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EXTERNAL BARREL TEMPERATURE OF THE M16A1 RIFLE

Ronald E. Elbe

Rock Island Arsenal
Rock Island, Illinois

July 1975

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R-TR-75-045

EXTERNAL BARREL TEMPERATURE OF THE M16A1 RIFLE

by

RONALD E. ELBE

JULY 1975

TECHNICAL REPORT

SMALL ARMS WEAPONS
SYSTEMS DIRECTORATE

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GENERAL THOMAS J. RODMAN LABORATORY
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This test program studies external barrel temperature of the M16A1 Rifle and the dependence of barrel temperature on the following five parameters: radial location on barrel, longitudinal location on barrel, rate of fire, mode of fire, and type of ammunition.

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ABSTRACT

This test program studies external barrel temperature of the M16A1 Rifle and the dependence of barrel temperature on the following five parameters: radial location on barrel, longitudinal location on barrel, rate of fire, mode of fire, and type of ammunition.

FOREWORD

The coordinated efforts of several employees were essential to the successful completion of this program. Thus, it is fitting that they be recognized below:

Loren F. Brunton	SARRI-LS-P
George H. Stewart	SARRI-LS-P
James N. Blecker	SARRI-LR-W

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INTRODUCTION

From time to time, limited tests have been conducted to determine external barrel temperatures on the M16A1 Rifle. However, these tests have been limited to only those measurements required to solve the problem of the moment. Repeated inquiries from other organizations as well as our own need for more barrel temperature data led to the initiation of this test program. The following report provides a record of external barrel temperature of the M16A1 Rifle under a variety of conditions. The effect of five variables on barrel temperature is evaluated. The five variables are: (1) radial location on barrel; (2) longitudinal location on barrel; (3) rate of fire; (4) mode of fire; and (5) type of ammunition.

BACKGROUND

This Directorate has recently initiated work on a product improvement program to improve the accuracy life of the M16A1 Rifle's barrel. A portion of the product improvement program is directed toward the reduction of bore temperatures by optimization of the heat transfer characteristics of the barrel's exterior. The barrel temperature test recorded in this report provides the data base necessary for the optimization of the barrel's external configuration. Only pertinent temperature data is recorded in depth in this report. Details of test instrumentation, data collection, and data reduction are presented elsewhere.[1]

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[1] Blecker, J.N., "M16A1 Thermal Barrel Firing Test, March 1975, Rodman Laboratory Technical Note #R-TN-75-009."

OBJECTIVE

The purpose of the firng tests recorded herein is to provide M16A1 Rifle external barrel temperature data for a broad spectrum of the most significant parameters such as location on barrel, rate and mode of fire, and type of ammunition.

TEST PROCEDURE

One M16A1 Rifle was prepared for the test by the installation of thirteen thermocouples. As shown in Figure 1, of Appendix B, thermocouples were attached on top of the barrel at locations 1, 2, 4, 6, 9, 12, 13.75, 15, 17, and 19 inches forward of the bolt face, and on the bottom of the barrel 4, 9, and 17 inches forward of the bolt face. The instrumented rifle was then fired eight three-hundred-round firing cycles as follows:

FIRING #	RATE OF FIRE	AMMUNITION
1	1 round each 6 seconds	M193 Ball
2	1 round each 3 seconds	M193 Ball
3	1 round each 1 second	M193 Ball
4	20 rounds each 20 seconds (full auto)	M193 Ball
5	20 rounds each 10 seconds (full auto)	M193 Ball
6	20 rounds each 5 seconds (full auto)	M193 Ball
7	1 round each 1 second	M196 Tracer
8	20 rounds each 20 seconds (full auto)	M196 Tracer

The rifle was cooled to ambient temperature after each 300 round cycle.

TEST RESULTS

Figures 2 through 9 in Appendix B graphically display maximum burst temperatures for firings 1 through 8 respectively. In order to simplify and clarify the graphs, actual round-to-round or burst-to-burst temperature variations are omitted. An example of actual temperature variation within a cycle is shown in Figure 10.

Firings 1, 6, and 7 included a test for projectile yaw. This test required that the gunner clear the weapon and go downrange to position the yaw target before he fired the last twenty rounds of the 300 round cycle. The delay thus incurred prevented the requested schedule from being maintained for more than 280 rounds. Therefore, for comparative purposes, barrel temperatures are recorded after 280 rounds of each cycle in Table I of Appendix A. Table II contains barrel temperature data after 140 rounds, the midpoint of the comparative cycle. No projectile yawing was found.

ANALYSIS OF TEST RESULTS

A comparison of location 4T with 4B, 9T with 9B, and 17T with 17B in Table I reveals an average circumferential temperature differential of less than 10^{0}F regardless of firing schedule or longitudinal location along barrel. As would be expected, the top of the barrel is several degrees hotter than the bottom of the barrel at the same longitudinal location after 280 rounds of firing.

Variation of temperature with longitudinal location along the barrel is graphically depicted in Figures 11 and 12. Those two graphs show that the hottest area of the barrel's exterior surface lies four to six inches ahead of the bolt face. It is also interesting to note that the hottest area on the barrel moves rearward with increasing rate of fire. At 10, 20, and 60 rounds per minute the hottest location recorded was six inches ahead of the bolt face while at 120 and 240 rounds the hottest location recorded was four inches ahead of the bolt face. Two relatively cool areas exist on the barrel. The first of these is the area over the chamber and throat (0 to 2 inches ahead of the bolt face). This cool area is attributed to several factors such as the upper receiver and barrel nut acting as heat sinks as well as removal of heat from the chamber by the extracting cartridge case. The other relatively cool area occurs between 13 and 15 inches ahead of the bolt face where the handguard cap and front sight act as heat sinks.

Figure 13 shows that maximum barrel temperature increases dramatically with increasing rate of fire for rates less than 50 rounds per minute. Above 50 rounds per minute, the maximum barrel temperature is much less affected by rate of fire.

Effect of mode of fire on exterior barrel temperature can be evaluated by noting that firings 3 and 4 (Figures 4 and 5) differ only in that firing 3 was semiautomatic while firing 4 was full automatic. A comparison of Figures 4 and 5 reveals that during the first 230 rounds at 60 rounds per minute, peak barrel temperatures are up to 100°F higher for full automatic than for semiautomatic fire. After 230 rounds at 60 rounds per minute there is little difference between the two modes except near the breech (0" - 2") where full automatic fire continued to produce a hotter surface. It is intuitively obvious that changing only the mode of fire has no effect on heat input to the barrel per round fired. Ergo, for a given rate of fire the average heat input per unit time must also be independent of mode of fire. However, full automatic fire inputs the heat from any one magazine of cartridges in a relatively short period of time which results in short periods of higher barrel temperatures although the average barrel temperature increase per unit time is not mode-of-fire dependent.

The last parameter to be studied is type of ammunition. Semiautomatic firings 3 and 7 are alike except that firing 3 used M193 Ball and firing 7 used M196 Tracer. Similarly, the full automatic firings 4 and 8 differ only by type of ammunition. A comparison of firing 3 with 7 and 4 with 8 in Tables I and II reveals an interesting phenomenum. In each case, the nine inches of the barrel nearest the breech was hotter with tracer ammunition than with ball while the rest of the barrel was hotter with ball ammunition than with tracer ammunition. This phenomenum is not too surprising when one considers that M193 Ball ammunition contains spherical ball propellant while M196 tracer contains tubular IMR propellant, propellants with different flame temperatures and burning characteristics.

CONCLUSIONS

The preceding analysis leads directly to the following seven conclusions:

(1) There is no significant temperature variation due to radial location on the barrel.

(2) The longitudinal location of maximum temperature lies four to six inches ahead of the bolt face when the bolt is in battery.

(3) The longitudinal location of maximum temperature lies further toward the breech for high rates of fire than it does for low rates of fire.

(4) The longitudinal location of minimum temperature is over the chamber. The next coolest location is under the front sight.

(5) Maximum barrel temperature increases very rapidly with increasing rate of fire for rates up to fifty rounds per minute. Increasing the rate of fire has much less effect on maximum barrel temperature for rates above fifty rounds per minute.

