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HUGHES TOOL COMPANY · AIRCRAFT DIVISION
Culver City, California

Report No. HTC-AD 64-10

Final Report

20MM MARK 4 GUN POD
250,000 ROUND RELIABILITY IMPROVEMENT PROGRAM

2 February 1964

Prepared under Navy, Bureau of Naval Weapons
Contract NOw 63-0585-d

HUGHES TOOL COMPANY -- AIRCRAFT DIVISION
Culver City, California

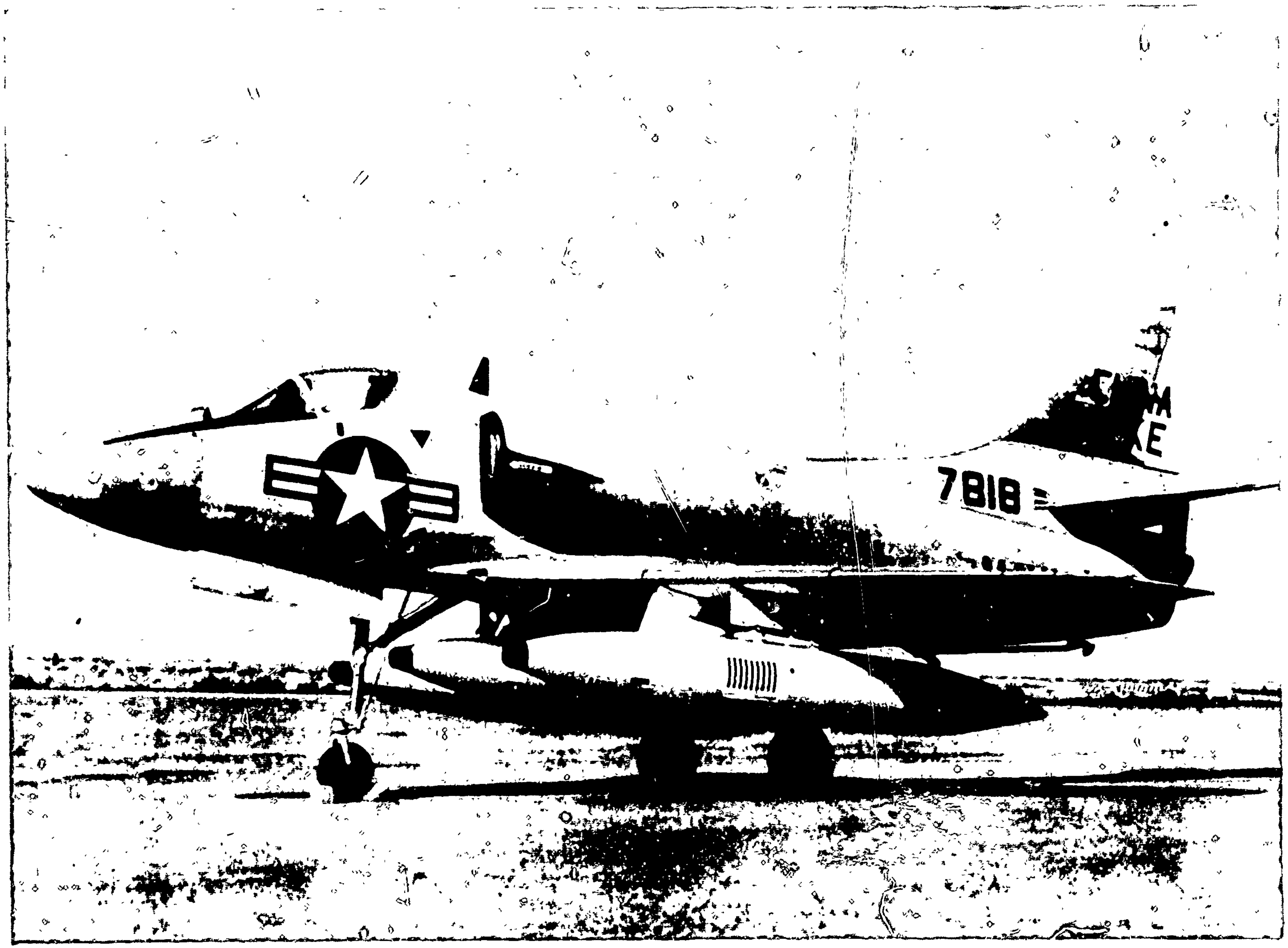

Figure 1. Frontispiece - Three Mk 4 Mod 0 Pods Mounted on A4 Aircraft

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SECTION I

SUMMARY

Flight Tests during the past year proved the Mark 4 Mod 0 Gun Pod to be a versatile and most effective air to ground weapon. Approximately 250,000 rounds were fired from 27 January 1963 through 2 February 1964 to prove the capabilities of the weapon system and to improve the reliability of the gun pod. This firing was divided into four categories, namely: Three-pod flight demonstration on the A4 aircraft at NOTS-China Lake, competitive evaluation on the F-100 aircraft at Eglin Air Force Base, reliability development and R & D firing at Hughes Tool Company's Culver City California Plant. Chart 1 is a plot of the total rounds fired during the past year.

The NOTS-China Lake firing program increased the firepower capability of the A4 airplane to 12,600 shots per minute. Combinations of one, two, and three pod installations were flown and fired without aircraft structural changes or flight restrictions. Normal flight conditions were reported during all flight maneuvers and performance was the same as that with comparable inert stores. The three pod system was demonstrated for the President of the United States and Military and Defense officials on 7 June 1963.

This work was followed by a competitive evaluation of the Navy Mark 4 Mod 0 Gun Pod and the Air Force SUU-16A Gun Pod at Eglin Air Force Base from 1 June through 18 August 1963. Two pods were flown and fired on the wing

pylons of an F-100 aircraft at air speeds to 600 knots and under flight loads from 0 to 6 "G". Burst lengths of five second duration were fired in air to air firing tests. The gun pods were also successfully fired after a cold-sweat-cold test during this period.

Air to ground firing for accuracy was closely controlled using 30 foot by 30 foot vertical targets. The results of these air to ground firing tests showed the wing pod 20mm guns to be as accurate as fuselage mounted guns. A maximum practical burst length for air to ground firing with a 400 knot airplane is 1-1/2 seconds, and the Mark 4 gun pod dispersion is close to optimum. Pilots reported acceptable vibration levels and no noticeable increase in drag due to a -2° misalignment of the pod with the aircraft water line.

On several occasions the pods were exchanged between three different aircraft, and the boresight shift was less than one mil. No corrections were necessary in front or rear lug adjustments of the pod due to this small change.

The Mark 4 gun pod proved to be simple, tough, and easy to maintain under flight line service conditions.

A 127,000 round reliability test program was fired at the Hughes Tool Company, Culver City plant from 15 July through 15 November, 1963. This represents the third phase of a program to fire one million rounds to achieve the final reliability of 95% and 7,000 rounds per stoppage (See Figure 2). Two Mark 4 Mod 0 gun pods were used in this test, and a 91.3% fireout was achieved during a 60,000 round sample of firing from the two pods. This exceeds the 90% fireout

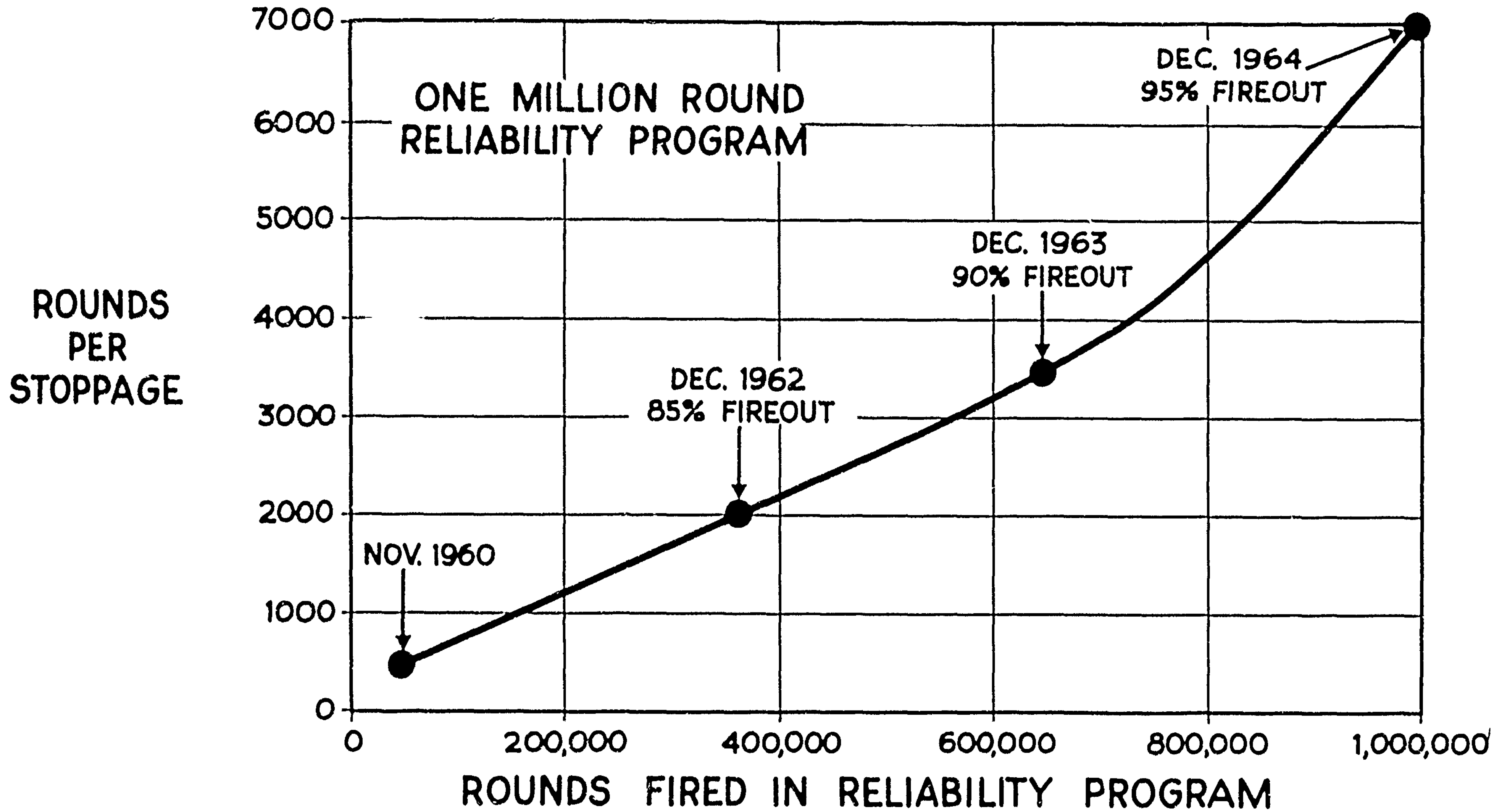


Figure 2. Reliability Program — Mk 4 Gun Pod

objective of Contract NOw 63-0585-d. Figure 3 shows the improvement in the gun pod from the start of the reliability program. During the 60,000 round sample the two gun pods had a stoppage rate of 3,330 rounds per stoppage.

The increase in the reliability of the Mark 4 Mod 0 gun pod was a result of the following major improvements:

Mark 11 Mod 5 Gun

1. Simplified gas takeoff system in booster housing
2. Increased case ejection velocities
3. More rugged gas transport system
4. Improved loader frame
5. Improved round positioner assembly

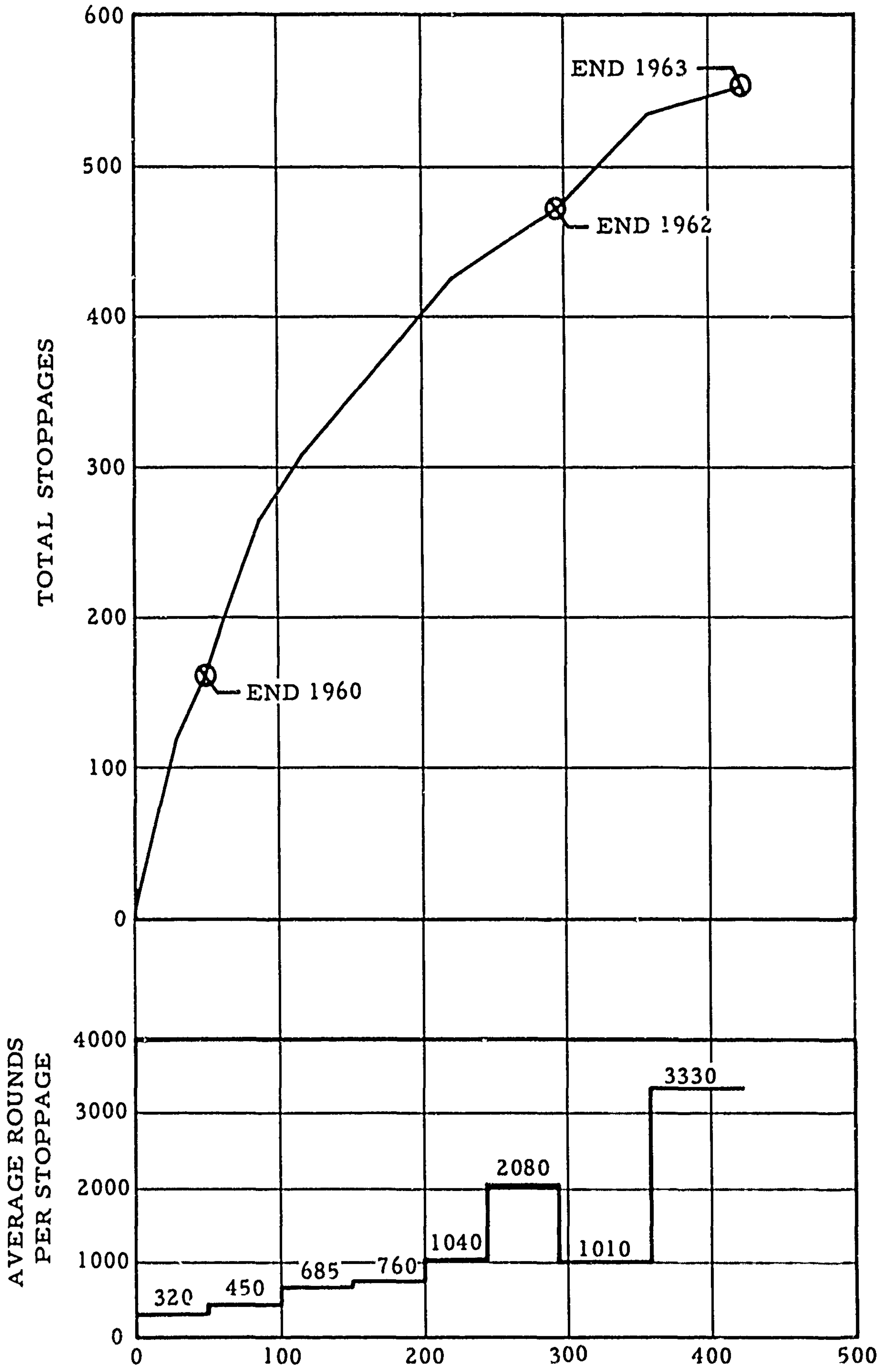
Mark 6 Mod 4 Link

1. Protective cap for radhaz protection
2. Stronger end permits higher case ejection velocities
3. Improved lug to eliminate belt separation

Gun Pod

1. Improved chutes of heavier gauge material
2. Cast blast suppressor to reduce blast loads on A4 fuselage
3. Stronger 10,000 pound nose latches
4. Stronger strongback (designed for F-100 loads)
5. Azimuth adjustment at rear lug
6. Removeable main access doors

STOPPAGES & STOPPAGE RATES VS. ROUNDS FIRED



RELIABILITY ROUNDS FIRED IN THOUSANDS

Figure 3

7. Last round switch for air motor shutoff

8. Stronger feed throats

9. Improved magazine

10. Motor type mount for pneumatic bottle

A number of improvements were made during this program that will make it possible to achieve the 7,000 round per stoppage by the end of the million round reliability program. The most significant improvement in the program was the installation of the ring seal cylinder. This has completely eliminated the eroding of the breech end of the barrel due to poor sealing between the cylinder and barrel. A change was made in the design of the ram assembly which has strengthened the part significantly and no further breakage is expected. Other improvements include redesigned firing pin holder, chrome plated firing pins, hardened cam followers, hardened case retainers, material change in check valve, and improved piston rings for ram.

Most of the R & D firing program was spent in improving the gun reliability for longer bursts. As a result of firing 2-3/4 second bursts the ring seals have been improved, the ram pistons and piston rings have been changed to different materials, and the gas eject tubes have been strengthened. Other design improvements to be incorporated in the guns will be the quick disconnect booster housing, simplified gas ejection tubes, and redesigned gas takeoff system in the booster housing to improve ram pressure.

SECTION II

NOTS-CHINA LAKE FIRING PROGRAM

The purpose of this test program was threefold:

(1) Establish the feasibility of a three pod installation on the A4 Aircraft.

(2) Flight test the improvements made in the pod system since the previous flight tests.

(3) Demonstrate the firepower of a three pod system in a weapons presentation for the President of the United States and Military and Defense officials.

Three EX-1 Gun Pods were converted to Mk 4 Mod 0 Gun Pods for this test. The mounting of the pods at the wing stations required adapters. These were necessary in order to mount the pod with a 30-inch lug spacing to the Aero 20a rack with a 14-inch hook spacing. Figure 4 is a view of the adapter furnished by the Hughes Tool Company.

A total of 11, 111 rounds of target practice, armor piercing-tracer and high explosive-incendiary ammunition was fired from 16 April to 19 July. Ten flights were made and 2911 rounds fired with a single pod on the centerline station of the A4A and A4C aircraft. Twelve flights were completed and 8200 rounds fired with a three pod installation, one on the centerline station and two on the inboard wing stations of the same aircraft.

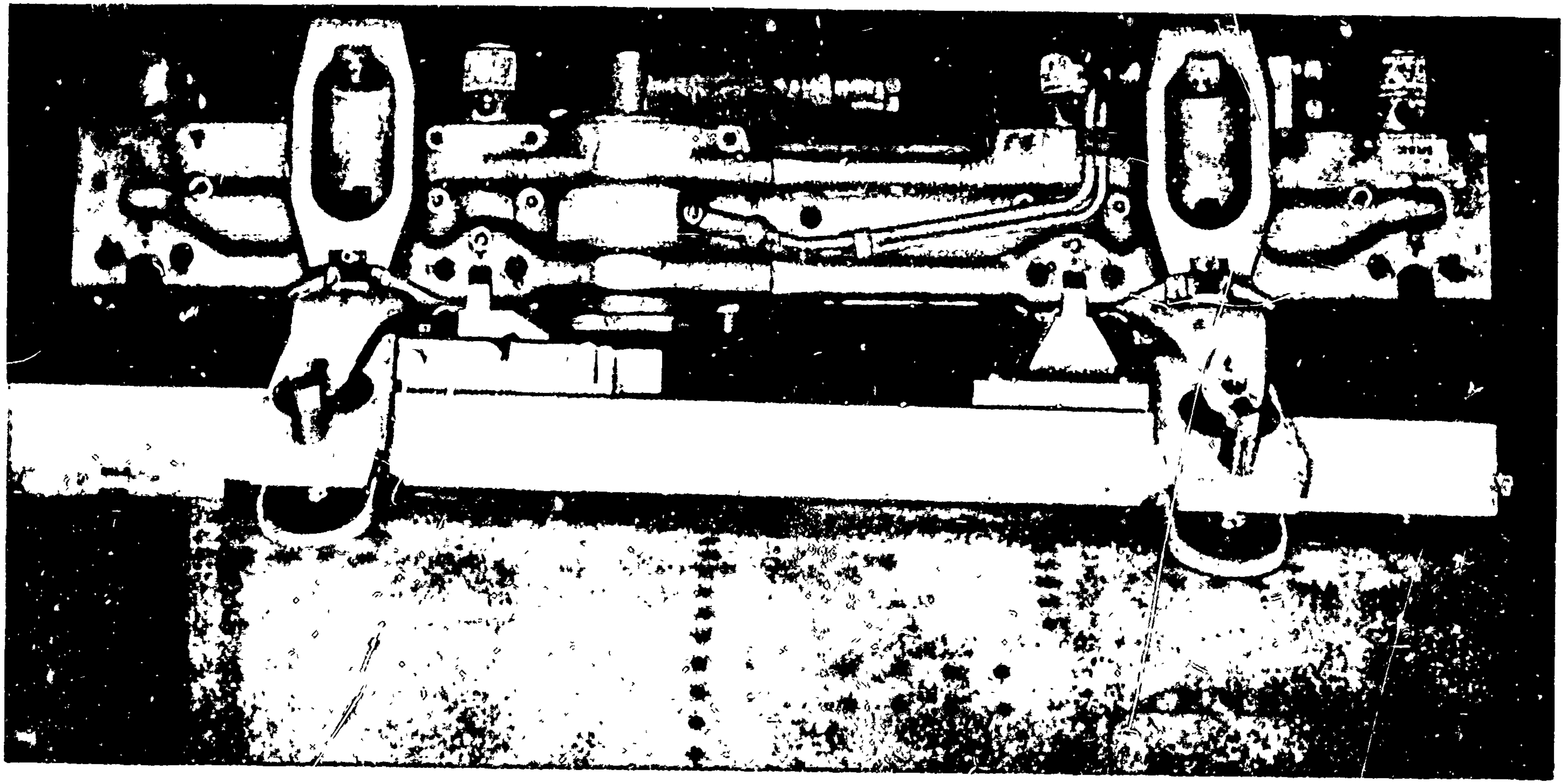


Figure 4. External Test Adaptor for A4 Wing Station

Eleven flights were fired air-to-air and eleven air-to-ground. In six of the air-to-ground flights, horizontal targets were used. In three flights for the firepower demonstrations, the target was a group of vehicles. In two flights for tactical demonstration, a medium tank was used as a target. Figure 5 and 6 are photographs of the tactical demonstrations.

Conclusions:

1. The tests demonstrated that one, two, or three 20mm Mk 4 Gun Pods can be installed, flown, and fired from the A4 airplane without aircraft structural changes or added flight restrictions.

2. The three pod installation increased the firepower capability of the A4 airplane to 12,600 shots per minute.

3. Pilots reported no adverse flight conditions during any flight maneuver and no adverse effects to control functions during either symmetrical or asymmetrical firing of a multiple pod system. Vibration and muzzle blast effects were at an acceptable level. Performance was the same as that with comparable inert stores.

4. Operational limits were pushed upward during these tests above what has previously been used for a single pod installation. Firing was accomplished under accelerations of 5.5 "G", a 50% increase. Burst length was increased to a four second maximum in flight. Firepower was increased to 12,600 shots per minute, a 300% increase. Rounds capacity was increased to 2250, a 300% increase.

Figure 5. A4 Aircraft Firing 12, 600 Shots Per Minute of 20mm Ammunition from Three Mk 4 Gun Pods.

Figure 6. Attack on a Tank with 12, 600 Shots Per Minute of 20mm.

5. The successful operation of the Mk 4 Pod under high altitude, low temperature and icing conditions (cold-sweat-cold) and during sustained speeds within a range of 280 - 450 KIAS was demonstrated.

Full details of the NOTS-China Lake test program are given in Hughes Tool Company Report HTC-63-56.

SECTION III

EGLIN AIR FORCE BASE EVALUATION TESTS

A competitive evaluation was made of the Navy Mk 4 Mod 0 Gun Pod and the Air Force SUU-16A Gun Pod at Eglin Air Force Base, Florida from 1 June through 18 August.

Two Mk 4 Mod 0 Gun Pods were installed on the wing pylons of an F-100 aircraft as shown in Figure 7. A total of 13,600 rounds were fired by the Mk 4 Gun Pod during this period. The test was very beneficial in determining the accuracy of gun pods on wing pylons and the performance of the gun pod under various environmental and flight conditions.

Test Results

1. The pods fired successfully after a cold-sweat-cold cycle of 15 minutes at 35,000 ft., a warm-up at 5000 ft., and a second cold cycle of five minutes at 35,000 ft. This test was also successfully passed at China Lake on an A4 aircraft except with 30-minute cold cycles.

2. Successful firing was accomplished at air speeds to 600 knots indicated and under flight loads from 0 to 6 "G".

3. Five-second bursts were fired with the pods, and the complete pod was fired out in 8 to 10 minutes on several occasions. Cookoff occurred as a result of a firing schedule more severe than programmed, however, tests are now being conducted with a ring seal type cylinder which should make the pod capable

TWO MK 4 MOD 0 GUN PODS MOUNTED ON F100 AIRPLANE

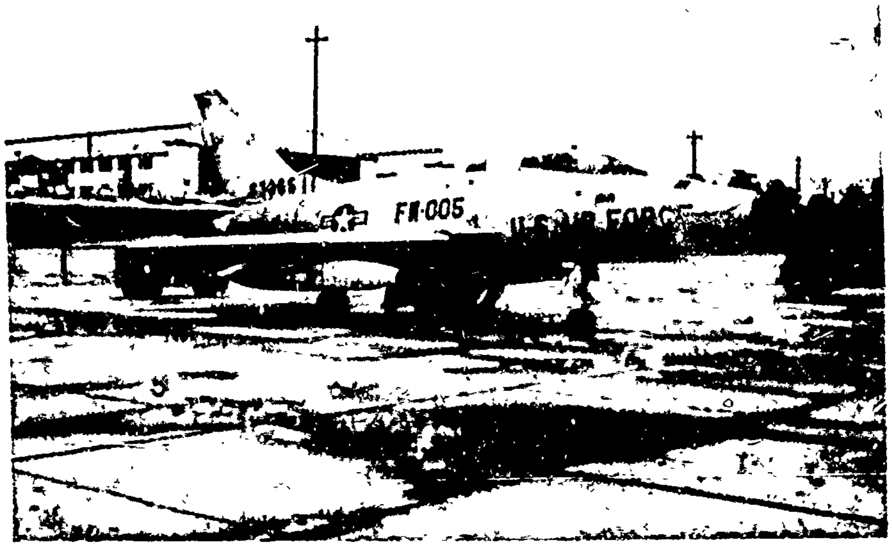


Figure 7.

of firing its complement (750 rounds) independent of schedule without cookoff. No cookoff occurred with shorter bursts, which proved to be practical in the air-to-ground firing.

4. The air-to-ground firing for accuracy demonstrated that the maximum useful burst length on a ground target with a 400 knot aircraft is about 1-1/2 seconds (from 3000 ft. to 2000 ft. range). Farther than 3000 ft. decrease the hit probability, closer than 2000 ft. increases the probability of ricochet hits on the aircraft. The accuracy of the wing mounted gun pods was equal to fuselage guns.

