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LABORATORY

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BALLISTIC LABORATORY

REPORT

ON HEATING EFFECTS AND ENDURANCE PROPERTIES OF THE 105 MM A.A. GUN MI AS DETERMINED BY RAPID FIRE TESTS.

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PROJECT: KC 65 - TESTS TO DETERMINE THE RISE OF TEMPERATURE OF CANNON DUE TO FIRING AND THEIR RATE OF COOLING.

By

N. A. Tolch

February 12, 1936.

ABERDEEN PROVING GROUND
ABERDEEN, MD.

Report No. 35

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WAR DEPARTMENT

WATERTOWN ARSENAL

WATERTOWN, MASS.

INTRAOFFICE MEMORANDUM

FOR USE WITHIN THE ARSENAL ONLY

2-10
(Date)

FROM: Capt Stumpf (Name), Heat Treat (Division)

TO: Major McCoy (Name), Lab (Division)

SUBJECT:

For your files. This started and as a pet project of mine when I was assigned to Lab — find the effects of heat (of firing) on cold work stresses.

You might want to look this over. You'll find some interesting calculations on bore temp.

NO CARBON COPY AND NO RECORD REQUIRED. PEN OR PENCIL MAY BE USED.

Report No. 35

NAT/emh
Aberdeen Proving Ground, Md.
February 12, 1936

HEATING EFFECTS AND ENDURANCE PROPERTIES OF THE 105 MM A.A. GUN M1 AS DETERMINED BY RAPID FIRE TESTS.

Project KC 65 - Tests to Determine the Rise of
Temperature of Cannon Due to Firing
and their Rate of Cooling.

Abstract

After 169 rounds of rapid fire, the gun could not be fired further because of malfunctioning of the firing mechanism. Erosion was found to be much greater during the rapid fire. Range dispersion increased somewhat during the firing. Heating effects of 1.4 to 3.5 deg. C rise per round were obtained. Temperature differences of as much as 120° deg. C between the bore surface and the outside surface were computed.

Introduction

Investigations have been made in the past of the endurance properties of guns when fired rapidly. For example, the endurance test of the 3" A.A. Gun T8 and the more recent test of the 3" A.A. Gun M3 were made with the primary object of testing the gun to destruction or to failure of some of its parts as a result of rapid fire. These investigations furnish information as to the number of rounds and the temperature at which failure is likely to occur. From the heating effects, the temperatures attained for various rates of fire can be calculated. This information, in conjunction with other considerations, can be utilized in establishing permissible rates and duration of fire.

The investigation of the endurance qualities of the 105 mm A.A. Gun M1 had the same primary object, that of testing the gun to destruction or failure to function as a result of continued rapid fire. Other important features of the test were the heating effects, erosion, and range dispersion.

Firings made

On March 7, 1935, 5 rounds were fired to establish the charge. On March 15, 1935, 20 preliminary rounds were fired to determine the heating effects so that a computation could be made of the gun temperature at which the crew should take cover. On March 22, 1935, 169 rounds were fired rapidly as an endurance test. The attached firing record No. 8283 gives a description of the firings.

Measurements of temperatures

Temperature measurements were made by means of thermocouples, of which three were welded to the gun, and a fourth to the recuperator. The thermocouples attached to the gun were .9, 7.35, and 13.7 feet from the muzzle. Figure 1 shows the position of the thermo-couples.

Results of preliminary firings

Plot 1 shows the temperatures attained as a result of the 20 preliminary rounds. From these data and from the cooling curve, the heating effects were computed and allowance made for the cooling.

The following table shows the heating effects obtained:

Distance from muzzle, ft.	.95	7.35	13.7
Heating effect, deg. C. rise per round.	3.52	2.79	2.61

Computation of bursting temperature of gun.

It was desirable to fire the gun rapidly for as long a time as possible in order to minimize the heat lost by cooling. Since the rate of fire is slower when the gun crew takes cover, it is advantageous to fire without taking cover until the danger temperature is reached. Hence, a calculation was made by J. R. Lane of the temperature at which it would be necessary to take cover.

Making use of Bennett's "Tables for Interior Ballistics", the maximum pressure occurring at various points along the bore was computed. From the maximum allowable pressure curve for the gun and from the computed maximum pressures, the safety factors were obtained as a function of the distance along the bore. Report No. 812/2 "Tension Properties of Centrifugally cast Molybdenum-vanadium Gun Steel at High and Low Temperature", Watertown Arsenal, furnishes data regarding the reduction in strength of gun steel with increase in temperature. Making use of these data, the temperature was found at which the safety factor was reduced to unity, or, in other words, the temperature at which failure should occur. Plot 2 shows the maximum allowable temperature as a function of the distance along the bore. Knowing the heating effect per round, the maximum number of rounds that could be fired before reaching the bursting temperature was calculated. After making certain allowances for safety, it was decided to take cover after firing 125 rounds.

RESULTS OF ENDURANCE TESTS

Although it was planned to fire the gun to destruction, it was necessary to stop firing after 169 rounds because of malfunctioning of the firing mechanism. On examination, it was found that the compression of the sear spring was not great enough to actuate the sear because of a loosened sear spring seat. Hence it was impossible to get enough force behind the firing pin to set off the primer.

The first 50 rounds of the endurance tests were fired with the regular 105 mm A.A. Proof Slug. The remaining rounds were fired with the Proof Slug modified in accordance with the attached drawing APG 2439-AD.

The maximum measured temperature at the breech thermocouple attained during the firing was 283° C which was well under the computed temperature of 400° at which the gun should burst from firing. The midpoint and muzzle maximum temperatures were also well under the computed maximum allowable temperature.

Erosion

Plots 3 and 4, made from the data of the star-gauging records, show the diameter of the lands and grooves when the rifling was new, and before and after the endurance firings.

The firings apparently produced a typical erosion curve as characterized by very marked erosion of the lands and grooves near the origin of rifling, copper deposits in the grooves, and extensive erosion of the lands beginning at approximately the mid-point of the rifling and continuing to the muzzle.

Aside from the enlargement near the origin of rifling, no increase in the diameter of the lands was noted as a result of firing the first 770 rounds during the routine firing of the gun. However, after firing 169 additional rounds rapid fire in the present investigation, a very appreciable erosion of lands is evident over the forward half of the barrel. It appears that the 169 rounds rapid fire produced much more erosion of lands than 770 rounds fired in the normal or routine life of the gun.

Deposit of copper in the grooves seemed to be well under way before beginning the rapid fire test. However, the deposit was confined to the rear portion of the barrel. After firing 169 rounds rapid fire, the copper deposits in the grooves extended practically the length of the rifling except for short clear portions at the breech and muzzle. There was some deposit of copper on the lands in the rear half of the barrel.

The attached photograph No. 34220 of a gutta percha impression at the muzzle shows noticeable wear at a section of lands between 8 and 11 o'clock facing the muzzle.

Chemical Analysis of Copper Deposit

Laboratory Report No. 15112, Frankford Arsenal, gives the results of the chemical analysis of the copper from the bore of liner of the 105 mm A.A. Gun M1, No. 2 as follows:

This material contains copper, iron, copper oxide, iron oxide, particles of wood and some oil.

Total Copper	71.42%
Total Lead	.33%
Total Iron	9.64%
	81 39
Oxygen combined as copper and iron oxide	18.61%
	100 00

Range Accuracy

Range observations were taken for the purpose of observing whether there was any change in the accuracy during the firings. Since the first 50 rounds were fired with the regular proof slug and also with different powders, the probable error was computed for this group separately. The remaining 119 rounds, which were fired with the modified proof slug, were divided into three groups of about 40 rounds each, which approximately divided these rounds into two groups of rapid fire, and one, the last, of fire from cover. Because of the rapidity of the fire, range observations could not be secured on every round and consequently there were proportionately more range observations for the fire from cover. The probable errors were computed by the method of successive differences for the purpose of eliminating the effect of a shift in range. In this connection, precautions were taken that the gun was correctly pointed during the firing. The following table shows the ranges and the probable errors:

Round No's.	No. Observations	Mean Range yds.	Range P.E. of 1 rd., yds.	P.E. of P.E., yds.	Remarks
1-50	25	8914	132	13	Rapid fire,Reg. proof
51-90	24	13388	34	3	" " Mod. "
91-129	29	13410	57	5	" " " "
130-169	39	13337	71	5	From cover, " "

The probable error of the first 50 rounds was considerably higher than those of the remaining rounds, but because of the different projectiles used, the probable errors should not be compared.

Of the three groups fired with the modified proof projectile, there was some increase in the probable error during the firing. Also, from the P.E. of the P.E., the increase is apparently significant.

It appears that the dispersion might reasonably increase during the firings because of erosion and because of the increase in the diameter of the bore due to heating of the gun. The star gauging measurements show that there was considerable erosion during the firing and that the erosion had proceeded to a degree that might reasonably decrease the accuracy. It is calculated that the increase in temperature which was about 300 deg. C, would increase the diameter of the bore about .012" which might also be a factor in diminishing the accuracy.

It is interesting to compare the trend of the probable errors during the endurance test of the 3" A.A. Gun M3 with that of the present investigation. The sequence of the probable errors for the 3" A.A. Gun M3 was 128, 81, 69, and 108 yds., indicating that the accuracy did not decrease appreciably during the firing whereas the present tests show a decrease in the accuracy during firing. The difference in degree of erosion of the two guns may be enough to explain this difference. As already pointed out, the erosion of the 105 mm Gun was well advanced, whereas that of the 3" Gun was moderate enough that the accuracy might not be seriously affected.

