ARMY RESEARCH LABORATORY

The Effect of an Unconditioned Barrel on Temperature Conditioned 5.56mm Cartridges

by Robert P. Kaste

ARL-TR-4748 **June 2009**

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14. ABSTRACT

Several organizations independently tested the same lot of 5.56mm ammunition temperature conditioned to –55, 125, and 160 °F and reported discrepancies in chamber pressures and muzzle velocities. These discrepancies precipitated this investigation into the time required to temperature condition 5.56mm ammunition and the effect of using an unconditioned weapon to fire conditioned ammunition. The unconditioned weapon dramatically affected the temperature of the conditioned ammunition. Substantial changes in the cartridge temperature occurred when the cartridge remained in the chamber, even for a short time. Cartridges loaded into a 30 round magazine took about 3 times as long to change temperature as did single rounds.

15. SUBJECT TERMS

small arms, temperature conditioned, thermo couples, magazine, ammunition

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1. Introduction

Several organizations recently conducted concurrent testing of the 5.56mm cartridges for the same program. These tests yielded significantly different pressures and velocities for the same lot of rounds conditioned to the same temperatures.

The most significant difference in the experiments done by these organizations was how the temperature-conditioned rounds were treated. One organization was capable of operating its testing at the temperature of conditioning, i.e., both the weapon and ammunition were conditioned to temperature and the actual firing was performed in a temperature-conditioned environment. Other organizations performed testing with temperature-conditioned ammunition fired from a weapon at ambient conditions. In these tests, the ammunition was removed from the conditioning chamber and placed in an insulated box for transportation to and storage at the firing site until the ammunition was actually fired. The times the ammunition was out of the conditioning chamber until it was fired varied, although attempts were made to keep this time to a minimum.

These differences in setup and execution were recognized; questions arose about the time required to condition the ammunition and how quickly the ammunition would return to ambient temperature.

2. Objectives

The U.S. Army Research Laboratory (ARL) performed small scale thermal testing to investigate the time required to temperature condition single cartridges, cartridges in a 30 round magazine and the effect of an ambient weapon on a chambered temperature-conditioned cartridge. The data collected included the time it took cartridges to reach the conditioning temperature and how quickly conditioned rounds returned to room temperature. Data were also collected on the time histories of temperature for internally monitored, temperature-conditioned cartridges that were chambered, but not fired, into an unconditioned weapon.

3. Testing and Procedures

3.1 General Setup

To perform this testing, four M855 cartridge cases were modified to measure temperature. One cartridge had a thermal couple taped to its base using high temperature tape (polyester with a

silicon adhesive). The second cartridge had a thermal couple taped to its side using high temperature tape. Two cartridges were modified by drilling holes though their projectiles. Thermal couples were inserted through the projectiles into the propellant beds. The base, side, and one of the internal instrumented cartridges can be seen in figure 1. Also shown in figure 1 is a thermal couple used to measure the ambient air temperature. This thermal couple remained outside of the conditioning chamber at all times and the cartridges were in its vicinity when they returned to ambient temperature. The data from this thermal couple are designated as "Air" on the plots in this report; the thermal couples used for these cartridges were "J" type with 36 gauge wires.

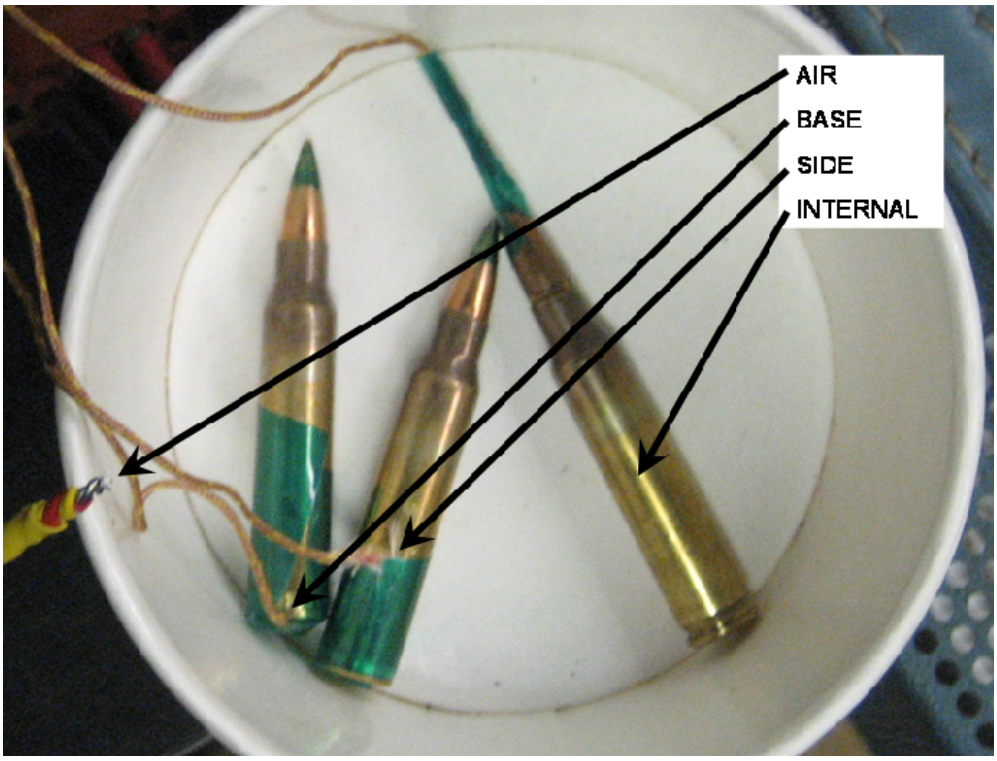

Figure 1. The 5.56mm cartridges instrumented with thermal couples.

The exterior of the barrel in the region of the chamber was also fitted with a thermal couple to monitor its temperature. This is seen in figure 2. The data from this thermal couple are labeled "Barrel" on the plots in this report. All thermal couples were connected to a Graphtec midi Logger GL200 with a USB memory stick that monitored and recorded the data, which was collected at a rate of 500 ms per sample. A conditioning chamber, Tenney Benchmaster, model BTC was used to condition the ammunition.