With prior knowledge of only one pod firing, the pilots found it possible to achieve hits in one-second bursts. Sufficient rudder was not available for steady state correction.

5. No boresighting shift occurred in 6000 rounds fired in each pod. Pods were removed and installed several times during the course of firing. The Mk 4 Gun Pods were exchanged between the three aircraft with a boresight shift of less than one mil.

6. The Mk 4 Gun Pod proved to be simple, tough, and easy to maintain. Stoppages were corrected in a short time (1/2 hour or less), and these did not compound by breaking additional parts. The maintenance times for some of the more common acts are listed in Table 1. Incorporation of the quick disconnect booster block now in work will cut about four minutes off barrel removal and installation.

TABLE 1

MAINTENANCE OPERATION	BEST TIME (MINUTES)
1. Remove pod from airplane	1.2*
2. Install pod on airplane	4.1*
3. Reload ammo and ready pod	6.8
4. Remove loader	0.5
5. Reinstall loader	0.5
6. Remove gun from pod	0.8
7. Install gun in pod	0.9
8. Remove barrels from gun	1.8
9. Replace barrels into gun	3.4
TOTAL ITEMS 4 thru 9	7.9 Minutes

*Using Mk 7 bomb dolly

Conclusions:

1. Wing pod 20mm guns are as accurate as fuselage mounted guns.

2. No boresighting shift in the pod due to firing and boresight shift was less than one mil when the pods were exchanged between three different aircraft.

3. Pilots reported acceptable vibration levels.

4. No noticeable increase in drag due to -2° misalignment of pod with aircraft waterline.

5. A maximum practical burst length for air-to-ground firing with a 400 knot airplane is 1-1/2 seconds.

6. Mk 4 Gun Pod dispersion is close to optimum.

7. The gun pods passed the environmental and flight tests.

8. The Mk 4 Gun Fod proved to be simple, tough, and easy to maintain.

Full details on the Eglin Field test program are given in Hughes Tool Company Report HTC-63-44.

SECTION IV

RELIABILITY TEST PROGRAM

Two new Mk 4 Mod 0 Gun Pods were installed in the enclosed firing range at the Hughes Tool Company Culver City plant for the reliability test program. The first pod (Serial #10) commenced firing on 15 July, and the second pod (Serial #12) joined the program on 24 July. For ease in identification, pod Serial #10 was designated as the "Red" pod and pod Serial #12 was called the "Green" pod throughout the program.

A total of 126,730 rounds were fired in the reliability program between 15 July and 15 November. Pod Serial #10 fired a total of 70,412 rounds and Serial #12 fired a total of 56,318 rounds. Charts 3 and 4 represents the total number of rounds fired and the stoppages for the two pods.

A 91.3% fireout was achieved during a 60,000 round sample of firing from the two pods. This exceeds the 90% fireout objective of Contract NOw 63-0585-d, and represents 47.5% of the total rounds fired in the reliability firing program during the past year.

The 60,000 round reliability firing sample was taken from both gun pods from mid-October to the finish of the reliability program. The last 38 consecutive pods were taken from Serial #10, and the last 42 consecutive pods from Serial #12. The sample includes podloads #58 through #95 for Serial #10 and podloads #35 through #76 for Serial #12.

Of the 60,480 rounds attempted, firing would have been limited to 55,264 rounds had each podload been terminated when a stoppage was encountered. The ratio provides the 91.3% fireout value. Actually, after each stoppage the problem was cleared and the firing continued so that 59,966 rounds were fired.

A total of 18 stoppages occurred during the sample, giving a stoppage rate of 3330 rounds per stoppage. Table 2 itemizes the 18 stoppages as to cause.

TABLE 2

STOPPAGE SUMMARY

FOR 60,000 ROUND SAMPLE

TYPE OF STOPPAGE	NUMBER OF STOPPAGES		
	GREEN (12)	RED (10)	TOTAL
Manufacturing Error			
1. Cylinder chamber finish 100 micro-inches; should be 16.	0	3	3
Sub-total	0	3	3
Ammunition			
1. Late fire	0	1	1
Sub-total	0	1	1
Link			
1. Lug to carrier failure	1	1	2
2. Bad spotweld in Radhaz cap	0	1	1
Sub-total	1	2	3
Loader			
1. Poppet failed to check	0	1	1
2. Rex 49 poppet shattered	0	1	1
3. Broken ram	1	0	1
4. Broken sear link	1	0	1
Sub-total	2	2	4
Gun			
1. Broken pin in round positioner	0	1	1
2. Firing pin holder - open circuit	0	1	1
3. Shorted firing pin	0	1	1
4. Gas transport tube broken	0	1	1
5. Case retainer failed	2	0	2
6. Cracked barrel insert	1	0	1
Sub-total	3	4	7
TOTAL	6	12	18
Rounds fired in sample:	31,480	28,486	59,966

Mk 4 Mod 0 Gun Pod

A number of improvements were made in the Mk 4 Mod 0 Gun Pod over the EX-1 Gun Pod used in the previous 300,000 round reliability test. The pod structure was strengthened by changing the forward strongback to stainless steel and beefing up the sway brace areas as shown in Figure 8. This made the pod capable of being flown at speeds up to Mach 1.2 on wing pylons. In addition the fore and aft loads were taken out in the forward lug as opposed to the aft lug on the EX-1, and the rear lug was provided with azimuth adjustment or $\pm 1^{\circ}$. The adjustable rear mount is shown in Figure 9. The bulkhead at Station 108 was changed to cast aluminum with a stronger stainless steel channel in order to take the fore and aft magazine loads out at this station rather than at the aft end of the magazine as was done in the EX-1 gun pod. This allowed the aft magazine support to be lighter and less complex, and also helped to control the tolerance buildup in the magazine drive gear. The location of the cast bulkhead is shown in Figure 10.

A motor-type mount was incorporated in the design to hold the 3000 psi pneumatic reservoir to the aft magazine support. This proved superior to the strap type on the EX-1, and no trouble was encountered in the reservoir mount or rear magazine support. Figure 11 shows the installation of the main pneumatic reservoir.

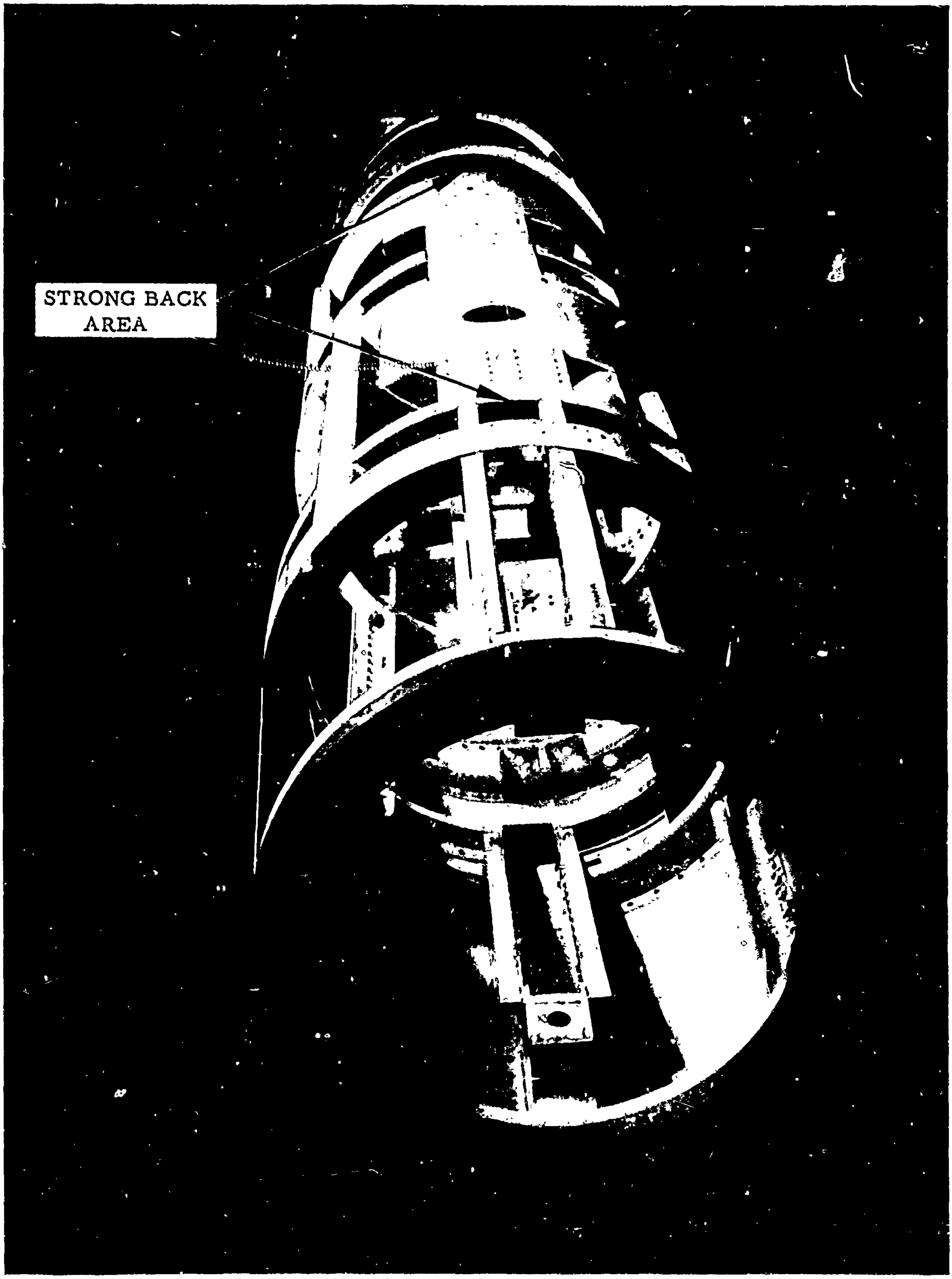


Figure 8. Strongback for F100

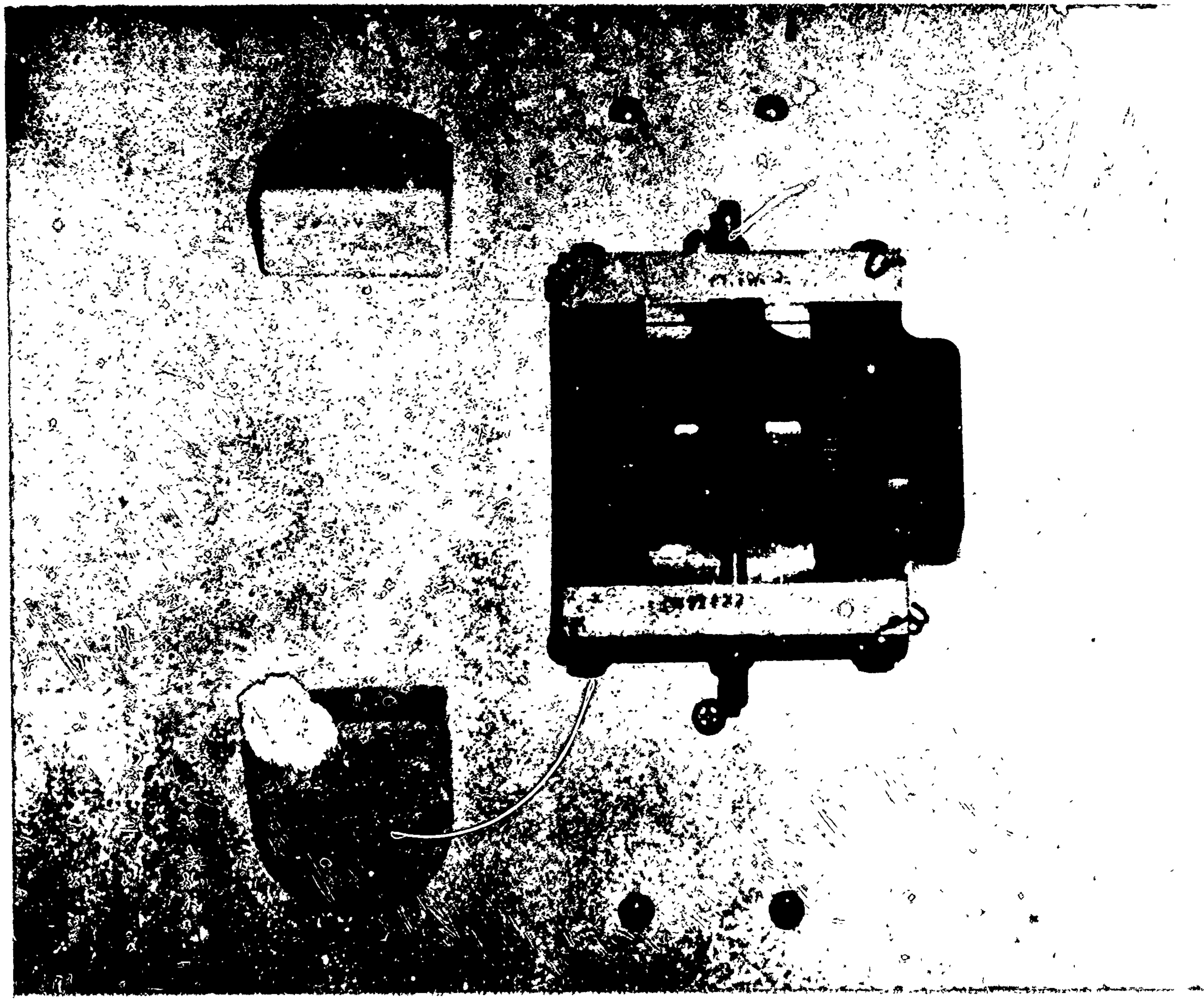


Figure 9. Adjustable Rear Mount for Azimuth Aim Control

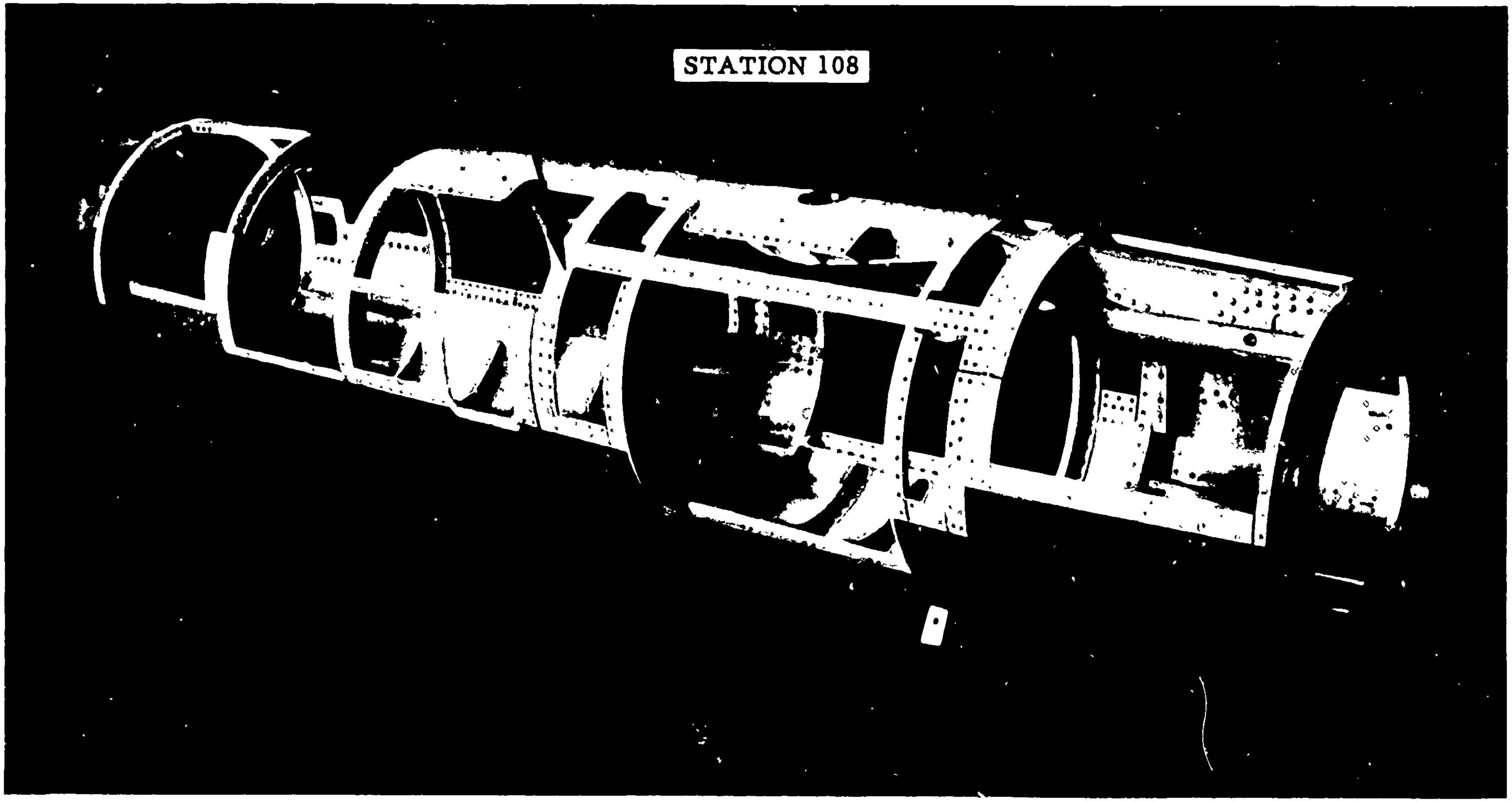


Figure 10. Cast Bulkhead at Sta. 108

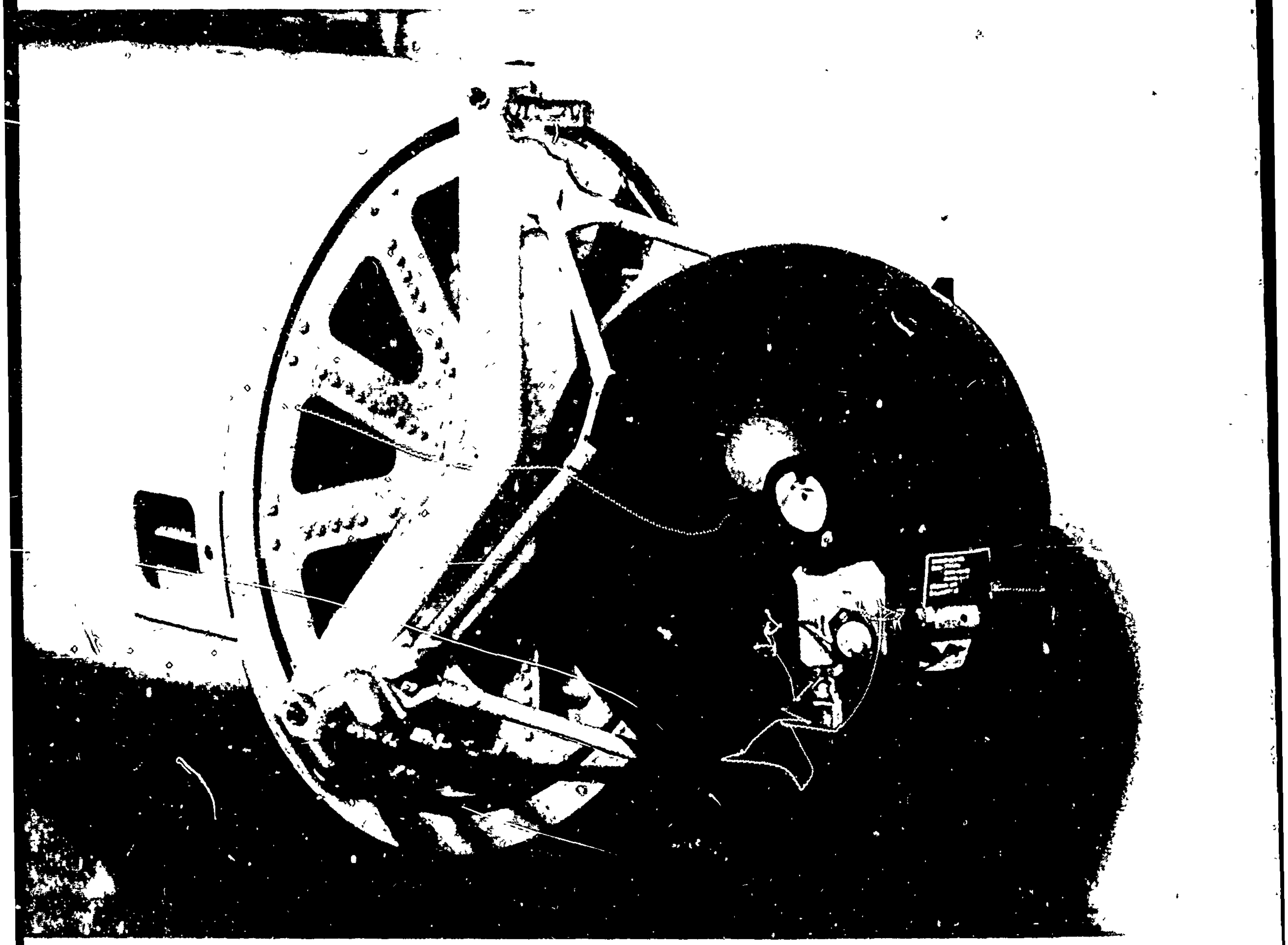


Figure 11. Motor Mount Type Structure for Pneumatic Reservoir Installation

The housings for the magazine drive assembly and the ammunition drive assembly were changed to cast aluminum to decrease production costs. Previously the parts were machined from aluminum bar stock. The ammunition feed mechanism is shown in Figure 12. All of the internal shaft and gear fits were designed to function at -65°F.

A switch was mounted on the ammunition drive sprocket to shut off the air motor. This switch opened when the last round in the magazine passed through, thus cutting the current to the air motor solenoid. Without this switch, the air motor would reach high rotational velocities and cause unnecessary wear. The last round switch is shown mounted in Figure 13. This switch may also be used to open the automatic charge circuit so that continuous charging would not take place after a fireout with a multiple pod installation. No problems were encountered using this switch, and the wear on the air motor was not noticeable at an inspection at 82,000 rounds of firing.

Figure 14 shows the magazine, which was simplified by using aluminum extrusions in the magazine dividers and the front end stiffened to decrease wear and improve loading characteristics.

Several changes were made in the pod nose. The safety pads for the trunnion latches were made more rugged, so the nose could not be put on the pod unless the trunnions were locked. A stronger nose latch was found to be necessary due to the increased forward loads of the blast suppressor. A 6000 lb. latch was first used, since it was interchangeable with the original 4000 lb.