(6) For short firing schedules (less than 200 rounds between cooling) full automatic fire results in slightly higher peak barrel temperatures than semiautomatic fire.

(7) The firing of M196 Tracer ammunition gives higher barrel temperatures on the breech-half of the barrel and cooler barrel temperatures on the muzzle-half than M193 Ball.

APPENDIX A

TABLE I

BARREL TEMPERATURES (^{o}F) AFTER 280 RDS

LOCATION FIRING	1	2	4T	4B	6	9T	9B	12	13.75	15	17T	17B	19
1 (1rd/6 sec,M193)	**	287	551	549	645	607	605	470	382	**	407	400	375
2 (1rd/3 sec,M193)	**	384	765	760	873	806	801	643	519	436	563	**	521
3 (1rd/1 sec,M193)	324	593	1125	1121	1173	1103	1096	957	765	777	889	885	810
4 (20rd/20 sec,M193)	366	647	1100	1095	1146	1072	1061	914	771	775	910	900	806
5 (20rd/10 sec,M193)	369	737	1221	1217	1225	1168	1155	1053	860	898	1047	1037	942
6 (20rd/5 sec,M193)	361	845	1297	1292	1269	1225	1211	**	941	**	1140	**	**
7 (1rd/1 sec,M196)	327	590	1137	1134	1191	1104	1097	931	730	762	859	857	784
8 (20rd/20 sec,M196)	383	679	1141	1137	1187	1115	1105	900	753	749	886	848	784

**Data not available

TABLE II

BARREL TEMPERATURE (^{o}F) AFTER 140 RDS

LOCATION FIRING	1	2	4T	4B	6	9T	9B	12	13.75	15	17T	17B	19
1 (1rd/6 sec,M193)	**	265	500	499	585	552	550	430	349	**	386	380	354
2 (1rd/3 sec,M193)	**	330	637	635	719	683	680	552	441	381	502	**	466
3 (1rd/1 sec,M193)	249	460	818	816	838	805	802	707	558	586	685	680	613
4 (20rd/20sec,M193)	257	488	802	797	812	789	781	685	556	590	702	695	620
5 (20rd/10sec,M193)	245	546	847	843	835	823	814	742*	610	657*	763	757*	670*
6 (20rd/5 sec,M193)	246	606	889	885	860	841	832	**	654	**	799	**	**
7 (1rd/1 sec, M196)	248	470	866	862	880	828	824	685	526	562	655	645	580
8 (20rd/20sec,M196)	276	526	872	868	901	873	867	682*	553	562*	695	670*	588*