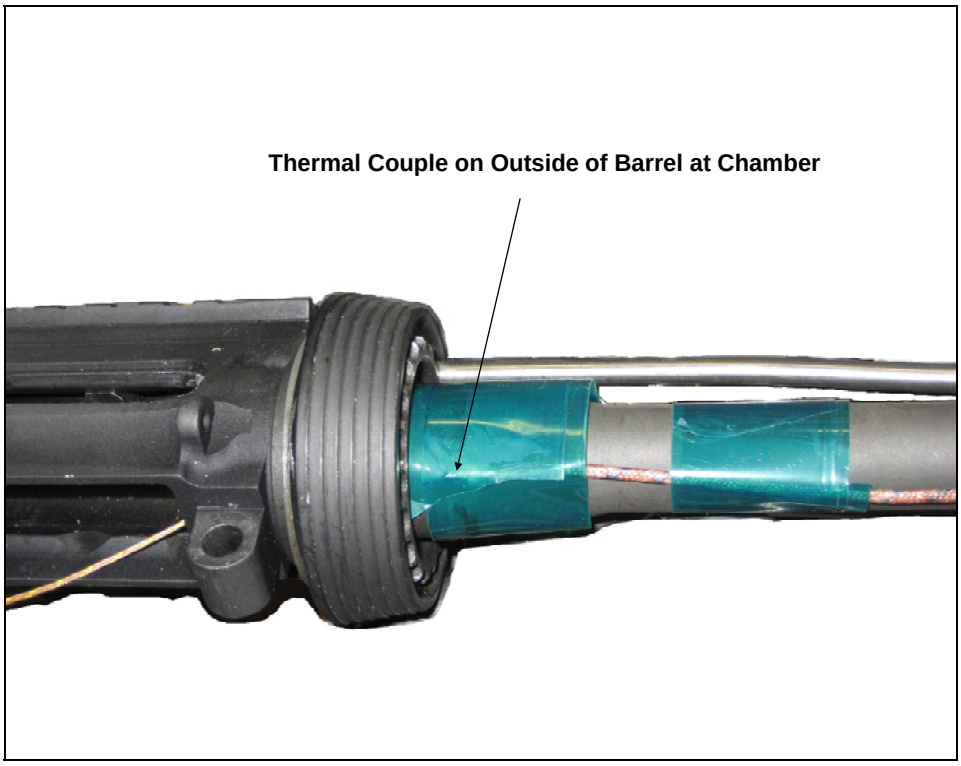

Figure 2. Thermal couple on barrel exterior.

Sitting on the bottom of the conditioning chamber were firebricks to provide a thermal barrier for the cartridges from the metallic chamber floor as seen in figure 3. The conditioning chamber was pre-conditioned to the desired temperature prior to the beginning of the tests. The air temperature within the conditioning chamber was monitored with a thermal couple, which can also be seen in figure 3. The data from this thermal couple are labeled “Oven” on the plots in this report.

Figure 3. Tenney Benchmaster, model BTC, temperature conditioning chamber and firebricks.

3.2 Single Cartridges

In the single round testing, three cartridges were placed in a paper cup (figure 1), one internally and the two externally measured cartridges. The other internally measured cartridge was used to observe the affect of chambering; its thermal couple wire was strung through an M4 barrel and an upper receiver. This allowed the cartridge's thermal couple to be continuously connected to the thermal couple reader, a Graphtec midi Logger GL200, throughout the conditioning and chambering processes. To begin the tests the data logger was set to capture data and record the initial temperatures of the cartridges, weapon, conditioning chamber, and ambient air. The paper cups containing the cartridges were then placed onto the firebricks inside of the conditioning chamber. The temperatures of all the thermal couples were monitored and recorded. After it was apparent that all the cartridges had achieved equilibrium with the conditioning chamber, they were removed from the conditioning chamber and placed in ambient air. The base and side instrumented cartridges and one internally instrumented cartridge remained in their paper cup container. This kept them from directly contacting room temperature surfaces and air currents but provided little insulation from the ambient air temperature.

The internally monitored cartridge that was used to see the effect of chambering into the unconditioned weapon was removed from the conditioning box and fed into the chamber by hand. The bolt carrier assembly was then pushed behind it to lock the round into the chamber. A second person gently pulled the thermal couple wire through the barrel so the cartridge could be chambered quickly without pinching or cutting the thermal couple wire. Figure 4 shows the

instrumented round prior to insertion into the chamber. Data were monitored and recorded until it was apparent that the cartridges had all reached equilibrium with the ambient air. Temperature and time data were collected via the Graphtec midi Logger GL200, read into Microsoft Excel files, and post-processed.

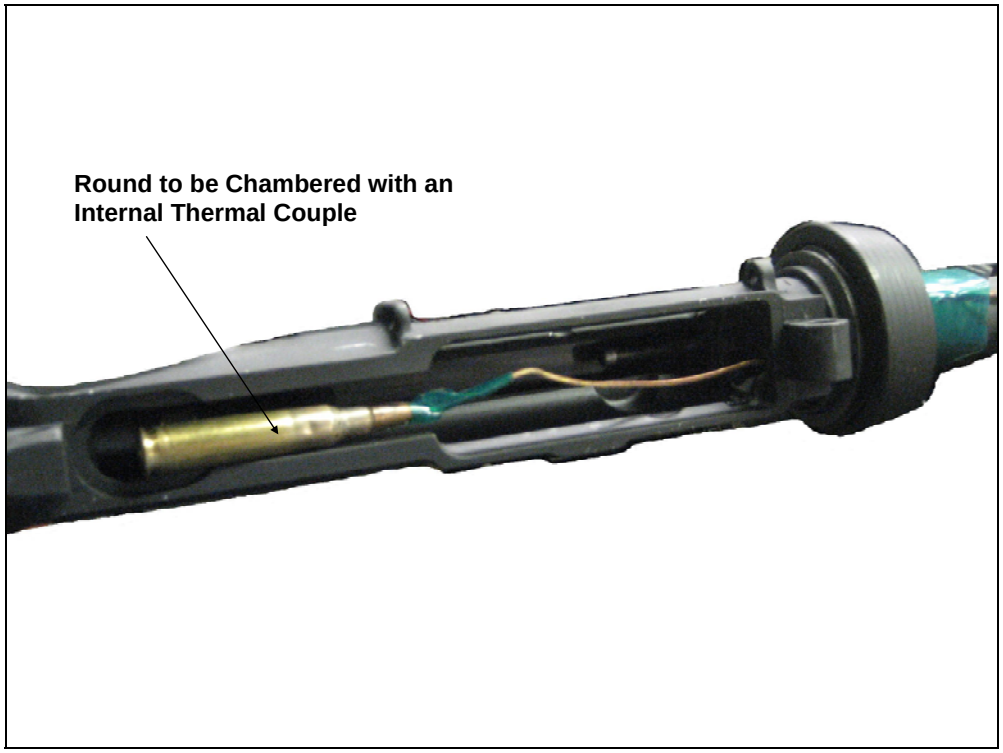

Figure 4. The 5.56mm cartridge with internal thermal couple for chambering into M4 barrel.