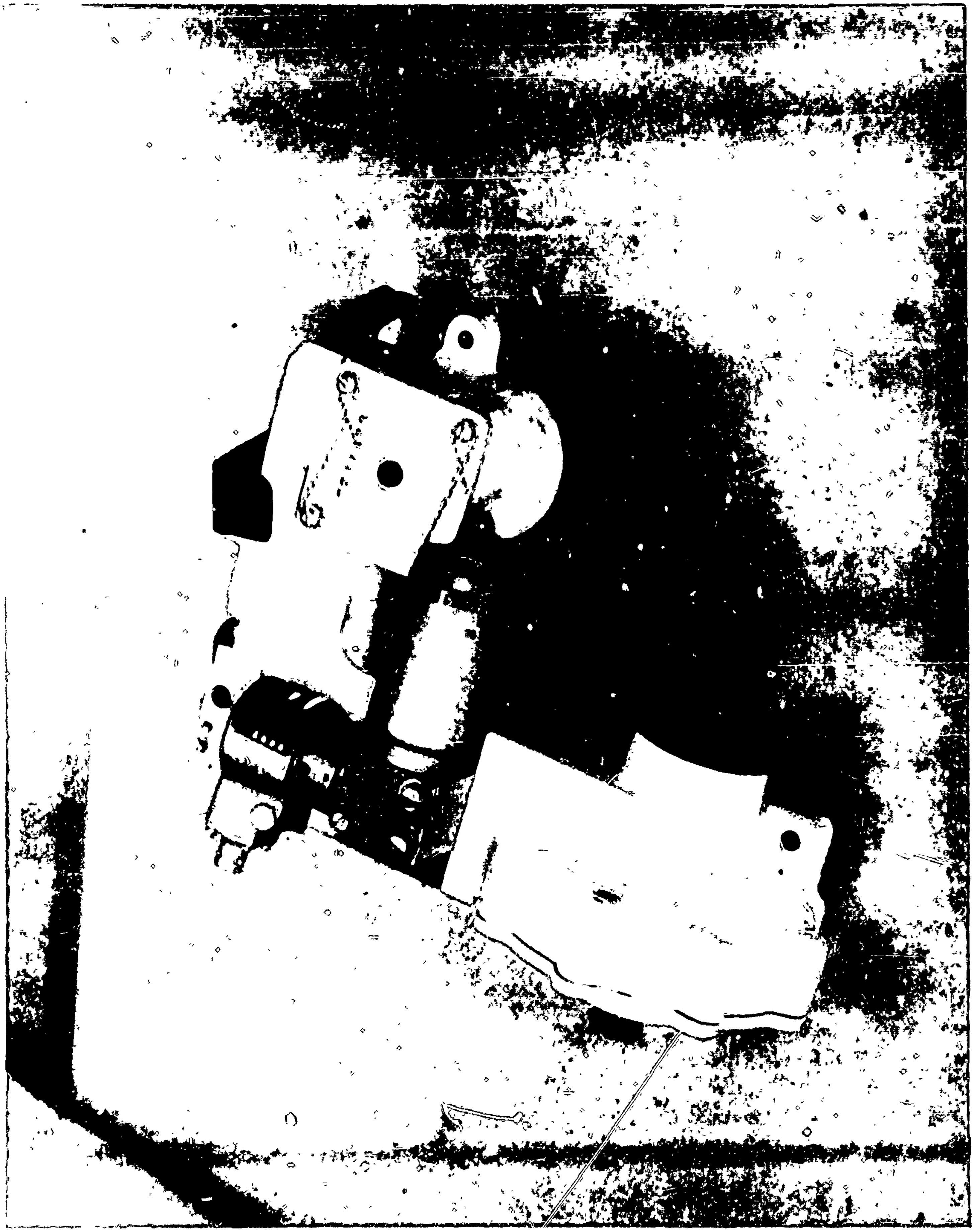


Figure 12. Ammunition Feed Mechanism Assembly

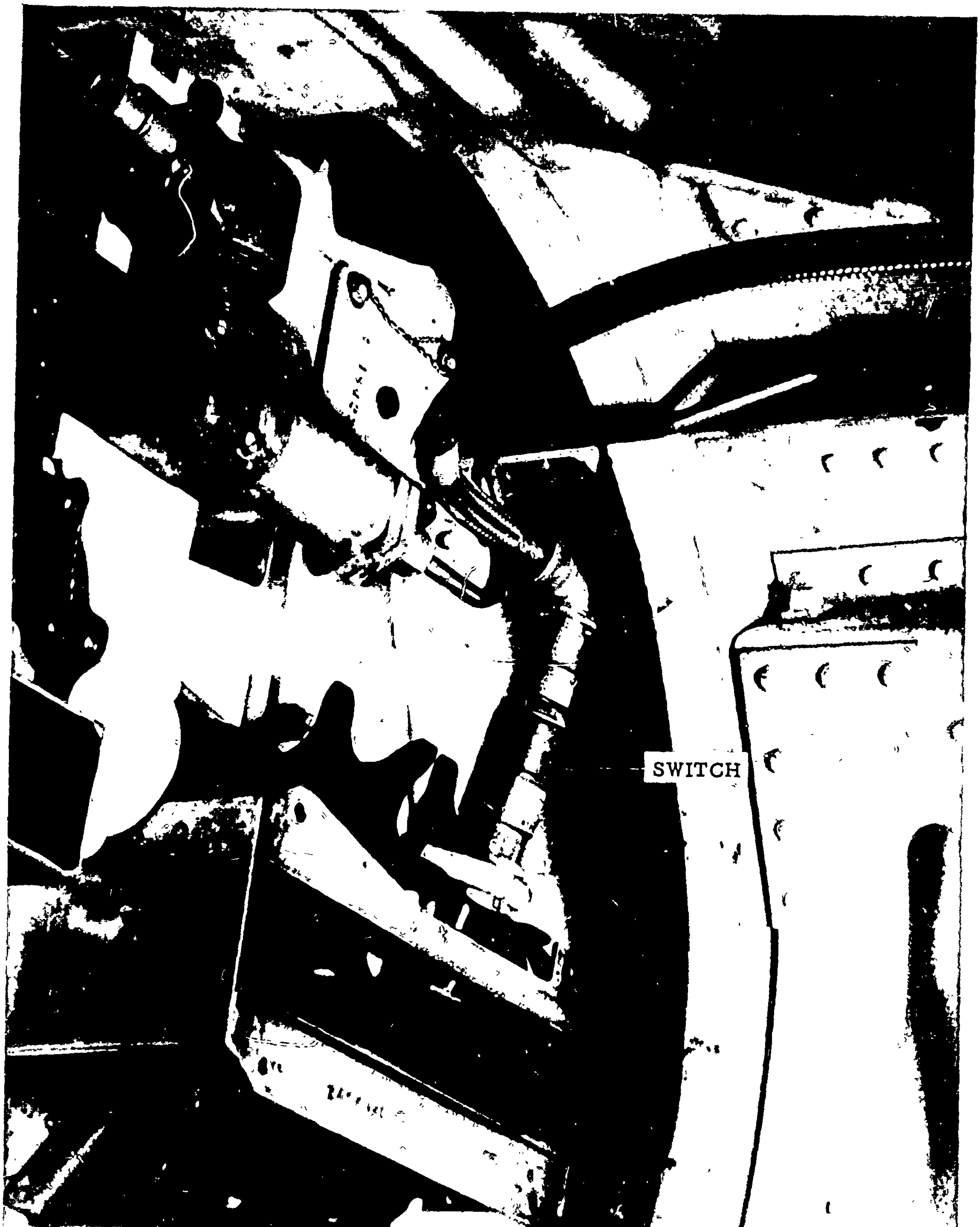


Figure 13. Last Round Switch

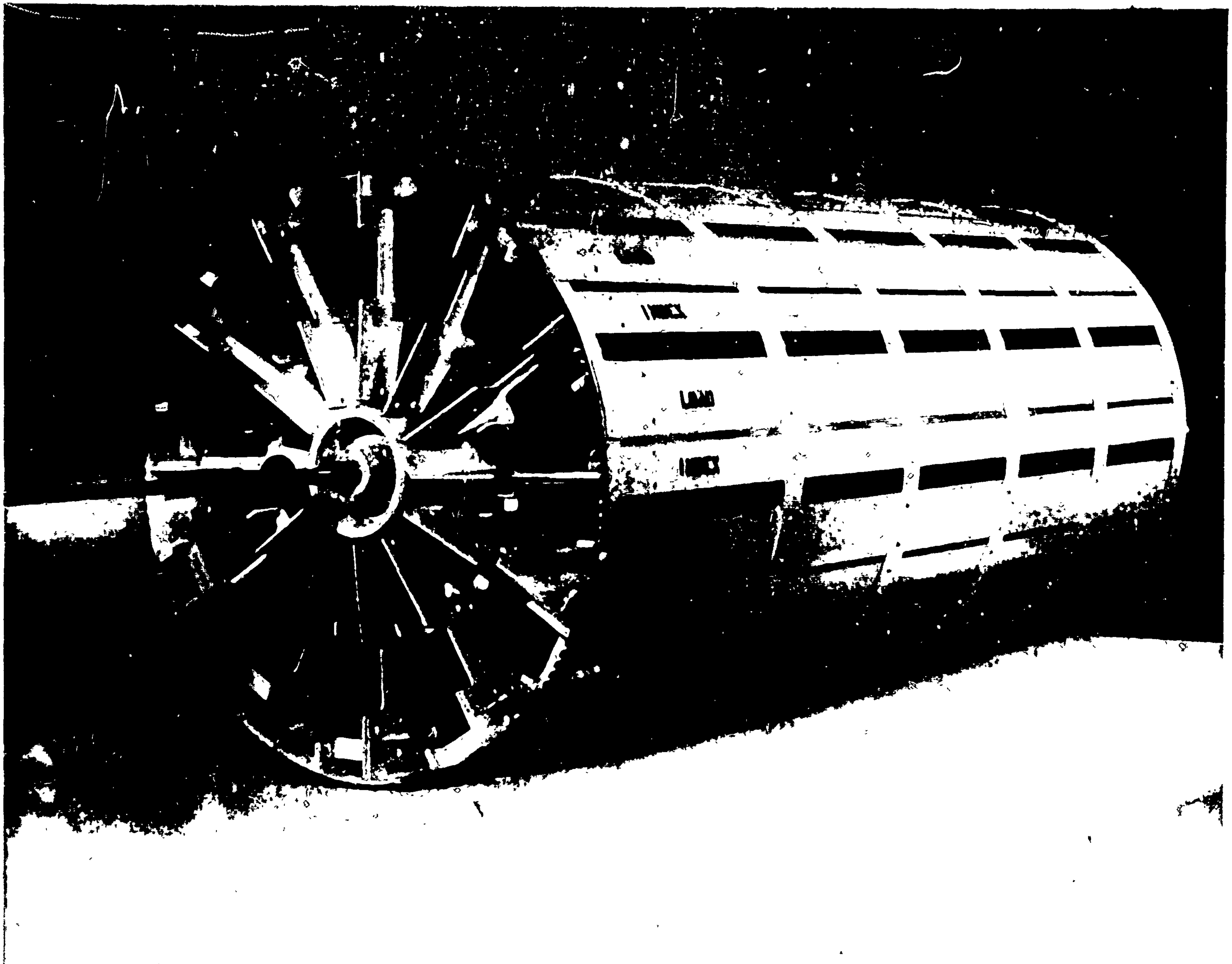


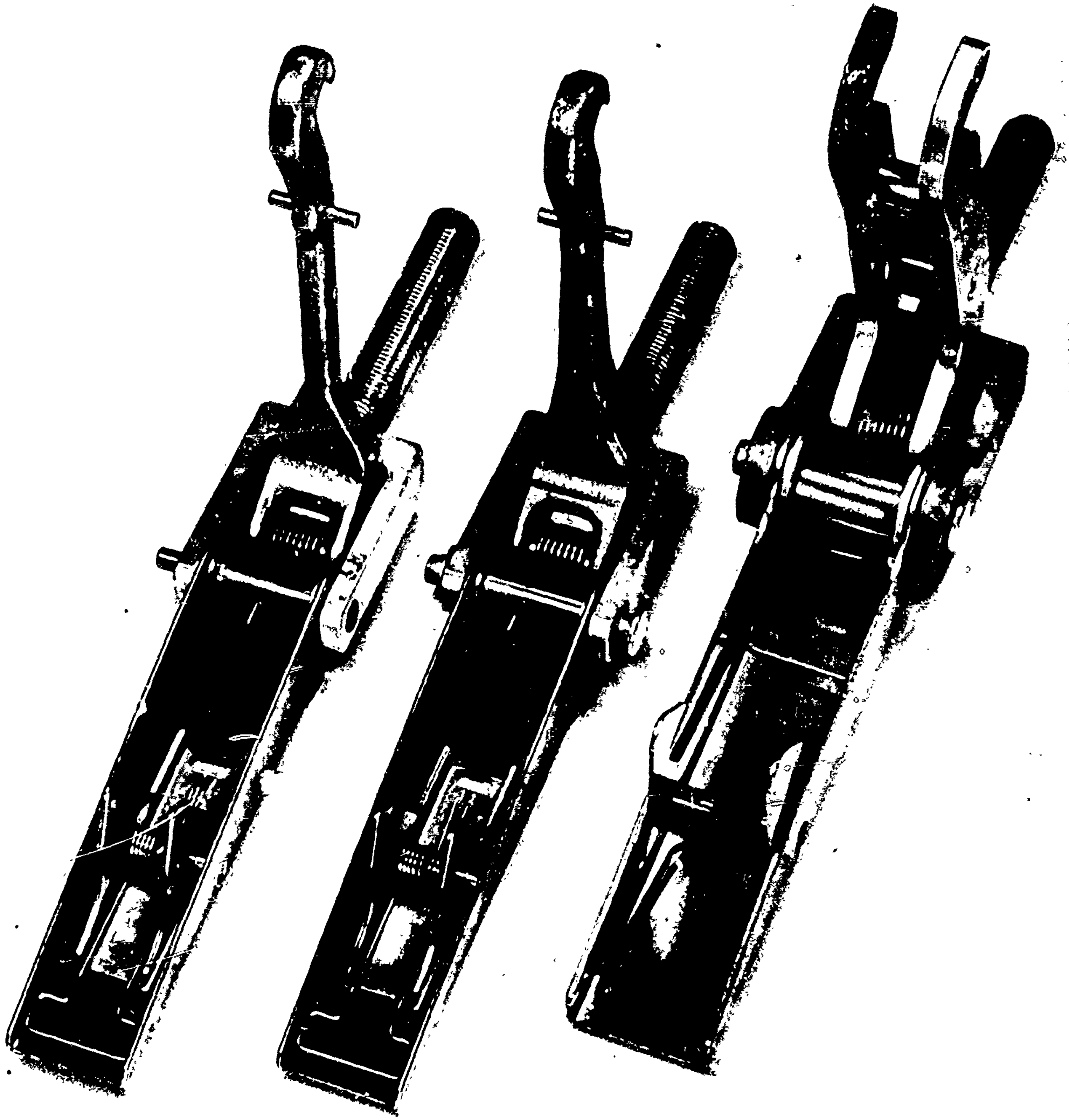
Figure 14. Ammunition Magazine Assembly

latch. This latch did not have the desired safety factor, however, and a 10,000 lb. latch was installed. There have been no latch failures with the 10,000 lb. latch installation. The blast suppressor was cast of 17-4PH corrosion resistant steel. The nose changes are shown in Figures 15, 16, 17, and 18.

The feed chutes were reshaped for smoother ammunition flow and were made of heavier gauge material where needed. The loader attaching end was strengthened with channel sections to eliminate deformation. Figure 19 shows the strengthened feed chute. No trouble was encountered with this chute and one set was fired 87,000 rounds before being replaced. The pod structure was also improved by strengthening the feed throats and making the main access doors removable.

Mk 11 Mod 5 Gun

Figure 20 shows the Mk 11 Mod 5 Gun used in the reliability program. Probably the most significant improvement in the Mk 11 Mod 5 Gun was the simplified gun gas system. By eliminating the flapper valve and shuttle valve in the booster block, most of the problems in the booster block were eliminated. Figure 21 shows the simplified 4330 cast steel booster block. The gas transport tube to the rammers was changed to corrosion resistant steel, and a heavier wall thickness was used to help eliminate failures with long burst firing. A two-piece manifold of 17-4PH corrosion resistant steel was used instead of the 4130 steel welded manifold in the Mk 11 Mod 4 Gun. Figure 22 shows the two-piece