The engraving of the rifling into the body of the projectile may also be a factor in the dispersion results of the two guns. It appears that engraving is greater in the larger caliber and longer barrel guns and that the engraving should increase with the temperature. Hence engraving may be an appreciable factor in the increase in dispersion during the firing of the 105 mm Gun, whereas it may not be appreciable for the 3" Gun because of its smaller caliber and shorter length barrel.

Heating Effects

Plots 5 and 6 show the temperature of the gun and recuperator as a function of the time. The first 58 rounds were fired at an average rate of 8.07 rounds/min. Following a short stoppage in firing, 66 rounds were fired at a rate of 11.54 rounds/min. and 28 rounds from cover at 4.88 rounds/min. It was desirable to compute heating effects for these three groups of firings and to compare these heating effects with the heating effect determined over the entire temperature range included in the firings.

Ordinarily, a cooling curve is obtained following a group of firings and this curve is extrapolated back to the end of firing to give the maximum temperature attained. In this case, however, cooling curves were not secured for each group and it was necessary to use the cooling constant obtained at the end of firing in allowing for the cooling for each group.

In computing the heating effect for a group of firings, the first portion of the firings, in which there is a time lag in the rise of temperature on the outside, was discarded. The temperature rise for the rounds considered was then determined and allowance made for the cooling. The following table shows the heating effects so obtained and also the heating effect over the entire temperature range:

Distance from muzzle ft.	o.D. Temperature range, deg. C	Heating effect, deg. C. rise per round
.95	51-157	2.61
"	183-254	1.66
"	269-282	1.41
"	25-287	2.01
7.35	37-125	2.11
"	152-244	1.94
"	269-297	1.89
"	23-305	2.06
13.7	33-117	1.99
"	146-222	1.58
"	251-279	1.71
"	24-289	1.89

Plot 7 shows the heating effects in degrees rise per round as a function of the mean of the temperature range from which the heating effect was determined, including those of the preliminary firings. In general, the heating effect decreases with increase in temperature. At the lower temperatures, the greatest heating effect was obtained at the muzzle, but at the higher temperatures the heating effect at the muzzle, was slightly less than at the midpoint or at the breech.

Plot 8 shows the calculated temperatures of the gun at various rates of fire as a function of the time. At 5 rounds per minute, the cooling becomes an important factor in the temperature rise of the gun at temperatures in excess of 200 deg. At 15 rounds per minute however, the cooling is relatively unimportant over the temperature range considered and the temperature rise is almost in proportion to the time or to the number of rounds fired.

From Plot 2 it is noted that the maximum allowable temperatures at .95, 7.35 and 13.7 ft. from the muzzle are 555, 550, and 405 deg. C. respectively. From Plot 8, it is evident that the maximum allowable temperature will be attained at the breech before it is at the midpoint or at the muzzle. Hence, the breech may be considered the danger point at the high temperatures.

Calculations were made of the rounds per minute necessary to maintain the gun at various temperatures and since the breech is the danger point, the calculations were made using the data from the breech thermocouple. The following table shows the results of the calculations:

O.D.

Temperature at breech, deg. C above atmospheric	Number rds. necessary to heat breech			Rounds per min. necessary to maintain breech
	at 5 rds/min.	at 10 rds/min.	at 15 rds/min.	
100	55	54	53	.4
200	115	110	109	.9
300	183	170	166	1.4
400	264	233	225	2.0

In explanation of the preceding table one would fire, for example, 55 rounds at 5 rds/min. to raise the temperature of the breech 100 deg. C above atmospheric and then it would only be necessary to fire .4 rds/min. to maintain the temperature. Or, one would fire 225 rounds at 15 rds/min. to attain 400 deg. C. excess temperature and then a rate of fire of 2.0 rds/min. would maintain the temperature. It is not implied, however, that 400 deg. C or even 300 deg. C is a practical temperature of firing because of danger of bursting the gun, excessive erosion, and perhaps many other reasons.

Calculation of heat absorbed.

In calculating the heat absorbed, the degrees rise per round was multiplied by the mean specific heat over the temperature range considered and the weight per cm^2 of bore surface, or per cm. length of barrel. The following table shows the results of the computations:

Distance from muz. ft.	O.D. Temperature range, deg. C	Heat Absorbed calories per round per cm^2 bore surface	per cm. length barrel
.95	51-157	11.4	376
"	183-254	7.7	253
"	269-282	6.7	222
"	25-287	9.0	297
7.35	37-125	15.4	507
"	152-244	14.9	490
"	269-297	15.2	502
"	23-305	15.6	514
13.7	33-117	21.4	705
"	146-222	17.6	581
"	251-279	20.2	665
"	24-289	20.9	690

From the above results, the heat absorbed was greatest at the breech, which agrees with the general experience in the heating of guns that the heat absorbed increases in the direction of muzzle to breech. The degrees rise, however, is affected by the heat capacity and may be least at the breech.

Computation of Cooling Constants and Emissivity

The cooling constants were computed from the cooling data by the use of the equation

$$k = \frac{\theta_2^{-.23} - \theta_1^{-.23}}{.23(t_2 - t_1)}$$

where θ is the excess temperature above atmospheric and t the time.

The emissivity was computed from the equation*

---

* Third Partial Report in Connection with the test of the 3" A.A. Gun T8 and Mount T-3", O.P. 5228, Oct. 26, 1934.

$$E = \frac{\rho c k(r_o^2 - r_1^2)}{2r_o}$$

where ρ is the density, c the specific heat, k the cooling constant, and r_o and r_1 the outer and inner radii.

The following table shows the results of the computations:

Date of Test	Wind Direction and M.P.H.	Distance from muzzle ft.	Cooling Coef. "k" $\mathrm{deg.}^{-.23}\,\mathrm{min}^{-1}$	Emissivity E $\mathrm{cal.\ cm}^{-2}\,\mathrm{deg.}^{-1.23}\,\mathrm{min}^{-1}$
March 15	S 12	.95	.0113	.030
"	"	7.35	.0062	.023
"	"	13.7	.0034	.016
March 22	NW 8	.95	.0047	.013
"	"	7.35	.0031	.012
"	"	13.7	.0024	.011

The higher wind velocity of March 15, as compared to March 22 is reflected in larger k's for the former date. Comparing the muzzle and breech, the greater k's were obtained at the muzzle. The emissivities for March 22, were approximately constant, but for the tests of March 15, the emissivity at the muzzle apparently was greater than at the breech.

Recuperator temperature.

Plots 1 and 6 show the temperatures observed with the thermocouple attached to the outside of the recuperator. In view of the small temperature rise, it appears that the observed temperature was not the temperature of the oil because of the large heat capacity of the recuperator parts.

Computation of bore temperature of the gun.

In a paper entitled "Temperature distribution in an air cooled machine gun barrel when firing a prolonged burst" by R. H. Kent, May 15, 1934, a method of calculating the temperature distribution was developed under the conditions of the steady state, where, after prolonged firing, the temperatures have settled down to a steady state, or in other words, the rate of heating is just equal to the cooling. In the present problem, the conditions of the steady state were not reached and it was necessary to extend the theory. The theory was applied to the conditions of the present problem by R. H. Kent, who made the necessary assumptions and furnished the solution for the differential equation.

In computing the temperature distribution, use is made of the Fourier equation for the flow of heat which in cylindrical coordinates is as follows:

$$\frac{\partial u}{\partial t} = a^2\left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r}\right)$$

In this equation, u is the temperature of the steel at any distance r from the axis of the bore, t is the time, and a^2 is the <u>thermometric</u> conductivity.

The assumption is made that the rate of change of the temperature is independent of the time and of the distance from the axis of the bore. Under this assumption

$$\frac{\partial u}{\partial t} = \text{a constant.}$$

This assumption appears to be a very plausible one providing that a sufficient time interval has elapsed after the beginning of firing for $\frac{\partial u}{\partial t}$ to assume a steady state, so to speak, and that the heat lost by cooling is relatively small in comparison to the heat added to the gun.

The general solution for the Fourier equation on the assumption that $\frac{\partial u}{\partial t}$ is a constant is as follows:

$$u = At + B \log r + Cr^2 + D.$$

The above equation contains four constants, A, B, C, and D and hence four conditions are necessary for their determination.

(1) The first condition is that the rate of temperature rise A is known from the data. The equation is

$$\frac{\partial u}{\partial t} = A$$

(2) The second condition is that the known rate of emission of heat at the surface is equal to the product of the thermal conductivity and the temperature gradient at the surface, which, as an equation is written

$$\left(\frac{dH}{dt}\right)_{r=r_o} = -2\pi\lambda\, r_o k \left(\frac{du}{dr}\right)_{r=r_o}$$

where λ is the length of barrel considered, r_o the outer radius, and k the thermal conductivity.