3.3 Cartridges in 30 Round Magazine

In testing the loaded 30 round magazine, 30 cartridges were loaded into a standard issue magazine. Rounds 1 and 2, the top two rounds, were cartridges with internal thermal couples; rounds 9 and 11 were cartridges with external thermal couples. Figure 5 shows the loaded magazine. In a similar manner as in the single cartridge testing, recording temperature data was begun prior to placing the magazine onto a firebrick in the pre-conditioned conditioning chamber. The magazine remained in the conditioning chamber until all the instrumented cartridges had achieved thermal equilibrium with the conditioning chamber. The magazine was then placed into a large cardboard box outside of the conditioning chamber. This was done to provide some insulation from the environment, i.e., the rounds were not placed in direct contact with a room temperature surface and were somewhat isolated from room air currents. The air temperature within the box was monitored as the magazine and cartridges returned to ambient temperature. Temperature and time data were collected via the Graphtec midi Logger GL200, read into Microsoft Excel files, and post-processed.

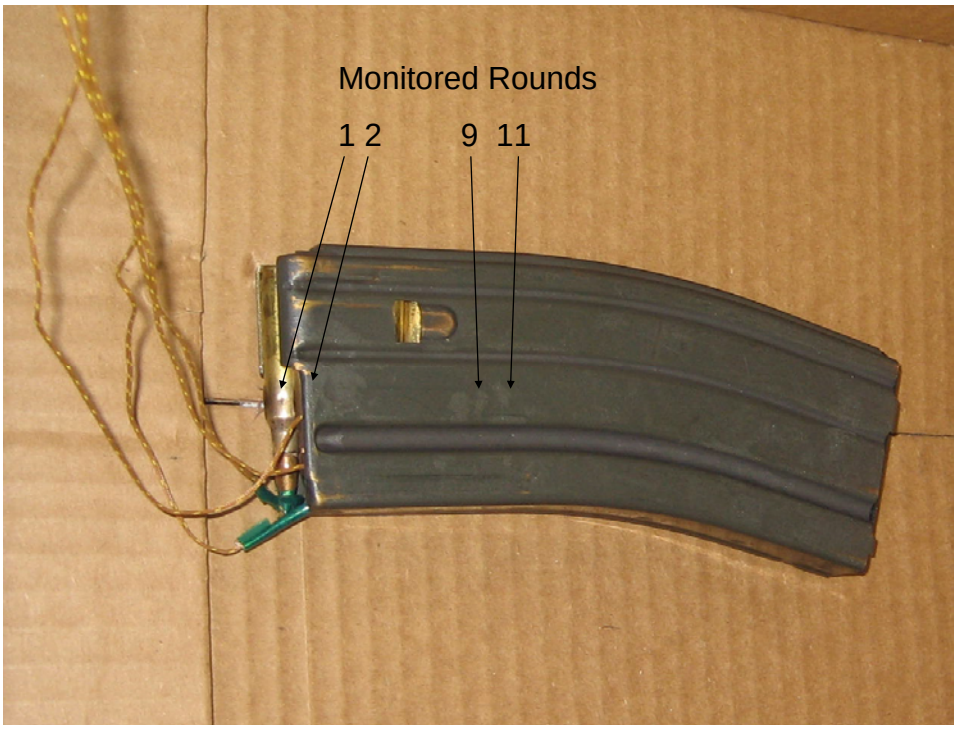

Figure 5. The 30 round magazine loaded with thermal coupled cartridges.

Both the single cartridge and 30 round magazine tests were performed for rounds conditioned to –55 °F (–48 °C), 125 °F (52 °C), and 160 °F (71 °C).

4. Results

4.1 Single Rounds versus Rounds in a Magazine

The temperature of single cartridges changed faster than the rounds loaded into the 30 round magazine. It took about 3 times longer to condition the cartridges in the magazine as compared to the single cartridges. Table 1 lists the times to condition and return to ambient temperature.

Table 1. Times to temperature condition and return to ambient temperature of rounds in a magazine and single rounds.

Temperature Change	30 Round Magazine	Single Round	Chambered Round
70 to –55 °F	40 min	14 min	NA
–55 to 70 °F	120 min	45 min	3 min
70 to 125 °F	NA	30 min	NA
125 to 70 °F	NA	31 min	3 min
70 to 160 °F	90 min	35 min	NA
160 to 70 °F	120 min	30 min	3 min

Plots of temperature histories while conditioning single cartridges are shown in figures 6, 7, and 8; these plots show that reported temperatures of the two internally thermal coupled cartridges changed temperature slower than the externally measured rounds as would be anticipated. Additionally, the cartridge used for chambering changes temperature slower than the other internally thermal coupled cartridge indicating perhaps that its thermal couple is centered better in the propellant bed.

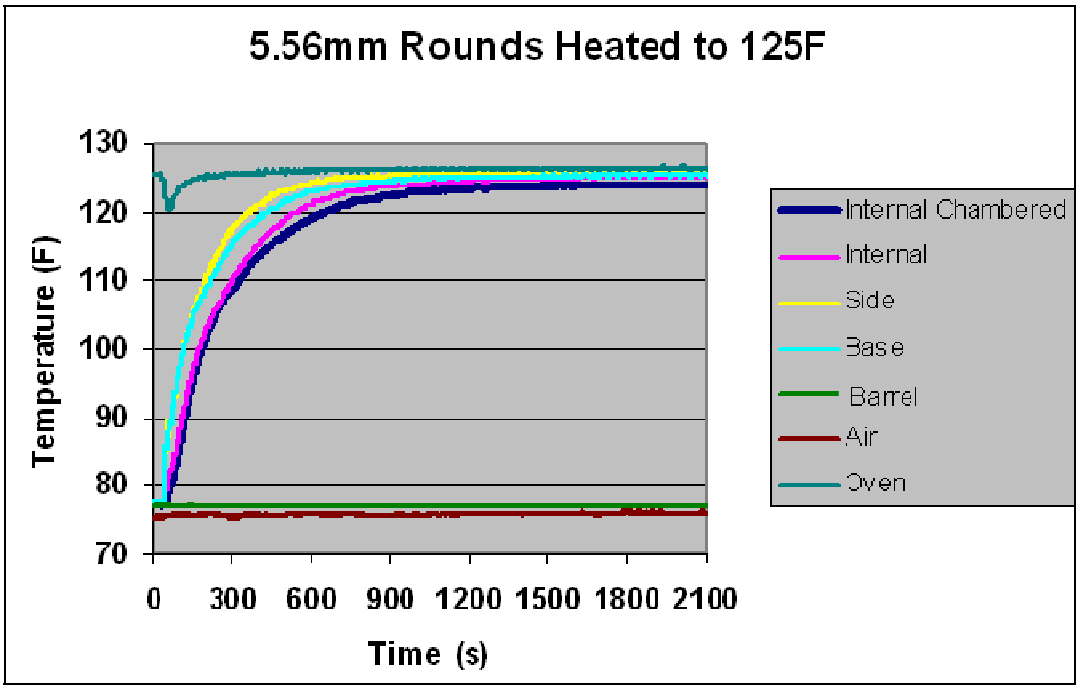

Figure 6. Time to condition single 5.56mm cartridges to 160 °F.

