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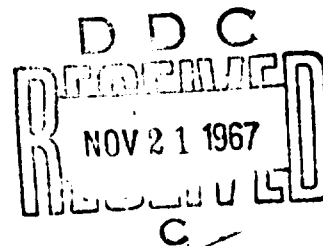
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Report No. SA-TR1-7025

DEVELOPMENT OF A STELLITE-LINED, CHROMIUM-PLATED BARREL FOR

5.56MM MACHINE GUN

Technical Report



Author W. J. Jarrett

Date 30 June 1967

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REPORT: SA-TR1-7025

DATE: 30 June 1967

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DEVELOPMENT OF A STELLITE-LINED, CHROMIUM-PLATED BARREL FOR
5.56MM MACHINE GUN

Technical Report

DA PROJECT TITLE: Small Arms Weapon Systems: Lined and Plated
5.56mm Machine Gun Barrels

DA PROJECT: 1W523901A30408

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patentable material, copyrighted and/or copyrightable materials.

ABSTRACT

The procedure as developed by Springfield Armory for design and fabrication of a stellite-lined, chromium-plated barrel for the 5.56mm machine gun is described. Results of erosion tests of the stellite-lined barrels, standard barrels, and two other types of barrels show that the stellite-lined barrels are superior in erosion resistance. One of the stellite-lined barrels was fired 43,994 rounds prior to rejection. A maximum of 12,476 rounds was fired from one of the standard barrels prior to rejection. The two other types of barrels - a standard barrel with a nitrided bore and a barrel of two-piece construction - were fired 29,874 and 990 rounds, respectively, before rejection. The two-piece barrel has an 18-inch forward section made from Cr-Mo-V steel and the rear section, including the chamber, is made entirely from stellite. All barrels were rejected on the basis of the projectile instability criterion - 15 degrees yaw of 20 per cent of the projectiles fired. All barrels were fired at an average rate of 200 shots per minute.

REPORT
SA-TR1-7025

CONTENTS

| | <u>Page</u> |
|---------------------------------------|-------------|
| Abstract | (1) |
| Subject | 1 |
| Objective | 1 |
| Summary of Conclusions | 1 |
| Recommendations | 2 |
| Introduction | 3 |
| Matériel | 3 |
| Procedure | 4 |
| Design | 4 |
| Development of Fabrication Techniques | 5 |
| Liner Assembly | 6 |
| Gaging | 6 |
| Test | 8 |
| Results and Discussion | 9 |
| APPENDICES | 13 |
| A - Calculations | 14 |
| B - Tabulated Data | 24 |
| C - Photographs | 26 |
| D - Drawings | 33 |
| E - Distribution | 40 |

SUBJECT

Development of a Stellite-Lined, Chromium-Plated Barrel for
5.56mm Machine Gun

OBJECTIVE

To design, develop, and fabricate a lined and chromium-plated 5.56mm machine gun barrel for improved erosion life under extreme rates of fire.

SUMMARY OF RESULTS

Of the four types of machine gun barrels tested, the Springfield Armory 3-piece, stellite-lined barrel with chromium-plated bore gave superior erosion resistance. Two barrels of this configuration, designated Proto 1 and Proto 2, were rejected after 33,433 and 43,994 rounds respectively, were fired. Rejection was based upon projectile instability criterion of 15 degrees yaw in 20 per cent of the shots fired during a test cycle - in this instance, 40 shots out of 200 shots fired.

The two standard barrels with nitrided bores were procured from Manufacturer X and were second in erosion resistance in that these barrels were fired 29,874 and 26,774 rounds before rejection. These barrels were designated N1 and N2, respectively.

The maximum erosion life of the standard unplated barrels in this test was 12,476 rounds for Barrel S11. Barrels 2, 3, 588, and 590B were rejected at 2509, 5088, 7116, and 4209 rounds, respectively.

The standard unplated barrels and the standard barrels with nitrided bores were made from 4150 resulfurized steel.

REPORT
SA-TR1-7025

SUMMARY OF RESULTS - Continued

Barrels 1, 2, 3, 542B, 588, 590B and Proto 1 were tested with both ball and tracer ammunition. All other barrels were tested with ball ammunition only. No definite conclusions can be made concerning the effects of tracer ammunition upon barrel erosion life since this test was not designed to evaluate the differences in erosion rates between tracer and ball ammunition. Ruptured projectile jackets were encountered with the tracer ammunition. Figure 6, Appendix C, shows that the jackets are stripped while the projectiles are in flight.

The barrel designated EX001 was designed and fabricated by Manufacturer X. This barrel was fabricated in two parts, an 18-inch forward section which was made from Cr-Mo-V steel and a rear section that included the chamber which was made entirely from stellite. This barrel was rejected after 990 rounds of the schedule were fired. A past history of 2000 rounds claimed by the manufacturer was not verified up to the time of the completion of the tests.

All of the barrel rejections were based upon the projectile instability criterion. None of the barrels exceeded the criterion of a loss of 200 feet per second or more in projectile velocity. The average firing rate used throughout this test was 200 shots per minute.

RECOMMENDATIONS

It is recommended that barrel of the Springfield Armory prototype design be considered to replace present monobloc, unlined, unplated barrel used in the 5.56mm SAWS candidate machine guns.

INTRODUCTION

In December 1964, a comprehensive study of all rifles and machine guns either being used by or being submitted to the field forces was initiated by the U.S. Army Materiel Command. This study included a class of weapons in which the 5.56mm cartridge is used. Springfield Armory's assignment in this effort was to test existing barrels and, if necessary, to develop a satisfactory barrel for military use.

A preliminary study on 5.56mm barrels showed that it would be extremely unlikely that a 4150 steel monobloc untreated barrel could withstand high temperatures and erosive effects of the propellant gases in repeated firing of a machine gun in the field. Sample calculations showing heat and stress in the barrel components during firing are shown in Appendix A. From these preliminary calculations, materials were selected and physical dimensions were determined for the retainer, the tube, and the liner for a 3-piece barrel. Drawings for the barrel were then prepared. Scaled-down prints of the detail and assembly drawings are included in Appendix D. Gages and fixtures needed for fabricating and inspecting components, assembling the liner, plating the bore, and for proof-firing were designed and built at Springfield Armory.

MATERIEL

Ammunition. 5.56mm Cartridge - Linked Metallic Belt, 4 Ball, M193,
1 Tracer, M196

Ammunition Lot. Ball Ra 5122; Tracer RA 5025

Test Receiver Assemblies. 5.56mm, M.G., Code X, with Trigger Assemblies,
Serial Nos. 000565, 000578, 000588, 001169,
001209, 001213, 002271

MATERIEL - Continued

Test Trigger Assemblies. Two, with Solenoid-Operated Triggers

Test Barrels. Eleven barrels were procured from Manufacturer X.

Eight of these barrels - Nos. 1, 2, 3, 542B, 588, 590B, 810, and 811 - were of the standard design and were made from 4150 resulphurized steel. Two barrels - Nos. N1 and N2 - were made from 4150 resulphurized steel with nitrided bores. Each of these barrels was equipped with a 3-position gas port adjustment valve. Barrel EX001 was made with a 2-piece construction, stellite breech threaded to an 18-inch Cr-Mo-V steel forward section. Barrels Proto 1 and Proto 2 were of the Springfield Armory 3-piece design with Cr-Mo-V steel tube, 6-inch stellite liner, and Cr-Mo-V steel retainer. The bores of these barrels, Proto 1 and Proto 2, were chromium-plated.

Chronograph. Electronics Counters Inc., Model 453, with Lumiline Screens

PROCEDURE

Design. After a preliminary study of the potential firing schedules for 5.56mm machine guns was made, a basic design was selected. The configuration of the design and the materials used in this design provided the greatest resistance to the high temperature and erosive effects of the propellant gases. The selected design was a 3-piece barrel which consisted of a 6-inch stellite liner, shrink-fitted into a chrome-moly-vanadium tube and retained in position by means of a chrome-moly-vanadium retainer. The retainer is threaded to the tube and is torqued in place. To obtain better wear and greater corrosive resistance, it was necessary to chromium-plate the bore of the tube to a thickness of .0005 to .0015 inch.

PROCEDURE - Continued

The design procedure was as follows: The physical dimensions of the retainer, the tube, and the liner were determined. The design criteria used in the determination of these dimensions were based upon the pressure and thermal stresses of the barrel components during firing. These procedures with sample calculations are included in Appendix A. These procedures are given in greater detail in Engineering Design Handbook: Gun Tubes, AMCP 706-252. Drawings were prepared on the basis of the calculations. A complete set of drawings - detail, subassembly and assembly - are included in Appendix D.