By differentiation and substitution one obtains

$$\left(\frac{\partial u}{\partial r}\right)_{r=r_o} = \frac{B}{r_o} + 2Cr_o = \frac{\left(\frac{dH}{dt}\right)_{r=r_o}}{-2\pi\lambda\, r_o k}$$

(3) By differentiation of the general equation and substitution in the differential equation, one obtains

$$\frac{\partial u}{\partial t} = 4a^2\, C = A$$

(4) The fourth condition is that the temperature at the outside surface is known when t equals zero, and hence

$$u_o = B \log r_o + C\, r_o^2 + D\ .$$

If one is interested in temperature differences rather than the general equation for the temperature, calculations are somewhat shortened by subtracting the general equations and simplifying the results. Letting the subscripts o and i denote outside and inside respectively, the following equation is obtained.

$$u_i - u_o = \left[At + B \log r_i + Cr_i^2 + D\right]$$

$$- \left[At + B \log r_o + Cr_o^2 + D\right]$$

$$= - B \log \frac{r_o}{r_i} - C(r_o^2 - r_i^2)$$

Results of computations

The following table shows the results of the computation of interior temperatures:

Rate of Fire for time interval considered rds/min.	Distance from muzzle ft.	Observed O.D Temp. at end of firing deg. C	Computed Temp. at Bore Surface deg. C	Diff. in Temp. deg. C
7.9	.95	157	189	32
11.2	"	254	286	32
5.4	"	282	299	17
7.9	7.35	125	182	57
11.2	"	244	318	74
5.4	"	297	341	44
7.9	13.7	117	215	98
11.2	"	222	341	119
5.4	"	279	349	70

Although the observed temperatures at the outer surface were somewhat lower at the breech than at either the midpoint or the muzzle, the computed temperatures at the bore surface were greatest at the breech. The greatest computed temperature differences between bore surface and outside occurred at the breech. This result is to some extent forecast by the computation of the heat absorbed at the bore surface. Since the heat absorbed and the wall thickness are greatest at the breech, the temperature difference between inside and outside should be greatest at the breech.

Effect of liner clearance on temperature.

The 105 A.A. Gun M1 has a removable liner with a tapering clearance between liner and tube of .007" at the muzzle to .003" at the breech. Before inserting the liner in the tube, the liner is coated with a mixture of grease and finely powdered graphite, the grease mixture consisting of 1 lb. of grease to 1 oz. of graphite. Hence, the clearance is probably in greater part filled with the grease mixture.

The actual clearance at a given point with the liner in place in the gun is probably a very indefinite quantity, depending on the manner in which the liner is seated in the tube, droop of the gun, and perhaps other reasons. Because of this indefiniteness, no attempt was made to correct the computed bore temperatures for the effect of the clearance, the gun being assumed mono-block for the purposes of the computations. However, the maximum temperature drop across the clearance may be calculated. In making the calculation, the maximum clearance was assumed and the clearance was considered to be filled with grease. The computations indicate that the temperature drop across the clearance may be as much as 30° C. Although the clearance was greater at the muzzle than at the breech which should result in a greater temperature difference, other conditions being equal, the heat flows were such that the temperature differences across the clearance at the breech and muzzle appear to be about the same. This computation indicates that the bore temperatures given in the table may be low by as much as 30° C depending on what the actual clearance was.

Irregularity of observed temperatures.

The observed temperatures, shown on Plots 5 and 6 are somewhat irregular; that is, the temperature curves lack the smoothness that was expected. It was thought that this irregularity might be due to the clearance between liner and tube causing a cyclic effect in the cooling of the gun. For example, suppose that because of the clearance between liner and tube, the liner remained at a relatively high temperature while the tube cooled rapidly. Then, as the result of the rapid cooling and contraction of the tube the clearance would be closed resulting in a rapid transfer of heat to the tube, and a rise in temperature on the outside surface. By repeating this process, a cyclic effect would be produced in the temperature at the exterior surface. However, computations indicate that the temperature difference between tube and

and liner during cooling is not great enough to permit of sufficient relative contraction and expansion for this cyclic effect to take place.

Wind velocities during the period of the firings and the cooling were classed as very steady by the Meteorological Station, indicating that the irregularities were not due to any particular gustiness of the wind.

Summary.

1. Although it was planned to fire the gun to destruction it was necessary to stop firing after 169 rounds of rapid fire because of malfunctioning of the firing mechanism. At the end of the firings, the temperature of the gun was well under the computed maximum allowable temperature.

2. The erosion produced by the 169 rounds of rapid fire was much greater than that of the previous 770 rounds of routine firing. Copper deposit in the grooves was well developed in the rear portion of the barrel before the rapid fire tests but this deposit was extended over practically the length of the barrel as a result of the rapid fire tests.

3. The sequence of the probable errors of the ranges was 34, 57, and 71 yds., indicating that the dispersion increased somewhat during the firing.

4. Heating effects of 1.41 to 3.52, 1.89 to 2.79, and 1.58 to 2.61 degrees C rise per round were obtained at the muzzle, mid-point, and breech respectively. As the temperature of the gun was increased, the heating effect decreased. The heat absorbed per round also decreased with increase in temperature, but the decrease was not as pronounced as that of the degrees rise per round.

5. On the assumption that the rate of temperature rise is a constant and that the rate of rise is the same on the inside as on the outside of the gun, the equation of the temperature as a function of the time and the distance from the axis of the bore was developed.

6. From the calculations, the greatest difference in temperature between the inside and outside of the gun occurred near the breech where as much as 120° C difference was computed.

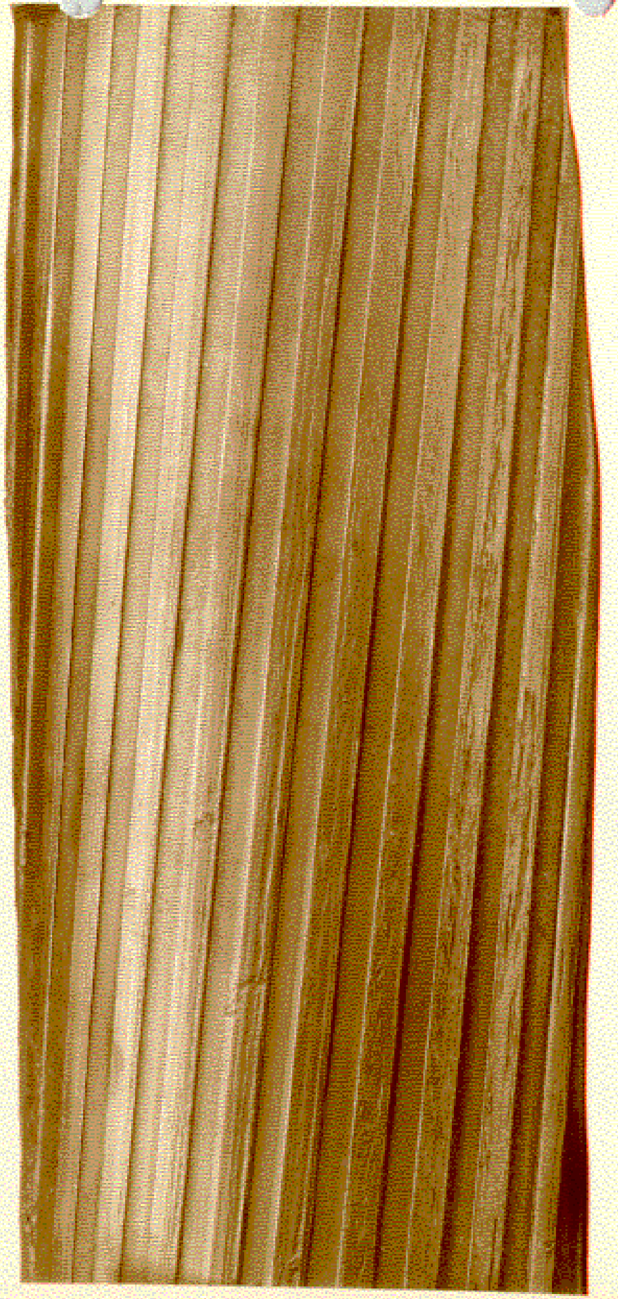
7. From the heating effects, the temperature rise of the gun for various rates of fire was computed and plots made of the results. The rate of fire necessary to maintain various temperatures was also computed.

8. It was computed that the maximum allowable or bursting temperature of the gun should be reached as a result of firing 264 rounds at 5 rds/min, or 233 rounds at 10 rds/min. or 225 rounds at 15 rds/min.

N. A. Tolch

N. A. Tolch.

H. H. Zornig,
Lt. Col., Ord. Dept.,
Chief Research Division



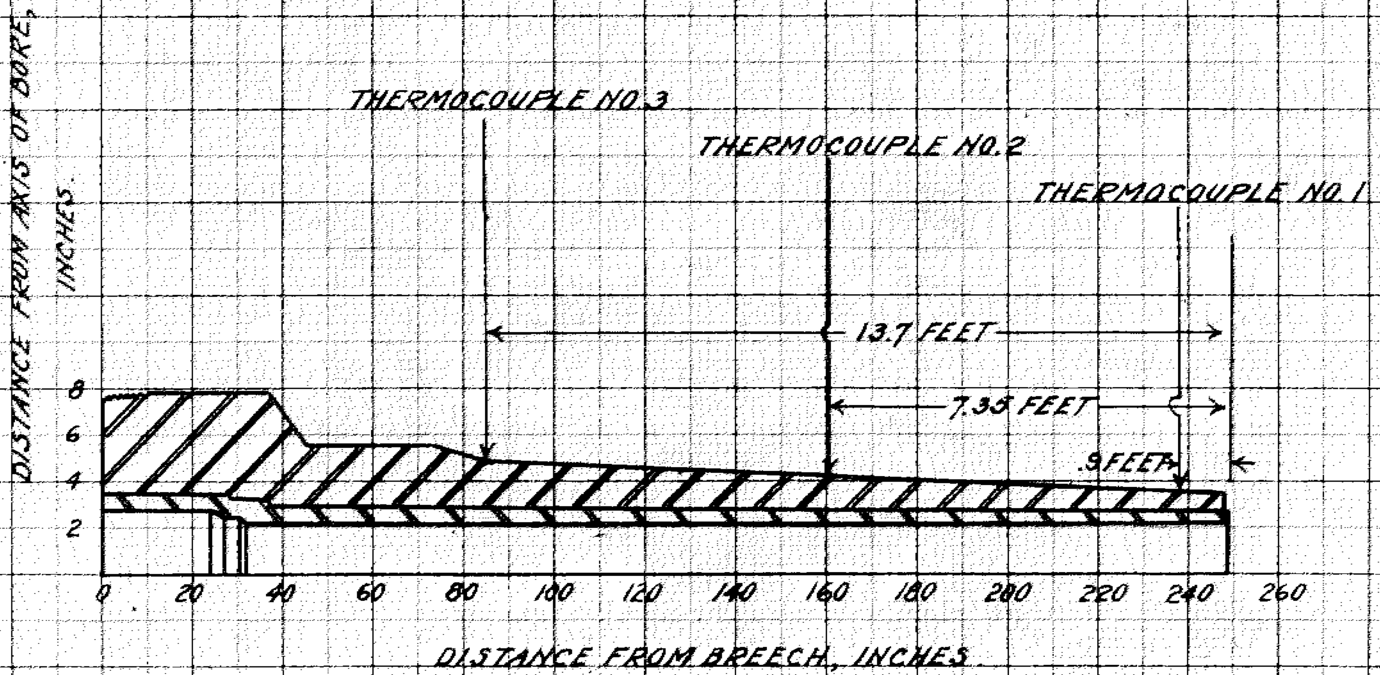
Wear on lands at the muzzle, between 8 and 11 o'clock (facing the muzzle)