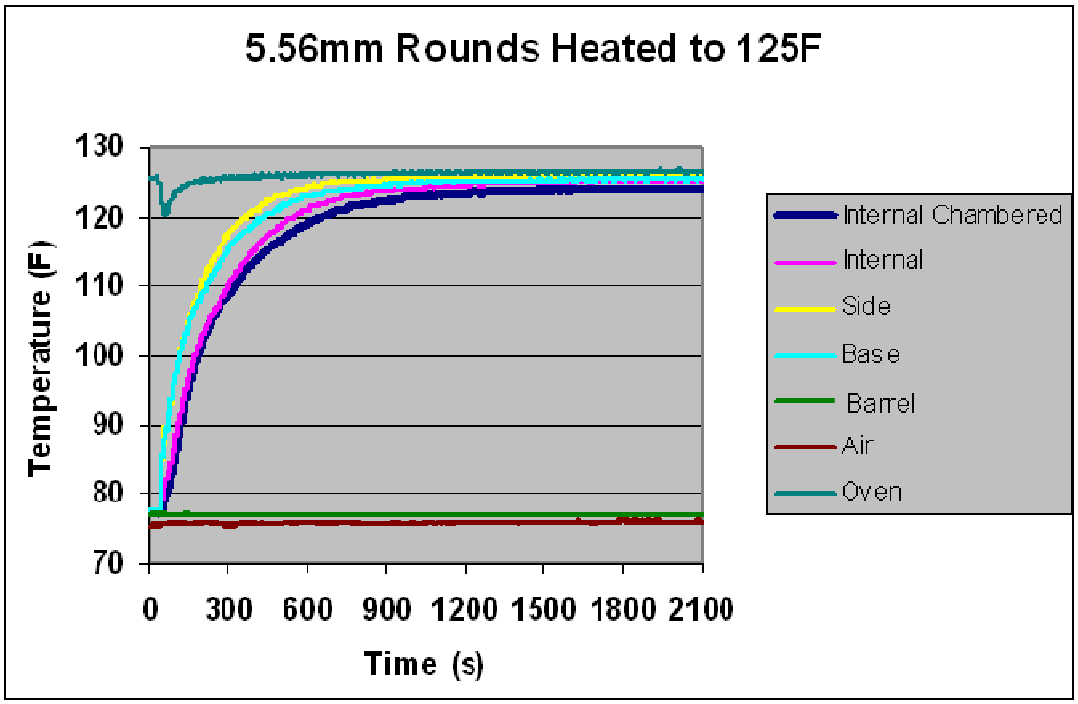

Figure 7. Time to condition single 5.56mm cartridges to 125 °F.

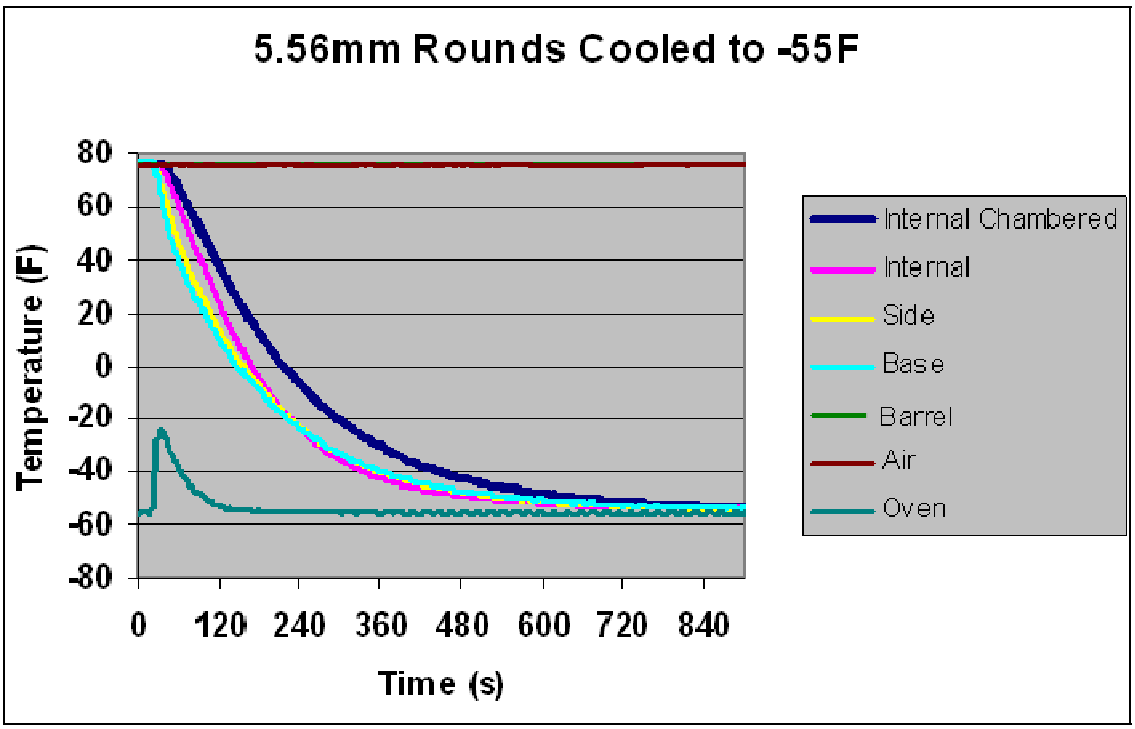

Figure 8. Time to condition single 5.56mm cartridges to –55 °F.

Figures 9 and 10 show time history data for conditioning single rounds and rounds in magazines to 160 °F and to –5 °F respectively.

