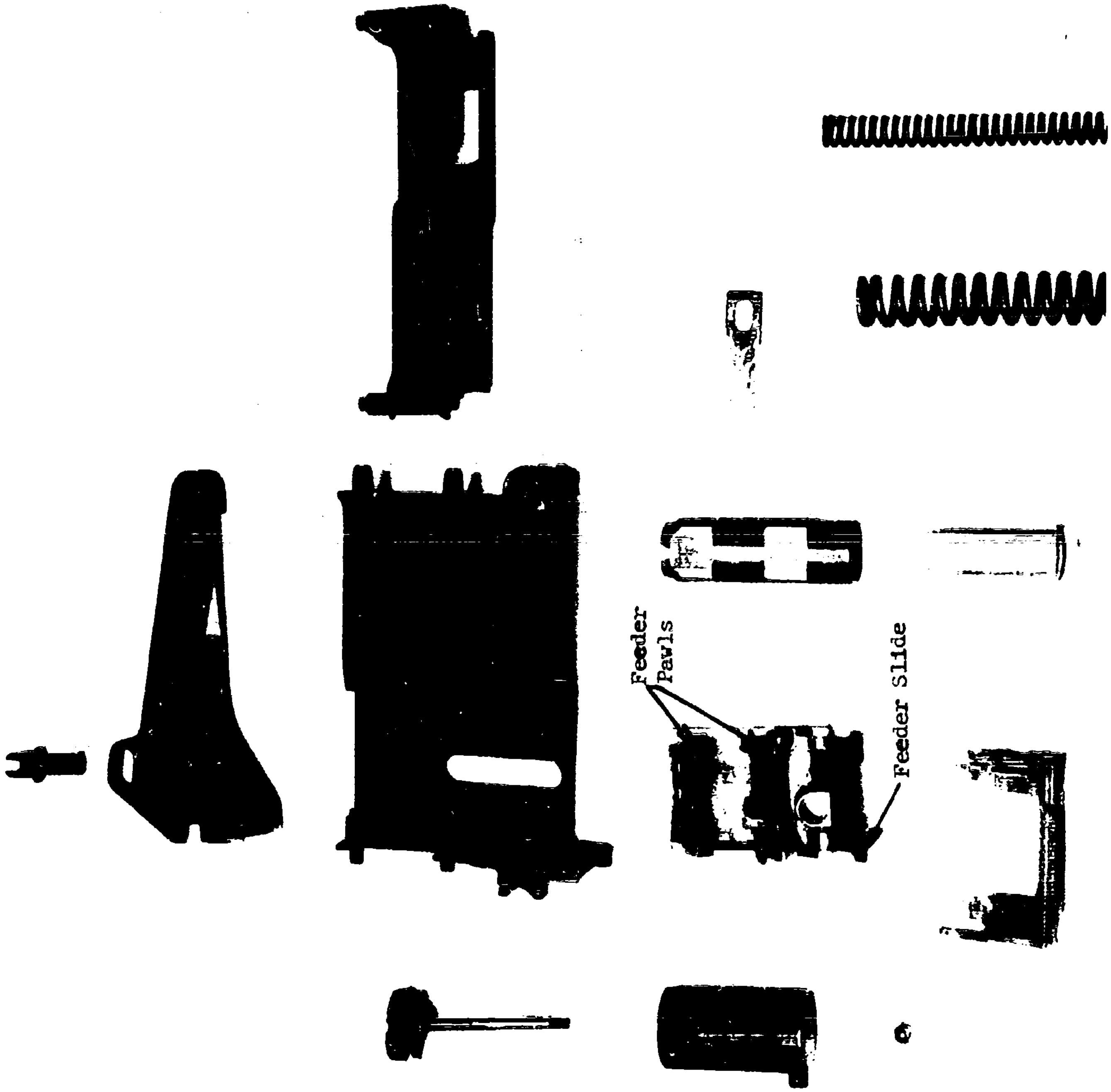

Fig. 16 FEEDER FOR 37MM NS GUN, DISASSEMBLED

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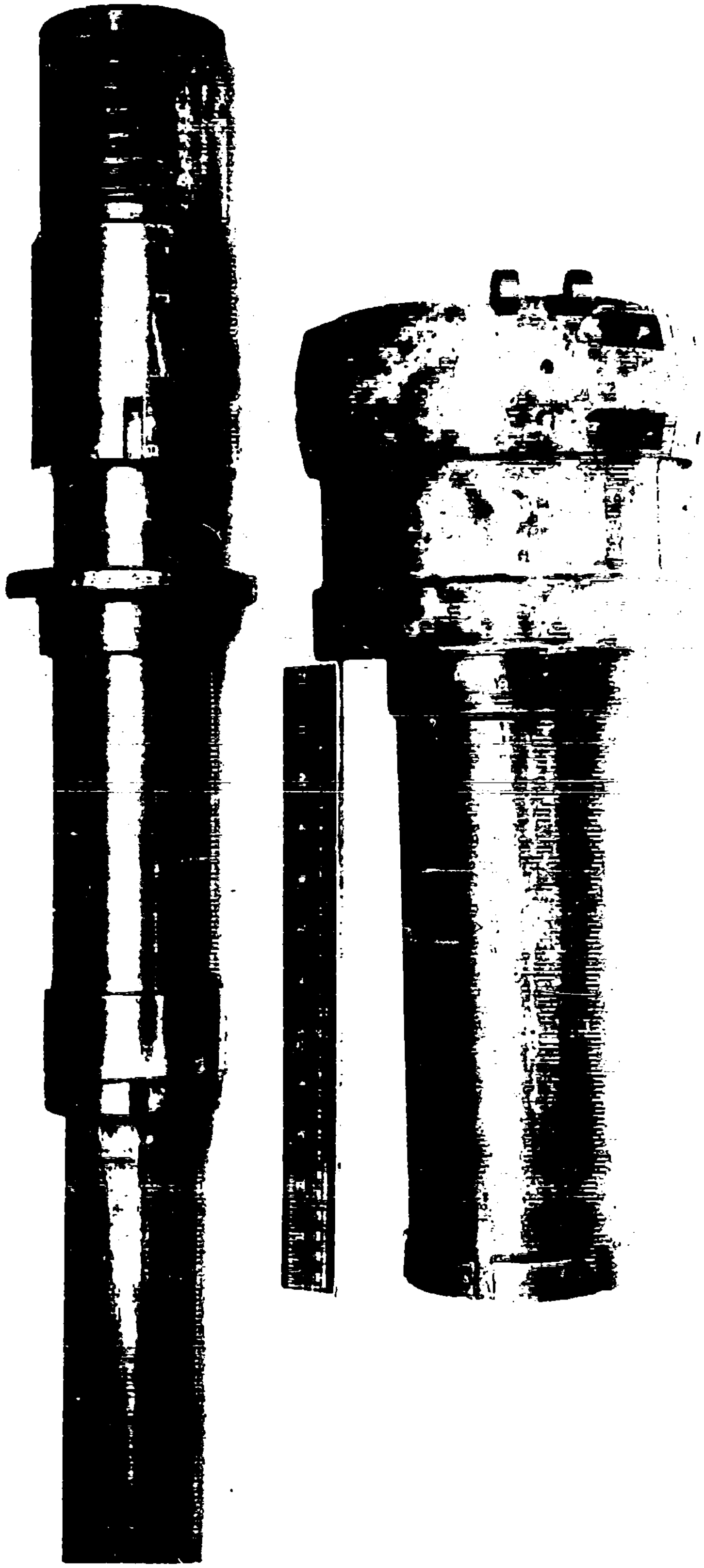

Fig. 17 BARREL SUPPORT AND REAR OF BARREL FOR 37MM NS GUN

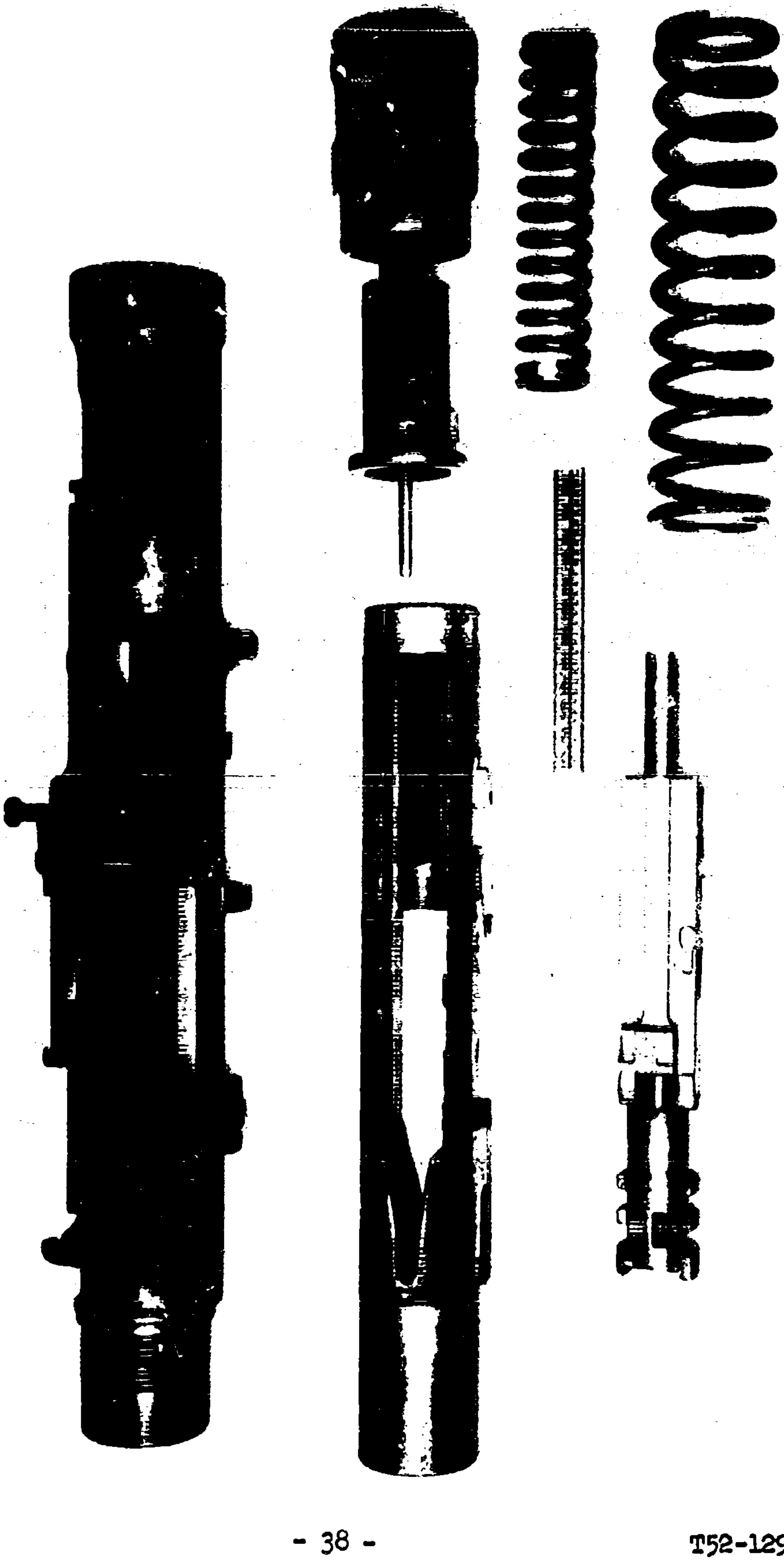

Fig. 18 RECEIVER, BARREL EXTENSION, RECOIL SPRINGS, AND BOLT FOR 37MM NS GUN

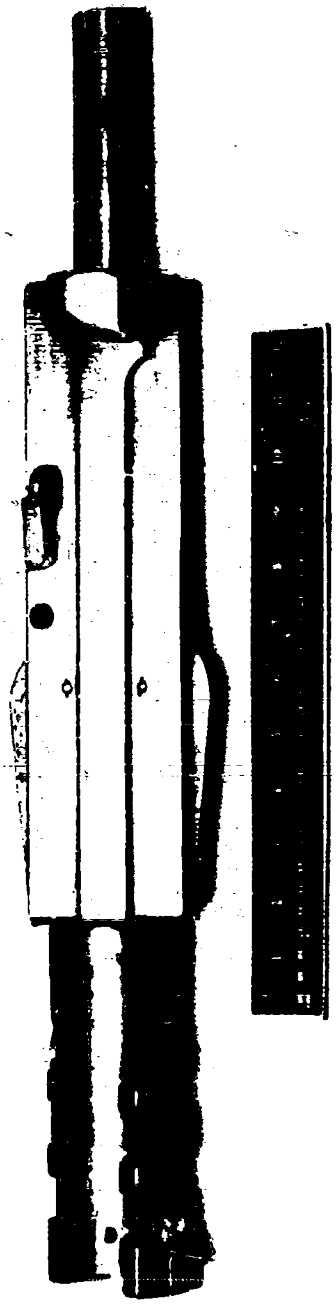

Fig. 19 BOLT FOR 37MM NS GUN, LOCKED POSITION

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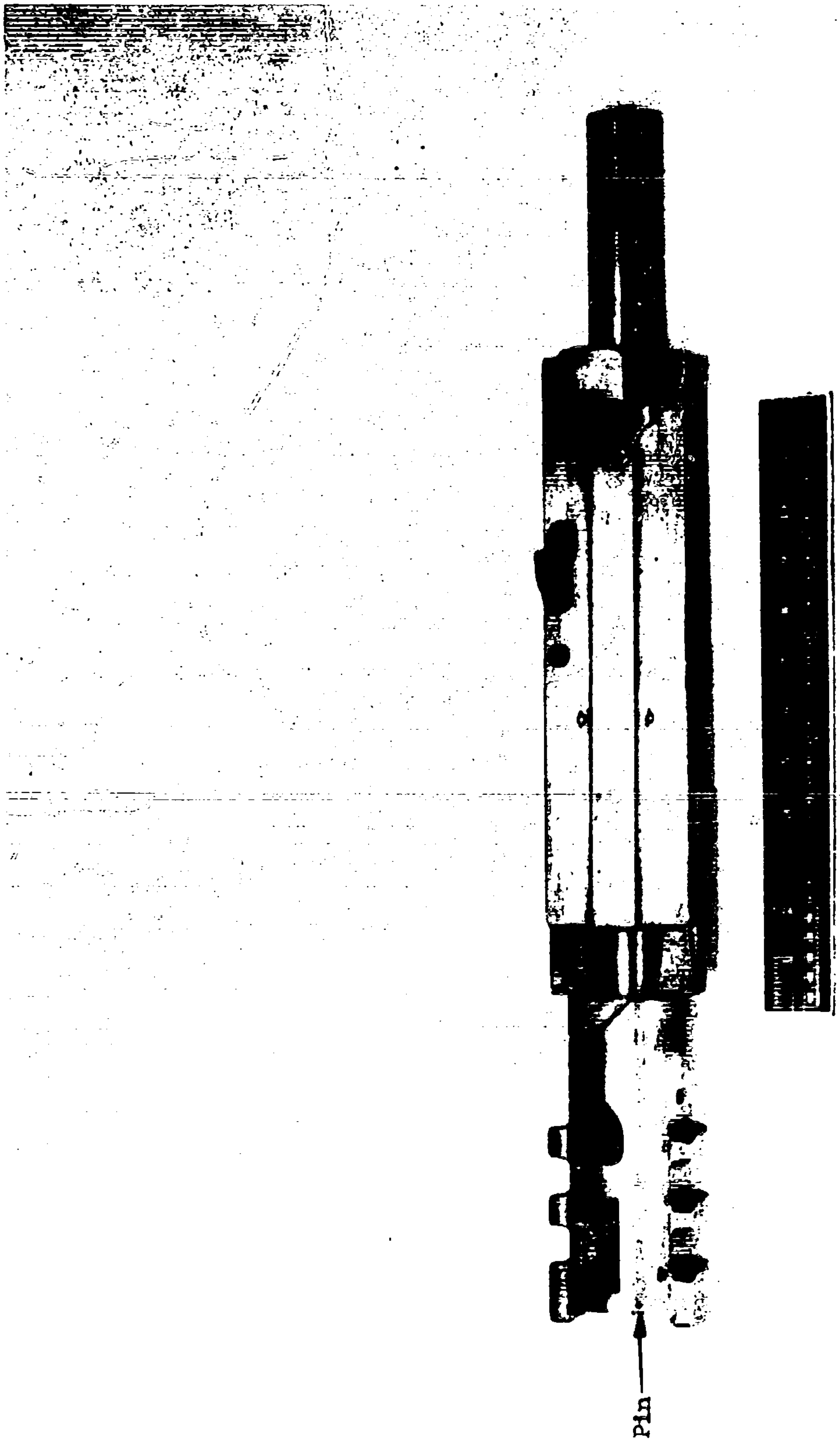

Fig. 20 BOLT FOR 37MM NS GUN, UNLOCKED POSITION

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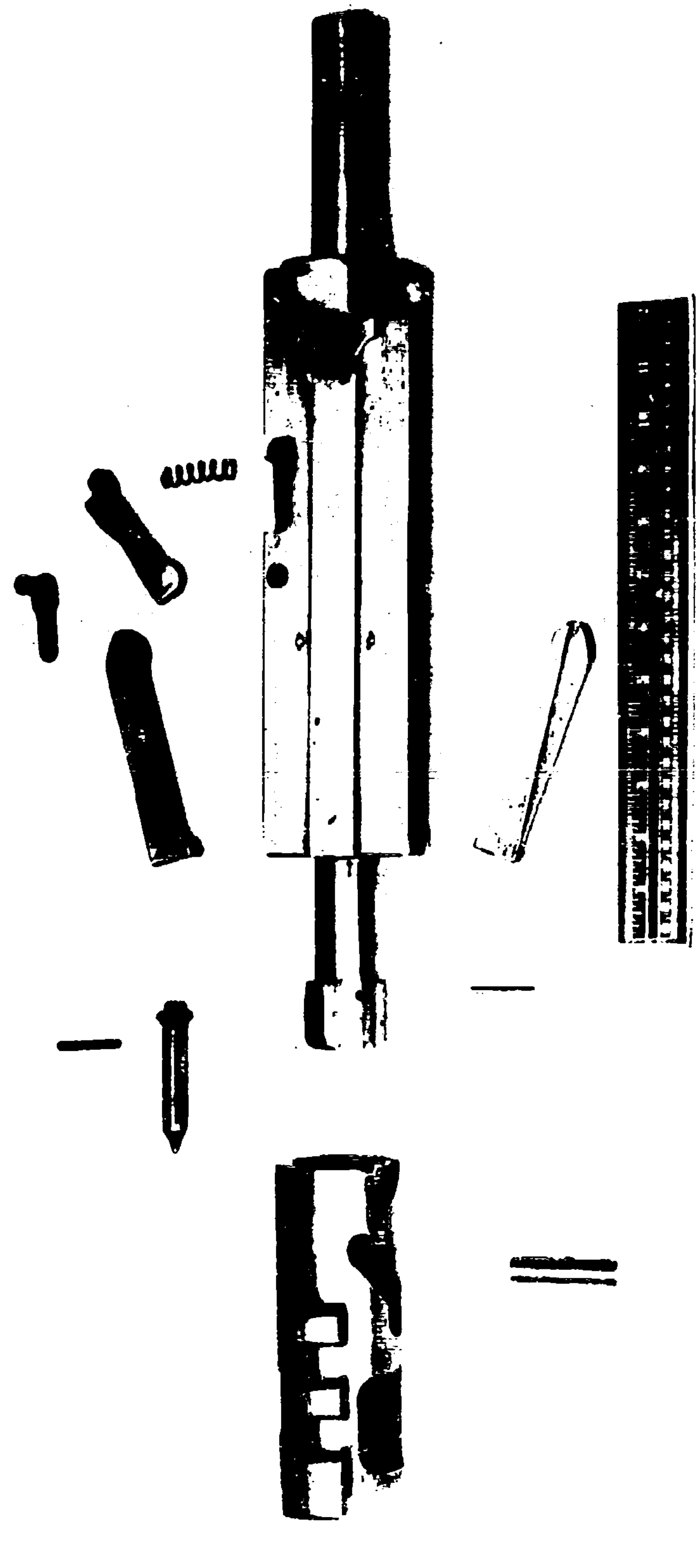

Fig. 21 BOLT FOR 37MM NS GUN, DISASSEMBLED

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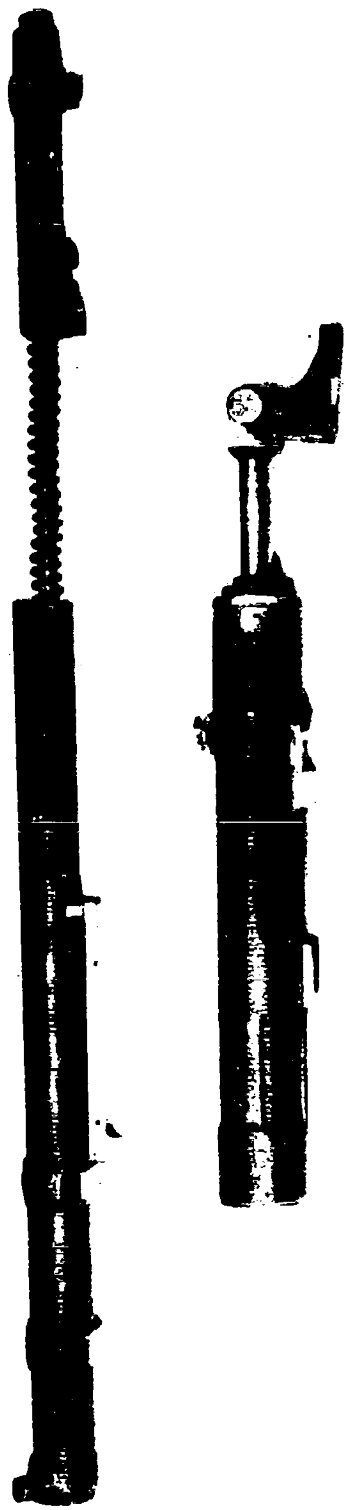

Fig. 22 BOLT CHARGER AND HYDRAULIC RECOIL BRAKE FOR 37-MM NS GUN

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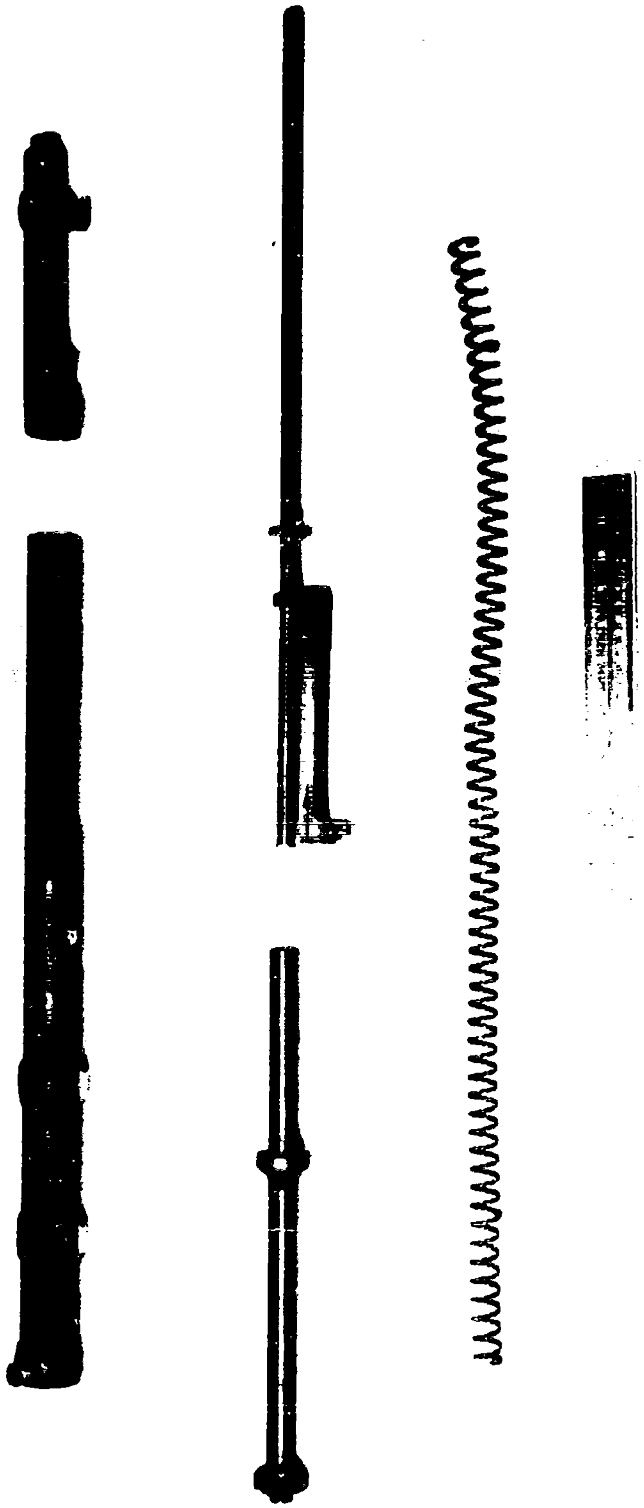