*Extrapolated data point

**Data not available

APPENDIX B

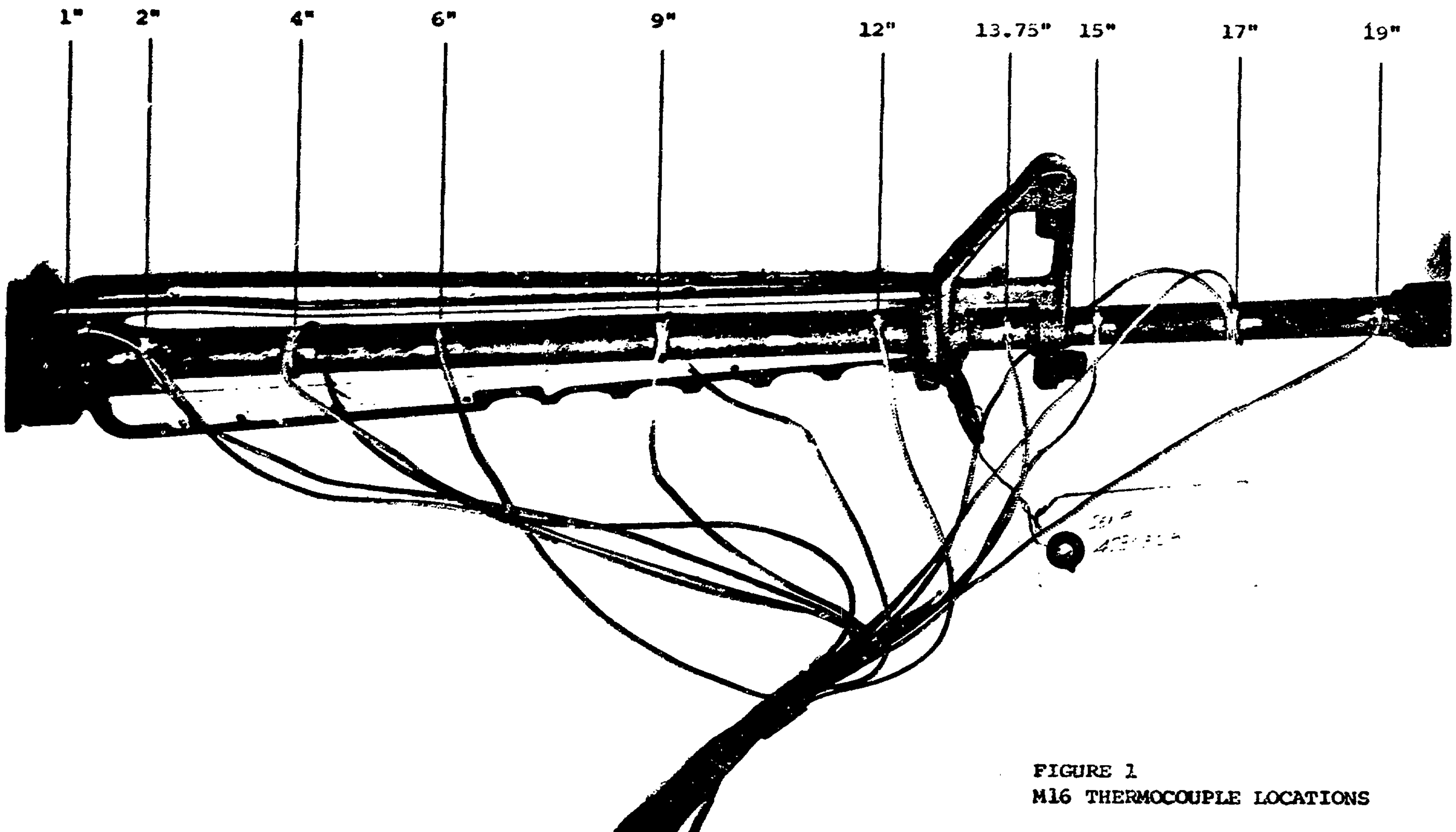


FIGURE 1
M16 THERMOCOUPLE LOCATIONS

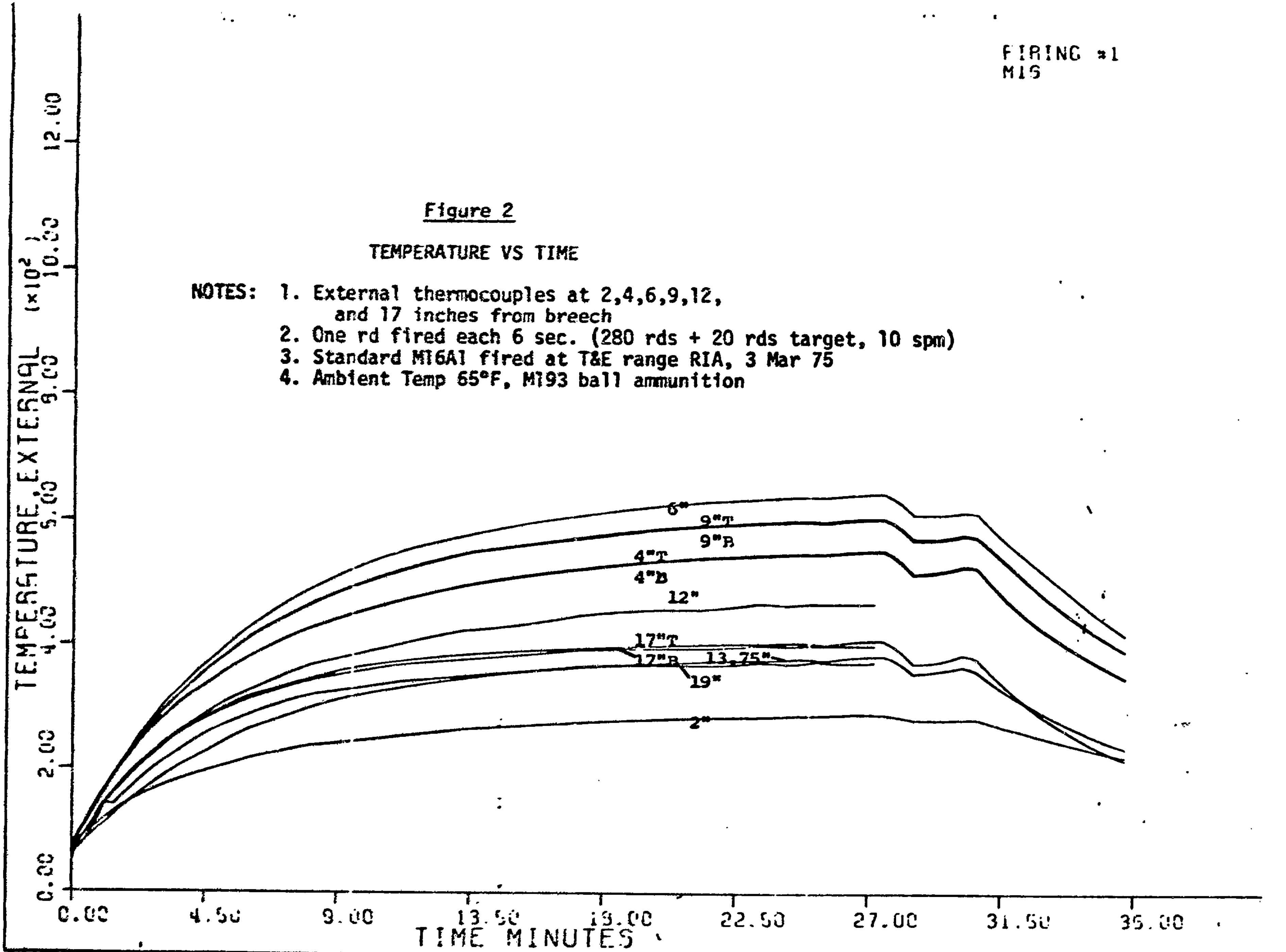


Figure 2

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 2,4,6,9,12, and 17 inches from breech
2. One rd fired each 6 sec. (280 rds + 20 rds target, 10 spm)
3. Standard M16A1 fired at T&E range RIA, 3 Mar 75
4. Ambient Temp 65°F, M193 ball ammunition

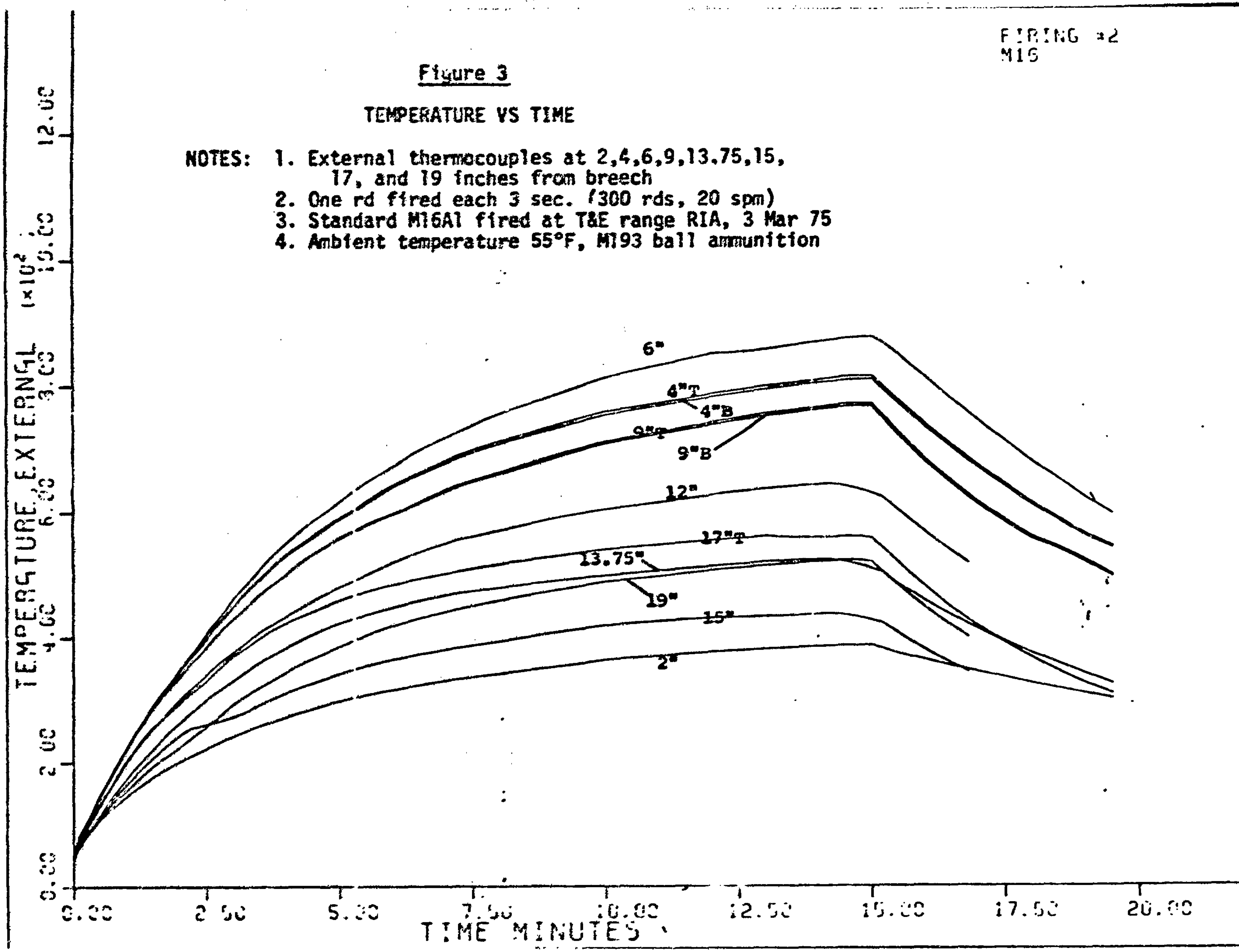


Figure 3

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 2,4,6,9,13.75,15, 17, and 19 inches from breech
2. One rd fired each 3 sec. (300 rds, 20 spm)
3. Standard M16A1 fired at T&E range RIA, 3 Mar 75
4. Ambient temperature 55°F, M193 ball ammunition

