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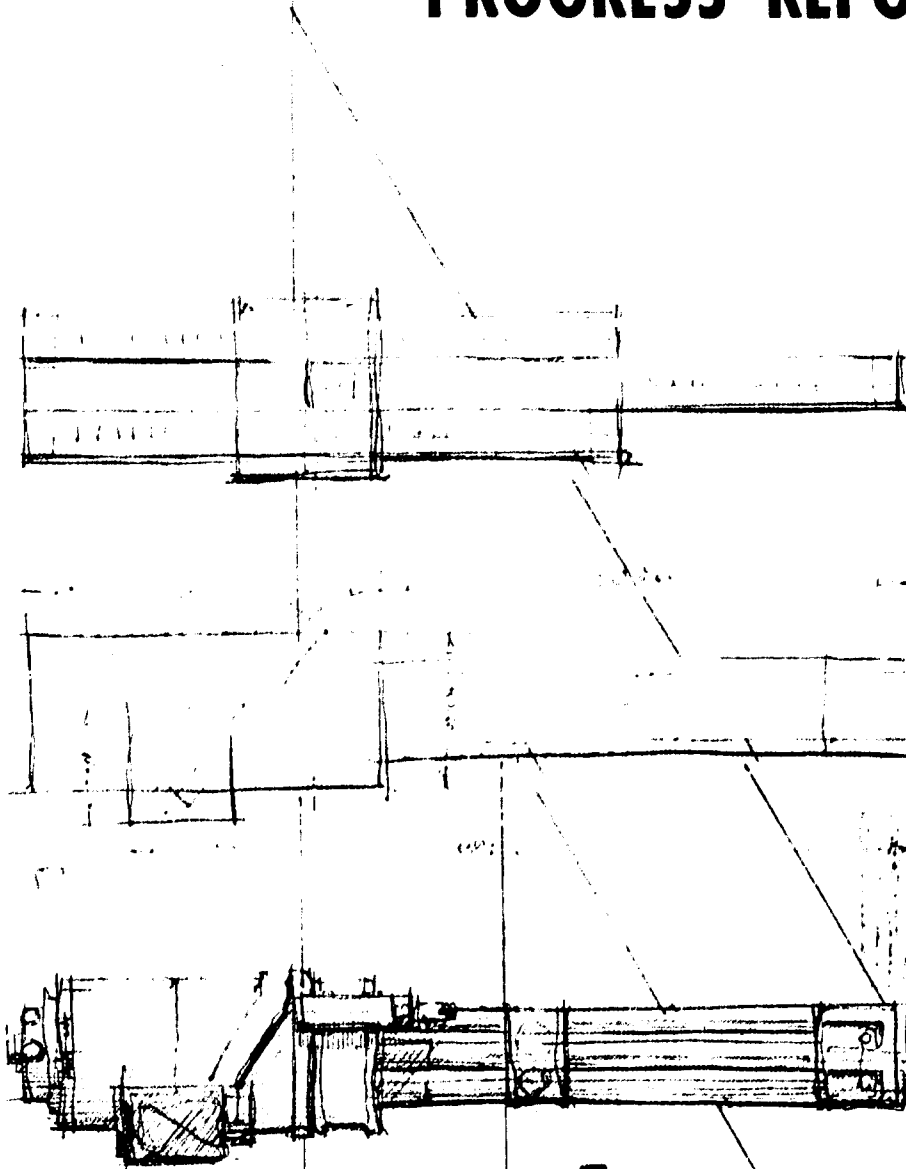


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PROGRESS REPORT 42



Project Vulcan.. **RESEARCH and DEVELOPMENT**

MISSILE AND ARMAMENT DEPARTMENT

GENERAL  **ELECTRIC**

BURLINGTON, VERMONT

63APB50
31 OCTOBER 1963

PROJECT VULCAN RESEARCH and DEVELOPMENT

PROGRESS REPORT NUMBER 42

**CONTRACT DA - 19 - 020 - ORD - 5455
1 AUGUST 1963 TO 30 SEPTEMBER 1963
BOSTON ORDNANCE DISTRICT
DEPARTMENT OF THE ARMY**