Fig. 23 BOLT CHARGER FOR 37MM NS GUN, DISASSEMBLED

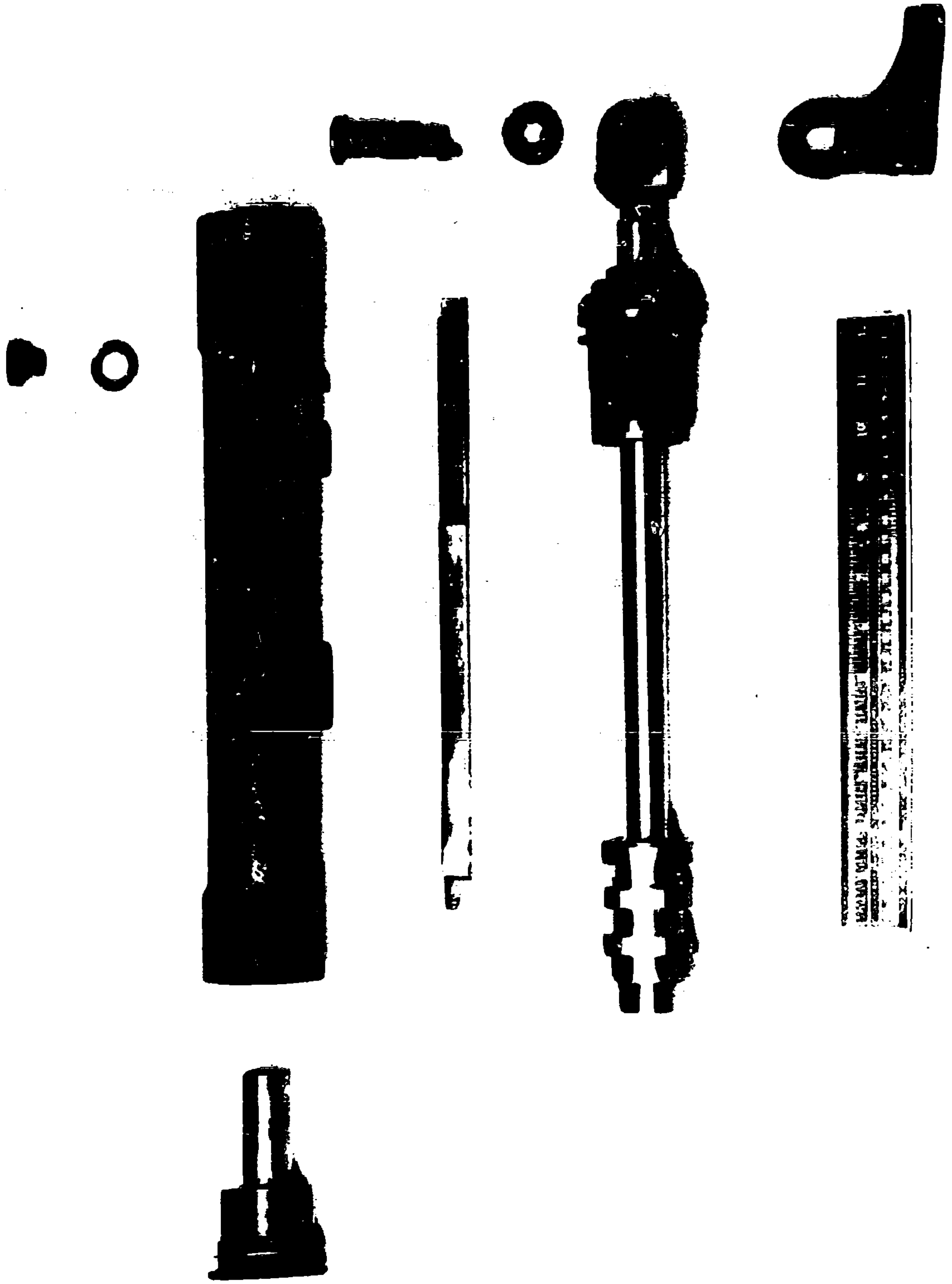

Fig. 24 DISASSEMBLED HYDRAULIC RECOIL BRAKE FOR 37MM NS GUN, SLIDE VALVE CLOSED

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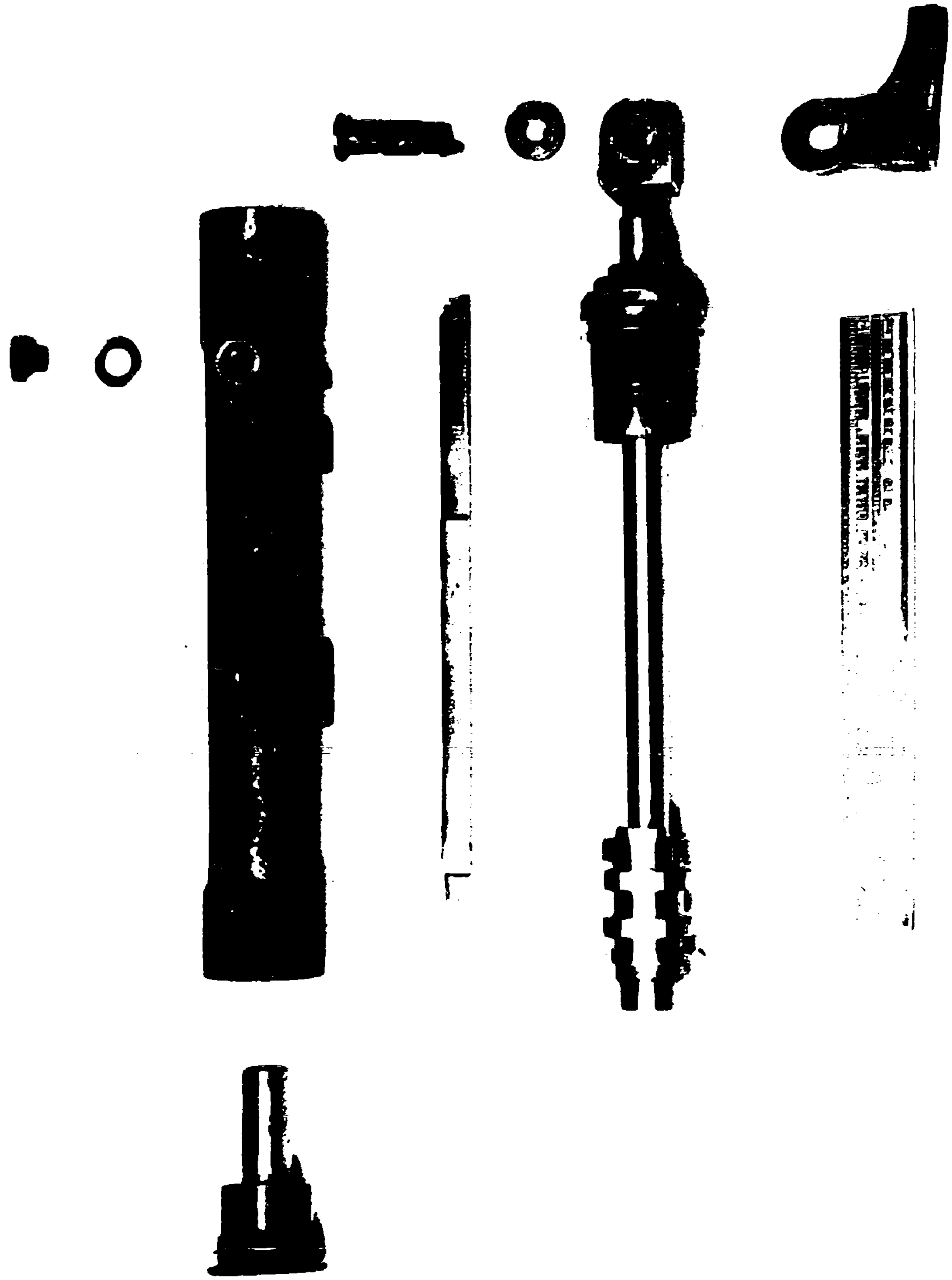

Fig. 25 DISASSEMBLED RECOIL BRAKE FOR 37MM M5 GUN, SLIDE VALVE OPEN

A10658

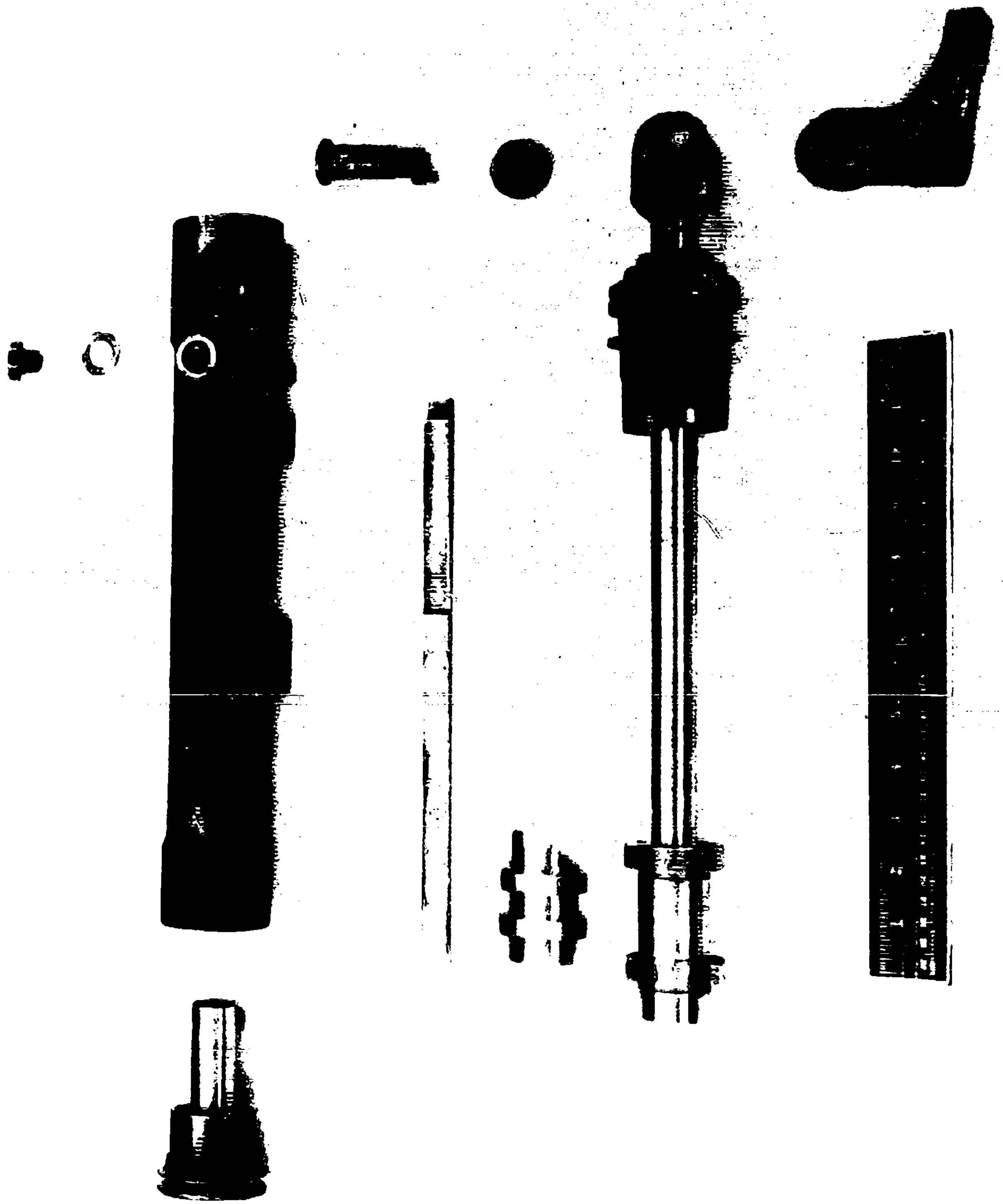

Fig. 26 DISASSEMBLED HYDRAULIC RECOIL BRAKE FOR 37MM NS GUN, SLIDE VALVE REMOVED

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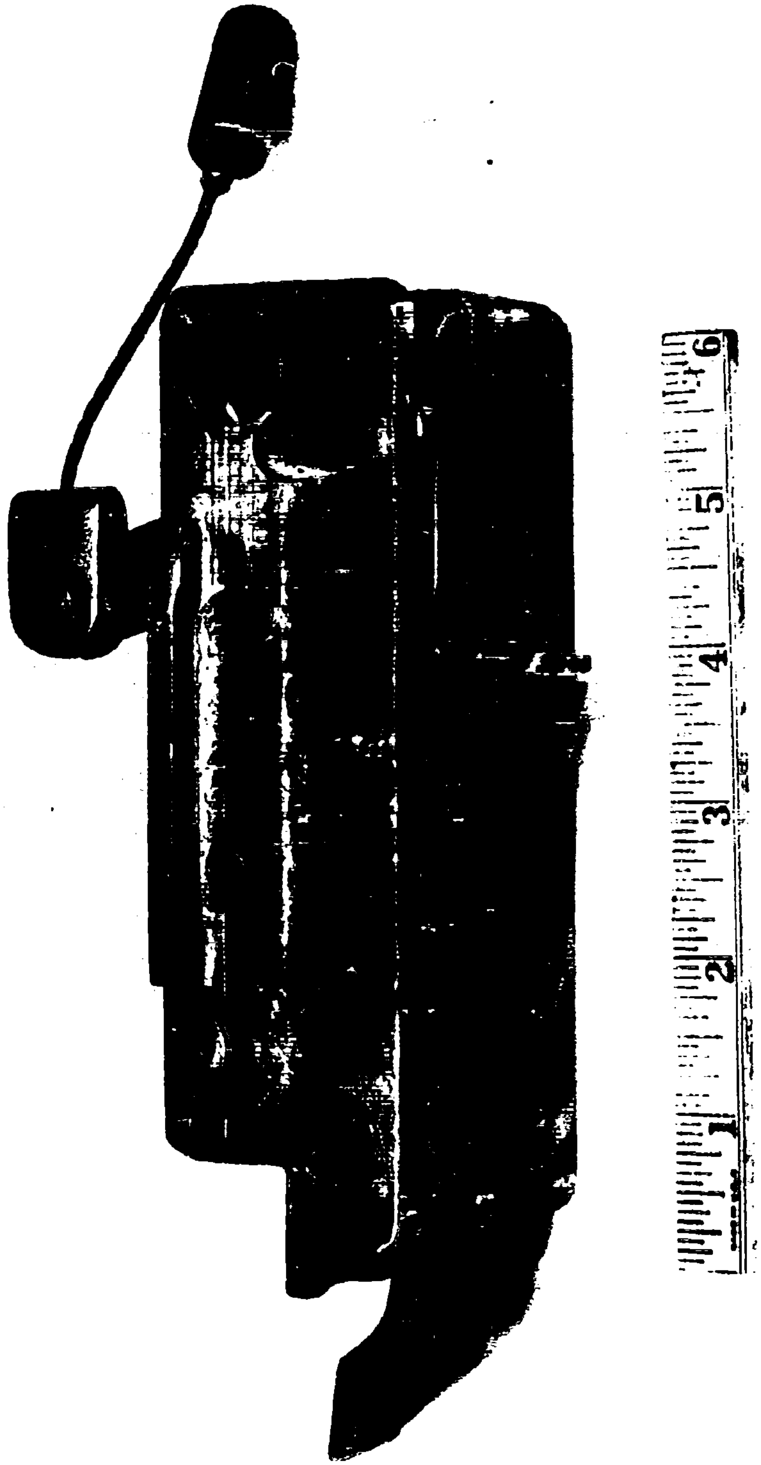

Fig. 27 SEAR FOR 37MM NS GUN

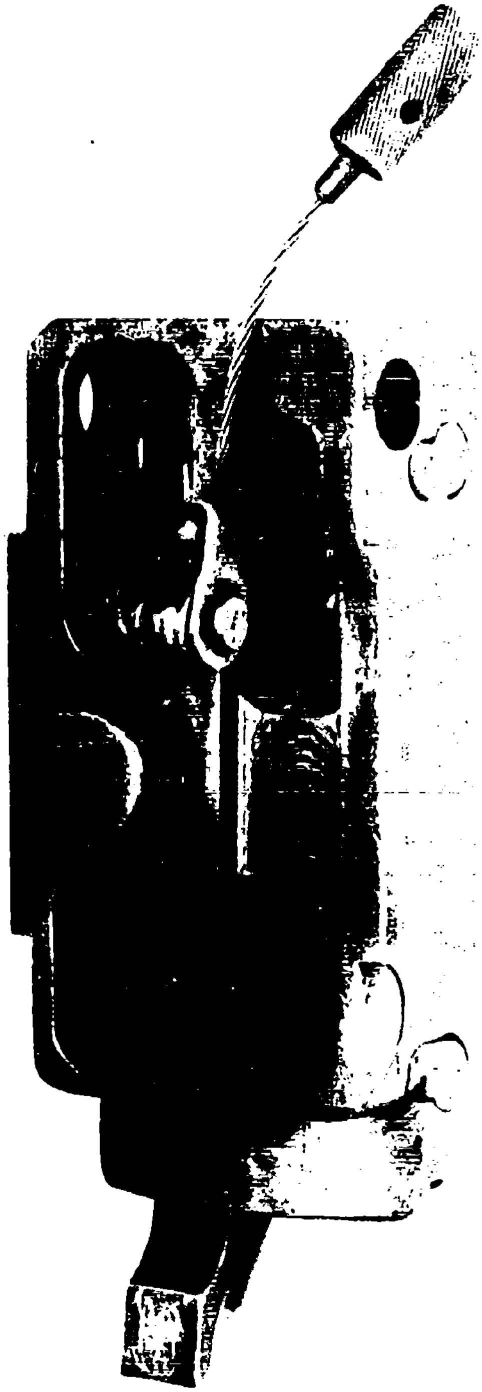

Fig. 28 SEAR FOR 37MM NS GUN

III. KINEMATIC ANALYSIS

A. Introduction

The purpose of this analysis is to determine the performance of the Soviet 37mm NS Gun. Of primary concern are the trunnion reaction and cyclic rate.

The trunnion reaction is determined by the sum of all the forces which act on the receiver.

The cyclic rate was determined analytically by the approximate energy method which was used in the evaluation of the Soviet 23mm NS Gun. The cycle time is the sum of (1) the recoil time, (2) the counterrecoil time up to the instant of feeder sear release, (3) the feeding time, and (4) the ramming time. Friction losses were accounted for by the introduction of the same efficiency factors which were determined for the various component operations in the evaluation of the Soviet 23mm NS Gun.

Because an exact analysis of the effect of the hydraulic recoil brake would have been quite difficult and much too complicated to warrant its inclusion in a simplified analysis of this type, the energy dissipated by the brake was apportioned to various phases of the recoil cycle. Although this simplified treatment may be slightly in error, the effect on the over-all cyclic rate is small in view of the fact that cyclic rate is a function of recoil and counterrecoil velocity which in turn varies as the square root of the kinetic energy.

This analysis was guided by the fact that the total recoil displacement was confined within the physical limits set by the gun mechanism.

B. Nomenclature

x = Barrel extension travel measured from battery, in.

y = Feeder slide travel, in.

z = Bolt travel measured from battery, in.

$\dot{x} = \frac{dx}{dt}$, fps

$\dot{y} = \frac{dy}{dt}$, fps

$\dot{z} = \frac{dz}{dt}$, fps

where x, y, and z are used as subscripts, reference is made to recoiling parts, feeder, and bolt assembly respectively.

K = Spring preload, lb

k = Spring constant, lb/in.

δ = Spring deflection

E = Potential energy, ft/lb

K.E. = Kinetic energy, ft/lb

θ = Angular displacement of feeder cam plate, radians

T = Torque acting on feeder cam plate, in-lb

η_F = Feeder efficiency

η_A = Accelerator efficiency

R = Accelerator ratio

W = Weight, lb

g = Acceleration due to gravity, (32.2 ft/sec^2)

m = Mass, $\frac{\text{lb-sec}^2}{\text{ft}}$

V_p = Muzzle velocity of projectile, fps

C. The Recoil and Counterrecoil Cycle

The recoil and counterrecoil cycle was divided into the following phases:

1. Recoil from battery position to the end of hydraulic recoil brake piston contact with counterrecoil buffer.

2. Recoil from the end of hydraulic recoil brake piston contact with counterrecoil buffer to bolt contact with accelerator.

3. Recoil from bolt contact with accelerator to end of contact.

4. Remainder of recoil.

5. Counterrecoil to end of contact with secondary recoil spring.

6. Counterrecoil from end of contact with secondary recoil spring to contact of hydraulic recoil brake piston with counterrecoil buffer.

7. Counterrecoil from contact of hydraulic recoil brake with buffer to feeder sear release.

8. Remainder of counterrecoil

Only the first seven phases were analyzed, because phase 8 has no influence on cyclic rate or maximum trunnion reaction.

As no ammunition is available for this gun, a value for initial recoil velocity was arrived at by employing the following semi-empirical formula.

$$\dot{x}_o = \frac{W_p V_p + 4700 W_c}{W_x + W_z}^{*}$$

where W_p = weight of projectile

W_c = weight of charge.

The values for propellant weight and muzzle velocity were taken from intelligence data. Unless they are substantially in error, the computed value of cyclic rate should not be greatly affected.

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*"Elements of Ordnance", T. J. Hayes, p.242, Eq. (4), 10th printing.

The initial recoil velocity is

$$\dot{x}_o = \frac{1.694\ (2950) + .452\ (4700)}{153.0 + 15.3}$$

$$\dot{x}_o = 42.2 \text{ fps.}$$

The kinetic energy of the recoiling masses, based on the above calculated velocity, is

$$K.E._{x+z} = K.E._x + K.E._z$$

$$K.E._{x+z} = 1/2\ \frac{153}{32.2}\ (42.2)^2 + 1/2\ \frac{15.3}{32.2}\ (42.2)^2$$

$$K.E._{x+z} = 4670 \text{ ft-lb}$$

The relative displacements of the various components are shown in Fig. 29.

1. Phase 1

This phase begins when the gun is fired and ends when the hydraulic recoil brake piston loses contact with the counterrecoil buffer. The main recoil spring, the bolt drive spring, the feeder spring and the hydraulic recoil brake act to resist recoil. The recoil displacement x varies from $x = 0$ to $x = 3$ inches.

The energy stored in any preloaded spring may be expressed as follows:

$$E_s = (K)\ (\delta - \delta_o) + 1/2\ (k)\ (\delta - \delta_o)^2$$

where

K = preload

δ = deflection from preloaded position

δ_o = predeflection

k = spring constant.

The energy stored in the recoil spring is

$$E_{x1} = 1/12 \left[601\ (3) + 1/2\ (209)\ (3)^2\right] = 229\ \text{ft-lb.}$$

The bolt displacement z varies from $z = 0$ to $z = 3$ inches, and the energy stored in the bolt drive spring is

$$E_{z1} = 1/12 \left[98\ (3) + 1/2\ (19.1)\ (3)^2\right] = 31.7\ \text{ft-lb.}$$

The energy input into the feeder during each phase may be expressed as

$$E_y = T_{ave} \cdot \Delta\theta$$

where

T_{ave} = average resisting torque acting on the feeder cam plate through an angle of rotation of $\Delta\theta$.