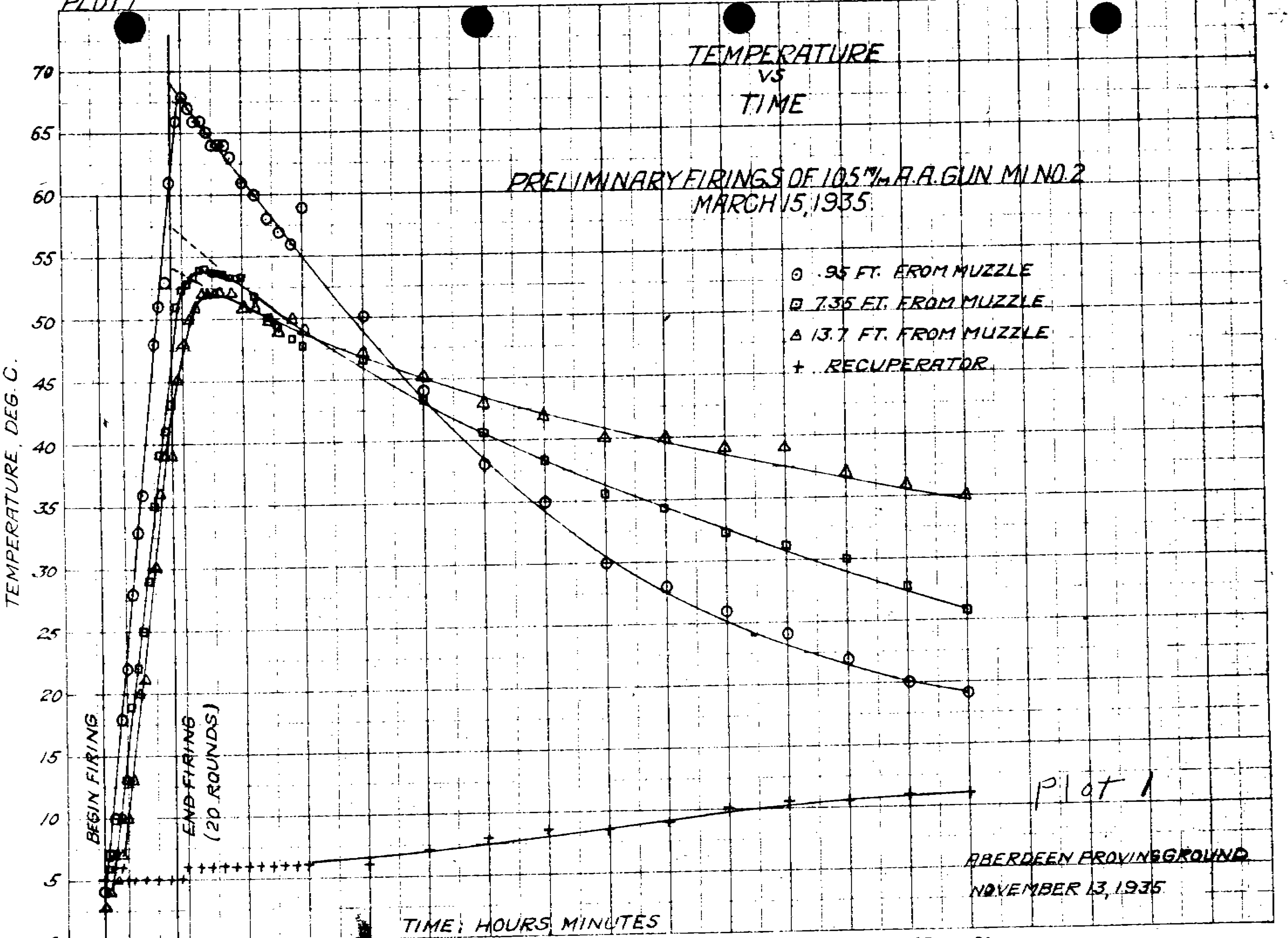
Normal lands at muzzle, between 2 and 5 o'clock (facing the muzzle)

ORDNANCE DEPARTMENT. A. P. G.
34220 - 11/1/35.
Impressions, 105 mm AA Gun #2, M1, W.A., after 939 rounds.

FIGURE 1.