**MISSILE AND ARMAMENT DEPARTMENT
GENERAL  ELECTRIC
BURLINGTON, VERMONT**

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General Electric Company, Burlington, Vermont
PROJECT VULCAN RESEARCH AND DEVELOPMENT
PROGRESS REPORT

G. E. Report 63APB47 November 1963 pp-incl. tables, curves
Unclassified Report

This report describes the work performed through the period 1 August 1963 to 31 September 1963. The following projects and studies are discussed: (1) Gun Gas Drive. (2) Gun Gas Drive Spring Starter. (3) Gentle Slope Unlock Cams. (4) Gun Bolt Inserts. (5) Front Track Bolts. (6) Boreighting and Target Study: production guns.

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1. Automatic Gun, 20mm, M61
2. Automatic Gun, 20mm, T171E3

- I. Title: Vulcan
- II. Contract DA-19-020-ORD-5455
- III. DA Project No. SA-7663

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Approved by R. R. Bernard
R. Bernard
Armament Engineer

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
I	General	1-1
II	Gun Gas Drive	2-1
III	Gun Gas Drive Spring Starter	3-1
IV	Improved Parts Life	4-1
	Front Track Bolts	4-1
V	Gun Components	5-1
	Gentle Slope Unlock Cams	5-1
	Replaceable Inserts	5-2
VI	Boresighting and Target Study	6-1

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
4-1	Front Track Bolt (Top View)	4-2
4-2	Front Track Bolt (Bottom View)	4-4
5-1	Replaceable Inserts (1-3)	5-3
5-2	Replaceable Inserts (4-6)	5-4

SECTION I

GENERAL

Contract DA-19-020-ORD-5455, awarded to the General Electric Company by the Department of the Army, Boston Ordnance District, provides for the continuation of research and development on the M61 Vulcan Gun.

This report describes the work performed through the period 1 August 1963 to 30 September 1963. The following projects and studies are discussed:

Gun Gas Drive.

Gun Gas Drive Spring Starter.

Gun Bolt Inserts

Front Track Bolt.

Gentle Slope Unlock Cams.

Range Firing Records.

SECTION II

GUN GAS DRIVE

Gas drive development was limited to flight and ground test in the ETU SUU/16A M61 pod at Eglin Air Force Base, Florida.

A 1.5 hp motor was used as a starter system during this test.

The gas drive pod system had exceedingly good results during its ground functional fire testing. There were no malfunctions or disorders during 1650 rounds. The flight tests were also very good with 3407 rounds being fired with only one drive malfunction. (This malfunction was caused by a breakage of the roller support and roller in the gas drive system.) The problem has been traced to faulty ball spline shaft. The only other problem was the inability of the 1.5hp temporary starter motor to function effectively during the 35,000 foot cold soak test.

Testing started 22 August 1963. The following is a summation of that test and the subsequent testing which ended 28 August 1963.

22 August 1963 - Ground firing

Right Wing

Fired full complement in eight bursts. The rates were 6060 spm at the start and 6710 spm at the conclusion.

Left Wing

Fired five bursts for targeting. Rates were from 5920 at the start to 6600 spm at the conclusion.

(No gas drive maintenance performed.)

23 August 1963 - Air-to-air firing with g loading.

Fired at 4380 spm at 1g, 4110 spm at 2 g's, did not fire at 3 g's, fired at 6000 spm at 5 g's.

All firing stopped after 4th burst due to the loosening of an electrical connector in the wing to pyton connection.

(No gas drive maintenance performed.)

26 August 1963 - Air-to-air firing with g loading.

Fired seven bursts from -2 g's to +5 g's. Firing rates varied from 3960 spm at -2 g's to 6000 spm at +5 g's.

The roller support shaft broke during the seventh burst. Subsequent detailed investigation of the damaged hardware revealed a faulty spline shaft.

27 August 1963 - Air-to-air at 35,000 feet for 30 minutes.

The small starter motor was not able to turn the gun enough to chamber a round. The pilot returned to 5000 feet and the gun began to fire normally. Pilot returned to base after only four bursts due to shortage of fuel.

(No gas drive maintenance performed.)

28 August 1963 - Air-to-air at 35,000 feet for 15 minutes.

Starter motor was able to start system slowly. Rates were low until system heated up (after 10th burst). The rates were 3080 at the start and 7080 at the end. A brake band was damaged. This, however, had little effect on performance of the drive system.