Development of Fabrication Techniques.

Fabrication processes and plating techniques for stellite-lined and chromium-plated machine gun barrels were previously developed at Springfield Armory and were used in the manufacture of the 7.62mm M73, the 7.62mm M60, and the caliber .50 M85 machine gun barrels. The basic components for a barrel of the Springfield Armory design are the tube, the retainer, and the liner. The components for the 5.56mm barrel were machined without difficulty even though the bore size was considerably smaller than that of the production 7.62mm barrels.

The tube and the retainer were made from Cr-Mo-V steel and the liner was made from stellite. The bore surface of the tube was chromium-plated to a depth of .0005 to .0015 inch. Even though the chromium-plating of a barrel bore of the 5.56mm caliber had been previously demonstrated,

PROCEDURE - Continued

Development of Fabrication Techniques.

a routine process had not yet been developed. Some experimentation in anode-sizing, anode holder design, and electrolyte-pumping rates was required to establish the proper plating techniques for plating the 5.56mm barrel tubes.

Liner Assembly.

Since the assembly of the liner to the tube requires a shrink-fit condition, the tube must be heated prior to assembly of the liner. In the present 7.62mm production methods, a special machine is used to force the tube over the liner and maintain rifling alignment of the liner during the assembly operation. Minor adjustments of the machine were required to assemble the 5.56mm liners and tubes since this machine was designed primarily for assembly of 7.62mm liners and tubes. A sectioned view of the liner and the tube is shown in Figure 2, Appendix C. It should be noted that the rifling in the liner and the tube in this photograph is not in alignment.

After the liner and the tube were assembled, a high pressure test cartridge was fired through the liner-tube assembly to set the liner. A firing fixture that would accept the liner-tube assembly was used to fire the high pressure test cartridge. After the retainer was assembled to the tube-liner assembly, a second high pressure test cartridge was fired in the assembly.

Gaging.

A complete set of gages was designed and fabricated by the Inspection Engineering Branch, Springfield Armory. These gages were used to measure

PROCEDURE - Continued

the chamber, headspace, and rifling alignment. The following Springfield Armory drawing numbers were assigned to these gages:

| <u>Drawing Number</u> | <u>Gage Title</u> |
|-----------------------|---|
| C-11703121 | Chamber Gaging Ring |
| C-11703122 | Taper Plug (Min. Rear Body Diameter) |
| C-11703123 | Taper Plug (Max. Rear Body Diameter) |
| C-11703124 | Taper Plug (Min. Front Body Diameter) |
| C-11703125 | Taper Plug (Max. Front Body Diameter) |
| C-11703126 | Taper Plug (Min. Cartridge Neck Diameter) |
| C-11703127 | Taper Plug (Max Cartridge Neck Diameter, Front) |
| C-11703128 | Taper Plug (Max Cartridge Neck Diameter, Rear) |
| C-11703129 | Taper Plug (Depth of Bullet Seat) |
| C-11703130 | Special Plug (Min. Bullet Seat Diameter) |
| C-11703131 | Special Plug (Max. Bullet Seat Diameter) |
| C-11703132 | Special Plug (Depth of Second Shoulder) |
| D-11703201 | Headspace |
| D-11703202 | Chamber Indicator and Setting Check (Depth of First Shoulder) |
| F-11703341 | Liner Alignment with Tube |

The bore and groove diameters were measured by use of the appropriate air spindles and associated air column accouterments.

PROCEDURE - Continued

Test.

In the test procedure established for the 5.56mm machine gun barrels, each barrel was subjected to a test schedule consisting of a series of 3000-shot complements at the end of which the bore and groove diameters of the barrel were gaged and a check was made against the two rejection criteria. One of the barrel rejection criterion was a 200 foot per second loss in projectile instrumental velocity. Projectile instrumental velocities were obtained by use of two Lumiline screens and a chronograph. The Lumiline screens were located 15 feet and 35 feet, respectively, from the muzzle of the gun. The recorded instrumental velocities are based upon the location of the Lumiline screens and represent a distance of 25 feet from the muzzle of the gun.

A second barrel rejection criterion was based upon projectile instability - 20 per cent of the projectiles fired exceed 15 degrees yaw when striking a paper target located 100 meters from the muzzle of the gun. Target hits were monitored by the continuously traversing target which is driven by an electrically powered roll.

The barrel test schedule was fired at an average rate of 200 shots per minute in bursts of 9 shots. A test complement of 3000 shots is obtained when the 200 shots per minute test schedule is maintained for 15 minutes.

Because of the excessive number of gun malfunctions occurring during the initial phases of the test, the original 3000-shot test complement was reduced to a 600-shot test complement.

PROCEDURE - Continued

Test.

The ammunition supplied for this test was the standard 5.56mm M193 ball and M196 tracer cartridges. This ammunition was shipped to Springfield Armory, linked in belts of 150 rounds each and arranged in a sequence of four ball cartridges followed by a tracer cartridge. During the early stages of the test, a revised link was substituted to correct the feed and belt separating problems which occurred during burst firing.

Use of the tracer cartridge was discontinued in the later stages of the test when it was discovered that the tracer projectiles were rupturing before striking the target. The ammunition types fired in the test are listed in Tabulated Data, Appendix B.

RESULTS AND DISCUSSION

The machine gun receiver assemblies used throughout this test were from a developmental weapon and the rate of malfunctioning was abnormally high for a weapon of this type. Since one of the primary objectives of this test was to fire as many projectiles through each barrel as possible, expedient action was taken to maintain the firing capabilities of the machine guns. This expedient action required, in many instances, that repair and replacement of parts be made at the expense of cannibalizing other receiver assemblies.

Even though the number and the nature of the gun malfunctions were recorded in the test data, this information was not provided in this report since the objective of this report is principally a barrel study.

RESULTS AND DISCUSSION - Continued

The test was initiated with standard barrel No. 1. A total of 514 rounds was fired through this barrel when gun failure required discontinuation of the test. Since this barrel-gun combination could not be made operable within the time allotted by the test schedule, this barrel was removed from the test and not rejected on the basis of the established rejection criteria.

Barrels 2 and 3 were of the standard design with untreated bores. These barrels were fired a total of 2,509 and 5,088 rounds, respectively, before rejection. Rejection was based upon the projectile stability criterion.

Barrel 542B also a standard barrel with untreated bore was removed from the tests after 1755 rounds were fired. This barrel was withdrawn because of a damaged barrel extension. A malfunction that resulted in a cook-off damaged the gun beyond repair.

Barrels 588 and 590B were fired a total of 7,116 and 4,209 rounds, respectively, prior to rejection which was based upon the projectile stability criterion. These barrels were also of the standard type with untreated bores.

Barrels S10 and S11 were of the standard design with untreated bores. These barrels were rejected after 7,842 and 12,476 rounds, respectively, were fired. The cartridge type used to test these barrels was restricted to the M193 ball ammunition since possible rupture of the tracer projectiles could affect the rejection criterion

RESULTS AND DISCUSSION - Continued

The barrels designated N1 and N2 had bores which were nitrided by a process devised by Manufacturer X. These barrels were injected into the test after the test had started and were fired 29,874 and 26,774 rounds prior to rejection. These barrels were rejected on the basis of the projectile stability criterion. The barrels had velocity losses of 30 and 75 feet per second, respectively.

The barrel identified by No. EX001 was designed and fabricated by Manufacturer X. This barrel was of the 2-piece construction design with an 18-inch forward section made entirely of Cr-Mo-V steel; the rear section which included the chamber was made of stellite. This barrel was rejected after 990 rounds of ball ammunition had been fired. The manufacturer claimed a previous history of 2000 rounds. No information was given by the manufacturer concerning the rate of fire, the firing schedule, or the type of ammunition fired.

Barrels Proto 1 and Proto 2 were designed and fabricated by Springfield Armory. These barrels were of the 3-piece construction design. The three pieces, or components, are the retainer, the stellite liner, and the tube. The tube has a chromium-plated bore. Drawings of these components are included in Appendix D. These barrels were rejected after 33,433 and 43,994 rounds, respectively, were fired. Velocity losses of 92 and 107 feet per second were recorded for these barrels. Rejection of these barrels was based on projectile instability.

