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NPG REPORT NO. 1195

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

Sixty-fourth Partial Report

on

3"/70 Caliber Gun Barrels

Final Report

on

Rapid Fire Life Tests of 3"/70 Caliber

Barrel Type C Mod 2 Serial 24483

Project No.: NPG-Re5a-21-1-53

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NPG REPORT NO. 1195

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

PART A

SYNOPSIS

1. This report covers the rapid-fire life tests of 3"/70 caliber barrel Type C Mod 2 Serial 24483, a barrel employing a water jacket for cooling purposes. This barrel was proof fired and subjected to a series of rapid fire programs similar to those carried out in Type C Mod 2 Barrel 24485 except that a double-base cool picrite powder was used exclusively. All rounds were fired at a rate of approximately 90 rounds per minute.

2. The tests reported herein were carried out for the following purposes:

a. To establish the wear rate in a water cooled 3"/70 caliber gun under rapid fire conditions when a cool picrite propellant is employed.

b. To obtain velocity and range data under rapid fire conditions.

c. To obtain information relative to the cooling characteristics of a water-jacketed barrel under rapid fire conditions.

3. As a result of these tests, it is concluded that:

a. The life of the Type C Mod 2 barrel fired under rapid fire conditions, with a cool double base picrite propellant having a nominal flame temperature of 2050°K, is approximately five times that of a similar barrel fired with nonhygroscopic powder having a flame temperature of 2450°K. This statement concerns erosion near the origin of bore only. Forward bore wear in barrel No. 24483 was unsatisfactory.

b. More than 700 rounds can be fired without loss in muzzle velocity.

c. The volume of erosion becomes sufficiently great to cause loss in muzzle velocity even though a perfect gas seal may be offered by the Probert type rifling.

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SECURITY INFORMATION

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

d. The ammunition-gun combination is unsatisfactory. Asymmetrical bore wear commences early in gun life and soon develops to an extent which makes range accuracy unacceptable.

e. Velocity uniformity is unacceptable. The indicated velocity variation may, however, be due in part to measurement error and thus not represent the true performance of the gun.

f. Water jacket cooling is approximately at the same level as in barrel No. 24485.

g. Further development work is required on the water jacket to improve its mechanical strength to the point where it can withstand the shocks encountered under rapid fire conditions. The water jacket employed with the Type D Mod O barrel in the Westinghouse Mount has given very satisfactory service.

CONFIDENTIAL

NPG REPORT NO. 1195

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

TABLE OF CONTENTS

	<u>Page</u>
SYNOPSIS	1
TABLE OF CONTENTS.	3
AUTHORITY.	4
REFERENCES	4
BACKGROUND	4
OBJECT OF TEST	5
PERIOD OF TEST	5
REPRESENTATIVES PRESENT.	5
DESCRIPTION OF ITEM UNDER TEST	5
DESCRIPTION OF TEST EQUIPMENT.	6
PROCEDURE.	7
RESULTS AND DISCUSSION	8
CONCLUSIONS.	11
RECOMMENDATIONS.	11
DISPOSITION OF MATERIAL.	12
APPENDIX A - EROSION DATA.	FIGURES 1-3 (Incl)
APPENDIX B - VELOCITY DATA	FIGURES 4-5 (Incl)
APPENDIX C - TABULATION OF VELOCITY DATA	TABLE I
APPENDIX D - D/R DATA.	FIGURE 6
APPENDIX E - TEMPERATURE-TIME CURVES	FIGURES 7-12 (Incl)
APPENDIX F - PHOTOGRAPH OF RUPTURED CARTRIDGE CASE.	FIGURE 13
APPENDIX G - DISTRIBUTION.	1 (Only)

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SECURITY INFORMATION

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

PART B

INTRODUCTION

1. AUTHORITY:

The work reported herein was conducted under Task Assignment NPG-Re5a-21-1 as established by reference (a). Specific authority for the tests is contained in reference (b).

2. REFERENCES:

- a. BUORD Conf ltr NP9 (Re5a-21)-RMS:cmj of 23 May 1949
- b. BUORD Conf ltr (Re5a)-FBW:cmj S74-1(3") of 28 June 1949
- c. BUORD Conf ltr Re5e-JWW:11h S74-1(3") of 28 Apr 1953
Ser 55919
- d. NPG Conf Report No. 365 of 9 Sep 1949
- e. NPG Conf Report No. 414 of 8 Nov 1949
- f. NPG Conf Report No. 745 of 16 Mar 1951
- g. NPG Conf Report No. 400 of 9 Nov 1949
- h. NPG Conf Report No. 865 of 19 Oct 1951

3. BACKGROUND:

a. Rapid fire tests have been conducted in 3"/70 Caliber guns to determine the erosion rate with a nonhygroscopic powder at a flame temperature of 2450°K, to compare the effectiveness of inter-face and water jacket cooling, and to compare the effectiveness of increasing twist tapered rifling with constant twist disappearing rifling. The results of these tests were reported in references (d), (e), and (f).

b. By reference (b) the Bureau of Ordnance requested that rapid fire tests be carried out in 3"/70 caliber barrel Type C Mod 2 Serial No. 24483 to determine the wear rate with a double case cool picrite propellant. In addition to the erosion studies, velocity, range and cooling water temperature data were to be obtained. A firing schedule as nearly identical as possible to that fired in the barrels of references (d), (e), and (f) was to be carried out.

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

4. OBJECT OF TEST:

- a. To establish the wear rate in 3"/70 caliber guns under rapid fire conditions when a double base cool picrite propellant is employed.
- b. To obtain velocity and range data under rapid fire conditions.
- c. To obtain information relative to the cooling characteristics of this type barrel under rapid fire conditions.

5. PERIOD OF TEST:

- | | |
|---------------------------|-------------------|
| a. Date of Project Letter | 28 June 1949 |
| b. Date Barrel Received | 15 June 1949 |
| c. Date Commenced Test | 14 September 1949 |
| d. Date Completed Test | 18 December 1952 |

6. REPRESENTATIVES PRESENT:

Mr. J. W. Widman	Bureau of Ordnance, Re5e
Mr. C. R. Wrasse	Naval Gun Factory

PART CDETAILS OF TEST

7. DESCRIPTION OF ITEM UNDER TEST:

- a. The 3"/70 caliber barrel Type C Mod 2 is of monoblock construction. The chamber and bore are plated with 0.006 of chromium. The rifling has constant twist of one turn in 25 calibers and tapers to a smooth bore 9.976 aft of the muzzle. The barrel is cooled by means of water pumped through an external jacket at the rate of approximately 92 gallons per minute.

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

b. A double base cool picrite propellant was used exclusively during this test. EX-6586 with a calculated flame temperature of 2065°K was used initially and after this index was exhausted, a ballistically similar propellant, EX-6827, with a calculated flame temperature of 2041°K, was used for the remainder of the test. Powder temperature was controlled at 90°F for the erosion check rounds. For the rapid fire rounds the powder temperature was not controlled but was between 70° and 90°F at the time the rounds were taken to the gun. Since the rounds were exposed to the outside temperature for an appreciable time, the powder temperatures were affected. The degree of this effect depended on the temperature differences prevailing and the length of exposure.

c. The XCM-11 primer was used on all rounds.

d. Projectile Type EX-11 was used exclusively during this test. This is a short projectile, the body length being 9.42, and it has a forward rotating band. The bands are made of gilding metal.

e. Rapid fire tests were conducted with the subject barrel mounted in the 3"/70 caliber mount Mk 35 Mod 0, a rapid fire mount capable of firing at the cyclic rate of 90 rounds per minute.