(No gas drive maintenance was performed.)

28 August 1963 - Air-to-air at 35,000 feet for 10 minutes, down to 5000 feet and back to 35,000 feet for 10 minutes.

Starter motor had difficulty accelerating the system. Rates were 2810 shots per minute at the start and in excess of 6000 spm after it warmed up.

(No gas drive maintenance was performed.)

SECTION III

GUN GAS DRIVE SPRING STARTER

Development of the split torque tube spring continued on 5 August with a third set of tubes, designed for 1,500 inch-pounds and incorporating the collars and other improvements. Initial testing was done with tubes numbers one and two assembled alone, to prove the end connections and material limitations. Three pins were used at each connection and the pin slots were parallel with the spring axis.

The spring gradient proved to be equal to the theoretical one, but rose steeply beyond 280 degrees. It was ascertained that the new collar was working perfectly, so effort was concentrated on the pinned connections. Reworking the pin slot to an angle, so that the slots retain their axial orientation even as the spring is torque up, resulted in maintaining the theoretical gradient. This was found to be necessary only on the lower stressed, corner slot. However, because of the problem of maintaining pin contact with curved surfaces, that spring corner was removed entirely. This eliminates some friction in the spring due to the corners warping and the gradient was not reduced.

Strength of the material has remained to be a major problem. The tubes were yielding and taking a permanent set at 97,200 psi calculated shear stress. The material was checked and there were no defects found

which would account for a reduced strength. Slight surface decarburization was found, but was not sufficient to significantly reduce strength. It was found that the material was on the low side of the specified hardness of Rc 48-52. Number one and two tubes were reheat-treated to Rc 50-52, which resulted in a gain in shear stress to 107,000 psi. It was concluded that a 1,500 inch-pound spring was beyond the materials strength limitations with ordinary metal technology. The thicknesses were reduced resulting in a 956 inch-pound spring which still overstressed the material, but less torque than that would be insufficient for starting the gun system.

Testing of the assembled five tubes began after the remaining tubes had been modified to match number one and two. Stepped pins were utilized for two tube connections so that all pins were trapped in the assembly. The gradient of the whole assembly was 150% higher than theoretical, believed to be due to friction and internal binding. Experience had shown that the spring gradient can be reduced by attaching the tubes only at the neutral pins. This was done on all connections and the gradient was decreased, although it rises above the theoretical at 280 degrees deflection.

Although the tubes tend to distort more with the single pin connections, the collars confine the ends to hold them circular and allow the spring

to be stressed mainly in torsion. Tubes one and five (with single pin connections) have to be constrained on the I.D. and O.D. respectively to remain on the pins and not interfere with the shaft or rotor. Friction accounts for a large loss in the assembly since it is proportional to the number of tubes. It represents about a 300 inch-pound loss in the five tube assembly and accounts for the unlinear gradient.

Consultation with a spring manufacturer, to develop greater strength in the material has led to a proposal to determine the feasibility of such strength requirements by 11 October 1963.

Experimentation with a prestraining-retempering process used for increasing the strength of ultra-high strength materials has been successful. Controlled samples of the 8740 material have been increased by at least 50% in tension. The third set of thinned down springs which had yielded considerable (prestraining) were retempered and show definite signs of a higher stress limit. The spring assembly apparently withstands 150,000 psi shear stress without yielding, which indicates a 50% gain in strength.

Development of the spring and starter mechanism began on 5 September 1963. Spring output to the gun is about 500 to 600 inch-pounds measured at the rotor. This spring accelerated a gun complete with

bolts, barrels, feeder and gas drive, while stripping dummy rounds from T-76 links, to a rate of 1,200 spm in 0.2 seconds. This system was fire tested at the range and the gun was accelerated to 6,000 spm in 0.65 seconds. M-14 links, which have a higher stripping torque than T-76 links, were used for the fire testing.

SECTION IV

IMPROVED PARTS LIFE

FRONT TRACK BOLTS

Front track bolts have been fired 22, 186 rounds without requiring tightening. The majority of the firing has been done in 200 round bursts and at a rate of 6000 shots per minute. The bolts were constructed with the thread configuration described fully in Progress Report 40, page 4-3. The bolts deviate from standard only in that they are produced by grinding rather than rolling the threads. Therefore, the configuration at the root of the thread is changed.