4,000# Latch | 6000# Latch | 10,000# Latch

Figure 15. Comparison of the Three Latches

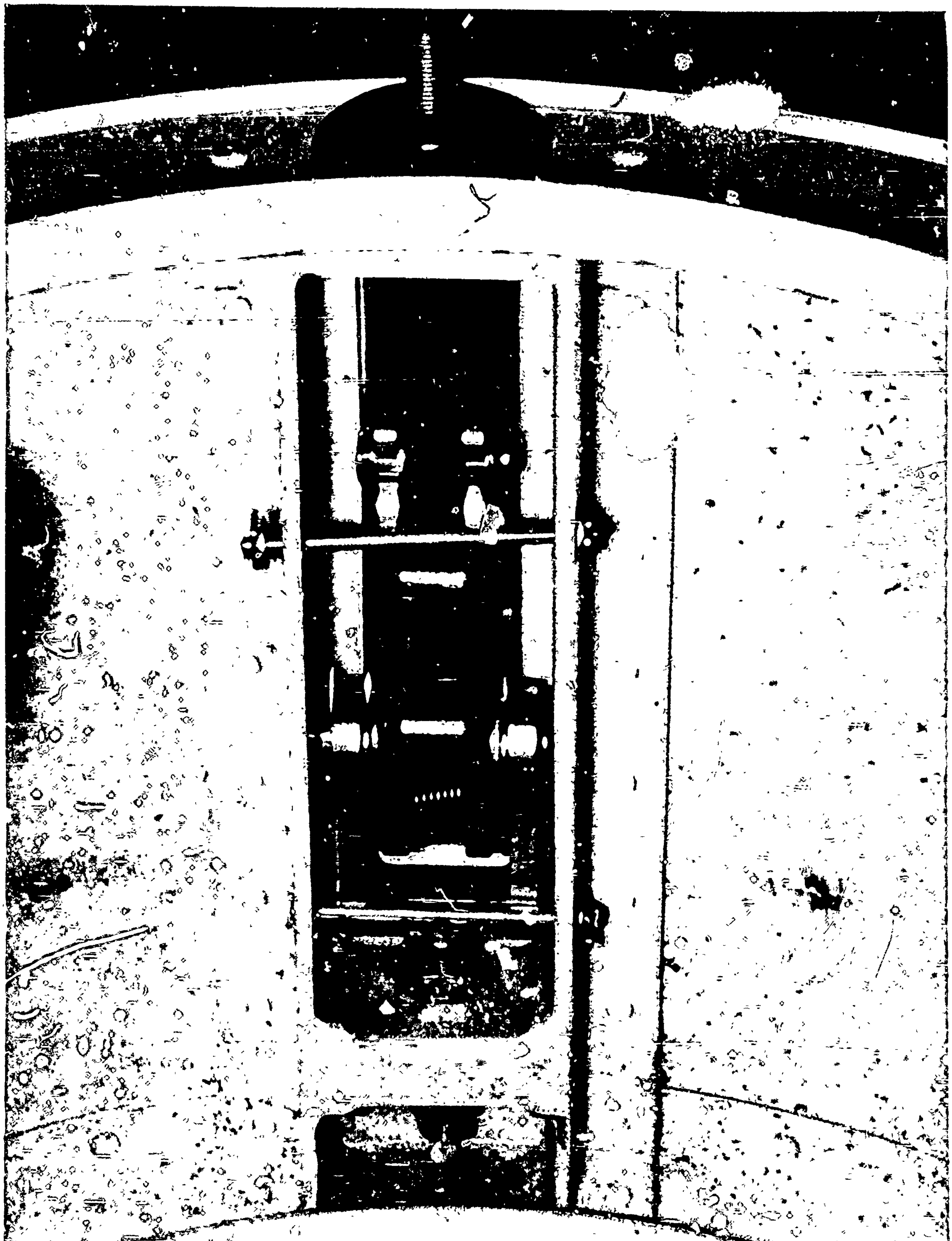


Figure 16. 10,000 lb. Nose Latches

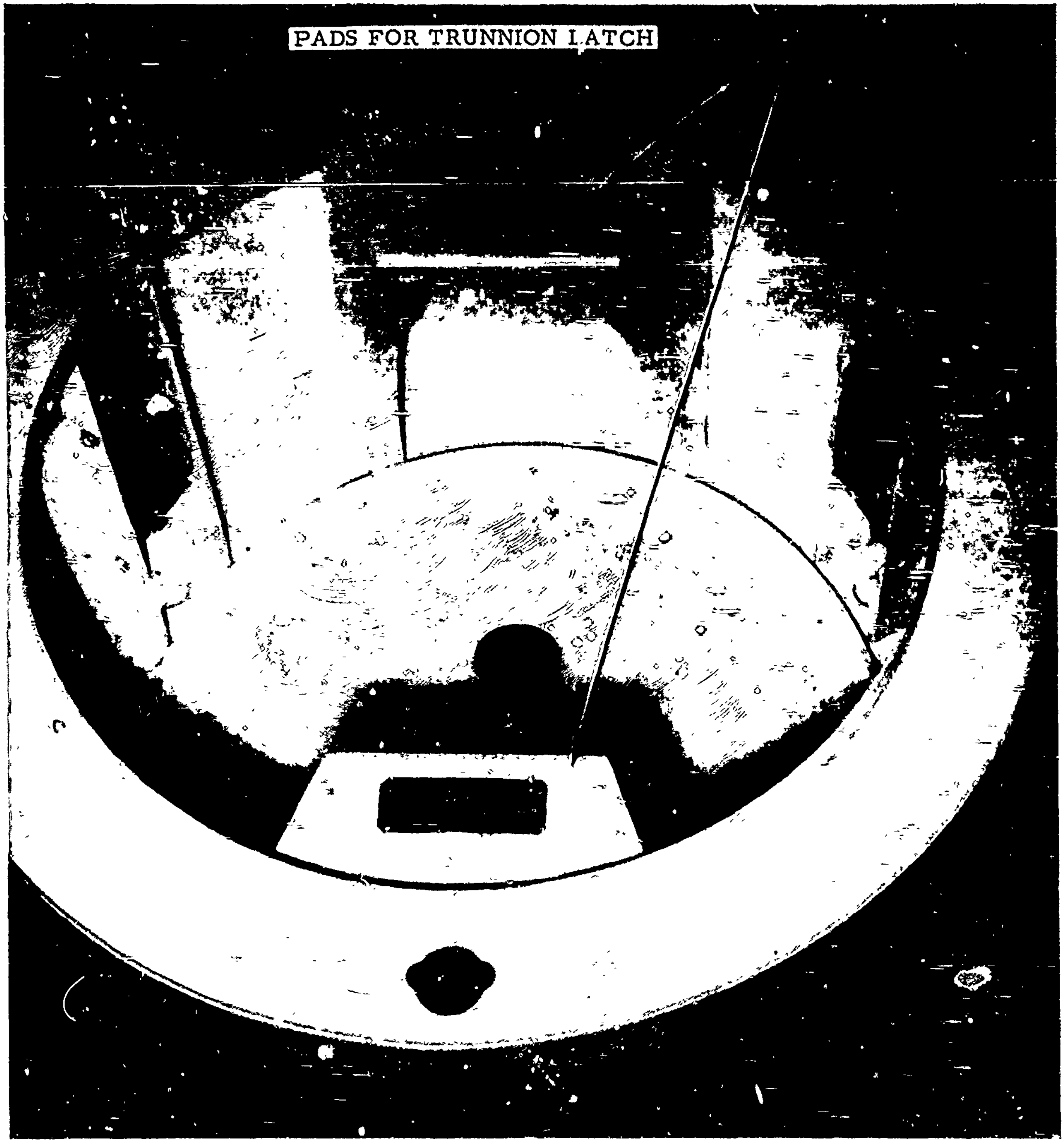


Figure 17. Ruggedized Pad for Trunnion Latch

Figure 18. Cast Blast Suppressor

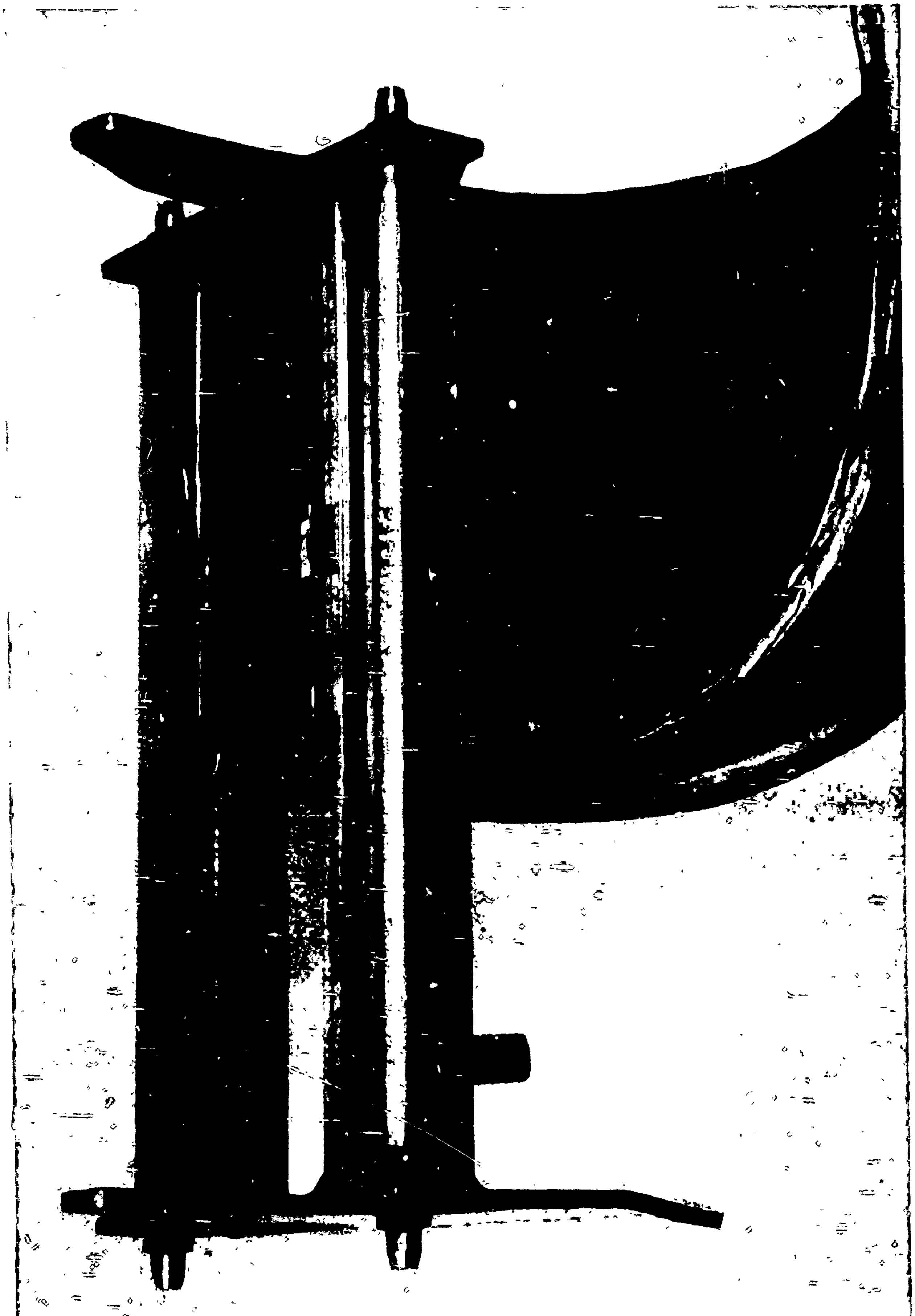


Figure 19. Feed Chute Assembly

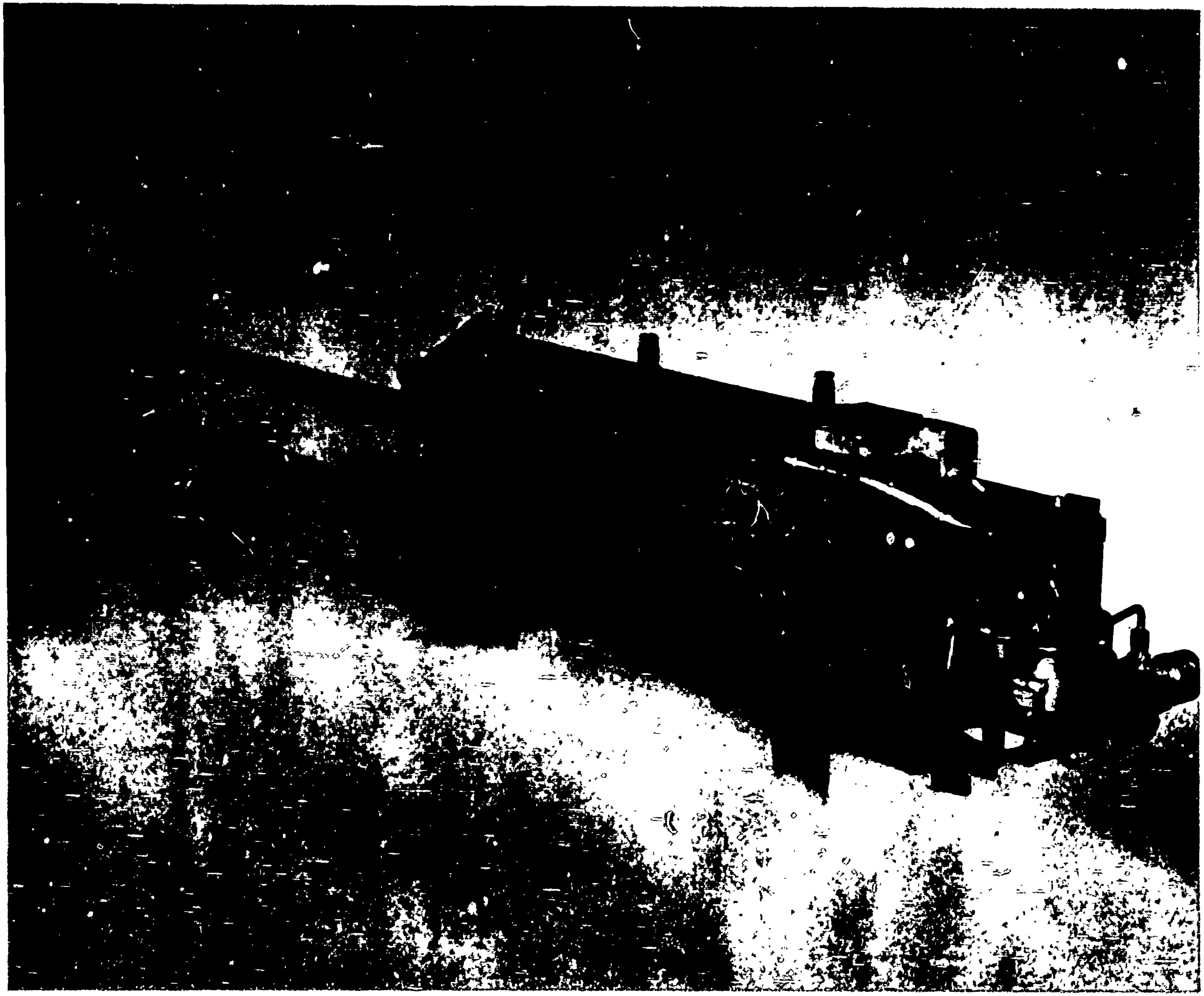


Figure 20. 20mm Mk 11 Mod 5 Gun

Figure 21. Cast Steel Block Booster Housing Assembly

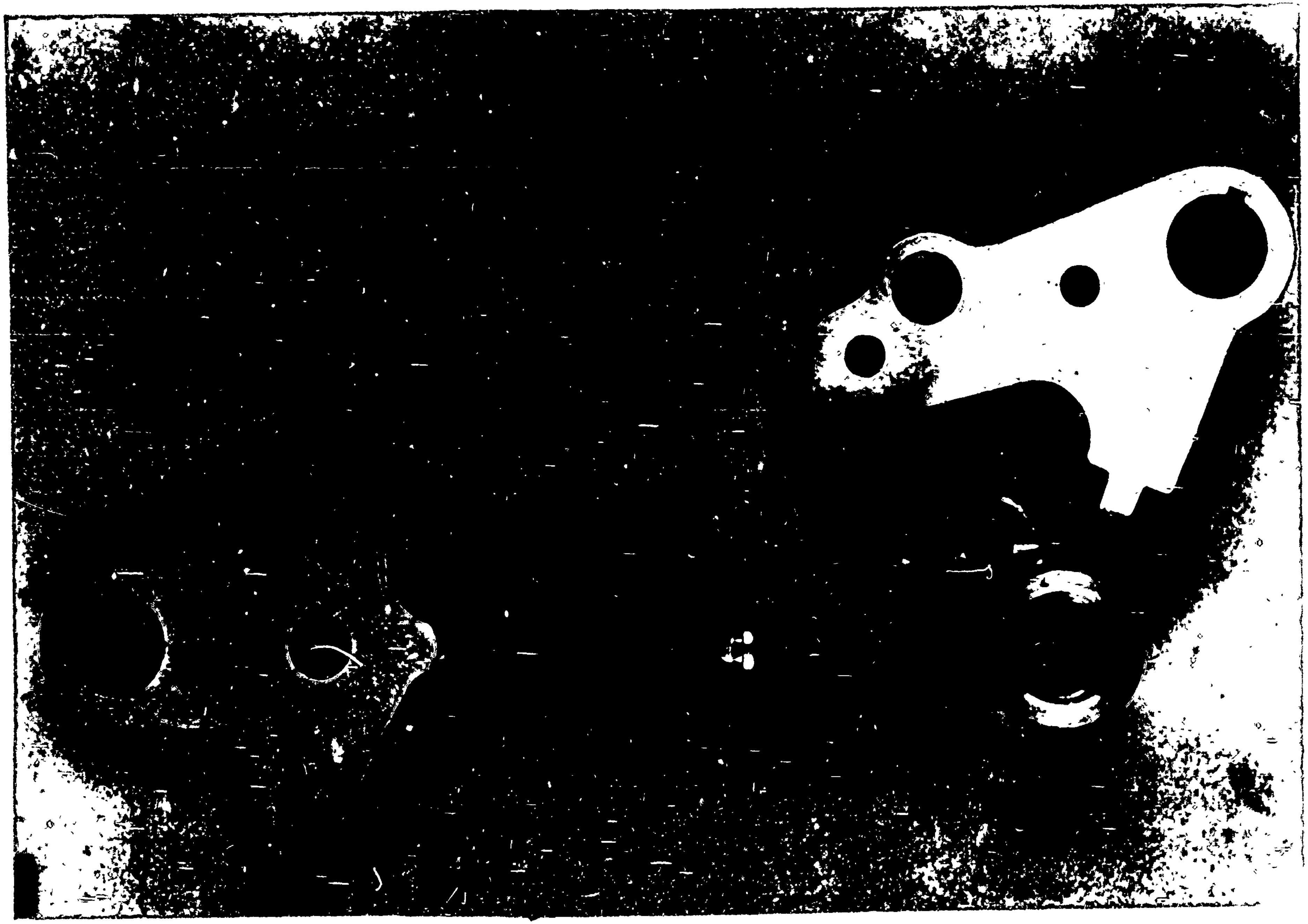


Figure 22. Two-piece Loader Manifold

manifold. This manifold showed no signs of warping or cracking during the entire reliability program, and the slip joint proved to be no problem as far as leakage was concerned.

Figure 23 shows the Mk 2 Mod 1 loader with the new gas manifold and "S" tube. The two rammers were tied to the side of the loader with two bolts in order to decrease the ram housing movement. During the gun checkout for the Eglin field test, it was found that the more rigid loader caused the sprockets to declutch during firing and it was necessary to increase the declutch spring load from 40 lbs. to 88 lbs. Most of the rivets in the side plates of the loader frame were changed to steel. The ammunition nose and heel guides were changed from an angle section to a T section in order to attach the guides more rigidly to the loader frame.

The gun junction box housing was changed from a welded-up structure to an aluminum casting as shown in Figure 24. A stiffer ring spring round positioner was added to the Mk 11 Mod 5 Gun, and this increased the force on the latches and detents to 50 lbs. in order to eliminate pre-ejection. Figure 25 shows the new ring spring round positioner.

<u>Mk 6 Mod 4 Link</u>

The new Mk 6 Mod 4 link with the radhaz protective cap was used for the entire reliability program, with good results. In addition to protecting the round from radhaz, the cap increased the ejection strength of the link by a factor

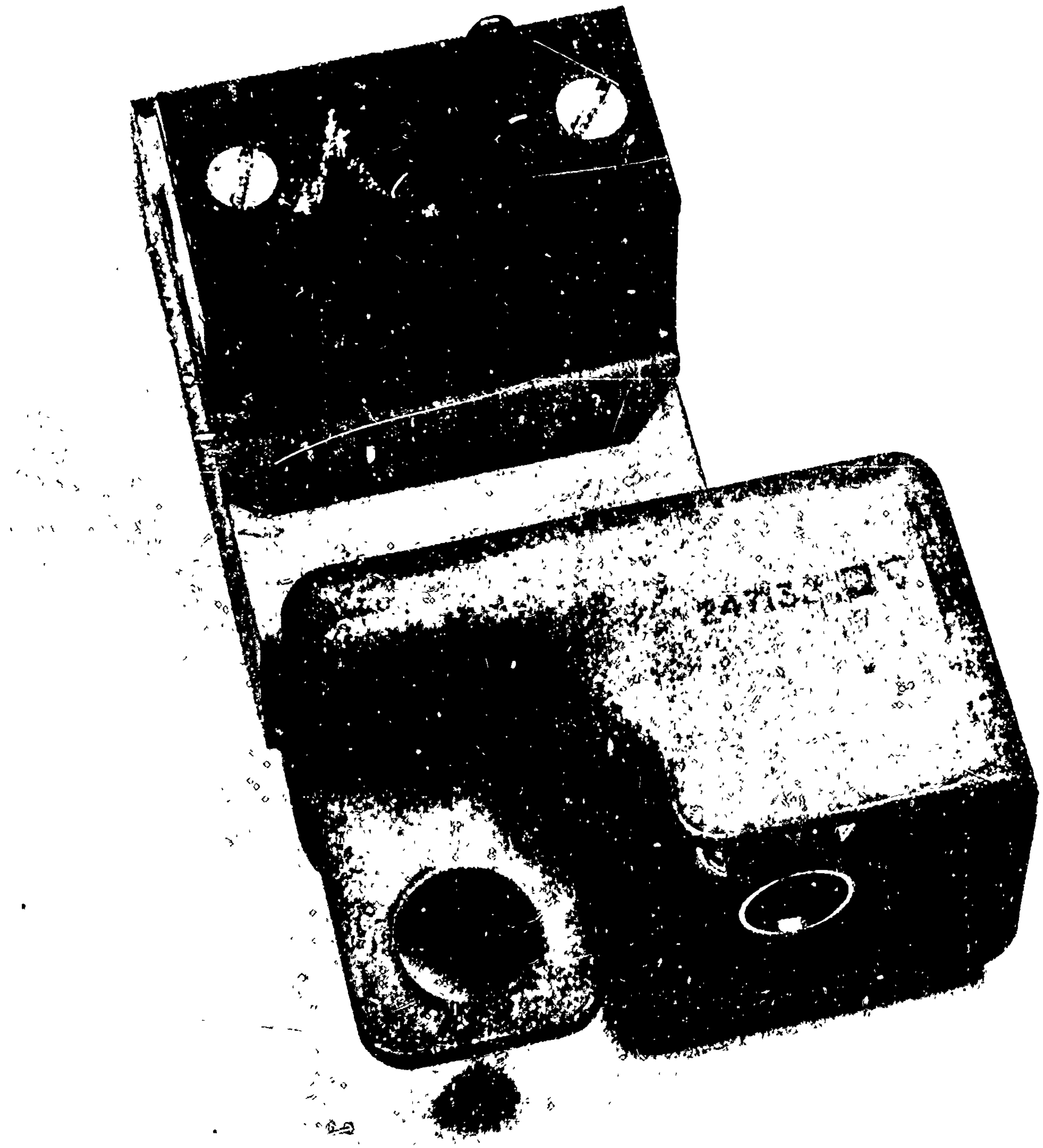


Figure 24. Cast Gun "J" Box

Figure 25. Round Positioner Assembly

of 2, thus making it possible to eject empty cases at higher velocities without passing through the link. Figure 26 shows the new Mk 6 Mod 4 link.

Firing Range

The 127,000 round reliability firing program was conducted in the same two-bay enclosed firing range as the last 300,000 round reliability test. The only change necessary in the two bays was the addition of a nose shroud to handle the gases emitted from the blast suppressor. This shroud worked very well for the entire program, and no trouble was encountered with the gun gases. Figure 27 shows the two-bay enclosed firing range located at the Culver City plant.

The two pods were hung on Douglas Aero 7A bomb racks to simulate firing from an aircraft pylon. The fire control system used for both pods was identical with an aircraft system, and the complete test was conducted as if a pilot were firing the guns. One exception was made in the fire control system in that the automatic charge was disconnected so stoppages could be analysed. If the gun stopped firing, the bay was entered and the gun visually checked. If everything appeared normal, the gun was charged over and firing continued. In case the gun was out of battery, or an obvious stoppage had occurred, the pod was opened and the cause of the stoppage determined.

Figure 26. Radhaz Link

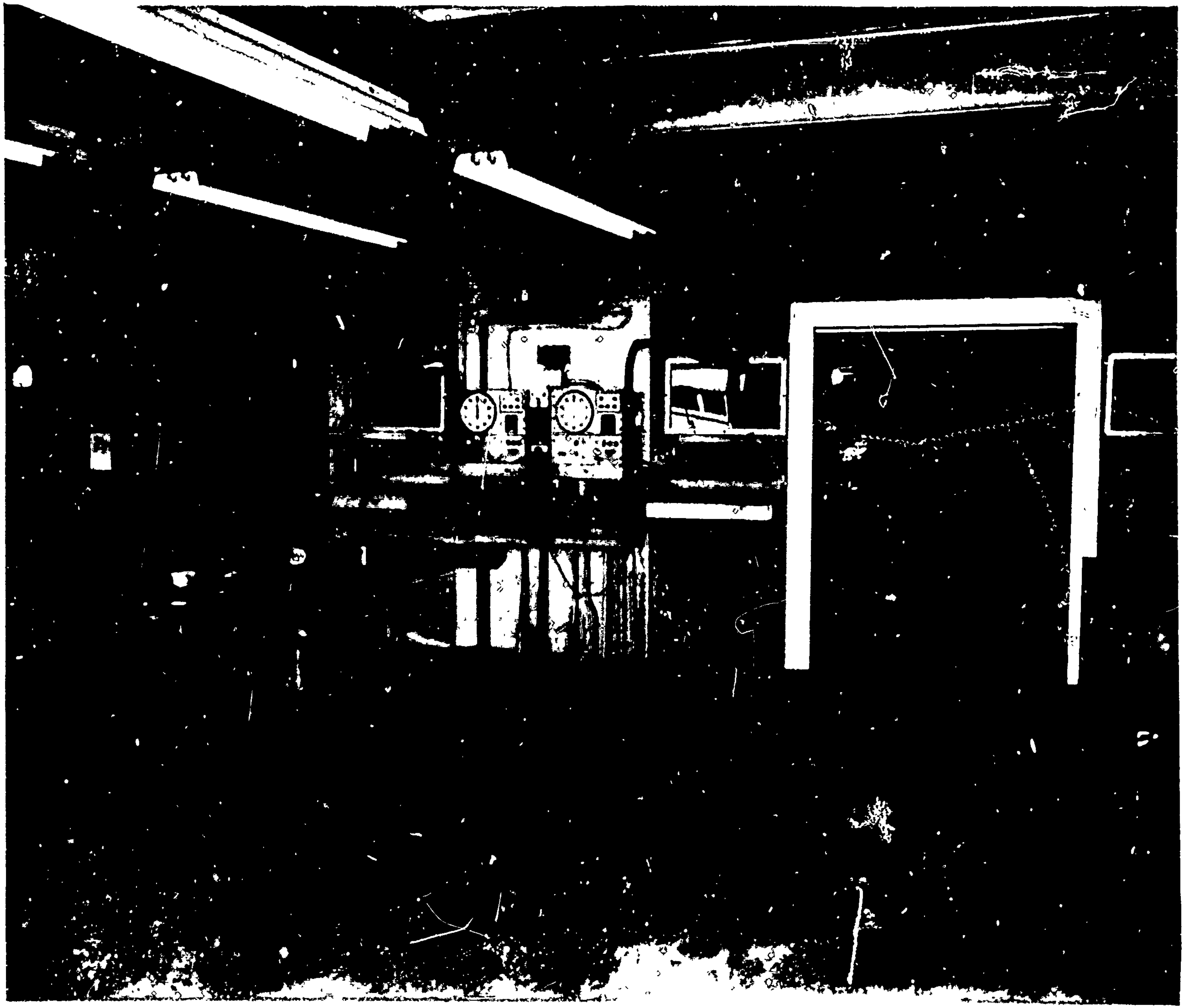


Figure 27. Two-Bay Enclosed Firing Range

The reliability program was carried out with the following firing schedule:

Four 100-round bursts with three minutes cooling between bursts, then 10 minutes cooling at mid-pod, followed by four more bursts with three minutes cooling between bursts to pod fireout. Cooling was accomplished with water spray and air directed on the barrels and cylinder.

Instrumentation

Recordings were made of all the reliability firings on an oscillograph. Traces were made of breech displacement, ram pressure, and firing voltages of the first and last/fire barrels. A typical firing trace is shown in Figure 28.

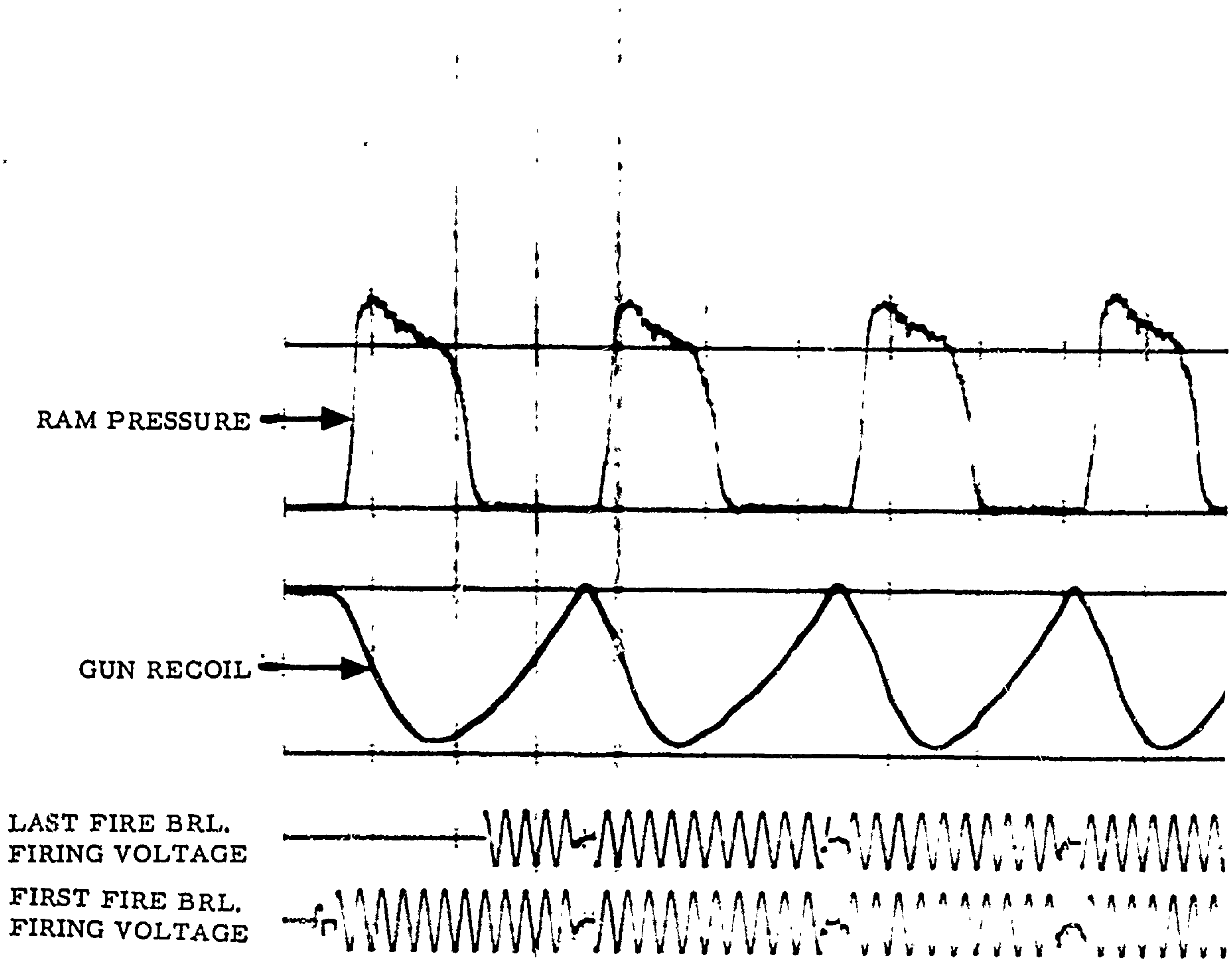


Figure 28. Typical Oscillogram Record of Firing

STOPPAGE ANALYSIS

The stoppages during the 127,000 round reliability program were broken down into eight categories as shown in Table 3. The total rounds fired by pod Serial #10 and #12 and the total stoppages of each pod are shown in Chart 2. The following is a discussion of the various stoppages and the corrective action taken or being taken to solve the problems.

1. Manufacturing Errors - 24.4% of total

All of the manufacturing errors tabulated should be eliminated by proper quality control in production. In the case of the oscillating guide, the print will be clarified so that it will be easier to produce and inspect.

2. Ammunition - 8.5% of total

Several lots of ammunition fired during the past year were restricted to ground firing due to rotating band separation. This did not present a problem since accuracy was not a requirement in the reliability program. Damage did occur to the blast diffuser inserts, however, due to the rotating band separating and this reduced the life of the part from what it would have been. Several lots had an excess of blue glyptol sealant over the primers. This acted as an insulator for the primer, and the firing pins had to be sharp or else it was not possible to scratch through the sealant to make electrical contact. Approximately ten rounds were found with shorted primers; but most of these could be charged out of the gun without causing a stoppage. Three rounds fired had soft cases which caused extraction failures.

TABLE 3

STOPPAGE ANALYSIS FOR 127,000 ROUND RELIABILITY TEST

TYPE OF STOPPAGE	NUMBER OF STOPPAGES	COMMENTS
Manufacturing Errors		
1. Improper huck bolt installed at eject chute attachment	4	To be corrected in production quality control.
2. Mislocated gas port in barrel	2	
3. Oscillating guide not to print	7	
4. Reworked barrel failed at sleeve	2	
5. Welded barrel with improper port	1	
6. Rammer housing out of tolerance	1	
7. Cylinder chamber finish 100 micro-inches should be 16.	3	
Total	20	
Ammunition		
1. Shorted primer	2	
2. Soft case	3	
3. Late fire	2	
Total	7	

TYPE OF STOPPAGE	NUMBER OF STOPPAGES	COMMENTS
Personnel Errors		
1. Misindexed leading link	1	
Total	1	
Loader		
1. Broken ram	6	Material changed.
2. Broken sear link	2	" "
3. Broken sear link pin	1	Correctable by changing parts to schedule.
4. Sear link latch spring jammed	1	Increased clearance.
5. Poppet failed to check	1	Random
6. Poppet nut failed	2	R & D Rex 49 Material
7. Poppet failed	1	" " " "
8. Faulty check valve	1	Correctable by changing parts to schedule.
9. Piston ring failed	1	Redesigned.
10. Fail to ram deep enough	1	
Total	17	

TYPE OF STOPPAGE	NUMBER OF STOPPAGES	COMMENTS
Gun Mechanism		
1. Washed barrel insert	12	Corrected with ring seal cylinder.
2. Cracked barrel insert	1	Changed material to 18% nickel steel.
3. Insufficient clearance at breech	4	Provided clearance.
4. Washed barrels (solid type)	2	Corrected with ring seal cylinder.
5. Galled cylinder shaft	2	Corrected with ring seal cylinder.
6. Washed booster housing	1	Correctable by changing barrels to schedule.
7. Leaks around obturating sleeve R & D part	2	Corrected with ring seal cylinder.
8. Case retainer failed	2	Part hardened.
9. Gas transport tube failed	1	Correctable by changing parts to schedule.
10. Damper rod failed	1	To be changed.
11. Yoke failed	1	To be changed.
12. Firing pin jam	1	Random.
13. Broken pin in round positioner	1	Part redesigned.
14. Open circuit in firing pin holder	1	Part redesigned.
15. Shorted firing pin holder	1	Random.
16. Dull firing pin	1	Corrected by changing parts to schedule.
Total	34	

TYPE OF STOPPAGE	NUMBER OF STOPPAGES	COMMENTS
Links		
1. Lug to carrier failure	2	
2. Bad spotweld in radhaz cap	1	
Total	3	
Pod	0	
R & D		
1. Rex 49 barrel insert cracked	1	
2. Plug in barrel eroded out	1	
Total	2 *	
TOTAL, ALL CATERGORIES	82	

(*Not included in total stoppages)

During the R & D tests following the reliability program, one lot of ammunition (ZS-3-62) was evidently poorly staked. A large percentage of the primer cups were blown out of the fired cases in ejection. No stoppages were encountered as a result of the blown primers, however, three hang fires occurred in 6,000 rounds of firing with this particular lot of ammunition. No definite conclusion was reached as to the cause of the hang fires.

3. Personnel Errors - 1.2% of total

The fact that only one stoppage occurred in 127,000 rounds of firing due to personnel error is proof of the simplicity of the system. Effort continues, however, to simplify the system even more and make it as fool proof as possible.

4. Loader - 20.8% of total

The stoppages caused by the loader were due either to the rammer or the check valve. Over one half of the stoppages were due to broken ram assemblies. One of the most significant improvements in the loader was to change the material of the ram and sear link to 18% nickel maraging steel. Prior to this change the rams were being replaced every 6,000 rounds and some failures occurred even with this replacement schedule. After changing the material in the ram and decreasing the gap between the base of the round and the ram finger, no stoppages were encountered.

One set of rams was fired over 30,000 rounds before being replaced. At that time no failure had occurred in the ram. A three second burst causes the ram pressures to increase by a factor of 1-1/2 over a one second burst. This aggravates the ram breakage problem since the resear load on the ram increases proportionally and the yield strength of the material decreases due to the higher temperaturrs involved. Tests are now being conducted to determine the life of the new rams with long burst firing. The results are very satisfactory; one set of the rams has been fired for over 14,000 rounds with 2-3/4 seconds burst firing without any failures.

The piston rings did not prove satisfactory during the program due to the ends breaking off. Although only one stoppage was attributed to the rings, the possibility of stoppages was ever present. In 2-3/4 second burst firing, the piston rings collapsed in two bursts and it was difficult to start the third burst due to loss of ram pressure. A concentrated effort is being made to improve the piston rings. A new design of two outer rings and one inner ring is now being tested in the R & D program.