8. DESCRIPTION OF TEST EQUIPMENT:

a. Projectile Muzzle Velocity Measurement:

Muzzle velocities were measured by means of a single pair of solenoids and a counter chronograph. The location of the solenoids with respect to the gun muzzle and the distance between solenoids fell into two main categories:

(1) Rounds 1 through 530:

Muzzle distance - 68!0

Distance between solenoids - 47!0

(2) Rounds 531 through 1442

Muzzle distance - 59!0

Distance between solenoids - 36!0

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

b. Maximum Chamber Pressure:

The maximum chamber pressure on the erosion check rounds was determined from three 1/30 area copper crusher gauges.

c. Range Measurements:

Ranges were measured by visual bearings from three shore stations.

d. Cooling Water:

Water for the cooling system was stored in an open tank containing approximately 2000 gallons. Water was circulated through the water jacket at a rate of 92 gallons per minute.

e. Cooling Water and Recoil Fluid Temperature:

Temperature data of the incoming and outgoing water, and of the recoil fluid, were obtained by the use of iron-constantan thermocouples and were recorded by a "Brown" recording potentiometer.

9. PROCEDURE:

a. It was desired to conduct the rapid-fire tests by firing a series of 75-round sequences, each sequence to consist of five 15-round bursts with a five second interval between bursts. All bursts were fired at a cyclic rate close to 90 rounds per minute. Frequent casualties in the operation of the automatic loader prevented completion of many of the scheduled 75-round sequences. Figure 1 of Appendix (A) indicates the burst lengths and total rounds of each sequence.

b. The barrel was bore-searched and star-gauged after each series and was sent to the Naval Gun Factory for bore-photographing and gauging at frequent intervals.

c. A 5-round, cold gun, single fire, erosion check was fired at intervals approximating 75 rounds of rapid fire. Chamber pressure, muzzle velocity and ranges were recorded for each round.

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

d. Rapid fire life tests were carried out until the erosion rate was well established.

e. Cooling water was pumped through the water jacket at a rate of 92 gallons per minute. Casualties to the water cooling system prevented complete water cooling on several programs.

10. RESULTS AND DISCUSSION:

a. The subject barrel was fired a total of 1444 actual rounds or 1442.3 ESR where the ESR factor was taken as 1.00 for a 3400 f/s charge with either powder index. A total of 1248 rounds was fired in automatic rapid fire and 196 rounds were fired single fire.

b. Erosion Data:

(1) Figure 1 of Appendix (A) is a plot of bore enlargement at the origin vs equivalent service rounds for barrel No. 24483 and for barrel No. 24485 which is included for reference purposes. Referring to the origin of the curve for barrel No. 24483, it is seen that the new gun diameter at the origin of bore was 3.009 as determined by Naval Proving Ground star-gauging. The Naval Gun Factory gauging indicated a diameter of 3.003. After 165 ESR both gaugings were in agreement. The change in bore diameter, 0.007 to 0.013, which took place at the origin of bore over the first 165 ESR is believed due to the peening action of the projectiles on the lands. The chromium plating remained intact for approximately 740 ESR. After plate removal commenced the average wear rate was 0.0001 per round. Similar figures for barrel No. 24485 are 130 ESR and 0.00045 per round. Gun life with the cool picrite propellant is increased by an approximate factor of five over the nonhygroscopic propellant. If the intended 75 round programs had been fired to completion each time, the wear rate would undoubtedly have increased to some extent. A higher strength gun steel which would resist a peening action might prolong the life of the plating at the origin of bore.

(2) Figure 2 is a family of bore profiles near the origin of bore. The point of maximum erosion is seen to be approximately 2.0 aft of the origin of bore with a secondary maximum 7.5 aft of the origin of bore. It is likely that the erosion near the origin of bore together with the large forward bore wear would cause loss in muzzle velocity.

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

(3) Figure 3 is a family of curves showing the progress of forward bore wear. The excessive wear is undoubtedly caused by projectile body contact with the lands during bore travel. A visual bore search indicated that the plating had commenced flaking and stripping in the forward bore area after 165 ESR had been fired, and spiral wear could be detected visually after 743 ESR. This condition was expected to occur and did not affect the primary purpose of this test, which was to determine the erosion rate near the origin of bore.

c. Velocity Data:

(1) Figure 4 of Appendix (B) is a plot of velocity loss vs bore enlargement at the origin of bore based on the single fire erosion check rounds. Data from barrel No. 24485 is again shown with that from barrel No. 24483. There is a definite velocity drop in barrel No. 24485 and this condition has been experienced in other 3"/70 Caliber barrels after erosion has taken place. The data obtained from barrel No. 24483 with propellant EX-6586 is too erratic to draw any conclusions. The data obtained from firings with propellant EX-6827 appear to indicate a velocity drop but this may be partly due to the charge assignment. The assessments of EX-6586 and EX-6827 were reported in references (g) and (h). EX-6827 is a slower propellant than EX-6586 and since the charge weight for each was established in a new gun, they may very well not match in a worn gun. On two occasions when both propellants were fired in barrel No. 24483 on the same day, their mean velocities differed by approximately 50 f/s, EX-6586 giving the higher velocity.

(2) Figure 5 of Appendix (B) shows single fire and rapid fire 5-round average velocities plotted against equivalent service rounds. The indicated velocity uniformity is unsatisfactory. It is not believed that the actual velocities are as erratic as indicated for the following reasons:

(a) After 531 ESR the near velocity solenoid was moved from 68!0 to 59!0 from the muzzle and the distance between solenoids reduced from 47!0 to 36!0. Recent visual observations of the near solenoid tower under these conditions revealed that excessive oscillations were set up by the muzzle blast and that they did not die out before the next round passed through the solenoid at the rate of fire maintained by the Mk 35 Mount. The solenoid towers are of wood construction and are very difficult to guy securely against the muzzle blast. The effect of the movement of the near solenoid on velocity measurement and of other factors such as timing errors is magnified by the short distance between solenoids.

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

(b) Occasionally empty cartridge cases ejected during rapid fire were observed to strike the base of the near solenoid tower adding to the movement produced by the muzzle blast.

(c) The reduced stability of the projectiles brought about by the forward bore wear may introduce an error into the velocity determination through the drag function used to correct measured velocity to muzzle velocity. It is not likely that this effect is very large.

(3) Appendix (C) is a table of velocity data and some statistical analyses carried out for certain rapid fire sequences. Those sequences with a definite trend in velocity were omitted as well as those with more than one index of powder and those with less than 35 rounds. Bartlett's test indicates that the first four sequences of the first five are homogeneous. After the fifth sequence of this analysis the solenoid and muzzle distances were reduced as indicated in paragraph 10c(2)(a) above. The sequences after this point were not homogeneous as a group, their standard deviations ranging from 13 to 23 ft/sec. The worst of those programs omitted from this analysis had a range between mean 5-round velocities of 74 ft/sec.

d. Range Data:

(1) Figure 6 of Appendix (D) shows the uncorrected D/R plotted against equivalent service rounds for the slow fire erosion check rounds. The range uniformity is poor as would be expected from the excessive forward bore wear.

e. Temperature Rise of Cooling Water and Recoil Fluid:

(1) Figures 7 through 12 of Appendix (E) are temperature vs time curves for the inlet and outlet cooling water temperatures for three rapid fire sequences and temperature vs time curves of the recoil cylinder fluid for six sequences. The maximum temperature rise in °C for the cooling water and the recoil fluid is shown in the following table:

CONFIDENTIAL

NPG REPORT NO. 1195

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

<u>Rounds</u>	<u>Cooling Water Temperature Rise</u>	<u>Recoil Fluid Temperature Rise</u>
48	-*	48
39	13*	42
75	-**	55
48	10	47
58	8***	43
62	-*	60

* Outlet water hose broke

** Water jacket muzzle lock nut flew off

*** 3" split developed in water jacket.

f. Figure 13 of Appendix (F) is a photograph of an EX-3 steel cartridge case which ruptured during rapid firing.