A new rotor was used in the test. The minor diameter of the front track bolt holes was increased to the maximum allowable by the print. The bolts were installed and torqued to 1500 to 1550 inch-pounds. The bolts were checked after 5000 rounds. Break away torque was found to be 1200 inch-pounds or more. They were not tightened until 22, 186 rounds had been fired. The bolts did not appear to turn even though they were not safety wired at any time during the test.

One bolt was damaged (the 12 point head was deformed) in a gun stoppage which occurred after approximately the first 4000 rounds (see Figure 4-1). Upon completion of the test the torque to loosen the bolt



Figure 4-1. Front Track Bolt (Top View)

was still in excess of 1200 inch-pounds. The bolt that had previously been damaged was then tightened and failed at 300 inch-pounds torque in the first thread. The reason for it failing after withstanding four times as much loosening torque has not been found. During analysis of the failure, two fatigue cracks starting on opposite sides of the first thread were found. These cracks reduced the effective cross section area of the bolt. The metal left in the middle failed in shear or a combination of shear and tension. See Figure 4-2.

After this failure the remaining bolts were removed from the rotor. Torque to loosen varied from 1300 to 1800 inch-pounds with the average at 1500 inch-pounds. Examination of these parts showed fatigue cracks in every bolt at the same place as the one which failed. This cracking has been attributed to the fact that the threads were ground rather than rolled. (Grinding creates an undersirable stress concentration.)

The condition of the front tracks (after 22, 186 rounds) was excellent, with no indication of fatigue in any track.

Further test firing was not considered safe after discovering the cracked bolts. Standard bolts were installed in the rotor and it was returned to service.



Figure 4-2. Front Track Bolt (Bottom View)

SECTION V
GUN COMPONENTS

GENTLE SLOPE UNLOCK CAMS

Test firing of the gentle slope unlocking cams had to be terminated after 3000 rounds due to the damage caused by a link separation. Therefore sufficient rounds were not fired to reach any definite conclusions as to the improved performance of these cams. Moreover all firing was done on a standard housing and results may be different on a cycloidal housing.

The tests did indicate that it may be necessary to modify the present gentle slope cam in the area after the roller has left forward dwell. This point showed excessive wear for the first 1000 rounds. However, after 1000 rounds the average drive torque stabilized approximately 20 inch-pounds (6000 spm rate) below the average drive torque with the standard unlock cams.

The wear on the unlock cams (except as previously noted) was very even and less severe than would be encountered on standard unlock cams. The wear point at which the top of the roller shaft bottoms out on the main cam (after unlocking) is moved somewhat with the redesign. This wear also appears to be somewhat less severe.

REPLACEABLE INSERTS

The Kel-F inserts have been test fired a total of 22,186 rounds. No problems were encountered for the first 20,000 rounds. At approximately 20,000 rounds, one firing cam pin failed due to fatigue. It is doubtful that this failure is attributable in any way to the insert even though the insert (1, figure 5-1) was damaged beyond further use. The remaining five were fired until a total of 22,186 rounds had been accumulated. They were then removed from the gun. One insert, (2, figure 5-1) while it was still operating satisfactorily, had been damaged in some unknown way. It appears as though foreign matter had worked its way between the lock block and bolt body. Consequently, it had been jammed into the insert during the unlocking cycle. No attempt was made to fire additional rounds on this insert.

During the 22,186 rounds there were a total of 12 misfires which can be attributed to failure of the insert or some unknown cause. The condition of the remaining four insulators (3, figure 5-1; 4, 5, 6, figure 5-2) is still very good and they have been returned to a gun for additional firing tests.

