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SMALL ARMS GUN BARREL THERMAL EXPERIMENTAL CORRELATION STUDIES

James N. Blecker

Rock Island Arsenal
Rock Island, Illinois

June 1974

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Results presented in this report represent a portion of the effort under a task entitled "Gun Barrel Thermal Analysis and Experimental Correlation Studies". The objective of this effort is to measure transient barrel temperatures for small arms guns as a correlation to analytically predicted data and as an attempt to establish a correlation between thermal results and metallurgical determinations.

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A description is given of the experimental methodologies including barrel instrumentation, firing procedure and data acquisition. Results are given comparing various barrel materials and geometries for both sporadic and continuous automatic weapon fire. These results are discussed relative to barrel life and thermal performance.(U) It was determined that barrel geometry is a salient parameter governing both transient barrel temperatures and barrel erosion. It can be concluded based on these experimental results that there is a continuing need for optimum barrel design to obtain maximum barrel life consistent with performance requirements and minimum weight.

ERRATA SHEET FOR R-TR-74-074

Caption for Figure 9, pg 15, should read "Temperature vs Time at Various Axial Positions for Barrel B4 Firing at 333 rds/min"

Caption for Figure 10, pg 15, should read "Temperature vs Time at Various Axial Positions for Barrel B6 Firing at 333 rds/min"

Caption for Figure 16, pg 20, should read "Muzzel End and End View of Barrels B6 and B7"

Figure 23, pg 24, the abscissa is "Time (sec)"

Figures 24 and 25, pg 25, inadvertently interchanged: captions for Figures 24 and 25 are correct

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INTRODUCTION

In these times of rapid digital computers and sophisticated analytical techniques the need for meaningful experimental correlations is often ignored. Reports typically present a comparison of numerical solution versus "closed-form" solutions. Little significance is placed on predicted results versus hardware performance. Parodoxically, designers continue to express lack of confidence in analytical predictions and demand a stronger emphasis on experimental evaluation. This situation is further complicated by the decrease in documented test results. Hence it is virtually impossible to obtain accurate experimental thermal data for small arms guns from the current literature.

It is interesting to note that any useful theoretical analysis depends on at least semi-empirically determined boundary conditions. Yet it is most difficult to obtain measured barrel temperatures, bore heat fluxes, or propellant gas temperature and convection coefficient data in the literature. Therefore, it is the purpose of this report to document some recently measured gun barrel thermal data, and to describe the test procedure involved in obtaining these data. It is hoped that these data can be applied as a tool in the design and analysis of future small arms gun barrels. Further, it is hoped that the publication of these results may encourage others involved in the experimental evaluation of gun systems to record and document these much needed thermal data.

Results from these experimental efforts are being applied in the verification of calculated data for past and current analytical efforts. Also, such boundary condition data as bore heat flux, propellant gas convection coefficients, and temperatures are determined by use of mathematical inverse schemes utilizing these temperature data. In addition these data, as described in this report, afford some initial insight into the strong relationship between barrel temperature and barrel erosion.

DESCRIPTION OF THERMAL TEST PROGRAM

The general philosophy of this test program was that of evaluating representative small arms machine guns that were economical to fire, readily available, and easy to instrument. On that basis the Browning 1919-A4 and A6, and the M60 machine guns were selected as the most suitable test vehicles. The three tasks of this test program involved the measurement of barrel life and temperature as a function of geometry, barrel temperature as a function of rate of fire, and barrel temperature as a function of barrel material. A general description of these three tasks follows:

A. Barrel Life and Temperature as a Function of Barrel Geometry

This experiment involved firing six barrels: two with constant diameter, two with a moderate axial taper, and two with large tapers. These barrels which can be seen in Figure 1 were fired to failure based on repetitions of a 750 rd firing schedule consisting of six 125 rd bursts with 10 seconds cooling between bursts. After each 750 rd schedule the barrels were allowed to cool to ambient temperature prior to initiating the next schedule. Failure determination was based on accuracy and yaw measurements. Targeting, consisting of a 10 rd burst, was taken after every 1500 rds.

Gun barrel geometries are shown in Figure 2. Barrels B1 and B3 had a constant outer diameter of 1.220 inches with a wall ratio and wall thickness of 4.07 and 0.460 inches respectively. Moderate taper barrels B4 and B5 measured 1.211 inches at the breech end and tapered down to 0.769 inch yielding a muzzle end wall ratio of 2.56 where the wall thickness

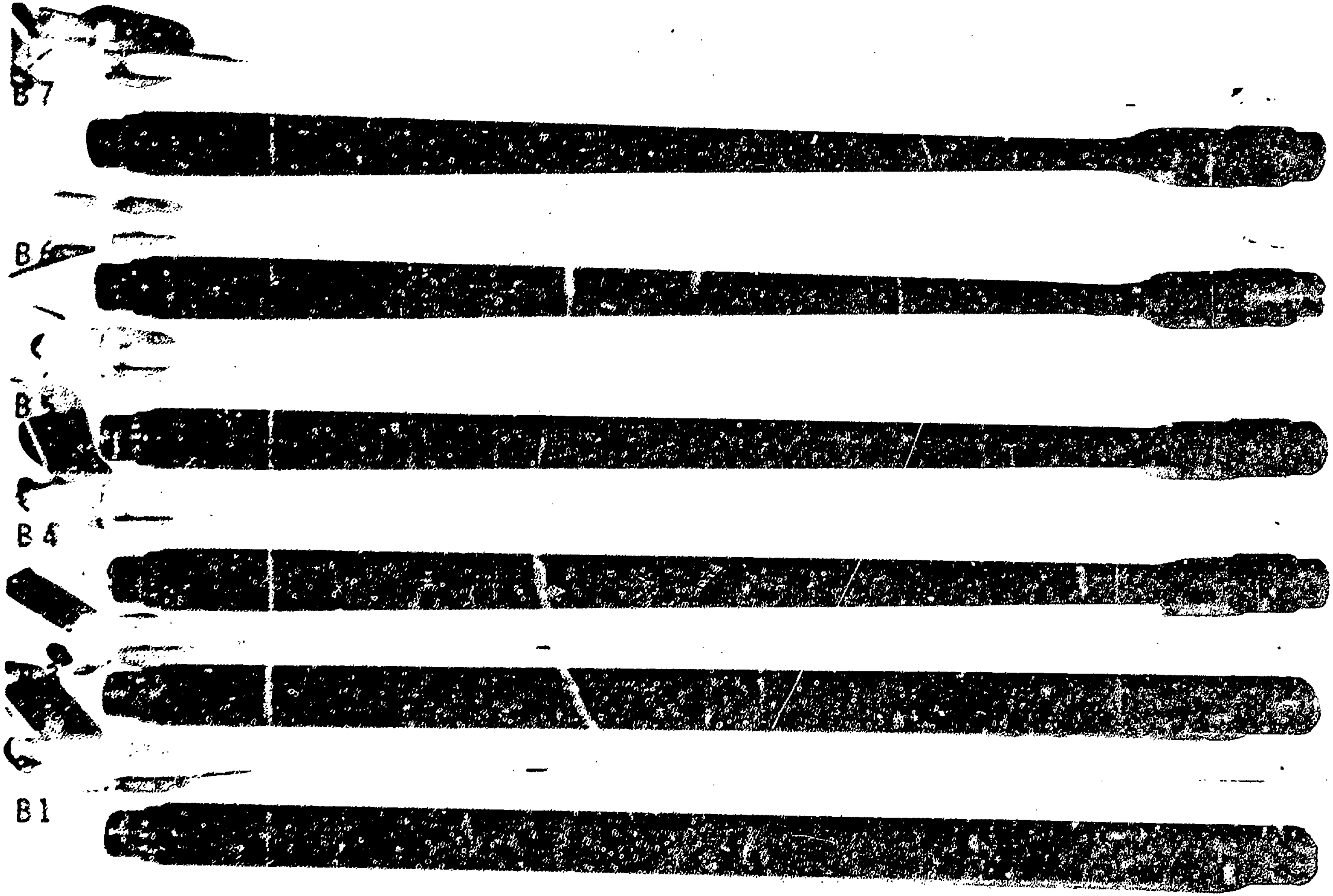

Figure 1 Browning 1919 Machine Gun Barrels

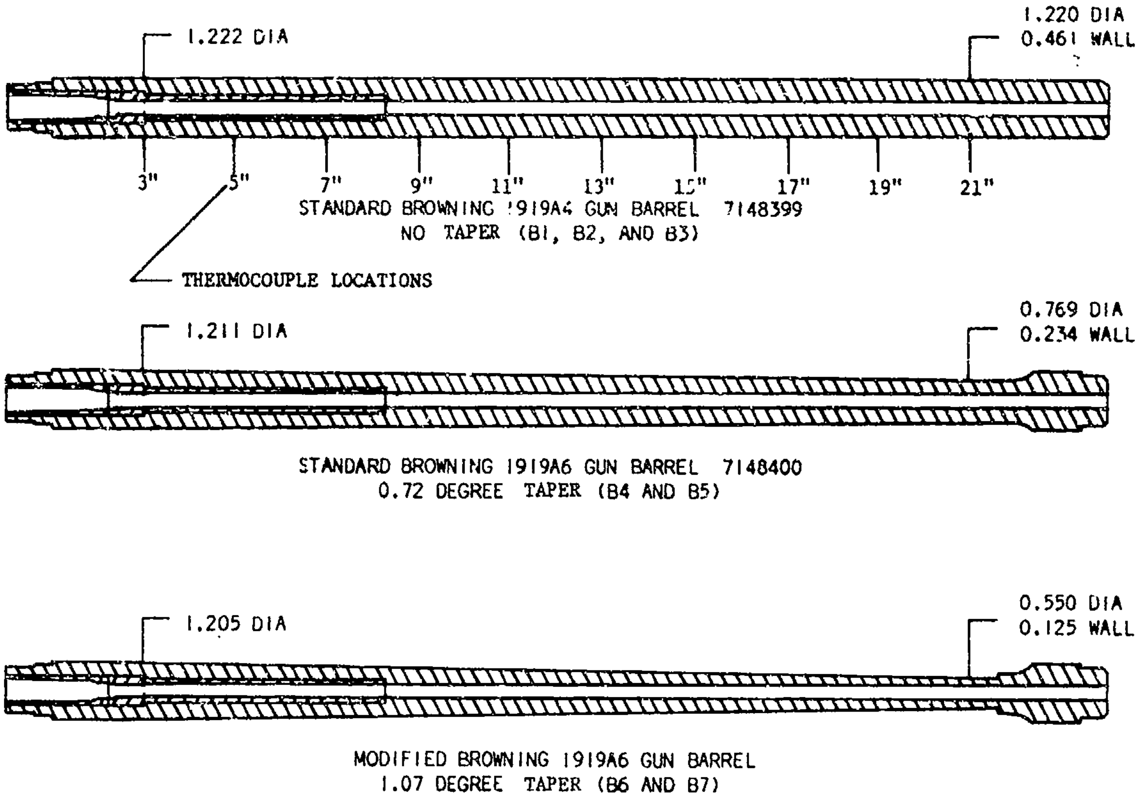

Figure 2 Cross Section Views and Thermocouple Locations

was 0.238 inch. The large taper barrels B6 and B7 had breech end outer diameters of 1.205 inches and tapered down to 0.550 inch where the muzzle end wall ratio was 1.83 and the wall thickness was 0.125 inch.

Gun barrel temperature measurements for the barrel life test were recorded every second at two inch intervals along the barrel length. Physical location of thermocouples is shown in Figure 2. A detailed description of instrumentation and recording techniques is given in the experimental methodologies section of this report.

B. Barrel Temperature as a Function of Rate of Fire

The second task of this effort was that of investigating the relationship between barrel temperature and rate of fire. Firing rates selected for these tests as presented in Table 1 were 75, 150, 300, and 600 rds per minute. Because the machine guns fired at a fixed rate of 600 rds per minute, sporadic schedules involving short bursts were fired to achieve the other desired effective rates of fire. An effective rate of 75 rds per minute was obtained by firing 15 rd bursts every 12 seconds for a total of 600 rds in eight minutes. The effective rate of 150 rds per minute was accomplished by firing 15 rd bursts every six seconds giving a total of 795 rds fired in 318 seconds. The 300 rd per minute rate was obtained by firing 25 rd bursts every 5 seconds for a total of 1000 rds in 200 seconds. For the 600 rd per minute rate, following every 200 rds the time was checked to determine if firing was on schedule, and any required correction was made. Barrels M1 and M2, Table 2, were fired in the M60 machine gun and constant diameter barrel B2 was fired in the Browning 1919-A4 machine gun. As in the previous test, external temperature measurements were taken every two inches along the length of the barrels.

C. Barrel Temperature as a Function of Material

The last task was that of determining the influence of barrel material on temperature. For these tests, five materials were used: Chrome-Moly-Van Steel (chrome plated), Chrome-Moly-Van-Steel (chrome plated with a stellite liner), Crucible CG27, Inconel 718, and Pyromet X-15. The barrels were fired in the M60 machine gun at a schedule consisting of six 125 rd bursts with a 10-second dwell between bursts for a total of 750 rds (referred to as the 750 rd firing schedule). These barrels, which were instrumented similar to barrels of the previous tests, were fired sufficient repetitions of the above schedule to give a statistical representation of the data.

TABLE 1 FIRING SCHEDULES

__Barrel life vs geometry__

750 RDS schedule (333 rds/min)
125 rds - 10 sec cool - 125 rds•••750 rds/125 sec
(A 125 rd burst is fired every 22.5 sec)
Test accuracy every 1500 rds.

__Temperature vs rate of fire__

15 rds - 10.5 sec cool - 15•••600 rds/8 min (75 rds/min)
(A 15 rd burst is fired every 12 sec)
15 rds - 4.5 sec cool - 15•••795 rds/5.3 min (150 rds/min)
(A 15 rd burst is fired every 5 sec)
25 rds - 2.5 sec cool - 25•••1000 rds/3.3 min (300 rds/min)
(A 25 rd burst is fired every 5 sec)
200 rds - 200 rds - 200•••1400 rds/2.3 min (600 rds/min)
(A 200 rd burst is fired every 20 sec)

__Material vs temperature__

750 rds schedule (333 rds/min)
125 rds - 10 sec cool - 125 rds•••750 rds/125sec
(A 125 rd burst is fired every 22.5 sec)

TABLE 2 TEST BARRELS

BROWNING MACHINE GUN				
B1	STANDARD 1919A4	7148399	CH.MOLY.VAN.	STELLITE LINER C.P.
B2	STANDARD 1919A4	7148399	CH.MOLY.VAN.	STELLITE LINER C.P.
B3	STANDARD 1919A4	7148399	CH.MOLY.VAN.	STELLITE LINER C.P.
B4	STANDARD 1919A6	7148400	CH.MOLY.VAN.	STELLITE LINER C.P.
B5	STANDARD 1919A6	7148400	CH.MOLY.VAN.	STELLITE LINER C.P.
B6	MODIFIED 1919A6		CH.MOLY.VAN.	STELLITE LINER C.P.
B7	MODIFIED 1919A6		CH.MOLY.VAN.	STELLITE LINER C.P.

M60 MACHINE GUN			
M1	STANDARD M60 7269028	CH.MOLY.VAN.	STELLITE LINER C.P.
M2	STANDARD M60 7269028	CH.MOLY.VAN	STELLITE LINER C.P.
M3	STANDARD M60 7269028	CH.MOLY.VAN	STELLITE LINER C.P.
M4	HOMOGENEOUS M60	CH.MOLY.VAN	C.P.
M5	PYROMET X-15 M60	HOMOGENEOUS	
M6	INCONEL 718	HOMOGENEOUS	
M7	INCONEL 718	HOMOGENEOUS	
M8	CRUCIBLE CG27	HOMOGENEOUS	
M9	CRUCIBLE CG27	HOMOGENEOUS	

NOTE: All guns fire at a rate of approximately 600 rds/min

EXPERIMENTAL METHODOLOGIES

Instrumentation procedures and data acquisition techniques applied in this program have evolved as a consequence of performing similar testing on a large number of past projects. The overall instrumentation schematic is given in Figure 3.

Type K, 30 gauge chromel-alumel thermocouple wire was selected because of its temperature range, low error, good weldability, and excellent corrosion properties. This wire, which has a stated accuracy of .375 percent, was shielded with a glass-wrap copper braid as supplied by the Claude S. Gordon Co.* Intrinsic type thermocouples were used where the junction was formed by fusing a one-eighth inch length of chromel-alumel wire to the barrel with a capacitive discharge welder. Barrel preparation involved grinding a one-fourth inch diameter pad, removing only the barrel surface finish and oxidation. At a location one fourth of an inch from the junction a stainless steel strap was positioned across the wire shield and welded to the barrel. This strap served a twofold purpose. First, it functioned as a support for the wire thereby removing any dynamic loading from the thermocouple junction during firing. Secondly, by heating the wire leading to the junction, heat transfer from the thermocouple was reduced resulting in a lower thermocouple error. Wire routing from the thermocouple wire into the extension lead and ultimately to the data acquisition system is shown in Figure 4.