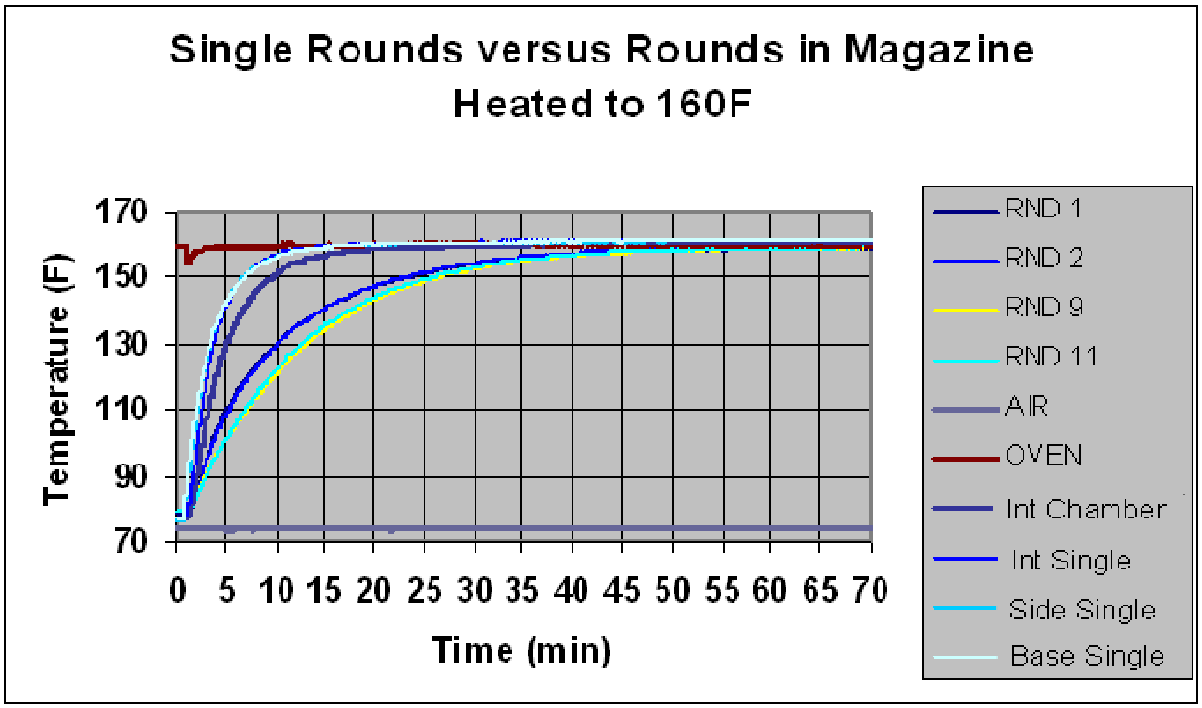

Figure 9. Conditioning to 160 °F of rounds loaded into a magazine and single rounds.

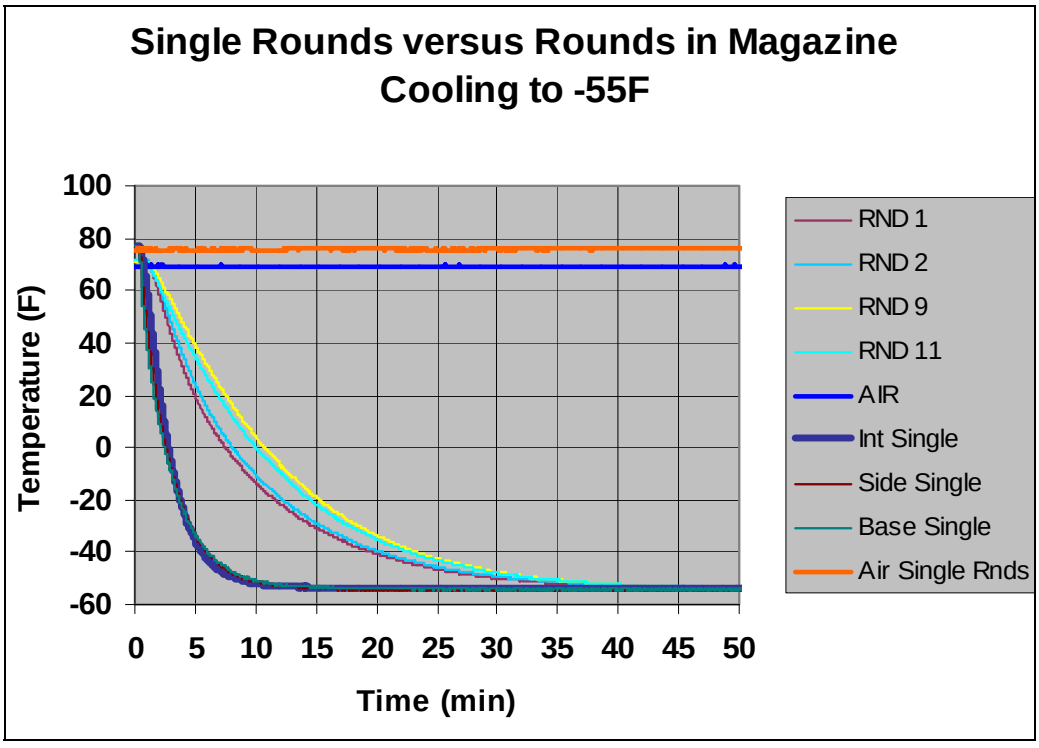

Figure 10. Time to condition rounds loaded into a magazine and single rounds to –55 °F.

Figures 11 and 12 show time history data for conditioned single rounds and rounds in magazines returning to ambient temperature from 160 °F and to –55 °F respectively.