The inserts have been found to operate satisfactorily at 265 degrees Fahrenheit with the parts free to actuate at that temperature. There is no large difference in parts life between standard insulation and the

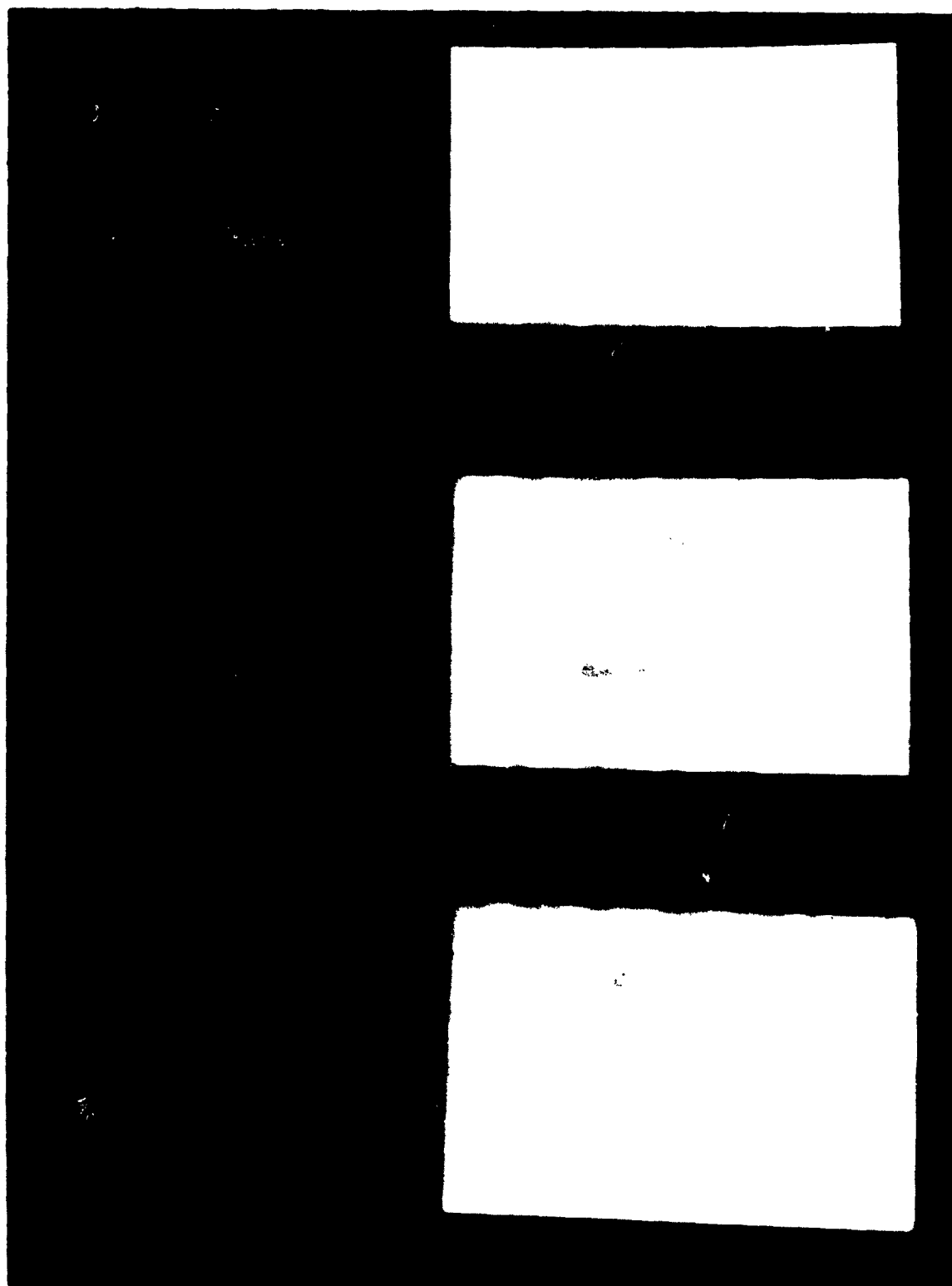


Figure 5-1. Replaceable Inserts (1-3)