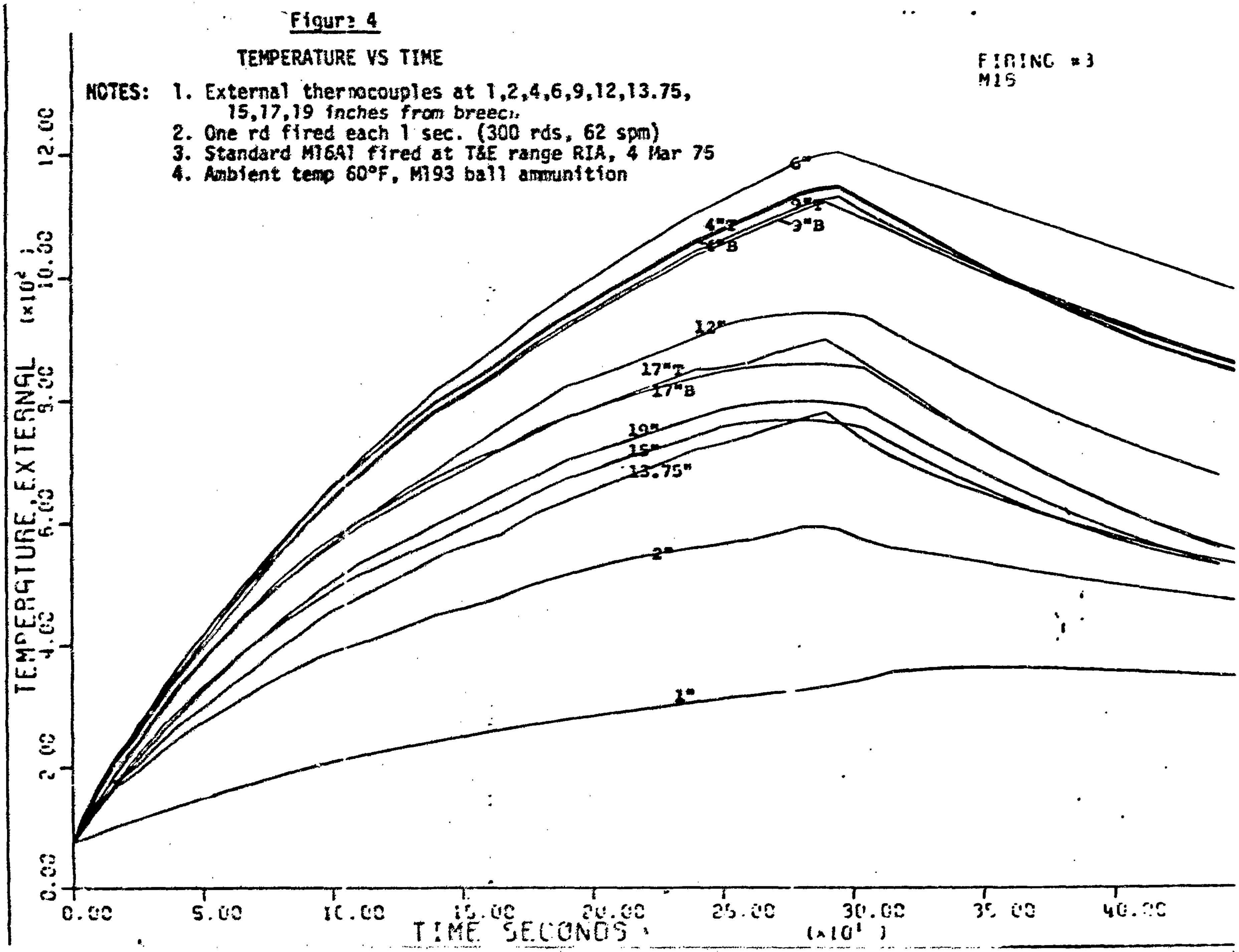
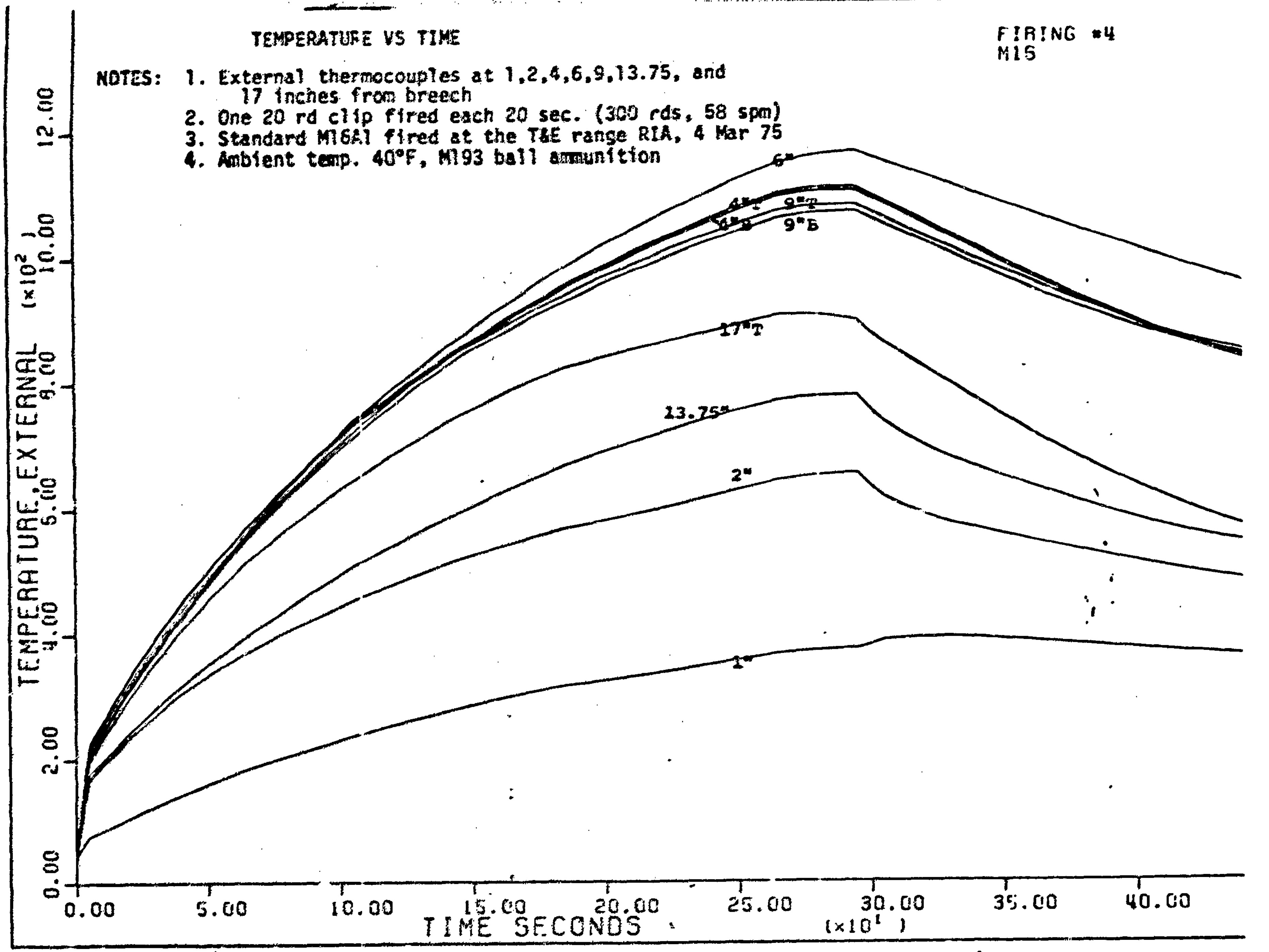


Figure 4

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 1,2,4,6,9,12,13.75, 15,17,19 inches from breech
2. One rd fired each 1 sec. (300 rds, 62 spm)
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temp 60°F, M193 ball ammunition


TEMPERATURE VS TIME
FIRING #4
M15
NOTES: 1. External thermocouples at 1,2,4,6,9,13.75, and 17 inches from breech
2. One 20 rd clip fired each 20 sec. (300 rds, 58 spm)
3. Standard M16A1 fired at the T&E range RIA, 4 Mar 75
4. Ambient temp. 40°F, M193 ball ammunition
6"
4"T
9"T
4"B
9"B
17"T
13.75"
2"
1"
TEMPERATURE, EXTERNAL (x10²)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
TIME SECONDS (x10¹)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00