The digital data acquisition system utilized in this investigation consisted of the following Vidar*components:

1. 10 channel digital 5401-2 unit
2. 641-02 controller
3. 624 digital clock
4. 604 scanner
5. 502 integrating digital voltmeter
6. 661 printer

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*This does not constitute an official endorsement

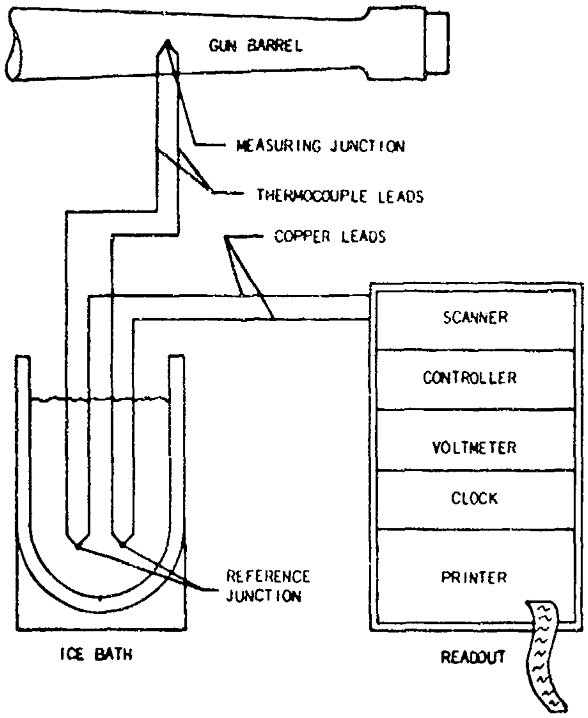


Figure 3 Thermocouple Instrumentation Schematic

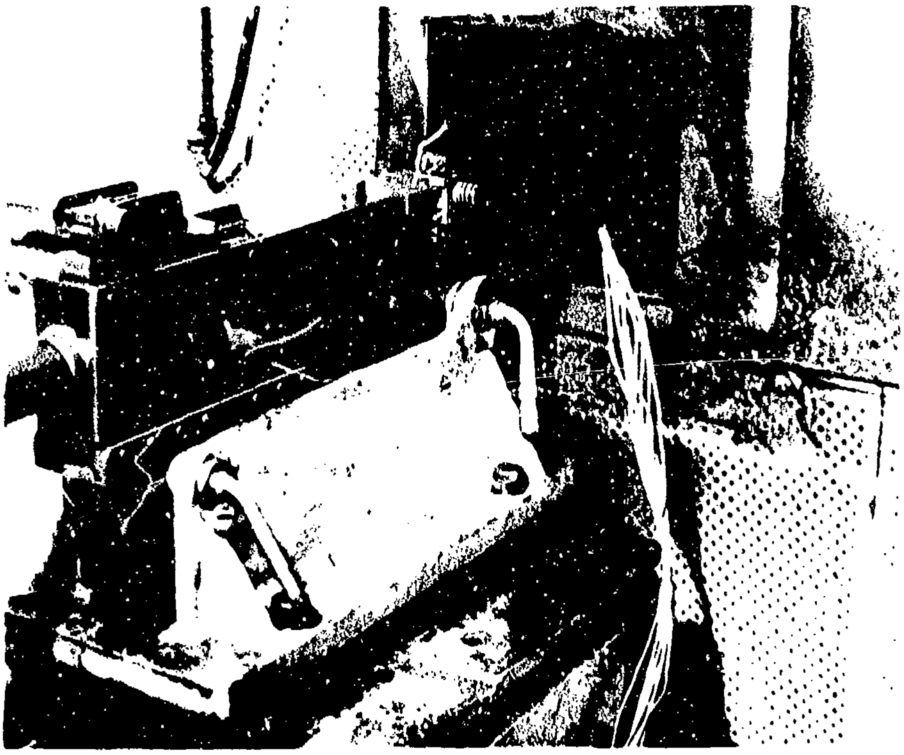


Figure 4 Instrumented Browning 1919A4 Machine Gun

Figure 5 shows the mounting fixture and the digital data acquisition system. For these tests, the ten channels were scanned at a rate of one cycle per second for the first thirty seconds followed by a scan rate of one cycle every two seconds for the remainder of the firing. Temperature data in the form of millivolt readings were printed out and subsequently reduced to temperatures. System calibration was accomplished by the RIA calibration lab prior to the start of testing and at prescribed time intervals during the test.

A conscientious effort was undertaken to minimize overall measurement error. Steps taken, some of which have been previously discussed, included:

1. Judicious routing and attachment of thermocouples.
2. Using highly accurate thermocouple (rated error of 0.375 percent) wire.
3. Periodic system calibration.
4. Firing based on accurate round count and digital timing.
5. Water-ice thermocouple reference bath.

One factor not corrected for was wind velocities across the barrel which typically varied from 10 mph at the breech end to 20 mph at the muzzle end. Simplified calculations have shown that the influence of these winds was not significant relative to the large gun barrel heat dissipation.

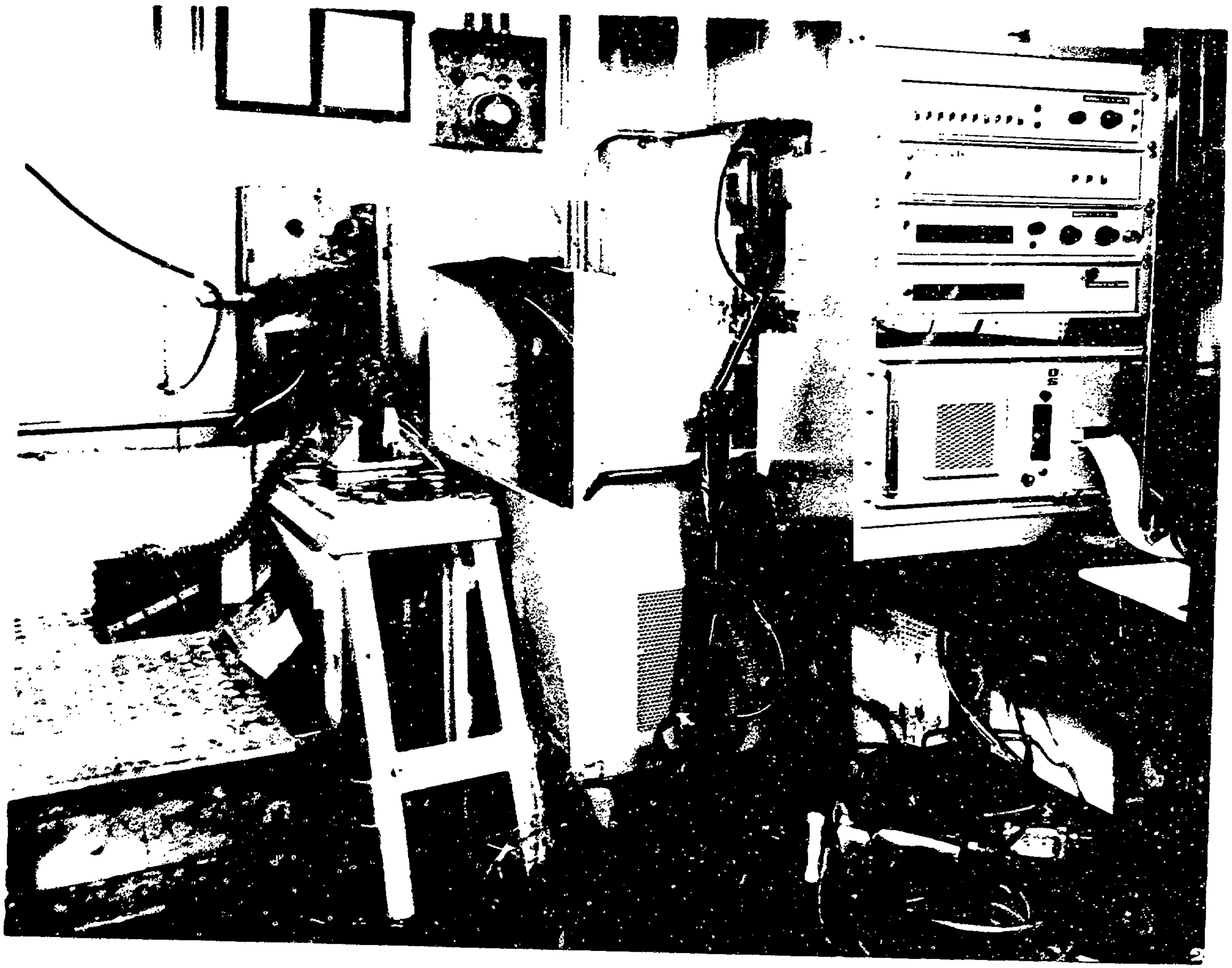


Figure 5 Test Setup

RESULTS AND CONCLUSIONS

Temperature data for these tests are shown in Figures 6 through 41. The influence of barrel geometry and likewise barrel temperature on barrel life can be seen in Figures 6 through 10 and bore surface replica photographs 13 through 15.

It can be seen that for a given firing schedule, barrel temperature is a function of barrel geometry, and barrel life is dependent on temperature. As the wall ratio decreases there is less material to absorb the heat and less surface area to transfer the heat, resulting in higher material temperatures. As the barrel temperature increases, Fiqure 12 shows that material strength severely decreases. It is believed that this plus melting accounts for the accelerated bore erosion at elevated temperatures, as indicated in Figures 6, 7c, and 17.

At the completion of firing tests when a barrel failed accuracy requirements, bore surface replicas, shown in Figures 13, 14, and 15, were made. These silicone rubber castings of the gun tube bore give a visual indication of land wear, which, together with temperature histories of the barrels, illustrate the relationship between barrel temperature and erosion. Results show that land wear increases dramatically with temperature until an upper material limit is reached and catastropic failure occurs. Figures 7, (a, b, c) show temperature distribution along the three barrel geometries and Figure 2 shows the three barrel cross sections.

Replicas from the constant diameter barrels B1 and B3 show that the rifling is completely eroded for the first four inches with notable wear in the remaining two inches of the liner. Rifling is again completely ablated at eight inches but improves a little toward the muzzle end due to the lower temperatures.

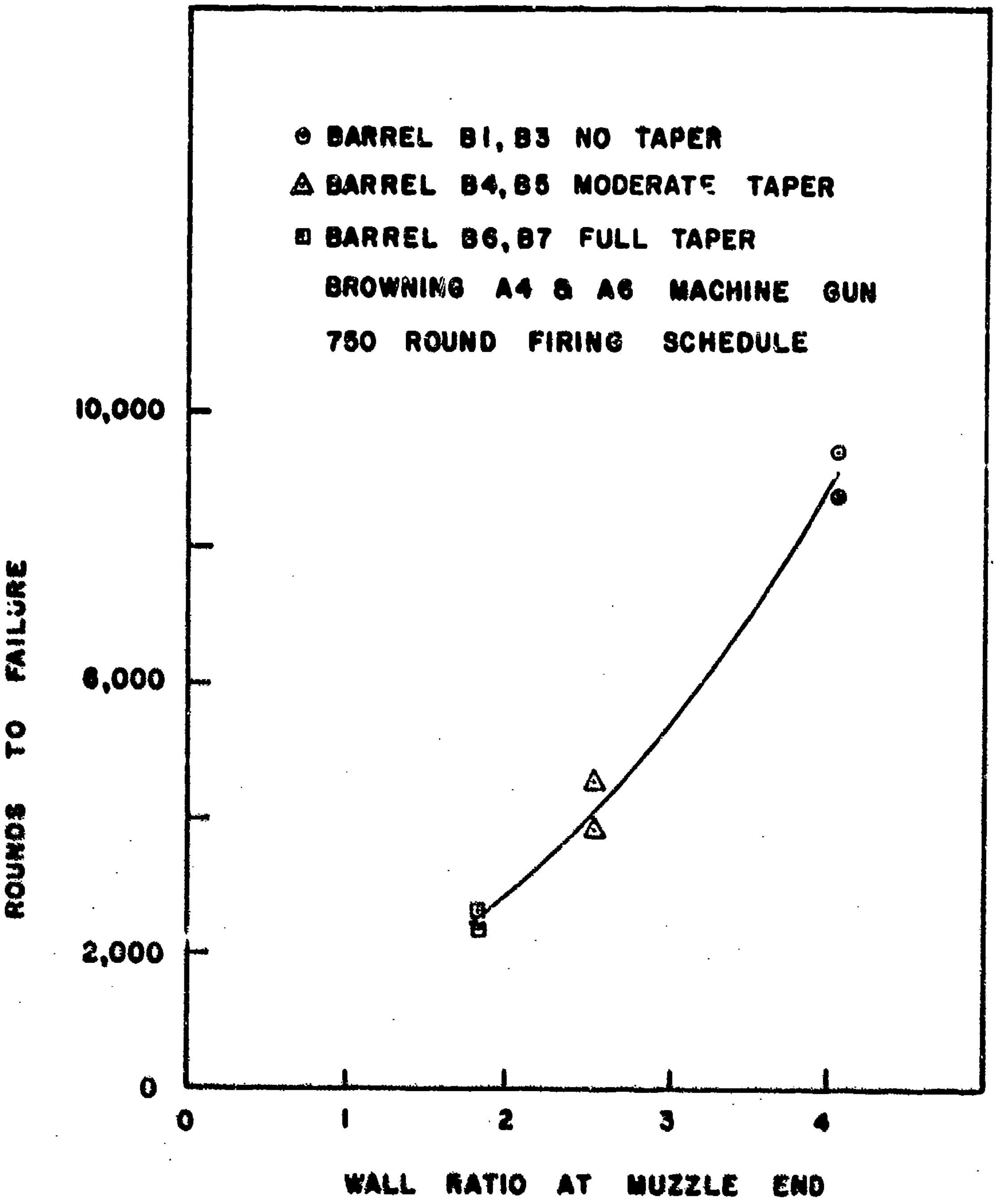


Figure 6 Geometry Effect on Barrel Life

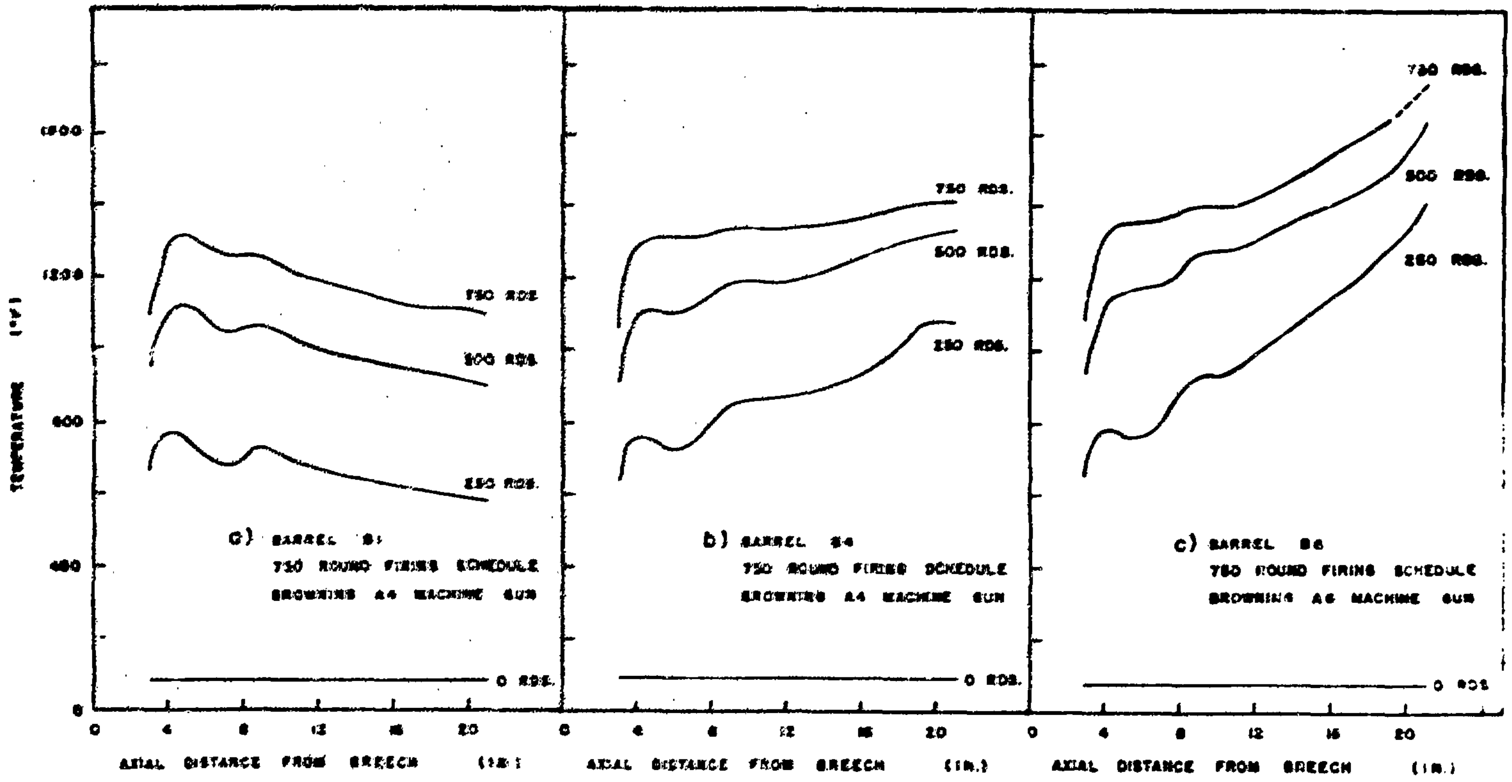


Figure 7 Temperature vs Axial Distance After 250,500, and 750 rds a) Barrel 1, b) Barrel 4, c) Barrel 6