The torque at any point is

$$T = K_y\ \ell_1 + k_y\ \ell^2_1\ \theta + F_p\ \ell_2$$

where

K_y = feeder spring preload

ℓ_1 = moment arm of spring force

ℓ_2 = moment arm of pawl force

k_y = feeder spring constant

ϕ = angular displacement of feeder cam plate measured from the feeder slide when gun is at battery.

F_p = force necessary to pull pawls under rounds.

During phase 1, the feeder cam plate rotates through an angle of 0.1182 radian. The torque on the feeder cam plate at the start of phase 1 is

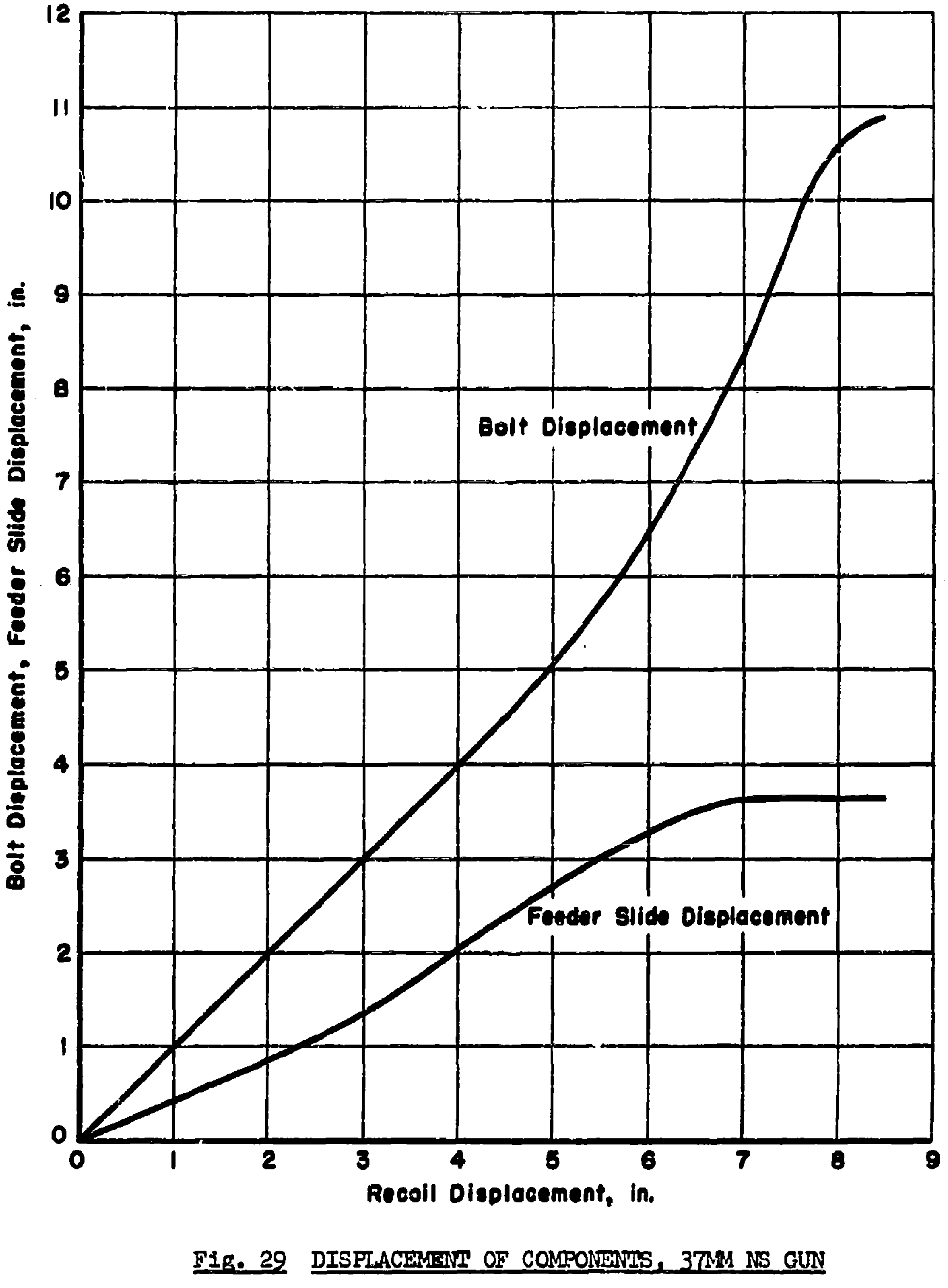

Fig. 29 DISPLACEMENT OF COMPONENTS, 37MM NS GUN

$$T_o = 1/12 \left[806 (6.75) + (474) (6.75)^2 (0) + 180 (11.25)\right]$$

$$T_o = 622 \text{ ft-lb.}$$

The torque at the end of phase 1 is

$$T_1 = 1/12 \left[806 (6.75) + (474) (6.75)^2 (.1182) + 180 (11.25)\right]$$

$$T_1 = 835 \text{ ft-lb.}$$

The energy input to the feeder is then

$$E_{y1} = \frac{622 + 835}{2} (.1182) = 86.1 \text{ ft-lb}$$

and with an efficiency of 27 per cent, the value determined in the analysis of the 23mm NS Gun, the energy taken from the recoiling masses is:

$$E'_{y1} = \frac{86.1}{.27} = 318 \text{ ft-lb.}$$

The energy lost to the hydraulic recoil brake is assumed to be 1400 ft-lb.

The kinetic energy of the recoiling parts at the end of phase 1 is

$$K.E._{x1} + K.E._{z1} = 4670 - 229 - 31.7 - 318 - 1400 = 2690 \text{ ft-lb.}$$

2. Phase 2

This phase begins when the hydraulic recoil brake piston loses contact with the counterrecoil buffer and ends when the bolt makes contact with the accelerator. The recoil spring, the bolt drive spring, the feeder spring and the hydraulic recoil brake act to resist recoil. The recoil displacement varies from $x = 3$ to $x = 4.5$.

The energy stored in the recoil spring is

$$E_{x2} = 1/12 \left[1228 (1.5) + 1/2 (209) (1.5)^2\right] = 173 \text{ ft-lb.}$$

The energy stored in the bolt drive spring is

$$E_{z2} = 1/12 \left[155.3\ (1.5) + 1/2\ (19.1)\ (1.5)^2\right] = 21.2 \text{ ft-lb.}$$

During this phase, the calculation of energy input into the feeder is divided into two parts. During the initial part, the pawls on the feeder slide are being pulled under the rounds. During the subsequent part, the pawls on the feeder slide are between rounds and therefore offer no resistance to the motion of the feeder slide. The angular displacement of the feeder cam varies from $\theta = 0.1182$ to $\theta = 0.2133$ radian.

The pawls on the feeder slide are depressed between $\theta = 0$ and $\theta = 0.1182$ radian. The torque acting at $\theta = 0.1822$ radian is

$$T_a = 1/12 \left[(806)\ (6.75) + (474)\ (6.75)^2\ (.1822) + (180)\ (11.25)\right]$$

$$T_a = 950 \text{ ft-lb.}$$

The energy input for this part is therefore

$$E_{ya} = \frac{835 + 950}{2}\ (.1822 - .1182)$$

$$E_{ya} = 57.1 \text{ ft-lb.}$$

The torque at the start of the second part is

$$T_b = 1/12 \left[(806)\ (6.75) + (474)\ (6.75)^2\ (.1822)\right]$$

$$T_b = 782 \text{ ft-lb.}$$

The torque at the end of phase 2 is

$$T_2 = 1/12 \left[(806)\ (6.75) + (474)\ (6.75)^2\ (.2133)\right]$$

$$T_2 = 838 \text{ ft-lb.}$$

The energy put into the feeder during the second part of phase 2 is

$$E_{yb} = \frac{782 + 838}{2}\ (.2133 - .1822)$$

$$E_{yb} = 25.2 \text{ ft-lb.}$$

The energy input to the feeder during phase 2 is

$$E_{y2} = E_{ya} + E_{yb}$$

$$E_{y2} = 82.3 \text{ ft-lb.}$$

The energy removed from the recoiling masses to supply the required feeder energy is

$$E'_{y2} = \frac{114}{.27} = 305 \text{ ft-lb.}$$

The energy lost to the hydraulic brake is assumed to be 360 ft-lb.

The kinetic energy of the recoiling parts at the end of phase 2 is

$$K.E._{x2} + K.E._{z2} = 2690 - 194 - 305 - 360 = 1831 \text{ ft-lb.}$$

3. Phase 3

During this phase of recoil, the bolt is unlocked from the barrel extension by the accelerator and continues to its rearmost position where it rebounds and is seared. The recoil spring, the bolt drive spring, and the feeder spring store energy. The kinetic energy imparted to the bolt by the accelerator in excess of the kinetic energy the bolt had at the start of this phase is neglected, because, while there is no way to determine it directly, its order of magnitude is small. The recoil displacement varies from x = 4.5 to x = 7.0 inches.

The secondary recoil spring starts to function during the last 0.06 inch of recoil travel in phase 3, and the energy absorbed by it must be added to the energy absorbed by the main recoil spring.

$$E_{x3} = 1/12 \left[(1540)(2.5) + 1/2(209)(2.5)^2\right]$$
$$+ 1/12 \left[(1720)(.06) + 1/2(362)(.06)^2\right]$$
$$E_{x3} = 384 \text{ ft-lb.}$$

The angular displacement of the feeder cam plate varies from $\phi = 0.2133$ to $\phi = 0.3244$ radian.

The torque on the feeder cam plate at the start of phase 3 is

$$T_2 = 838 \text{ ft-lb.}$$

The torque on the feeder cam plate at the end of phase 3 is

$$T_3 = 1/12 \left[(806)\ (6.75) + (474)\ (6.75)^2\ (.3244)\right]$$

$$T_3 = 1040 \text{ ft-lb.}$$

The energy input to the feeder is therefore

$$E_{y3} = \frac{1040 + 838}{2}\ (.3244 - .2133)$$

$$E_{y3} = 104 \text{ ft-lb.}$$

The energy removed from the recoiling masses is

$$E'_{y3} = \frac{104}{.27} = 386 \text{ ft-lb.}$$

The energy absorbed by the bolt drive spring is

$$E_{z3} = 1/12 \left[(184)\ (3.85) + 1/2\ (19.1)\ (3.85)^2\right]$$

$$E_{z3} = 70.8 \text{ ft-lb.}$$

This energy is supplied through the accelerator at an efficiency of 34 per cent, (the value determined in the analysis of the 23mm NS Gun). The energy removed from the recoiling parts therefore is

$$E'_{z3} = \frac{70.8}{.34} = 208 \text{ ft-lb.}$$

Since the bolt separates from the recoiling parts by the end of this phase, it removes its share of kinetic energy from the recoiling parts. The kinetic energy removed by the bolt may be determined by computing the energy required to compress the bolt drive spring to the bolt sear position, allowing enough kinetic energy to accommodate variations.

It is assumed the bolt strikes the rear stop with a velocity of 5 fps. This figure seems reasonable because a high striking velocity could result in parts breakage, and insufficient velocity would cause the bolt to stop short of the rear sear, resulting in a failure to fire.

$$K.E._{z3} = 1/12 \left[(257)(6.4) + 1/2\,(19.1)(6.4)^2\right] + 1/2\,\frac{15.3}{32.2}(5)^2$$

$$K.E._{z3} = 176 \text{ ft-lb.}$$

It is assumed that the hydraulic recoil brake absorbs 315 ft-lb of energy during this phase.

The kinetic energy of the recoiling parts at the end of phase 3 is

$$K.E._{x3} = 1831 - 384 - 386 - 208 - 176 - 315 = 362 \text{ ft-lb.}$$

4. <u>Phase 4</u>

During this phase, the recoiling parts continue to recoil until all the remaining energy is removed by the hydraulic recoil brake and the recoil springs.

It is assumed the hydraulic recoil brake absorbs 125 ft-lb of energy during this phase. The remaining kinetic energy is therefore absorbed by the recoil spring. The energy absorbed by the recoil spring is

$$E_{x4} = 362 - 125 = 239 \text{ ft-lb.}$$

The travel of the recoiling masses beyond x = 7 is determined from the energy equation

$$239 = 1/12 \left[(2060)(d) + 1/2\,(209)d^2\right]$$

$$d = .71 \text{ inch.}$$

The total recoil travel is therefore 7.71 inches. This figure seems reasonable since a minimum recoil travel of 5.61 inches is required to sear the feeder and a recoil travel of 8.47 inches would produce interference between the recoiling and stationary parts of the gun.

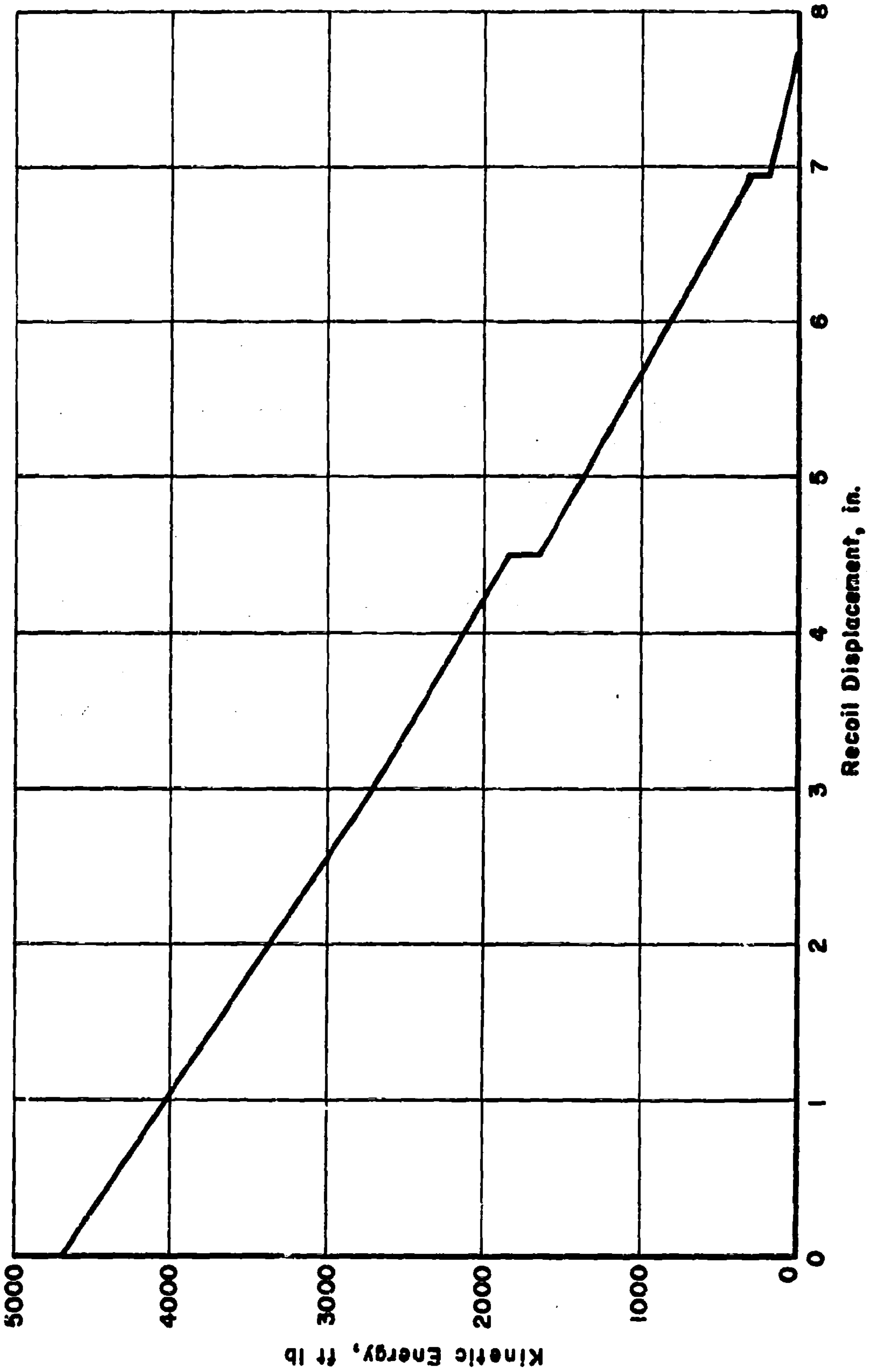

Fig. 30 RECOIL KINETIC ENERGY, 37MM MS GUN

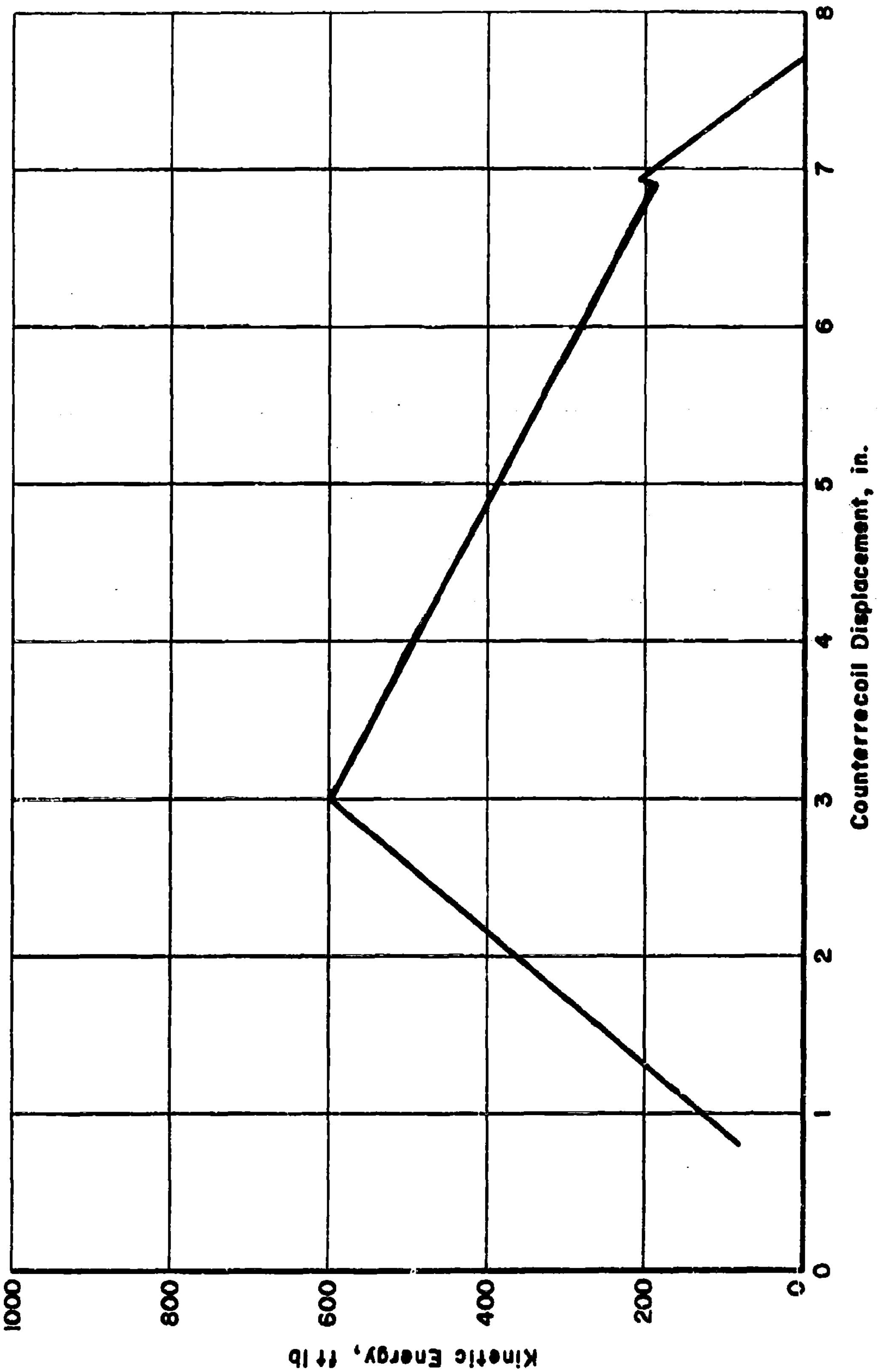

Fig. 31 COUNTER RECOIL KINETIC ENERGY, 37MM N5 GUN

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With this much known, the time required for the recoil stroke may be calculated. Knowing the kinetic energy of the recoiling parts at various points of recoil travel, and assuming linear variation with respect to recoil between points as is shown in Fig. 30, the recoil time may be calculated. Linear variation of kinetic energy with respect to recoil is of course not strictly true; however, since velocity varies as the square root of kinetic energy the error introduced is small. Time was calculated by the integral

$$t = \int_0^x \frac{dx}{\dot{x}}$$

where $\dot{x}$, the recoil velocity is

$$\dot{x} = \sqrt{\frac{2(K.E._{x+z})g}{W_x + W_z}}, \qquad 0 \leq x \leq 4.5$$

$$\dot{x} = \sqrt{\frac{2(K.E._x)g}{W_x}}, \qquad 4.5 \leq x \leq 8.47$$

On this basis, the time for recoil was determined to be 0.0313 second.

5. Phase 5

This phase of counterrecoil begins at the point of maximum recoil x_{max} = 7.71 inches and ends at x = 6.94 inches, where the secondary recoil spring ends contact with the counterrecoiling parts. The potential energy which is released from the main and secondary recoil springs is converted into kinetic energy of the counterrecoiling parts. As the recoil brake also acts in counterrecoil, the energy which it absorbs must also be taken into account. Since the recoil brake defies simplified analysis, and since even a large error in estimation of the energy absorbed by the recoil brake has small effect on the cyclic rate, it was assumed that 80 per cent of the potential energy available appears as kinetic energy at the end of this phase. Further, it was assumed that the kinetic energy increased linearly with respect to counterrecoil displacement, as is shown in Fig. 31.

The potential energy released from the recoil springs is

$$E_{x5} = 1/12 \left[(2050)\ (.77) + 1/2\ (209)\ (.77)^2\right]$$

$$+ 1/12 \left[(1720)\ (.77) + 1/2\ (362)\ (.77)^2\right]$$

$$E_{x5} = 256 \text{ ft-lb.}$$

The kinetic energy in the counterrecoiling mass at the end of phase 5, is 80 per cent of this energy.

$$K.E._5 = (0.80)\ (256) = 205 \text{ ft-lb.}$$

6. <u>Phase 6</u>

This phase begins at the point where the secondary recoil spring ends contact with the counterrecoiling masses, and ends where the counterrcoil buffer makes contact with the hydraulic recoil brake piston. The displacement varies from x = 6.94 to x = 3.00 inches. As in the preceding phase, it is assumed that 20 per cent of the kinetic energy will be lost to the hydraulic recoil brake.

The potential energy released by the recoil spring is

$$E_{x6} = 1/12 \left[(1230)\ (3.94) + 1/2\ (209)\ (3.94)^2\right]$$

$$E_{x6} = 538 \text{ ft-lb.}$$

To this, the kinetic energy which the counterrecoiling parts had at the start of this phase is added. As only 80 per cent appears as kinetic energy at the end of this phase

$K.E._{x6} = (0.80)\ (538 + 205) = 595$ ft-lb.

7. Phase 7

This phase begins where the counterrecoil buffer makes contact with the piston in the hydraulic recoil cylinder and ends when the feeder sear is released. The displacement varies from $x = 3.00$ to $x = 0.80$ inch. As the counterrecoil buffer causes large energy losses, it is assumed that 90 per cent of the kinetic energy is dissipated in the hydraulic recoil brake.

The potential energy released by the recoil spring is

$$E_{x7} = 1/12 \left[(768)\ (1.2) + 1/2\ (209)\ (1.2)^2\right]$$

$$E_{x7} = 89.4 \text{ ft-lb.}$$

To this the kinetic energy which the counterrecoiling parts had at the start of the phase must be added. As only 10 per cent of the input appears as kinetic energy at the end of this phase,

$$K.E._{x7} = (0.10)\ (89.4 + 595)$$

$$K.E._{x7} = 68.4 \text{ ft-lb.}$$

The counterrecoil time was calculated in the same manner as the recoil time and was found to be 0.0504 seconds.