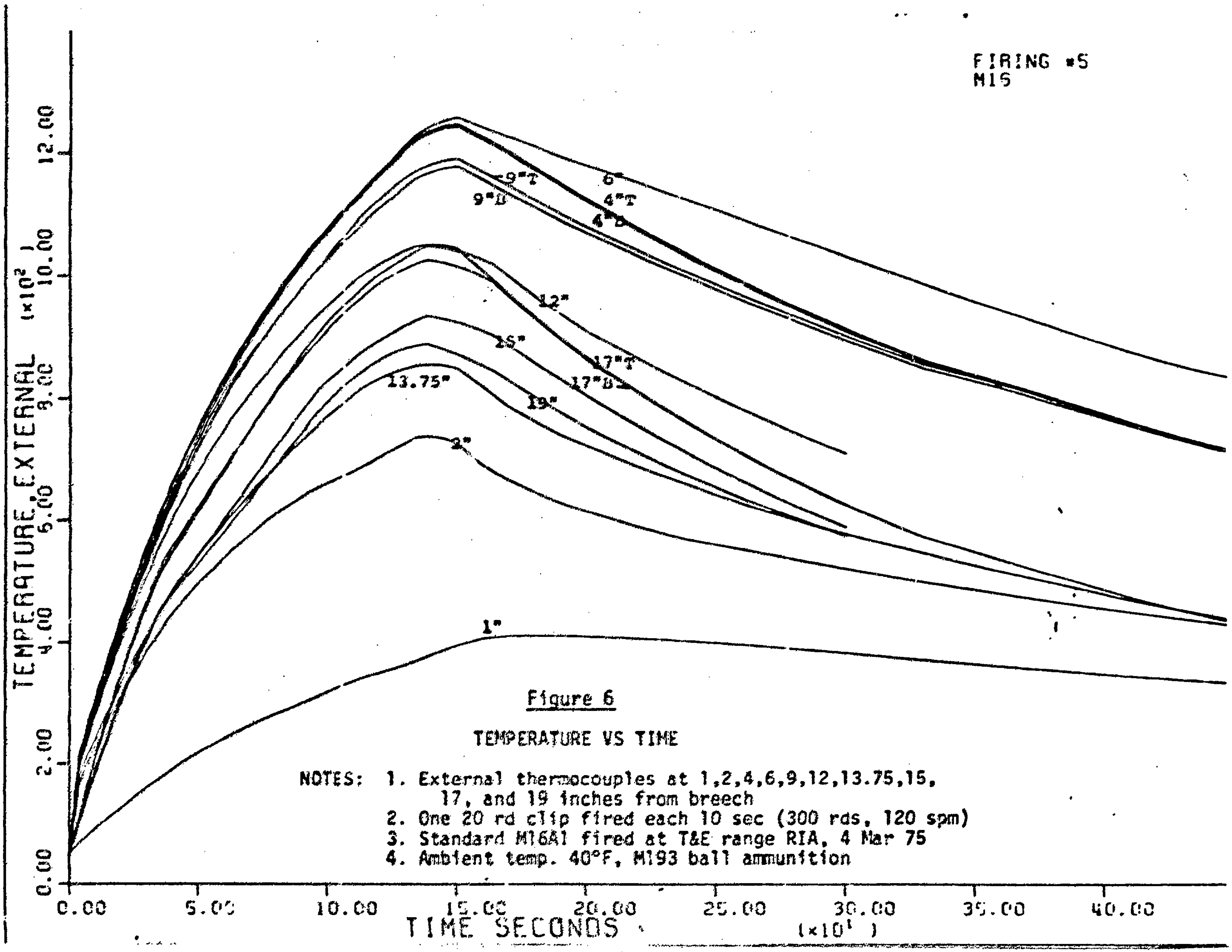


Figure 6

TEMPERATURE VS TIME

NOTES: 1. External thermocouples at 1,2,4,6,9,12,13.75,15, 17, and 19 inches from breech
2. One 20 rd clip fired each 10 sec (300 rds, 120 spm)
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temp. 40°F, M193 ball ammunition

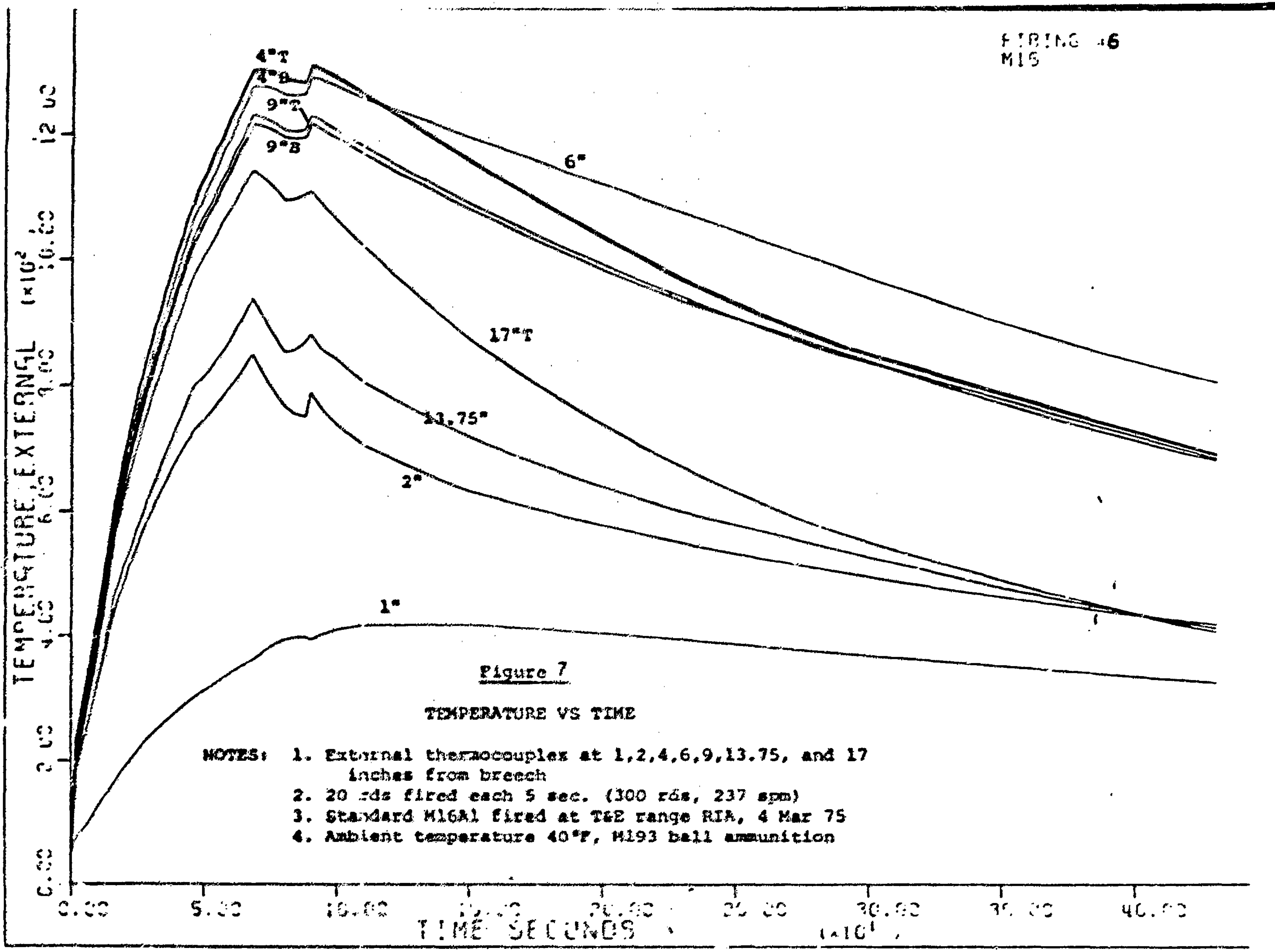


Figure 7

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 1,2,4,6,9,13.75, and 17 inches from breech
2. 20 rds fired each 5 sec. (300 rds, 237 spm)
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temperature 40°F, M193 ball ammunition