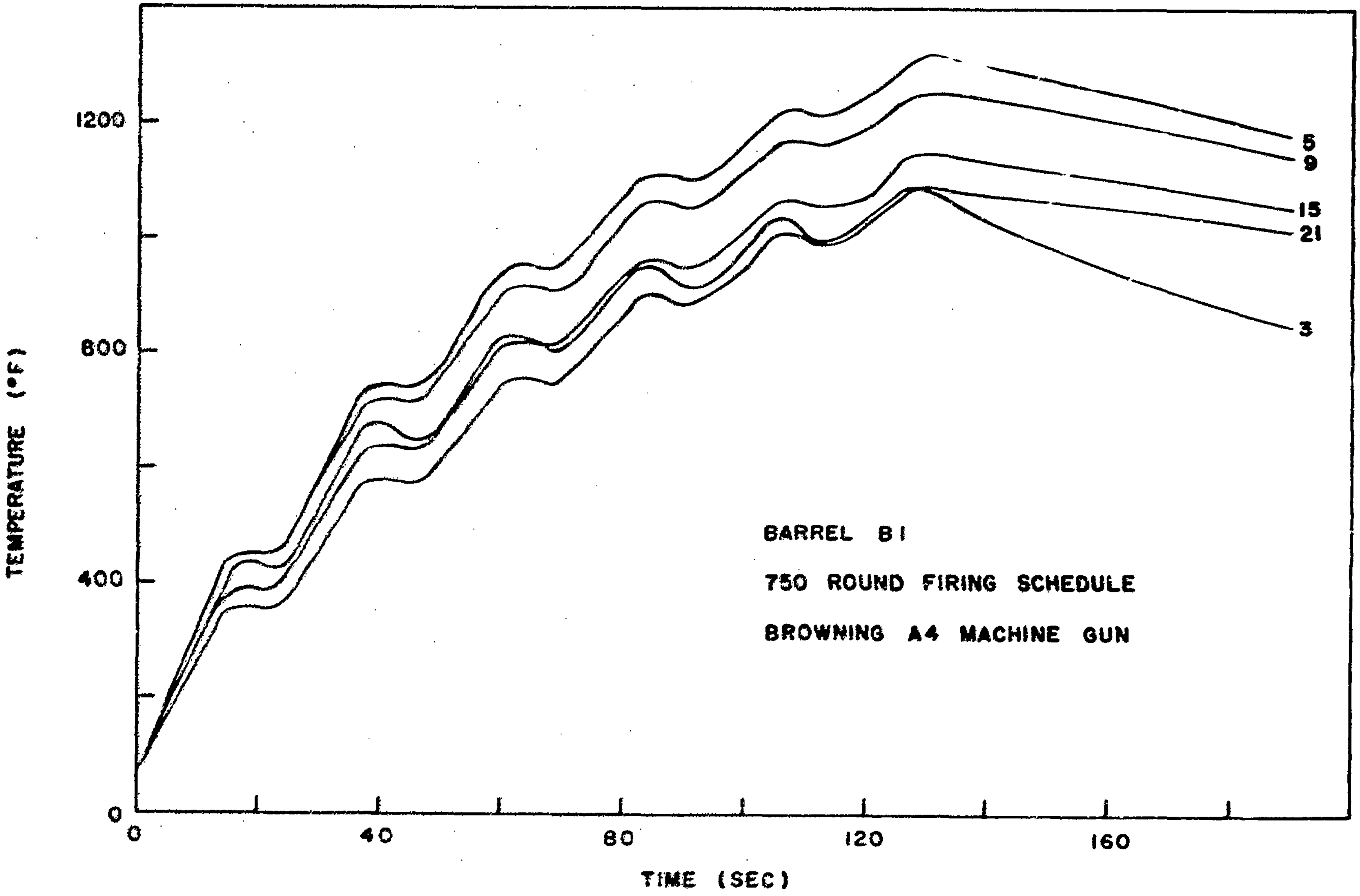


Figure 8 Temperature vs Time at Various Axial Positions

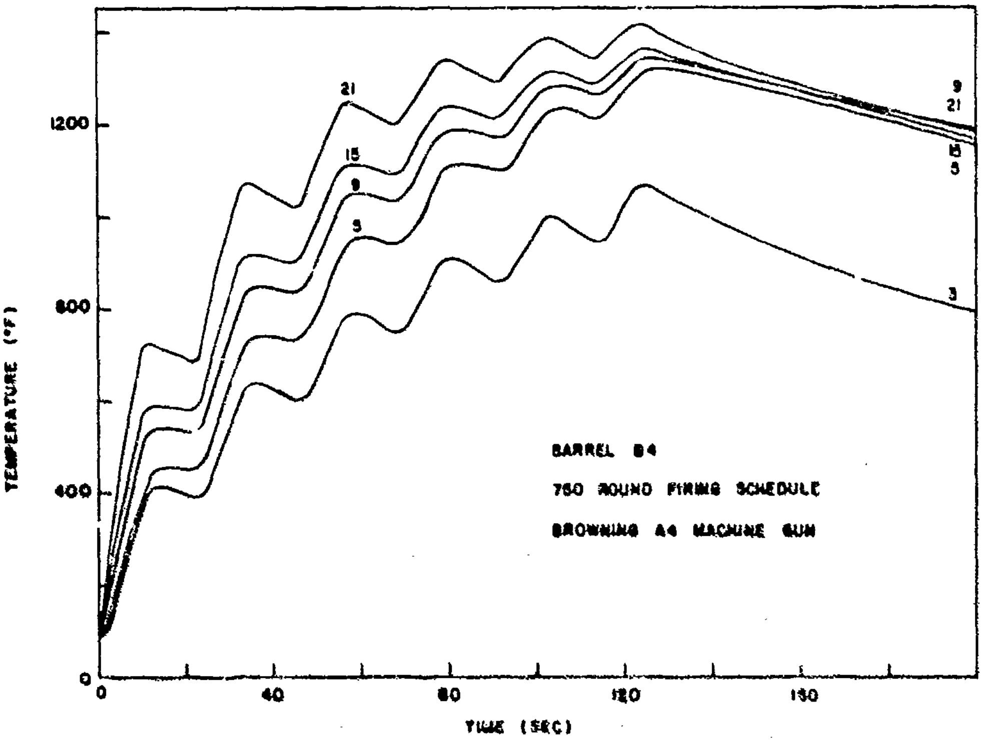


Figure 9 Temperature vs Time at Various Axial Positions for Barrel B4 Firing at 750 rds/min

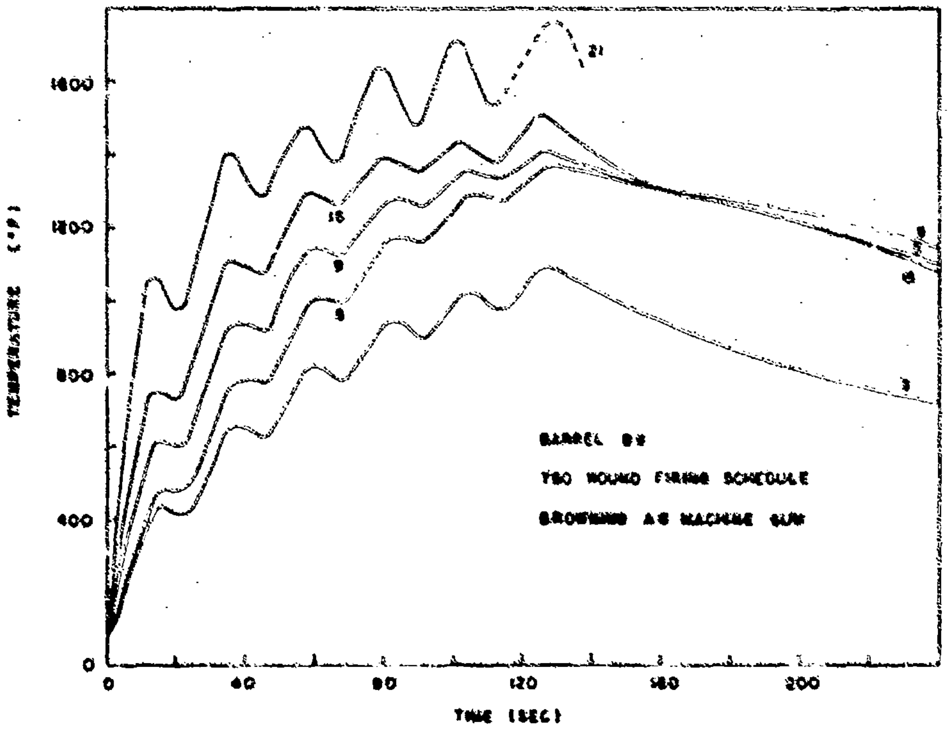


Figure 10 Temperature vs Time at Various Axial Positions for Barrel B6 Firing at 750 rds/min

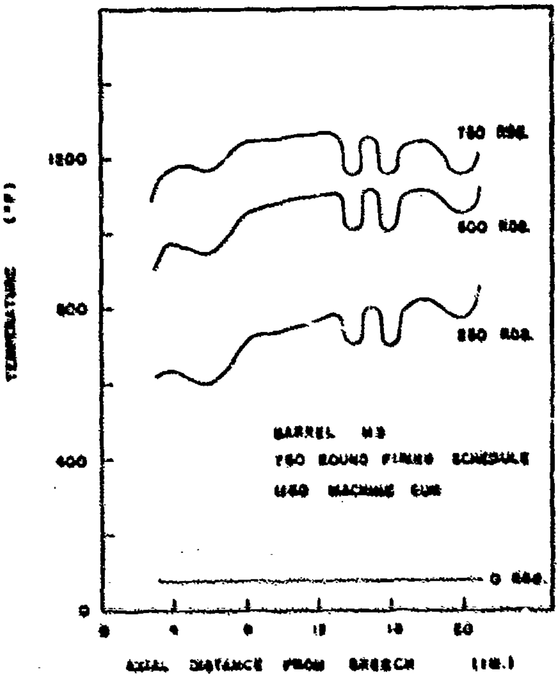


Figure 11 Temperature vs Axial Distance After 250,500 & 750 Rounds (Barrel M3)

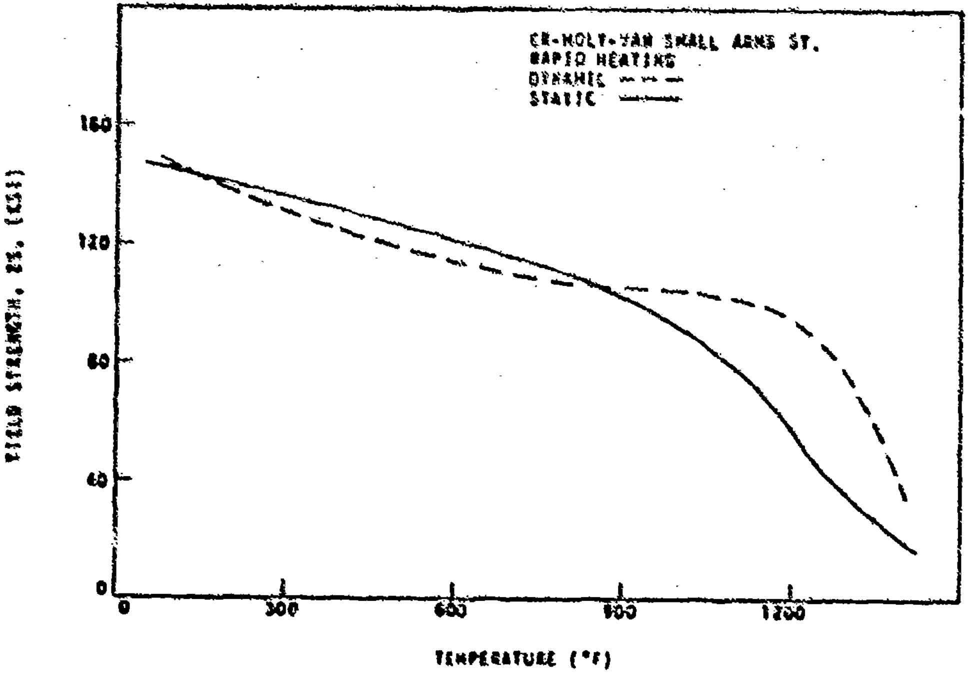


Figure 12 Strength vs Temperature Cr-Moly-Van Steel

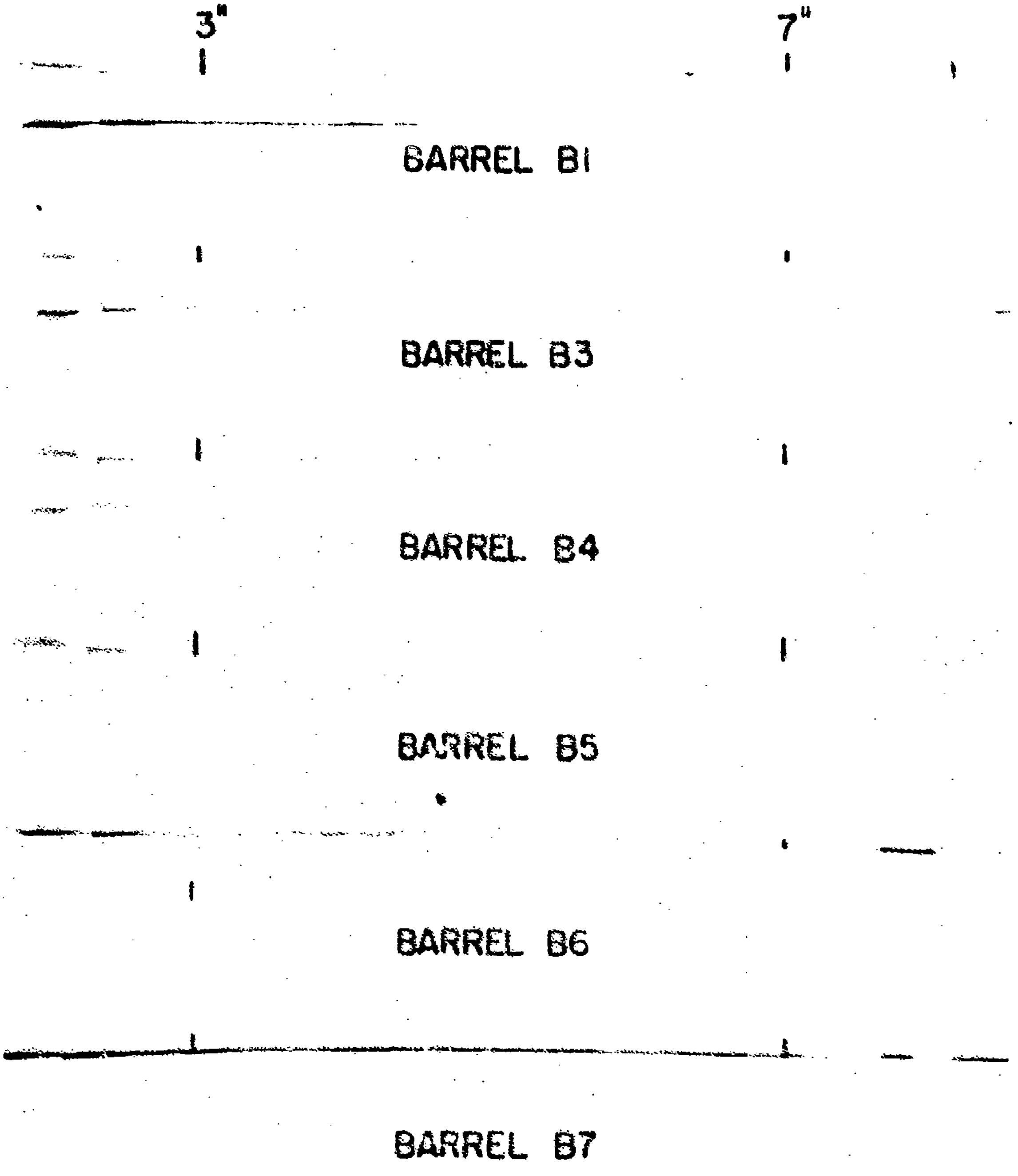


Figure 13 Bore Surface Replicas - Breech End (1" - 8")

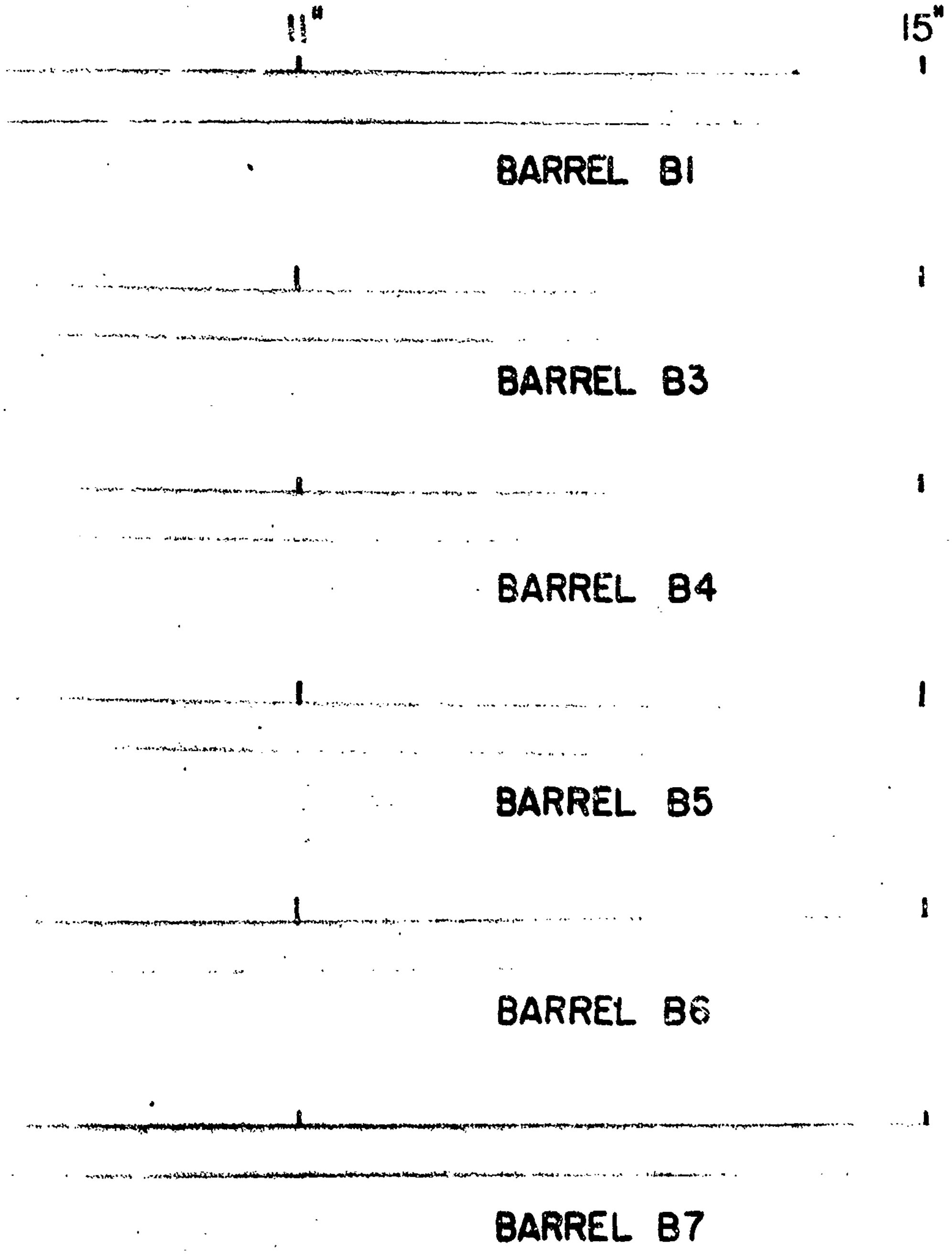


Figure 14 Bore Surface Replicas - Mid Section (9" - 16")