D. The Feeding Motion

A free-body diagram of the feeder cam plate is shown in Fig. 32.

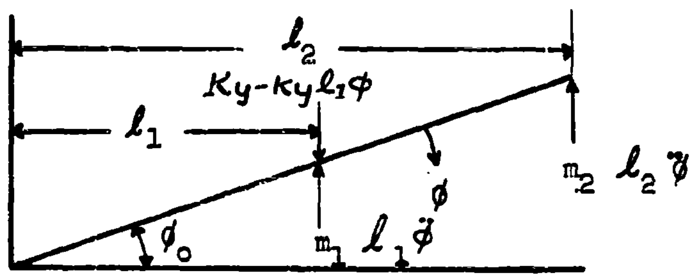

Fig. 32 FREE BODY DIAGRAM OF FEEDER CAM PLATE DURING FEEDING STROKE

The feeding time was obtained by analysis. The equation of motion of the feeder is

$$I\ddot{\phi} = (K_y - k_y \ell_1 \phi)\,\ell_1 - m_1 \ell_1^2 \ddot{\phi} - m_2 \ell_2^2 \ddot{\phi}$$

the solution of which for initial conditions, $\phi(0)$ and $\dot{\phi}(0)$ is

$$\phi = \frac{K_y}{k_y \ell_1}(1 - \cos\omega t)$$

where

$$\omega = \sqrt{\frac{k_y \ell_1^2}{I + m_1 \ell_1^2 + m_2 \ell_2^2}} = \text{natural circular frequency.}$$

K_y = feeder spring preload

k_y = feeder spring rate

m_1 = equivalent mass of feeder spring and cap

m_2 = mass of feeder slide and rounds

ϕ = angular deflection of the feeder cam plate

The time for full feeder deflection $\phi = \phi_o$ is the principal value of

$$t_1 = \frac{1}{\omega}\,\text{arc cos}\left(1 - \frac{k_y \ell_1}{K_y}\phi_c\right)$$

with the following values for the constants

k_y = 474 lb/in.

K_y = 2135 lb

ℓ_1 = 6.75 in.

ℓ_2 = 11.25 in.

I = 1.1046 lb-sec^2-in.

$m_1 = 0.00435\ \text{lb-sec}^2/\text{in.}$

$m_2 = 0.1017\ \text{lb-sec}^2/\text{in.}$

$\phi_o = 15.65° = .2729$ radian

t_1 was found to be 0.0240 seconds. An additional 0.002 second was allowed for stripping the link from the round, bringing the total feeding time to 0.026 seconds.

E. Bolt Ramming Time

The bolt ramming time was determined by considering the bolt and bolt drive spring as a simple spring mass system as shown in Fig. 33. The effects of friction were neglected.

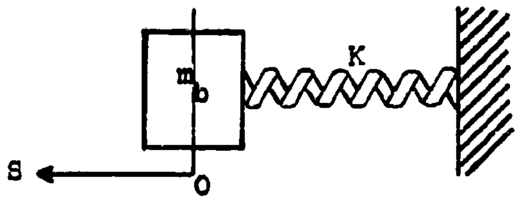

Fig. 33 SCHEMATIC DIAGRAM OF BOLT AND DRIVE SPRING, 37MM NS GUN

From Newton's law of motion, the differential equation of motion is obtained:

$$m_b \ddot{s} = K - ks$$

The general solution of which, with initial conditions $s(0) = 0$ and $\dot{s}(0) = V_o$ is

$$s = \frac{K}{k}(1 - \cos\omega t) + \frac{V_o}{\omega}\sin\omega t$$

where

$$\omega = \sqrt{\frac{k}{m_b}}$$

K = drive spring preload

k = spring rate

m_b = mass of bolt

V_o = initial bolt velocity

t = time.

An expression for velocity may be had by differentiating the above equation with respect to time

$$\dot{s} = \frac{K}{k}\,\omega \sin \omega t + V_o \cos \omega t$$

The belt drive spring was calibrated and was approximated with two spring rates in unloading as is shown in Fig. 34. Therefore, it was necessary to divide the analysis of the ramming stroke into two parts.

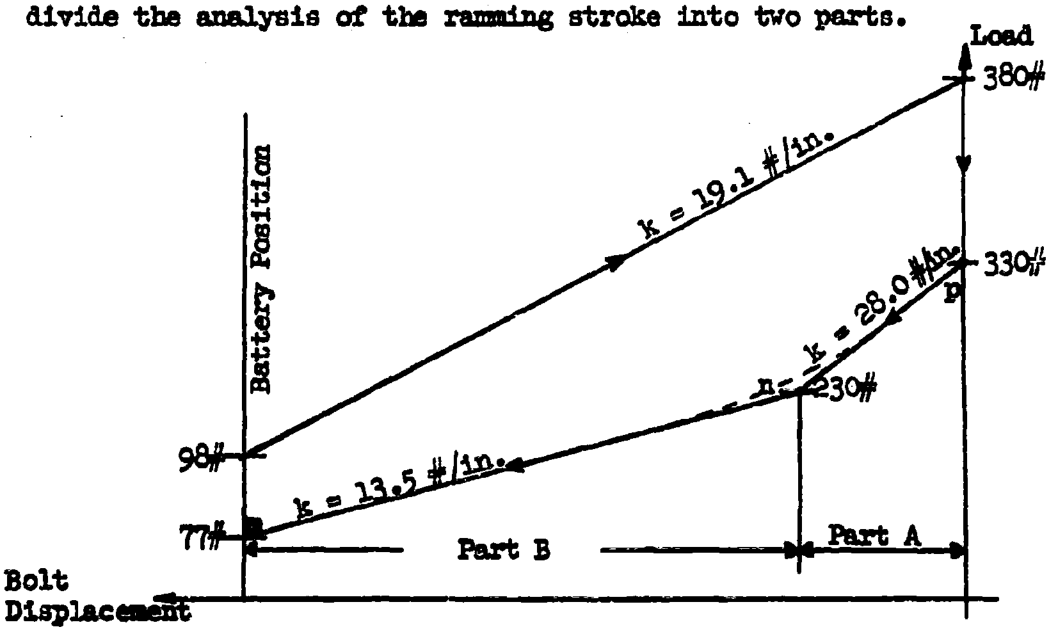

Fig. 34 CALIBRATION OF BOLT DRIVE SPRING

PART A

The natural frequency of the spring mass system for Part A is

$$\omega_A' = \sqrt{\frac{k_A}{m_b}}$$

$$\omega_A = \sqrt{\frac{28.0 \times 386.4}{18.46}} = 24.2 \text{ rad/sec}$$

The time required for the bolt to move from point p to point n can be calculated by use of the displacement equation

$$s = \frac{K}{k}(1 - \cos\omega t) + \frac{V_o}{\omega}\sin\omega t$$

$$s_n = \frac{330}{28.0}(1 - \cos 24.2\, t) = 3.55$$

$$t = .0329 \text{ sec.}$$

The velocity of the bolt at point n is

$$\dot{s} = \frac{K}{k}\omega \sin\omega t + V_o \cos\omega t$$

$$\dot{s}_n = \frac{330}{28.0}(24.2) \sin 24.2\,(.0329)$$

$$\dot{s}_n = 204.0 \text{ in./sec}$$

PART B

The natural frequency of the spring mass system for Part B is

$$\omega_B = \sqrt{\frac{k_B}{m_b}}$$

$$\omega_B = \frac{13.5 \times 386.4}{18.46} = 16.85 \text{ rad/sec}$$

Considering point n as a new origin, with an initial velocity, the time required for the bolt to move from point n to point m can be calculated by use of the displacement equation

$$s = \frac{K}{k}(1 - \cos\omega t) + \frac{V_o}{\omega}\sin\omega t$$

$$s_m - s_n = \frac{230}{13.5}(1 - \cos 16.85\, t) + \frac{204.0}{16.85}\sin 16.85\, t - 11.33$$

$$t = .0404 \text{ sec.}$$

The total bolt ramming time is the sum of the time intervals for Part A and Part B or 0.0733 seconds.

F. Cyclic Rate

The cycle time is the sum of the time intervals of recoil, counter-recoil to the point of feeder release, feeding and ramming. The cycle time is .1807 seconds, which corresponds to a cyclic rate of 332 rounds per minute.

G. Trunnion Reaction

It is probable that the maximum trunnion reaction occurs when the bolt reaches the rearmost position of its travel and bottoms against the recoil spring stud. The maximum trunnion reaction would then be the sum of the recoil spring force, the bolt drive spring force and the impact of the bolt striking the recoil spring stud. The recoil spring force and the bolt drive spring force can readily be determined, but the impact force cannot be readily computed. It is principally a function of receiver stiffness, mount stiffness, and impact velocity, which was arbitrarily assumed to be 5 fps. The impact force in all probability is much greater in magnitude than the recoil spring and bolt drive spring forces combined. The maximum combined recoil spring and bolt drive spring force is 4600 pounds. This quantity, although of interest, is not the maximum reaction. It should be noted that the maximum force will be of very short duration.

IV. CALCULATIONS OF PRESSURE-TIME AND PRESSURE-TRAVEL CURVES

It was necessary to know if the required muzzle velocity could be obtained with the given barrel length, projectile, and propellant wieghts. The required energy input to shot ejection was calculated by the following formula.

$$E_{input} = \frac{1}{2}\left(\frac{W_p + \frac{1}{2}W_c}{g}\right)(x_o)^2$$

where

W_p = projectile weight

W_c = weight of propellant

x_o = muzzle velocity

The area under a pressure-projectile travel curve represents energy input. By assuming a reasonable peak powder pressure and considering the area required under the curve, the pressure-projectile travel curve in Fig. 35 was drawn. From this pressure-projectile travel curve, the energy input up to any point of projectile travel is readily determined, from which a velocity-travel curve can be drawn. From the velocity travel curve, a pressure-time curve, Fig. 36, can be drawn. Since the pressure-time curve appears reasonable, it is concluded that the required muzzle velocity can be obtained with the given propellant weight and barrel length.

V. ANALYSIS OF RECOIL SPRING

The outer recoil spring for the 37mm NS Gun was studied in some detail. Computations indicate that all helical springs in this weapon are stressed to a very high level during operation, and the outer recoil spring was selected as typical for detailed study.

Calculations showed that at closed height this spring was subjected to a maximum torsional shearing stress of 178000 lb/in.^{2}, which is extremely high for this wire size. The chemical analysis of the spring material is compared in Table II with that of AISI 9262, which is a material used for high duty springs at a hardness of Rockwell C50 to C54. The hardness of the Soviet steel was measured at Rockwell C58, which corresponds to a tensile ultimate stress of 320,000 lb/in.^{2}.

Table II

CHEMICAL ANALYSIS

	Soviet Spring	AISI 9262
Carbon	0.67	0.55 - 0.65
Silicon	1.72	1.70 - 2.20
Manganese	1.23	0.70 - 1.05
Nickel	0.21	---- ----
Chromium	0.57	0.20 - 0.50
Molybdenum	0.15	---- ----
Vanadium	0.03	---- ----

Compression load-deflection tests of the spring showed elastic behavior all the way to closed height, corresponding to a load of approximately 2400 pounds. In tensile load-deflection tests, a yield load of only 1000 pounds was obtained. This is an indication that residual stresses exist in the spring, which effectively raise the yield in compression.

This existence of residual stresses in compression springs is not unusual. It is a result of a normal manufacturing operation known as bulldozing or scragging. During this operation a compression spring wound to a length greater than the design free length is compressed rapidly several times to the closed height. During this operation the spring takes a set such that the original free height less the set will give the design free height. This bulldozing or setting operation builds up a residual stress field that opposes the stress field set up during spring compression, thus giving an apparent increase in yield strength. In railroad spring design in the United States some compression springs are designed on the basis of a torsional yield stress of 165,000 lb/in.^{2} with materials having a torsional yield stress of only 140,000 lb/in.^{2} thus taking advantage of the residual stresses of the setting operation.

It appears, therefore, that the Soviet technique in spring design is to select an unusually high strength material (tensile ultimate of approximately 320,000 lb/in.^{2} torsional yield of approximately 150,000 lb/in.^{2}), and then to work to a design stress about 20 per cent in excess of the torsional yield in order to take full advantage of the residual stresses resulting from the setting operation.

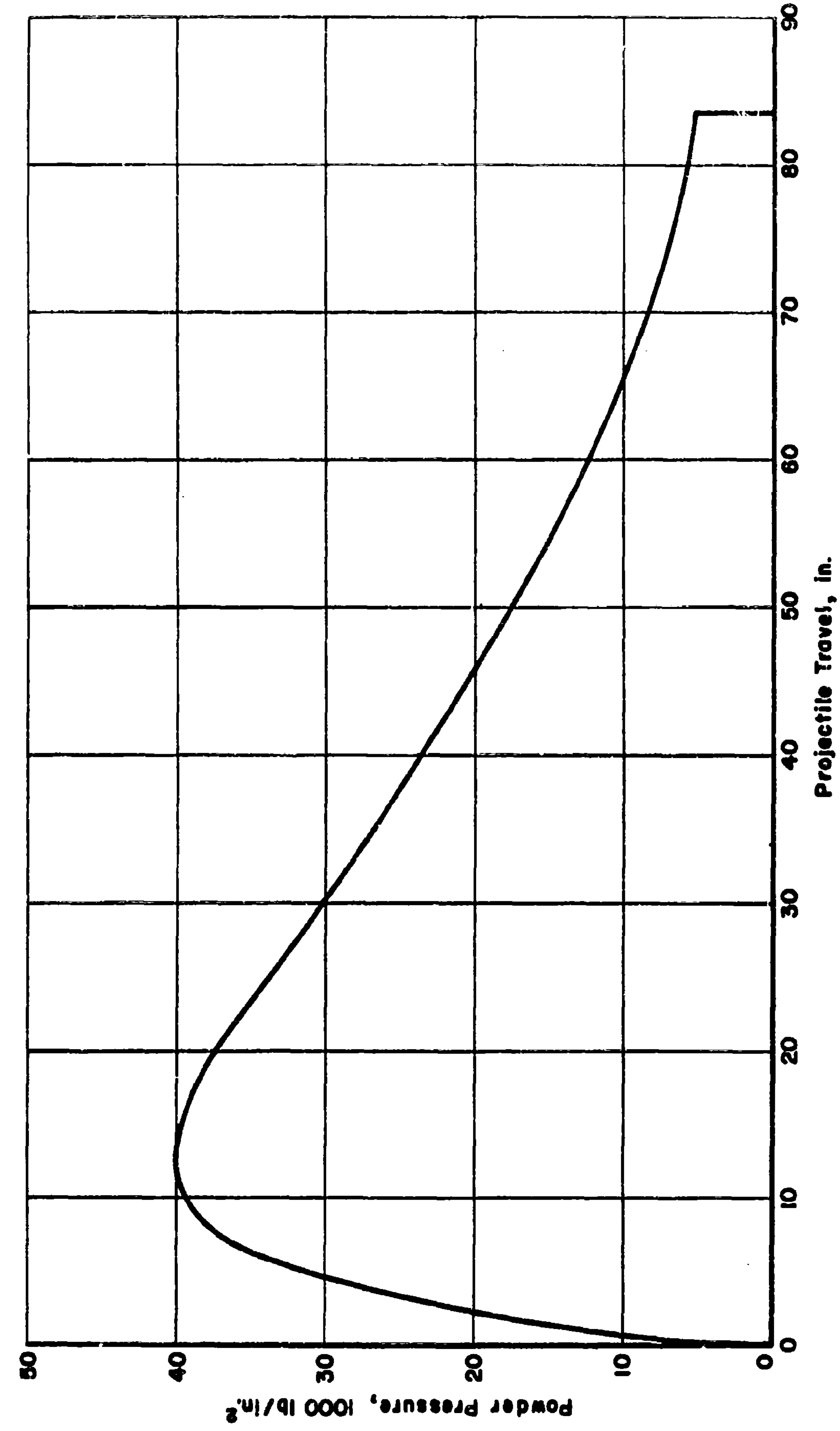

Fig. 35 ARBITRARY PRESSURE-TRAVEL CURVE FOR 37MM M5 GUN

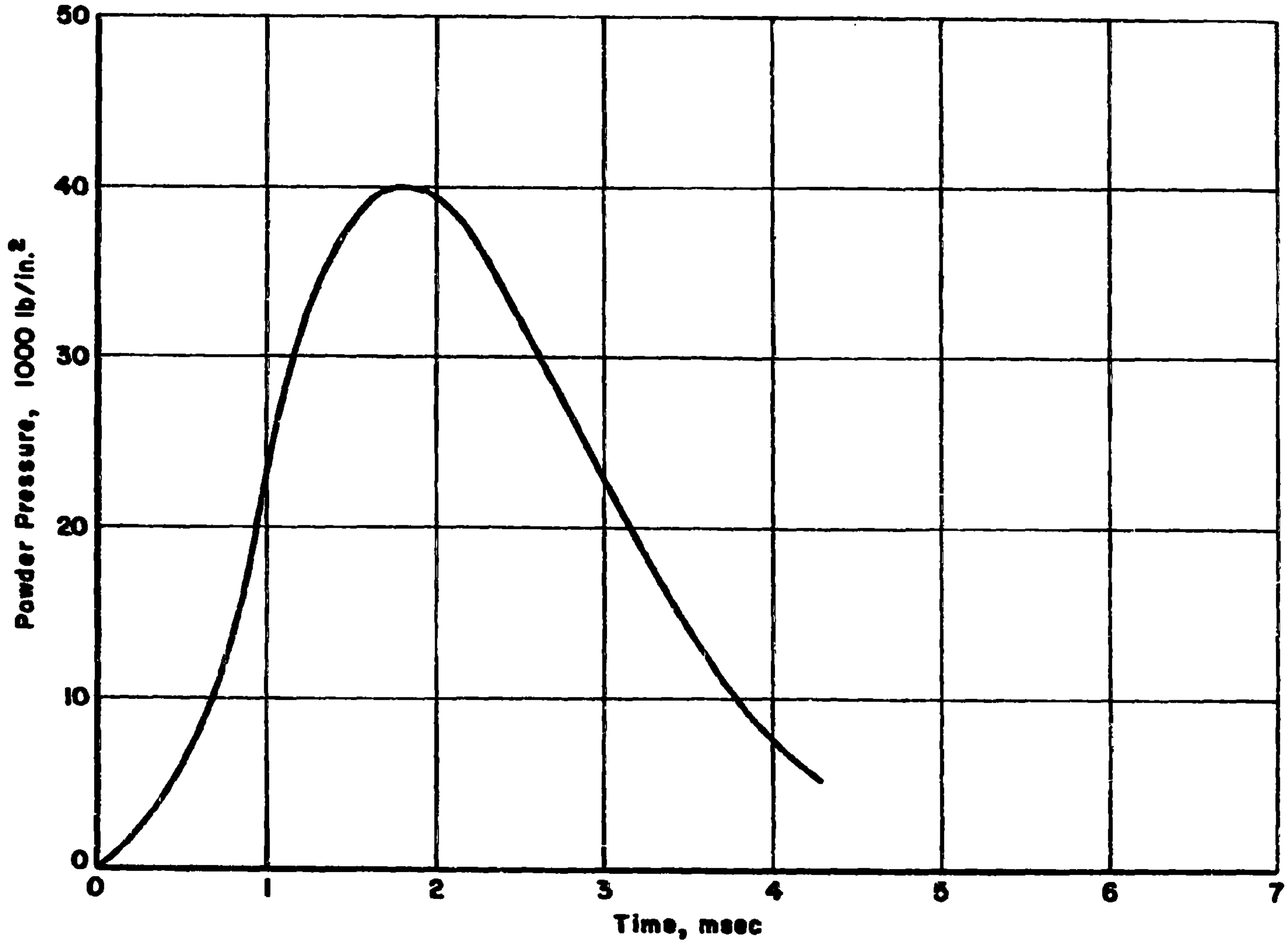

Fig. 36 ARBITRARY PRESSURE-TIME CURVE FOR 37MM M5 GUN

PART II

REPORT ON THE SOVIET 37MM N AUTOMATIC AIRCRAFT GUN

I. PHYSICAL CHARACTERISTICS OF 37MM N GUN

A. General

It is assumed in this report that the 37mm N Gun is identical in kinematic principles with the 37mm and 23mm NS Guns. The imprint in the section of fairing recovered from the Soviet MIG-15 fighter indicated that the recoil spring was mounted forward around the barrel as on the 23mm NS Gun, rather than within the receiver as on the 37mm NS Gun. The recoil systems and the ammunition constitute the main differences between the 37mm Guns. The smaller propelling charge used in the 37mm N Gun makes it possible for all of the gun structure to be lighter because of the smaller loads it must withstand. The shorter cartridge and the smaller energy input to the 37mm N Gun makes possible a shorter bolt stroke and recoil stroke, and these factors lead to a higher cyclic rate. The gun portrayed in Figs. 3 and 48 conforms to all known data about the 37mm N Gun and is theoretically capable of delivering the performance listed on page 4, about 2400 fps muzzle velocity, with a cyclic rate of from 400 to 450 rounds per minute.

A cartridge case, ammunition belt link, and an API-T projectile for this gun were recovered and appear in Fig. 37. The wind screen is removed from this projectile. The muzzle velocity of the projectile was computed by matching its drop with the drop of the 23mm NS Gun projectile out to 1200 yards assuming an altitude of 30,000 feet and a forward airplane velocity of 600 mph. It was determined that the cartridge case has sufficient capacity for propellant to produce the required muzzle velocity, although the exact powder composition could not be determined.

Mounting provisions are assumed to be similar to those for the 23mm and 37mm NS Guns.

B. Basic Gun Data

Physical data of the gun illustrated in Fig. 48 are shown below. Items designated by an asterisk are those for which physical evidence exists. All other data are deduced or computed from the hypothetical design.

Weight of gun (with pneumatic line assembly, solenoid, and valve,) lb	300
'eight of pneumatic line assembly, lb	3-1/2
Over-all length of gun, in.	92-3/4
Over-all height of gun, in.	9-1/8
Over-all width of gun, in.	14
Length of barrel, in.	62
Weight of barrel, lb	73
Weight of recoiling parts (including bolt), lb	142
Weight of bolt assembly, lb	15.3
Weight of feeder assembly, lb	39.3
Weight of sear mechanism, lb	7
Muzzle velocity (HEI-T), fps	2400
Muzzle velocity (API-T), fps	2340
Rate of fire (fixed gun, free firing), rpm	400-450
Maximum trunnion reaction, lb (See Section VII)	6000+

Rifling (Assumed identical to 37mm NS rifling)

No. of grooves	16
Depth of grooves, in.	0.018
Width of grooves, in.	0.191
Width of lands, in.	0.097
Twist (uniform, RH)	approx. 1 turn in 30-1/2 calibers (6°)
Length, in.	55.25

Bore of Barrel

Across rifling lands, in.	1.460
Across rifling grooves, in.	1.496
Travel of projectile in barrel, in.	55.75

Springs (Only main operating springs are included)

Drive Spring (four strand)

Outside diameter, in.	1-1/8
Free length, in.	40.0
Number of coils	66
Diameter of wire, in. (four strands)	0.240
Rate, variable, lb/in.	See Fig. 32

Feeder Spring, Outer

Outside diameter, in.	1-15/16
Free length, in.	8-7/8
Number of coils	14
Diameter of wire, in.	0.355
Rate, lb/in.	426

Feeder Spring, Inner

Outside diameter, in.	1-3/16
Free length, in.	10-1/4
Number of coils	28
Diameter of wire, in.	0.175
Rate, lb/in.	48-1/2

Recoil Spring, Main

*Outside diameter, in.	4.25
Free length, in.	20.63

*Number of coils	16	
*Diameter of wire, in.	0.568	
Rate, lb/in.	204.8	
Recoil Spring, Secondary		
Outside diameter, in.	3.87	
Free length, in.	15.3	
Number of coils	12	
Diameter of wire, in.	0.50	
Rate, lb/in.	203	
Diameter of charging piston (bolt, in.)	1-9/16	
Diameter of charging piston (feeder, in.)	2-9/16	

C. Ammunition Data

	API-T	HEI-T
*Over-all length of cartridge, in.	11.18	11.4
*Length of projectile, in.	6.56	7.0
*Length of cartridge case, in.	6.06	6.06
*Diameter of projectile over rotating band, in.	1.469	1.469
Diameter of projectile over bourrelet, in.	1.457	1.457
Weight of complete round, lb	2.79	2.71
Weight of projectile, lb.	1.694	1.61
*Weight of cartridge case, lb	0.88	0.88
Weight of propellant, grains approx.	1938	1938
Capacity of cartridge case (to base of projectile) cc	159	159
Density of loading, volume basis	unknown	

Density of loading, weight basis, gram/cc, assumed	0.79	0.79
Weight of belt link, lb	0.25	0.25

II. DESCRIPTION OF THE GUN ACTION

The hypothetical design for the 37mm N Gun as shown in Fig. 43 has firing and charging actions identical to those described for the 37mm NS Gun in pages 8 through 12. Schematic diagrams illustrating the operations of both the firing and charging cycles appear in Fig. 49 and 50.