SKETCH OF 105 M/M A.A. GUN, M1.
SHOWING POSITION OF THERMOCOUPLES



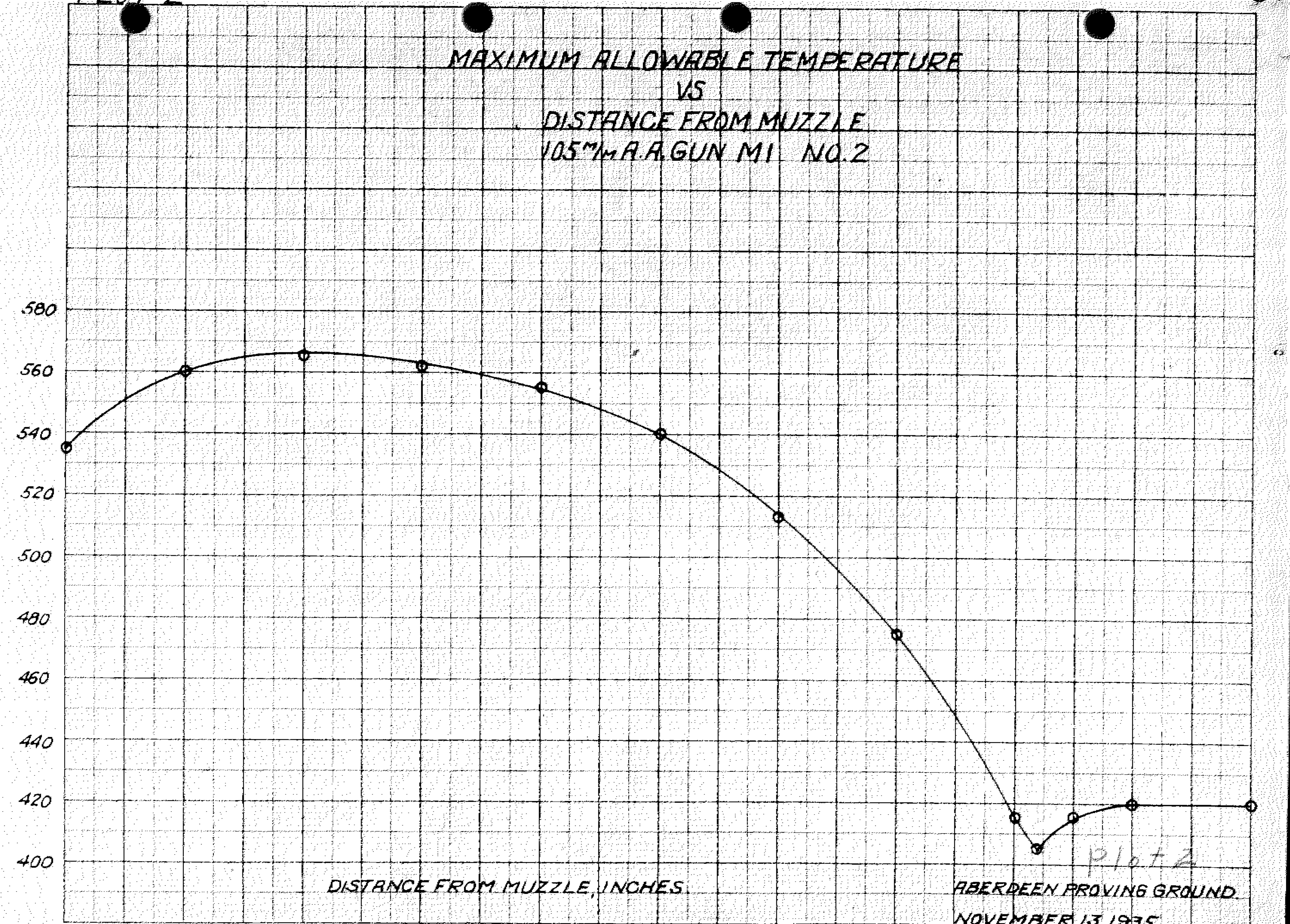


TEMPERATURE VS TIME

PRELIMINARY FIRINGS OF 105 m/m A.A. GUN M1 NO. 2
MARCH 15, 1935

Plot 1

ABERDEEN PROVING GROUND
NOVEMBER 13, 1935



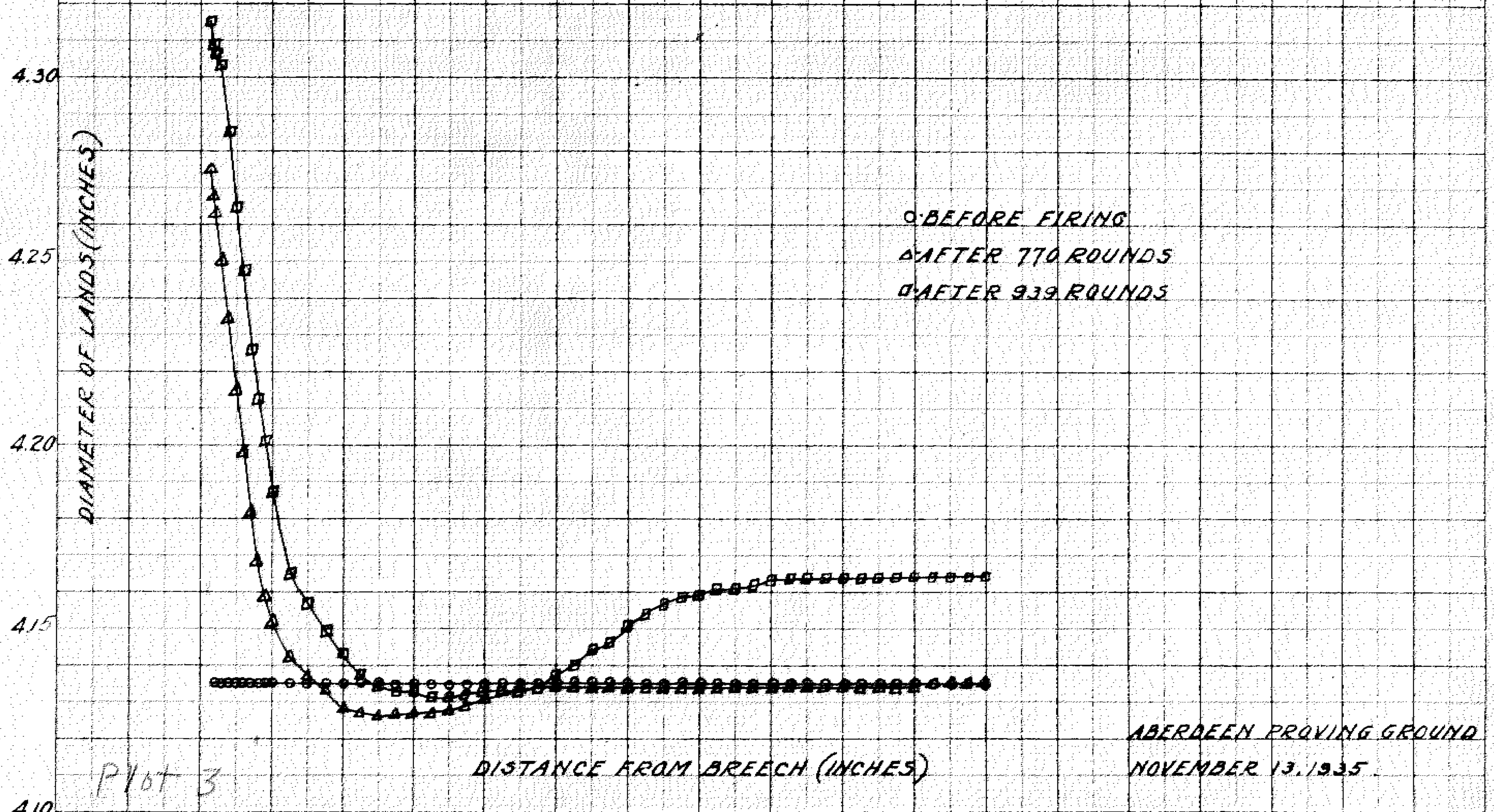
MAXIMUM ALLOWABLE TEMPERATURE
VS
DISTANCE FROM MUZZLE
105 M/M A.A. GUN M1 NO.2

Plot 2

ABERDEEN PROVING GROUND.
NOVEMBER 13 1935

PLO 3

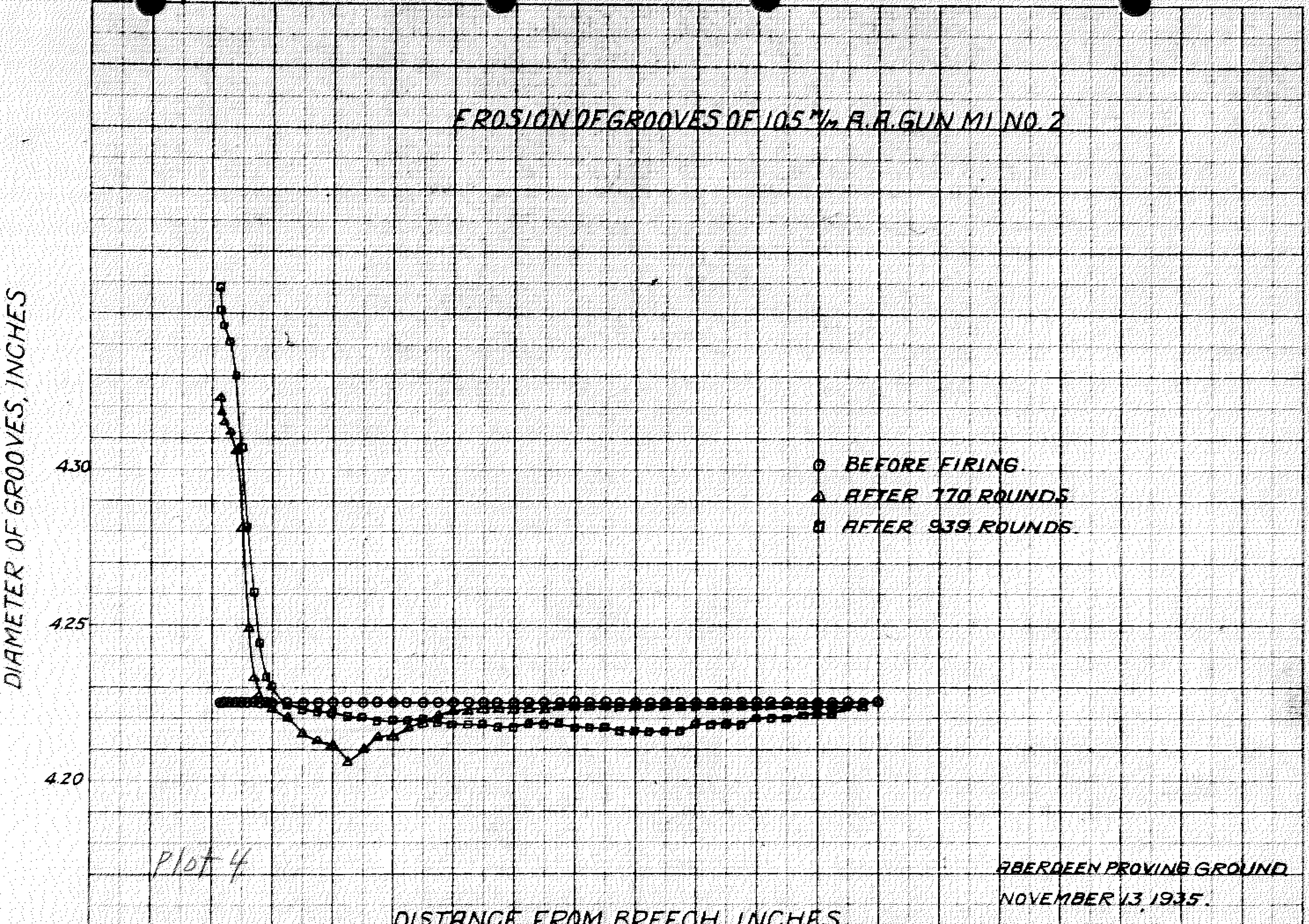
EROSION OF LANDS OF 105 M/M A.A. GUN, M1 NO. 2