PART D

CONCLUSIONS

11. As a result of these tests it is concluded that:

a. The life of the Type C Mod 2 barrel fired under rapid fire conditions, with a double base cool picrite propellant having a nominal flame temperature of 2050°K, is approximately five times that of a similar barrel fired with nonhygroscopic powder having a flame temperature of 2450°K. This statement concerns erosion near the origin of bore. Forward bore wear in barrel No. 24483 was unsatisfactory.

b. More than 700 rounds can be fired without loss in muzzle velocity.

c. The volume of erosion becomes sufficiently great to cause loss in muzzle velocity even though a perfect gas seal may be offered by the Probert type rifling.

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SECURITY INFORMATION

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

d. The ammunition component assembly in the Type C Mod 2 barrel is unsatisfactory. Asymmetrical bore wear commences early in gun life and soon develops to an extent which makes range accuracy unacceptable.

e. Velocity uniformity is unacceptable. The indicated velocity variations may, however, be due to measurement and thus not represent the true performance of the gun.

f. Water jacket cooling is approximately at the same level as in barrel No. 24485.

g. Further development work is required on the water jacket to bring it to a performance level where it can withstand the shocks encountered under rapid fire conditions.

PART E

RECOMMENDATIONS

12. It is recommended that:

a. A reliable master standard powder be established for the 3"/70 caliber gun.

b. That the master powder be used in conjunction with the test powder in erosion check firings conducted in connection with erosion trials.

c. That hot gun erosion checks be fired immediately after rapid fire.

PART F

DISPOSITION OF MATERIAL

13. The subject barrel is in storage at the Naval Proving Ground and may be of further use for special tests.

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NPG REPORT NO. 1195

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

The tests upon which this report is based were conducted by:
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By direction

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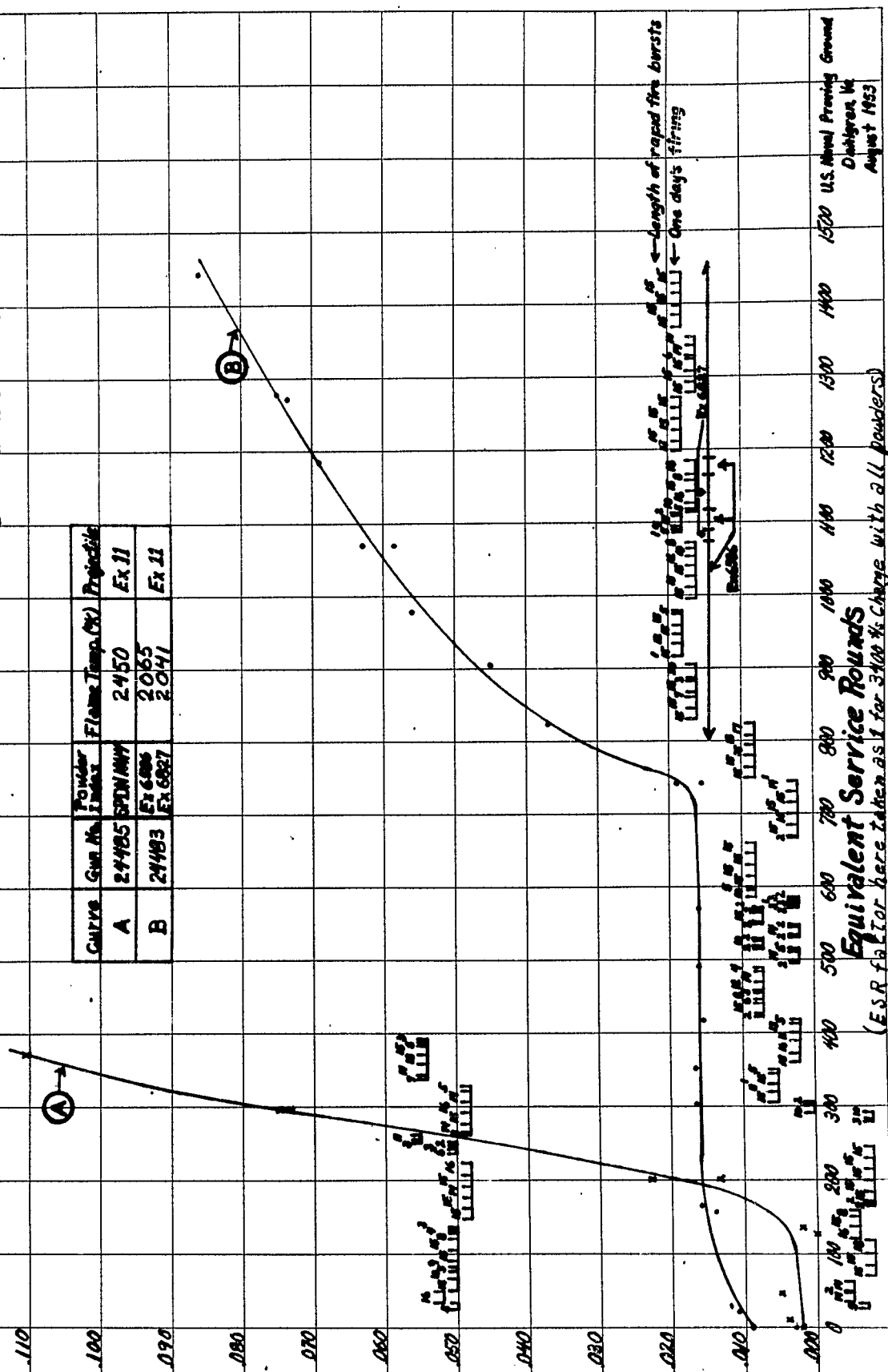
3770 Caliber Gun Type C-2

Relative Erosion under Rapid Fire Conditions
due to NH and Cool Picrite Propellants

Bore Enlargement at Origin vs Equivalent Service Rounds

Firing Schedule: 75 round programs in 15 round bursts with 5 second intervals between bursts.