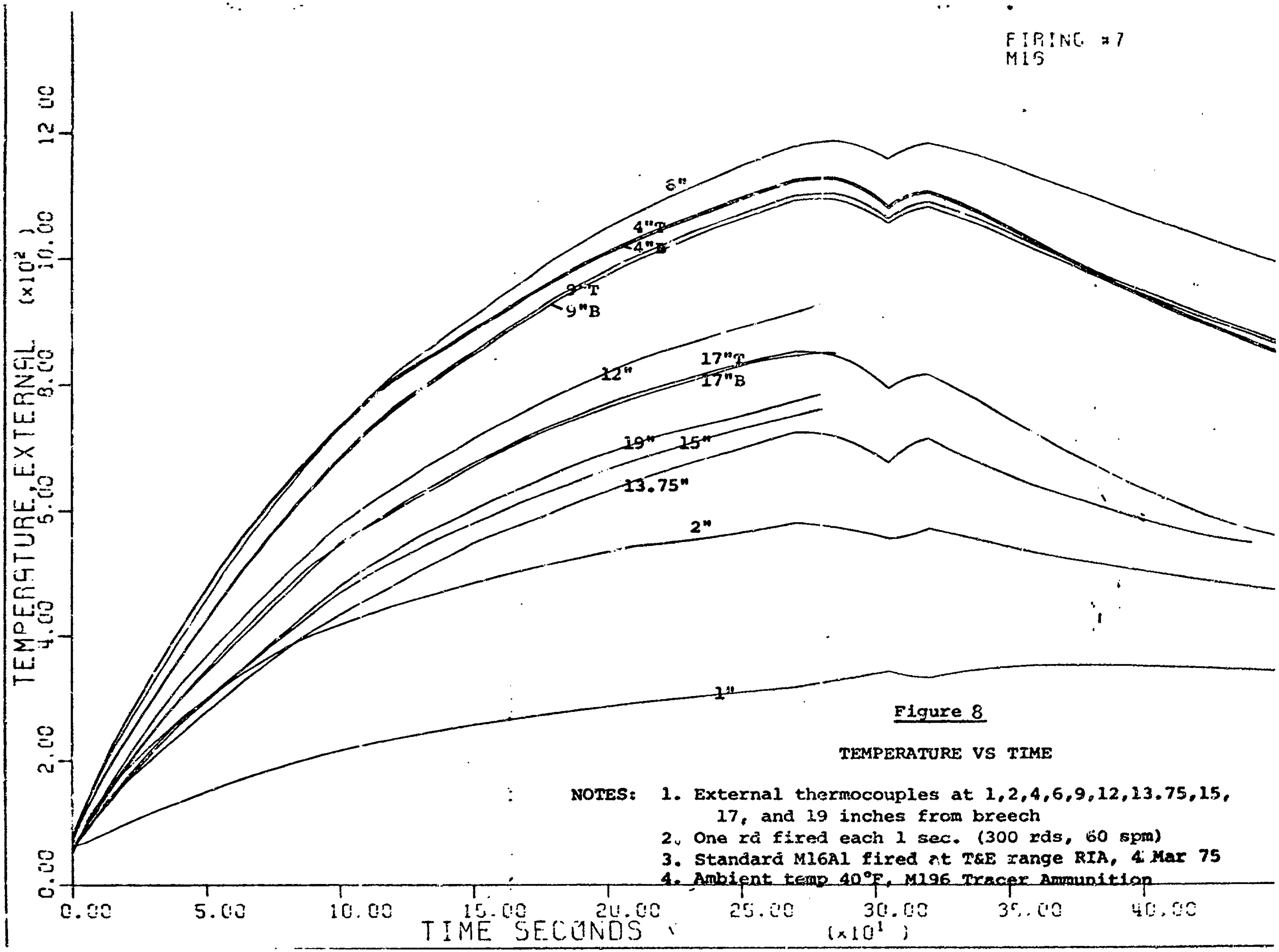


Figure 8

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 1,2,4,6,9,12,13.75,15, 17, and 19 inches from breech
2. One rd fired each 1 sec. (300 rds, 60 spm)
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temp 40°F, M196 Tracer Ammunition

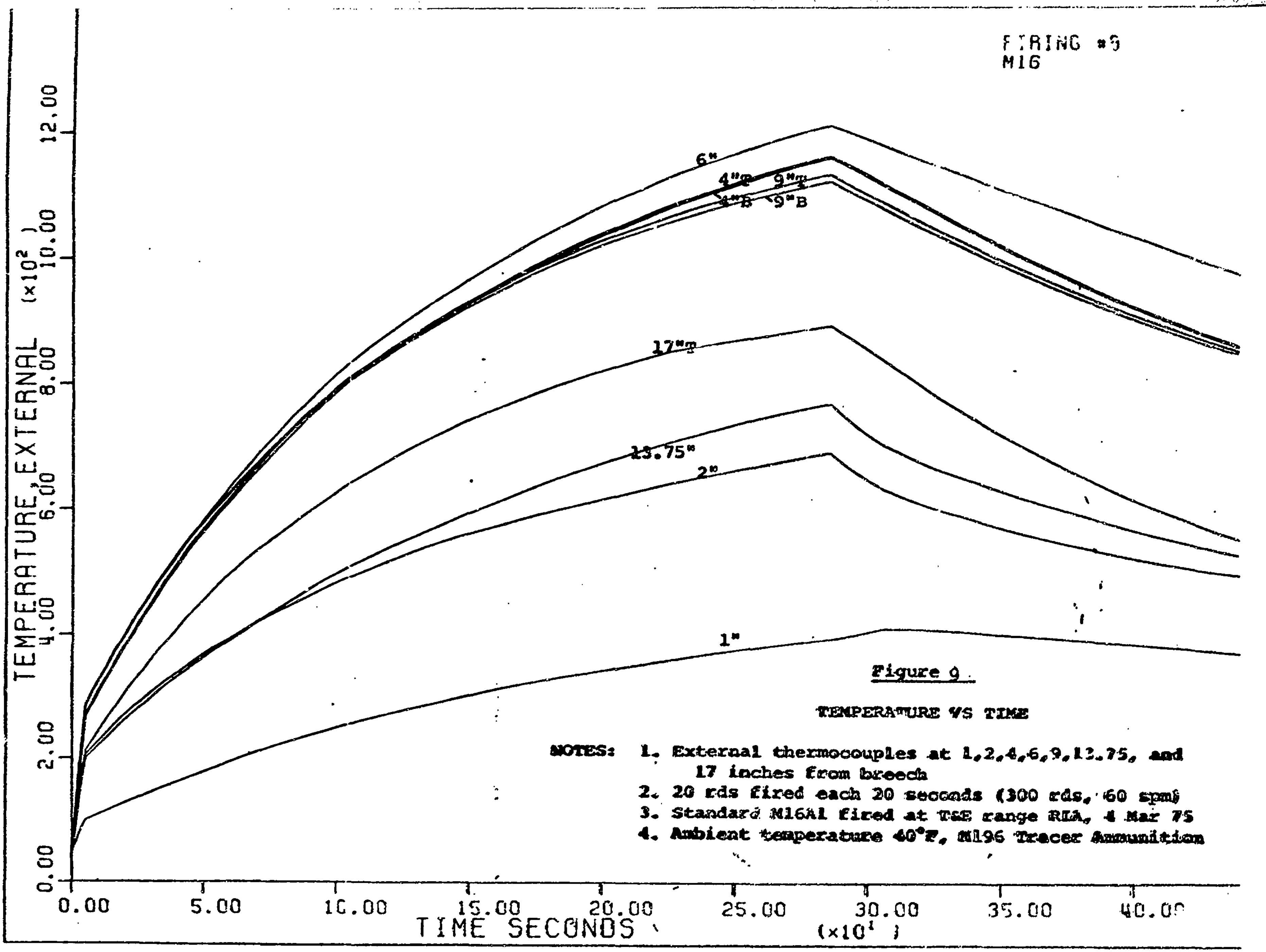


Figure 9

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 1,2,4,6,9,13.75, and 17 inches from breech
2. 20 rds fired each 20 seconds (300 rds, 60 spm)
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temperature 40°F, M196 Tracer Ammunition