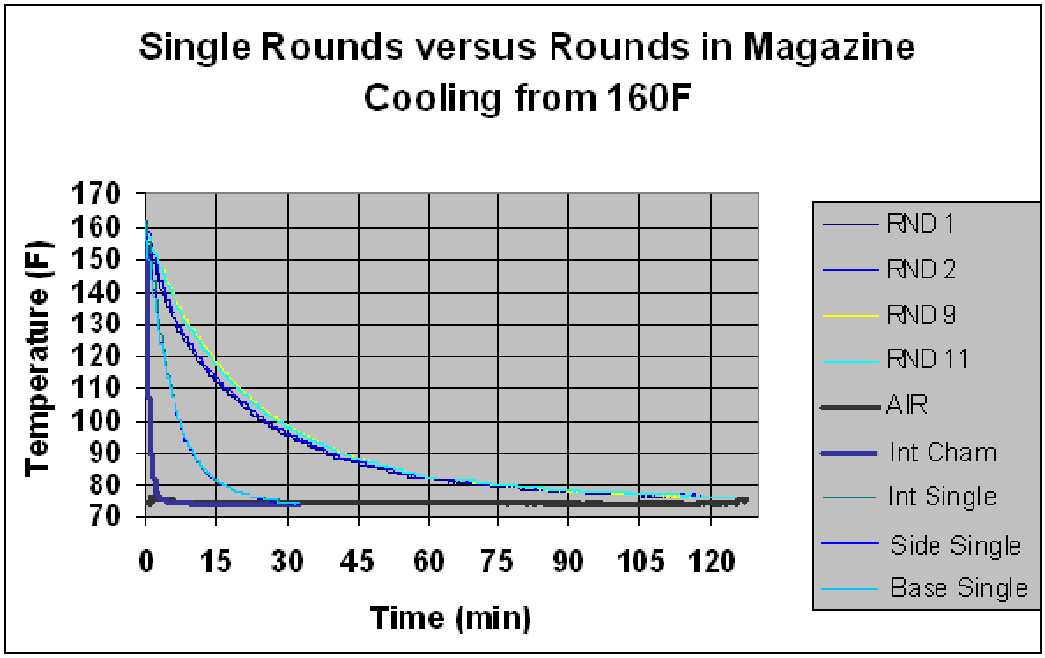

Figure 11. The return of rounds conditioning to160 °F loaded into a magazine and single rounds to ambient temperature.

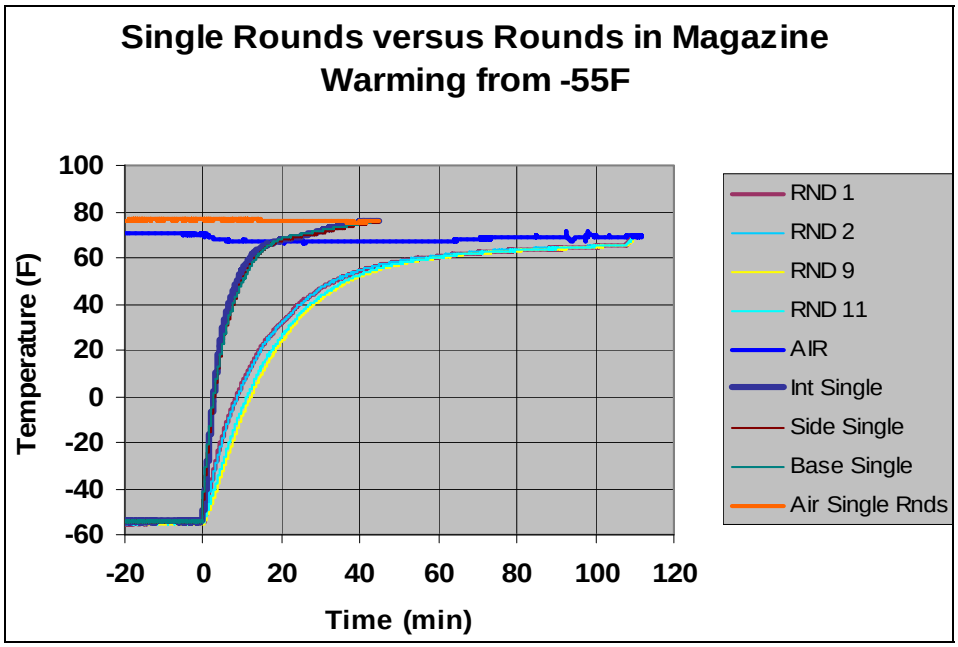

Figure 12. Time to return rounds loaded into a magazine and single rounds conditioned to –55 °F to ambient temperature.

4.2 Effect of Unconditioned Barrel on the Temperature of Conditioned Cartridges

Also presented in table 1 and again in figures 13–16 are the effects of chambering conditioned rounds into an unconditioned barrel for the temperature extremes considered. The rates of return to ambient temperature are quite high for a chambered cartridge. In figure 16, the results from the three conditioning temperatures are plotted together. As seen in this figure, a cartridge left in the chamber for 30 s prior to firing has changed temperature significantly—a cartridge left in the chamber for 20 s can no longer be considered conditioned at its original temperature. While the exact location of the thermal couple is unknown, the thermal couple is inside the cartridge nominally in the propellant bed. There was slight difficulty in chambering the round conditioned to 125 °F which is seen in the small plateau in the data in the first 10 s.

In this study, the un-chambered cartridges were protected from convection exchange with the air by a paper cup albeit not insulated. The average rates of change in temperature for un-chambered internally instrumented, single cartridges, for the first 3 min after removal from the conditioning chamber, were approximately 6°, 11°, and 17 °F per min. The internally instrumented cartridges in magazines had temperature change rates of about 6° and 7 °F per minute as an average for the first 3 min after removal from the conditioning chamber. The heat exchange rates for the chambered cartridges were much less linear with time in nature. Within 3 min, they all were at the temperature of the weapon. In the first 30 s of chambering, their average rates of change were between 60° and 125 °F per min.