Curve	Gun No.	Powder	Flame Temp. (°K)	Projectile
A	24485	SPDNMH	2450	Ex 11
B	24483	Ex 686 Ex 6827	2065 2041	Ex 11



Equivalent Service Rounds

(E.S.R. factor here taken as 1 for 3400 ft Charge with all powders)

1500 U.S. Naval Proving Ground
Dahlgren, Va.
August 1953

Figure 1

3"/70 CALIBER GUN TYPE C-2 NO 24483

EROSION DUE TO COOL PICRITE PROPELLANTS UNDER RAPID FIRE CONDITIONS
"BORE" ENLARGEMENT VS DISTANCE FORWARD OF ORIGIN OF BORE

Propellants: Ex 6586 (9.26 lbs)
Ex 6827 (9.44 lbs)
Projectiles: Ex 11

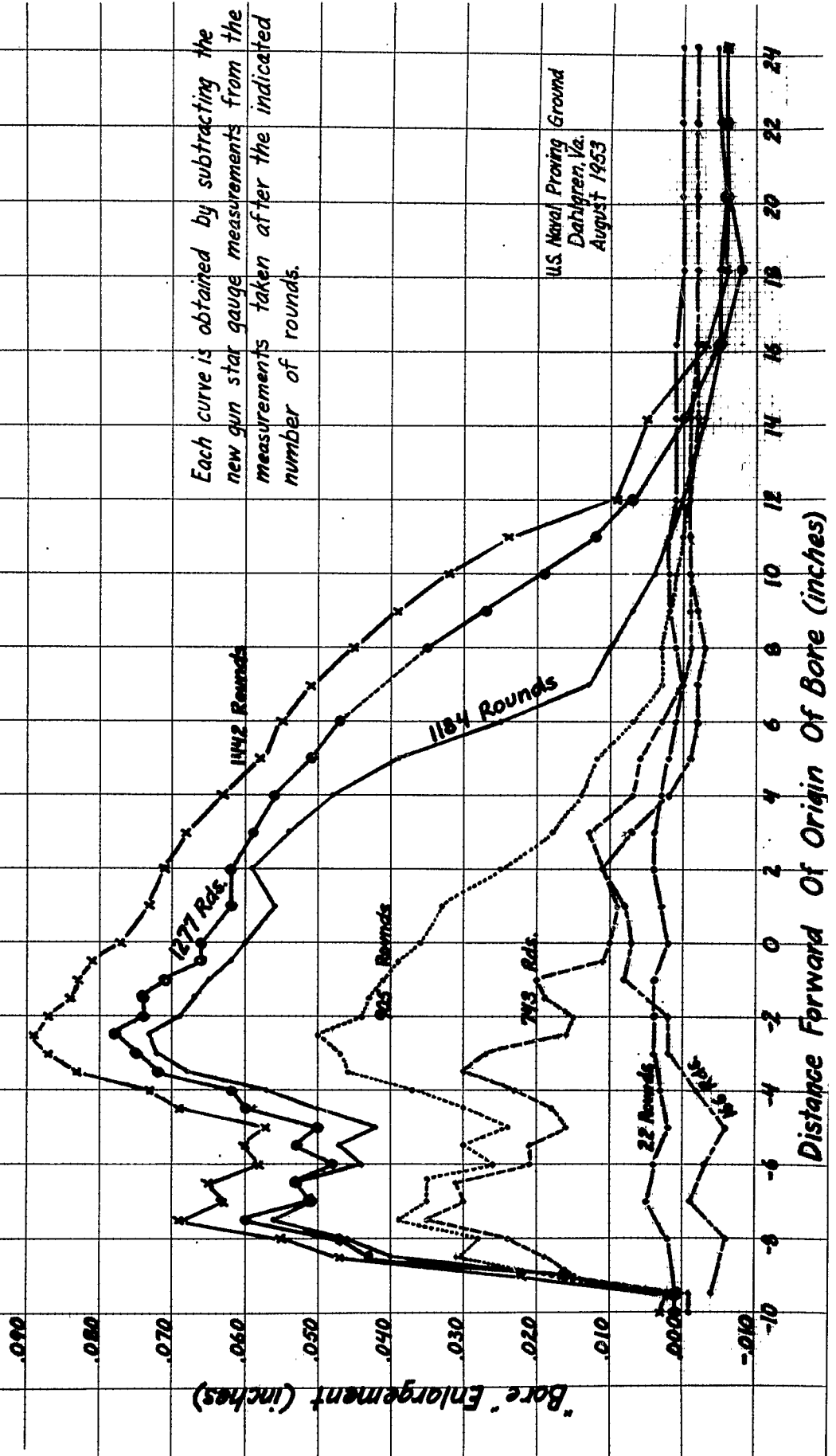
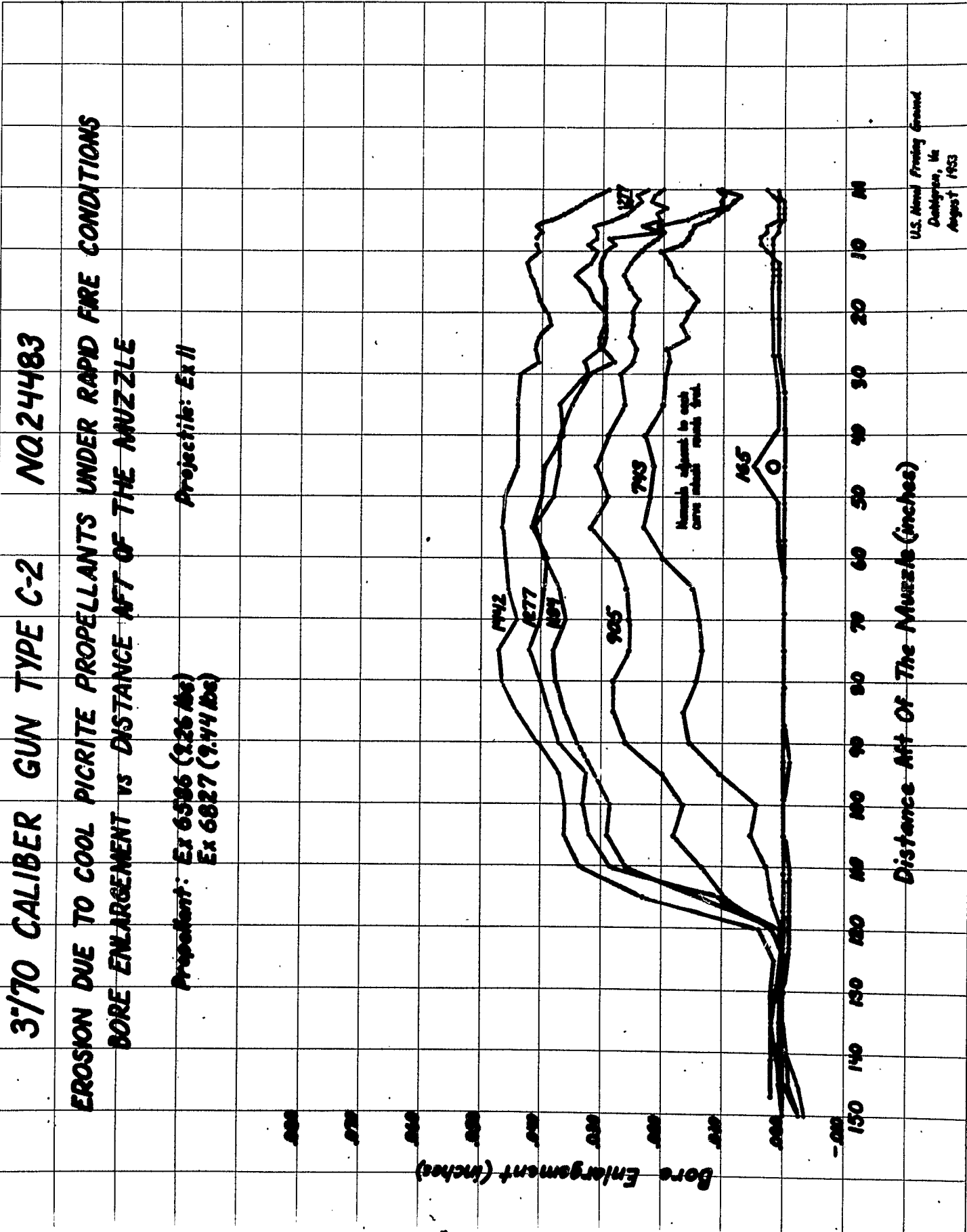
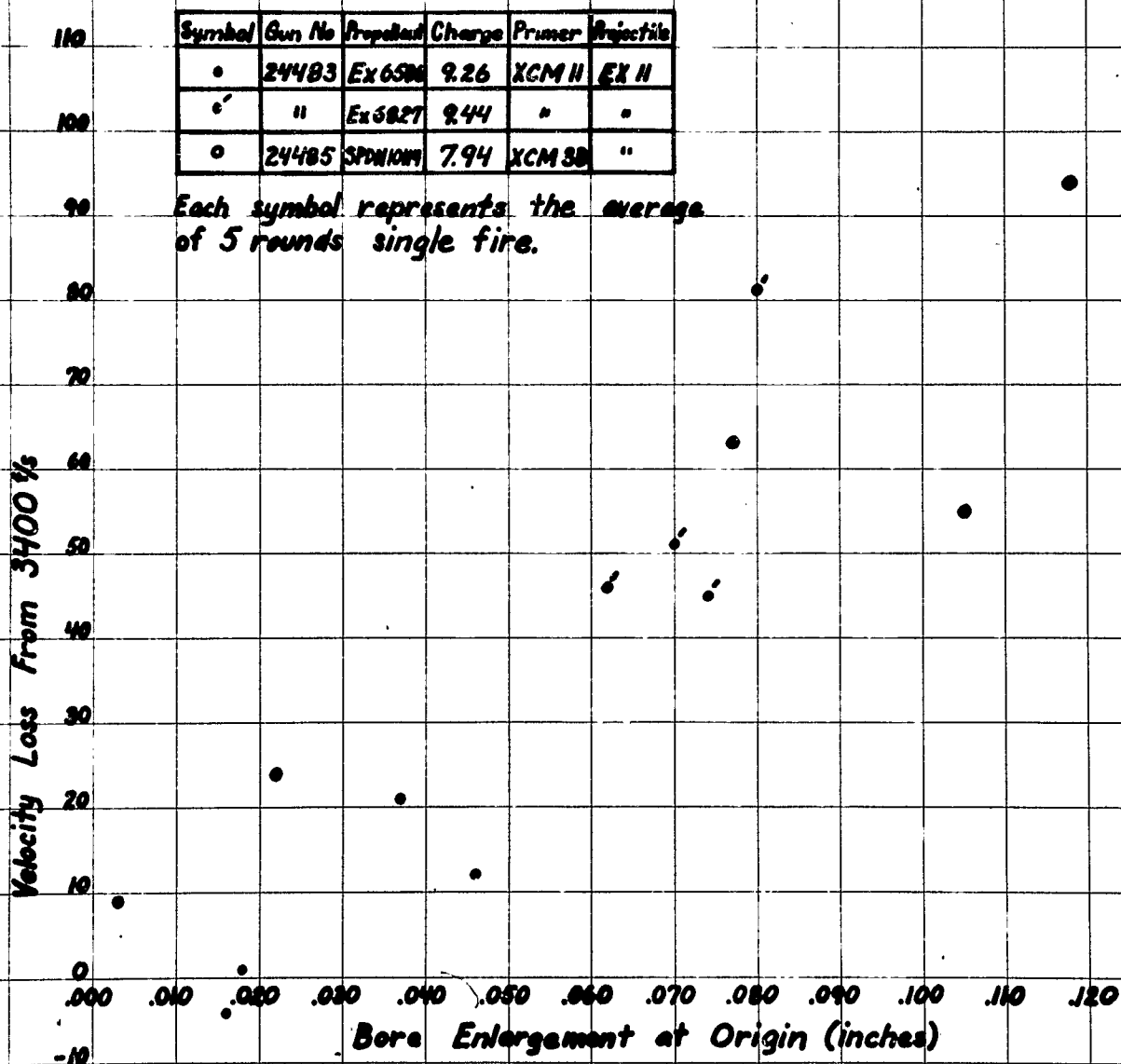