RESULTS AND DISCUSSION - Continued

Even though the machine guns used as test vehicles for the barrel erosion tests had an excessive number of malfunctions, test results revealed that the stellite-lined and chromium-plated barrels exhibited superior erosion resistance. It was also evident that the barrels with nitrided bores showed sufficient improvement over the standard barrels with untreated bores to be considered also as a replacement for the standard barrels with untreated bores.

A study of the economics of fabrication for the various types of barrels would be required to provide cost effectiveness data for the various types of barrels. This study should include the various aspects of logistics occurring in field maintenance.

APPENDICES

**REPORT
SA-TRI-7025**

- A - Calculations
- B - Tabulated Data
- C - Photographs
- D - Drawings
- E - Distribution

REPORT
SA-TR107025

APPENDIX A

CALCULATIONS

DEVELOPMENT OF A STELLITE-LINED, CHROMIUM-PLATED BARREL FOR THE
5.56MM MACHINE GUN

Shrink Fit Stresses in Liner and RETAINER

Shrink Fit Pressure between tube and liner

 P_{sl} = Shrink fit pressure between tube and liner r_1 = Radius of Bore = $\frac{.220}{2}$ = .110" r_1 = Outside Radius of Liner = $\frac{.407}{2}$ = .2035" r_2 = Outside Radius of Tube = $\frac{.716}{2}$ = .358 I_1 = Interference between tube and liner = .0012" E_j = Modulus for steel = 30×10^6 psi E_L = Modulus for Stellite = 35×10^6 psi U_j = Poisson's Ratio of Steel = 0.3 U_L = Poisson's Ratio of Stellite = 0.3

$$P_{sl} = \frac{I_1}{r_1 \left[\frac{1}{E_j} \left(\frac{r_2^2 + r_1^2}{r_2^2 - r_1^2} + U_j \right) + \frac{1}{E_L} \left(\frac{r_1^2 + r_1^2}{r_1^2 - r_1^2} - U_L \right) \right]}$$

$$= \frac{.0012}{.2035 \left[\frac{1}{30 \times 10^6} \left(\frac{.358^2 + .2035^2}{.358^2 - .2035^2} + 0.3 \right) + \frac{1}{35 \times 10^6} \left(\frac{.2035^2 + .110^2}{.2035^2 - .110^2} - .3 \right) \right]}$$

$$= 49,660 \text{ psi}$$

Shrink Fit Pressure between tube and retainer

P_{s2} = Shrink fit pressure between tube and retainer

r_o = Outside radius of retainers = $\frac{1.025}{2} = .5125''$

I_2 = Interference between tube and retainer = .0012"

$$P_{s2} = \frac{E_1 I_2 (r_2^2 - r_1^2) (r_o^2 - r_2^2)}{2 r_2^3 (r_o^2 - r_1^2)}$$

$$= \frac{30 \times 10^6 (.0012) (.358^2 - .2035^2) (.5125^2 - .358^2)}{2 (.358)^3 (.5125^2 - .110^2)}$$

$$P_{s2} = 18272 \text{ psi}$$

Shrink fit stress at inner surface of liner

S_{ts1} = Stress resulting from P_{s1}

$$S_{ts1} = -P_{s1} \frac{2 r_1^2}{r_1^2 - r_i^2}$$

$$= -49,660 (2) \left(\frac{.2035^2}{.2035^2 - .110^2} \right)$$

$$= -140,319 \text{ psi}$$

S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = -P_{s2} \frac{2 r_2^2}{r_2^2 - r_1^2}$$

$$= -18272 (2) \left(\frac{.358^2}{.358^2 - .110^2} \right)$$

$$= -40,352 \text{ psi}$$

Shrink fit stress at outer surface of liner

 S_{ts1} = Stress resulting from P_{s1}

$$S_{ts1} = -P_{s1} \frac{r_1^2 + r_i^2}{r_1^2 - r_i^2}$$

$$= -49,660 (1.8256)$$

$$= -90,659 \text{ psi}$$

 S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = -P_{s2} \frac{r_2^2}{r_1^2} \left(\frac{r_1^2 + r_i^2}{r_2^2 - r_i^2} \right)$$

$$S_{ts2} = 18,272 \left(\frac{.128164}{.041412} \right) \left(\frac{.05351225}{.128164 - .0121} \right)$$

$$= -26,072 \text{ psi}$$

Shrink fit stress at inner surface of the tube

 S_{ts1} = Stress resulting from P_{s1}

$$S_{ts1} = P_{s1} \frac{(r_2^2 + r_1^2)}{r_2^2 - r_1^2}$$

$$= 49,660 (1.9547)$$

$$= 97,070 \text{ psi}$$

 S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = -P_{s2} \frac{r_2^2}{r_1^2} \left(\frac{r_1^2 + r_i^2}{r_2^2 - r_i^2} \right)$$

$$= -26,072 \text{ psi}$$

Shrink fit stress at outer surface of tube

S_{ts1} = Stress resulting from P_{s1}

$$S_{ts1} = P_{s1} \frac{2 r_1^2}{r_2^2 - r_1^2}$$

$$= 49660 (2) \left(\frac{.041412}{.086752} \right) = 47,411 \text{ psi}$$

S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = - P_{s2} \left(\frac{r_2^2 + r_i^2}{r_2^2 - r_i^2} \right)$$

$$S_{ts2} = - 18,272 \left(\frac{.128164 + .0121}{.116064} \right) = -22,082 \text{ psi}$$

Shrink fit stress at inner surface of retainer

S_{ts1} = Stress resulting from P_{s1}

$$S_{ts1} = 0$$

S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = P_{s2} \left(\frac{r_o^2 + r_2^2}{r_o^2 - r_2^2} \right)$$

$$= 49,660 \left(\frac{.262655 + .128164}{.134492} \right) = 49,660 \left(\frac{.390820}{.134492} \right)$$

$$= 144,307 \text{ psi}$$

APPENDIX A

Shrink fit outer surface of retainer

S_{ts1} = Stress resulting from P_{s1}

$S_{ts1} = 0$

S_{ts2} = Stress resulting from P_{s2}

$$S_{ts2} = P_{s2} \frac{2 r_2^2}{r_o^2 - r_2^2}$$

$$= 49,660 (2) \left(\frac{.128164}{.134492} \right) = 94,642 \text{ psi}$$

Gas Pressure Stress at inner surface of liner

S_{tp} = Stress resulting from gas pressure

P_d = Propellant gas pressure = 56,000 psi

$$S_{tp} = P_d \frac{(r_o^2 + r_i^2)}{r_o^2 - r_i^2}$$

$$= 56000 \left(\frac{.262656 + .0121}{.250556} \right)$$

$$= 61,410 \text{ psi}$$

Gas Pressure Stress outer surface of liner

$$S_{tp} = P_d \frac{r_i^2}{r_l^2} \left(\frac{r_o^2 + r_2^2}{r_o^2 - r_i^2} \right)$$

$$S_{tp} = 56000 \left(\frac{.0121}{.041412} \right) \left(\frac{.262656 + .128164}{.250556} \right)$$

$$= 25,521 \text{ psi}$$

Gas Pressure stress inner surface of tube

$$S_{tp} = 25,521 \text{ psi}$$

Gas Pressure stress at outer surface of tube

$$\begin{aligned} S_{tp} &= P_d \frac{r_i^2}{r_o^2 - r_i^2} \left(\frac{r_o^2 + r_i^2}{r_o^2 - r_i^2} \right) \\ &= 56000 \left(\frac{.0121}{.128164} \right) (1.5598) \\ &= 8,246 \text{ psi} \end{aligned}$$

Gas Pressure Stress at inner surface of retainer

$$S_{tp} = 8,246 \text{ psi}$$

Gas pressure stress at outer surface of retainer

$$\begin{aligned} S_{tp} &= P_d \frac{2 r_i^2}{r_o^2 - r_i^2} \\ &= 56000 (2) \left(\frac{.0121}{.250556} \right) \\ &= 5,408 \text{ psi} \end{aligned}$$

Combined stress at inner surface of liner

$$S_{cil} = \text{Combined stress at inner surface}$$

$$S_{ts1} = \text{Tangential Stress due to } P_{s1} = -140,319 \text{ psi (see page 16)}$$

$$S_{ts2} = \text{Tangential Stress due to } P_{s2} = -40,352 \text{ psi (see page 16)}$$

$$S_{tp} = \text{Tangential Stress due to Gas Pressure} = 61,410 \text{ psi (see page 19)}$$

$$\begin{aligned}
 S_{cil} &= S_{ts1} + S_{ts2} + S_{tp} \\
 &= -140,319 - 40,352 + 61,410
 \end{aligned}$$

$$S_{cil} = -119,261 \text{ psi}$$

Combined Stress of outer surface of liner

S_{col} = combined stress

S_{ts1} = Tangential Stress due to P_{s1} = -90,659 psi (see page 17)