Most of the check valve failures were due to using an untested material for the check valve nut and poppet. The material tested was Rex 49 High Speed Steel, produced by Crucible Steel Company of America. The failure of this material was due to improper heat treat. Subsequent firing of this material with the proper heat treat was exceptionally good. The average life of the check valve in the previous 300,000 round program was 4,000 rounds. One assembly of Rex 49 material was fired 20,551 rounds without failure. This check valve is shown in Figure 29. The "red hardness" of this material is approximately

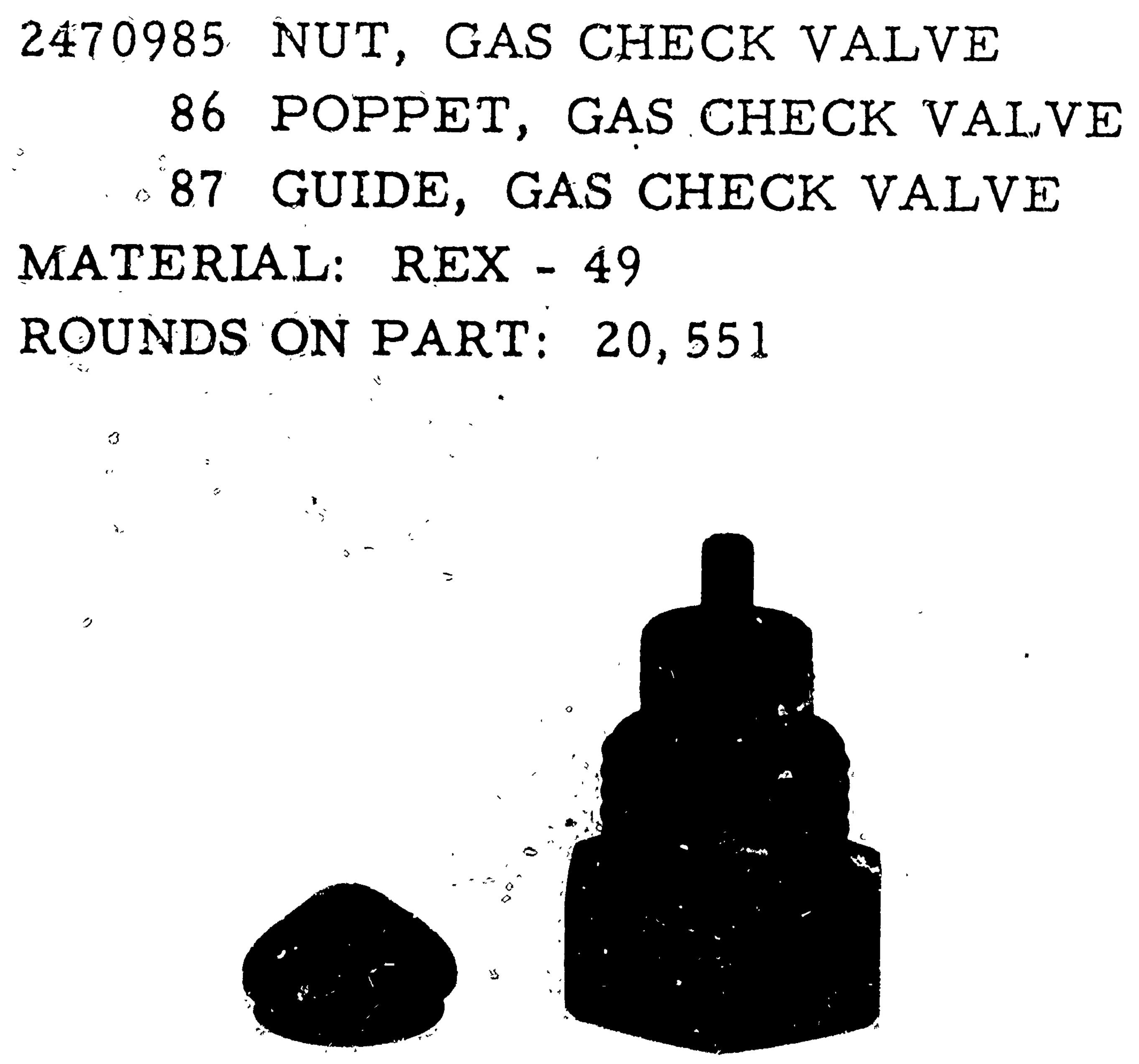


Figure 29. Check Valve Assembly

double that of the previous tool steel used in these parts. The expected life of this part should now be 18,000 rounds with 100 round burst firing.

5. Gun Mechanism - 41.5% of total

Over one half of the stoppages in the gun mechanism were caused by improper sealing of the obturating sleeve with the end of the barrel. Some firing had been done with a ring seal type cylinder in the previous R & D program with successful results. Only one ring seal type cylinder was available for the reliability program. As soon as this ring seal cylinder was installed the eroding of the barrel ends was eliminated completely an no problems remained even with the long burst firing. At the present time, all the firing guns have the ring seal type cylinder, and 2-3/4 second bursts are being fired without sealing problems.

Early in the reliability program some trouble was experienced in ramming the rounds due to interference with the side of the breech. In order to provide adequate clearance for the round to chamber in the cylinder, the breech was machined at both ram stations. A similar machine cut was also made at the eject stations since the tolerances of the breech forging were not adequate to control the clearances.

The average firing rate of the guns during the reliability program was approximately 4,100 rounds per minute, and at times the rate was as high as 4,400. This rate was higher than the previous reliability programs due to the new booster block configuration, and the increase in the efficiency of the gun. The main reason for the increase in the gun efficiency was the harder cylinders which reduced cam distortion appreciably.

The higher cyclic rate produced higher recoil loads. A damper rod and yoke failed on gun serial #10 after firing 50,000 rounds, indicating a marginal fatigue life. An effort is being made to improve the life of these parts.

One stoppage occurred as a result of a broken contact in the firing pin holder. Several times the contact broke on the last fire barrel and firing continued with only one barrel. The contacts receive high loads from the firing pins, and this causes the epoxy potting compound to fail. The contact loosens and either the electrical wire leading to the contact breaks or the small end of the contact breaks. A change was made in the epoxy compound and the life of the part was improved but not considered satisfactory. Two new designs are now being tested to improve the firing pin holder. One design used the improved epoxy and contacts with increased bearing area to eliminate the loosening of the contact. In the other design the contact is embedded in phenolic material.

The other gun mechanism stoppages were minor and have been solved by design changes or by replacing parts to a predetermined schedule.

6. <u>Links - 3.5% of total</u>

Only three stoppages occurred with the Mark 6 Mod 4 links. The radhaz caps have allowed the case ejection velocities to be increased, and as a result of this no ejection stoppages were caused by slow ejection in the complete reliability program. Improvements in manufacturing technique and quality control made by this company will further increase the reliability of the links.

7. Pod - 0% of total

No stoppages were caused by the gun pod for the entire reliability program, and maintenance was negligible. Improvements were made during the program which could increase the life of the pod structure to 130,000 rounds without maintenance. Pod serial #10 and #12 were both checked at approximately 60,000 rounds of firing, and all rivets were replaced that appeared to be loose. Rivets around the main access doors and strongback appeared to loosen within the first 10,000 rounds of firing, but did not progress further during the next 50,000 rounds. It is quite possible that these rivets would last 130,000 rounds without causing any trouble.

The new blast suppressor created loads in the nose that caused the rivets to loosen around the latches, and along the intercostals in the pod body that carry the latch loads. These areas were strengthened by increasing the number of rivets. Since these areas have been reworked there has been no apparent loosening of the rivets.

Some cracks started in the pneumatic valve tray, and the material was changed from aluminum to steel. Since the steel trays have been installed, no further cracks have been noticed.

The inboard side of the throats also cracked through on the supporting flange. The complete side has been changed from stainless steel to heat treated 4130 and the sheet thickness increased. The throats also appear to be satisfactory since this change has been made.

Improvements have been made in loading the magazine by moving the loading tool support from the outer adapter to the inner adapter. This holds the loading tools in a rigid position. Before this change was made the loading tools could move with the loading trays, tending to change the index position of the magazine. The older loading tools were made of 1020 steel and tended to bend. These have been changed to 4130 heat treated steel, and the weak sections deepened where possible in order to carry higher bending loads. Once the magazine is indexed for loading the belted rounds, the rounds can be cranked into the tray with very little effort with the new design.

Prototype inner adapters with the new loading tool mount are now in service along with the new loading tools. Both parts are working very well. The production inner and outer adapters will be made from a stainless steel casting.

8. R & D

Two stoppages were not counted in the total stoppages because the parts that failed were not proven and were of an experimental type. Actually, five other stoppages could have been prevented if new barrels would have been available. It was necessary early in the program to use old style barrels because of an inadequate supply of new barrels.

PARTS LIFE

The complete Reliability Program was fired with two pods, two guns, and three loaders. Pod Serial #10 used gun Serial #916 and loaders Serial #13 and #15. Pod Serial #12 used gun Serial #917 and loader Serial #12.

Subsequent to the reliability firing program, a considerable amount of R & D test firing was accomplished with bursts of 2-3/4 second duration. The purpose of this firing was to solve the problems involved in the longer burst firing, and as a result make the gun even more reliable for bursts of 1-1/2 second duration. Gun Serial #924 and loader Serial #21 were added to pod Serial #12 after the reliability program was completed.

The following tabulation gives the rounds fired on the green and red pod, including both reliability and R & D firing:

Pod Ser. No. 10 (Red)

Total reliability rounds:	70,412
Total R & D rounds:	30,172
Grand total:	100,584

Gun Ser. No. 916

Total reliability rounds:	70,412
Total R & D rounds:	30,172
Grand total:	100,584

Loader Ser. No. 13

Total reliability rounds:	32,264
Total R & D rounds:	12,004
Grand total:	44,268

Loader Ser. No. 15

Total reliability rounds fired:		37,400
Total R & D rounds:		15,303
	Grand total:	52,703

Pod Ser. No. 12 (Green)

Total reliability rounds:		56,318
Total R & D rounds:		17,674
	Grand total:	73,992

Gun Ser. No. 917

Total reliability rounds:		56,318
Total R & D rounds:		5,969
	Grand total:	62,287

Loader Ser. No. 12

Total reliability rounds:		56,318
Total R & D rounds:		16,146
	Grand total:	72,464

Gun Ser. No. 924

Total R & D rounds fired:	11,705

Loader Ser. No. 21

Total R & D rounds fired:	1,216

Every 3000 rounds fired, the guns were disassembled, cleaned, and inspected for wear. Worn parts were replaced as needed, and the gun was greased and reassembled for firing. The gun pod was also inspected at this time and any maintenance required was performed. Complete records were kept of the maintenance required and of the parts replaced, including the number of rounds fired with these parts. Table 4 shows the life of the parts

TABLE 4

ANALYSIS OF THE REPLACED PARTS FOR THE 127,000 ROUND RELIABILITY TESTS

GUN MECHANISM

PART NUMBER	PART NAME	NO. IN GUN	PARTS REPLACED NO.	GUN ROUNDS MIN.	GUN ROUNDS MAX.	GUN ROUNDS AVG.	COMMENTS	EST. LIFE-ROUNDS
2471305	Tube, Ejection Gas	2	16	5,311	38,870	14,719	Obsolete	
1633926	Spring, Hold-Forward, Inner	1	6	8,818	43,856	24,857	To be shot peened	50,000
1700603	Retainer, Hold Fwd., Spring	1	2	27,564	94,573	61,068		
1700608	Cap, Hold Fwd., Assembly	1	2	34,357	63,756	49,056		
1700486	Rod, Hold Fwd.	1	2	22,646	51,030	36,838		
2470944	Latch, Round Positioner	2	9	2,170	38,945	13,076		
2470945	Spring, Round Positioner	1	7	7,218	20,211	14,151		
2470943	Retainer, Round Positioner	2	13	7,218	25,548	12,021	Changed to maraging steel	27,000
2471156	Extractor, Round Positioner	2	4	6,744	27,639	17,538		
2471382	Positioner, Round Machining	1	5	7,380	27,639	16,419		
2310596	Nut, Sealing	1	1	--	--	34,368		
2470844	Elbow, Gas	1	4	25,914	34,368	28,731		
2470843	Collar, Gas Seal	1	4	25,914	34,368	28,731		
2471306	Valve, Pneumatic, Solenoid-Operated, Two Way	1	2	6,715	36,313	21,514		
2470834	Shaft	2	1	--	--	70,136		
1700628	Pin, Firing	2	16	3,768	13,234	8,666		
1633918	Anvil	2	5	20,244	36,841	26,732		
1700632	Spring, Firing Pin	2	1	--	--	101,322		
2470823	Nut, Anvil	2	2	25,548	71,465	48,506		
2470836	Pin	1	1	--	--	48,995		
2470833	Sleeve Assembly	2	8	1,653	28,578	15,831		
2310647	Holder, Firing Pin Assembly	1	13	2,705	18,253	8,314	Strengthened by redesign	25,000
2310585	Switch, Sequencing - Assembly	1	4	7,899	29,170	20,613		
1735772	Body, Switch - Assembly	1	1	--	--	13,707		
	Misc. & Connecting Parts							
1633915	Link, Slider Connecting	1	1	--	--	51,031		
1633916	Yoke	2	1	--	--	51,031		
1633917	Slider	1	5	16,686	43,338	31,570	Strengthened by redesign	50,000
1633919	Retainer, Obturating Sleeve	1	12	428	50,330	12,001		
1633925	Sleeve, Obturating, Aft	8	10	999	48,779	10,489	Obsolete	
1700620	Key, Cam Follower Lock	1	5	16,686	57,955	29,822		
1700624	Link, Breech Connecting	4	4	--	--	102,814		
1700625	Follower, Cam	2	12	2,694	19,458	13,076	Hardness to be increased	
1700627	Shaft, Breech Connecting Link	1	2	23,187	68,765	45,976		
1700638	Support, Ejection Gas Tube	2	5	2,170	52,993	32,134	Obsolete	
1700649	Sleeve, Obturating, Forward	8	20	409	29,536	4,645	Obsolete	
2470948	Tube, Gas Transport	1	3	25,914	73,378	52,472		
2051054	Extractor, Case, Outer	2	1	--	--	79,290		
2051065	Rod, Damper	1	1	--	--	48,995	Obsolete	
2094312	Shaft, Cylinder	1	2	61,874	82,919	72,406		
LOADER								
1700666	Washer, Tab	2	1	--	--	20,244		
1633939	Piston, Rammer	2	5	5,683	34,073	25,682	Strengthened by redesign	27,000
1633940	Ram	2	32	2,233	10,607	5,673	Changed to maraging steel	27,000
1700619	Washer, Stop, Buffer	2	10	5,939	16,313	11,700		
2248413	Spring, Sear Link	2	3	26,993	35,317	31,301		
1700660	Ring, Piston Rammer	4	60	1,814	6,758	2,309		
2051056	Retainer, Damper Spring	2	2	25,758	35,967	30,862		
2310603	Link, Sear	2	6	2,245	35,317	14,569	Changed to maraging steel	27,000
2094311	Check Valve, Buffer - Assy.	2	1	--	--	55,114		
2051058	Check, Buffer Check Valve	2	1	--	--	32,905		

Table 4 (Loader cont'd)

PART NUMBER	PART NAME	NO. IN GUN	PARTS REPLACED NO.	GUN ROUNDS MIN.	GUN ROUNDS MAX.	GUN ROUNDS AVG.	COMMENTS	EST. LIFE-ROUNDS
2471388	Housing, Rammer-Weldment	2	3	29,943	61,148	41,693	To be cast	
2310597	Cap, Rammer Housing	2	1	--	--	11,319		
2310598	Cap, Rammer Housing	2	1	--	--	11,319		
2470846	Spring, Rammer Housing	2	30	240	18,961	5,659		
2470847	Spring, Rammer Housing	2	30	240	18,961	5,659		
1633958	Guide, Ejection, Aft	2	2	31,158	39,236	35,197		
1700674	Pin, Oscillating Guide	2	3	33,317	44,848	40,753		
2470976	Guide, Ammo Forward	2	2	37,395	43,704	40,549		
2470977	Guide, Ammo, Aft	2	2	37,395	43,704	40,549		
2094328	Plate	1	1	--	--	39,236	Damaged by malfunction	
2094330	Deflector, Case-Machining	2	2	1,953	34,073	18,003	" " "	Life of Ldr.
2094331	Guide, Oscillating-Machining	2	5	17,720	35,594	33,374	Strengthened by redesign	
2471160	Valve Body, Manifold-Machining	1	1	--	--	63,579		Life of Ldr.
2471161	Terminal, Manifold	1	1	--	--	63,579		
2470913	Check Valve, Heat Barrier - Assembly	1	1	--	--	68,453		Life of Ldr.
2471114	Tube, Rammer Valve - Assy.	1	2	19,811	25,970	22,890		
1633964	Tube, Declutch, Cylinder - Assembly	1	1	--	--	25,758		
2471113	Tube, Buffer, Common - Assy.	1	4	18,511	32,905	25,280		
2094325	Tube Buffer - Assembly	1	2	32,905	53,798	43,351		
2094326	Tube Buffer - Assembly	1	3	25,758	27,718	27,000		
	Misc. & Connecting Parts							
2471345 -1	Coupling Half	1	2	27,718	42,015	34,866		
2470915	Gasket, Rammer Valve	1	2	1,147	19,811	10,479		
1700655	Washer, Manifold Seal	2	3	10,209	35,214	27,002		
2470849	Retainer, Manifold Seal	2	3	20,244	45,423	32,071		
1633951	Roller, Sear	2	1	--	--	41,802		
1700668	Pin, Sear Roller	2	1	--	--	11,939		
<u>POD</u>								
1633985	Shield	1	2	25,758	43,781	39,769	Damage by malfunction No further barrel wash	Life of pod
2094283	Ejection Tube, Upper	1	1	--	--	70,585		
2208848	Control Box	1	1	--	--	82,465		
2310624	Conduit, Flexible	1	2	52,323	73,266	62,795		
2471315	Tray, Valve Mounting	1	3	24,979	82,275	48,107	Changed to steel	Life of pod
2470856	Pin, Dowel	1	1	--	--	85,878		
2470864	Orifice, Blast Suppressor	2	4	21,603	35,784	28,693		18,000

replaced in the 127, 000 round reliability program. Also included is the estimated life of the parts under service conditions.

Gun Mechanism

Under normal firing conditions of 1-1/2 sec. bursts, a life of 130, 000 rounds of firing seems assured with four of the major gun components, namely, the breech, receiver, damper assembly, and the booster housing. The life of the booster housing can be affected by long burst firing due to the erosion from the gas ports in the barrel. Ways of prolonging the life of the booster housing to 130, 000 rounds under all conditions of firing are now being investigated.

Gun Ser. No. 916 now has over 110, 000 rounds of firing, and the breech, receiver, and damper assembly are in excellent condition. The booster housing was replaced at 80, 973 rounds to try a booster housing with the interior chrome plated. Figure 30 shows the booster housing that was replaced, and the amount of erosion at that time.

Cylinder

The cylinder life has been improved with the harder cylinder, but some distortion of the cams still exists. The present cylinder life is 65, 000 rounds. It is possible to fire the cylinder longer as far as the cycle efficiency is concerned, because the elliptical cam shape remains essentially the same. The side of the cam does not remain perpendicular, however, and this causes a force on the cam follower that tends to push it out of the cam. Very high bearing loads are applied to the cam follower and keys as a result of this force,

2471308
BOOSTER HOUSING
80,973 ROUNDS

Figure 30.

and their expected life decreases. Some of the cam distortion is a result of cam follower distortion, and therefore the hardness of the cam followers has been increased in an effort to improve both cam and cam follower distortion. This increased hardness has improved both parts, but more firing will have to be accomplished to determine a new life for the cylinder. It is possible that an 18% nickel maraging steel cylinder would allow the cylinder to be fired the life of the gun or 130, 000 rounds, since the hardness would be increased from Rockwell Rc 42 to Rc 52. This material also lends itself to be cast with only a 10% loss in yield strength. A feasibility study is being made of the possible use of this material.

Ring Seal

The life expectancy of the ring seal is dependent upon burst length. One set of seals was fired over 37, 000 rounds with 1-3/4 second bursts. When the burst length is increased to 2-3/4 sec. in length, the same erosion is reached in about 10, 000 rounds of firing. Under normal service conditions the ring seal should be good for 27, 000 rounds of firing.

Obturating Sleeve Retainer

Failure of this part was due to barrel erosion. It is possible for this part to reach a life of 130, 000 rounds.

Hold Forward Spring Assembly

The life of this assembly is approximately 27, 000 rounds. Improvements are being made on the components and it is probable that the life can be doubled. Springs are being shot peened to increase fatigue life, and stress concentrations are being removed from the other parts.

Cam Followers

The life of the cam follower is dependent upon the condition of the cylinder. Cam followers in a new cylinder have been used for 25, 000 rounds; however, the average life during this program was 13, 076 rounds. The more the cylinder cams distort the more frequently the cam followers have to be replaced. The probability of increasing the life of this part is good by increasing the hardness of the follower and cylinder.

Firing Pins

Improvements have been made in the firing pins by flash chrome plating the parts. The plating wears through in approximately 6000 rounds, so a heavier chrome plate of probably . 003 thick will be tried. If the excess glyptol on the base of the rounds were removed, the firing pins would not have to be changed as often. In order to fire the rounds with the heavy glyptol coating it is necessary to keep sharp firing pins installed.

Firing Pin Holder Assembly

The firing pin holder average life was 8314 gun rounds. This low life was due to the firing pin contacts loosening in the epoxy, and causing a broken electrical connection. Improvements are now being made to this part, and a life of at least 25, 000 rounds is expected.

Barrels

Barrel life is dependent on burst length. The barrels and barrel inserts were replaced every four pods or 3000 rounds of firing during the reliability program. Attempts to improve the barrel life by use of Methyl Centralite coated IMR powder and a different barrel design are now being made.

Loader

A loader life of 65,000 rounds is a realistic one. Loader serial No. 12 was fired 72,464 rounds before being retired.

Loader Frame

The loader frame has been strengthened by replacing the aluminum rivets in the side plates with monel rivets, and increasing the size of the rivets in the case deflector. Very little maintenance was required on the loader frame and the life is 65,000 rounds.

Rammer Assembly

The rammer assembly is made up of the ram, piston, rammer housing, damper spring, and buffer assembly. Expected replacement life for this assembly is 27,000 rounds.

1. Ram - The average life of the 4130 steel rams was 5,673 rounds. Eleven percent of the total stoppages were caused by broken ram assemblies. As soon as the 2-3/4 second bursts were fired the life of these rams decreased even further due to the increase in ram

pressure and resear loads on the rams. The material has been changed to 18% nickel maraging steel and rams and sear links have exceeded 30,000 rounds with this material.

2. Piston - The average life of the ram piston was 25,682 rounds. As soon as the 2-3/4 second bursts were fired the ends of the piston deformed and broke due to the excess heat. The piston has now been redesigned and made of 18% nickel maraging steel to accommodate long burst firing.

3. Rammer Housing - Average life was 41,693 rounds. The sear link anti-bounce springs were replaced frequently at the start of the program due to damage and lack of clearance. After the clearance was increased and the rams were replaced to stop damage, these springs lasted about 12,000 rounds.

4. Damper Spring - The damper spring will easily last the life of the rammer assembly.

5. Buffer Assembly - Only one buffer assembly was replaced in the program at 55,114 rounds. All other assemblies are still in service or were retired with the complete loader.

6. Rammer Piston Ring - The average life on the two-ring type piston ring was 2,309 rounds. This part is now obsolete and the new design of two outer rings and one inner ring of higher temperature material has improved the life of the rings and the reliability of the gun. More firing will be necessary to obtain a life with the new type piston rings.

Rammer Check Valve

The check valve nut, poppet, and guide are not shown on the table since experimental parts were being tested a large part of the time. The Halcomb 218 tool steel used in the last program was replaced every 3,000 rounds during the program. An improved steel of Rex 49 material was incorporated in the latter part of the program, and these parts exceeded 20,000 rounds of firing with 1-1/2 second bursts. With a 2-3/4 second burst the parts life decreases to approximately 2,000 rounds. More research is being done to further improve these parts.

Manifold

The two piece manifold of 17-4PH stainless steel has worked very well for both long and short bursts without deformation or leaking. The manifold from loader No. 12 was removed for test purposes at 63,579 rounds, and it was still in good condition. The life of the manifold should equal the life of the loader.

Miscellaneous Parts

Other parts in the loader such as the sprockets, clear mechanism, ram and clear valves will normally last the life of the loader. It is necessary to replace the air tube assemblies at 18,000 rounds to insure reliability.

Pod

A life of 130,000 rounds is assured with the pod. Very little maintenance is required, and the parts replacement will be negligible. Pod serial

Nos. 10 and 12 were both checked at approximately 65,000 rounds of firing with the following results:

Pod Structure - All rivets that appeared to be loose were replaced. These rivets had not changed in appearance for the last 50,000 rounds, and it is quite possible that they would last 130,000 rounds without any trouble. All of the 10,000 pound latches in the nose were satisfactory. It was necessary to increase the number of rivets around the latches in the nose and also the pod body due to the high loads from the blast suppressor. Since the additional rivets have been installed there has not been any loosening or failure of the rivets in this area.

Pneumatic Tray - Cracks developed in the corners of the aluminum pneumatic tray and this part was changed to steel. Since the part was changed, no further problems exist. The new part should last 130,000 rounds.

Throats - Cracks developed in the inboard side of the throats in both pods, and the throats were repaired by changing the side from stainless steel to heat treated 4130 steel and also increasing the thickness of the material. This correction appears satisfactory and the part life should be increased to 130,000 rounds.

Pneumatic System - The pneumatic system required very little maintenance. At the 65,000 round check the air motor was disassembled and all parts were in excellent condition. Every four pods the motor is lubricated with gun oil and this is satisfactory to give the motor a life of 130, 000 rounds. The pneumatic dump valve did require replacement of "O" ring seals on the 3, 000 psi side of the valve two times on each pod. A solution to this seal problem is being investigated in an effort to increase the life of the valve to 130, 000 rounds.

Drive System - No problems were encountered with the drive system, and the parts showed no noticeable wear at the 65, 000 round inspection. The life expectancy on this system is 130, 000 rounds.

Electrical System - All of the cable assemblies should last the life of the pod with the exception of the electrical connections. The three connectors to the ram valve, clear valve, and charge valve should be replaced every 27, 000 rounds due to wire fatigue. All other electrical connectors should be replaced every 65, 000 rounds. The control box has a reliable life of 65, 000 rounds, and this possibly can be increased to 130, 000 rounds with minor design changes.

Ejection Tubes and Feed Chutes - These parts have been adequately strengthened to have a reliable life of 65, 000 rounds.

SECTION V

R & D TEST PROGRAM

A total of 75,310 rounds were fired in the R & D test program during the past year. Of this total, approximately 45,000 rounds were fired in bursts of 2-3/4 seconds duration or longer in order to improve the reliability of the gun and increase the life of the parts. Heat from the longer bursts presents problems that are not noticeable with the shorter 100 round burst length.

The following problems have been solved or are now being solved as a result of the long burst firing:

1. Eroded sealing face on barrel or barrel insert
2. Cracked barrel inserts
3. Cracked ring seals
4. Ram piston failure
5. Collapsed piston rings

Ring Seal Cylinder

Attempts to fire long bursts have been plagued in the past due to the eroding (washing) of the sealing end of the barrel.

The ring seal cylinder, as shown in Figure 31, has solved this problem. The ring seal is shorter and lighter than the 1700649 obturating sleeve used in the past, and it is able to align and seal against the barrel end without difficulty. A cylinder with these seals was fired over 37,000 rounds with 1-3/4 second bursts

Figure 31. Cylinder with Ring Seals

without changing ring seals. Although the ring seals stopped the eroding of the barrel face, it was found that the seals themselves would crack within a fe , thousand rounds with the 2-3/4 second burst firing. Figure 32 shows a cracked ring seal due to the long burst firing. The material in the ring seal was changed from S. A. E. H-13 tool steel to a maraging 18 percent nickel steel. The maraging steel is not sensitive to thermal cycling and shock. Ring seals manufactured of maraging steel have been fired over 9,000 rounds with 2-3/4 second burst firing without any cracking or detrimental effects.