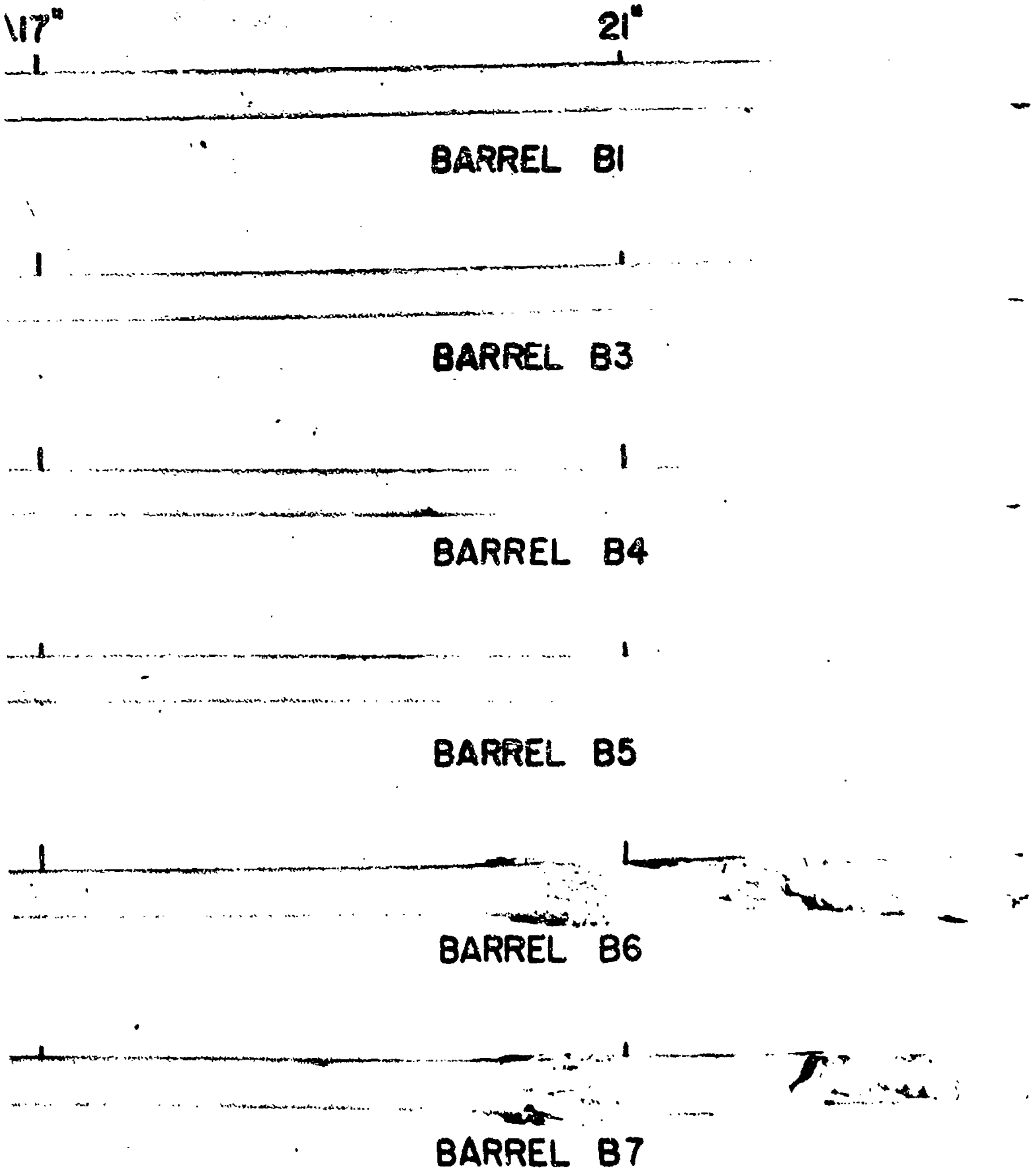


Figure 15 Bore Surface Replicas - Muzzle End (17" - 24")

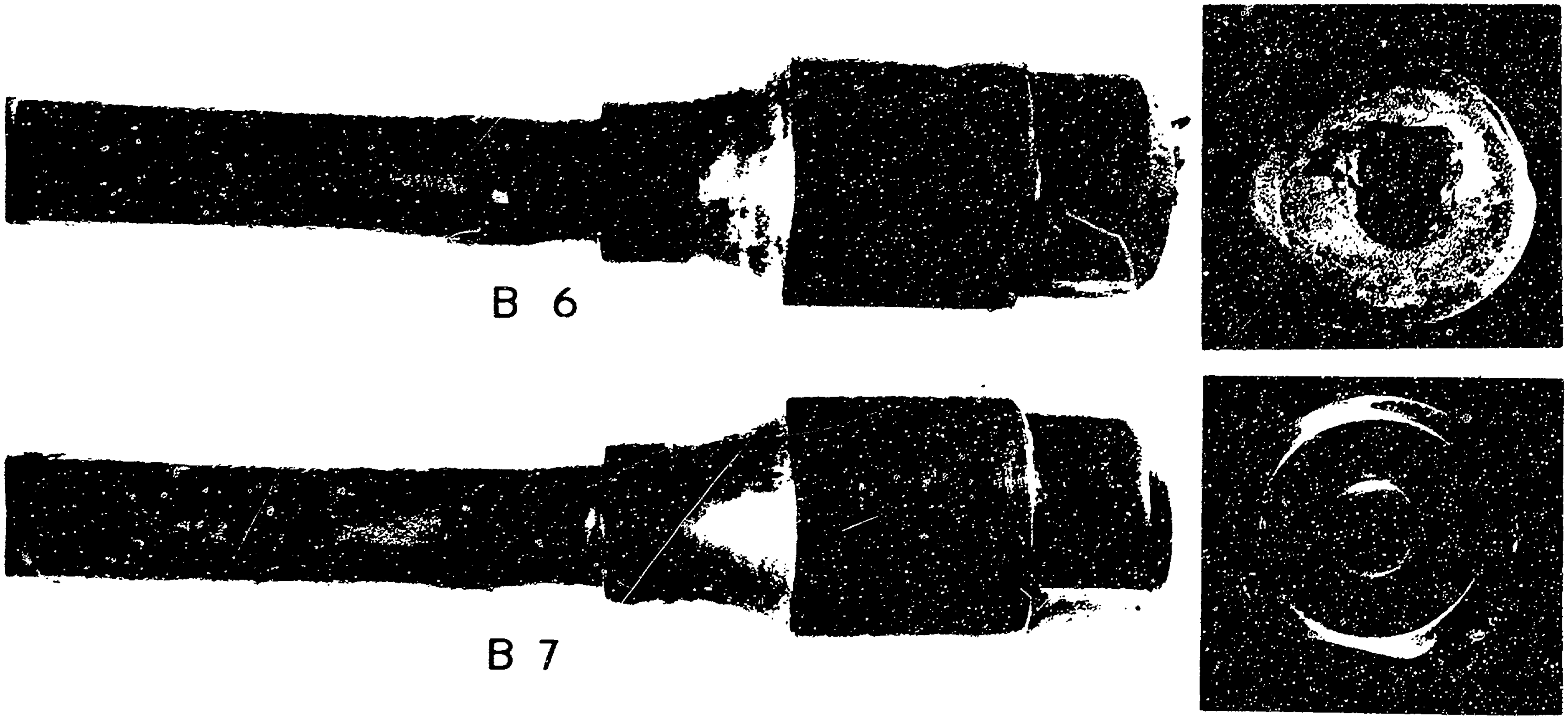
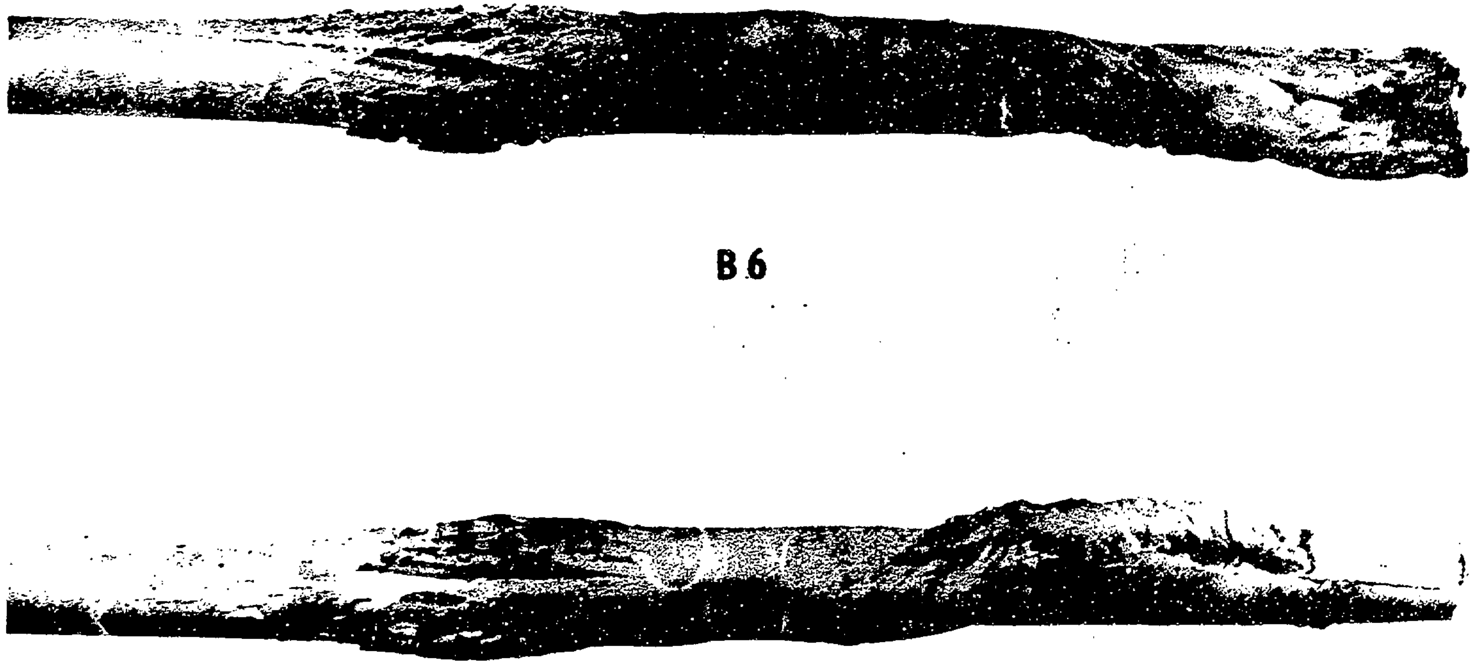


Figure 16 Muzzle End and End View of Barre



B6

B7

Figure 17 Bore Surface Replicas of B6 and B7

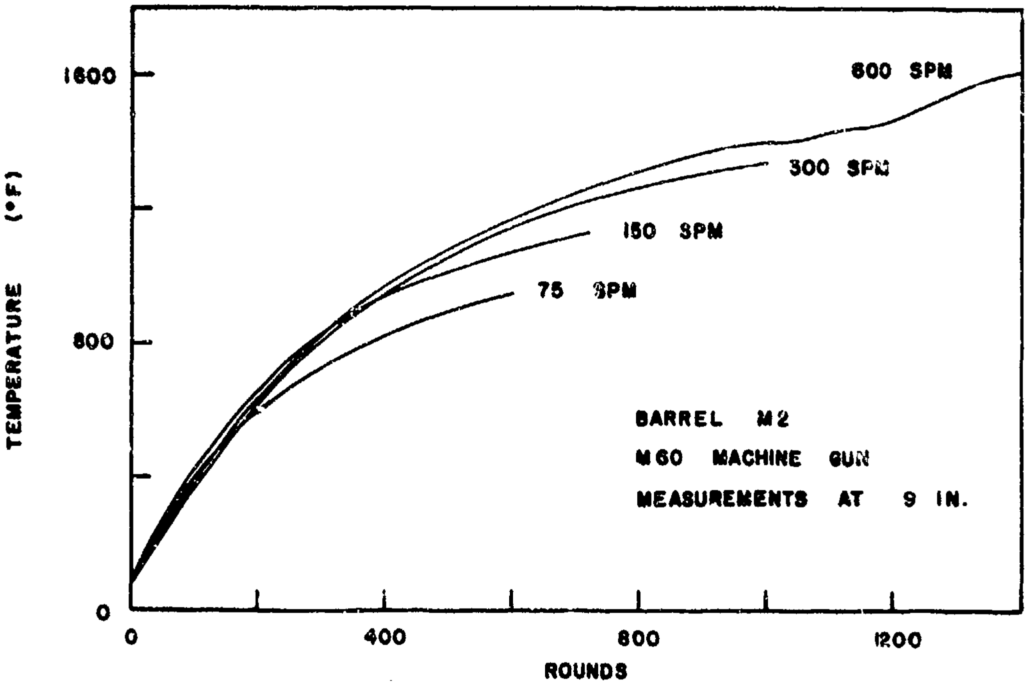


Figure 18 Temperature vs Rounds Fired for Various Firing Rates of Barrel M2, Measured at 9 in.

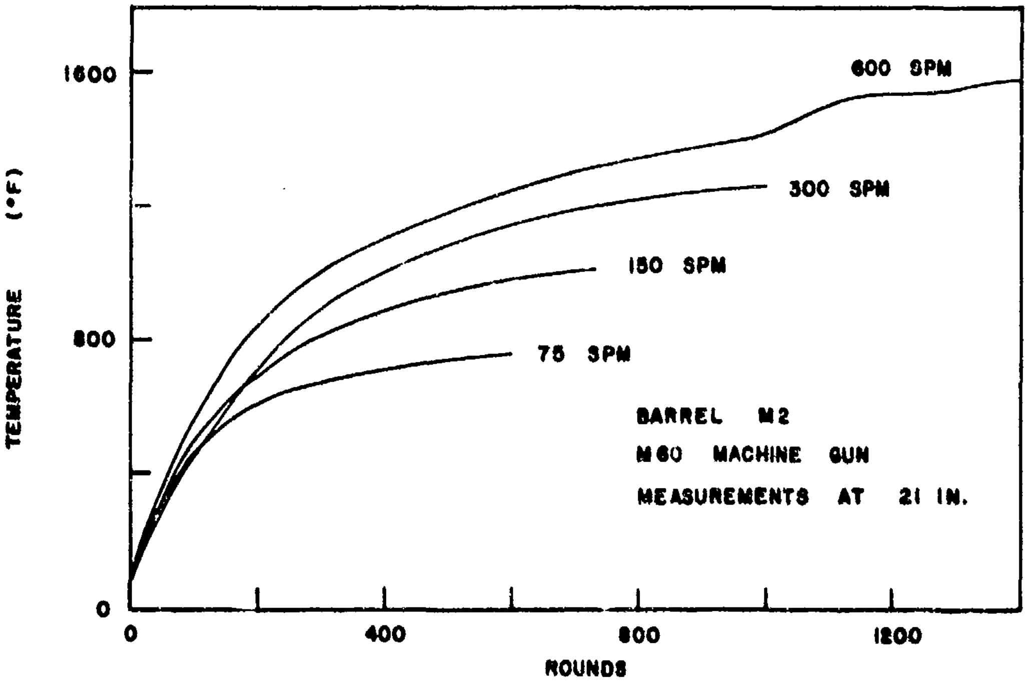


Figure 19 Temperature vs Rounds Fired for Various Firing Rates of Barrel M2, Measured at 21 in.