Figure 2-2
APPENDIX A



3"/70 CALIBER GUNS TYPE C-2

EROSION DATA VELOCITY LOSS vs BORE ENLARGEMENT AT ORIGIN



3"170 CALIBER GUN TYPE C-2 NO.24483

MUZZLE VELOCITY VS EQUIVALENT SERVICE ROUNDS*

Ambient Temperature

78 69 64 53 51 47 46 45 36 35 25 21 38 75 58

3520
3500
3480
3460
3440
3420
3400
3380
3360
3340
3320
3300
0

Muzzle Velocity (f/s)

Vertical lines indicate short stoppages during rapid fire

200 400 600 800 1000 1200 1400 1600

Equivalent Service Rounds*

Ex 4 Cases
Ex 3 Cases

*ESR Factor taken as 1 for 3400 f/s charge all powders

Symbol	Powder	Charge	Projectile	Type of fire
•	Ex6586	9.26	Ex II	Erosion Check
○	Ex6827	9.44	"	"
•	Ex6586	9.26	"	Rapid Fire
x	Ex6827	9.44	"	"

U.S. Naval Proving Ground
Dahlgren, Va.
August 1953

Figure 5
APPENDIX B

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NPG REPORT NO. 1195

Rapid Fire Life Tests of 3"/70 Caliber
Barrel Type C Mod 2 Serial 24483

TABLE I

Velocity Uniformity Within Sequences*

<u>All Rounds of Sequence Included</u>				<u>Rounds Greater Than 2.5^S From the Mean Omitted</u>		
Rounds	$\bar{X}$	N	s ²	N	s ²	s
70-115	3439	48	87.9	46	68.1	8.2
120-155	3438	37	172.3	35	96.6	9.8
168-243	3440	77	189.7	73	76.2	8.7
305-350	3495	42	121.8	41	100.4	10.0
360-415	3465	58	256.2	57	213.3	14.6
670-735	3362	69	404.0	66	297.3	17.2
750-825	3374	74	269.2	73	206.2	14.4
920-980	3398	61	488.5	57	158.2	12.6
995-1070	3403	75	590.9	71	334.4	18.3
1125-1165	3356	40	220.4	40	220.4	14.8
1200-1270	3328	72	556.0	71	514.1	22.7
1370-1445	3315	75	291.2	68	157.6	12.5

* Those sequences with a definite trend in velocity are not included.