The barrel inserts of Halcomb 218 tool steel also started to crack with the longer burst firing due to thermal shock. The tool steel barrel inserts have been removed from testing as a result of this problem, and barrel inserts of maraging steel are now being used. No further problems of barrel erosion, cracked ring seals, or cracked barrel inserts are expected as a result of these improvements. Tests will also be made to determine if the ring seal cylinder will solve the cookoff problem experienced during the Eglin Air Force tests.

The increased heat in long burst firing caused the end of the ram piston to fail in both bearing and shear due to the low yield strength of the material at elevated temperatures. The end of the piston went out of round, and the piston ring groove was narrowed by bearing failure, causing the rings to stick in the grooves. A change of material to high strength maraging steel helped, but did not solve the problem. The piston ring groove was then moved back to increase

Figure 32. Cracked Ring Seal

the bearing area of the piston, and also remove the groove from the point of load application. Figure 33 shows a comparison of the old and new ram piston. This change has proven satisfactory thus far and tests will continue with this configuration.

After two bursts of 2-3/4 seconds firing the piston rings collapsed due to heat, and it was difficult to start a third burst due to loss of ram pressure caused by excessive leakage past the rings. A three ring seal was then tried with an improvement; however, these rings also collapsed after one pod firing, and it was difficult to start the second pod. A concentrated effort is being made to solve this problem and rings made of a different material able to withstand higher temperatures will soon be tested.

The three ring seal configuration is shown in Figure 33.

Quick Disconnect Booster

An experimental quick disconnect booster block was built in October, and approximately 13,000 rounds have been fired with this part with good results. The booster block attaches to the receiver with four quick disconnects. By rotating the quick disconnects 180 degrees, the booster is locked in place. The booster block also locks the barrels in place by preventing barrel rotation. To remove the barrels the booster block is removed from the gun and the barrels are then rotated to decouple them from the interrupted threads in the breech. Figure 34 shows the booster block decoupled from the receiver. In the final design of the booster housing, it is anticipated using three quick disconnects instead of four in

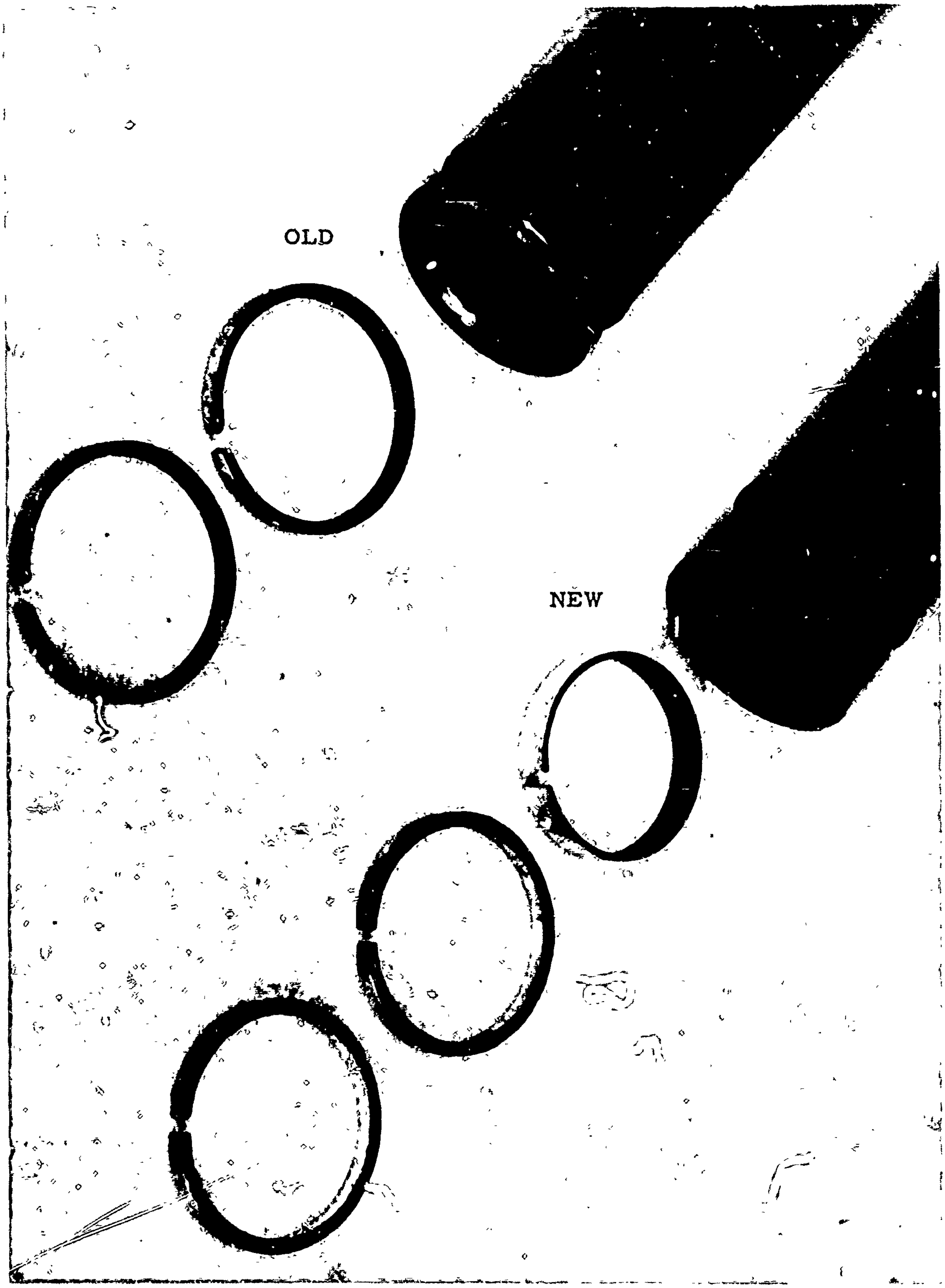


Figure 33. Rammer Piston and Ring Configuration

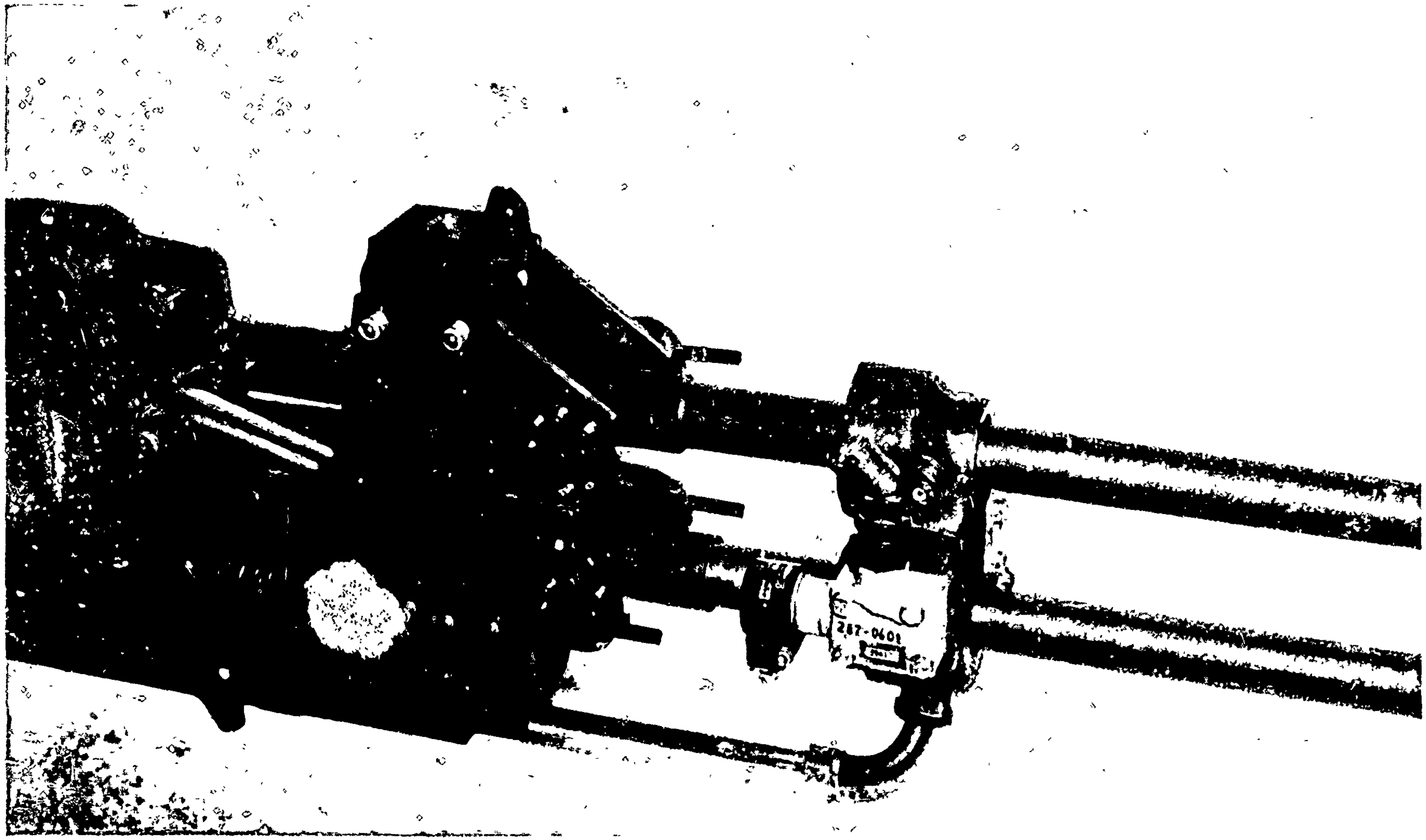


Figure 34. Booster Decoupled from Receiver

order to make the part simpler, and reduce the tolerances involved with the four quick disconnect system.

Along with the quick disconnect feature, the new booster block has been designed with the booster area separated from the ram and eject gas take-off systems. This was done for two reasons: (1) to increase the ram pressure, (2) to be able to control firing rate without effecting ram or eject pressures. The final design will be incorporated in the next reliability program.

Gas Ejection System

The gas ejection system has been redesigned to improve production and reliability of the parts. Two stainless steel tubes are used to transport the gases from the booster block to the cylinder for case or round ejection. One tube ducts the gun gas for ejection during firing, and the other tube ducts the air for air eject during a charge cycle. These tubes are joined together at a "Y" connection between the booster housing and cylinder. The remaining duct to the cylinder is common to both systems.

Some trouble was encountered in joining the tubes together at the "Y" section by welding. The weld material would flow into the tubes and cause a restriction which would give low eject velocities unless the material was removed. In order to solve this problem, it was decided to cast the "Y" section and let the two tubes slide in the cast section. Tests were conducted with this type of system and it was found to be even more efficient than the welded "Y" section. As a result, clearances have been increased between the tube O.D. and the cast "Y" support to allow for carbon build up between the two parts and still permit reciprocating action without binding. Figure 35 shows the two types of gas ejection systems.

The new system will have to be strengthened for long burst firing however, as the gas eject tube softens and backs out of the "Y" support. Tests are now in progress to solve this problem.

Cool Propellant

Approximately 1400 rounds of Methyl Centralite coated IMR propellant (cool propellant) was fired in the Mk 11 gun. The firing rate was the same as with standard IMR powder, but the firing initiating time was longer and most of the cycles fired in the buffer. The late firing did not affect firing rate, in that the buffers added energy and increased recoil velocity.

The pressures produced by the cool propellant at the booster and rammer were approximately the same as those produced by standard ammunition. Ejection velocity was the same. The pressure in the rammers, however, was inconsistent, which may be attributable to the hand loading of the cool propellant rounds. The pressure varied from cycle to cycle as much as 350 psi. Further testing will be necessary before any definite conclusions can be reached.

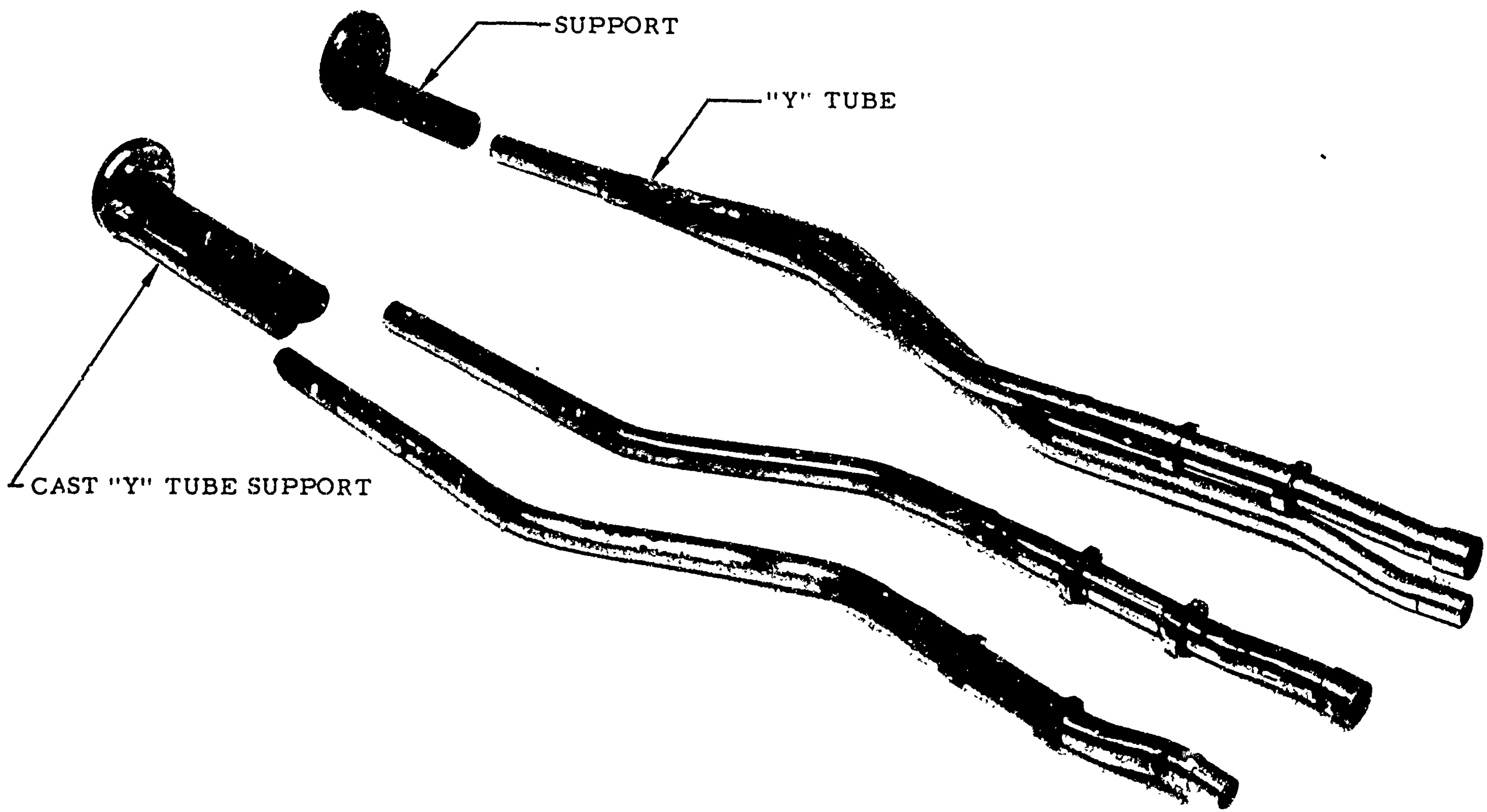


Figure 35. "Y" Tube Improvements

CONTINUATION OF RELIABILITY DEVELOPMENT

The results of this third phase of the one million round Reliability Program show that the reliability improvement is on schedule and the objectives of the total program will be met. The 90% fireout objective of the third phase has been exceeded and 3330 rounds per stoppage demonstrated.

The objective of the million round program, 95% fireout and 7000 rounds per stoppage, will be met during the fourth phase with an additional 300,000 rounds of firing. This work will be completed in 1964.