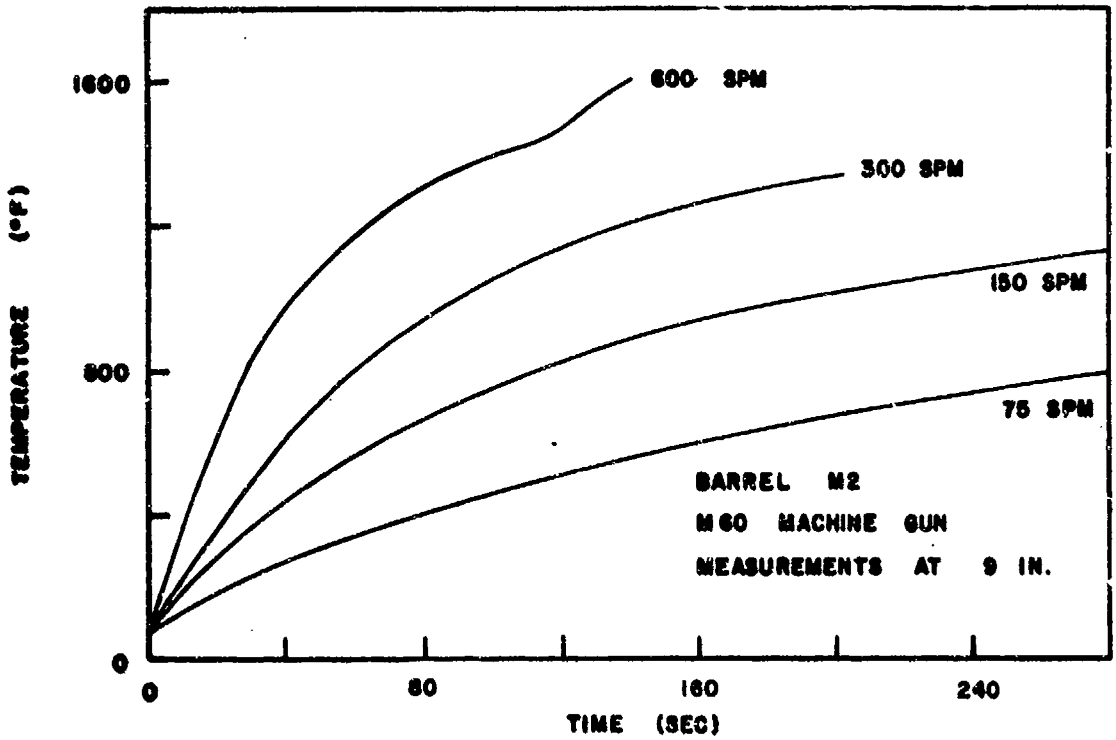


Figure 20 Temperature vs Time for Various Firing Rates

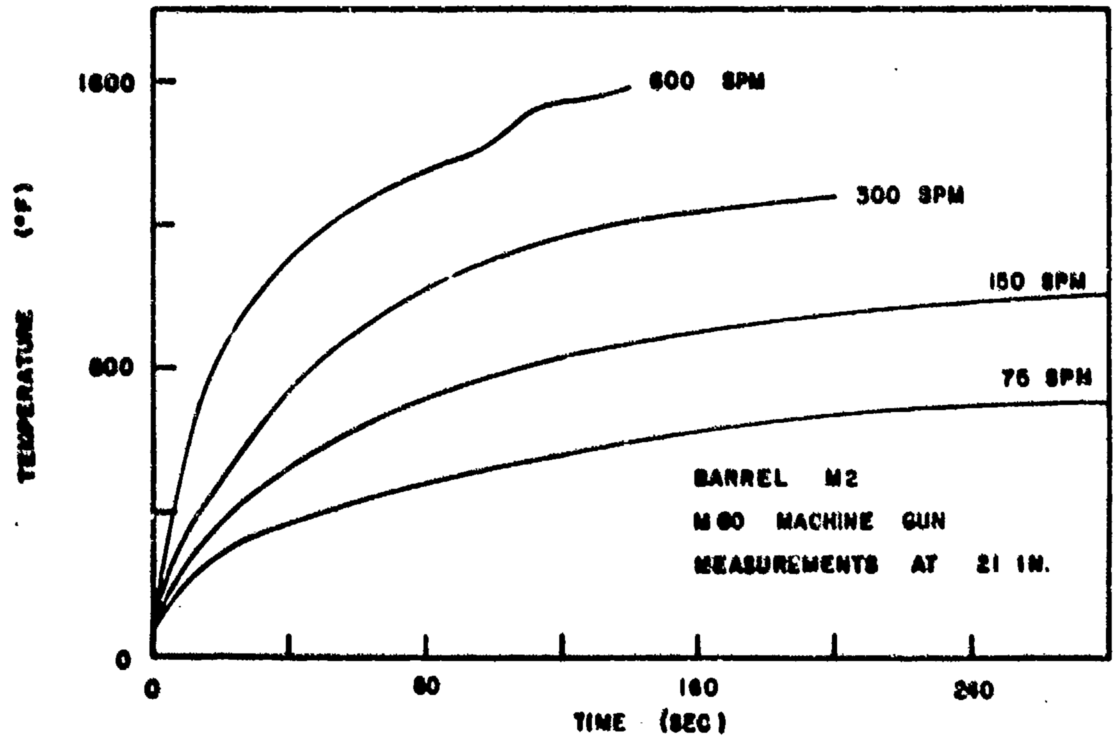


Figure 21 Temperature vs Time for Various Firing Rates

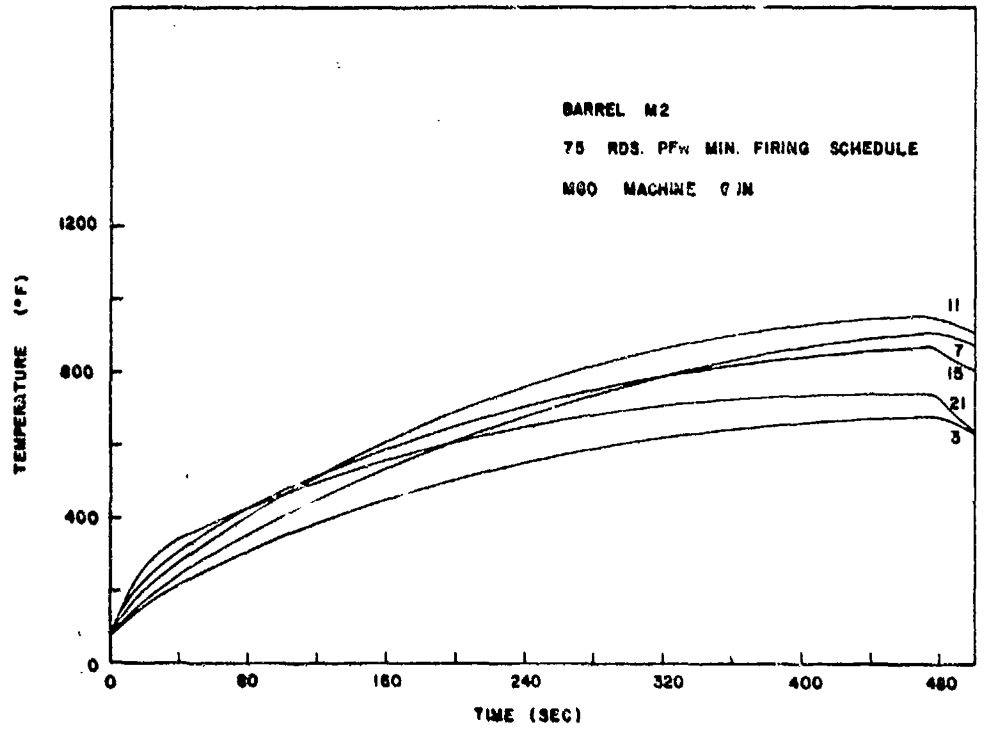


Figure 22 Temperature vs Time at Various Axial Positions for Barrel M2 Firing at 75 rds/min

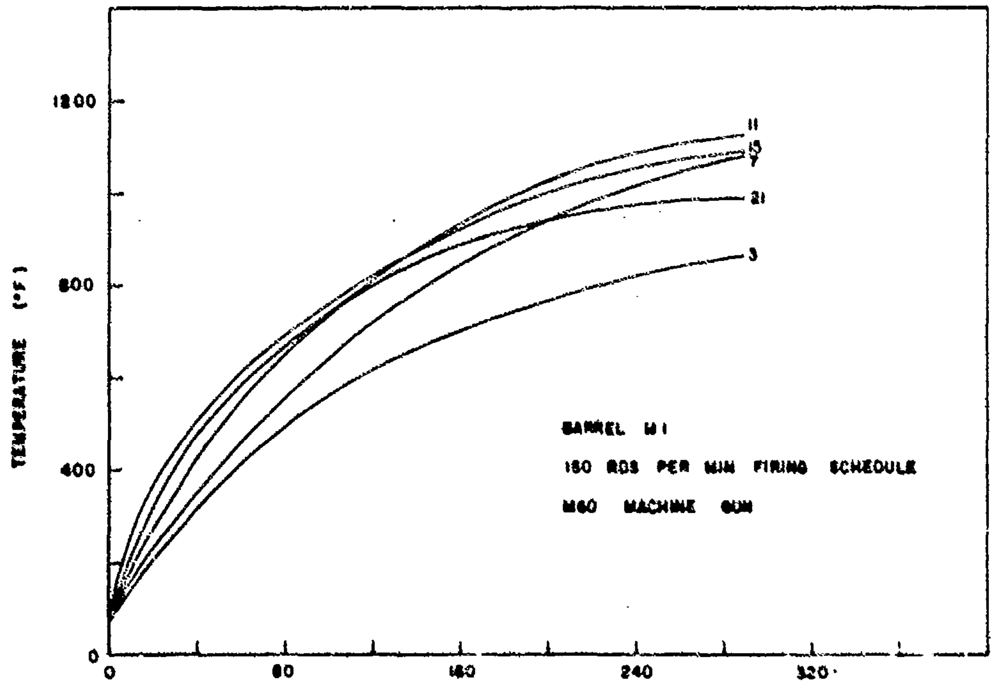


Figure 23 Temperature vs Time at Various Axial Positions for Barrel M1 Firing at 150 rds/min

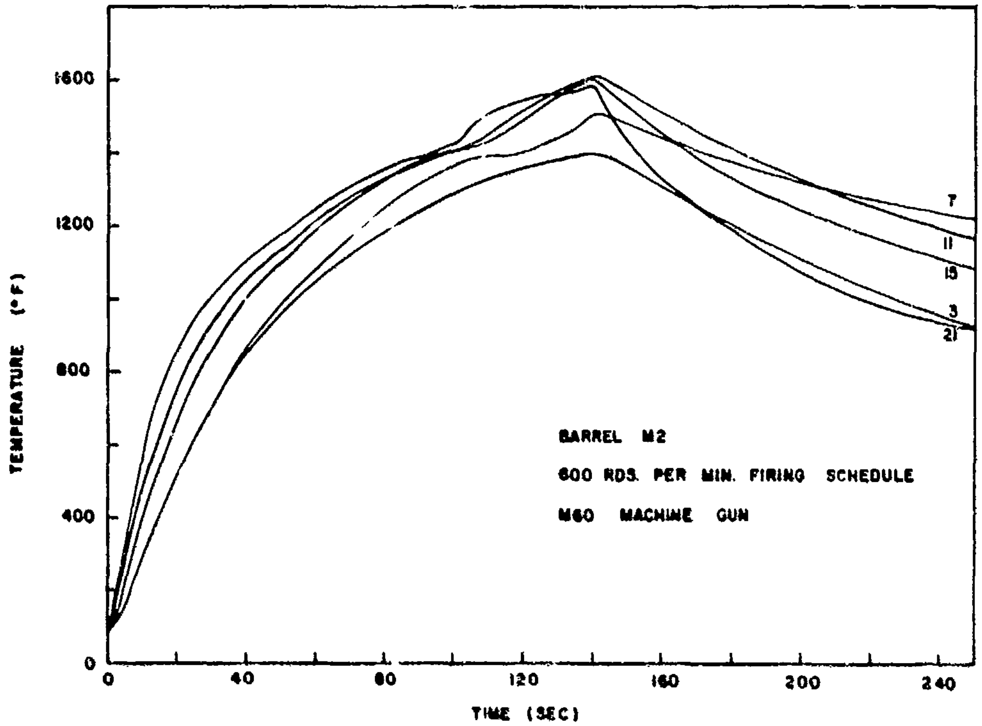


Figure 24 Temperature vs Time at Various Axial Positions for Barrel M2 Firing at 300 rds/min

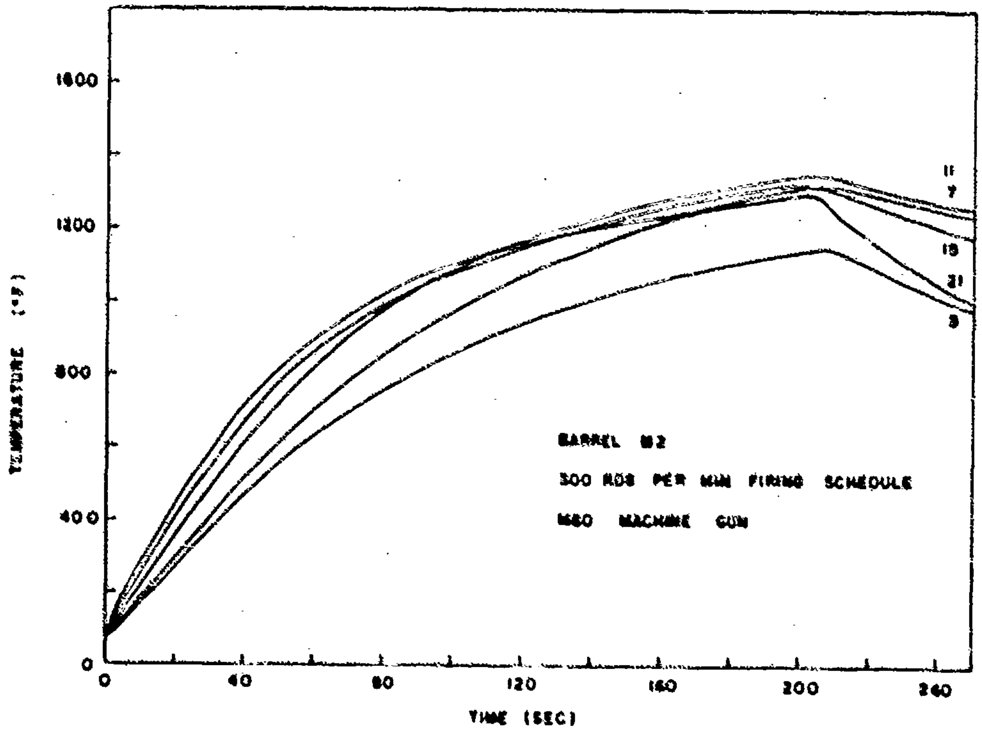


Figure 25 Temperature vs Time at Various Axial Positions for Barrel M2 Firing at 600 rds/min

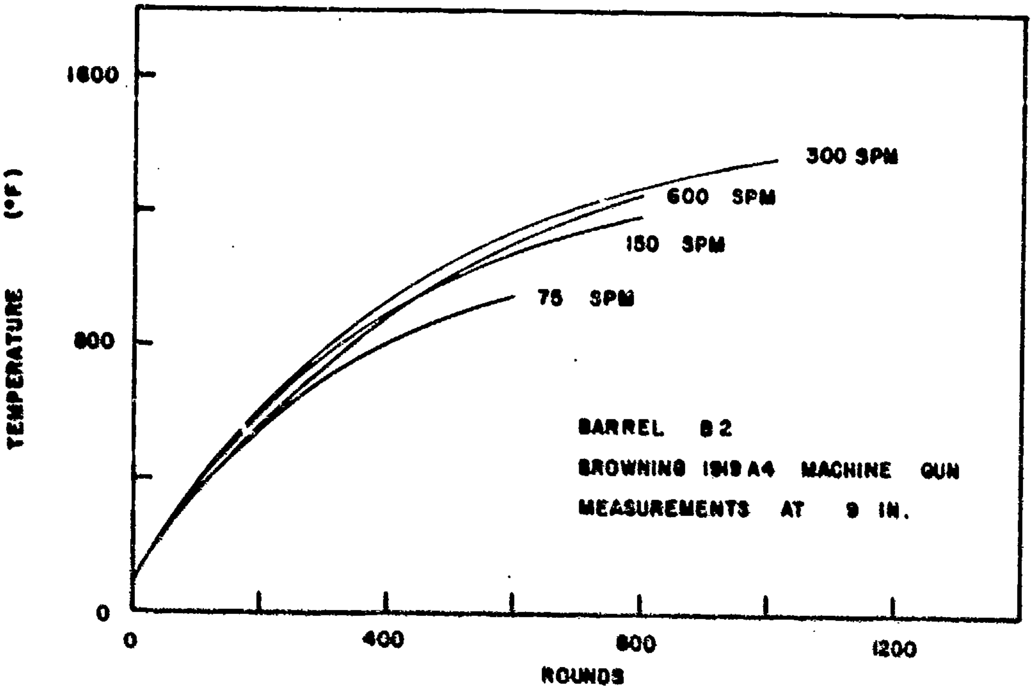


Figure 26 Temperature vs Rounds Fired for Various Firing Rates of Barrel B2, Measured at 9 in.

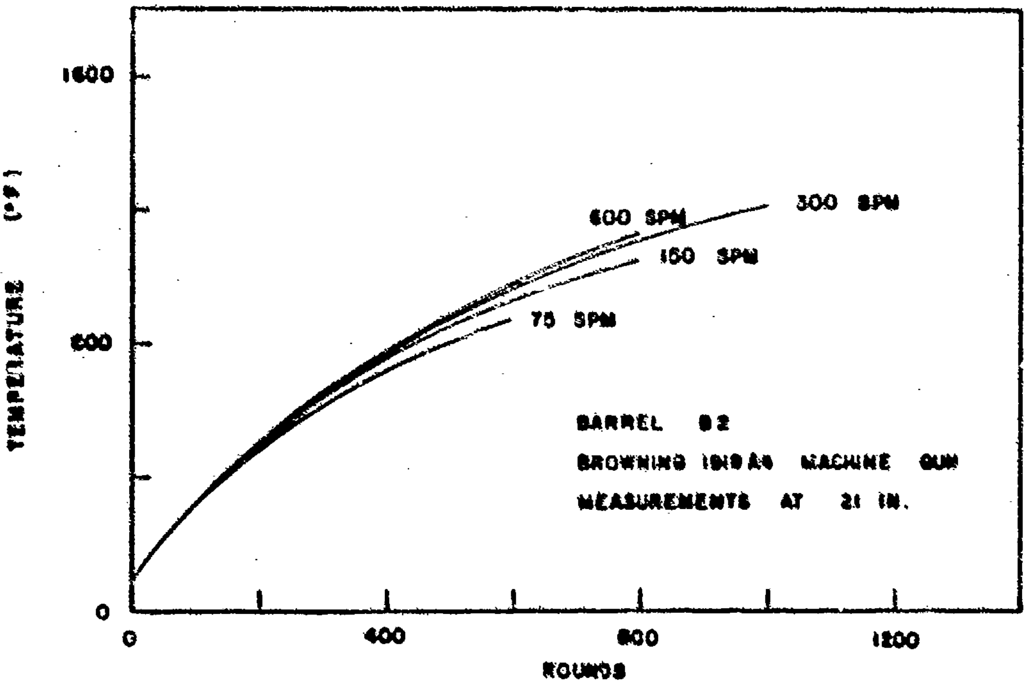


Figure 27 Temperature vs Rounds Fired for Various Firing Rates of Barrel B2, Measured at 21 in.