3"/70 CALIBER GUNS TYPE C-2 NO.24483

$\frac{D}{R}$ vs ESR

% Uncorrected (%)

Projectiles: Ex II
Propellant : Ex 6586 and Ex 6827

U.S. Naval Proving Ground
Dahlgren, Va.
August 1953

Equivalent Service Rounds

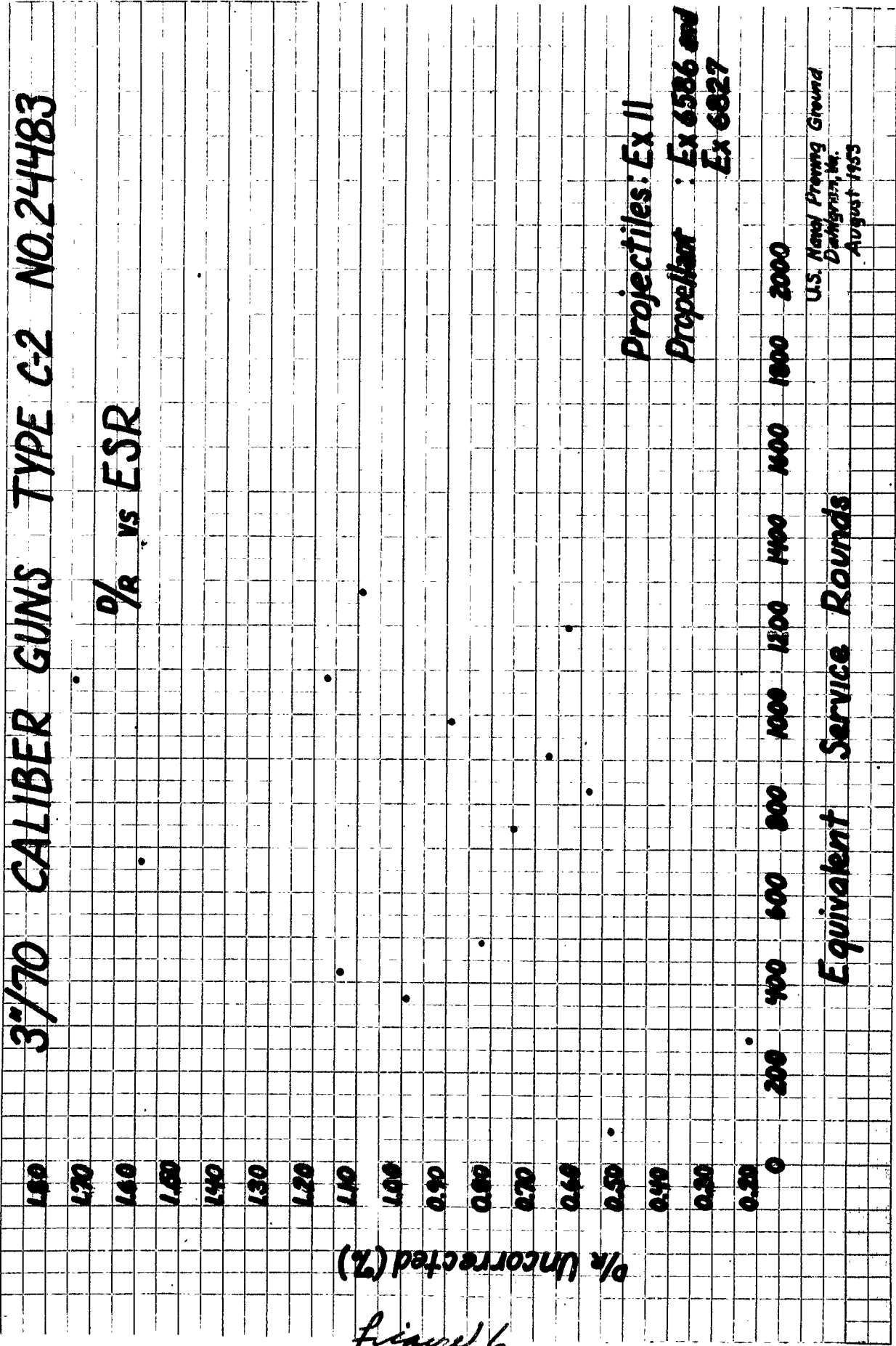


Figure 6

WFO-39503

3"/10 AUTOMATIC PILOT MOUNT MK. 35, GUN NO. 24483

40 ROUNDS RAPID FIRE

CHART I - TEMPERATURE OF RECOIL FLUID

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15 SEPTEMBER 1949

End of Firing
↓

DEGREES CENTIGRADE

100

90

80

70

60

50

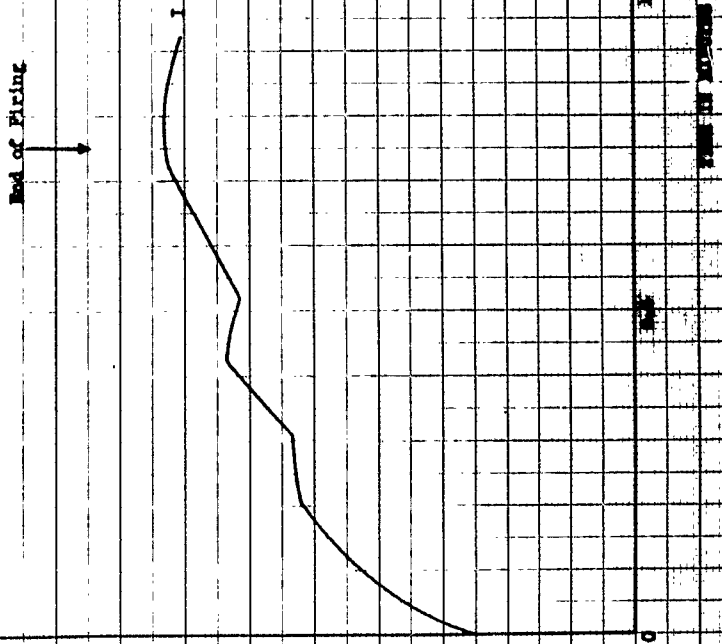
40

30

20

10

0



1.5

1.5

TIME IN SECONDS

WFO AUTOMATIC PILOT UNIT WT. 16. GUN NO. 24455

NO. 10. 24455

CURVE I - TEMPERATURE OF INLET WATER

CURVE II - TEMPERATURE OF OUTLET WATER

CURVE III - TEMPERATURE OF RECOIL FLUID

RATE OF WATER FLOW: 86 GALS. PER MIN.