S_{ts2} = Tangential stress due to P_{s2} = -26,072 psi (see page 17)

S_{tp} = Tangential Stress due to Gas Pressure = 25,521 psi (see page 19)

$$\begin{aligned}
 S_{col} &= S_{ts1} + S_{ts2} + S_{tp} \\
 &= -90,659 - 26,072 + 25,521 \\
 &= -91,210 \text{ psi}
 \end{aligned}$$

Combined stress of inner surface of tube

S_{cit} = combined stress at inner surface

S_{ts1} = Tangential stress due to P_{s1} = 97,070 psi (see page 17)

S_{ts2} = Tangential stress due to P_{s2} = -26,072 psi (see page 17)

S_{tp} = Tangential stress due to gas pressure = 25,521 psi (see page 19)

$$\begin{aligned}
 S_{cit} &= S_{ts1} + S_{ts2} + S_{tp} \\
 &= 97,070 - 26,072 + 25,521 \\
 &= 96,519 \text{ psi}
 \end{aligned}$$

Combined Stress at outer surface of tube

S_{cot} = combined stress at outer surface

S_{ts_1} = Tan stress due to P_{s1} = 47,411 psi (see page 18)

S_{ts_2} = Tan stress due to P_{s2} = -22,082 psi (see page 18)

S_{tp} = Tan stress due to gas pressure = 8,246 psi (see page 20)

$S_{cot} = S_{ts_1} + S_{ts_2} + S_{tp}$

$S_{cot} = 47,411 - 22,082 + 8,246$

$= 33,575 \text{ psi}$

Combined stress at inner surface of retainer

S_{cil} = combined stress at inner surface

S_{ts_1} = Tan stress due to P_{s1} = 0 (see page 19)

S_{ts_2} = Tan stress due to P_{s2} = 144,307 psi (see page 18)

S_{tp} = Tan stress due to Gas pressure = 8,246 psi (see page 20)

$S_{cil} = S_{ts_1} + S_{ts_2} + S_{tp}$

$= 0 + 144,307 + 8,246$

$= 152,553 \text{ psi}$

Combined stress at outer surface of retainer

S_{coc} = combined stress at outer surface

S_{ts1} = Tan stress due to P_{s1} = 0 (see page 19)

S_{ts2} = Tan stress due to P_{s2} = 94,642 psi (see page 19)

S_{tp} = Tan stress due to gas pressure = 5,408 psi (see page 20)

$$S_{coc} = S_{ts1} + S_{ts2} + S_{tp}$$

$$= 0 + 94,642 + 5,408$$

$$= 100,050 \text{ psi}$$

Maximum stress of assembly occurs at inner surface of retainer and has a value of 152,553 psi.

REPORT
SA-TR1-7025

APPENDIX B

TABULATED DATA

APPENDIX B
 TABULATED DATA
 SPRINGFIELD ARMORY
 MACHINE GUN BARREL EROSION TEST RESULTS
 WEAPON: CODE X M.G.
 PROGRAM: JAWS
 CAL: 5.56 MM
 DATE: 16 JAN 67

| BARREL DESIGNA- TION NO. | CONSTRUC- TION | MANUFAC- TURER | TUBE MATERIAL | PARTIAL LINER | LINER MATERIAL | BOF- TREATMENT | AMMUNITION TYPE | FIRING SCHEDULE RDS/MIN | ROUNDS FIRED | VELOCITY - FT/SEC | | REASON FOR REJEC- TION | REASON FOR TEST TERMINA- TION |
|--------------------------------|-------------------|-------------------|------------------|------------------|-------------------|-------------------|--------------------|-------------------------------|-----------------|-------------------|-------|------------------------------|-------------------------------------|
| | | | | | | | | | | INITIAL | FINAL | | |
| 1 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 514 | 3159 | 3143 | -45 | WEAPON FAILURE |
| 2 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 2509 | 3164 | 3155 | -9 | --- |
| 3 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 5088 | --- | --- | --- | --- |
| 542B | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 1755 | --- | --- | --- | WEAPON FAILURE |
| 58B | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 7116 | 3135 | 3132 | +47 | --- |
| 590B | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL & TRACER | 200 | 4209 | 3190 | 3125 | -65 | --- |
| S10 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL | 200 | 7842 | 3154 | 3094 | -60 | --- |
| S11 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | UNPLATED | BALL | 200 | 12476 | 3134 | 3083 | -51 | --- |
| N1 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | NITRIDED | BALL | 200 | 29874 | 3130 | 3100 | -30 | --- |
| N2 | 1-PIECE | CODE X | 4150 STEEL | NO | --- | NITRIDED | BALL | 200 | 26774 | 3172 | 3097 | -75 | --- |
| EX.001 | 2-PIECE | CODE X | * | NO | --- | UNPLATED | BALL | 200 | 990 | 3121 | --- | --- | --- |
| PROTO 1 | 3-PIECE | S.A. | CR-MO-V STL | YES | STELLITE | CR-PLATED | BALL & TRACER | 200 | 33433 | 3206 | 3114 | -92 | --- |
| PROTO 2 | 3-PIECE | S.A. | CR-MO-V STL | YES | STELLITE | CR-PLATED | BALL | 200 | 43994 | 3199 | 3092 | -107 | --- |

* STELLITE REAR OR BREECH SECTION WITH CR-MO-V FORGABLE SECTION
 Δ 15° YAW IN 40 OUT OF 200 SHOTS FIRED.

PHOTOGRAPHS

Figure

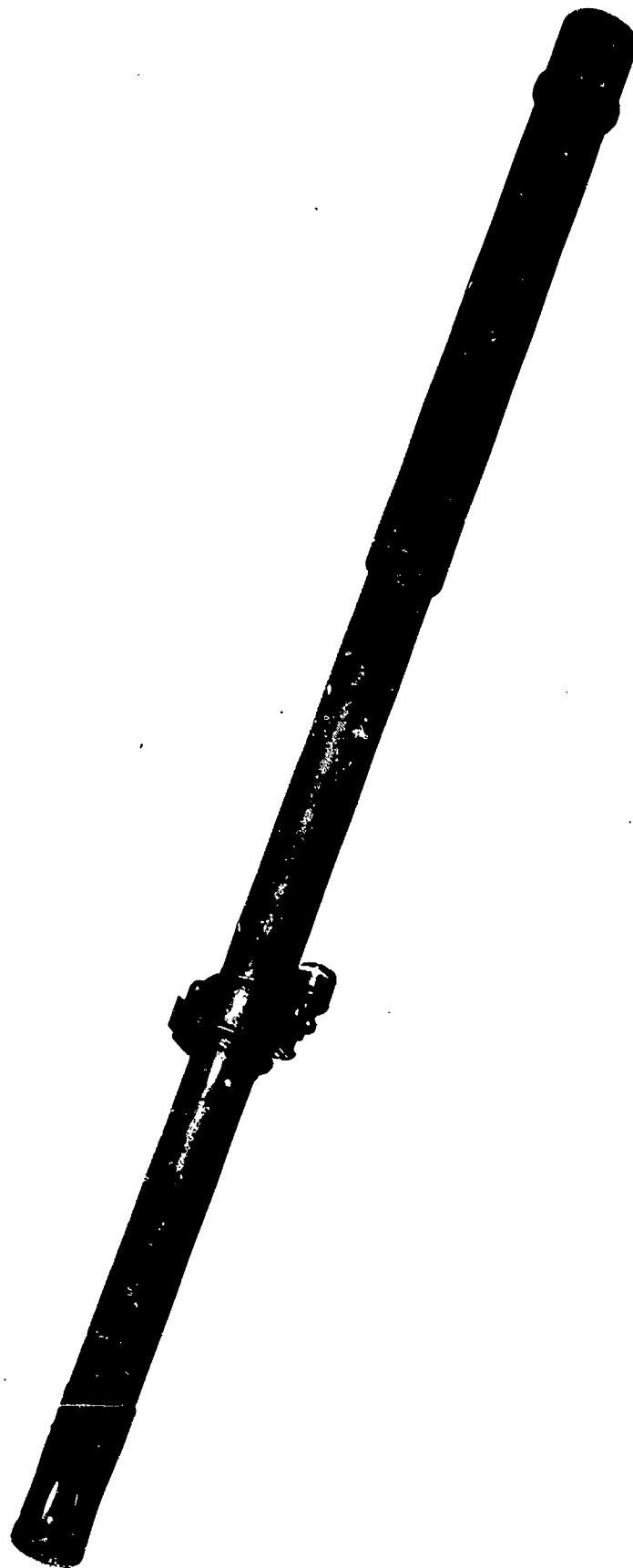
Caption

- 1 5.56mm Lined Machine Gun Barrel
 Springfield Armory Design
- 2 5.56mm Tracer Projectiles
 Fired from Machine Gun during Erosion Test
- 3 Tooling Setup Barrel:
 Tube and Liner Rifling Alignment for
 5.56mm Lined Machine Gun Barrel
- 4 5.56mm Machine Gun Firing RA5025 Tracer Ammunition:

 Upper Left. L2 Barrel - Ball Am. 16 In. from Muzzle
 Upper Right. L2 Barrel - Tracer Am. 16 In. from Muzzle
 Lower Left. L2 Barrel - Tracer Am. 16 In. from Muzzle
 Lower Right. New Barrel - Tracer Am. 16 In. from Muzzle
- 5 5.56mm Machine Gun Firing RA5025 Tracer Ammunition:

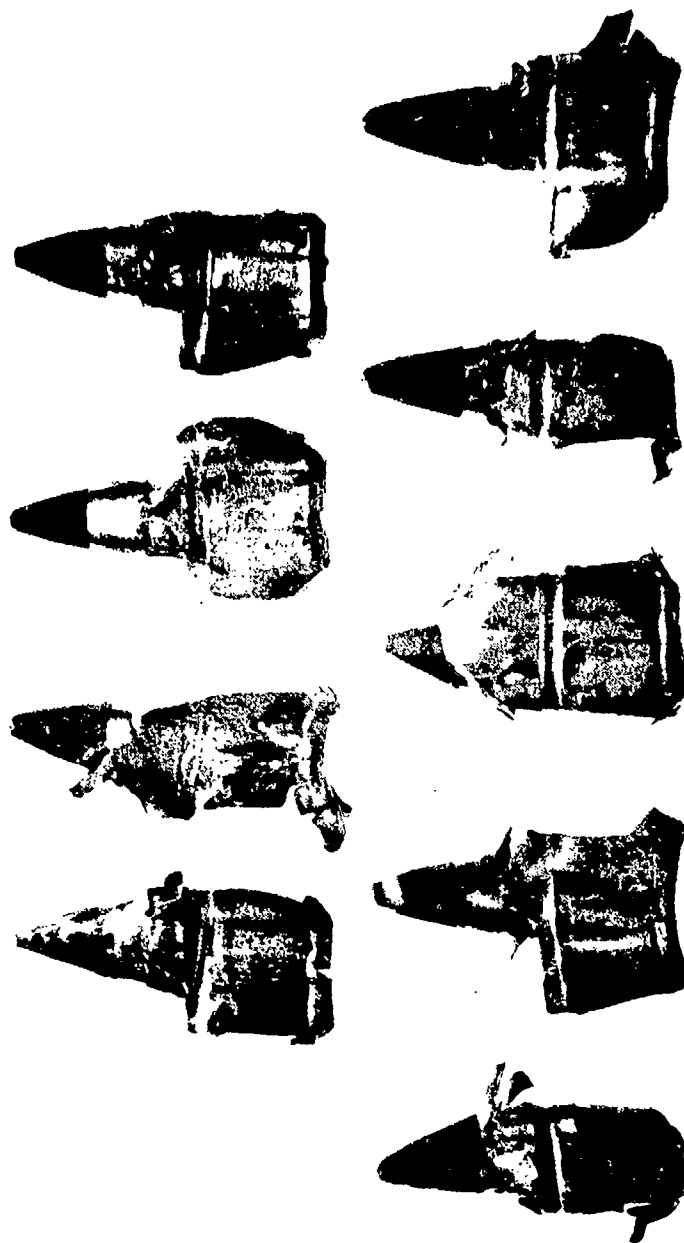
 Upper Left. L2 Barrel - Tracer Am. 11 In. from Muzzle
 Upper Right. L2 Barrel - Tracer Am. 16 In. from Muzzle
 Lower Left. L2 Barrel (Cold) - Tracer Am. 16 In. from Muzzle
 Lower Right. L2 Barrel (Hot) - Tracer Am. 16 In. from Muzzle
- 6 5.56mm Machine Gun Firing RA5025 Tracer Ammunition:

 Left. L2 Barrel - Tracer Am. 16 In. from Muzzle
 Right. L2 Barrel - Tracer Am. 16 In. from Muzzle



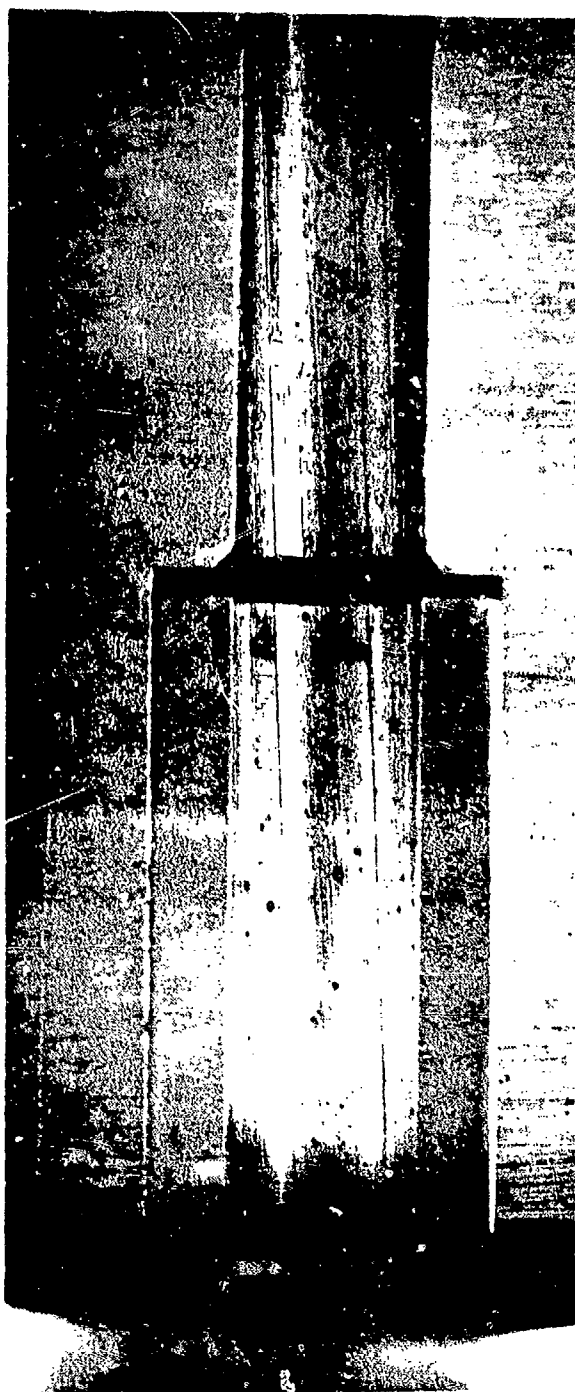
5.56MM LINED MACHINE GUN BARREL - SPRINGFIELD ARMORY DESIGN