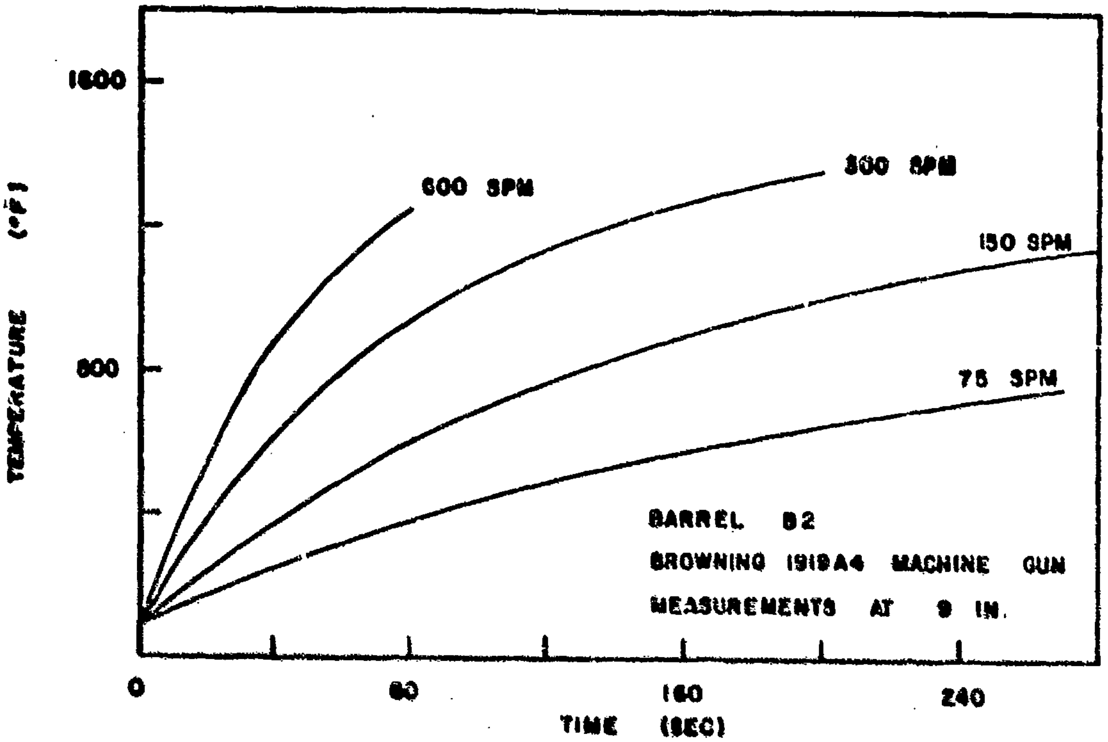


Figure 28 Temperature vs Time for Various Firing Rates of Barrel B2 Measured at 9 in.

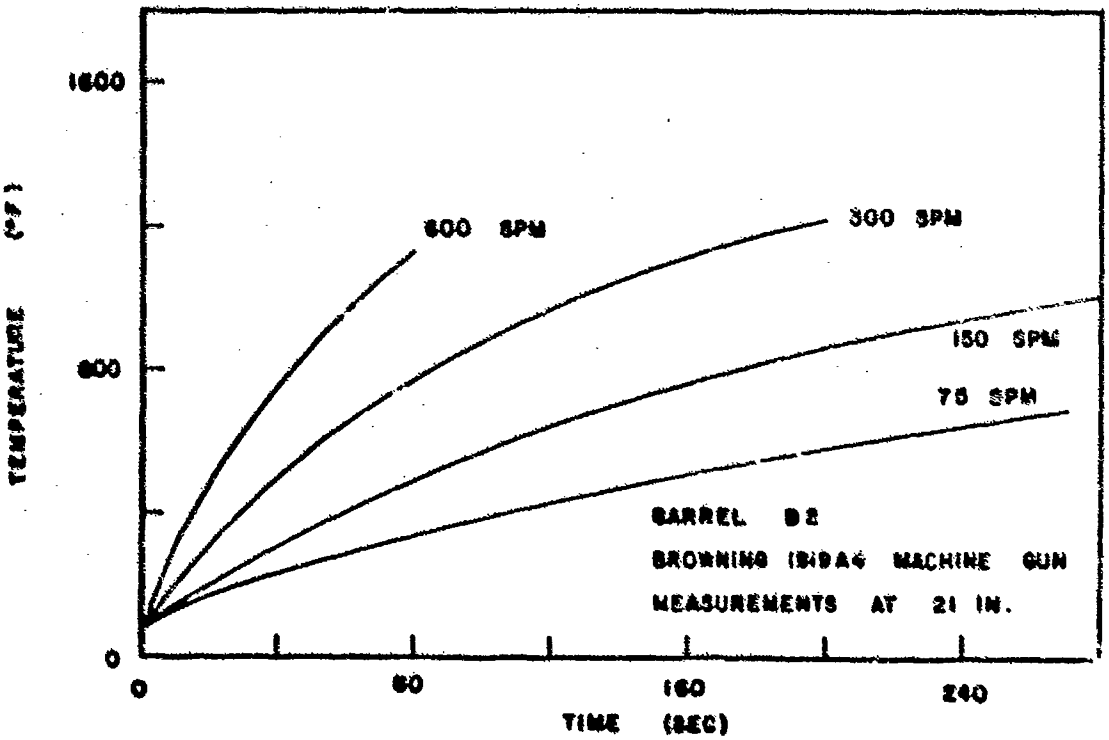


Figure 29 Temperature vs Time for Various Firing Rates of Barrel B2 Measured at 21 in.

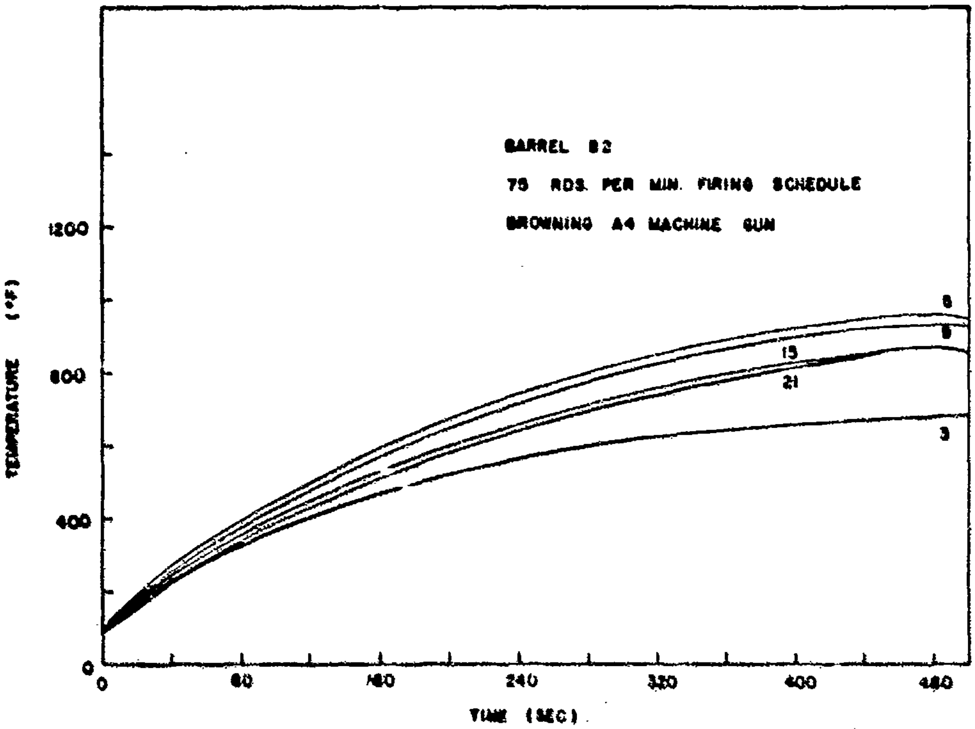


Figure 30 Temperature vs Time at Various Axial Positions of Barrel B2, Firing at 75 rds/min

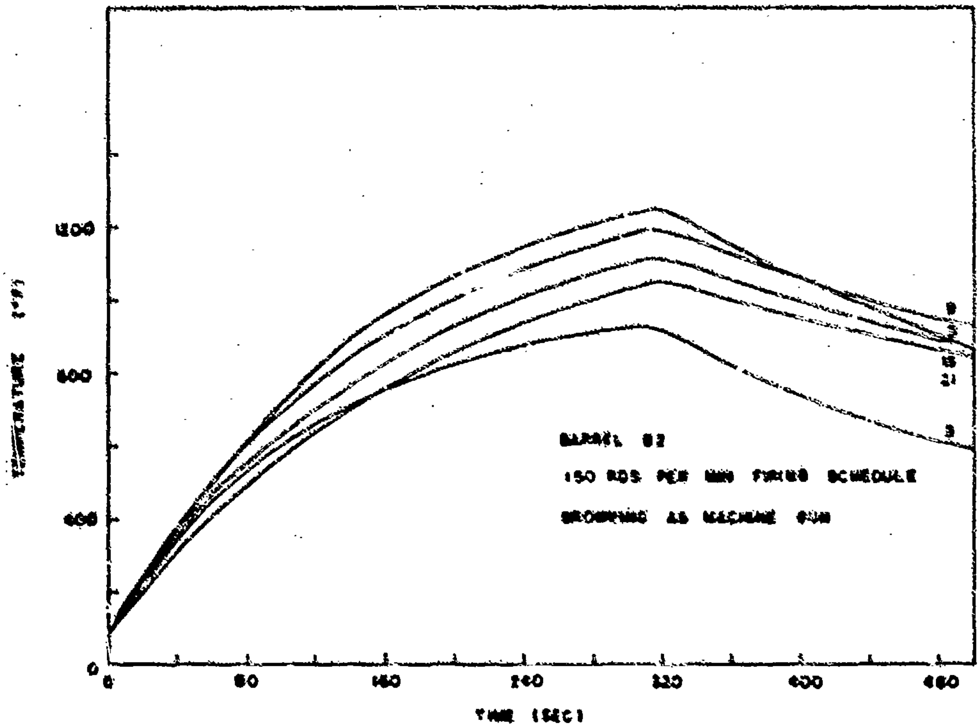


Figure 31 Temperature vs Time at Various Axial Positions for Barrel B2. Firing at 150 rds/min

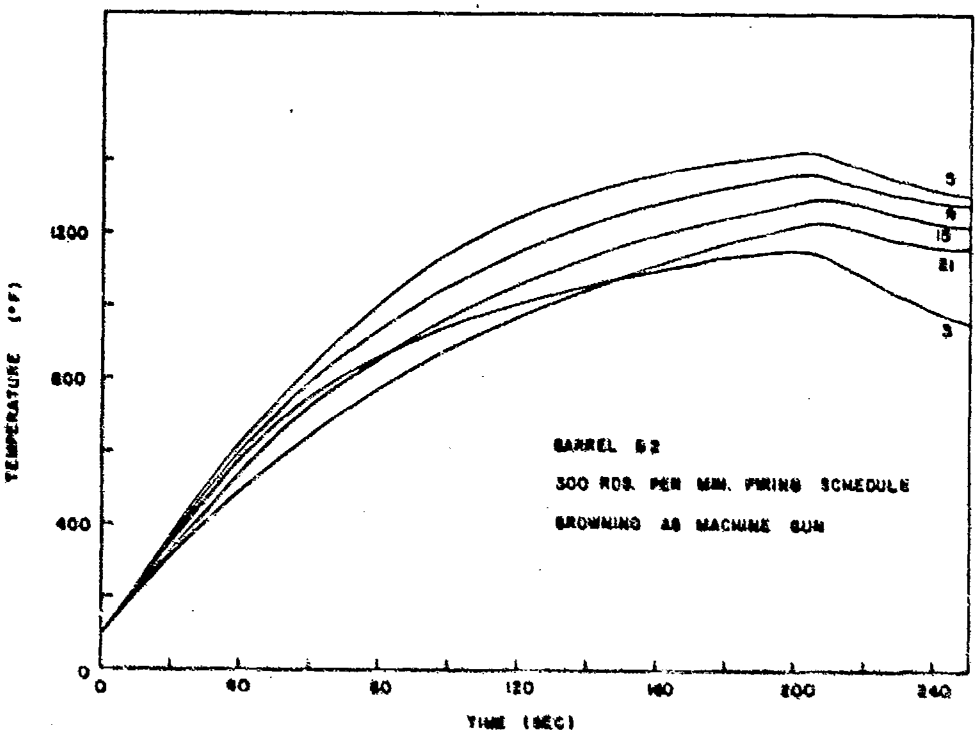


Figure 32 Temperature vs Time at Various Axial Positions for Barrel B2 Fired at 300 rds/min

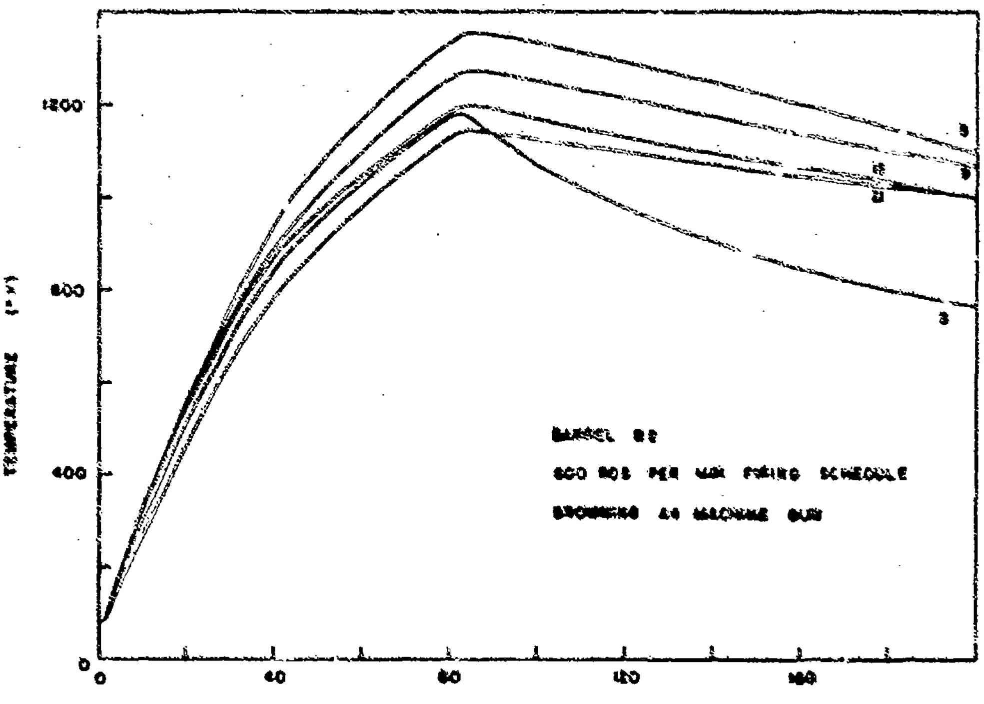


Figure 33 Temperature vs Time at Various Axial Positions for Barrel B2, Fired at 600 rds/min

THERMOCOUPLE LOCATIONS

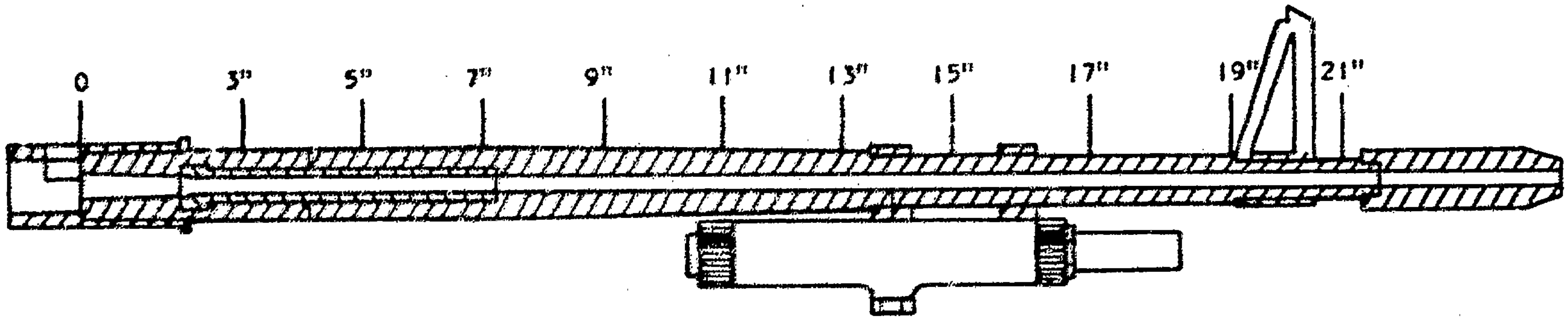


Figure 34 Cross Section View and Thermocouple Locations for M60 Gun Barrels M1 through M9