III. KINEMATIC ANALYSIS

A. Introduction

The purpose of this analysis is to determine the approximate performance of the Soviet 37mm N Gun. The method of analysis is identical with that used for the Soviet 37mm NS Gun, which is presented earlier in this report, therefore only a minimum of detail will be presented here.

B. Nomenclature

The nomenclature is identical to that used for the analysis of the Soviet 37mm NS Gun.

C. The Recoil and Counterrecoil Cycle

The recoil and counterrecoil cycle was divided into the following phases:

1. Recoil from battery position to bolt contact with accelerator.
2. Recoil during bolt contact with accelerator.
3. Remainder of recoil.
4. Counterrecoil to end of contact with secondary recoil spring.
5. Counterrecoil from end of contact with secondary recoil spring to contact with counterrecoil buffer.

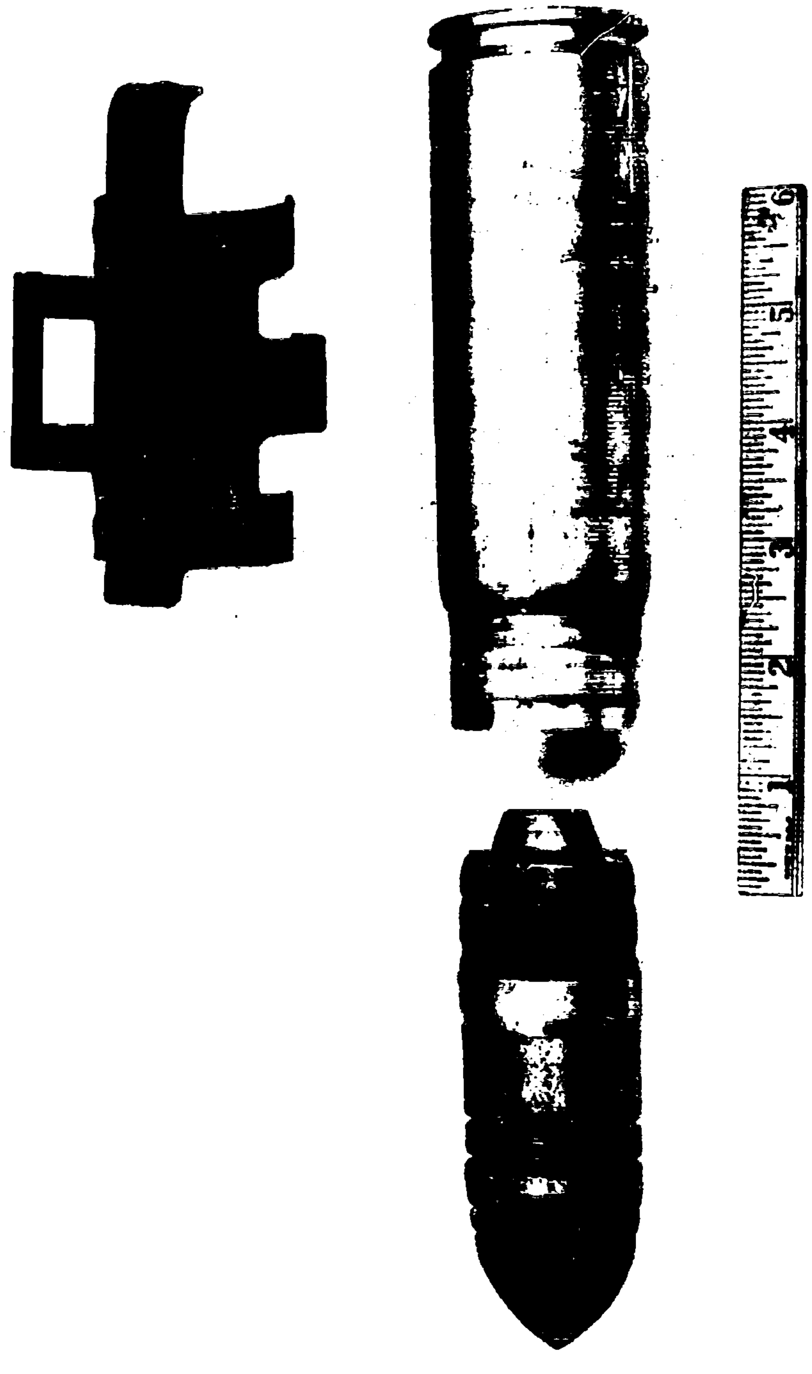

Fig. 37 AMMUNITION AND LINK FOR 37MM I [illegible], DISASSEMBLED

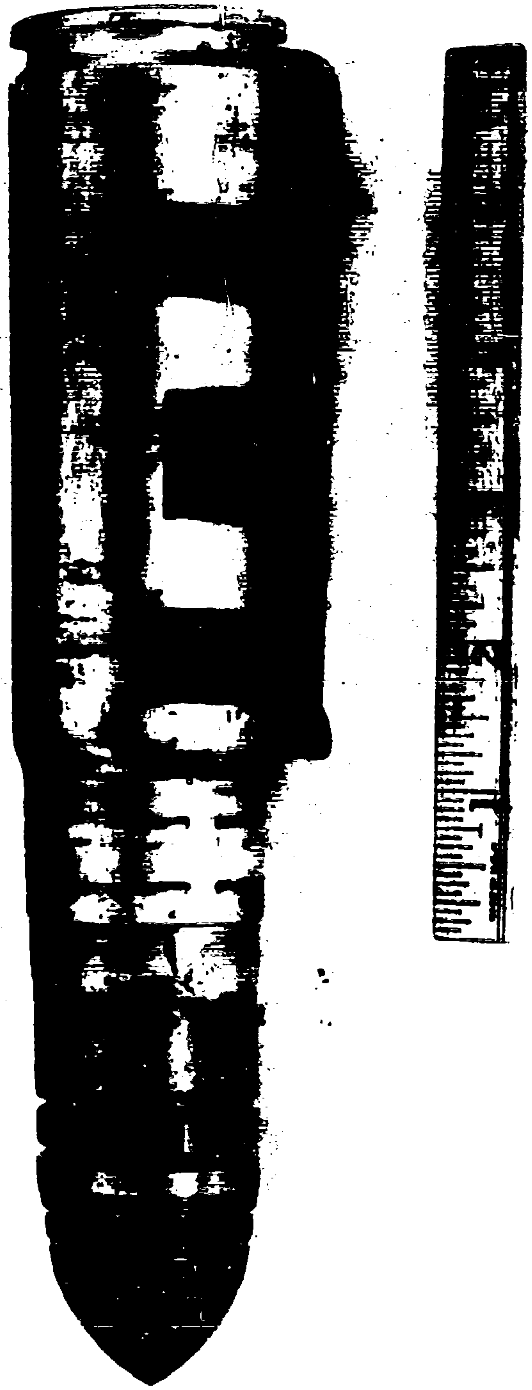

Fig. 38 AMMUNITION AND LINK FOR 37MM N GUN

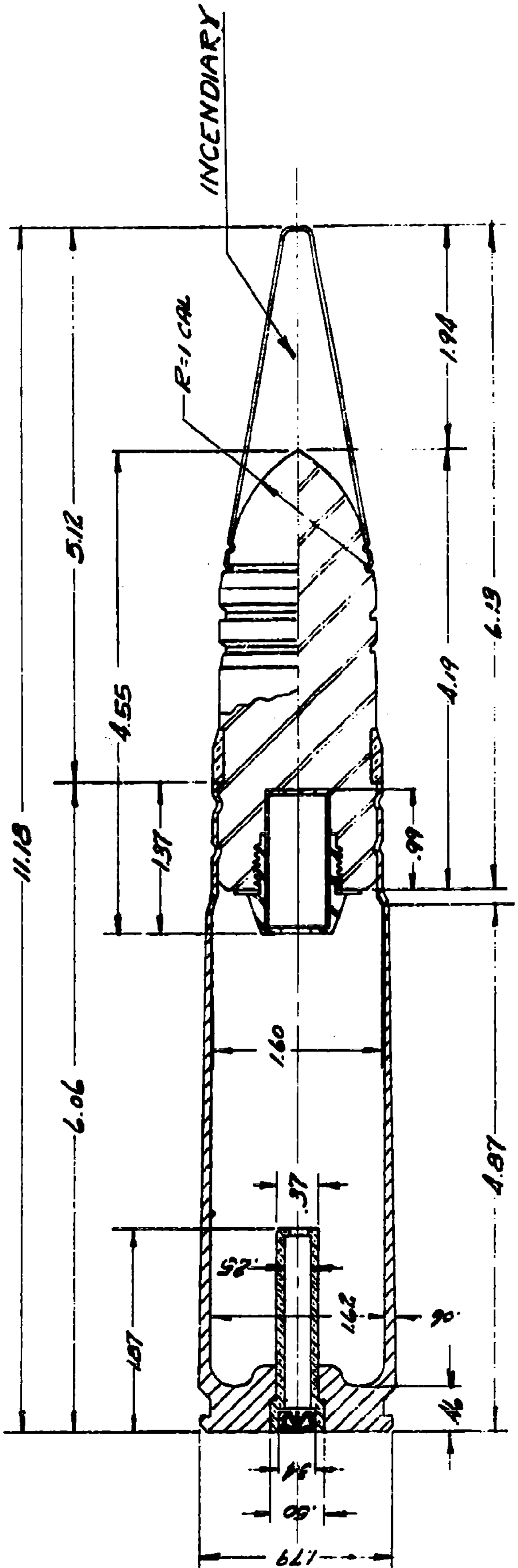

Fig. 39 CARTRIDGE, API-T, 37 MM FOR SOVIET 37 MM N GUN

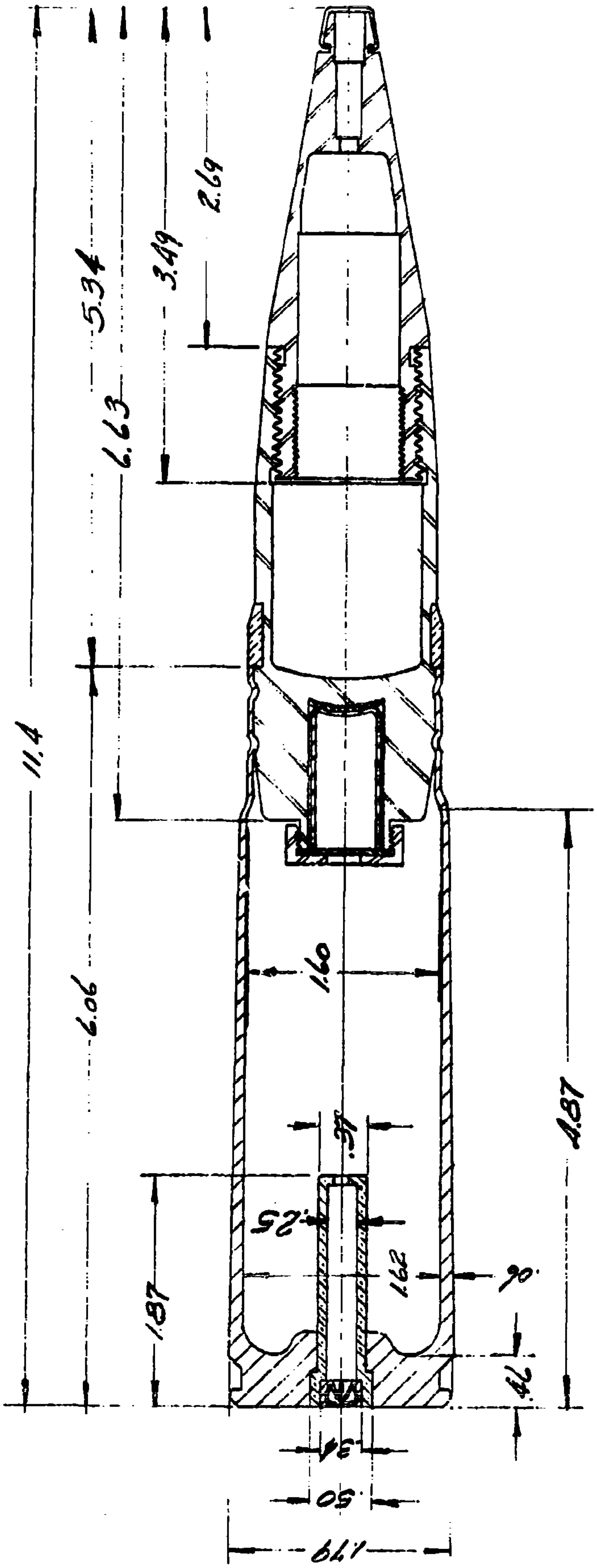

Fig. 40 CARTRIDGE, HEI-T, 37MM FOR SOVIET 37 MM N GUN

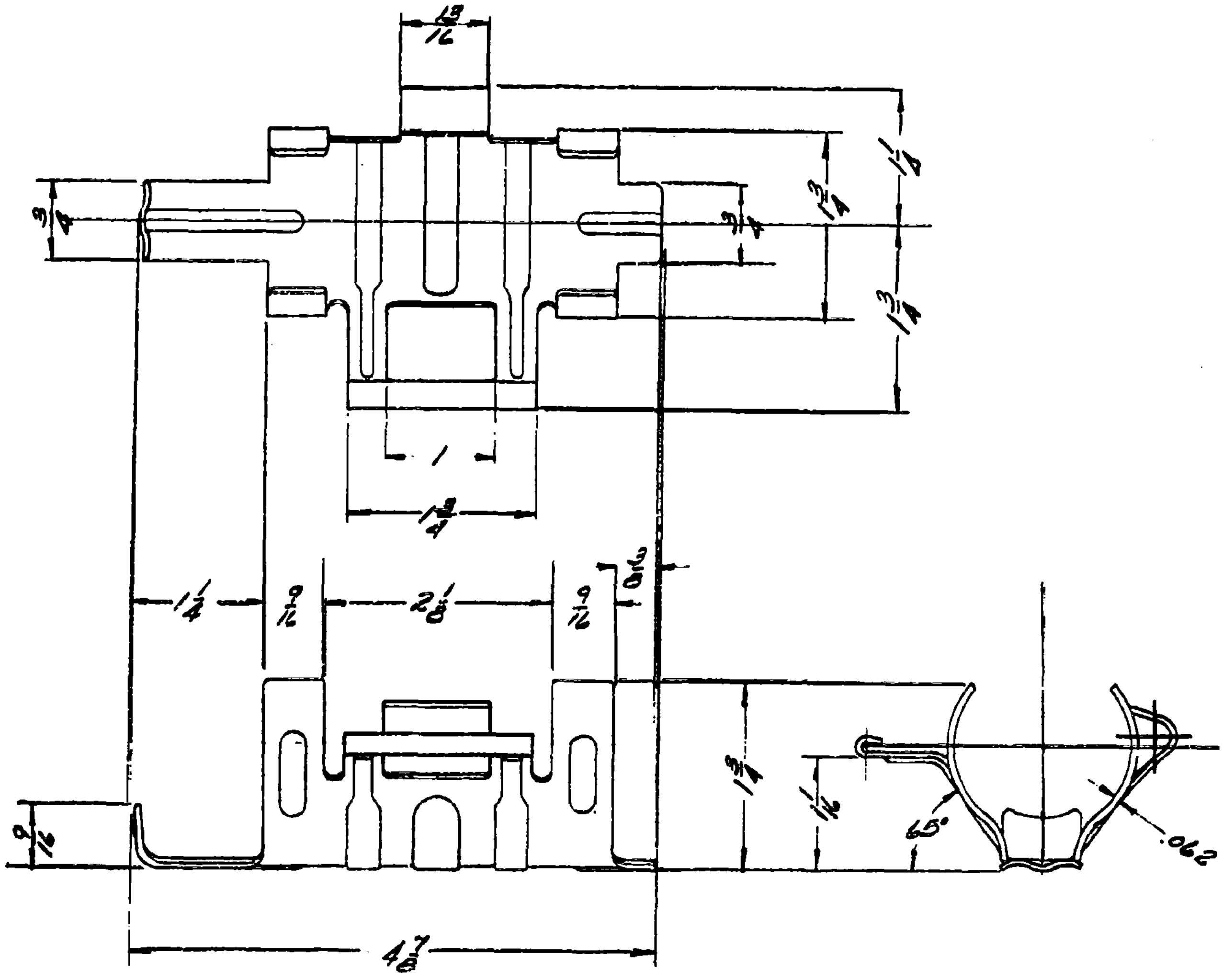

Fig. 41 LINK FOR SOVIET 37 MM N GUN

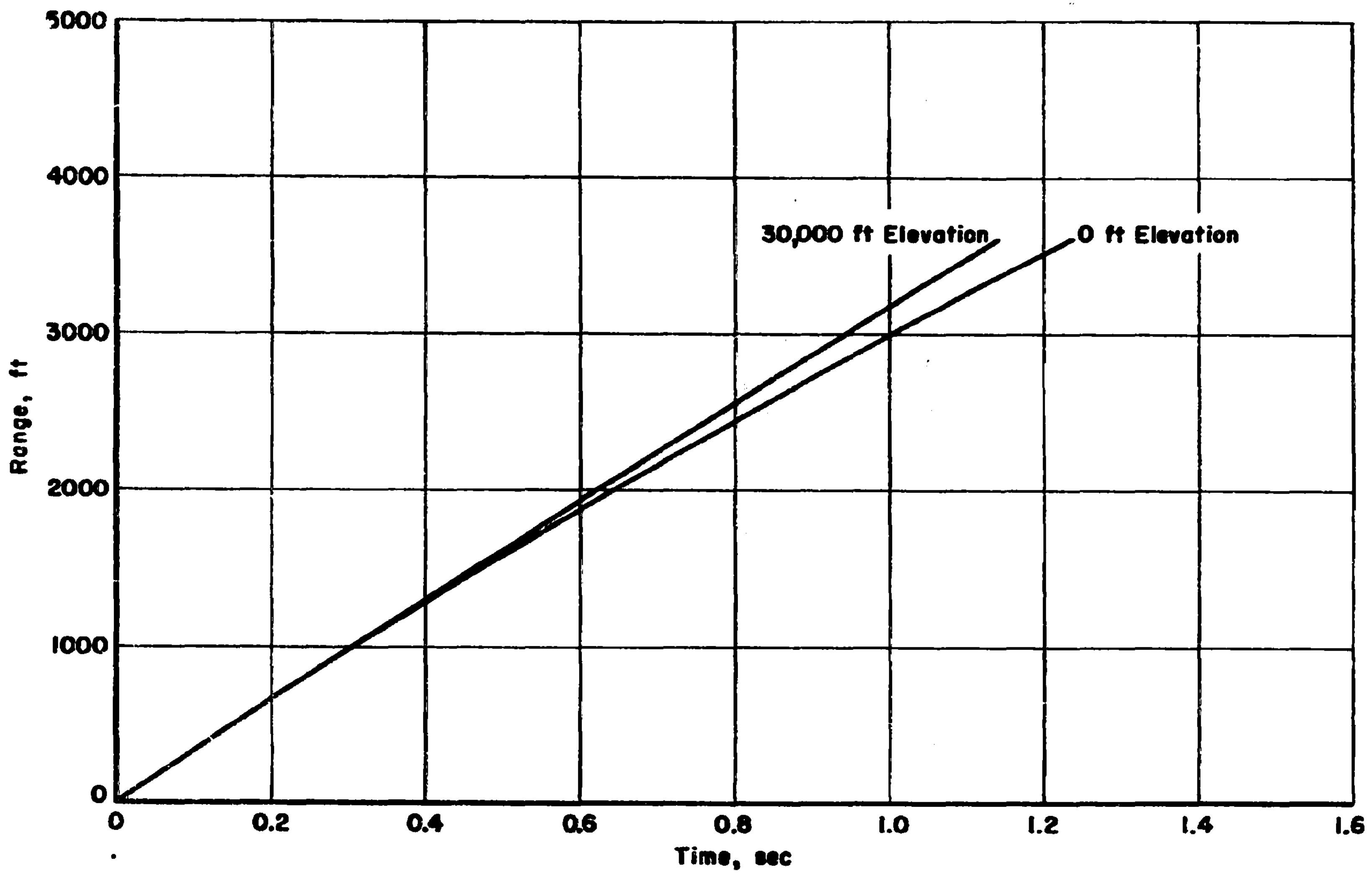

Fig. 42 HORIZONTAL COMPONENT OF TRAJECTORY FOR 37MM N GUN, API-T AMMUNITION

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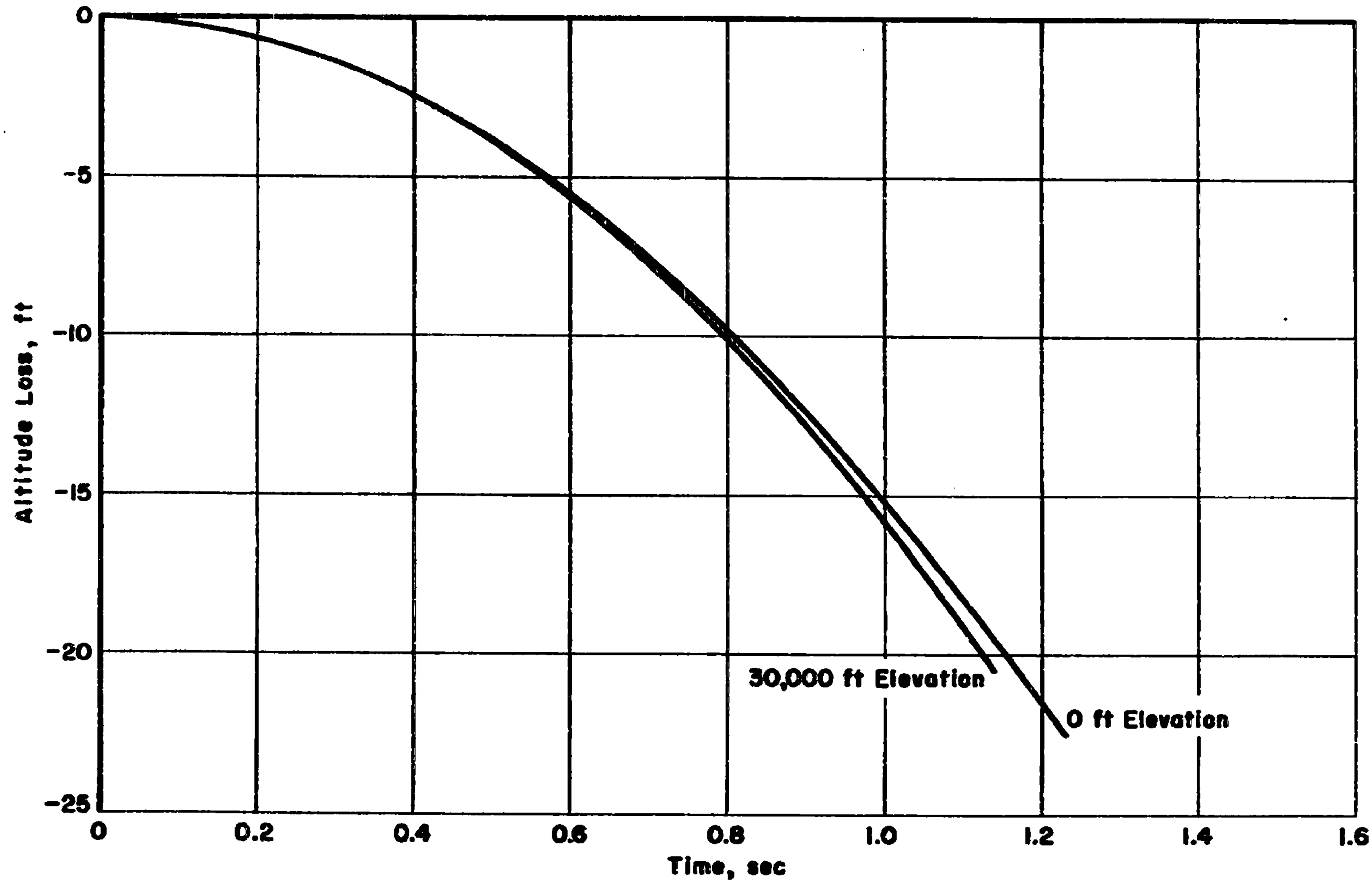