ABERDEEN PROVING GROUND
NOVEMBER 13, 1935

Plot 3

PLOT 4

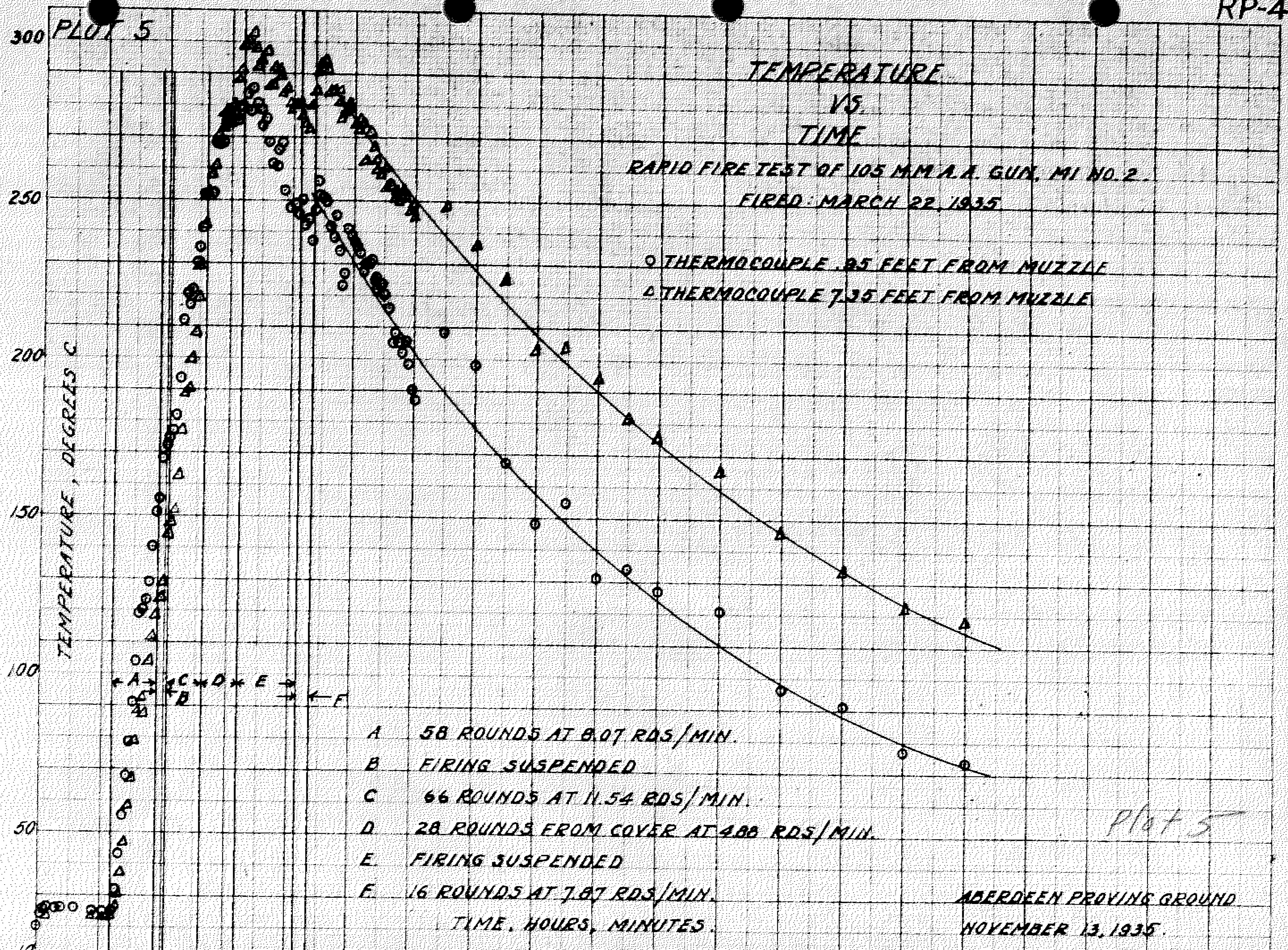


EROSION OF GROOVES OF 105 M/M A.A. GUN M1 NO. 2

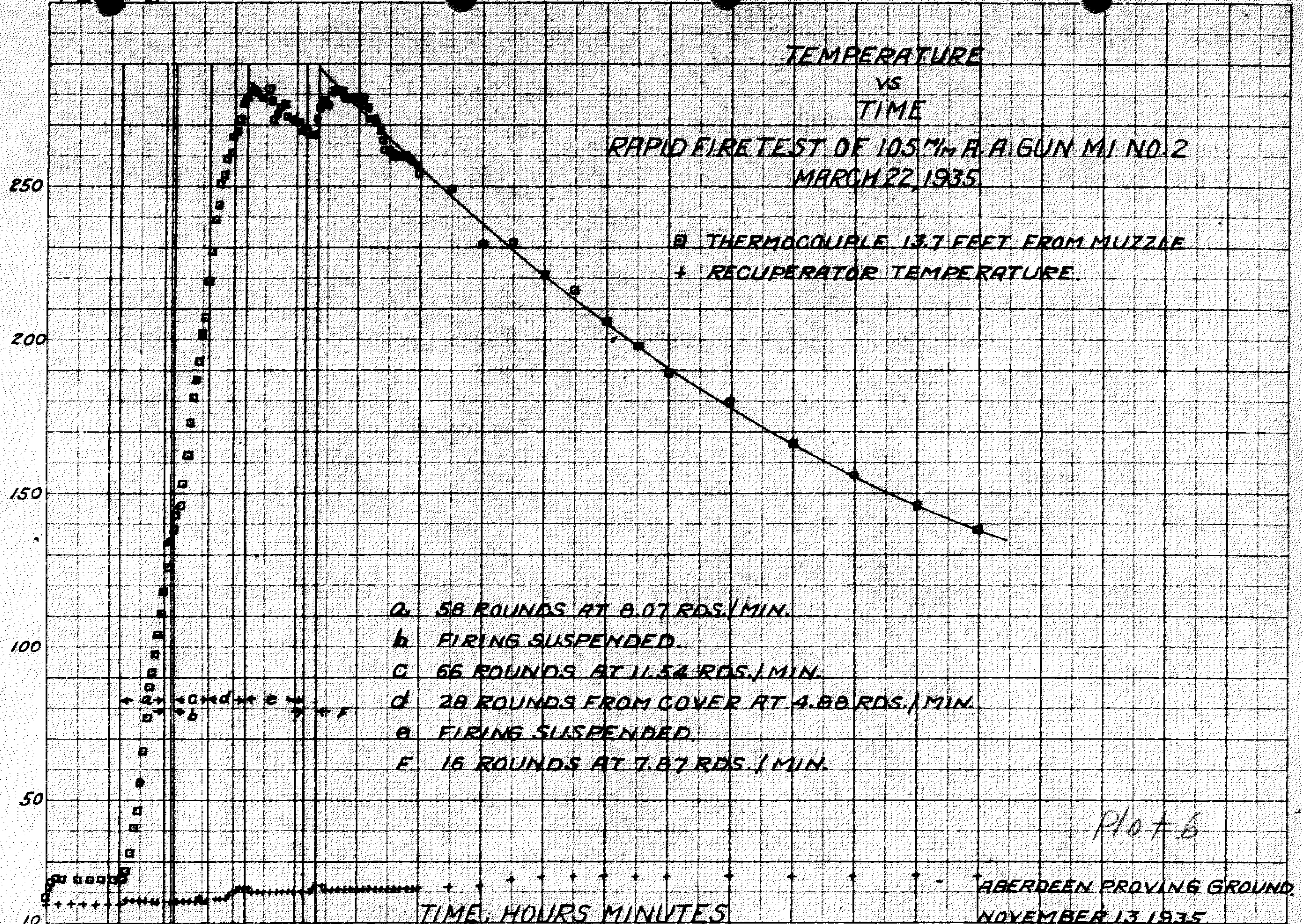
ABERDEEN PROVING GROUND
NOVEMBER 13, 1935.