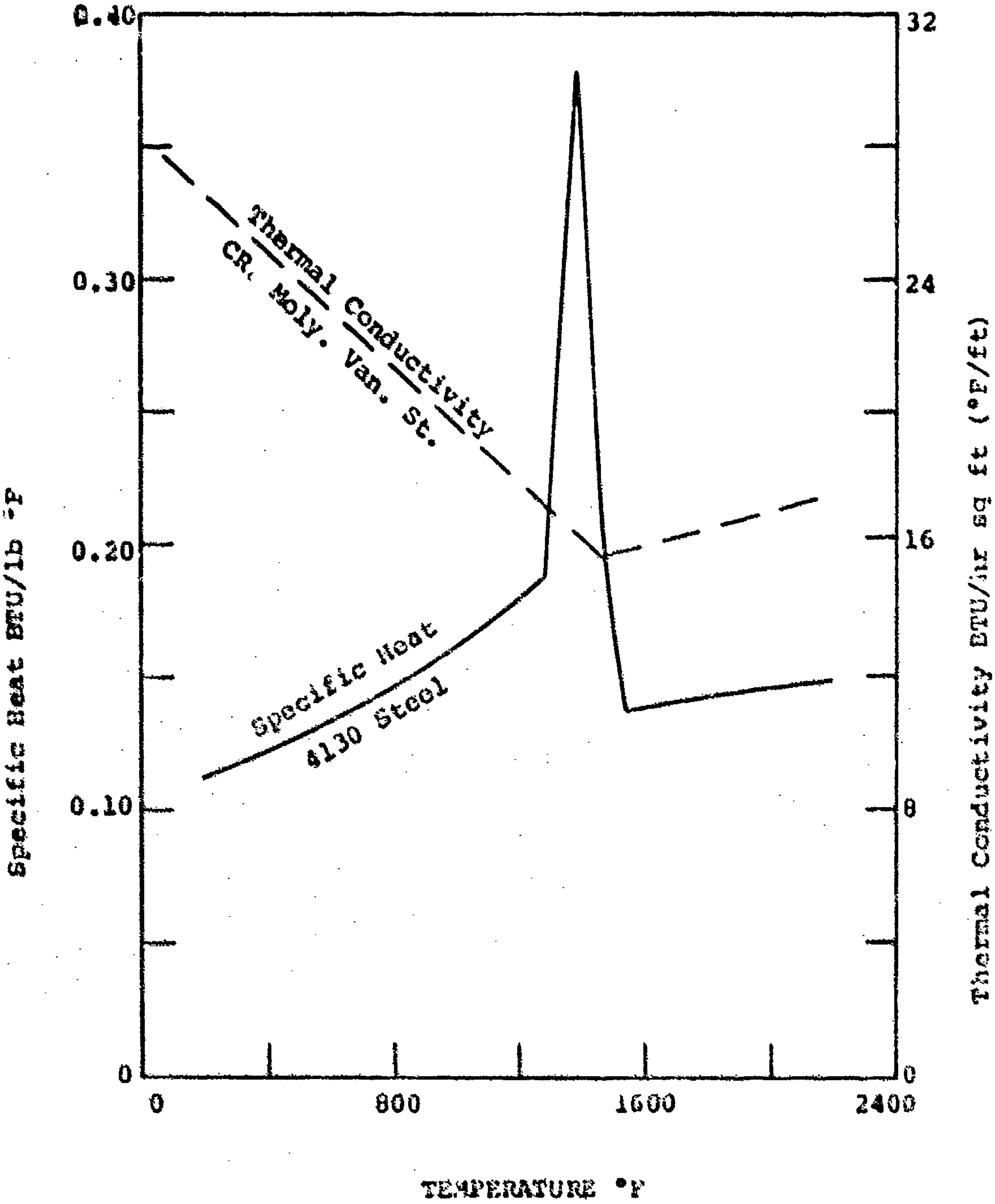


Figure 35 Specific Heat and Thermal Conductivity vs Temperature

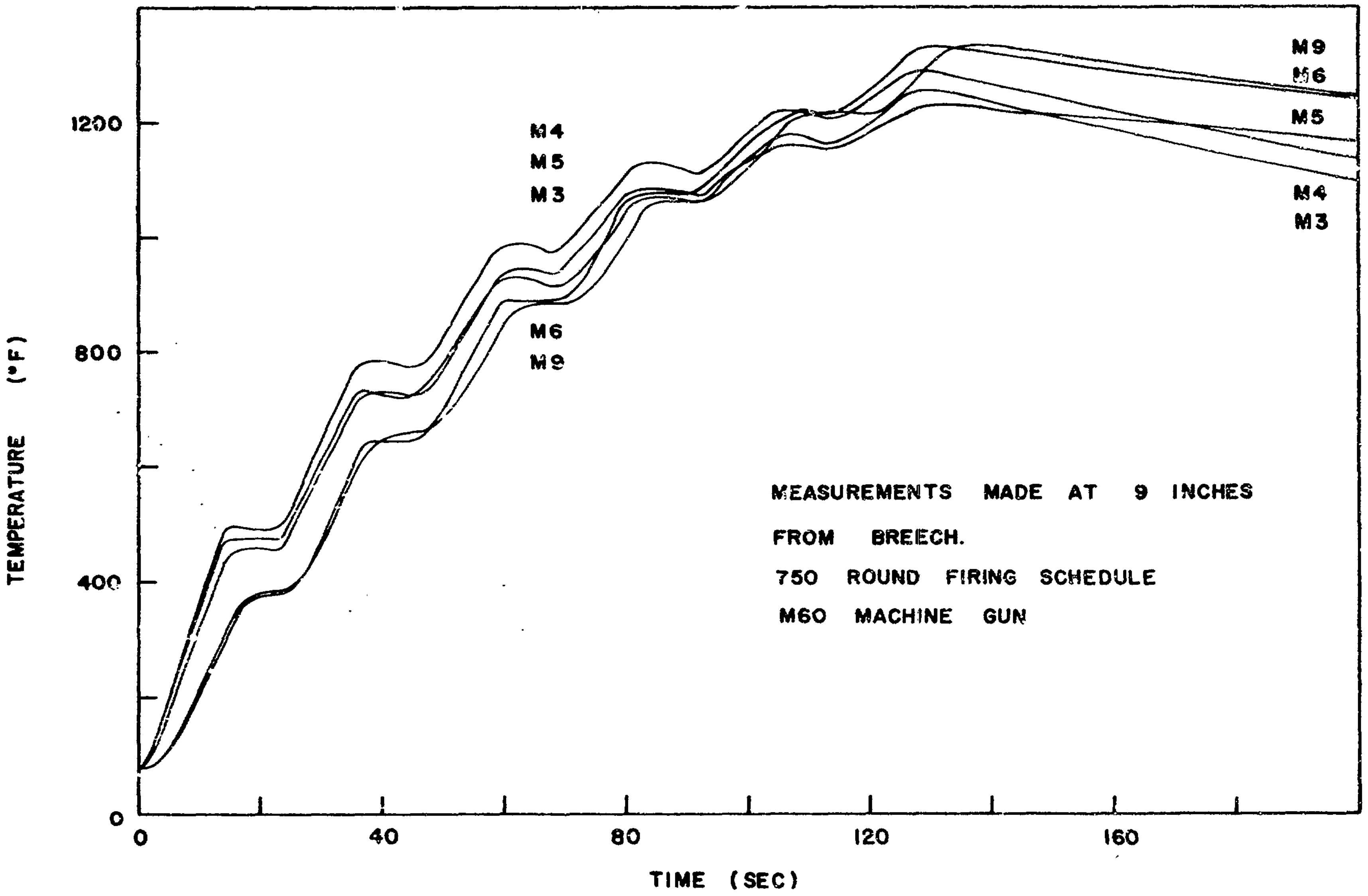


Figure 36 Temperature vs Time for Five Barrel Materials

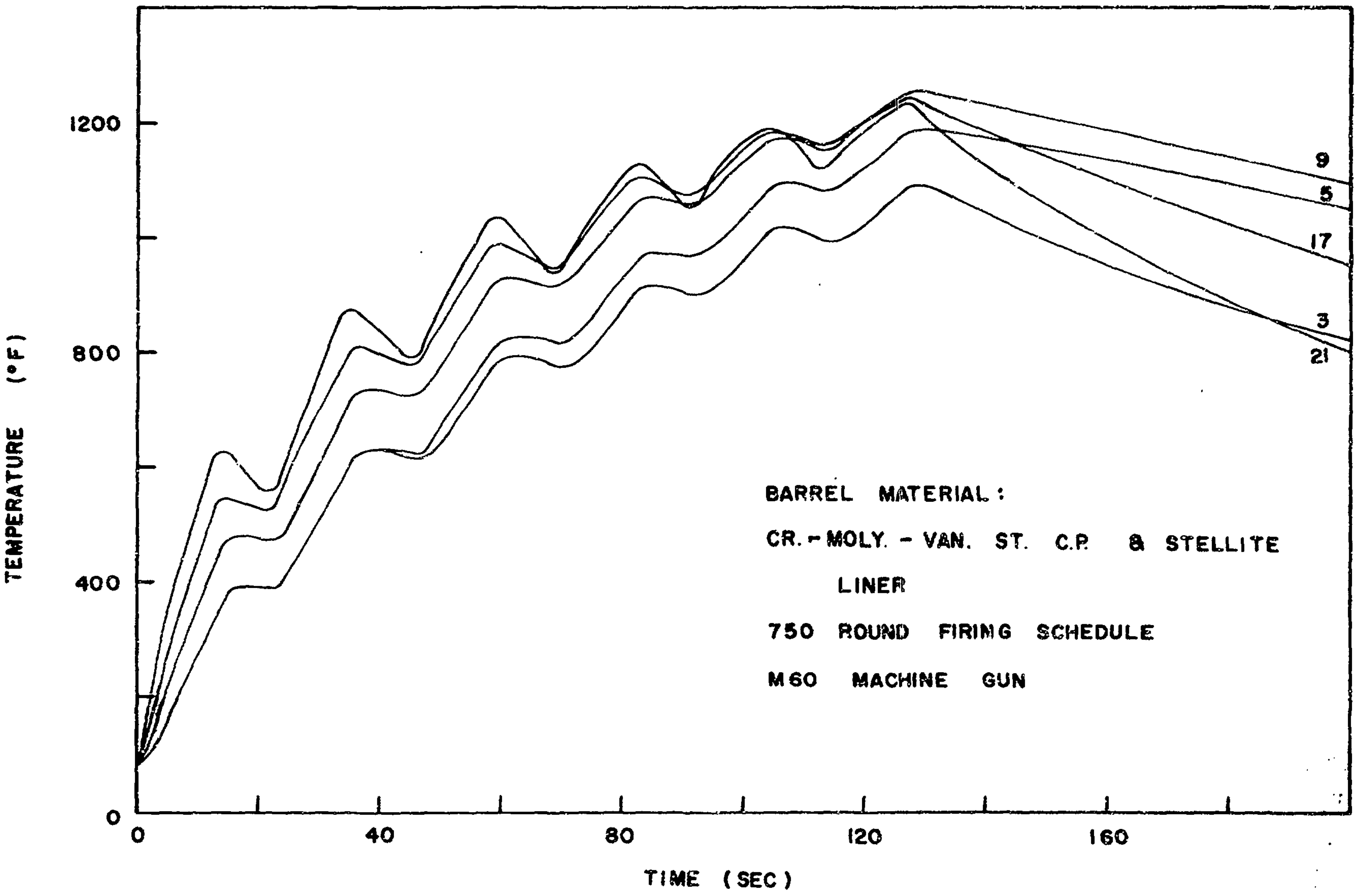


Figure 37 Temperature vs Time at Various Axial Positions

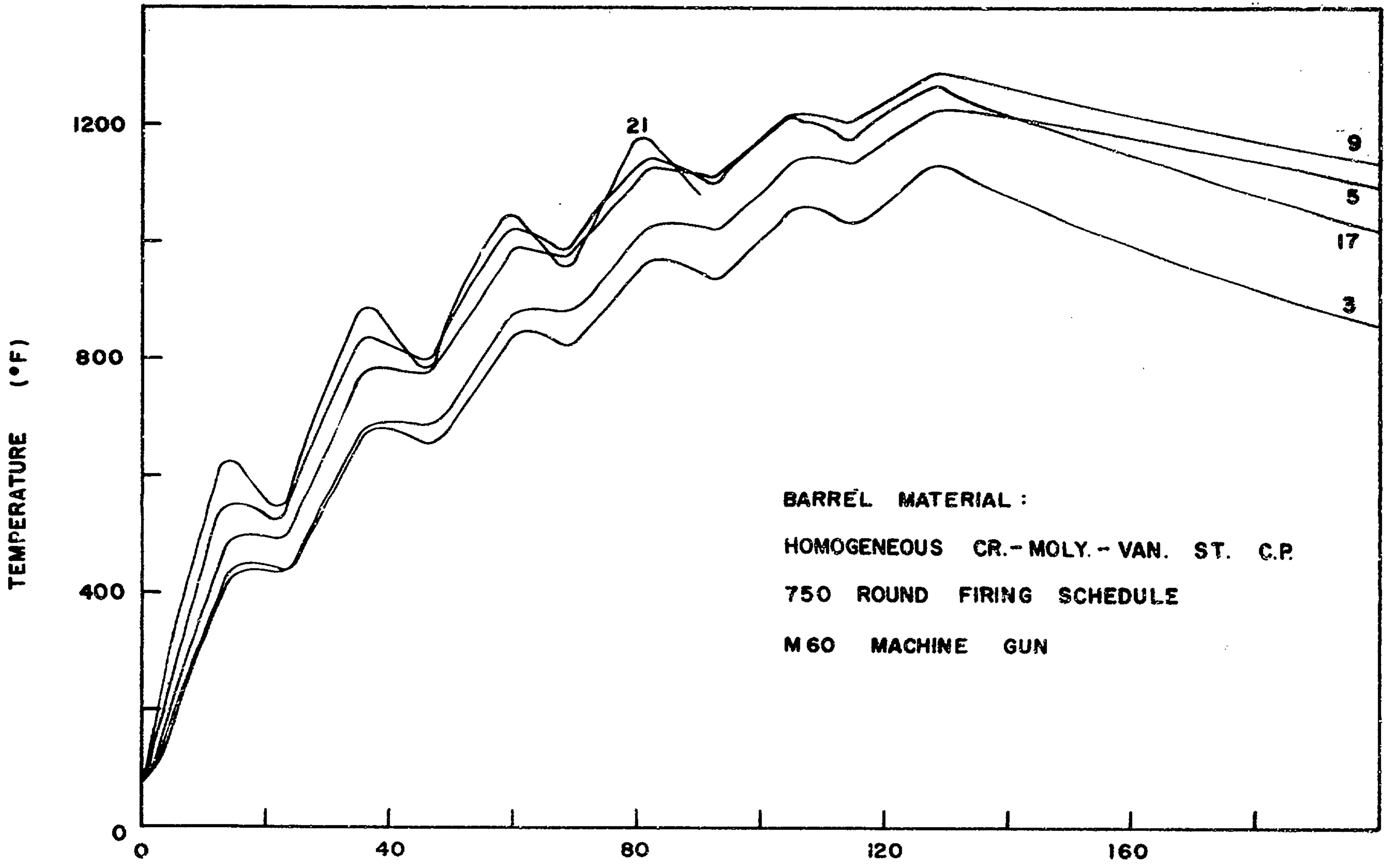


Figure 38 Temperature vs Time at Various Axial Positions

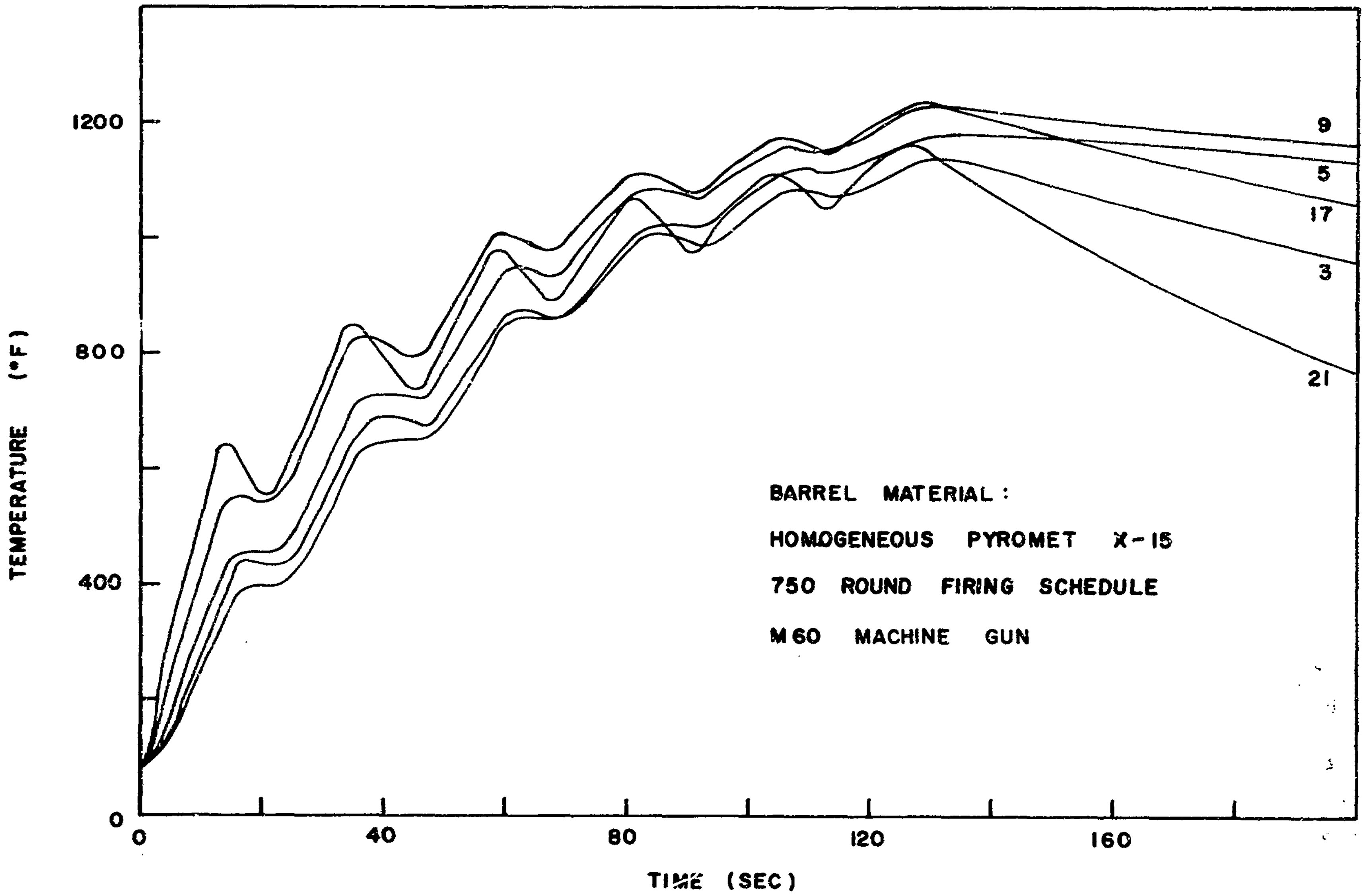


Figure 39 Temperature vs Time at Various Axial Positions

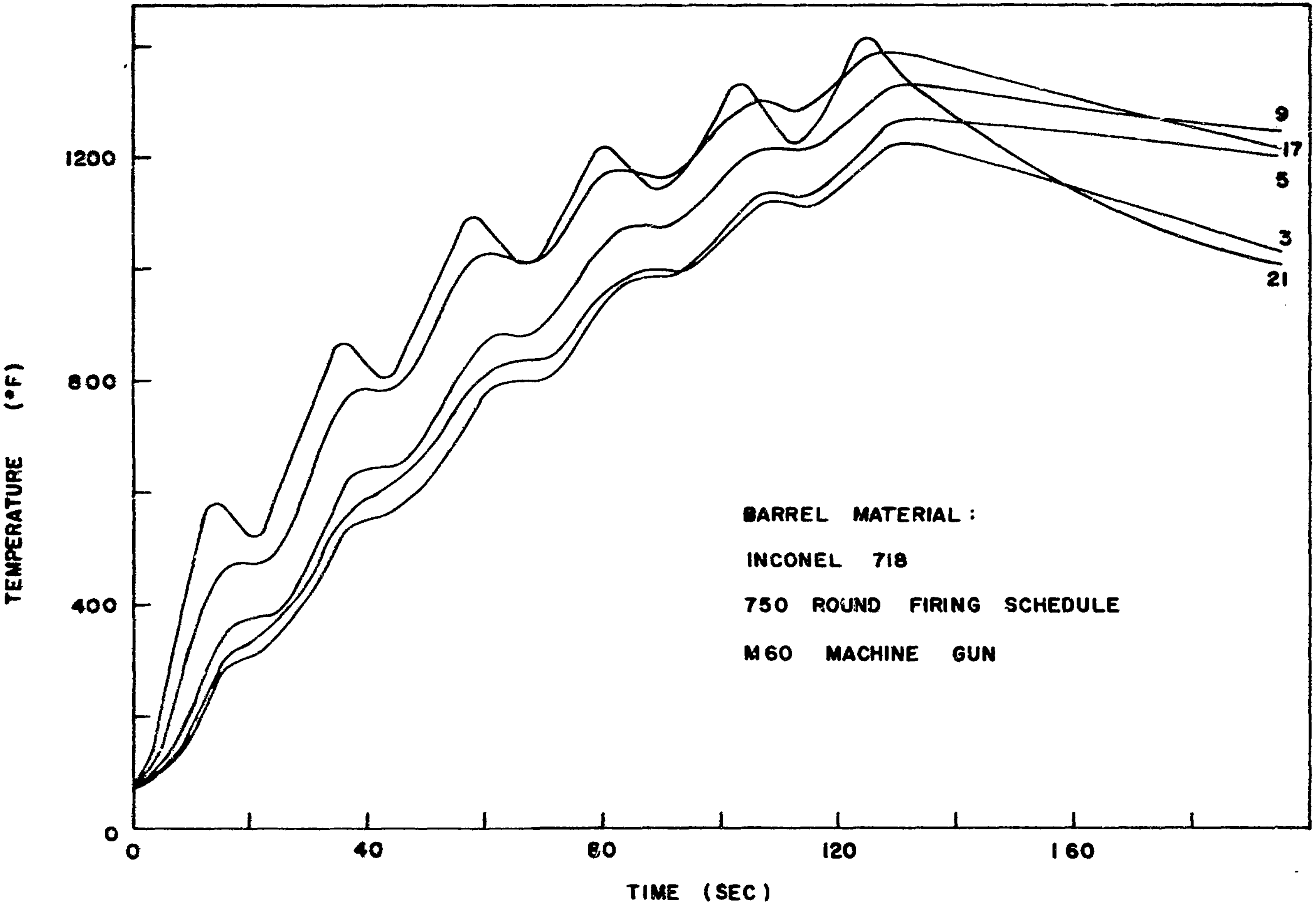


Figure 40 Temperature vs Time at Various Axial Positions

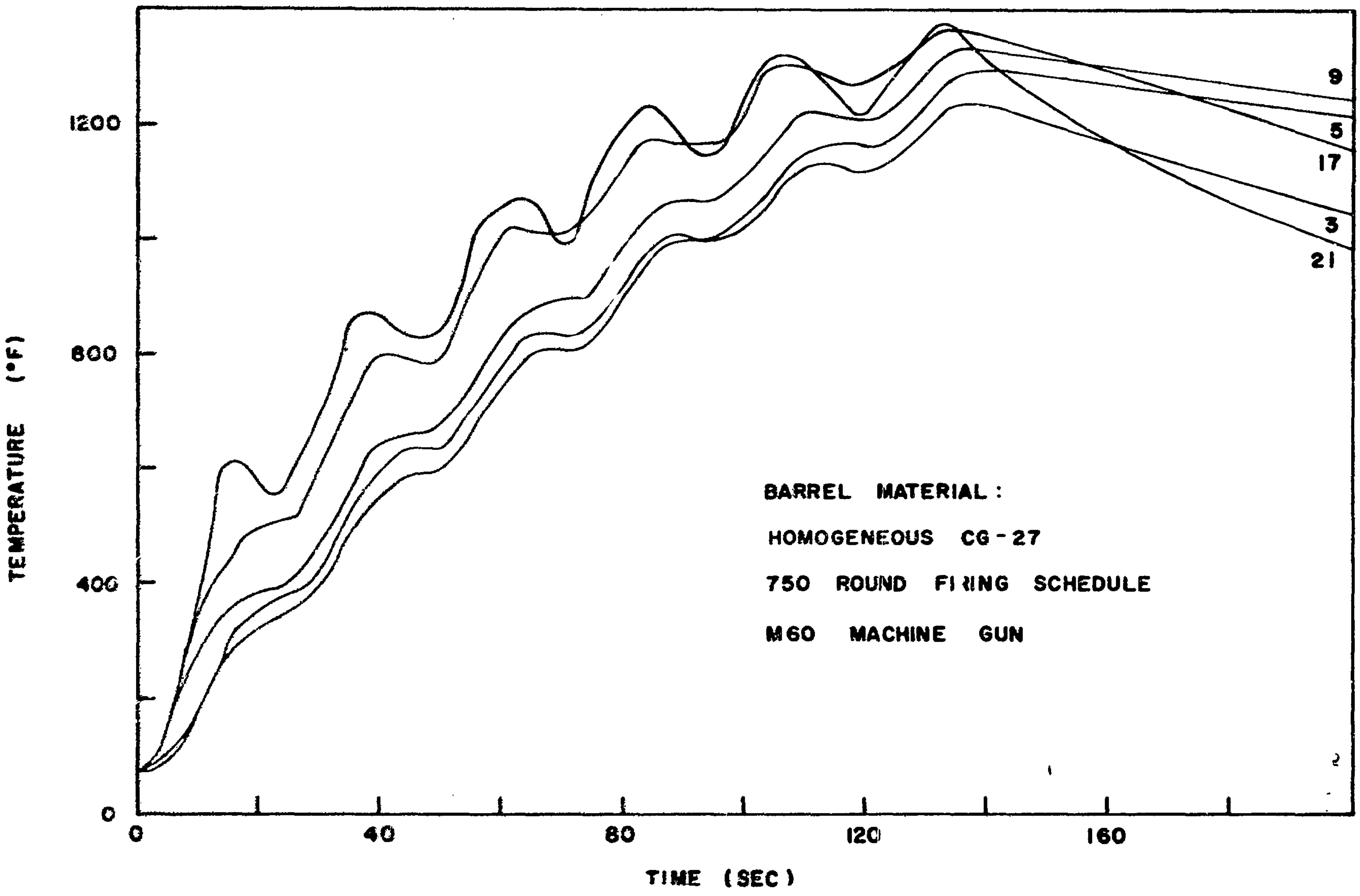


Figure 41 Temperature vs Time at Various Axial Positions

A stellite liner is now used in the 30 cal. Browning Machine Gun to give improved breech end wear. Test results show, as mentioned above, that at the liner-barrel interface the rifling is in significantly better condition in the stellite, indicating desirable results. Proceeding from breech to muzzle end, Figure 7a, there is an almost linear temperature drop for the constant diameter barrels. Test results show that land wear decreases along the barrel, lending support to the relationship between temperature and erosion.

Tapered barrels B4 and B5 were fired 3818 and 4523 rounds respectively. Bore surface replicas reveal that the stellite liners have slightly better rifling, but the lands are absent along the remaining barrel length. The B4 bore replica, with 15 percent fewer rounds than B5, shows a trace of rifling. The muzzle end of these barrels were 300°F hotter than B1 and B3 at the end of a 750 round schedule, further illustrating the relationship between barrel temperature and erosion. Barrels B1 and B3 had a life of over twice that of B4 and B5.

Full tapered barrels B6 and B7 failed at 2628 and 2399 rounds respectively. Bore surface replicas show that the liner rifling is in relatively good condition with the remainder of the barrel containing a trace of rifling. Muzzle end external temperatures reached 1760°F causing catastrophic failure with increased barrel diameter, bending, and loss of bore material, as can be seen in Figures 16 and 17. These light barrels caused many gun malfunctions by not providing sufficient momentum to recycle. Failure to complete the schedule no doubt prolonged barrel life, since the barrel temperature stayed below the critical temperature limit until complete 750 round schedules were achieved. Table 3 shows the history of these barrels.

Historically, barrels failed from severe breech end erosion; however, this problem has been improved with the use of liners made of high strength, high temperature

TABLE 3 ROUNDS FIRED PER EACH SCHEDULE

BARREL	B1	B3	B4	B5	B6	B7
	12[1]	12[1]	12[1]	750	12[1]	12[1]
	537[2]	130	22	12[1]	456	317
	10+20	100	750	320	63	58[4]
	198	20	260	417	16	750
	628	750	750	750	80	750
	18	640	500	750	130	12[1]
	307	750	12[1]	12[1]	750[4]	500[5]
	627	250	750	750[3]	359	2399
	602	12[1]	750	750	12[1]	
	375	750	12[1]	12[1]	750[5]	
	13	750	3818	4523	2628	
	65	12[1]				
	170	750				
	185	750				
	135	12[1]				
	315	750				
	750[3]	750				
	19[1]	12[1]				
	750	125				
	12	625				
	750	750				
	750	12[1]				
	12[1]	750				
	750	12[1]				
	50+700	9474				
	12[1]					
	9772					

NOTES:

1. Target, two rds fired for placement and ten rds for accuracy.
2. Burst lengths less than 750 rds are the result of a gun malfunction.
3. New Gun
4. Browning 1919A6 for remainder of test.
5. Damaged barrel.

materials. On many tapered barrels the problem is now erosion at the muzzle end due to high temperature and projectile velocities. Tapered barrels are clearly desirable due to the weight savings, but Figures 6 and 7 show that adding a taper adversely affects barrel life and temperature distribution. An ideal barrel design would distribute material for optimum external axial temperature distribution, thereby yielding maxiumum life.