Fig. 43 VERTICAL COMPONENT OF TRAJECTORY FOR 37MM N GUN, API-T AMMUNITION

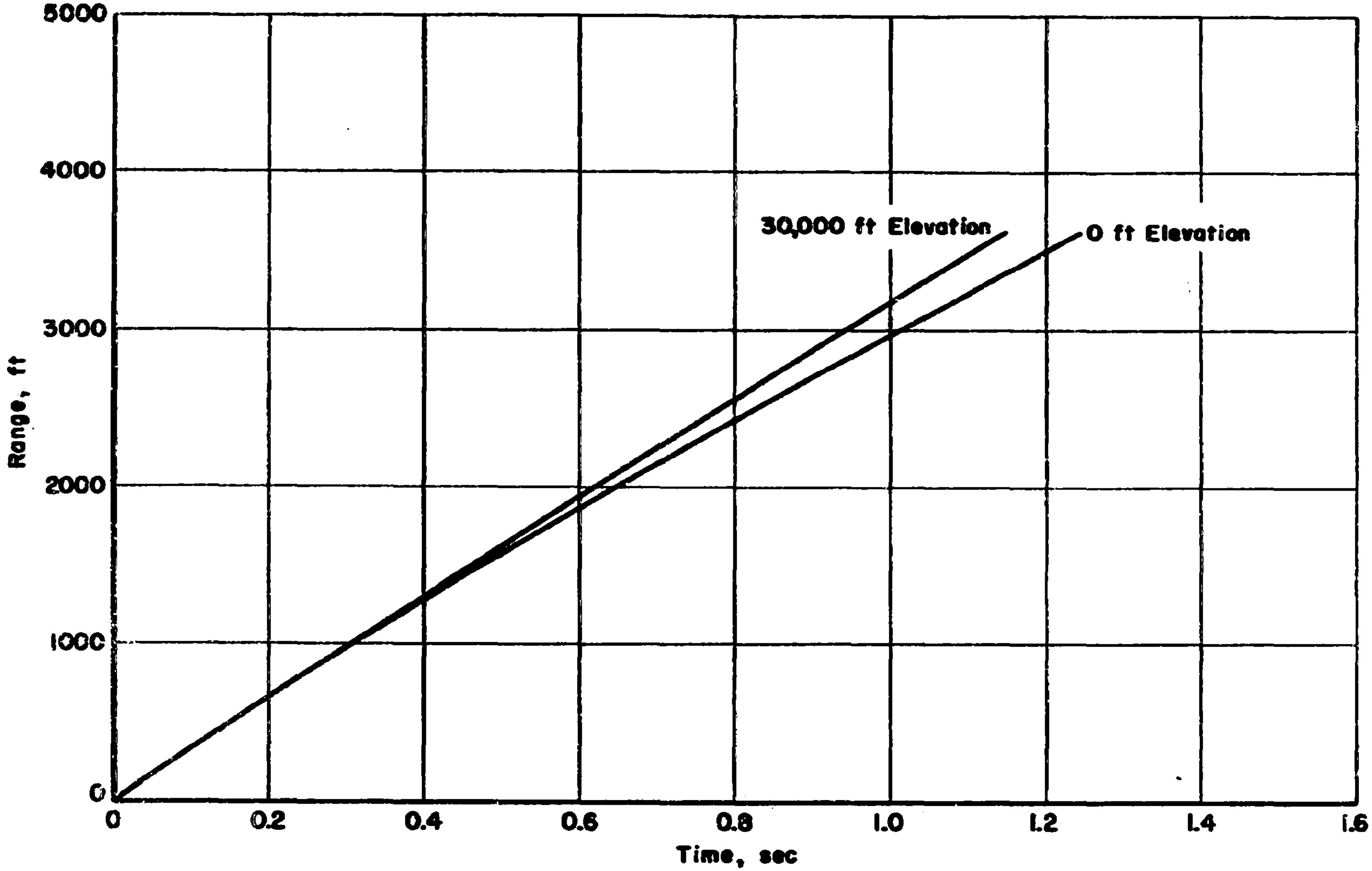

Fig. 44 HORIZONTAL COMPONENT OF TRAJECTORY FOR 37MM N GUN, HEI-T AMMUNITION

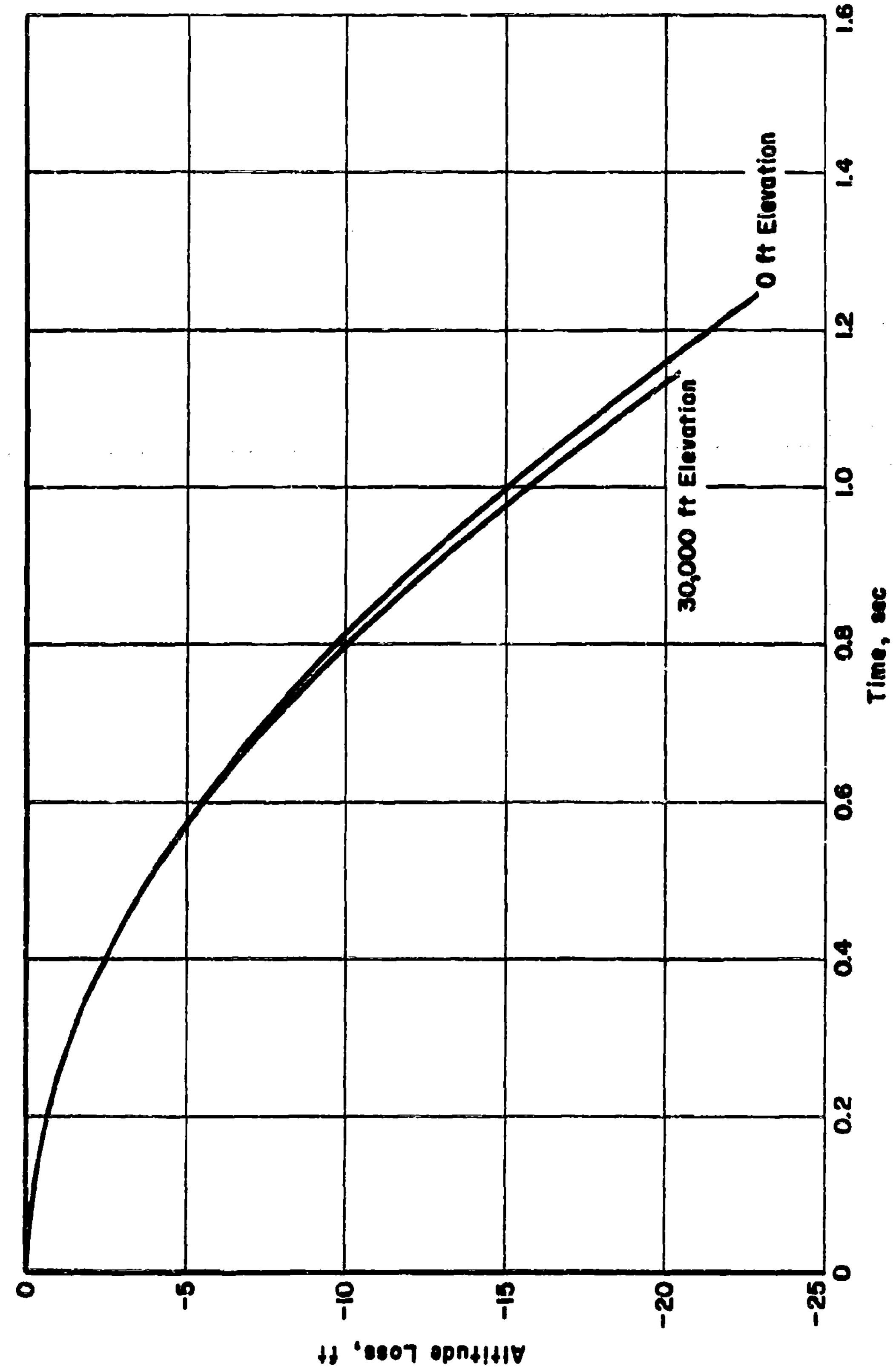

Fig. 45 VERTICAL COMPONENT OF TRAJECTORY FOR 37MM N GUN, HEI-T AMMUNITION

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Fig. 46 IMPRINT OF 37MM N GUN IN FAIRING RECOVERED FROM MIG-15

Fig. 47 IMPRINT OF 37MM N GUN IN FAIRING RECOVERED FROM MIG-15

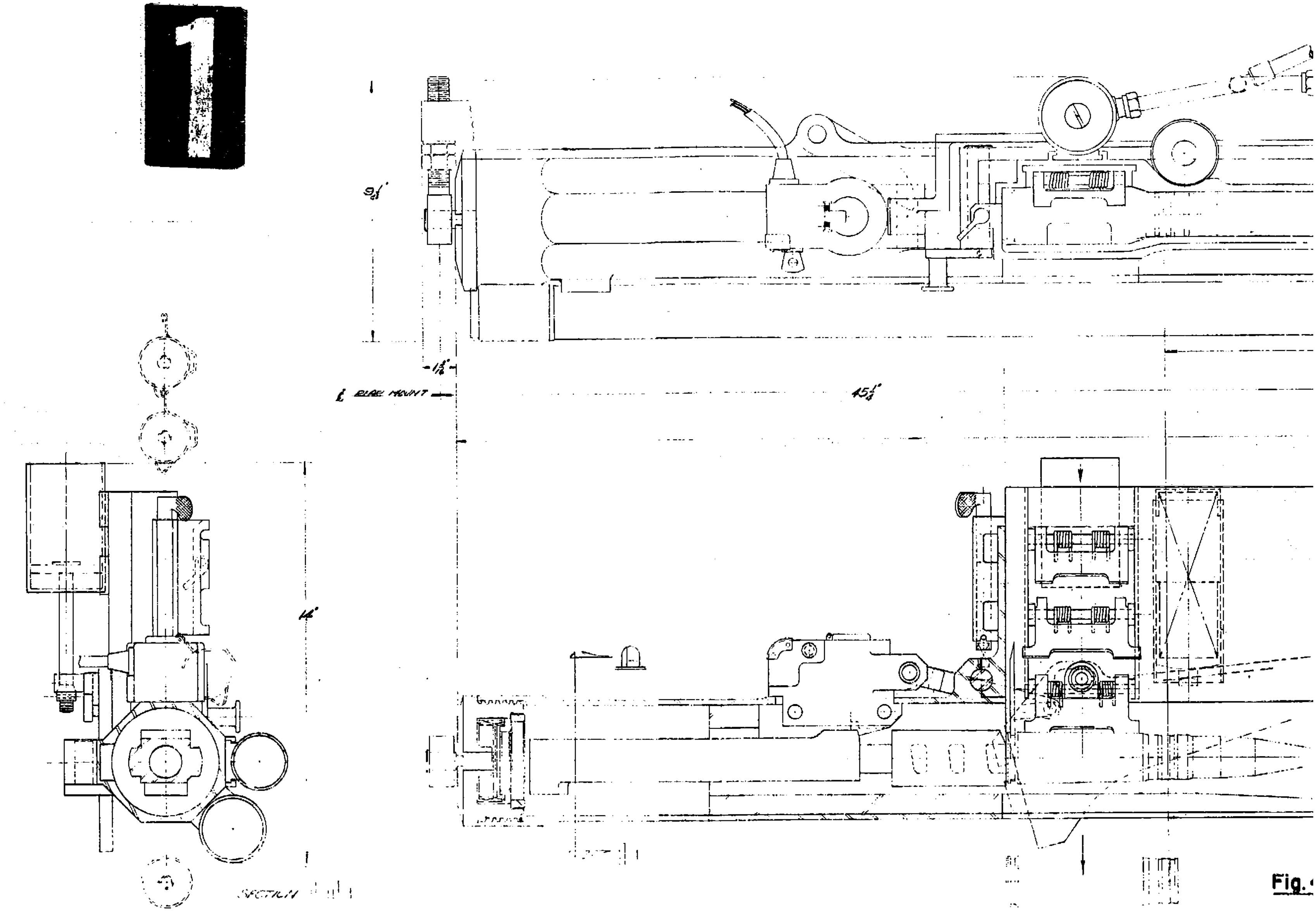

Fig.

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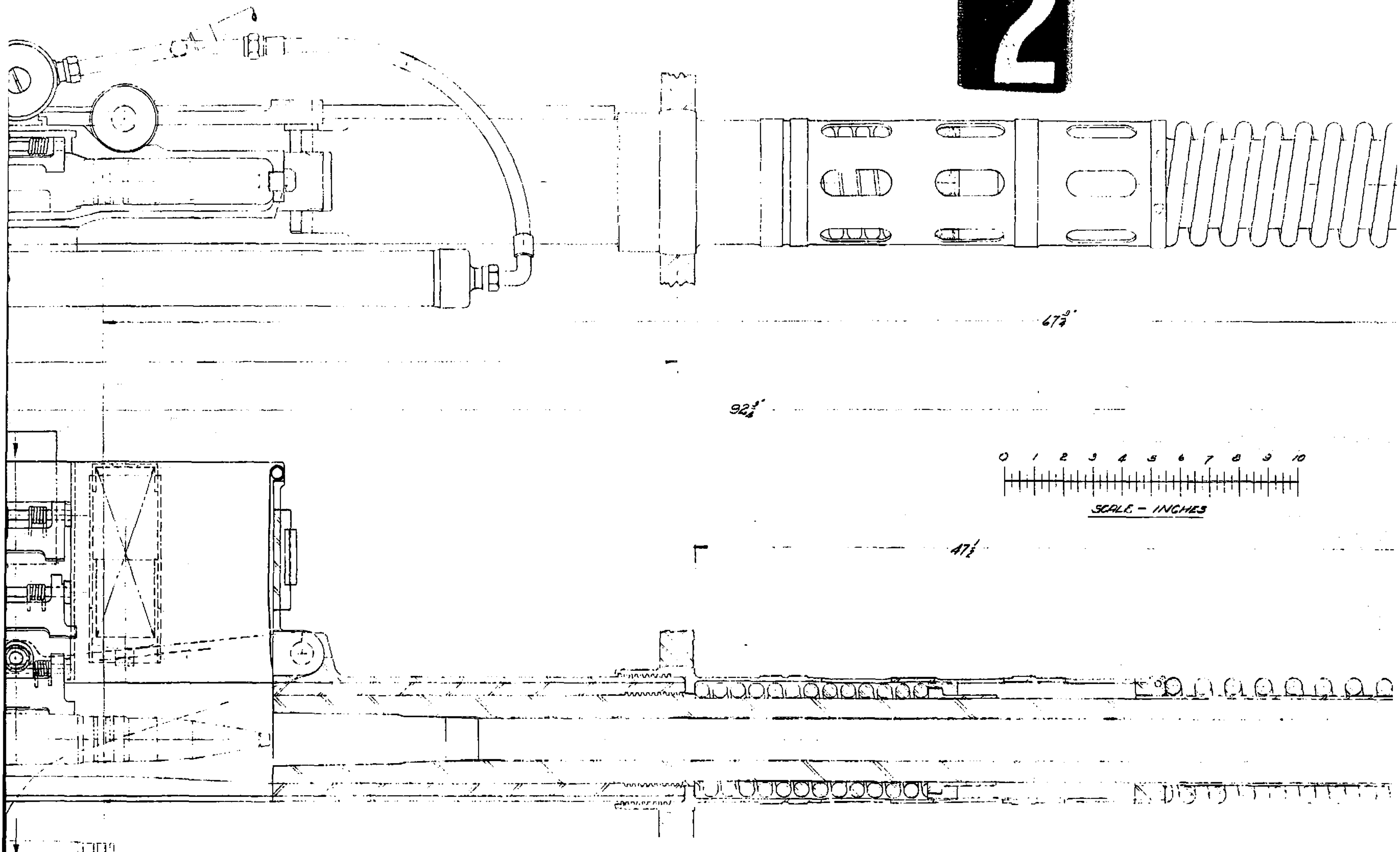

Fig. 48 HYPOTHETICAL DESIGN OF SOVIET 37 MM N GUN

x

3

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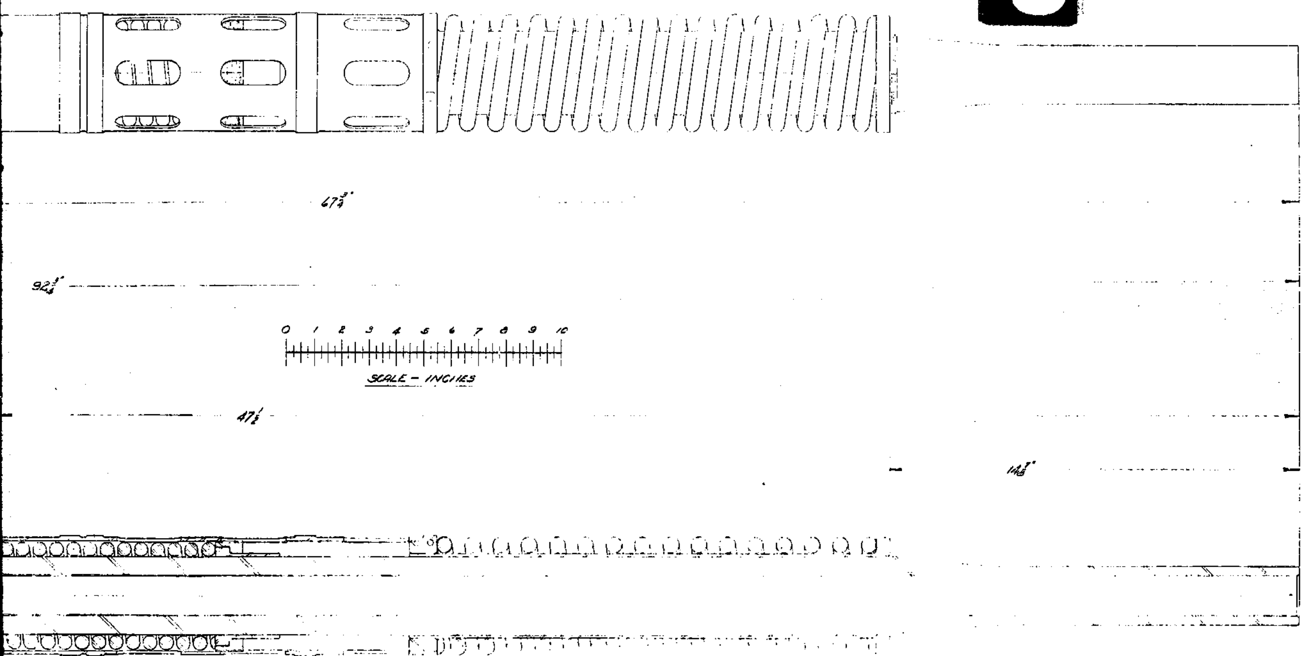
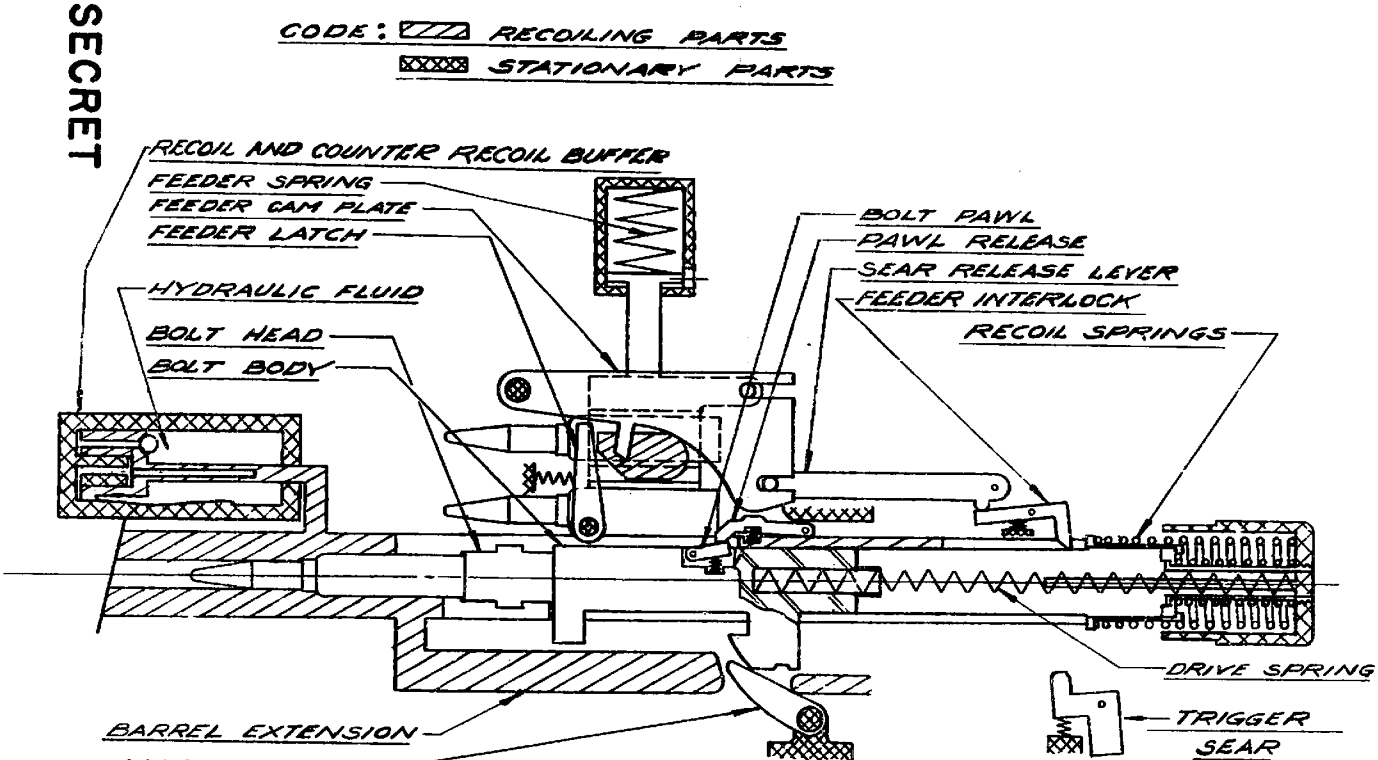
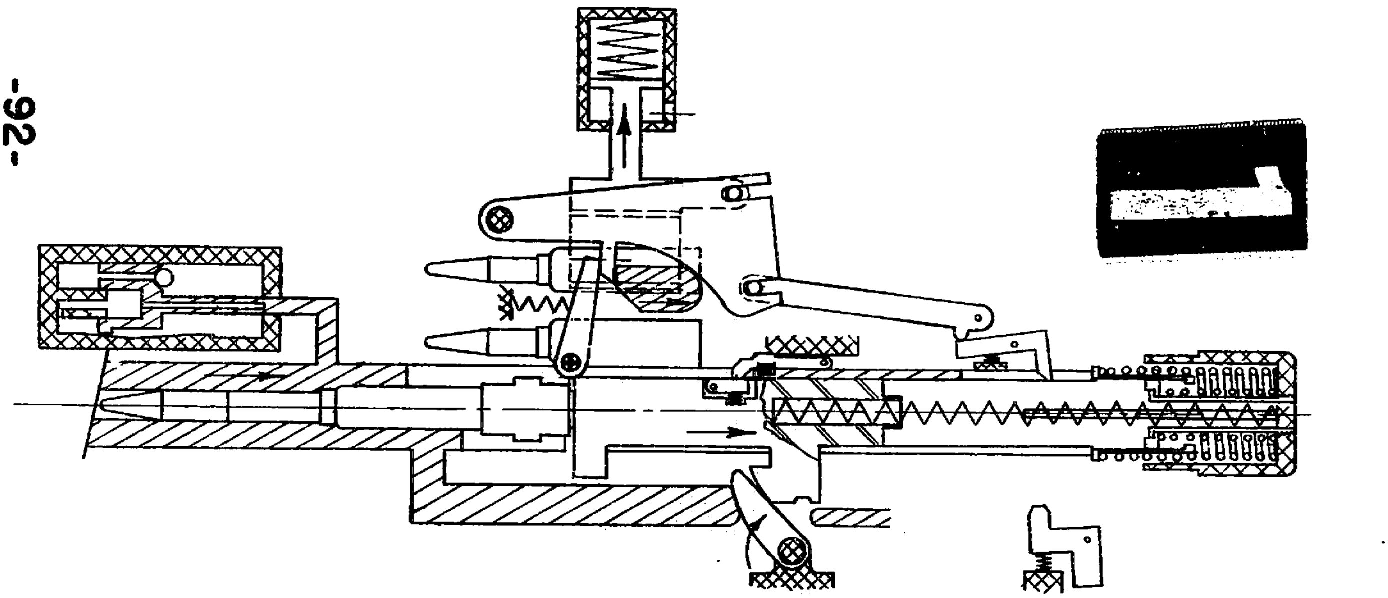