APPENDIX

CHART 1 - ROUNDS FIRED VS. TIME

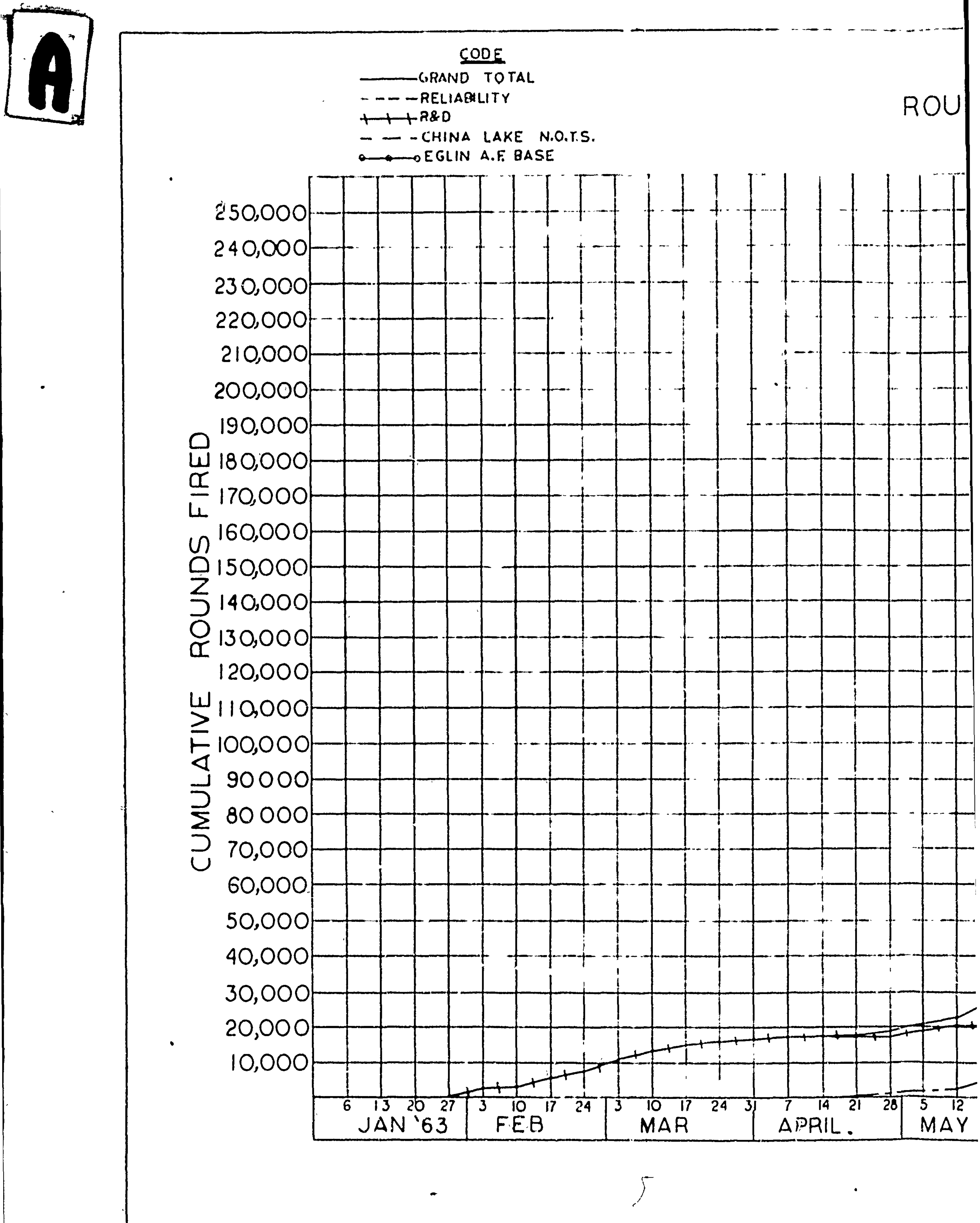
CHART 2 - RELIABILITY ROUNDS FIRED VS. TIME - STOPPAGES VS. ROUNDS FIRED

CHART 3 - ROUNDS FIRED AND STOPPAGES FOR EACH PODFUL - POD #10

CHART 4 - ROUNDS FIRED AND STOPPAGES FOR EACH PODFUL - POD #12

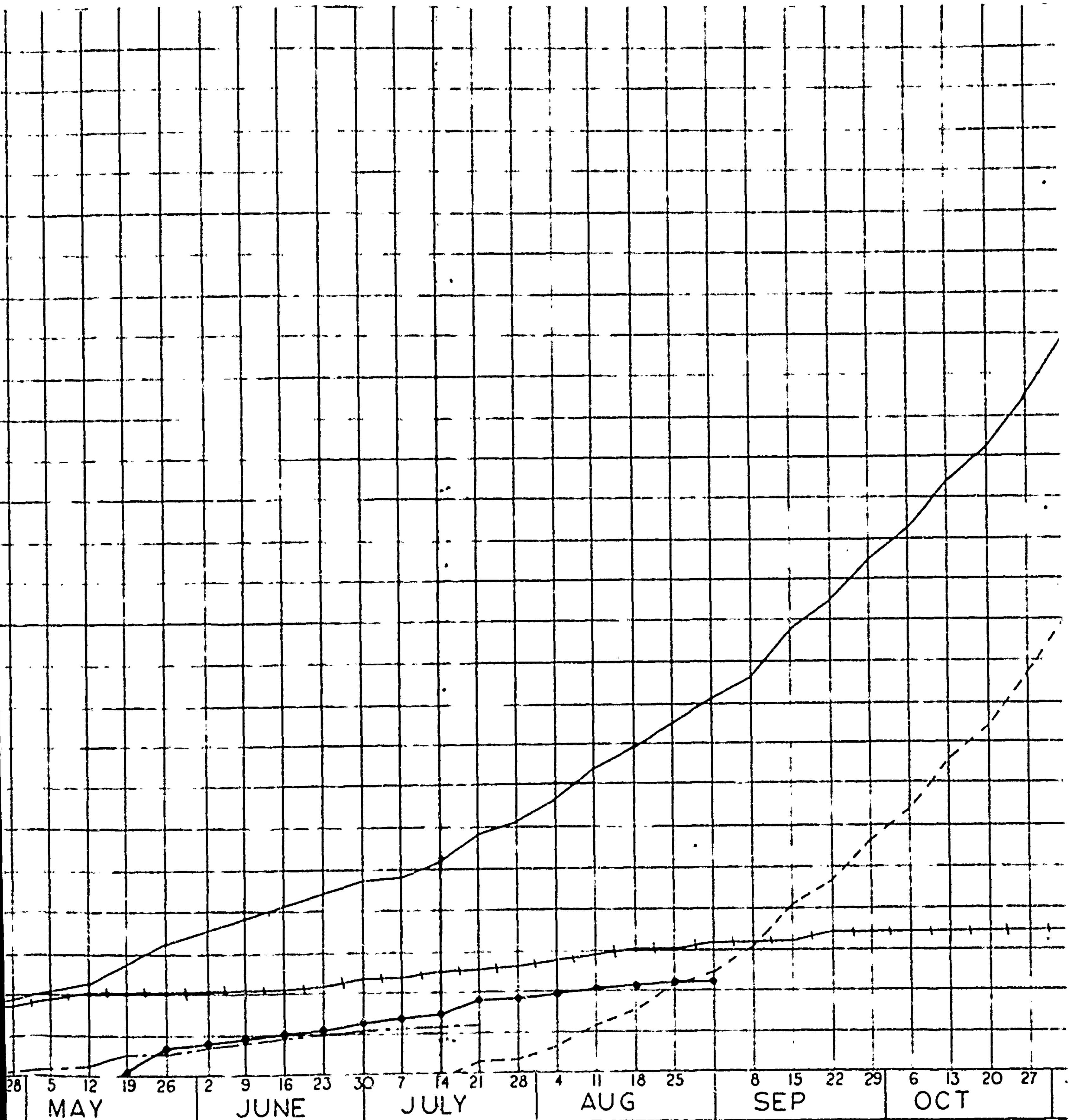
TABLE 5 - STOPPAGE SUMMARY - POD #10

TABLE 6 - STOPPAGE SUMMARY - POD #12

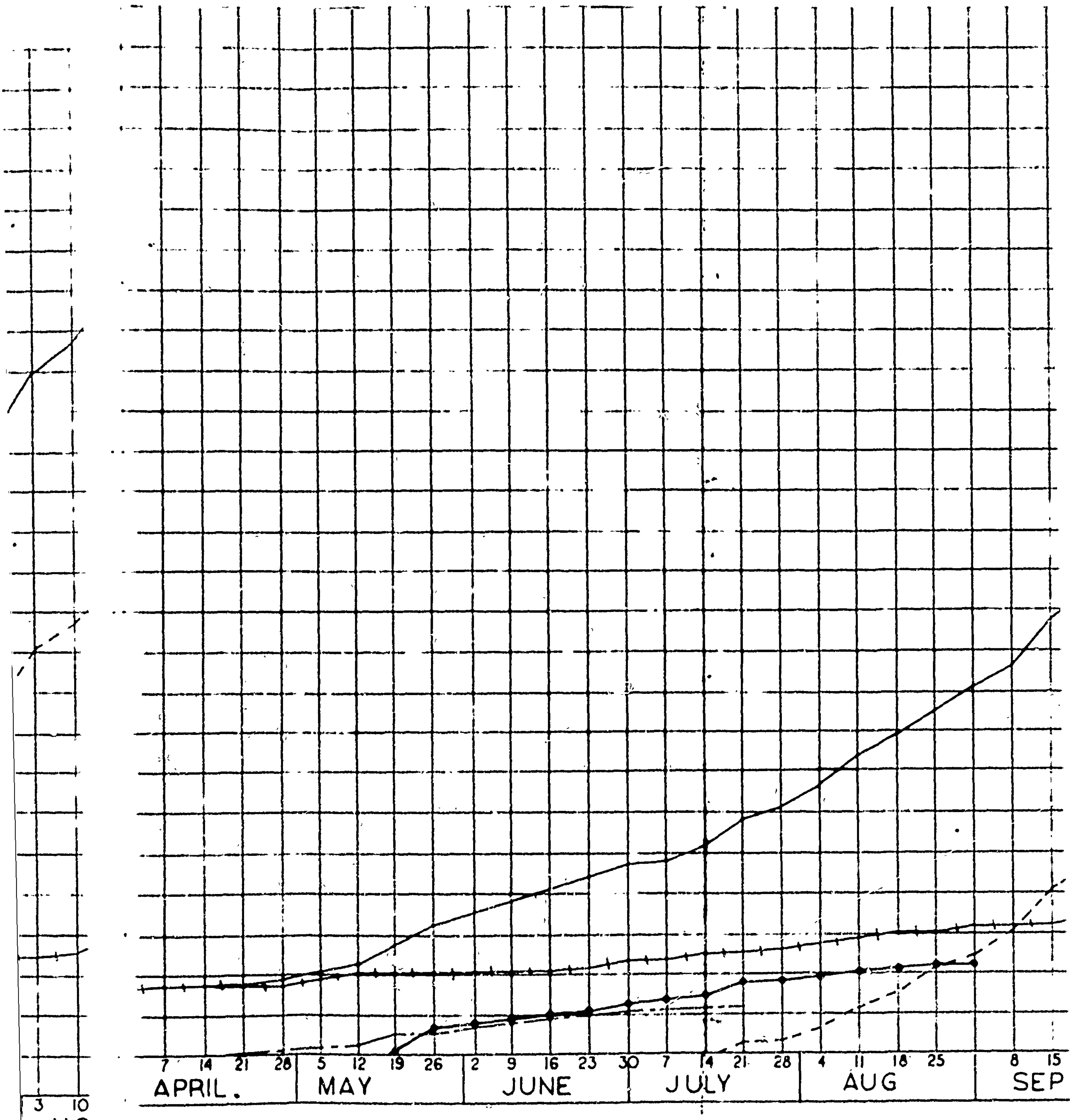


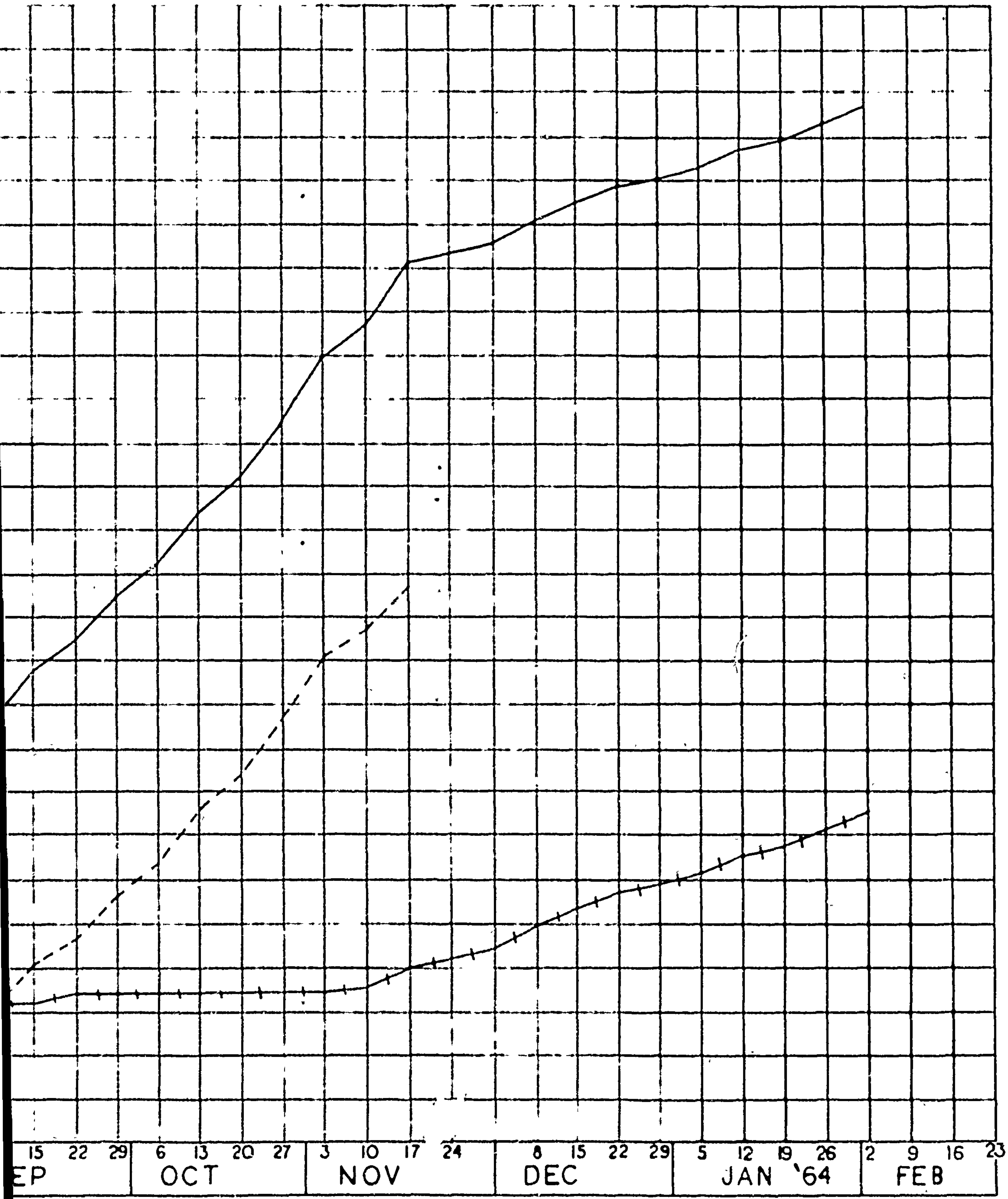
A
CODE
GRAND TOTAL
RELIABILITY
R&D
CHINA LAKE N.O.T.S.
EGLIN A.F. BASE
ROU
CUMULATIVE ROUNDS FIRED
250,000
240,000
230,000
220,000
210,000
200,000
190,000
180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90000
80 000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
6 13 20 27
JAN '63
3 10 17 24
FEB
3 10 17 24 31
MAR
7 14 21 28
APRIL.
5 12
MAY

ROUNDS FIRED VS. TIME



ROUNDS FIRED VS. TIME

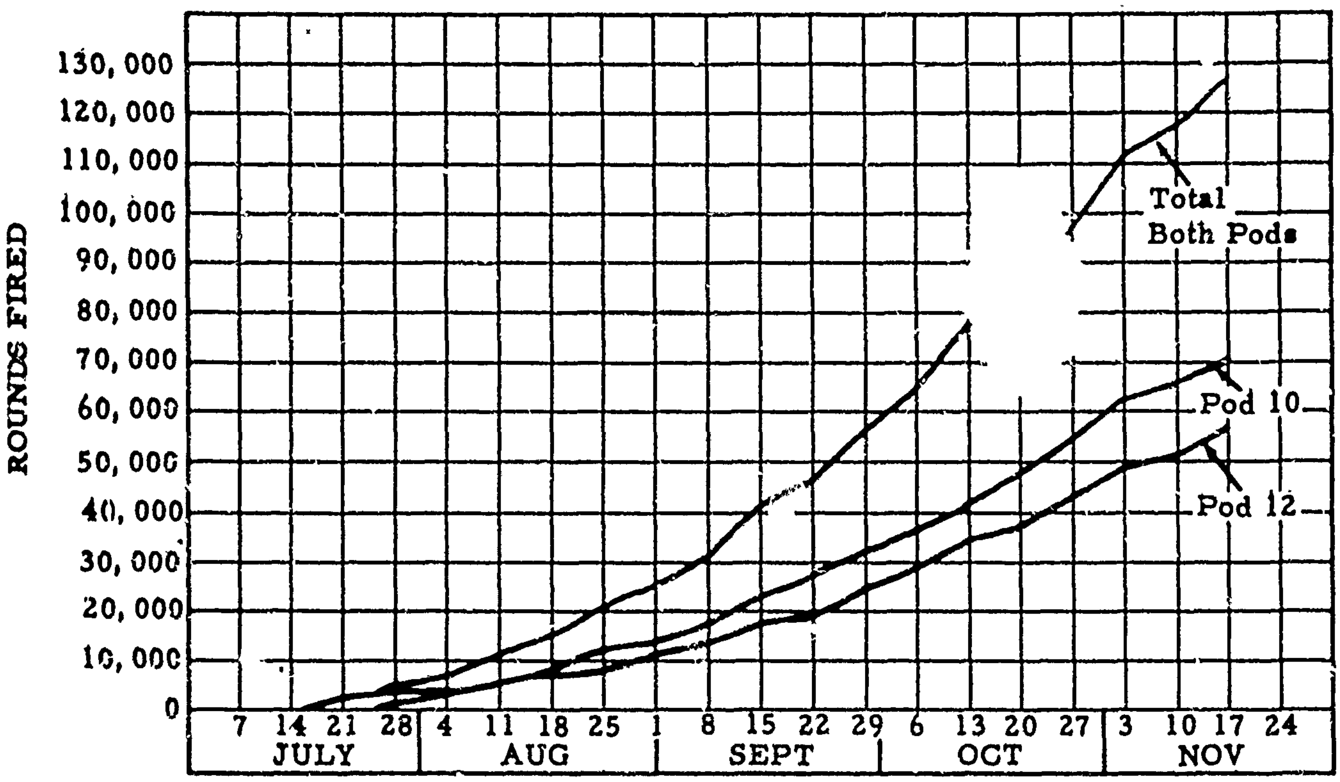




15 22 29 6 13 20 27 3 10 17 24 8 15 22 29 5 12 19 26 2 9 16 23
EP OCT NOV DEC JAN '64 FEB

CHART 1

RELIABILITY ROUNDS FIRED VS. TIME



STOPPAGES VS. ROUNDS FIRED

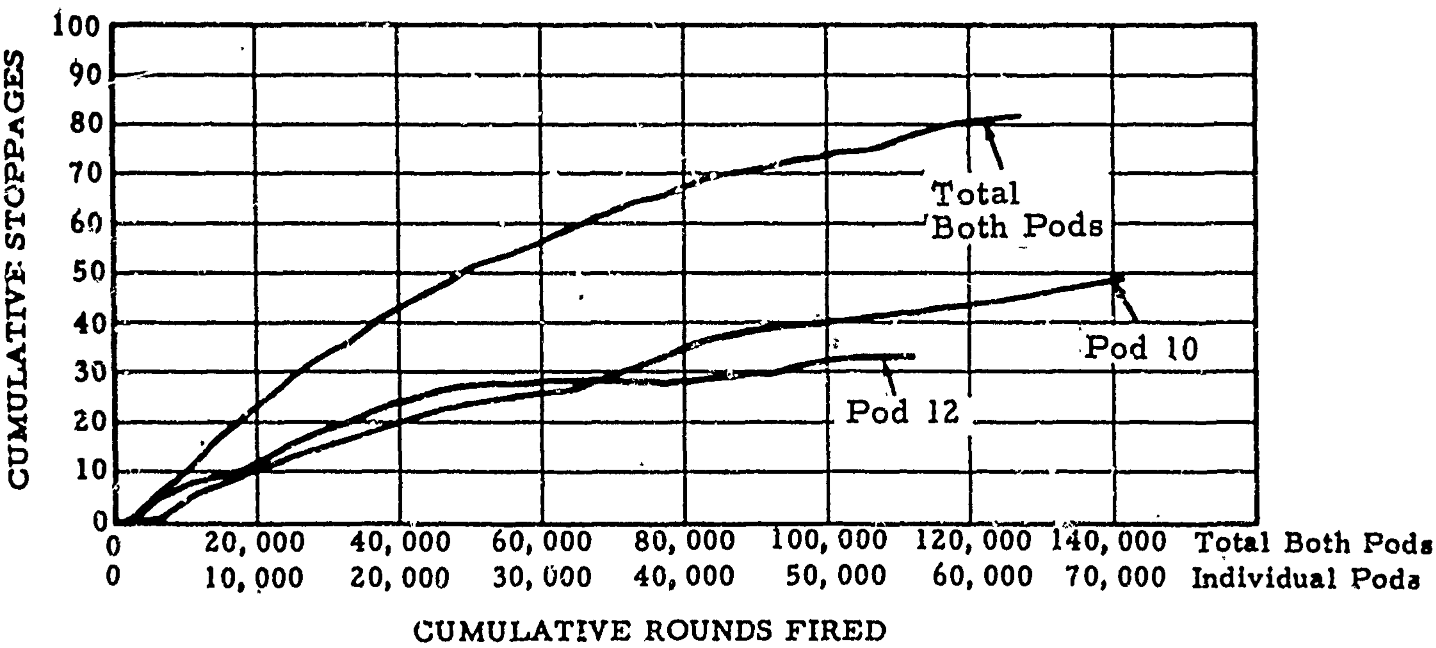
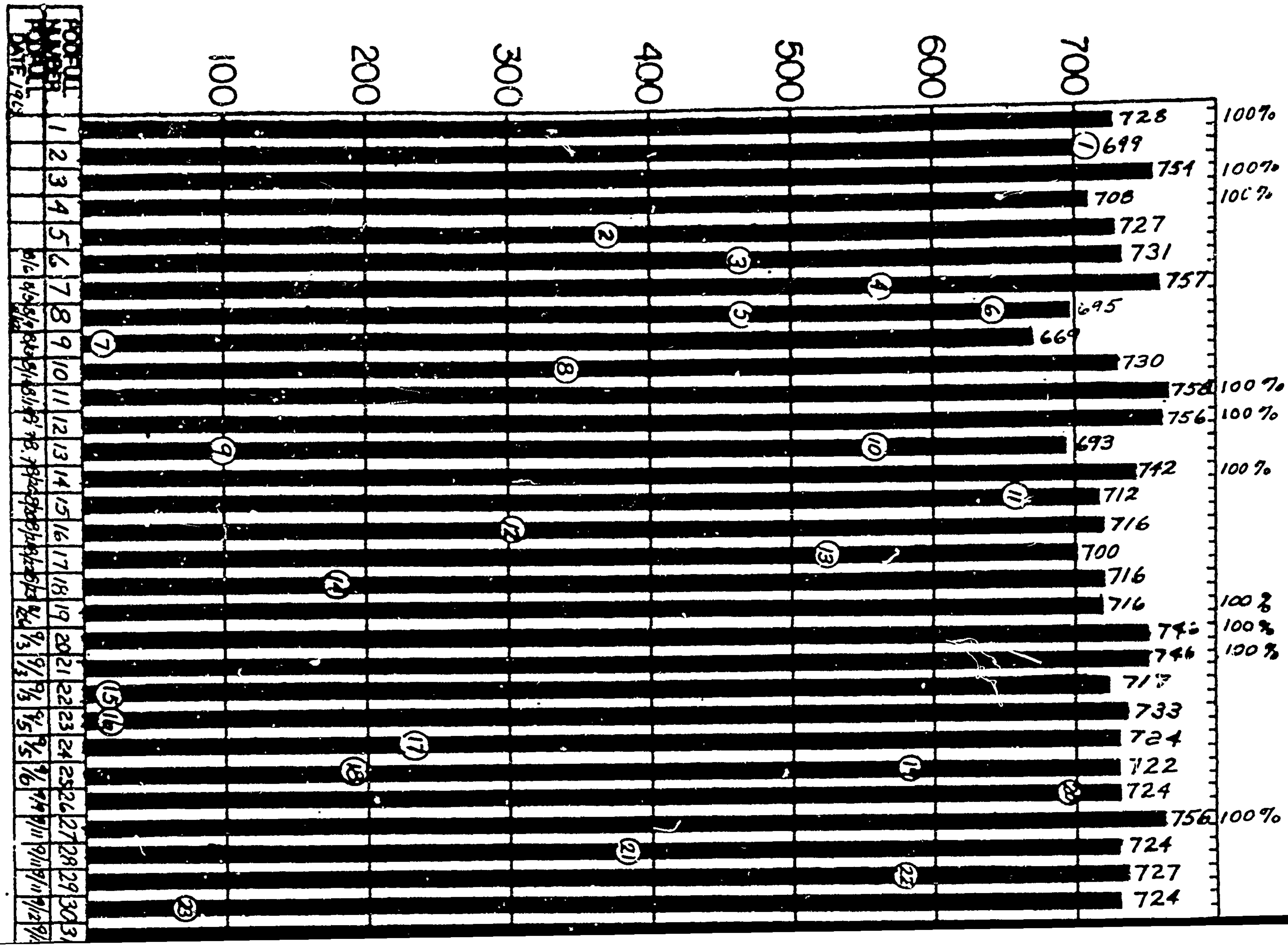