The temperature as a function of rate of fire tests shows that on a round-for-round basis the firing rate has minimal effect on barrel temperatures, as can be seen in Figures 18, 19, 26, and 27. For an equal number of rounds, approximately equal barrel temperatures are achieved. Each time the firing schedule (Table 1, Temperature vs Rate of Fire) is doubled (75 to 150 to 300 to 600 spm), one might expect the barrel temperature to double, on a time basis. However, results show a temperature increase of only approximately 80%. It is believed that on a time basis, the temperature does not double along with the firing schedule since the hotter average bore temperature with the faster schedule yields a lower effective bore heat transfer coefficient. There is a relatively small amount of heat given off during a firing schedule (verified by cooling curves) which accounts for slightly lower temperatures on a round-for-round basis for a slower firing schedule.

The muzzle end of the M60 barrel, Figures 34 and 19, does not follow this consistent temperature level for a given number of rounds. It is believed this temperature spread is due to the fact that the thin high temperature barrel wall has a significant level of radiant cooling and because of conduction to the more massive, lower temperature flash suppressor and sight.

The last task was determining the influence of barrel material on temperature. The five materials investigated were in a rather narrow temperature envelope indicating that the material choice has little effect on resulting temperature levels. Material structural properties at these elevated temperatures are more significant parameters in the selection of barrel materials.

Table 4, which lists thermal properties of these materials, shows that the thermal conductivity increases with an increase in temperature for Crucible CG27 and Inconel 718 while the reverse is true for Cr-Moly-Van and Pyromet X 15. Figure 36 demonstrates the effect of this where the temperature of barrels M6 and M9 initially lagged and then surpassed the temperatures of the other barrels.

TABLE 4 THERMAL PROPERTIES OF BARREL MATERIALS

MATERIAL	SPECIFIC HEAT 70°F BTU/LB°F	MELTING PT OR SOLIDUS °F	DENSITY LB/IN³	THERMAL CONDUCTIVITY BTU/HrFt°F 70	1000	1200	1600
Cr-Moly-Van	.107	2560	0.283	27.0	19.7	18.0	16.0
Crucible CG27	.11	2412	0.290	5.4	11.5	12.8	15.3
Inconel 718	.11	2500	0.297	12.0	13.6	13.9	14.5
Pyromet X 15		2642	0.286	14.2		16.4	
Stellite	.10	2665	0.300			12.0	

APPENDIX A

TABLE 5 GUNS FIRED

AMMUNITION:

M60 Machine Gun Lot TW18527-69 7.62 NATO M80
Browning Machine Gun Lot LC L39293 Cal 30 BALL M2

GUNS:

Browning 1919A4 SN 757072 Saginaw General Motors Steering Gear Division
Browning 1919A4 SN 796328 Saginaw General Motors Steering Gear Division
Browning 1919A4 SN 436311 Saginaw General Motors Steering Gear Division
Browning 1919A6 SN 966512 Rock Island Arsenal
M60 SN 67562 Saco Lowell Shops Maremont Corp
M60 SN 95089 Saco Lowell Shops Maremont Corp

AMBIENT CONDITIONS: Indoor ranges approximately 80°F, exhaust fans on

TABLE 6 BARREL DIAMETER AT THERMOCOUPLE LOCATIONS

LOCATION	BARREL						
	B1	B2	B3	B4	B5	B6	B7
3	1.226	1.222	1.222	1.211	1.208	1.200	1.205
5	1.221	1.220	1.226	1.165	1.154	1.126	1.132
7	1.219	1.221	1.212	1.116	1.099	1.052	1.160
9	1.220	1.220	1.216	1.066	1.070	0.981	0.988
11	1.224	1.221	1.218	1.020	1.028	0.909	0.913
13	1.218	1.216	1.218	0.977	0.993	0.838	0.840
15	1.219	1.214	1.220	0.926	0.943	0.765	0.767
17	1.218	1.215	1.221	0.871	0.882	0.693	0.703
19	1.216	1.220	1.217	0.827	0.827	0.618	0.623
21	1.218	1.219	1.220	0.769	0.768	0.548	0.550

LOCATION	BARREL						
	M1	M2	M3	M4	M5	M6	M8
3	1.190	1.192	1.195	1.192	1.190	1.196	1.194
5	1.190	1.192	1.195	1.195	1.190	1.197	1.195
7	1.108	1.118	1.108	1.108	1.098		1.122
9	1.058	1.065	1.058	1.060	1.049	1.062	1.080
11	1.009	1.012	1.007	1.009	1.005		1.041
13	0.962	0.959	0.955	0.959	0.955	0.958	0.960
15	0.854	0.857	0.836	0.854	0.863		0.862
17	0.832	0.831	0.836	0.832	0.835	0.840	[illegible]
19	0.836	0.830	0.834	0.834	0.828		[illegible]
21	0.702	0.697	0.699	0.700	0.704	0.750	0.703

TABLE 7 LENGTH OF BURSTS (SEC.)

BURST	BARREL				
	B1	B4	B6	M3	M5
1	13.4	10.0	12.2	12.1	12.1
2	13.4	10.0	12.2	12.1	12.1
3	13.2	9.4	12.0	12.1	12.1
4	13.2	9.6	12.0	12.1	12.1
5	12.2	9.8	11.6	12.1	12.1
6	12.2	9.6	12.0	12.1	12.1