Figure 1



5.56MM TRACER PROJECTILES FIRED FROM MACHINE GUN DURING

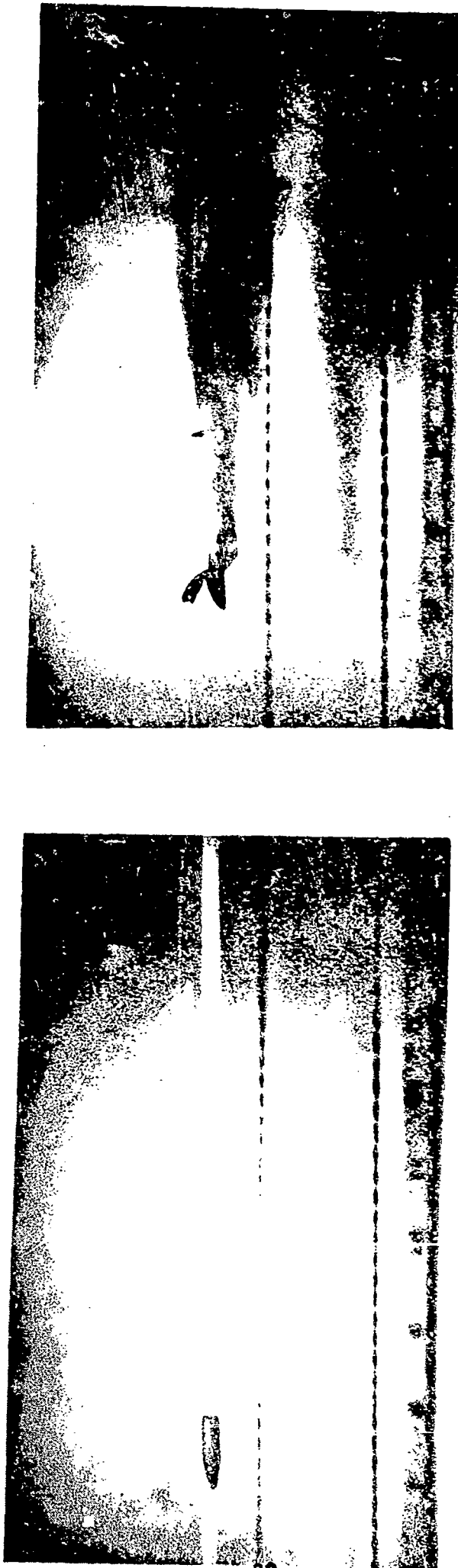
Figure 2



TOOLING SETUP BARREL

Tube and Liner Rifling Alignment for 5.56mm Lined Machine Gun Barrel

FIGURE 3



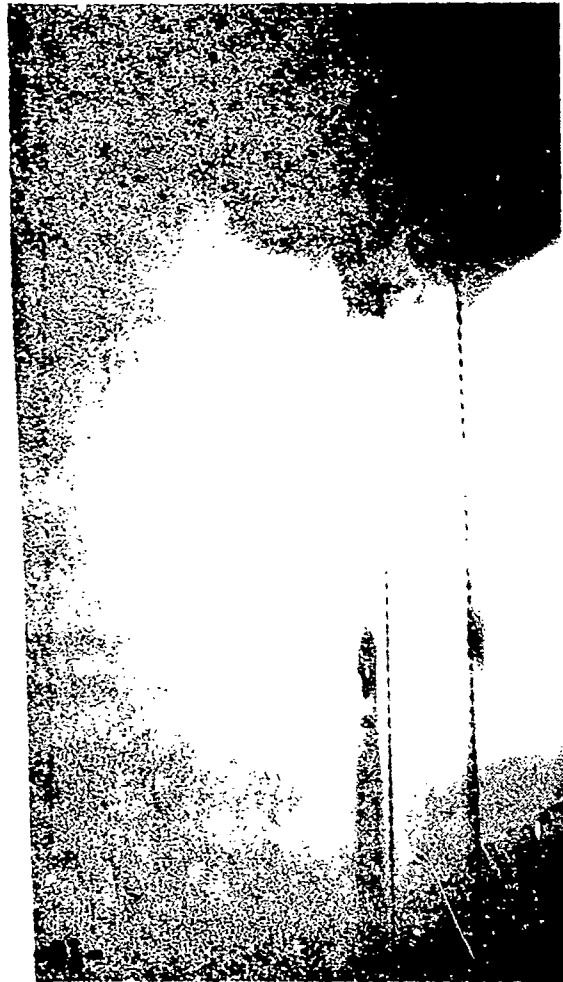
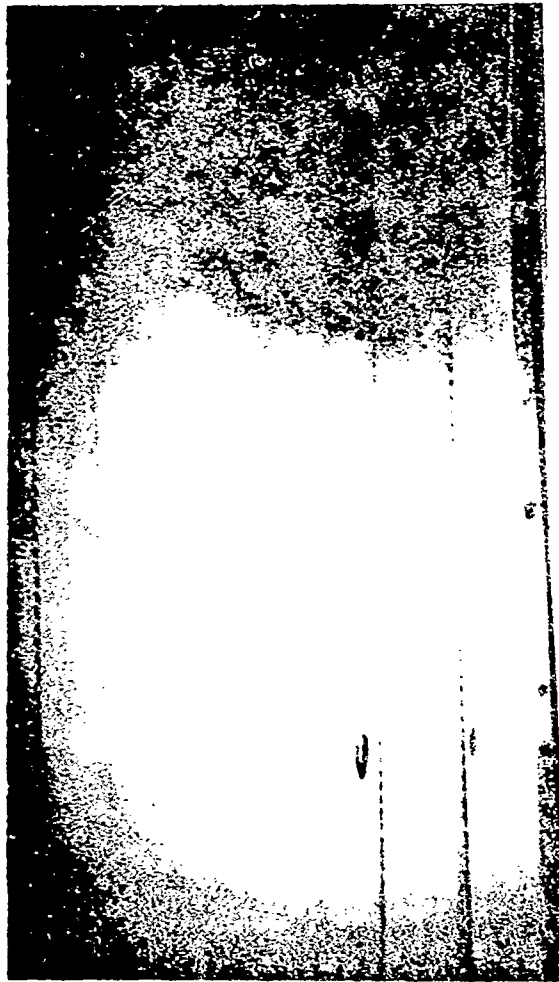
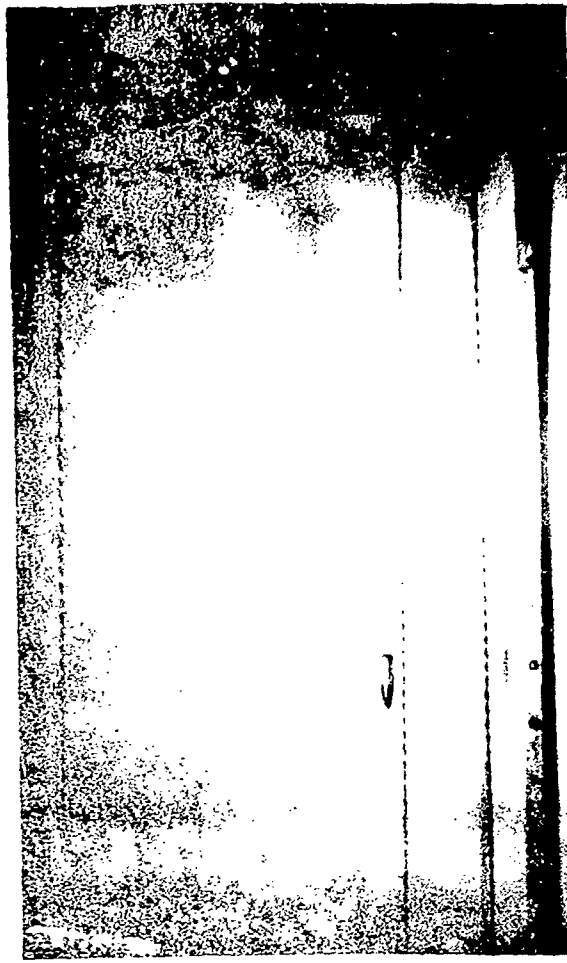
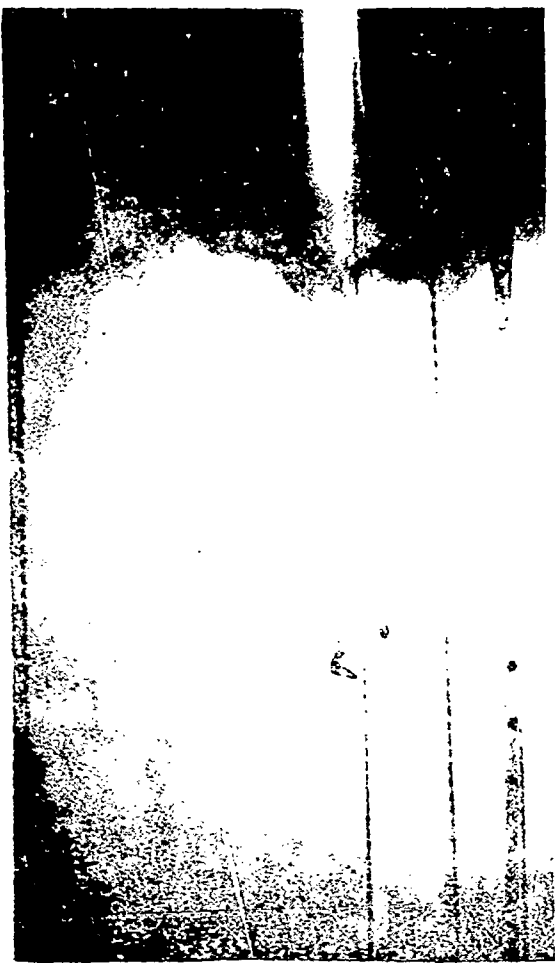
-30-