7 MM N GUN

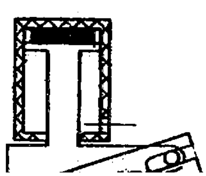
SECRET



1 BATTERY POSITION

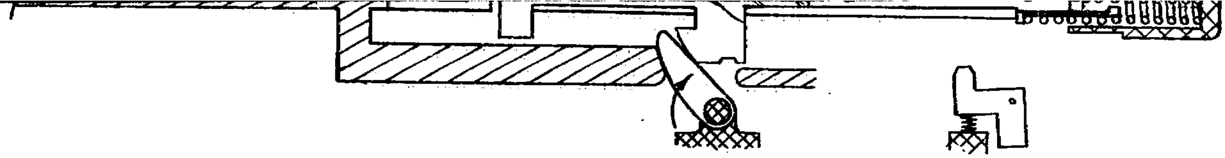


2 START OF UNLOCKING

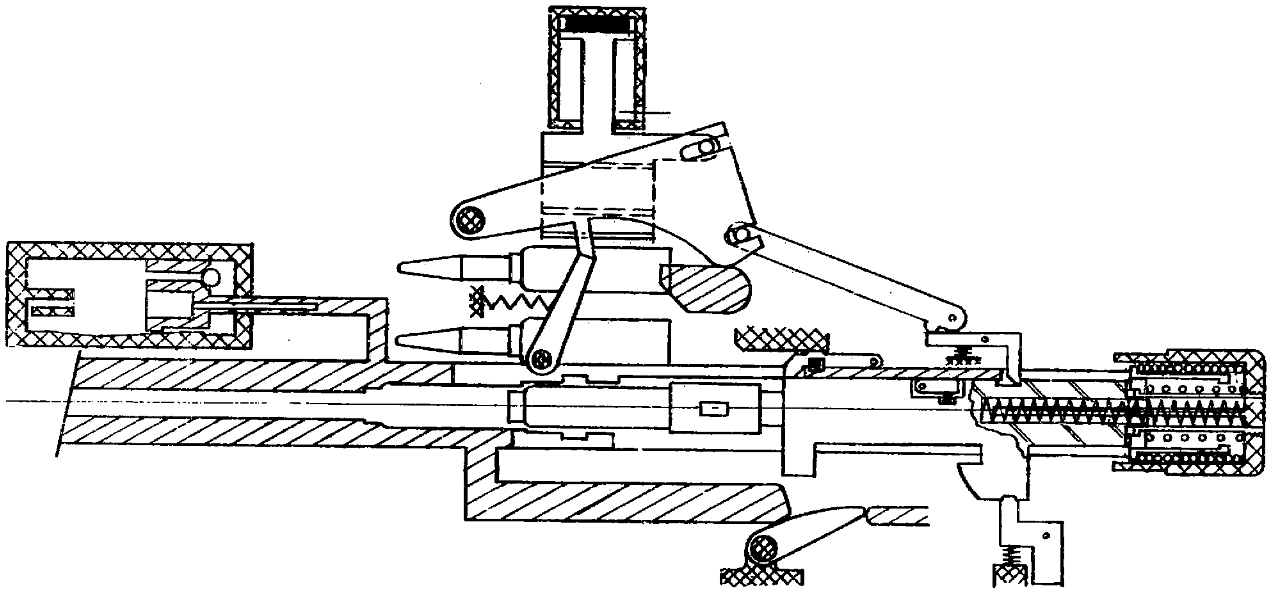


SECRET

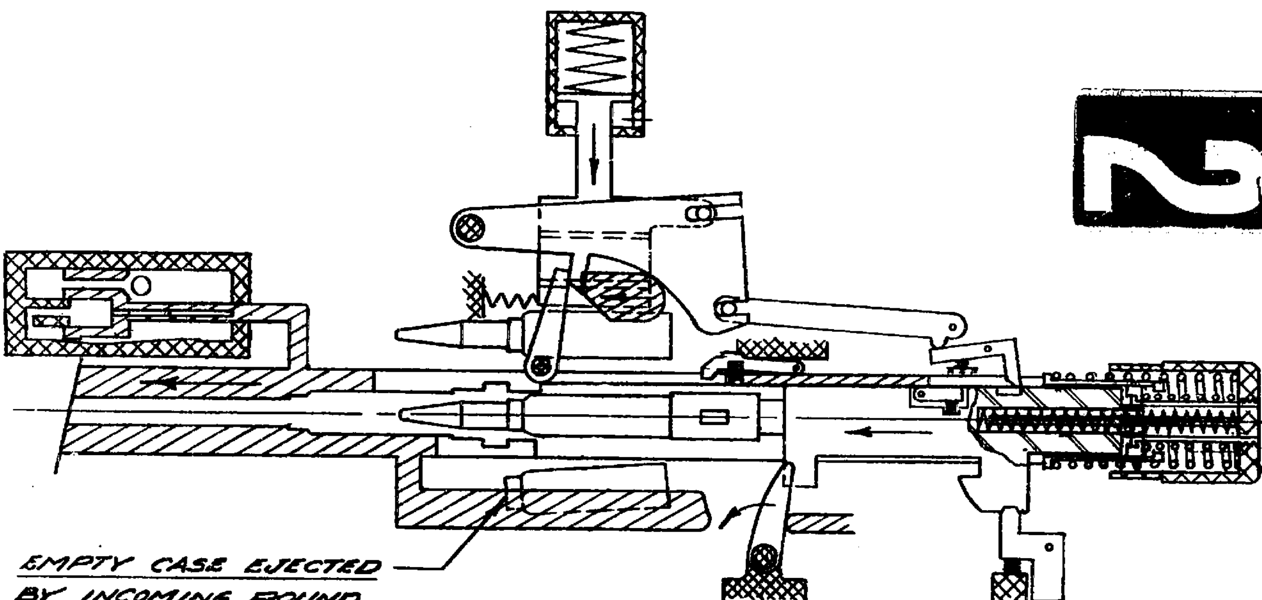
2



2 START OF UNLOCKING

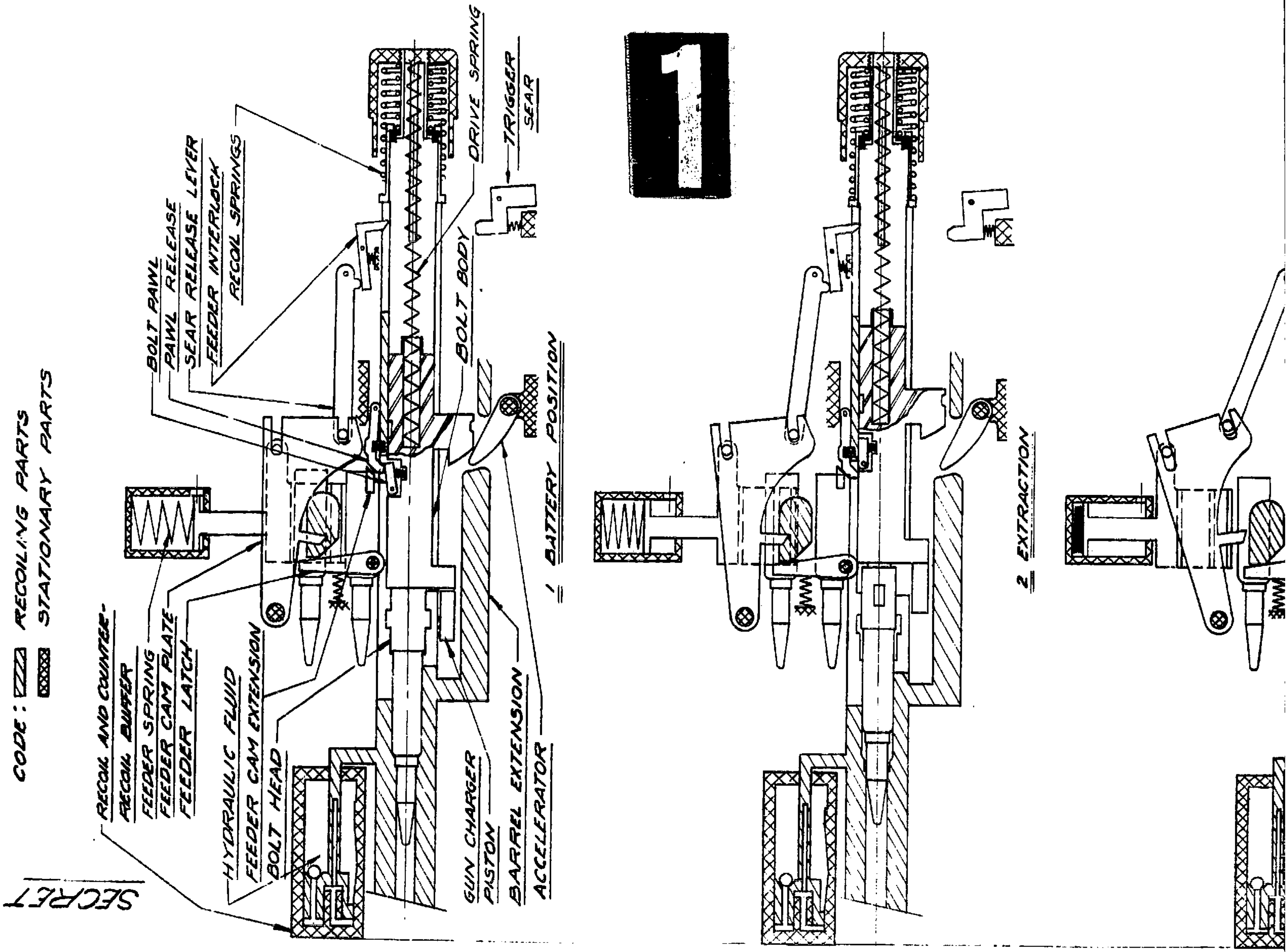


3 REAR SEARED POSITION



4 EJECTION POSITION

Fig. 49 SCHEMATIC FIRING CYCLE FOR 37 MM N GUN


CODE: RECOILING PARTS
STATIONARY PARTS
RECOIL AND COUNTER-RECOIL BUFFER
FEEDER SPRING
FEEDER CAM PLATE
FEEDER LATCH
HYDRAULIC FLUID
FEEDER CAM EXTENSION
BOLT HEAD
GUN CHARGER PISTON
BARREL EXTENSION
ACCELERATOR
BOLT PAWL
PAWL RELEASE
SEAR RELEASE LEVER
FEEDER INTERLOCK
RECOIL SPRINGS
BOLT BODY
DRIVE SPRING
TRIGGER SEAR
1 BATTERY POSITION
1
2 EXTRACTION
SECRET

SECRET

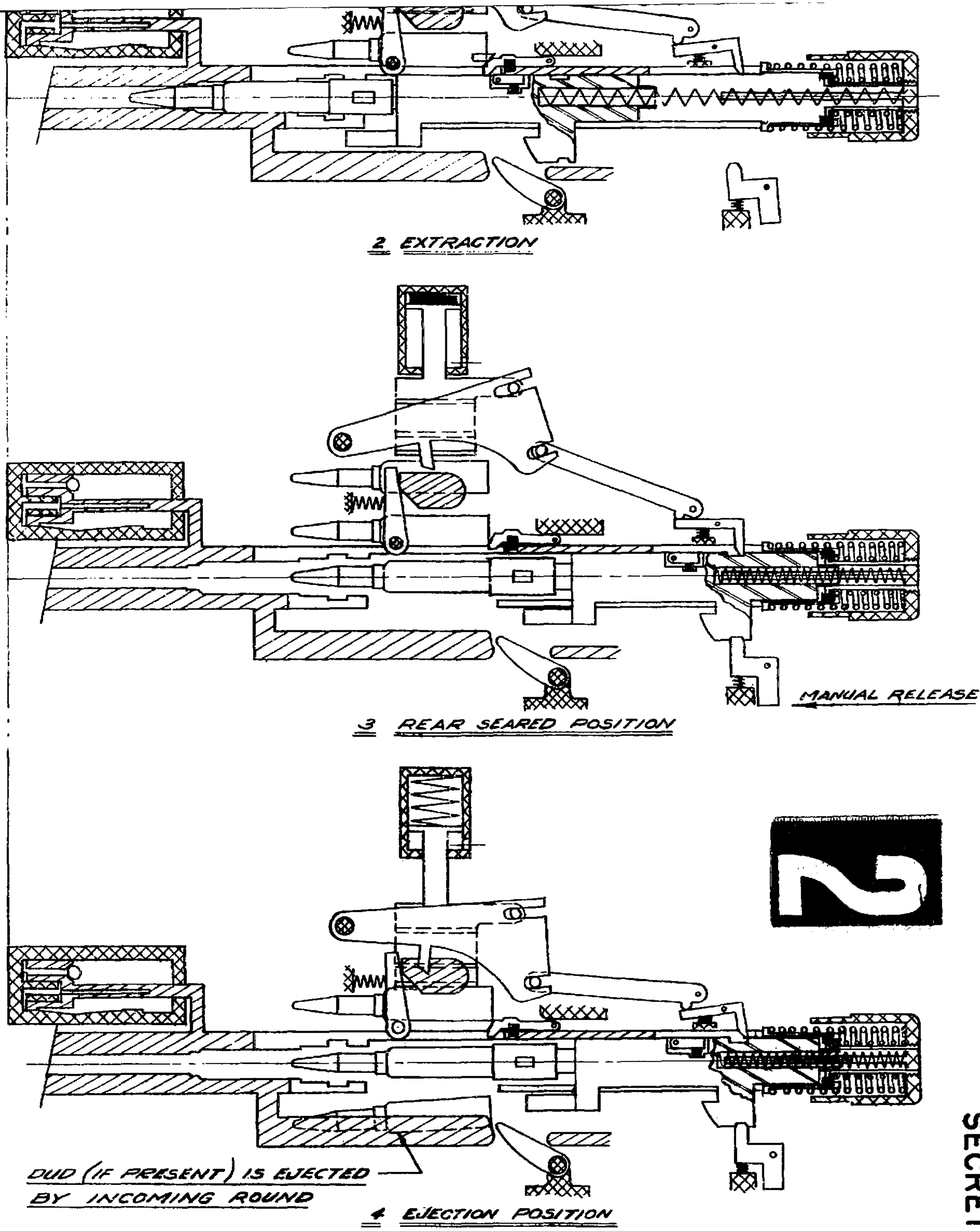


Fig. 50 SCHEMATIC CHARGING CYCLE. FOR 37 MM N GUN

6. Counterrecoil from contact with counterrecoil buffer to feeder sear release.

7. Remainder of counterrecoil.

Only the first six phases were analysed because phase 7 does not have any influence on cyclic rate.

As there was no complete round available and the exact barrel length was unknown, the value for initial recoil velocity was computed by the same semi-empirical formula which was used in the analysis of the 37mm NS Gun.

$$x_o = \frac{W_p V_p + 4700 W_c}{W_x + W_z}$$

The value for muzzle velocity was computed as explained on page 75, and the propellant weight was assumed to be that which would give a density of loading comparable to the 37mm NS and 23mm NS weapons.

$$x_o = \frac{1.694 (2400) + 4700 (.277)}{126.2 + 15.33}$$

$$x_o = 37.8 \text{ fps.}$$

The kinetic energy in the recoiling mass at the start of recoil is

$$K.E._{x + z} = 1/2 \frac{(126.2 + 15.33)}{32.2} (37.8)^2$$

$$K.E._{x + z} = 3150 \text{ ft-lb.}$$

It was necessary to assume relative displacement curves for the various component parts. Considering the caliber, length of round, probable length of recoil, and similar curves for the Soviet 37mm NS and 23mm NS Guns, the curves in Fig. 52 were drawn. Although these curves are arbitrary, the amount by which they may be in error should not have a significant effect on the cyclic rate.

1. Phase 1

This phase begins when the gun is fired and ends when the bolt makes contact with the accelerator. The recoil spring, the bolt drive spring, the feeder spring and the hydraulic buffer are acting to resist recoil during this phase.

The recoil displacement, x, varies from x = o to x = 1.5 inches. The energy stored in the recoil spring is

$$E_{x1} = 138 \text{ ft-lb.}$$

The bolt displacement varies from z = o to z = 1.5 inches. The energy stored in the bolt drive spring is

$$E_{z1} = 22.1 \text{ ft-lb.}$$

The energy removed from the recoiling parts to operate the feeder is

$$E'_{y1} = 234 \text{ ft-lb.}$$

The energy put into the hydraulic buffer is assumed at 900.0 ft-lb. The kinetic energy of the recoiling parts at the end of phase 1 is

$$K.E._{x1} + K.E._{z1} = 3150 - 138 - 22.1 - 234 - 900.0 = 1856 \text{ ft-lb.}$$

2. Phase 2

During this phase of recoil, the bolt is unlocked from the barrel extension by the accelerator and continues to its rearmost position where it rebounds and is seared. The recoil spring, the bolt drive spring, and the feeder spring store energy. The kinetic energy imparted to the bolt by the accelerator in excess of the kinetic energy which the bolt had at the start of this phase is neglected, because there is no way to determine it directly and its order of magnitude is small.

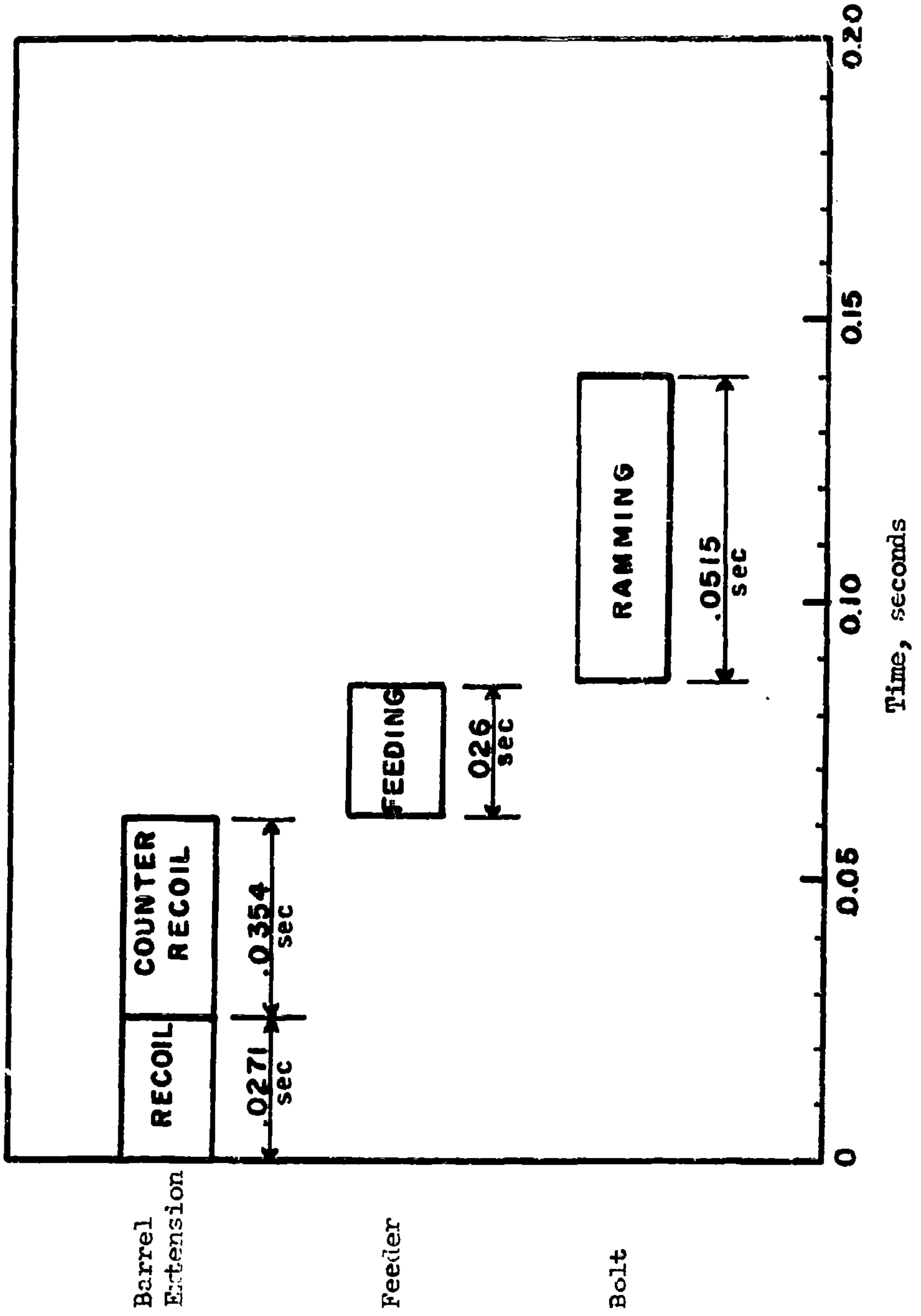


Fig. 51 TIMING DIAGRAM FOR 37MM N GUN

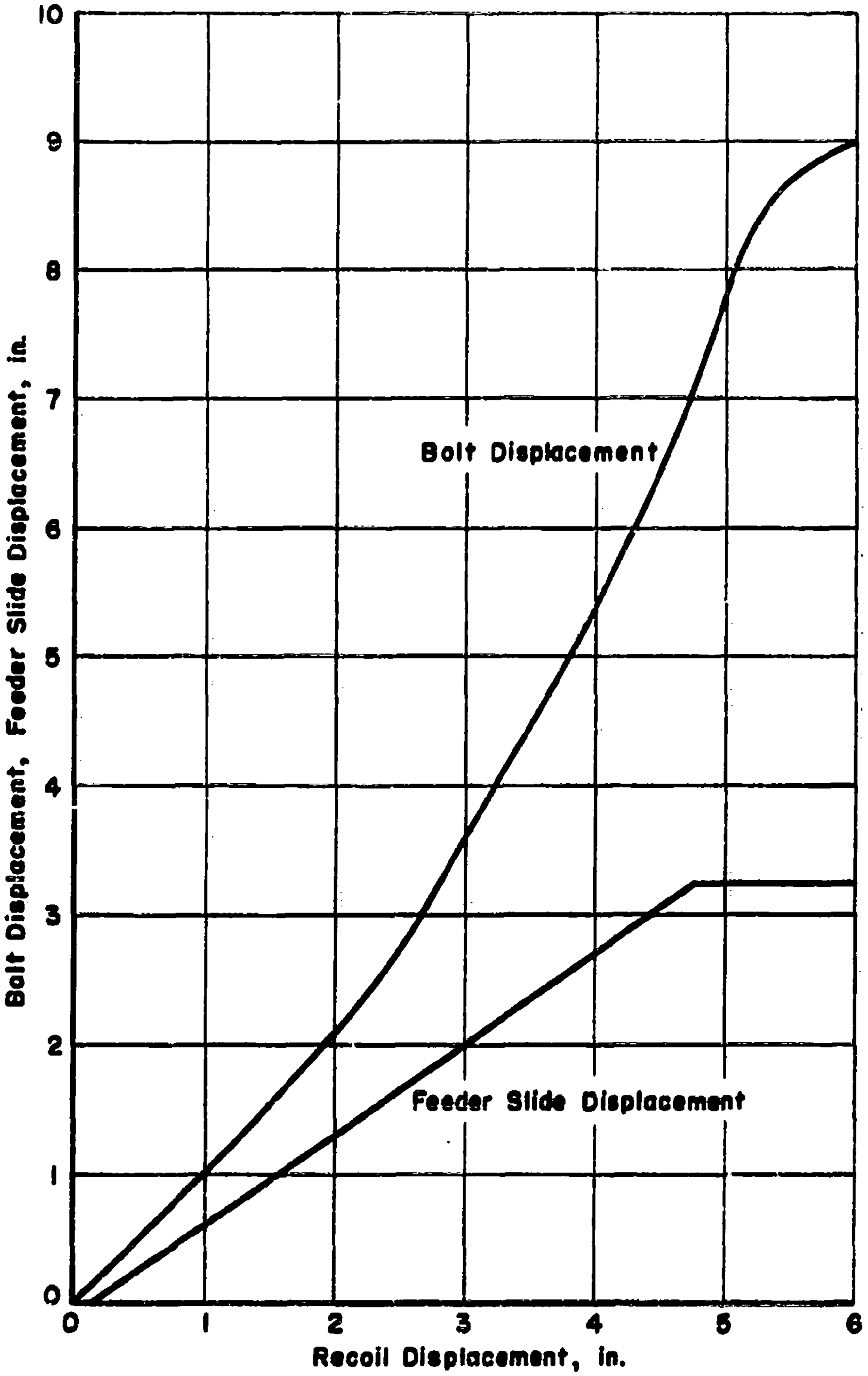


Fig. 52 DISPLACEMENT OF COMPONENTS, 37MM N GUN

The hydraulic buffer acts during the first 1/2 inch of travel in this phase, absorbing an assumed 150 ft-lb of energy.