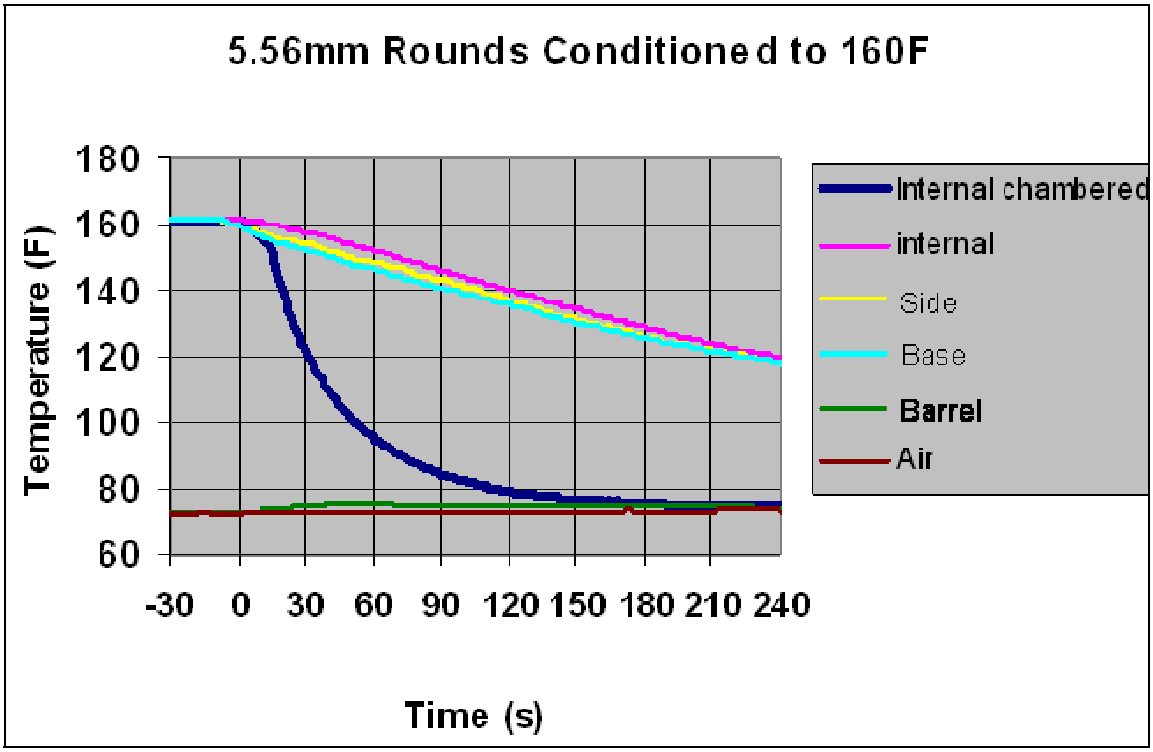

Figure 13. Time to cool single 5.56mm cartridges from160 °F to ambient.

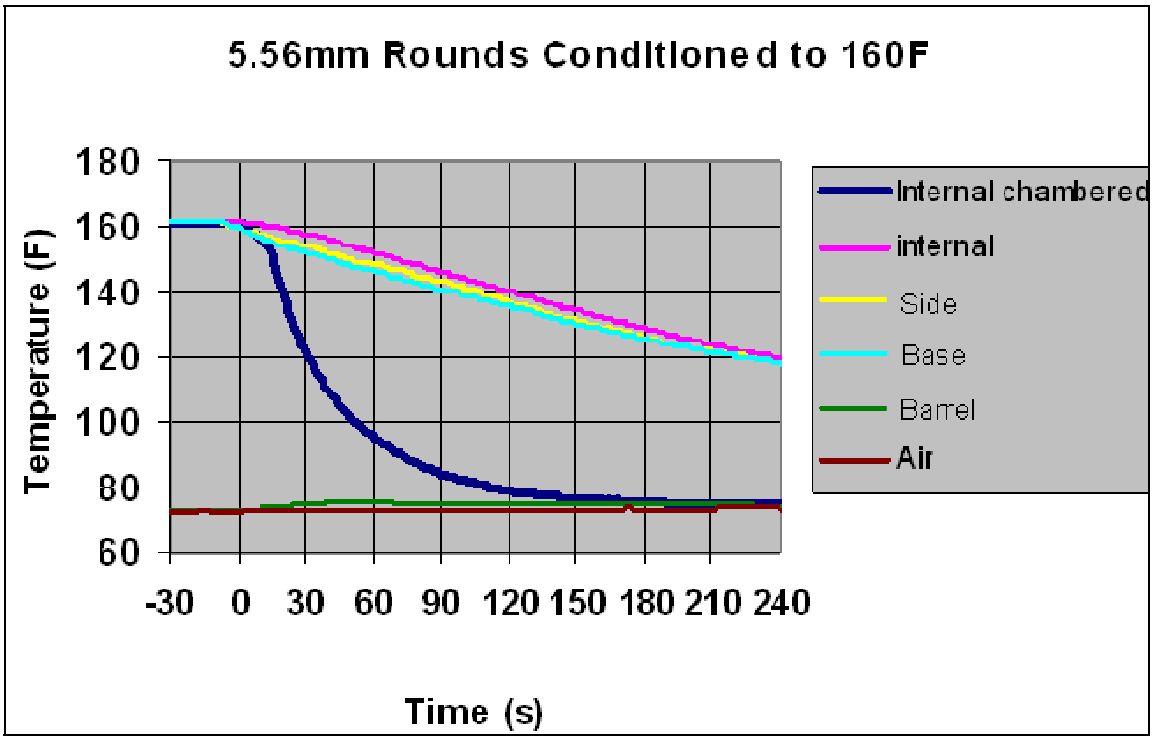

Figure 14. Time to cool single 5.56mm cartridges from125 °F to ambient.

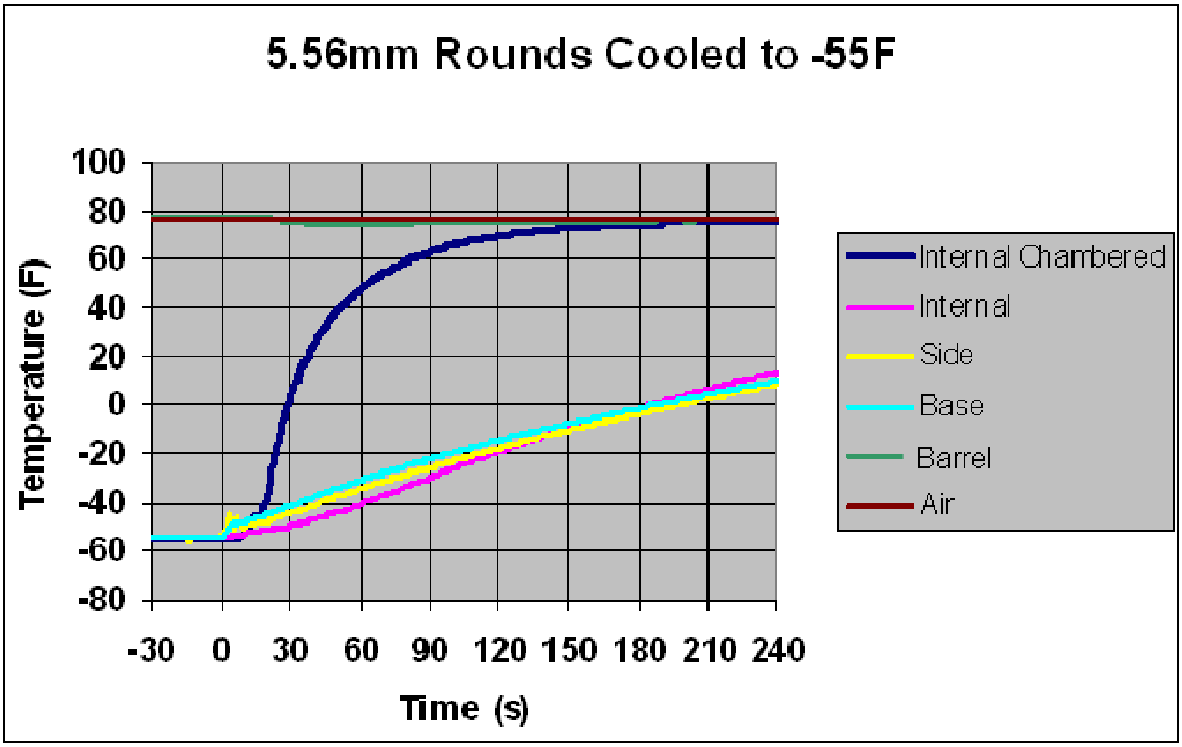

Figure 15. Time to warm single 5.56mm cartridges from –55 °F to ambient.