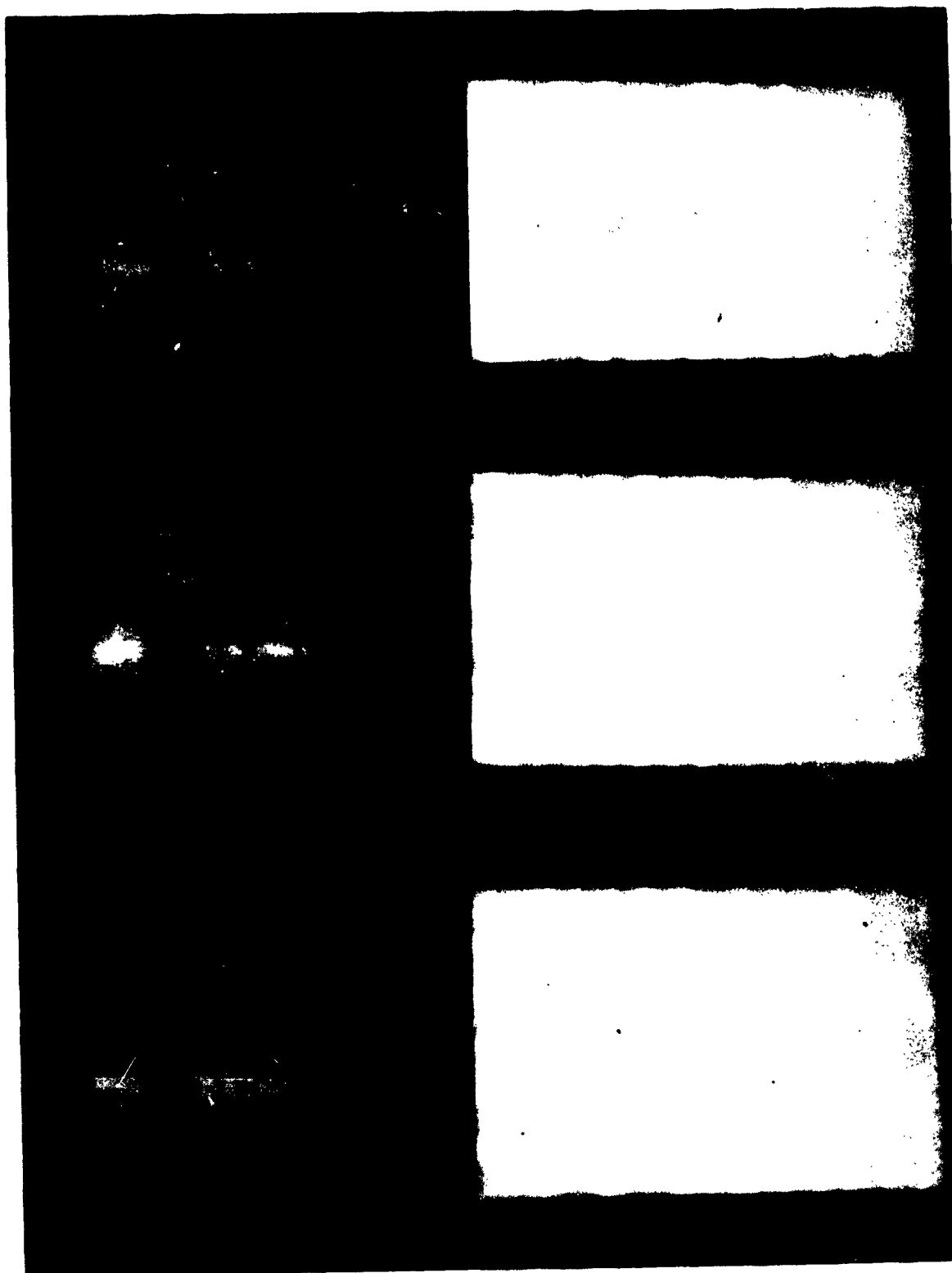


Figure 5-2. Replaceable Inserts (4-6)

replaceable inserts at elevated temperatures (265°F). Both designs fail on approximately the same number of cycles. However, these are failures of material rather than geometry of the parts.

SECTION VI

BORESIGHTING AND TARGET STUDY

Data has been collected on targeting of production guns. A comparison of the new data and that of the past 24 months appears below.

All firing was accomplished at "D" rate (6000 spm).

	24 Month Average	August	September
No. of guns tested	-----	56	54
Distance from average center of impact area (mils)	.06 right .15 down	.33 right 1.0 down	.18 left .70 down
Average Dispersion (mils) 80%	5.1	5.3	5.5

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