Plot 4

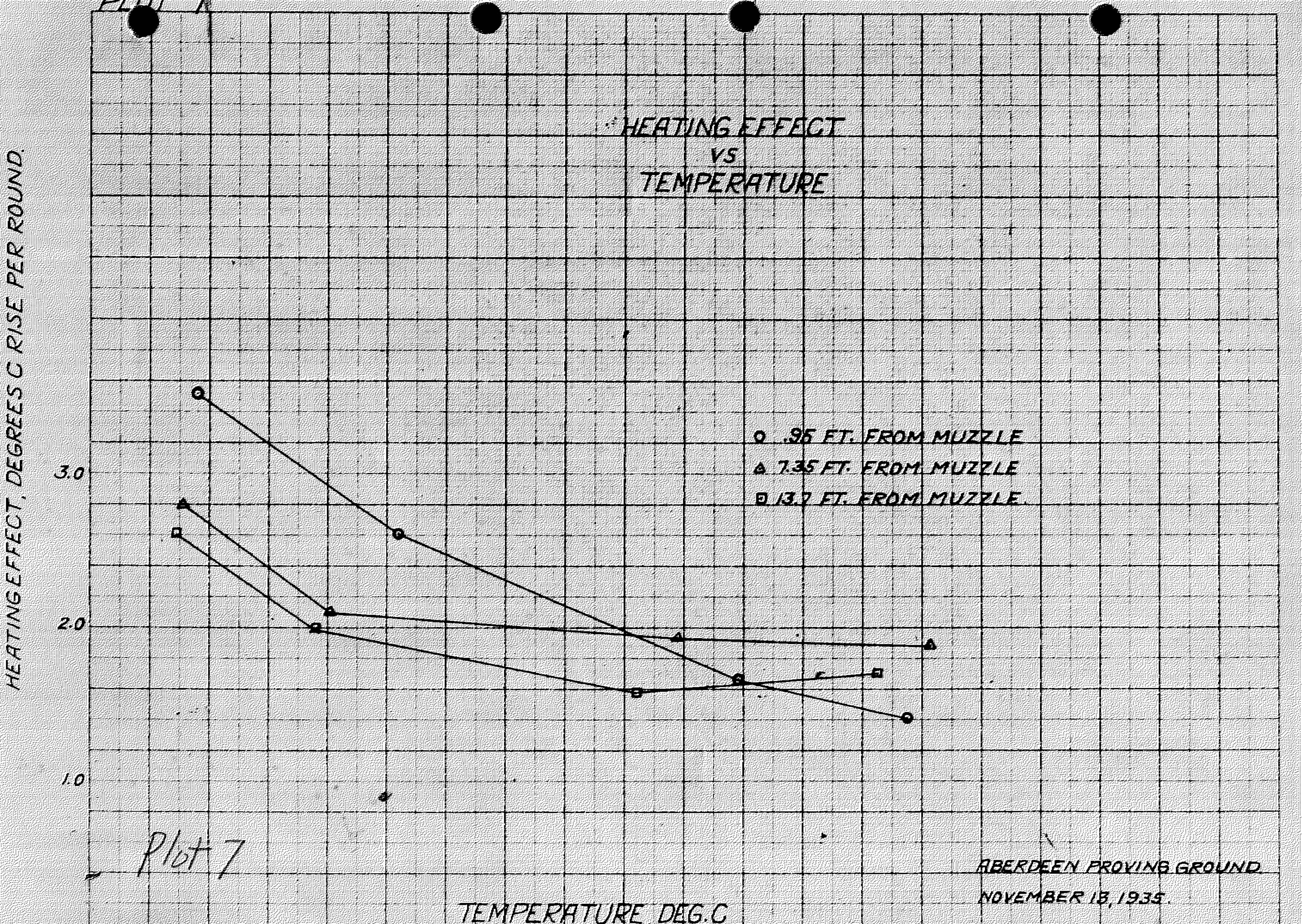
RP-4


PLOT 5
TEMPERATURE
VS.
TIME
RAPID FIRE TEST OF 105 MM A.A. GUN, M1 NO. 2.
FIRED: MARCH 22, 1935
○ THERMOCOUPLE .35 FEET FROM MUZZLE
△ THERMOCOUPLE 7.35 FEET FROM MUZZLE
300
250
200
150
100
50
TEMPERATURE, DEGREES C
A
B
C
D
E
F
A 58 ROUNDS AT 8.07 RDS/MIN.
B FIRING SUSPENDED
C 66 ROUNDS AT 11.54 RDS/MIN.
D 28 ROUNDS FROM COVER AT 4.88 RDS/MIN.
E FIRING SUSPENDED
F 16 ROUNDS AT 7.87 RDS/MIN.
TIME, HOURS, MINUTES.
ABERDEEN PROVING GROUND
NOVEMBER 13, 1935.
Plot 5

PLOT 6


TEMPERATURE
VS
TIME
RAPID FIRE TEST OF 105 M/M A.A. GUN M1 NO. 2
MARCH 22, 1935
▣ THERMOCOUPLE 13.7 FEET FROM MUZZLE
+ RECUPERATOR TEMPERATURE.
a 58 ROUNDS AT 8.07 RDS./MIN.
b FIRING SUSPENDED.
c 66 ROUNDS AT 11.54 RDS./MIN.
d 28 ROUNDS FROM COVER AT 4.88 RDS./MIN.
e FIRING SUSPENDED.
f 16 ROUNDS AT 7.87 RDS./MIN.
a
b
c
d
e
f
250
200
150
100
50
10
TIME: HOURS MINUTES
ABERDEEN PROVING GROUND.
NOVEMBER 13, 1935

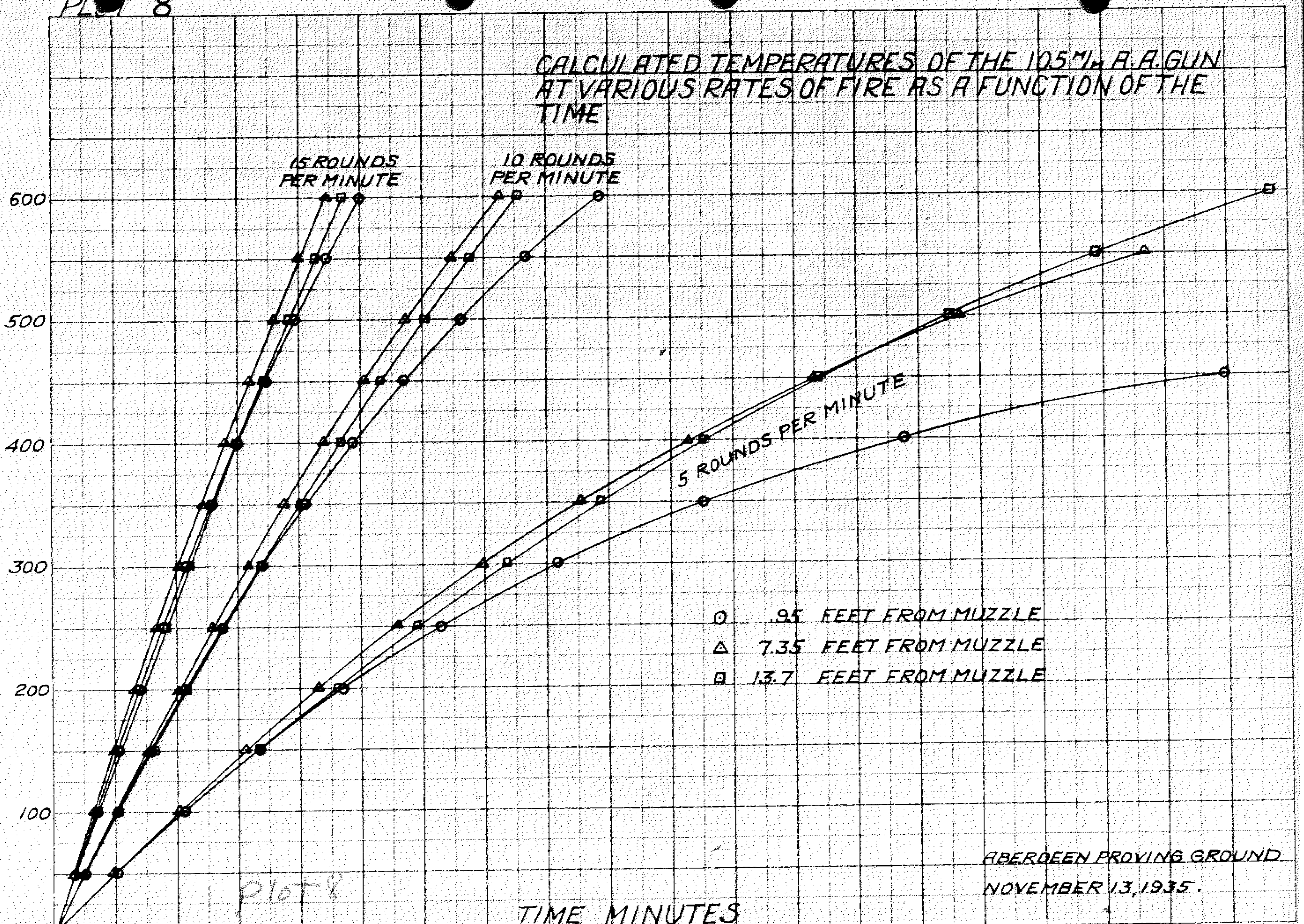
Plot 6



Plot 7

ABERDEEN PROVING GROUND.
NOVEMBER 18, 1935.

PLOT 8



CALCULATED TEMPERATURES OF THE 105 M/M A.A. GUN AT VARIOUS RATES OF FIRE AS A FUNCTION OF THE TIME.

ABERDEEN PROVING GROUND
NOVEMBER 13, 1935.

Plot 8

Form No. [illegible]
[illegible]

REC[illegible]D OF FIRINGS AT ABERDEEN PROVING GROUND, MARYLAND

105 M/M A.A. GUN Model of M1 No. 2 Mfr. WATERVLIET ARSENAL

Mounted on 105 M/M A.A. GUN MOUNT

Carriage, Model of. M1 No. 2 Mfr. WATERTOWN ARSENAL

Recuperator, Model of No. Mfr.

Object of firing RAPID FIRE TEST OF 105 M/M A.A. GUN

Powder D.P. SMOKELESS LOT 1483 FOR 6" GUN
D.P. FNH LOT X-3675 FOR 3" A.A. GUN
D.P. FNH LOT EX 4264 FOR 105 M/M A.A. GUN

Igniter

Primers M21, P.A. LOT 6339-2

Projectile 105 M/M A.A. PROOF SLUG, DRG. G.A. 1065 (RDS. 729 -820)
105 M/M A.A. PROOF SLUG, MODIFIED IN ACCORDANCE WITH A.
P.G. DRG. 2439-AD. (RDS. 821 - 939)

Fuse

T. S. T. P. Item No.
~~[illegible]~~ A.P.C. K065
O. O. File No. 472.93/4007 & 472.93/4187
A. P. G. File 472.220/63 & 472.220/63-1
Work Order No. 3417-1-4