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19 SEPTEMBER 1949

WFO-20455

150

140

130

120

110

DEGREES CENTIGRADE

End of Firing

III

II

I

0.5

1.0

1.5

2.0

TIME IN MINUTES

Figure 5

WFO-30004

WFO AUTOMATIC PILOT REPORT NO. 15, GEN NO. 14113

75 MOONDA RAPID FIRE (5 - 15 RD. ROUNDS)

CHART 7 - TEMPERATURE OF MAGAZINE FLUID

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24 SEPTEMBER 1949

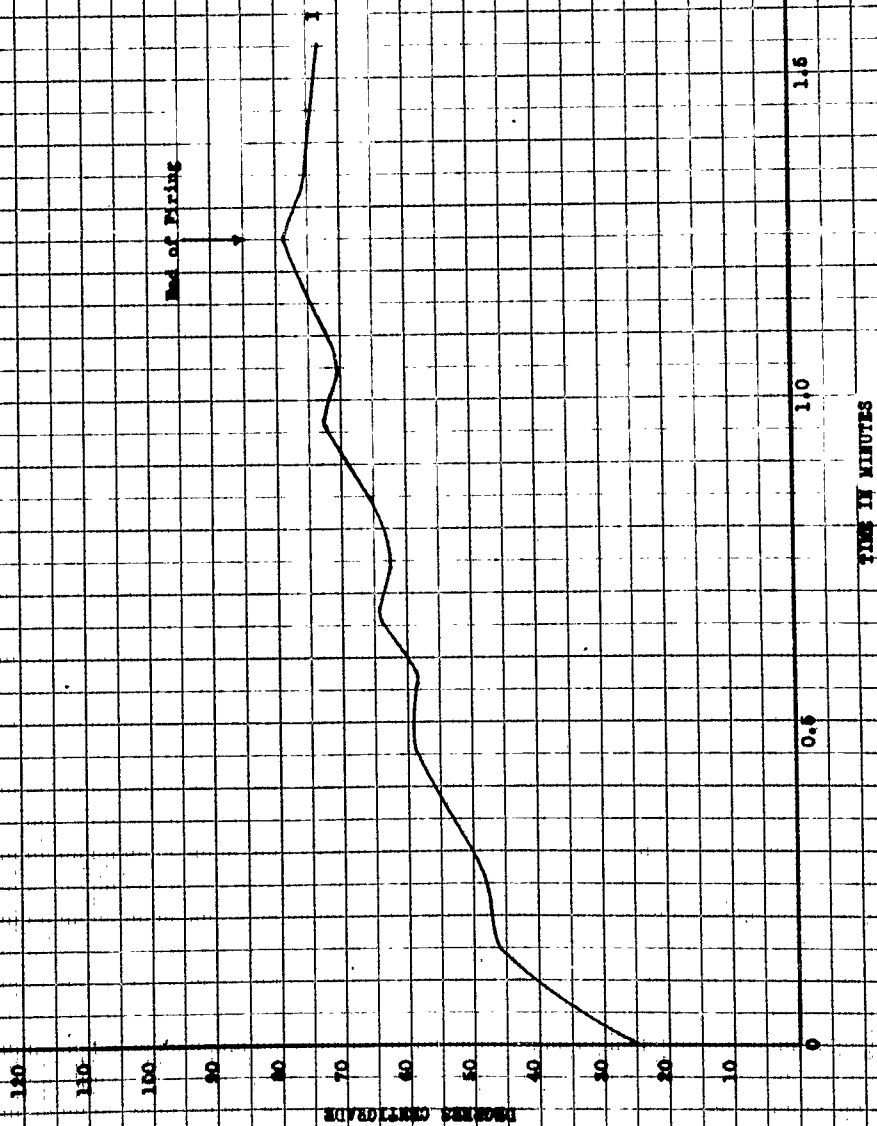
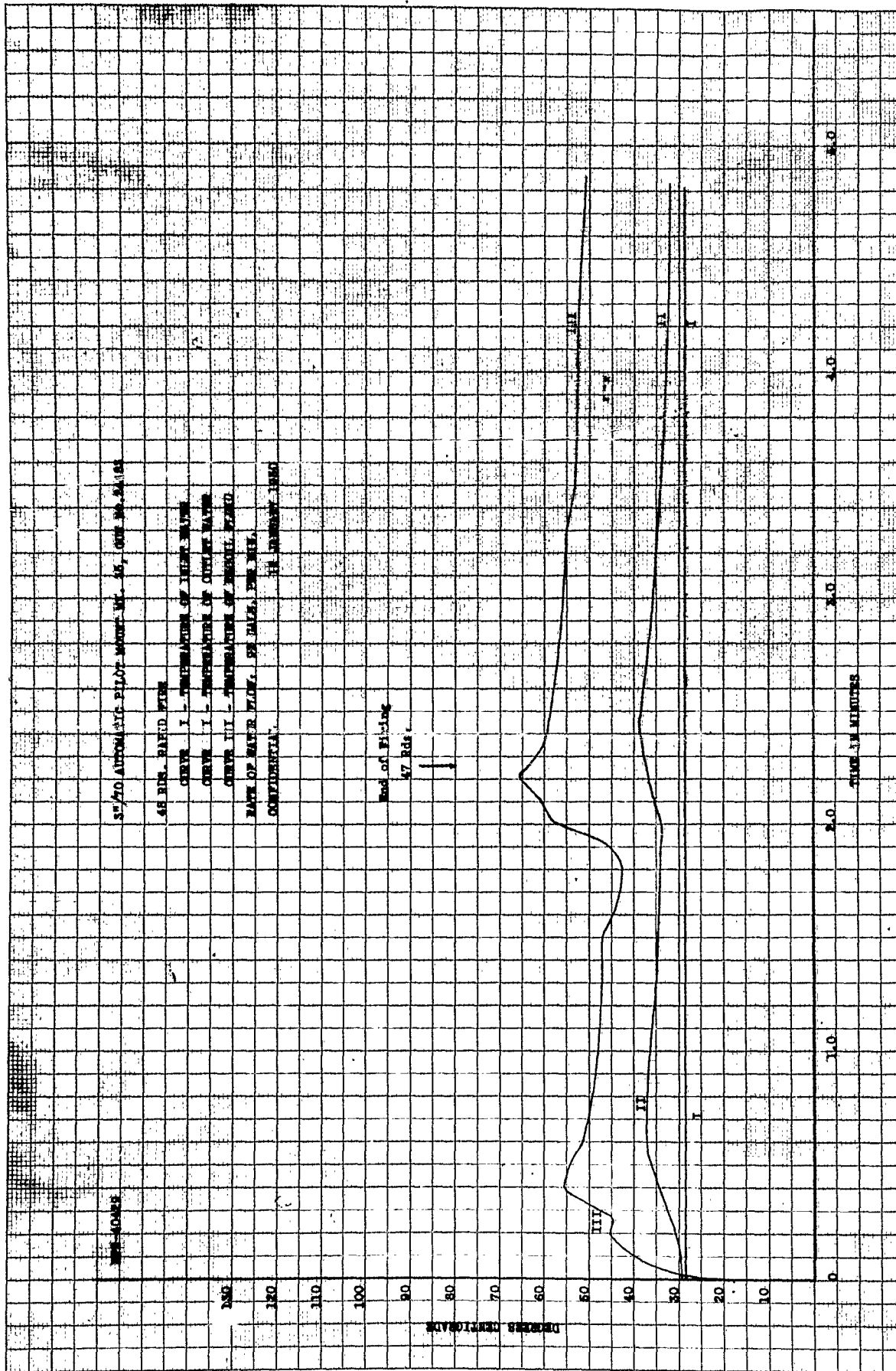


Figure 9



MP-40640

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6 February 1950

W/10 AUTOMATIC PILOT BURNER M. 15, GUN NO. 24483

36 Rounds, Rapid Fire

CURVE I - Temperature of Inlet Water
CURVE II - Temperature of Outlet Water
CURVE III - Temperature of Recirc Fluid

Rate of Water Flow: 92 gallons per minute.