CHART No. 2

A

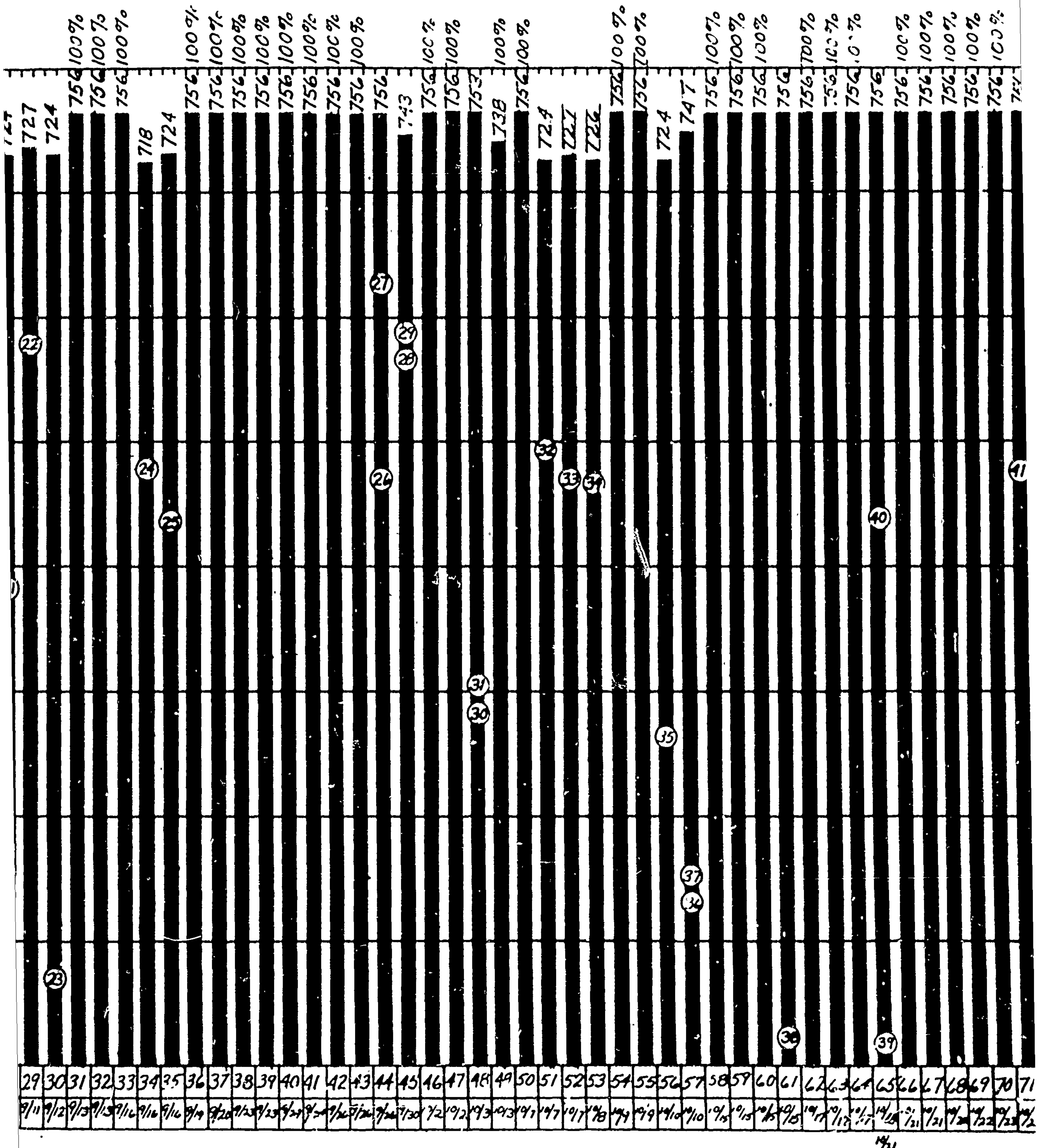
ROUNDS FIRED IN EACH PODFULL



GUN POD RELIABILITY IMPROVEMENT TEST

ROUNDS FIRED AND STOPPAGES FOR EACH PODFULL

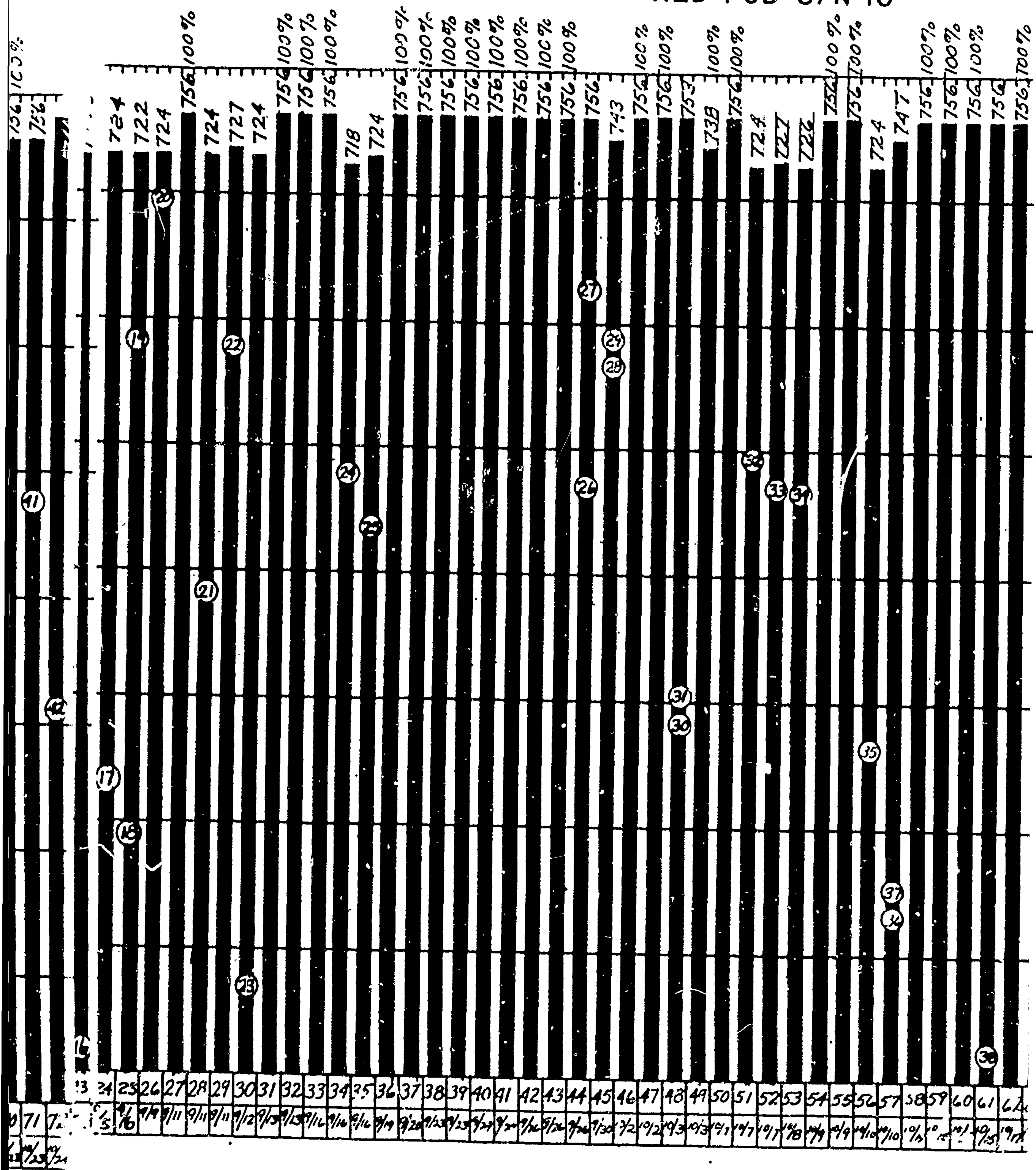
RED POD S/N 10



GUN POD RELIABILITY IMPROVEME

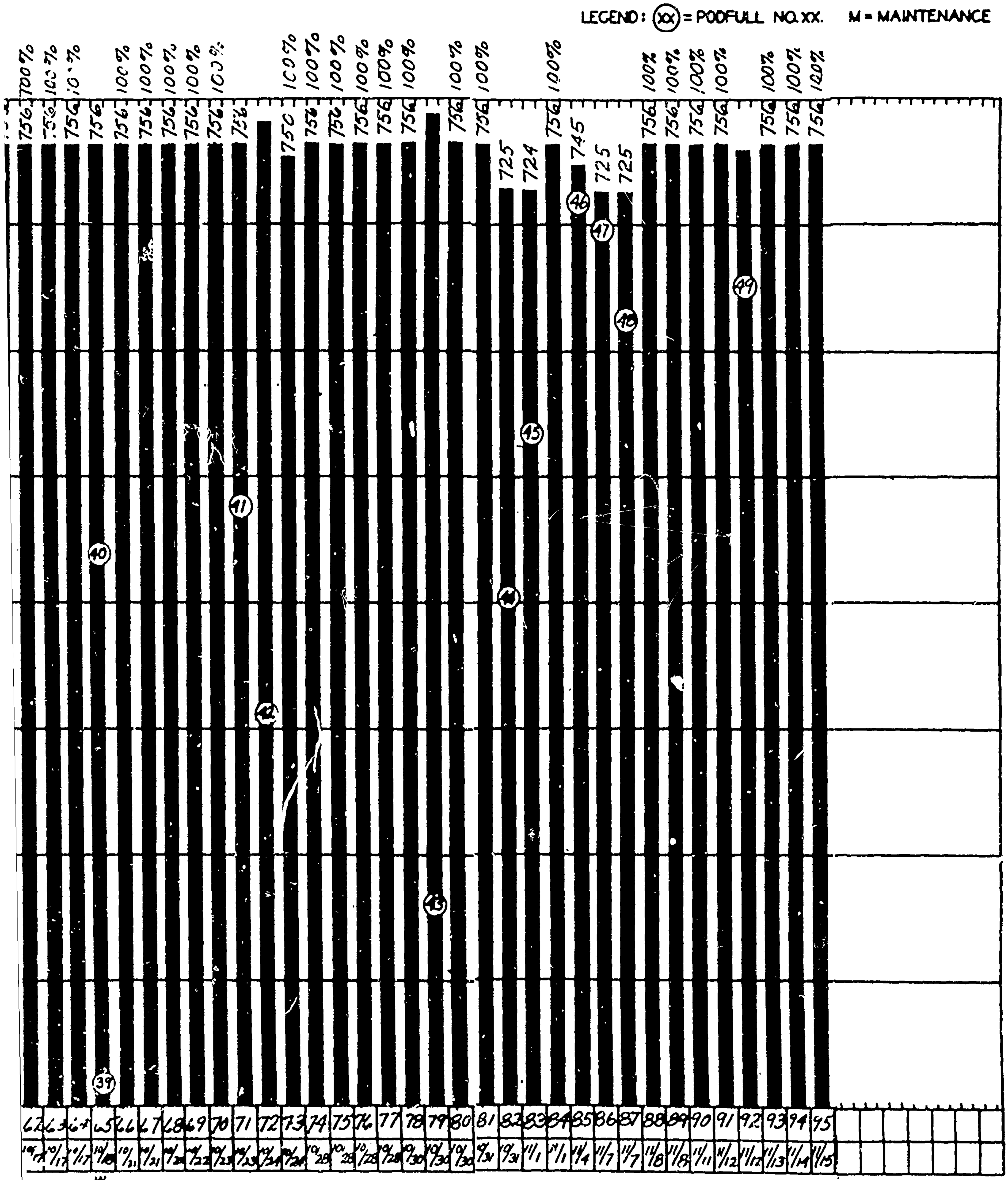
ROUNDS FIRED AND STOPPAGES FOR EAC

RED POD S/N 10



MENT TEST
ACH PODFULL

B



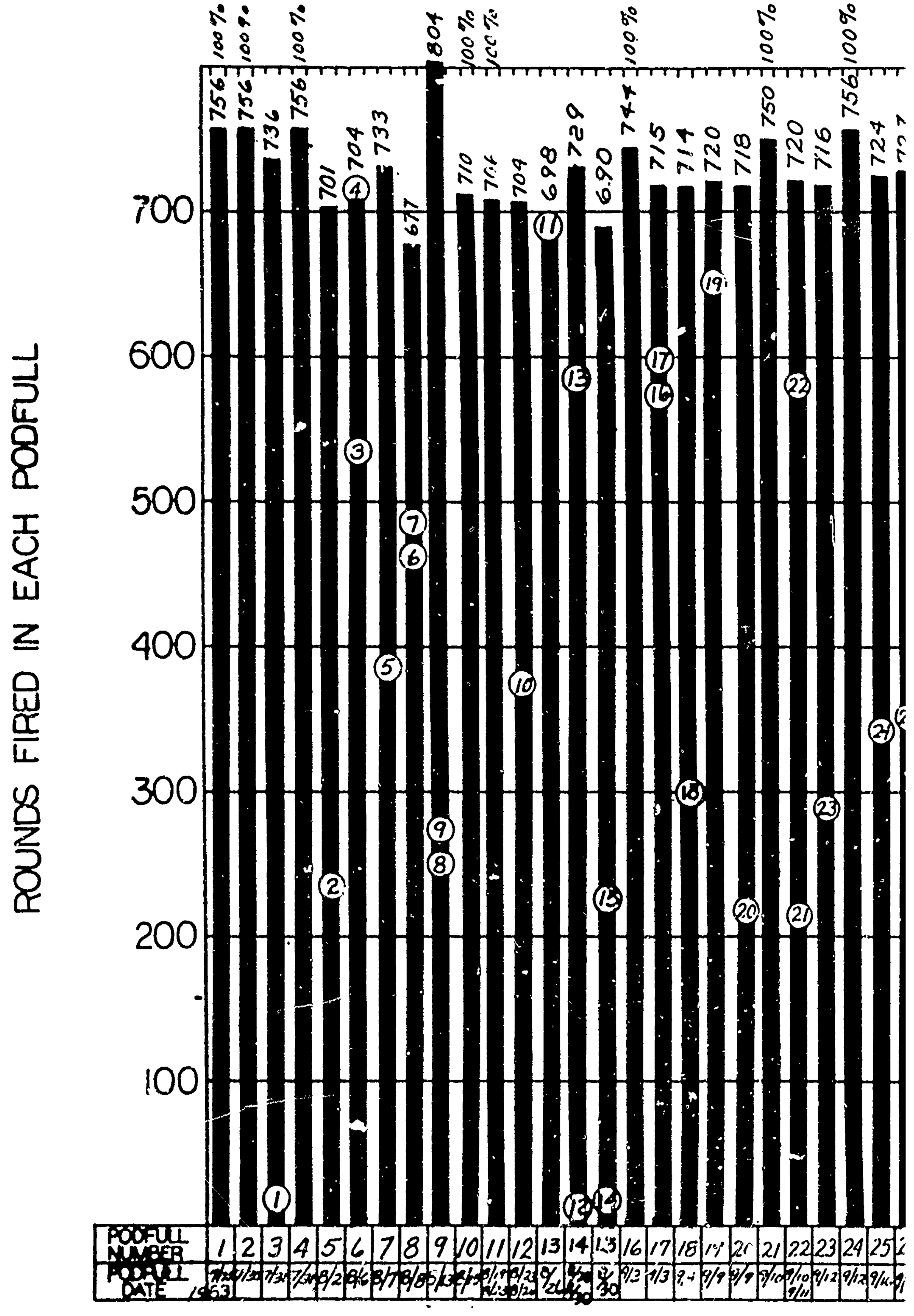
HUGHES TOOL CO., AIRCRAFT DIVISION

CHART 3

A

GUN PO

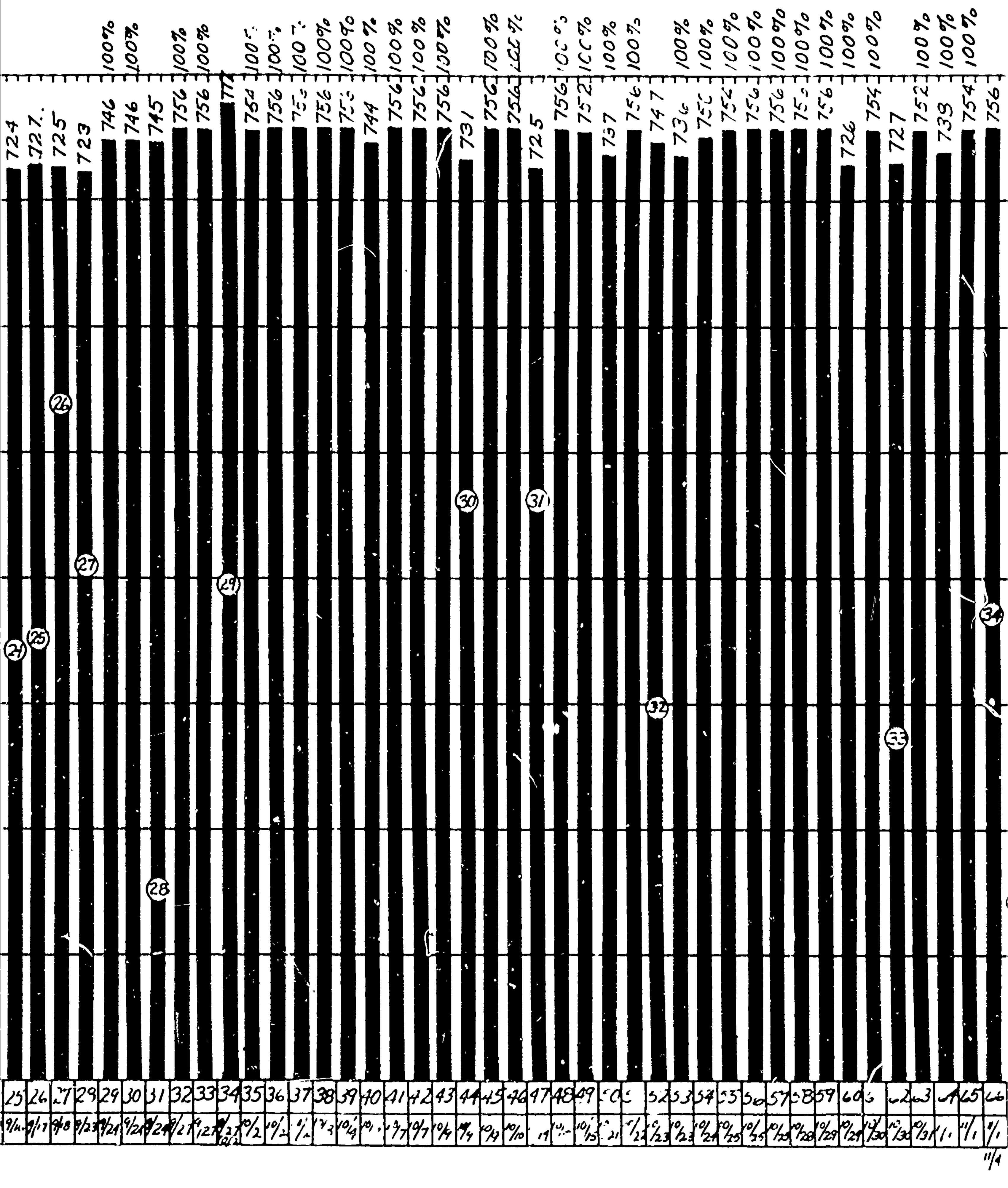
ROUNDS FI



POD RELIABILITY IMPROVEMENT TEST

FIRED AND STOPPAGES FOR EACH PODFULL

GREEN POD S/N 12

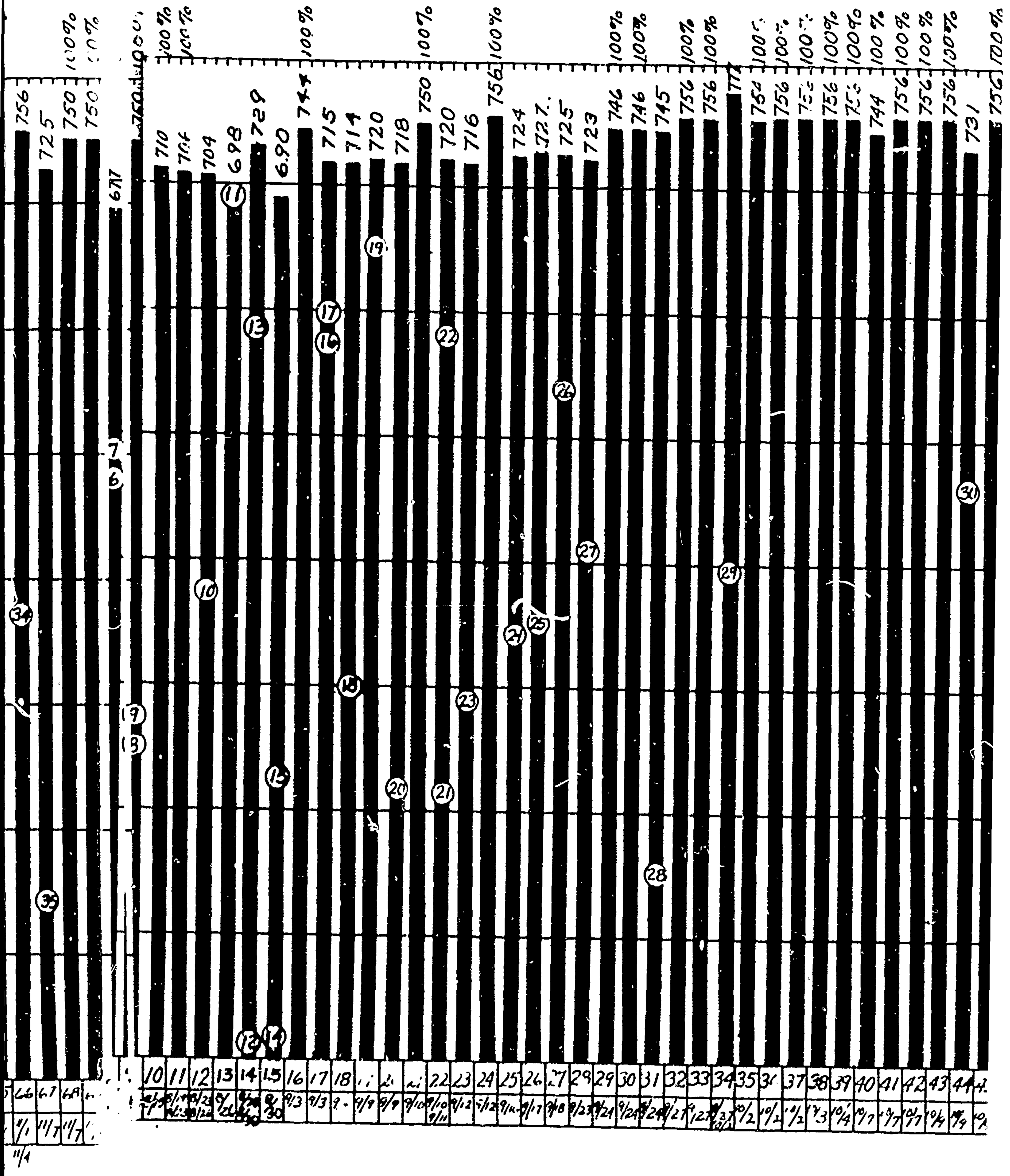


GUN POD RELIABILITY IMPROVE

ROUNDS FIRED AND STOPPAGES FOR E

GREEN POD S/N 12

LEGEND

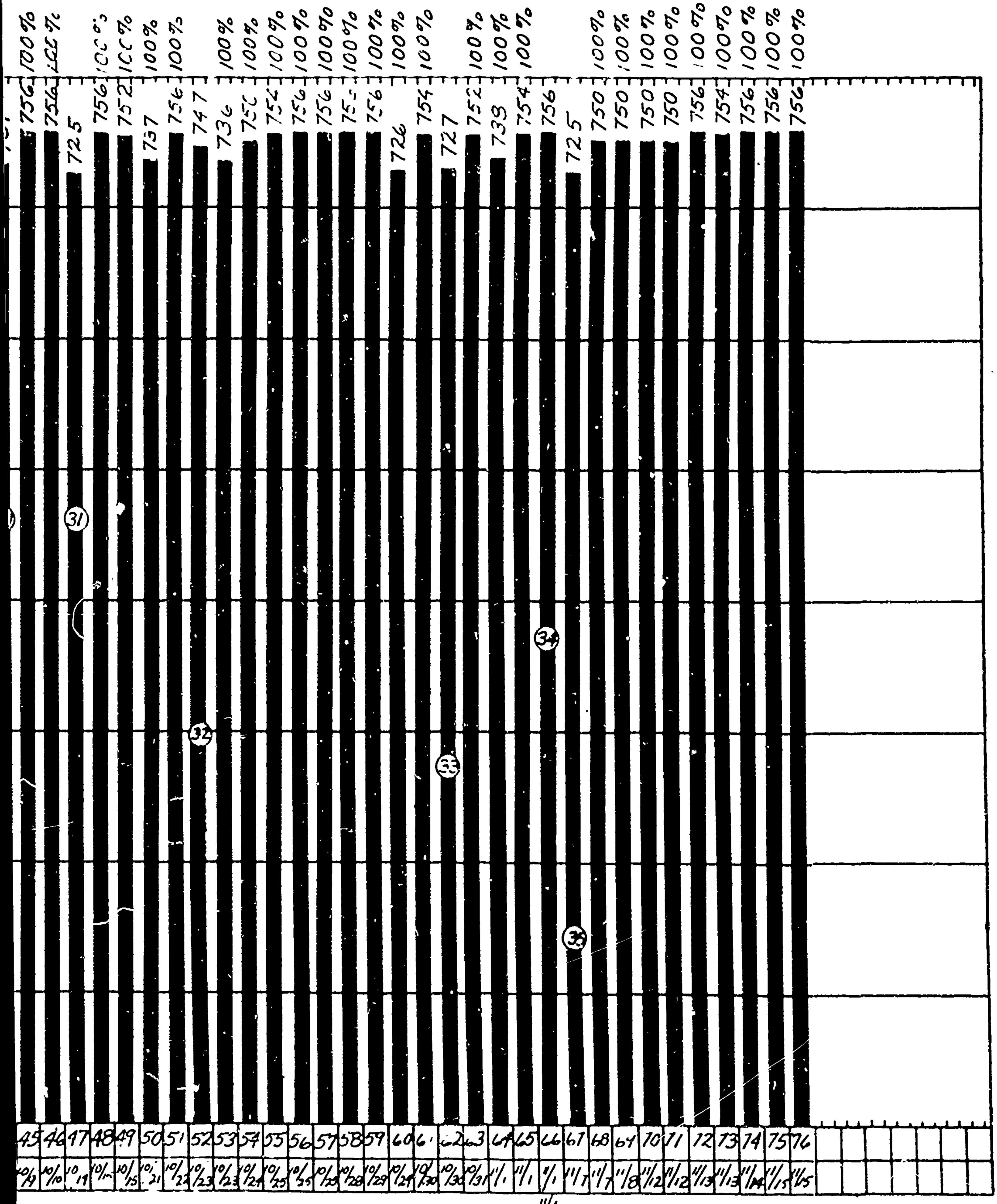


…VEMENT TEST

… EACH PODFULL

B

LEGEND: (XX) = PODFULL NO. XX. M = MAINTENANCE



HUGHES TOOL CO., AIRCRAFT DIVISION

CHART 4

TABLE 5

STOPPAGE SUMMARY - POD #10

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
1.			100% Fireout.	
2.	1	803	Loader. R & D Poppet shattered (Rex 49). Heat treat too high.	
3.			100% Fireout.	
4.			100% Fireout.	
5.	2	2461	Gun. * Insufficient clearance at Breech.	
6.	3	875	Manufacturing Error. Mislocated gas port in old barrel, causing low ram pressure.	
7.	4	831	Loader. (Fail to resear) Sear link latch spring jammed in rammer housing.	
8.	5	649	Manufacturing Error. Improper huck bolt and collar failed at eject chute attachment.	
	6	150	Gun. ** Barrel insert failed (heavy two-piece obturating sleeves installed at time).	
9.	7	67	Gun. * Insufficient clearance at Breech.	
10.	8	992	Gun. ** Barrel insert (F/F) failed.	
11.			100% Fireout.	
12.			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-fall No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
13.	9	2002	Gun. ** Barrel insert (F/F) failed.	
	10	481	Manufacturing Error. Mislocated port in old barrel, causing low ram pressure.	
14.			100% Fireout.	
15.	11	1532	Gun. ** Barrel insert (F/F) failed.	
16.	12	358	Loader. Sear link pin failed (L/F). (16,671 rounds)	
17.	13	900	Gun. ** Barrel insert failed.	
18.	14	364	Loader. Ram failed. (4489 rounds)	
19.			100% Fireout.	
			* Remachined Breech for more clearance after Stoppage #7.	
			** Ring seals installed at end of month (August).	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-Fall No.	Stoppage No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
20.			100% Fireout.	
21.			100% Fireout.	
22.	15	2759	Loader. Check valve function faulty. (15,448 rounds)	
23.	16	717	Manufacturing Error. Oscillating guide not to print, causing link squeeze which caused ram failure.	
24.	17	952	Ammunition. Grounded primer.	
25.	18	696	Manufacturing Error. Improper huck bolt at eject chute attachment.	
	19	388	Loader. Ram failed. (6806 rounds)	
26.	20	694	Loader. Sear link failed. (7278 rounds)	
27.			100% Fireout.	
28.	21	1308	Ammunition. Soft case.	
29.	22	579	Manufacturing Error. Improper huck bolt at eject chute attachment.	
30.	23	218	Manufacturing Error. Fail to ram. Same as Stoppage #16, but cause not determined until later.	
31.			100% Fireout.	

STOPPAGE UMMARY

FOR POD NO. 10

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
32.			100% Fireout.	
33.			100% Fireout.	
34.	24	3399	Loader. Piston ring failed.	
35.	25	677	Loader. Broken ram, L/F. (7215 rounds)	
36.			100% Fireout.	
37.			100% Fireout.	
38.			100% Fireout.	
39.			100% Fireout.	
40.			100% Fireout.	
41.			100% Fireout.	
42.			100% Fireout.	
43.			100% Fireout.	
44.	26	6805	Manufacturing Error. Same as #16 - Oscillating guide not to print, causing ram failure.	

STOPPAGE SUMMARY

FOR POD NO. 19

Pod-fall No.	Stoppage No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
	23	158	Ammunition. Late fire.	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-full No.	Stoppage No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
45.	28	704	Manufacturing Error. Rammer housing out of tolerance. Fail to resear.	
	29	3	Manufacturing Error. Oscillating guid. not to print; link jam.	
46.			100% Fireout.	
47.			100% Fireout.	
48.	30	1968	Ammunition. Soft case; fail to eject.	
	31	7	Manufacturing Error. Oscillating guide not to print; link squeeze causing ram failure.	
49.			100% Fireout.	
50.			100% Fireout.	
51.	32	1958	Ammunition. Soft case; fail to eject.	
52.	33	701	Loader. Rex 49 Poppet nut improperly heat treated.	
53.	34	723	Gun. Damper rod failed. (48,995 rounds)	
54.			100% Fireout.	
55.			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-ful No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
56.	35	2036	Gun. Yoke failed. (51,031 rounds)	
57.	36	590	Gun. Firing pin jam; L/F barrel.	
	37	7	Manufacturing Error. Same as Stoppage #31; cause not found until later.	
58.			100% Fireout.	
59.			100% Fireout.	
60.			100% Fireout.	
61.	38	2897	Gun. Broken spring pin in round positioner.	
62.			100% Fireout.	
63.			100% Fireout.	
64.			100% Fireout.	
65.	39	3018	Loader. Poppet failed to check; one cycle.	
	40	424	Gun. Firing pin holder; open circuit (Y). (2705 rounds)	
66.			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
67.			100% Fireout.	
68.			100% Fireout.	
69.			100% Fireout.	
70.			100% Fireout.	
71.	41	4570	Link. Lug tore out of Carrier.	
72.	42	594	Gun. SLorted firing pin.	
73.			100% Fireout.	
74.			100% Fireout.	
75.			100% Fireout.	
76.			100% Fireout.	
77.			100% Fireout.	
78.			100% Fireout.	
79.	43	5126	Ammunition. Late fire - last round. (Stopped out of battery)	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
80.			100% Fireout.	
81.			100% Fireout.	
82.	44	2802	Loader. Rex 49 Poppet shattered, improper heat treat	

STOPPAGE SUMMARY

FOR POD NO. 10

Pod-full No.	Stoppage No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
83.	45	856	Link - Spotweld failed in Radhaz cap.	
84.	--	----	100%	
85.	46	1663	Gun - Gas transport tube broken. (73,238 rounds)	
86.	47	723	Mfg. Error - Cylinder chamber finish 100 micro-inches should be 16.	
87.	48	655	Mfg. Error - Cylinder chamber finish 100 micro-inches should be 16.	
88.	--	----	100%	
89.	--	----	100%	
90.	--	----	100%	
91.	--	----	100%	
92.	49	3775	Mfg. Error - Cylinder chamber finish 100 micro-inches should be 16.	
93.	--	----	100%	
94.	--	----	100%	
95.	--	----	100%	

TABLE 6

STOPPAGE SUMMARY - POD #12

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
1.			100% Fireout.	
2.			100% Fireout.	
3.	1	1519	Gun. Insufficient clearance at Breech. (Fail to ram deep enough.)	
4.			100% Fireout.	
5.	2	1694	Gun. F/F barrel insert failed (heavy two-piece obturating sleeves installed at time).	
6.	3	971	Gun. (Same as Podful No. 5)	
	4	169	Gun. Washed barrel (no insert installed).	
7.	5	385	Gun. Washed both barrels (no inserts). 2-3/4 sec. bursts above here.	
8	6	310	1.7 sec. bursts starting here. Manufacturing Error. Sleeved barrel failed at port (old barrel rework).	
	7	11	(Same as above) High rate prevented ramming.	
9.	8	445	Gun. Excessive clearance around obturating sleeve. (Brazed aft obturating sleeve installed at this time.)	
	9	13	Gun. Insufficient clearance at Breech.	
10.			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-fall No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
11.			100% Fireout.	
12.	10	2331	Gun. Barrel insert failed.	
13	11	1037	Gun. Fail to ram deep enough. (Leaks around obturating sleeve.)	
14.	12	1	(Changed from ZS14 to ZS3 Ammunition) Personnel Error. Misindexing of lead link.	
	13	592	Gun. Galled cylinder shaft (from seal leaks).	
15.	14	144	Fail to ram deep enough (F/F). Cause not determined.	
	15	226	Ammunition. Shorted primer.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
16.			100% Fireout.	
17.	16	1784	Gun. Galled shaft caused by barrel flash.	
	17	3	Manufacturing Error. Barrel (welded) - port not properly indexed.	
18.	18	428	Loader. Broken ram, F/F (5562 rounds).	
19.	19	1068	Loader. Broken ram, L/F (6791 rounds).	
20.	20	284	Manufacturing Error. Improper bolt at eject chute attachment.	
21.			100% Fireout.	
22.	21	1454	R & D. Plug in F/F barrel washed out. (R & D part)	
	22	380	R & D. Rex 49 barrel insert failed.	
23.	23	428	Gun. Washed F/F barrel insert.	
24.			100% Fireout.	
25.	24	1524	Gun. Washed F/F barrel insert.	
26.	25	731	Gun. Dull firing pins.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
27.	26	915	Gun. Washed F/F barrel insert.	
28.	27	575	Gun. Washed F/F barrel insert.	
29.			100% Fireout.	
30.			100% Fireout.	
31.	28	1957	Manufacturing Error. Oscillating guide not to print; caused link jam which caused ram jam.	
32.			100% Fireout.	
33.			100% Fireout.	
34.	29	2501	Gun. Washed booster housing from eroded barrel.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
35.			100% Fireout.	
36.			100% Fireout.	
37.			100% Fireout.	
38.			100% Fireout.	
39.			100% Fireout.	
40.			100% Fireout.	
41.			100% Fireout.	
42.			100% Fireout.	
43.			100% Fireout.	
44	30	7646	Loader. Broken L/F ram. (4229 rounds)	
45.			100% Fireout.	
46.			100% Fireout.	
47.	31	2245	Loader. Broken sear link - L/F side. (2245 rounds)	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
48.			100% Fireout.	
49.			100% Fireout.	
50.			100% Fireout.	
51.			100% Fireout.	
52.	32	3560	Gun. L/F case retainer failed; soft R_c 31 should be 34-38. (15,345 rounds)	
53.			100% Fireout.	
54.			100% Fireout.	
55.			100% Fireout.	
56.			100% Fireout.	
57.			100% Fireout.	
58.			100% Fireout.	
59.			100% Fireout.	
60			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
61.			100% Fireout.	
62.	33	6724	Link. Lug backed out of slot in link, causing separation.	
63.			100% Fireout.	

STOPPAGE SUMMARY

FOR POD NO. 12

Pod-full No.	Stop-page No.	Rounds Since Stoppage	Stoppage	Gun & Ldr. No.
64.			100%	
65.			100%	
66.	34	3066	Gun - Case retainer broken at 10,510 rounds.	
67.	35	525	Gun - Cracked barrel insert. Halcomb #218 material.	
68.			100%	
69.			100%	
70.			100%	
71.			100%	
72.			100%	
73.			100%	
74.			100%	
75.			100%	
76.			100%	