1e

Record No. 6283

Sheet 1 of 2 sheets

Date 1935	Number of Fire: Gun	Carriage	Recuperator	Time of Firing	Temp. of Powd. °F	Powder: Lot No.	Powder Weight: Lbs.	Powder Weight: Ozs.	Projectile Weight: Lbs.	Projectile Weight: Ozs.	Seating of Projectile, Ins.	Elevation: Deg.	Elevation: Min.	Recoil, Inches	Velocity: Measured at Muzzle ft. SOL.	Velocity: Corr. Meas. BOUL.	Pressure: Measured in Lbs. per Sq. Inch	Pressure: Cor. for Erosion	Ground Observation at Gun: Flash Size	Flash Color	Smoke Amount	Smoke Color	Air Observation at 10,000 Ft. SMOKE	Remarks
MARCH 7	729			9:48		1483	9	0	32	10		1	25½		2495	2503	23500							Fired to establish charge.
	730			9:59		"	10	"	32	12		"	"		Lost	2706	28275							
	731			10:17		"	11	"	32	13		"	"		2909	2911	35675							
	732			10:35		"	10	7½	32	14		"	"		2801	2799	31950							
	733			10:47		"	"	"	"	"		"	"		2790	2782	31125							
15	751 to 770. 20 rds.			10:38 to 10:41		"	10	8	(APPROX.) 33	0		29	00			Est. 2800	Est. 32000							
22	771			11:30		3675	10	5	"	"		"	"			2750	33000		None		Medium	Light Gray	1 round Light Gray	
	772			11:42		"	"	"	"	"		"	"			"	"		"		"	" "		
	773					"	"	"	"	"		"	"			"	"		"		"	" "		
	774					"	"	"	"	"		"	"			"	"		"		"	" "		
	775					"	"	"	"	"		"	"			"	"		"		"	" "		
	776					4264	10	9	"	"		"	"			2775	34500		"		"	" "	Light Gray	
	777					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	778					"	"	"	"	"		"	"			"	"		Muzzle" Glow		"	" "	" "	
	779					"	"	"	"	"		"	"			"	"		" "		"	" "	" "	
	780					"	"	"	"	"		"	"			"	"		None		"	" "	" "	
	781					3675	10	5	"	"		"	"			2750	33000		"		"	" "	" "	
	782					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	783					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	784					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	785					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	786					4264	10	9	"	"		"	"			2775	34500		"		"	" "	Heavy Gray	
	787					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	788					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	789					"	"	"	"	"		"	"			"	"		Muzzle Glow		"	" "	" "	
	790					"	"	"	"	"		"	"			"	"		None		"	" "	" "	
	791					3675	10	5	"	"		"	"			2750	33000		"		"	Gray	Dark "	
	792					"	"	"	"	"		"	"			"	"		"		"	"	" "	
	793					"	"	"	"	"		"	"			"	"		"		"	"	" "	
	794					"	"	"	"	"		"	"			"	"		"		"	"	" "	
	795					"	"	"	"	"		"	"			"	"		"		"	"	" "	
	796					4264	10	9	"	"		"	"			2775	34500		"		"	Light Gray	Light "	
	797					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	798					"	"	"	"	"		"	"			"	"		Muzzle Glow		"	" "	" "	
	799					"	"	"	"	"		"	"			"	"		" "		"	" "	" "	
	800					"	"	"	"	"		"	"			"	"		" "		"	" "	" "	
	801					3675	10	5	"	"		"	"			2750	33000		None		"	Gray	Black	
	802					"	"	"	"	"		"	"			"	"		"		"	"	"	
	803					"	"	"	"	"		"	"			"	"		"		"	"	"	
	804					"	"	"	"	"		"	"			"	"		Muzzle Glow		"	"	"	
	805					"	"	"	"	"		"	"			"	"		" "		"	"	"	
	806					4264	10	9	"	"		"	"			2775	34500		None		"	Light Gray	Light Gray	
	807					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	808					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	809					"	"	"	"	"		"	"			"	"		"		"	" "	" "	
	810					"	"	"	"	"		"	"			"	"		"		"	" "	" "	

Continued on following sheet.

METEOROLOGICAL DATA

DATE	TIME	BAROMETER	THERMOMETER	HUMIDITY	WIND DIR.	WIND MPH
Mar.7th	10 AM	30.13	41.0	51	NE	17
Mar.15th	10 AM	29.62	57.2	92	S	12
Mar. 22nd	12 Noon	29.77	62.0	40	NW	8

Form No. 2344 a
[illegible]

RECORD OF FIRINGS AT ABERDEEN PROVING GROUND, MARYLAND

105 M/M A.A. GUN Model of M1 No. 2 Mfr. WATERVLIET ARSENAL

Mounted on 105 M/M A.A. GUN MOUNT Carriage, Model of M1 No. 2 Mfr. WATERTOWN ARSENAL

Recuperator, Model of No. Mfr.

T. S. T. P. Item No.

~~Ord. Dwg. No.~~ A.P.G. KC65

O. O. File No. 472.93/4007 & 472.93/4187

A. P. G. File 472.220/63 & 472.220/63-1

Work Order No. 3417-1-4

Object of firing RAPID FIRE TEST OF 105 M/M A.A. GUN

Powder

Igniter

Primers

Projectile

Fuse

Continued from preceding sheet.

DATE 193	NUMBER OF FIRE			TIME OF FIRING	TEMP. OF POWD. F.	POWDER			PROJECTILE		SEATING OF PROJECTILE, INS.	ELEVATION		RECOIL, INCHES	VELOCITY		PRESSURE		GROUND OBSERVATION AT GUN				AIR OBSERVATION AT 10,000 FT.
	Gun	Carriage	Recuperator			Lot No.	Weight Lbs.	Weight Ozs.	Weight Lbs.	Weight Ozs.		Deg.	Min.		Measured at Muzzle f/s	Cor. to Lbs. Wt. of Proj. and Erosion	Measured in Lbs. per Sq. Inch	Cor. for Erosion	FLASH Size	FLASH Color	SMOKE Amount	SMOKE Color	SMOKE
1935									APPROX.						EST.		EST.						
MARCH 22	811					3675	10	5	33	0		29			2750		32000		None		Medium	Gray	Black
	812					"	"	"	"	"		"			"		"		"		"	"	"
	813					"	"	"	"	"		"			"		"		"		"	"	"
	814					"	"	"	"	"		"			"		"		Muzzle glow		"	"	"
	815					"	"	"	"	"		"			"		"		None		"	"	"
	816					4264	10	9	"	"		"			2775		34500		Muzzle glow		"	Light Gray	Light Gray
	817					"	"	"	"	"		"			"		"		None		"	"	"
	818					"	"	"	"	"		"			"		"		Muzzle glow		"	"	"
	819					"	"	"	"	"		"			"		"		None		"	"	"
	820			11:48		"	"	"	"	"		"			"		"		Muzzle glow		"	"	"
	821			11:48½																			
	to			to																			
	895	103 rds.		11:56		1483	10	8	"	"		"			2860		32000						
	to			to																			
	923			12:02																			
	924			12:12																			
	to	16 rds.		to		1483	10	8	"	"		"			"		"						
	939			12:14																			

Remarks Continued: An examination of cartridge cases showed the following : 2 cases ruptured at neck, 1 case ruptured at neck with impressions on the upper part of the case indicating something had been between cartridge case and chamber wall of gun when fired, 3 cases split at mouth, 4 cases torn at mouth, 13 cases dented longitudinally at neck, 68 cases without primers or primer bodies. Forty-nine M21 primer bodies were found on the ground around the gun. All indicated that the body had broken off at the forward thread flush with the forward part of the head. It is understood since this lot of primers (6339-2) was manufactured that the body has been strengthened at the threaded sector in subsequent lots.

The air observer reported no visible flash or glow on Rds. 771 - 820. Also that light smoke was slightly easier to pick up than the dark smoke against the dark background.

The proof officer observed flash and smoke at the gun.

1st Lt. J. H. Binrichs observed flash and smoke from the air.

Mr. B.E. Anderson, Office of the Chief of Ordnance, and Dr. W.A. Dew, Du Pont Co. were air observers on Rds. 771 - 820.

Mr. R. G. Woodbridge, Du Pont Co. was present at test.

Rates of Fire: (Rds. 772 - 820) 8-1/6 rds. per minute. (Rds. 821 - 895) 9-3/8 rds. per minute. (aRds. 896 - 923) 4-2/5 rds. per minute. (bRds. 924 - 939) 8 rds. per minute.

a - After firing Rd. 895, personnel took cover after each round, thereafter materially slowing up the rate of fire. b - First ten rounds fired without personnel taking cover. On remainder of group, cover was taken for each round.

Average rate of fire (Rds. 772 - 939 incl. was 5.25 rounds per minute on total elapsed time or 7.64 rds. per minute excluding the ten minute interval between Rds. 923 & 924.

With Powder Lot 3675 a five oz. black powder front igniter pad was used held in place by attaching it to a cheesecloth bag containing 3 lbs. of Powder, Lot 3675. This was the front part of the propelling charge.

REMARKS Record No. 8283

Sheet 2 of 2 sheets

Screen Distances:

(Solenoid) Gun to 1st Coil - 10 ft.
Between Coils - 199.26 ft.

(Boulenge) Gun to 1st Screen - 100 ft.
Between Screens - 199.20 ft.

This test was conducted in accordance with O.O. 472.93/4007, A.P.G. 472.220/63 as modified by O.O. 472.93/4187, A.P.G. 472.220/63-1.

During Rds. 751 - 770 incl. the trigger failed several times.

Breech block stuck on Rds. 830 & 852 due to piece of broken primer caught between breech block and breech of gun.

On Rds. 868 & 869 several jerks of the lanyard were required to fire them.

Rd. 924 failed to fire on first trial. Firing mechanism examined and worn sear found. Replaced with new sear.

Rd. 940 failed to fire. Firing pin found not to be hitting primer. Three combinations of firing pins and sears tried without success. Firing was stopped. Breech block removed from gun and disassembled.

It was discovered that Sear Spring Seat (A12531) against which the sear spring acts had unscrewed due to the jar of firing to such an extent that the compression of the sear spring was not sufficient to actuate the sear. Hence the sear did not catch the firing pin holder (B8098) as it moved back after firing Rd. 939 and consequently it was impossible to get enough force behind the firing pin to set off the primer.

The bases of all cartridge cases showed a radial groove or scratch indicating a dragging of the firing pin as the breech block dropped from firing position.

Apparently the movement of the firing pin to the rear after firing was too slow to clear the base of the cartridge case as the breech block dropped.

Nut B124076 on left housing D8469 (Elevating mechanism) loosened causing binding between worm wheel (C8760) and worm (C8762).

It is recommended that the authority be given to modify the elevating mechanism by using a spline screw to prevent the nut from turning on the housing.

No distance wadding used.

A large percentage of primers were fired out the muzzle of the gun.

GEORGE W. PALMER,
1st Lt., Ord. Dept.,
Proof Officer.

R. S. BARR,
Major, Ord. Dept.,
Chief Proof Officer,
Gun Testing Division.

APPROVED:

C. M. WESSON,
Col., Ord. Dept.,
Commanding.