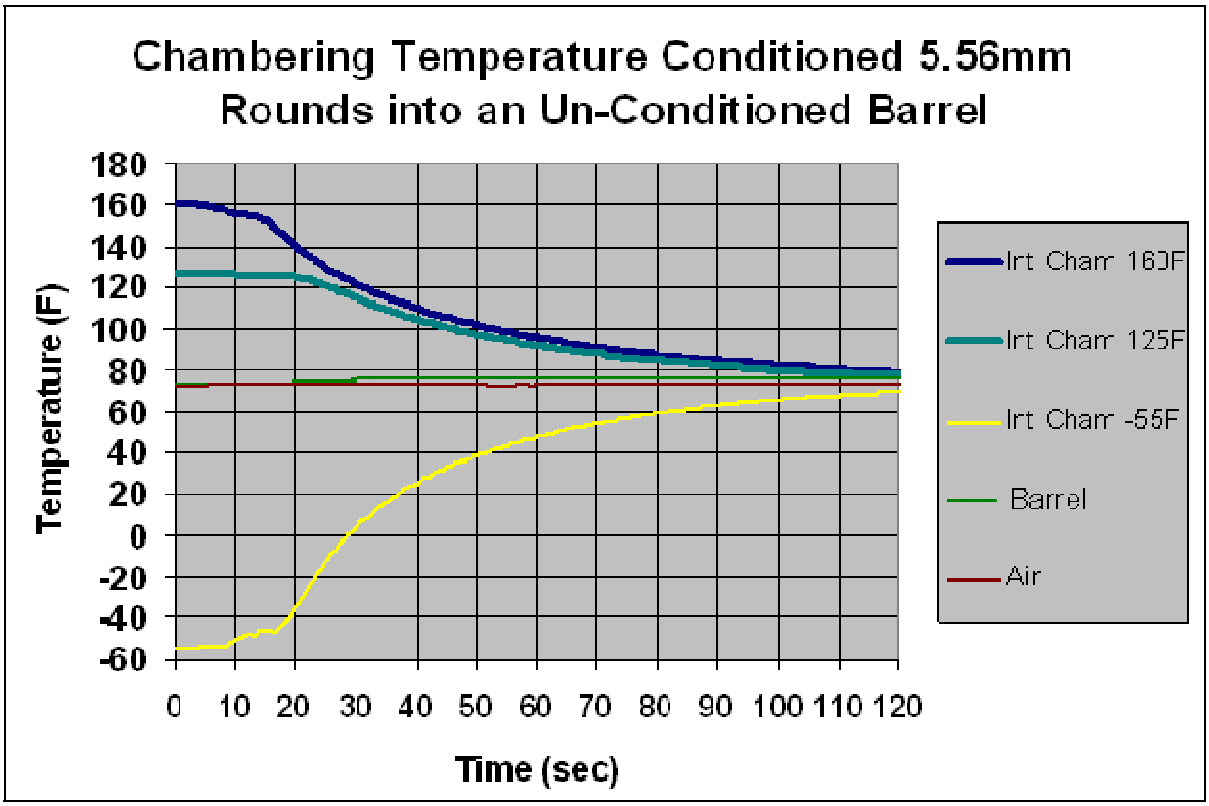

Figure 16. The effect of chambering temperature-conditioned 5.56mm cartridges into an unconditioned barrel.

5. Discussion

The data presented from this study provide insight into the inconsistencies in the earlier performance results reported from varying test procedures. The variation in the actual temperatures of the rounds when they were fired resulted in varying pressure and velocity measurements. The data presented here show how quickly the temperature of the weapon can change the temperature of the ammunition for a 5.56mm system. It is most important that testing conditions properly reflect the situation that is intended to be examined. There are scenarios where both the weapon and the ammunition are at the same temperature (at least initially) and where they are not. When determining the response of a cartridge to temperature conditions it is probably best to condition both the weapon and the ammunition to that temperature. Appropriate precautions should be taken with the instrumentation on a weapon conditioned to extreme conditions to maintain measurement accuracy. Conditioned ammunition removed from the conditioning chamber, particularly if it is not in an insulated container, will not remain near its conditioned temperature for long. If the ammunition must be out of the conditioning chamber for any significant time, it should be kept in an insulated box, which has been conditioned to

temperature as well. This study did not include any investigation into how quickly a temperature-conditioned weapon changed temperature.

The time required to condition rounds to temperature is quite dependent on the packaging of the ammunition. In this test, single rounds and one loaded 30 round magazine were placed into a relatively large preconditioned temperature chamber. A short disturbance in the air temperature due to opening the door to insert the rounds was observed. This disturbance was on the order of 2.5 min and less than 10 °F for the heated conditioning chamber and less than 30 °F for the –55 °F tests. The single magazine took about 40 to 90 min to reach temperature depending on the chamber temperature. If more magazines were conditioned, particularly if they were stacked on each other or boxed, more time would be needed. Likewise, the power of the conditioning chamber will affect the time required to condition ammunition particularly when the ammunition's thermal mass is large relative to that of the conditioning chamber.

6. Conclusions

The mixed results of pressure and velocity data collected from the previous testing of temperature-conditioned ammunition were due to variations in the actual temperature of the cartridges as they were fired. These variations stemmed from the various procedures used but were primarily due to the use of temperature conditioned and non-temperature conditioned weapons to fire the conditioned ammunition. The data reported here show that the temperature of a 5.56mm cartridge left chambered in a barrel of a different temperature, for only a short time can change dramatically. It takes considerably longer to condition ammunition in a magazine as compared to loose rounds.

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