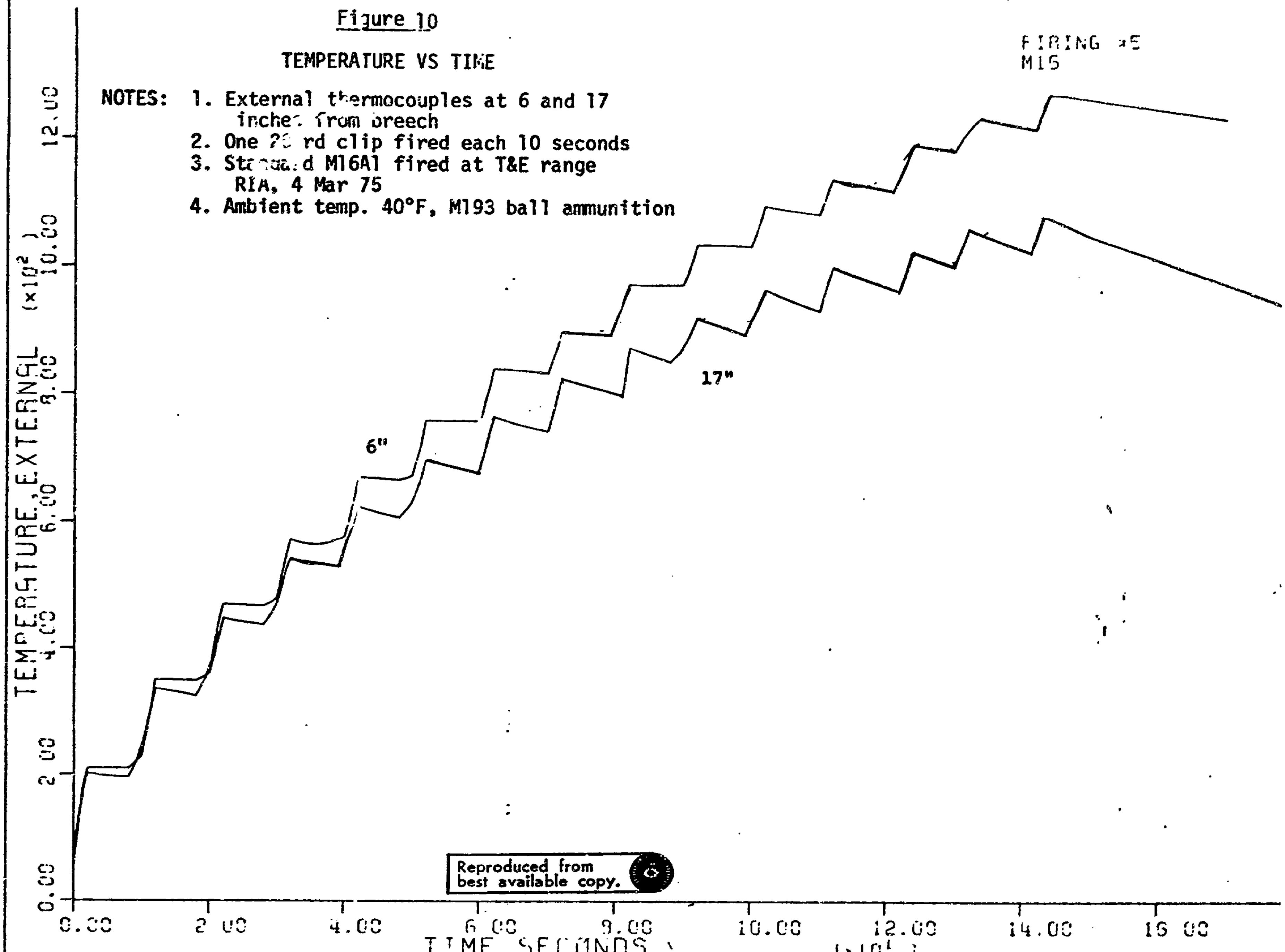


Figure 10

TEMPERATURE VS TIME

NOTES:
1. External thermocouples at 6 and 17 inches from breech
2. One 20 rd clip fired each 10 seconds
3. Standard M16A1 fired at T&E range RIA, 4 Mar 75
4. Ambient temp. 40°F, M193 ball ammunition

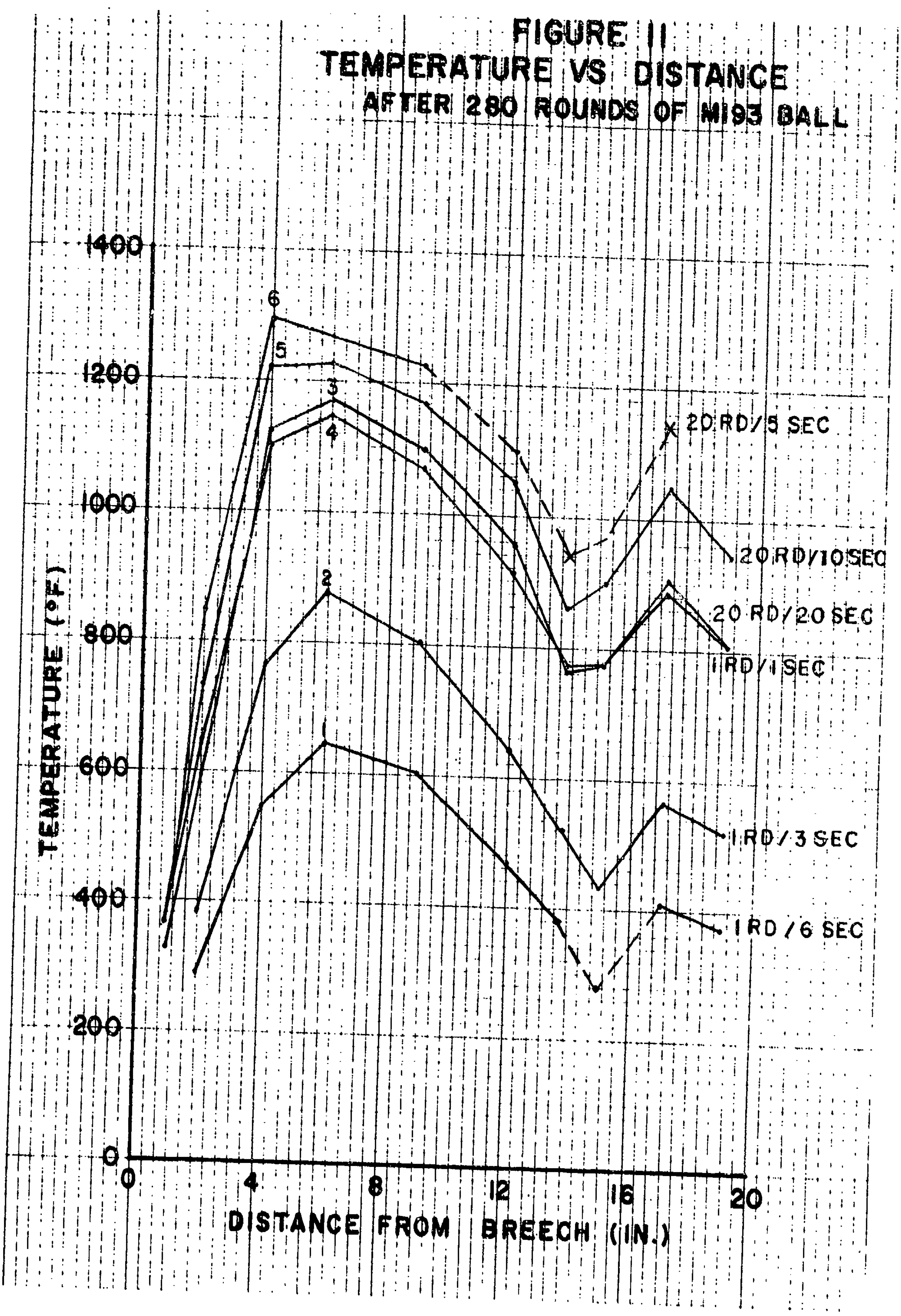


FIGURE 11
TEMPERATURE VS DISTANCE
AFTER 280 ROUNDS OF M193 BALL
TEMPERATURE (°F)
DISTANCE FROM BREECH (IN.)
20 RD/5 SEC
20 RD/10 SEC
20 RD/20 SEC
1 RD/1 SEC
1 RD/3 SEC
1 RD/6 SEC