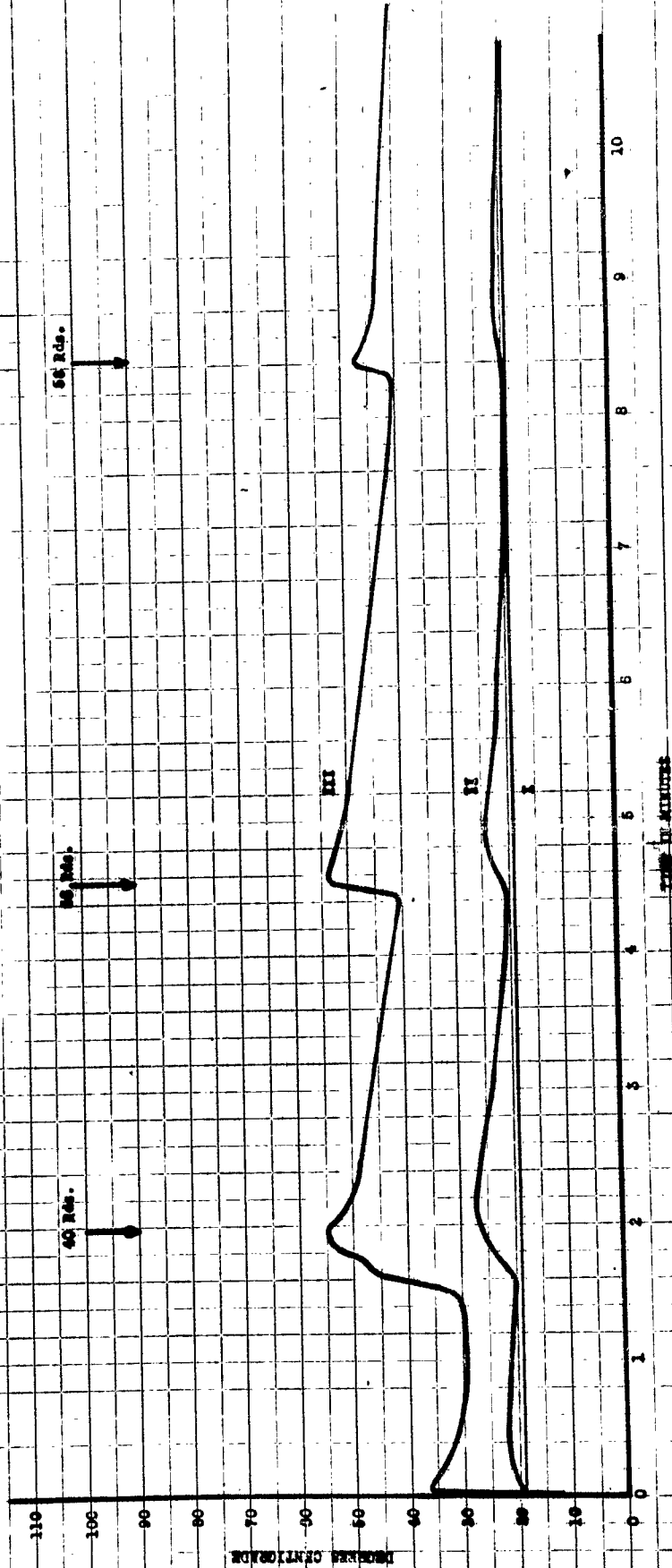


Figure 11

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5770 AUTOMATIC PILOT MT. MK 35, GUN NO. 24483

NP9-41948

02:00:00 RAPID FIRE (WITH INTERRUPTIONS)

26 JUNE 1950

TEMPERATURE OF RECOIL FLUID

RECOIL FLUID WAS NOT WATER COOLED.

ZERO TIME IS THE TIME OF BEGINNING OF RAPID FIRE.

ROS FIRED:

100 90 80 70 60 50 40 30 20 10 0

DEGREES CENTIGRADE

32 44 56

10

20

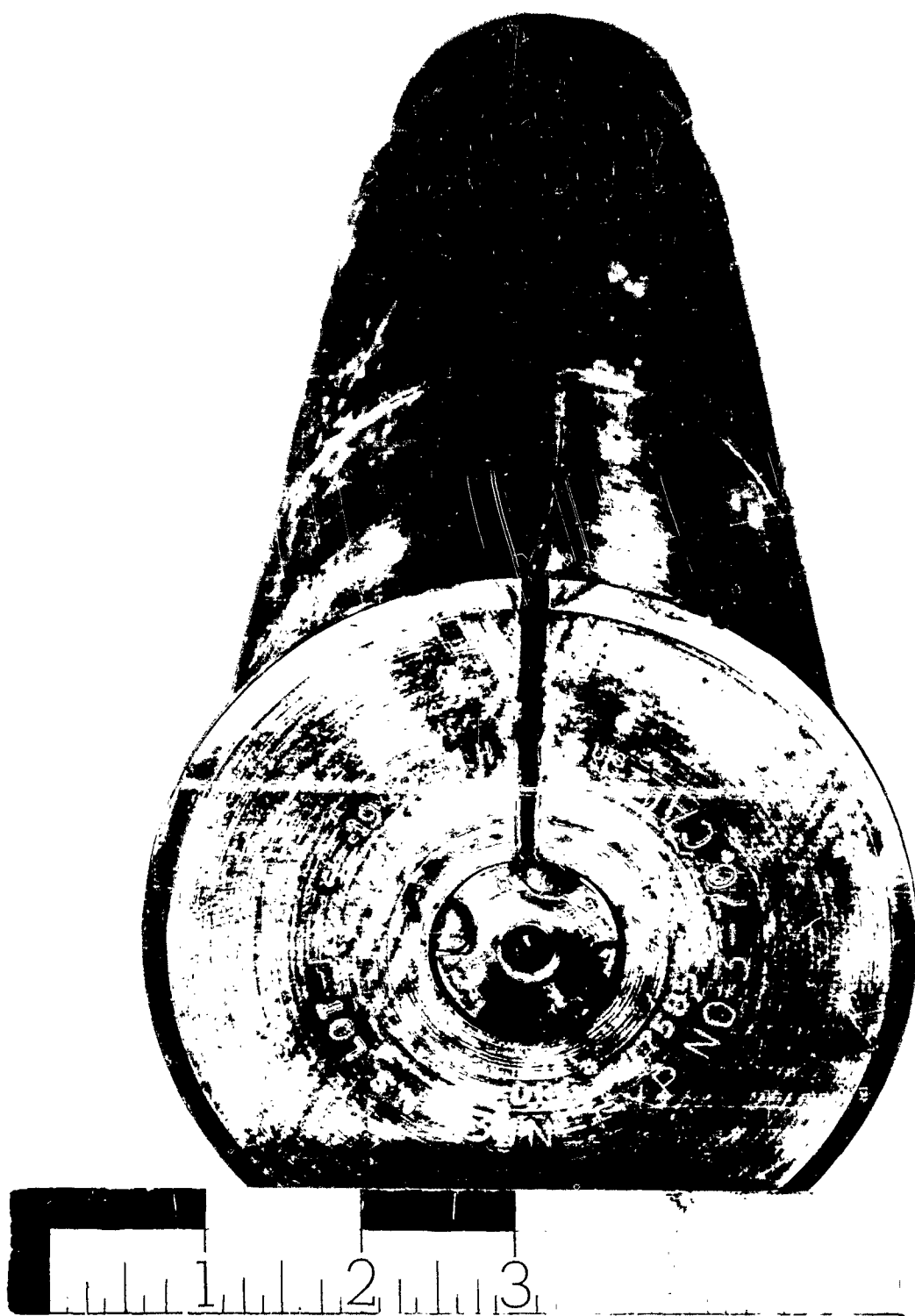
30

40

50

TIME IN MINUTES

Engine 12



NP9-44181
 End view of 3"/70 Caliber steel case, Lot 3 which split when fired
 in the 3"/70 Mount Mark 35, 100-O. Primer XC-M11. Powder Index EX-6586.
 Service charge weight 6.26 lbs.

CONFIDENTIAL

Figure 13

Appendix 7