The recoil displacement during phase 3 varies from $x = 1.5$ to $x = 4.75$ inches. The energy input to the recoil springs is

$$E_{x2} = 430 \text{ ft-lb.}$$

The bolt displacement varies from $z = 1.5$ to $z = 7.1$ inches. The energy stored in the bolt drive spring is

$$E_{z2} = 118 \text{ ft-lb.}$$

As this energy is supplied through the accelerator, the energy removed from the recoiling mass, considering the accelerator efficiency,

$$E'_{z2} = \frac{118}{.34} = 346 \text{ ft-lb.}$$

The kinetic energy which the bolt must have to compress the bolt drive spring the required amount and sear properly is also removed from the recoiling masses. The kinetic energy of the bolt at the end of phase 2 is

$$K.E._{z2} = 127 \text{ ft-lb.}$$

The energy taken from the recoiling parts for feeder operation during phase 3 is

$$E'_{y2} = 648 \text{ ft-lb.}$$

The kinetic energy of the recoiling parts at the end of phase 3 is

$$K.E._{x2} = 1856 - 430 - 346 - 127 - 648 - 150 = 155 \text{ ft-lb.}$$

3. <u>Phase 3</u>

This phase begins where the bolt leaves contact with accelerator and ends at the maximum recoil position. It is assumed that in addition to the main recoil spring, a secondary recoil spring (See page 6) starts to function at the start of phase 3, and acts during the remainder of recoil. The recoil displacement varies from $x = 4.75$ to $x = 5.29$ inches.

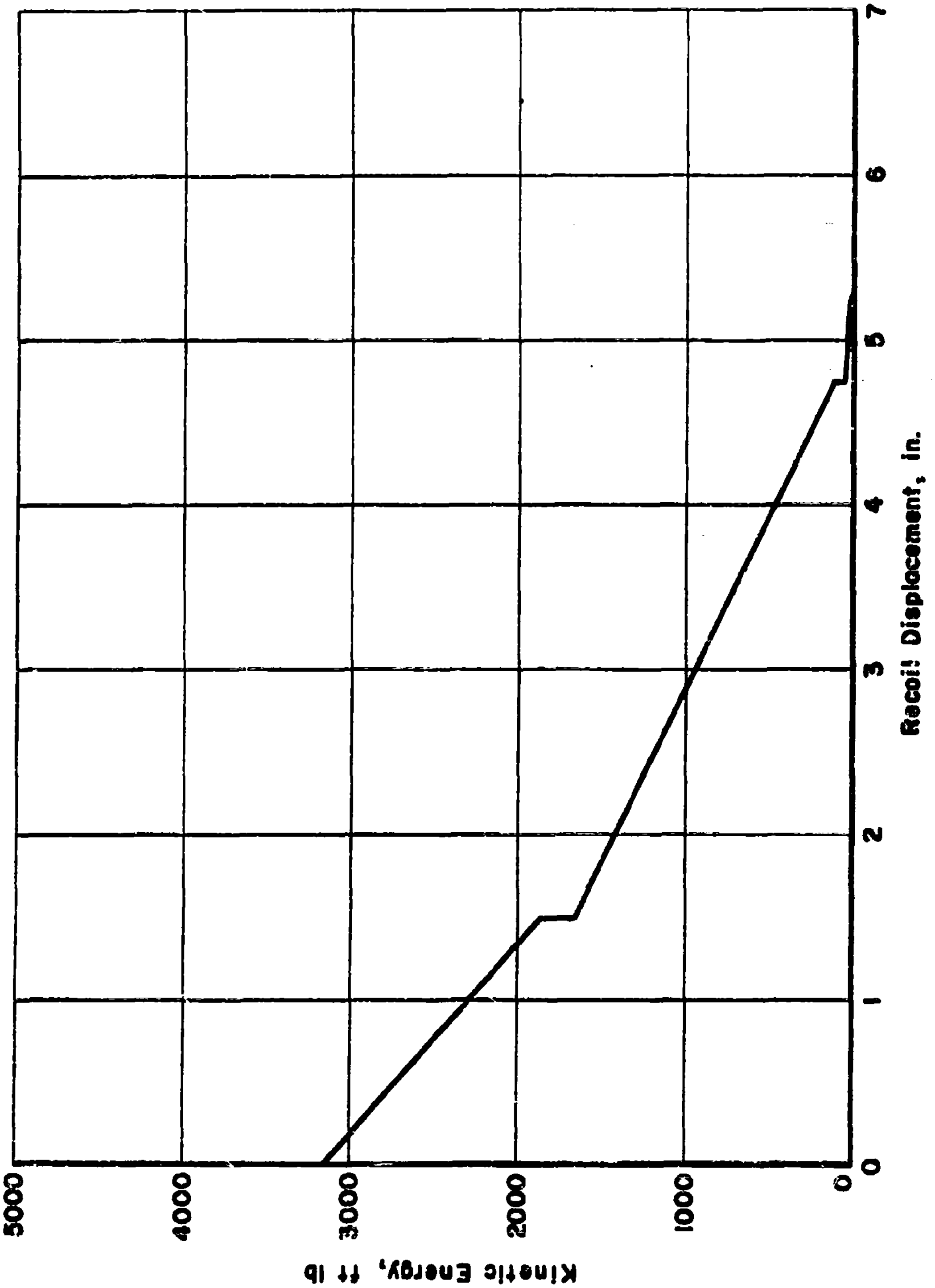


Fig. 53 RECOIL KINETIC ENERGY, 37MM N GUN

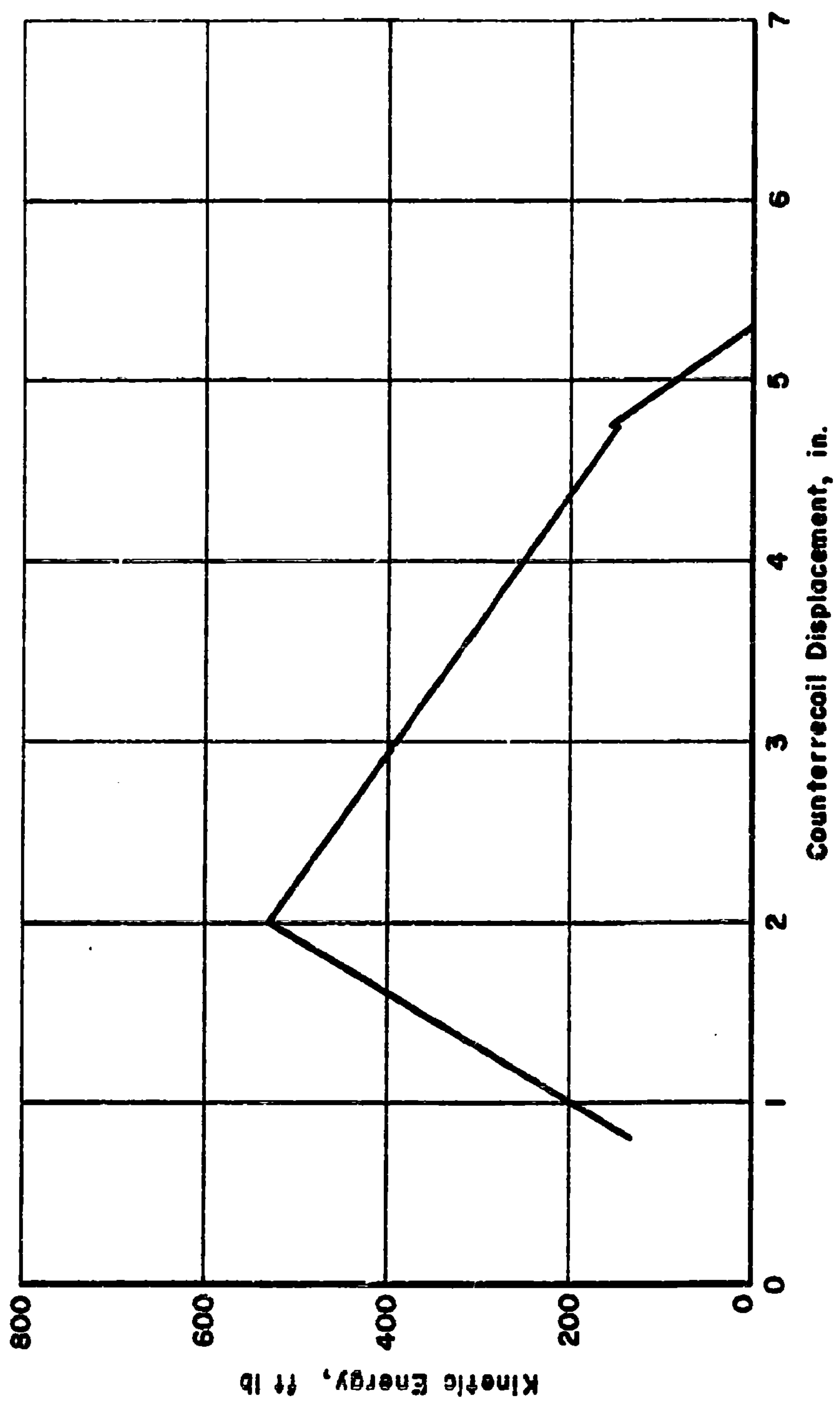


Fig. 54 COUNTER RECOIL KINETIC ENERGY, 37MM N GUN

The time required for the recoil stroke of the cycle may now be calculated by assuming linear variation of kinetic energy during the various phases (Fig. 53) as in the 37mm NS analysis. The time for the recoil stroke is 0.0271 seconds.

4. Phase 4

This phase of counterrecoil begins at $x = 5.29$ and ends at $x = 4.75$ where the counterrecoiling parts leave the secondary recoil spring. All the potential energy removed from the recoil springs is converted to kinetic energy. The kinetic energy of the counterrecoiling parts at the end of phase 4 is

$$K.E._{x4} = 159 \text{ ft-lb.}$$

5. Phase 5

This phase begins at the point where the counterrecoiling parts leave the secondary recoil spring, and ends where the counterrecoil buffer starts to act.

The displacement varies from $x = 4.75$ to $x = 2$. All the potential energy removed from the recoil spring is converted to kinetic energy. The kinetic energy of the counterrecoiling parts at the end of phase 5 is

$$K.E._{x5} = 530 \text{ ft-lb.}$$

6. Phase 6

This phase begins where the counterrecoil buffer makes contact with the counterrecoiling parts and ends where the feeder sear releases.

The displacement varies from $x = 2$ to $x = 0.8$, whereupon the feeder sear releases. It is assumed that only 20 per cent of the energy available at the end of this phase appears as kinetic energy, due to the action of the counterrecoil buffer. The kinetic energy of the counterrecoiling parts at the end of phase 6 is

$$K.E._{x6} = 131 \text{ ft-lb.}$$

The time for the counterrecoil stroke may now be calculated in the same way as for the recoil stroke, that is, by assuming linear energy variation during the various phases as shown in Fig. 54. The counterrecoil time was found to be 0.0354 seconds.

D. The Feeding Motion

It was assumed the feeding time is the same as for the 37mm NS Gun, (0.026 seconds).

E. Bolt Ramming Time

The bolt ramming time was calculated in the same way as for the 37mm NS Gun and was found to be 0.0515 seconds.

F. Cyclic Rate

The cycle time is .140 sec which corresponds to a cyclic rate of 429 rpm.

G. Trunnion Reaction

The maximum trunnion reaction of this weapon is equal to the sum of the forces exerted by the two recoil springs, the bolt drive spring, and the buffer spring at the instant the kinetic energy in the bolt has been absorbed by the buffer. The recoil spring and drive spring forces may readily be computed, however, the buffer spring force is a function of the velocity with which the bolt strikes the buffer.

The assumptions made yield a bolt velocity of 5 fps at the time it strikes the buffer, therefore the energy which the buffer spring must absorb is

$$K.E._{z3} = 1/2\,\frac{15.3}{32.2}\,(5)^2 = 5.95 \text{ ft-lb.}$$

Then if k is the buffer spring rate and u the buffer spring deflection

$$K.E._{z3} = 1/2\;k\;u^2$$

or

$$71.4 = \frac{97600}{2}\;u^2$$ (assuming a buffer of force characteristics equivalent to that on the 23mm NS Gun)

from which

$$u = .038 \text{ in.}$$

and the buffer spring force is

$$F_u = 3710 \text{ lb.}$$

The recoil spring force at this instant is

$$F_x = 1920 \text{ lb.}$$

The bolt drive spring force is

$$F_z = 396 \text{ lb}$$

and the total reaction is

$$F = F_u + F_z + F_x = 6026 \text{ lb.}$$

It must be noted that this force can be greatly in error, depending upon the accuracy of the assumption for bolt velocity striking the buffer, and buffer spring rate, both of which have been arbitrarily assumed. The maximum force as given in the above computation is in effect only for a very short time interval, and drops to a much lower value as soon as the kinetic energy in the bolt has been transmitted to the buffer.

IV. CALCULATION OF PRESSURE-TIME AND PRESSURE-TRAVEL CURVES

It was necessary to verify the assumption that the required muzzle velocity could be obtained with the length of barrel shown in Fig. 48, with the weight of the projectile known and an assumed weight of propellant based on a density of loading similar to the 23 and 37mm NS Guns. By the method described in the analysis for the 37mm NS Gun, page 70 the curves in Figs. 55 and 56 were drawn. These curves are reasonable, and it is concluded that the muzzle velocity required can be attained with the projectile, propellant weight, and barrel indicated.

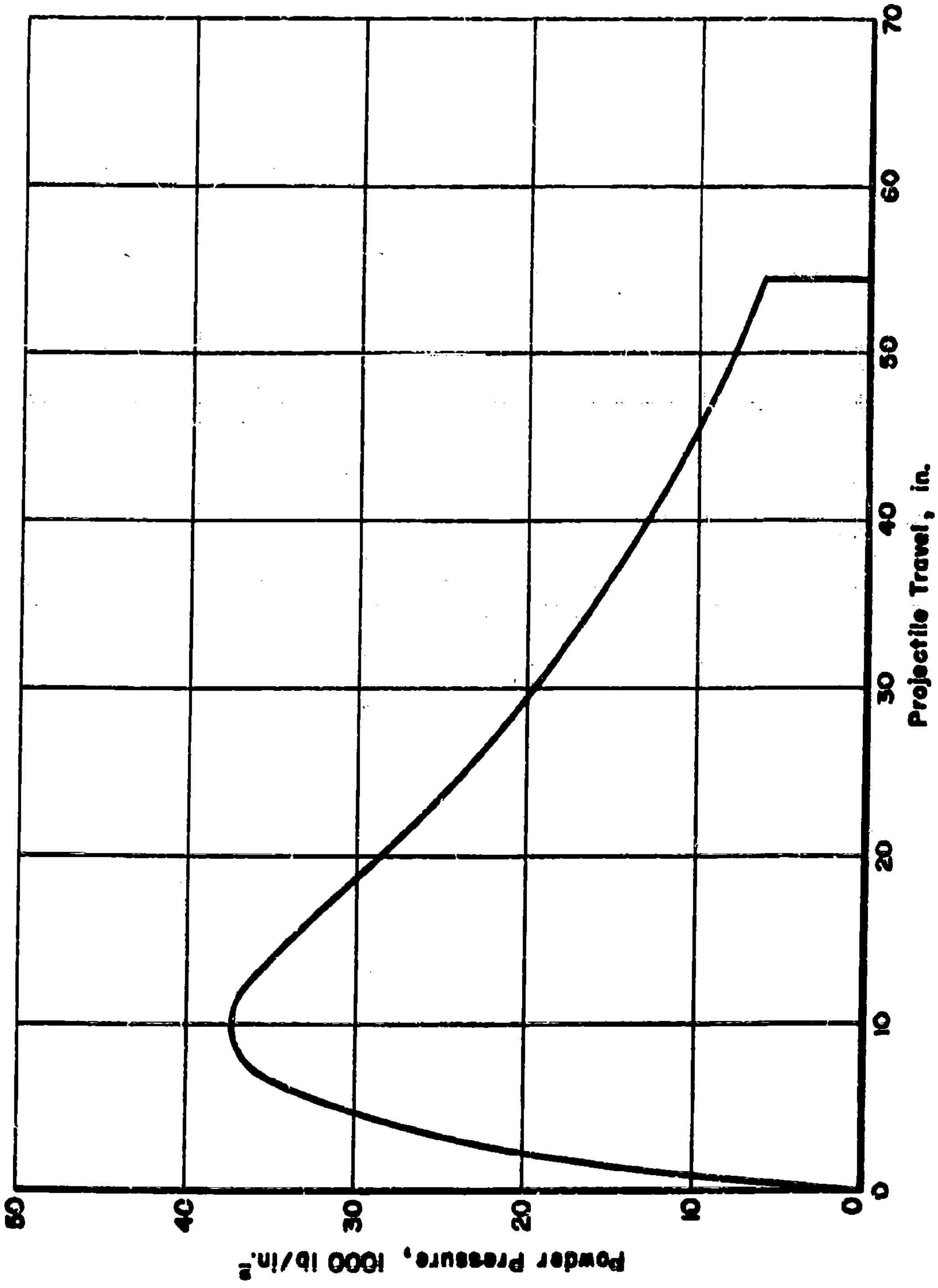


Fig. 55 ARBITRARY PRESSURE-TRAVEL CURVE FOR 37MM N GUN

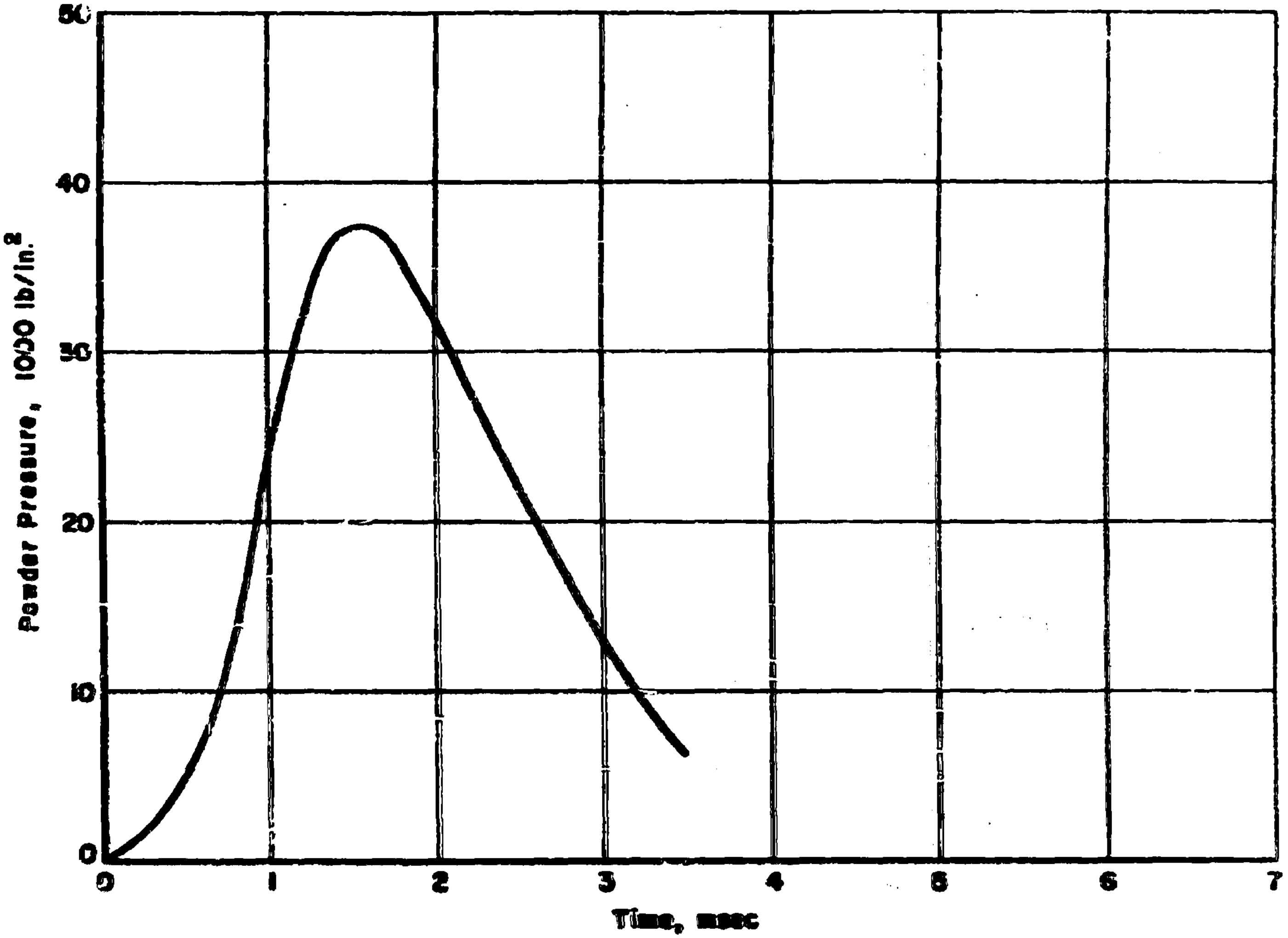


Fig. 56 ARBITRARY PRESSURE-TIME CURVE FOR 37MM M GUN

DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

23 June 2010

HAF/IMIO (MDR)
1000 Air Force Pentagon
Washington, DC 20330-1000

Bobby Sammons.
P.O. Box 1680
Cloudcroft, NM 88317-1680

Dear Mr. Sammons

Reference to your letter, undated (attachment 1) requesting a Mandatory Declassification Review (MDR) for Defense Technical Information Center (DTIC) documents:

AD004521	AD005224
AD005736	AD005735
AD006796	AD004876
AD005809	AD003234
AD005808	AD004232

The review for the documents have been completed and the declassification has been downgraded to UNCLASSIFIED and copies are attached for your information.

Address any questions concerning this review to the undersigned at (703) 692-9979 and refer to our case number 07-MDR-076.

Sincerely

JOANNE MCLEAN
Mandatory Declassification Review Specialist

2 Attachments
1. Letter, Request for Documents
2. 10 DTIC Documents

cc: DTIC w/o documents