5.56MM MACHINE GUN FIRING RA5025 TRACER AMMUNITION

UPPER LEFT: L2 Barrel - Ball Ammunition 16 Inches from Muzzle
UPPER RIGHT: L2 Barrel - Tracer Ammunition 16 Inches from Muzzle
LOWER LEFT: L2 Barrel - Tracer Ammunition 16 Inches from Muzzle
LOWER RIGHT: New Barrel - Tracer Ammunition 16 Inches from Muzzle

FIGURE 4

*Photom
copy
6/19/70*

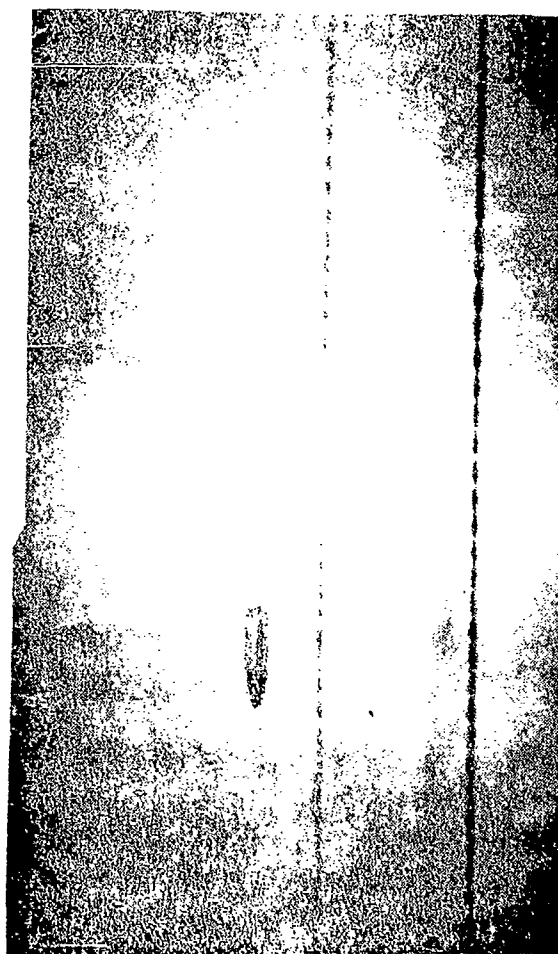
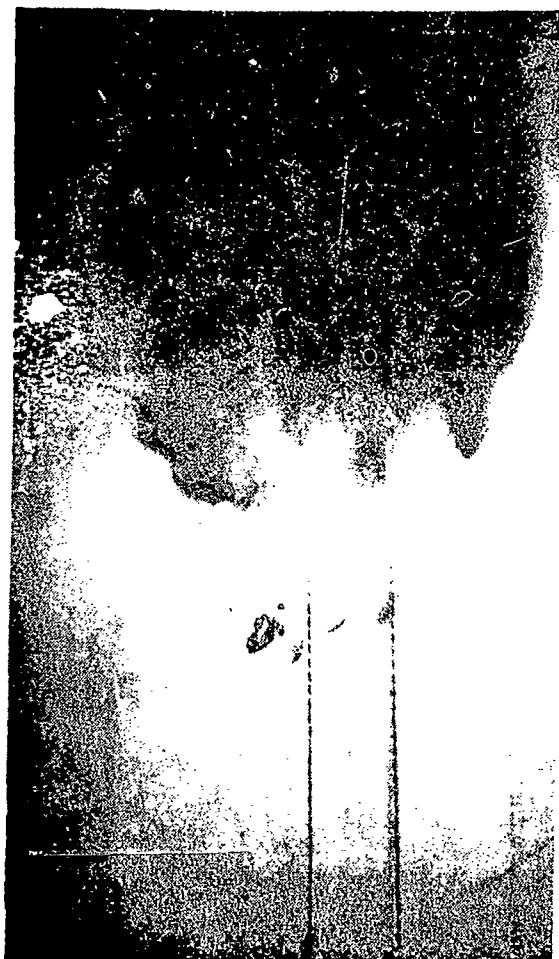


5.56MM MACHINE GUN FIRING RA5025 TRACER AMMUNITION

UPPER LEFT: L2 Barrel - Tracer Ammunition 11 Inches from Muzzle
UPPER RIGHT: L2 Barrel - Tracer Ammunition 16 Inches from Muzzle

LOWER LEFT: L2 Barrel (Cold) - Tracer Ammunition 16 Inches from Muzzle
LOWER RIGHT: L2 Barrel (Hot) - Tracer Ammunition 16 Inches from Muzzle

FIG /RE 5



5.56MM MACHINE GUN FIRING RA5025 TRACER AMMUNITION

LEFT: L2 Barrel - Tracer Ammunition 16 Inches from Muzzle

RIGHT: L2 Barrel - Tracer Ammunition 16 Inches from Muzzle

FIGURE 6

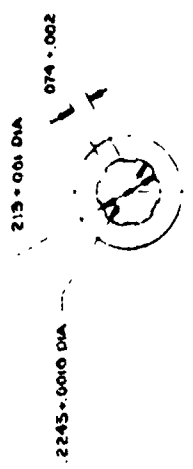
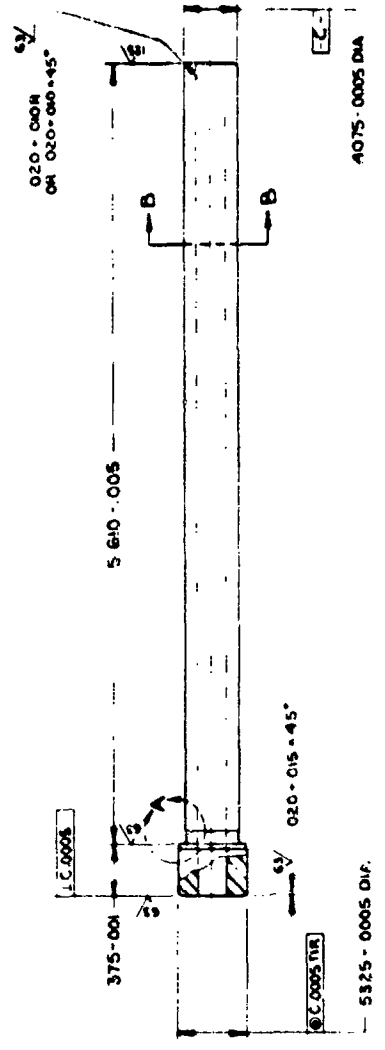
Handwritten signature and date:
4/24/80

DRAWINGS

| <u>Number</u> | <u>Title</u> |
|---------------|-------------------------|
| SAF51210 | Tube, Barrel |
| SAD51211 | Liner, Tube |
| SAD51212 | Retainer, Liner |
| SAF51213 | Barrel Tube Subassembly |
| SAD51214 | Barrel, Tube Assembly |
| SAD51215 | Barrel Subassembly |

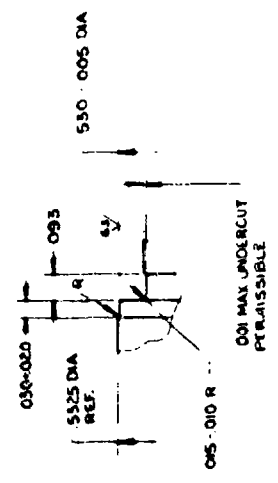
| REV | DESCRIPTION | DATE | APPROVED |
|-----|-------------|------|----------|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |

NOTE
1 SURFACE FINISH $\sqrt{16}$ UNLESS OTHERWISE SPECIFIED



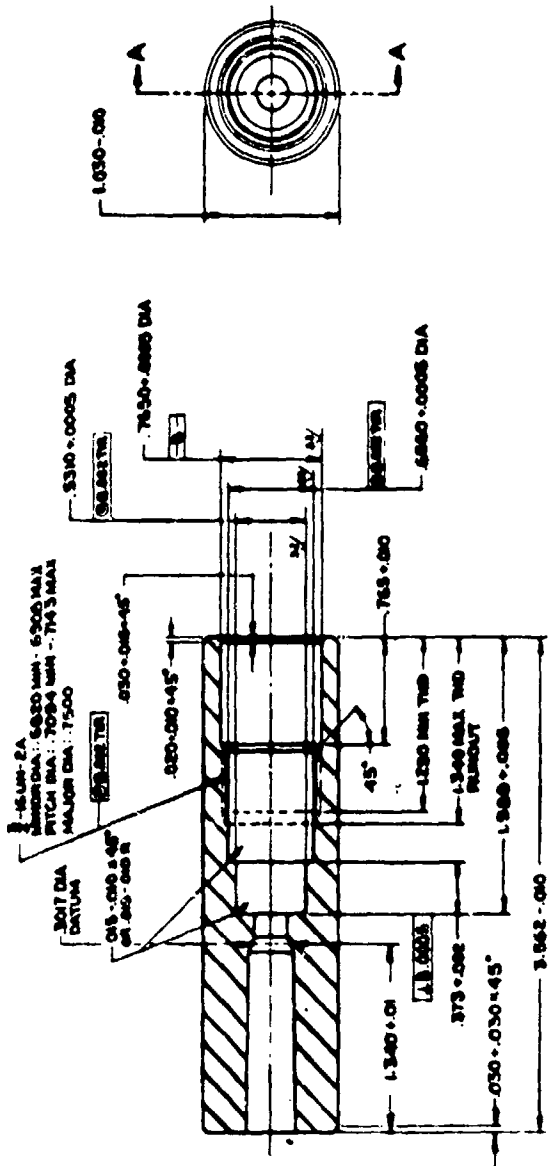
SECTION B-B
SCALE 4/1

RIFLING SHALL CONSIST OF 6 GROOVES
EQUALLY SPACED
1 TURN IN 12 INCHES R/H
PERMISSIBLE ECCENTRICITY BETWEEN GROOVE AND RIFLING .002 TIR
BUT DEPTH OF GROOVE NOT TO VARY MORE THAN .001 IN ENTIRE LENGTH



DETAIL A
SCALE 4/1

| | | | | | |
|-------------|--|-----------------|--|------------------|--|
| PART NO. | | DATE OF DRAWING | | DATE OF REVISION | |
| D 19205 | | JUNE 65 | | | |
| SA-D51211 | | REVISION | | | |
| LITERATURE | | APPROVED | | | |
| DRAWN BY | | CHECKED BY | | | |
| DESIGNED BY | | ENGINEER | | | |
| MATERIAL | | SPECIFICATION | | | |
| TREATMENT | | FINISH | | | |
| APPROVED | | DATE | | | |
| BY | | DATE | | | |

[illegible]

SECTION A-A

NOTE:
1 FOR FINAL CHAMBER DIMENSIONS SEE DRAWING SA-F1213
2 MATERIAL, STEEL, SPEC. NO.: S-11095
CARBIDE: POLYTRON-HARDUM.
3 MEAT TREATMENT: BEFORE MACHINING.
HEAT AT 160°F ± 25°F. QUENCH IN AGITATED OIL. TEMPER TO 1400°F ± 35°F.
4 SURFACE FINISH: 125 UNLESS OTHERWISE SPECIFIED. MEAT TREATMENT METHOD IS FOR GUIDANCE.
5 SURFACE FINISH: 125 UNLESS OTHERWISE SPECIFIED.

[illegible][illegible]

77
 CLOSING TIME: 10:00-11:00 PM
 1000 10th Ave. S.W. Seattle, WA 98104



WITH MATING SURFACES AND
THREADED FLASH SUPPRESSOR
AND BARREL SUB-ASSEMBLY DRY
AND FREE OF LUBRICANT.
REPLACE FLASH SUPPRESSOR
IN BARREL AND TORQUE
TO 30 LB FT-LBS TORQUE.

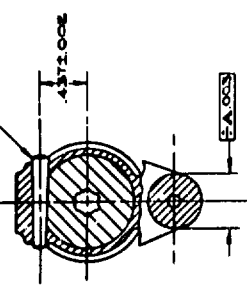
BASE, FRONT SIGHT
CADILLAC GAGE PART 2021

SUPPRESSOR, FLASH
CADILLAC GAGE PART 2057

BARREL TUBE ASSY
SAD 51214

15.85 ± 0.030 DIA. (HOLE)
TUBE ASSEMBLY TAPER REAM
FOR AN365A10P7.

AN 365A10P7



SECTION A-A

6. LUBRICANT
7. LUBRICANT
8. LUBRICANT
9. LUBRICANT
10. LUBRICANT
11. LUBRICANT
12. LUBRICANT
13. LUBRICANT
14. LUBRICANT
15. LUBRICANT

PART NO.

| | | | | | |
|------------------------------------|--|------------------------------------|--|------------------------------------|--|
| ORIGINAL DATE JUNE 59 | | DESIGNED BY JUN 59 | | CHECKED BY JUN 59 | |
| TOLERANCES ON DIMENSIONS ± .005 | | TOLERANCES ON DIMENSIONS ± .005 | | TOLERANCES ON DIMENSIONS ± .005 | |
| MATERIAL STEEL | | MATERIAL STEEL | | MATERIAL STEEL | |
| HEAT TREATMENT NONE | | HEAT TREATMENT NONE | | HEAT TREATMENT NONE | |
| FINISH NONE | | FINISH NONE | | FINISH NONE | |
| APPROVED JUN 59 | | APPROVED JUN 59 | | APPROVED JUN 59 | |
| BY JUN 59 | | BY JUN 59 | | BY JUN 59 | |
| FOR JUN 59 | | FOR JUN 59 | | FOR JUN 59 | |
| PART NO. SAD 51215 | | PART NO. SAD 51215 | | PART NO. SAD 51215 | |
| SUB-ASSEMBLY BARREL | | SUB-ASSEMBLY BARREL | | SUB-ASSEMBLY BARREL | |
| 1920S D | | 1920S D | | 1920S D | |
| SAD 51215 | | SAD 51215 | | SAD 51215 | |

UNCLASSIFIED

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|---|--|------------------------------------|
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| Springfield Armory, Springfield, Mass. 01101 | | Unclassified |
| | | 2b. GROUP |
| | | N.A. |
| 3. REPORT TITLE | | |
| DEVELOPMENT OF A STELLITE-LINED, CHROMIUM-PLATED BARREL FOR 5.56MM MACHINE GUN | | |
| 4. DESCRIPTIVE NOTES (Type of report and inclusive dates) | | |
| Technical Report | | |
| 5. AUTHOR(S) (Last name, first name, initial) | | |
| Jarrett, W. J. - Registered Professional Engineer, Commonwealth of Massachusetts Registration No. 19767 | | |
| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
| 30 June 1967 | 45 | None. |
| 8a. CONTRACT OR GRANT NO. | 8a. ORIGINATOR'S REPORT NUMBER(S) | |
| N.A. | SA-TRI-7025 | |
| b. PROJECT NO. | 8b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) | |
| 1W523801A30408 | None. | |
| c. AMCIS CODE | | |
| 5523.11.45808.08.01 | | |
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| None. | | U.S. Army Materiel Command |
| 13. ABSTRACT | | |
| <p>The procedure as developed by Springfield Armory for design and fabrication of a stellite-lined, chromium-plated barrel for the 5.56mm machine gun is described. Results of erosion tests of the stellite-lined barrels, standard barrels, and two other types of barrels show that the stellite-lined barrels are superior in erosion resistance. One of the stellite-lined barrels was fired 43,994 rounds prior to rejection. A maximum of 12,475 rounds was fired from one of the standard barrels prior to rejection. The two other types of barrels - a standard barrel with a nitrided bore and a barrel of two-piece construction - were fired 29,874 and 990 rounds, respectively, before rejection. The two-piece barrel has an 18-inch forward section made from Cr-Mo-V steel and the rear section, including the chamber, is made entirely from stellite. All barrels were rejected on the basis of the projectile instability criterion - 15 degrees yaw of 20 per cent of the projectiles fired. All barrels were fired at an average rate of 100 shots per minute.</p> | | |

DD FORM 1473

FORM
1 JAN 64

UNCLASSIFIED

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|---|--------|----|--------|----|--------|----|
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| 1. Barrels, Machine Gun, 5.56mm | | | | | | |
| 2. Stellite-lined Machine Gun Barrels, 5.56mm | | | | | | |
| 3. Erosion in Small Arms Machine Guns | | | | | | |
| 4. Small Arms Weapon Systems (SAWS) | | | | | | |

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