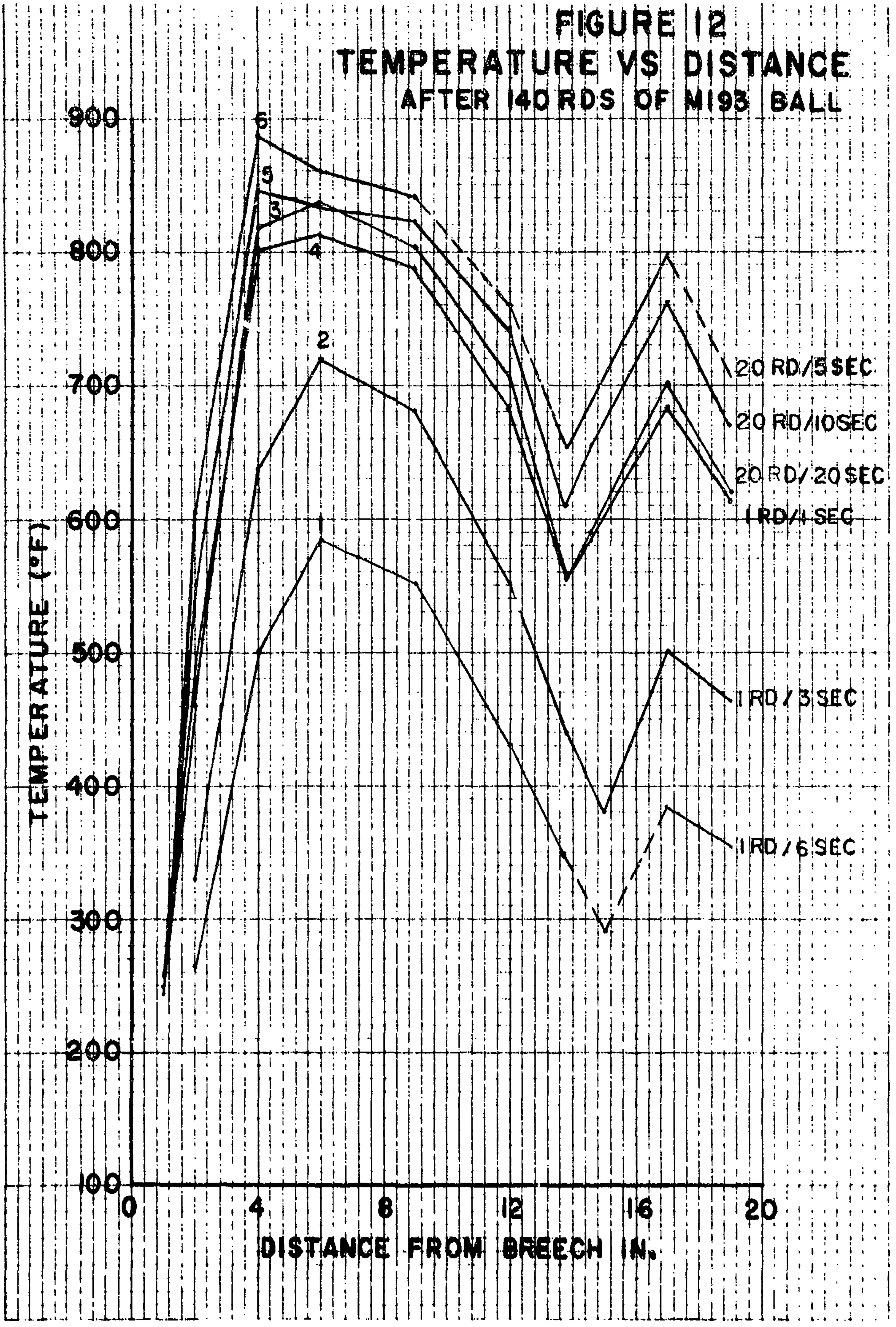


FIGURE 12
TEMPERATURE VS DISTANCE
AFTER 140 RDS OF M193 BALL
TEMPERATURE (°F)
DISTANCE FROM BREECH IN.
900
800
700
600
500
400
300
200
100
0
4
8
12
16
20
6
5
3
4
2
1
20 RD/5 SEC
20 RD/10 SEC
20 RD/20 SEC
1 RD/1 SEC
1 RD/3 SEC
1 RD/6 SEC

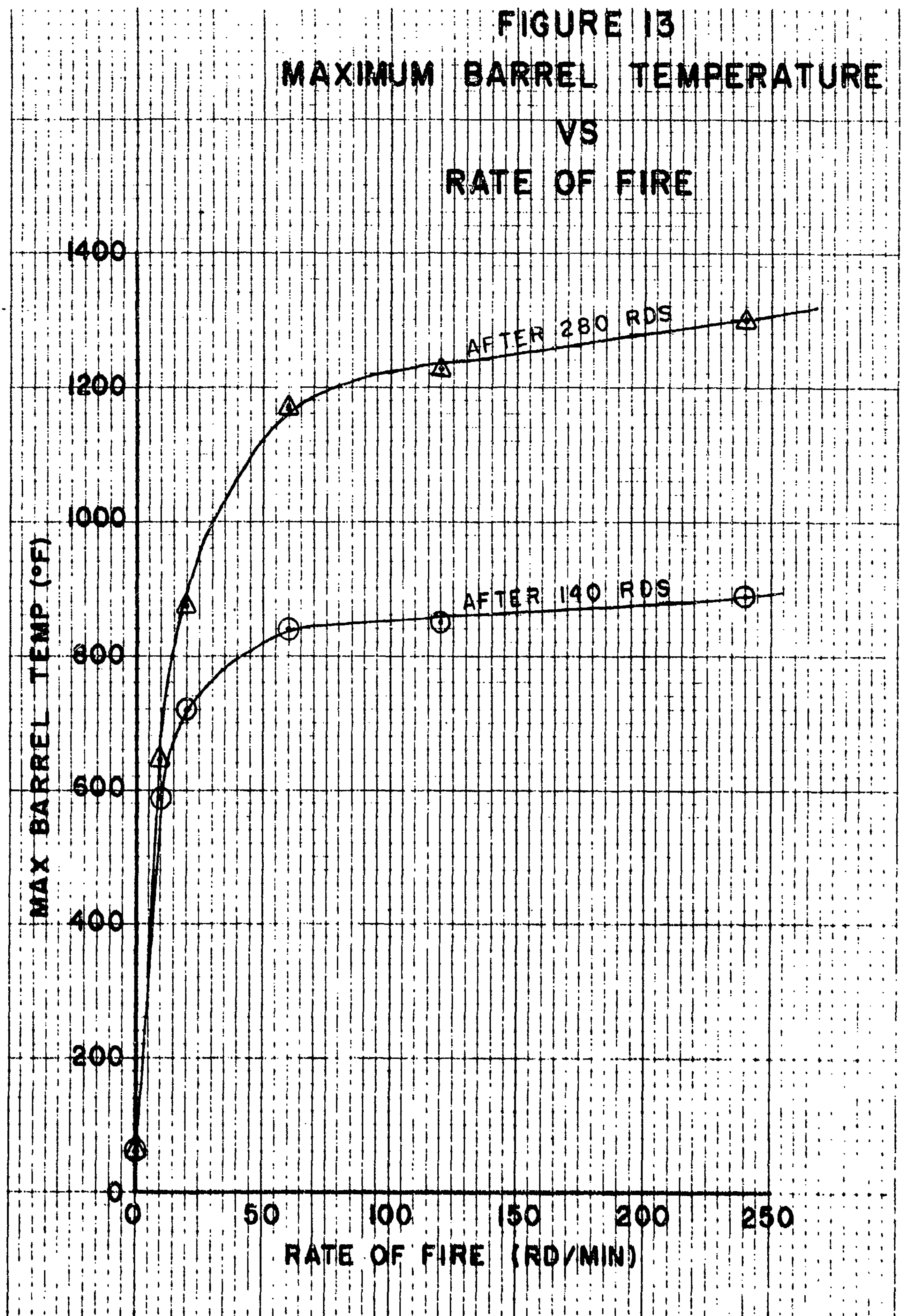


FIGURE 13
MAXIMUM BARREL TEMPERATURE
VS
RATE OF FIRE
MAX BARREL TEMP (°F)
1400
1200
1000
800
600
400
200
0
AFTER 280 RDS
AFTER 140 RDS
0
50
100
150
200
250
RATE OF FIRE (RD/MIN)

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