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CHANGE IN MUZZLE VELOCITY DUE TO A CHANGE IN PROPELLANT TEMPERATURE FOR SMALL ARMS AMMUNITION

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U.S. ARMY LABORATORY COMMAND

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The available muzzle velocity test data for small arms ammunition were analyzed to determine the change in muzzle velocity due to variations in propellant temperature. This change in muzzle velocity must be quantified in order to provide range safety data for the small arms weapon systems. This task was accomplished through the analysis of Ball and Improved Military Rifle (IMR) propellants.

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I. Introduction

Modifications to the firing tables for direct fire weapons are being developed to assist range safety officials in the determination of range safety limits for a variety of nonstandard conditions. Currently, firing tables only list the range/superelevation relationship achieved under standard conditions; therefore, a set of range correction values for nonstandard conditions are needed. These range correction values are provided for three nonstandard conditions which typically cause the largest effects, namely, changes in air density, range wind (head or tail) and muzzle velocity.

The change in muzzle velocity is the most difficult to obtain of the three nonstandard conditions included in the firing table modifications. The most obvious and significant contributor to the change in muzzle velocity is the change in propellant temperature. Therefore, an effort was undertaken to establish muzzle velocity variations for nonstandard propellant temperatures for direct fire weapon systems. For some ammunition types, muzzle velocity data as a function of propellant temperature were easily accessible. However, the data were not readily available for small arms ammunition. Therefore, an analysis of test results (muzzle velocities for different propellant temperatures) was conducted. Muzzle velocity data as a function of propellant temperature between -65° F and 160° F were obtained from several sources[1-5] and analyzed.

II. Results

The muzzle velocity data used in this analysis were gathered on a variety of small arms ammunition which use Ball and IMR type propellants. Table 1 is a listing of the specific small arms ammuniton presented in this report.

Table 1. Small Arms Ammunition Used in Data Analysis

Ammunition Type	Propellant Type
5.56mm NATO, M193	Ball
6mm Remington (Commercial)	Ball and IMR
7mm Remington Magnum (Commercial)	Ball and IMR
.308 Winchester (7.62mm NATO, Commercial)	Ball and IMR
.340 Weatherby Magnum (Commercial)	IMR
25mm, HEI-T, M792	Ball
30mm, HEDP, M789	Ball

A muzzle velocity propellant temperature factor, $\frac{MV}{MV_{STD}}$, was determined and plotted as a function of propellant temperature for the two propellant types (Ball and IMR)

where:

$$MV = muzzle\ velocity\ at\ a\ given\ propellant\ temperature$$

$$MV_{STD} = standard\ muzzle\ velocity\ at\ a\ propellant\ temperature\ of\ 70°F.$$

A least squares fit was then used to determine the muzzle velocity propellant temperature coefficient as a function of propellant temperature for each propellant type. Figures 1 and 2 graphically display the muzzle velocity data and the least squares fits for the Ball and IMR propellants, respectively. Since these fits proved to be very similar and their overall spread at each propellant temperature was similar, the muzzle velocity data for both the Ball and IMR propellants were combined and one muzzle velocity propellant temperature coefficient was determined. Figure 3 shows the combined muzzle velocity data and least squares fits for Ball and IMR propellants. The muzzle velocity propellant temperature coefficients were determined as follows:

$$\frac{MV}{MV_{STD}} = 1 + a(PT - 70°F) \tag{1}$$

or,

$$MV = [1 + a(PT - 70°F)] * MV_{STD} \tag{2}$$

where:

$$a = muzzle\ velocity\ propellant\ temperature\ coefficient,$$

$$PT = propellant\ temperature\ (°F)$$

and the change in muzzle velocity with respect to propellant temperature $\left(\frac{\delta MV}{\delta PT}\right)$ is

$$\frac{\delta MV}{\delta PT} = a\, MV_{STD} \tag{3}$$

As determined by the least squares fitting technique, the muzzle velocity propellant temperature coefficients (a), their standard deviations (σ_a) and the root mean square errors (ERMS) of the fits are provided in the following table. The fits match the observed data points with root means square errors of no more than 1.4 percent.

Table 2. Muzzle Velocity Temperature Coefficients

Propellant Type	a $(1/°F)$	σ_a $(1/°F)$	ERMS
Ball	.000408	.000010	.014
IMR	.000373	.000026	.011
Ball and IMR	.000405	.000010	.013

The original expectation was that projectiles fired with the Ball and IMR propellants would show a significantly different change in muzzle velocity due to propellant temperature. A statistical analysis of the fits to determine if they had the same slopes, indicated that there were significant differences between the two. However, the data base for the Ball propellant is much larger than that of the IMR propellant, with data located at the two extremes beyond the data available for the IMR propellant, affecting the outcome of such a comparison. Testing the means of the two propellants, where data existed for both propellant types, indicated that there is no significant differences between the mean values $(\frac{MV}{MV_{STD}})$ at those temperatures.

From a practical standpoint, one fit combining both propellant types would be more desirable. To determine if one fit would be adequate, a comparsion was made between the delta muzzle velocities obtained using the fits for the respective propellants and the combined fit for a small sample of projectiles using Ball and IMR propellants . That is, a comparison was made between the delta muzzle velocity obtained using the Ball propellant fit and the combined fit; and a comparison was made using the IMR propellant fit and the combined fit. Although the differences between the IMR fit and the combined fit were higher than that of the Ball fit and the combined fit, the differences are within one round-to-round standard deviation in muzzle velocity.

III. Conclusions

The muzzle velocity propellant temperature coefficients determined by the least squares fitting techniques and subsequent analysis indicated very similar trends for the Ball and IMR type propellants. Therefore, one muzzle velocity propellant temperature coefficient can be used to determine the change in muzzle velocity for nonstandard propellant temperatures for the small arms ammunition using the Ball and IMR type propellants.

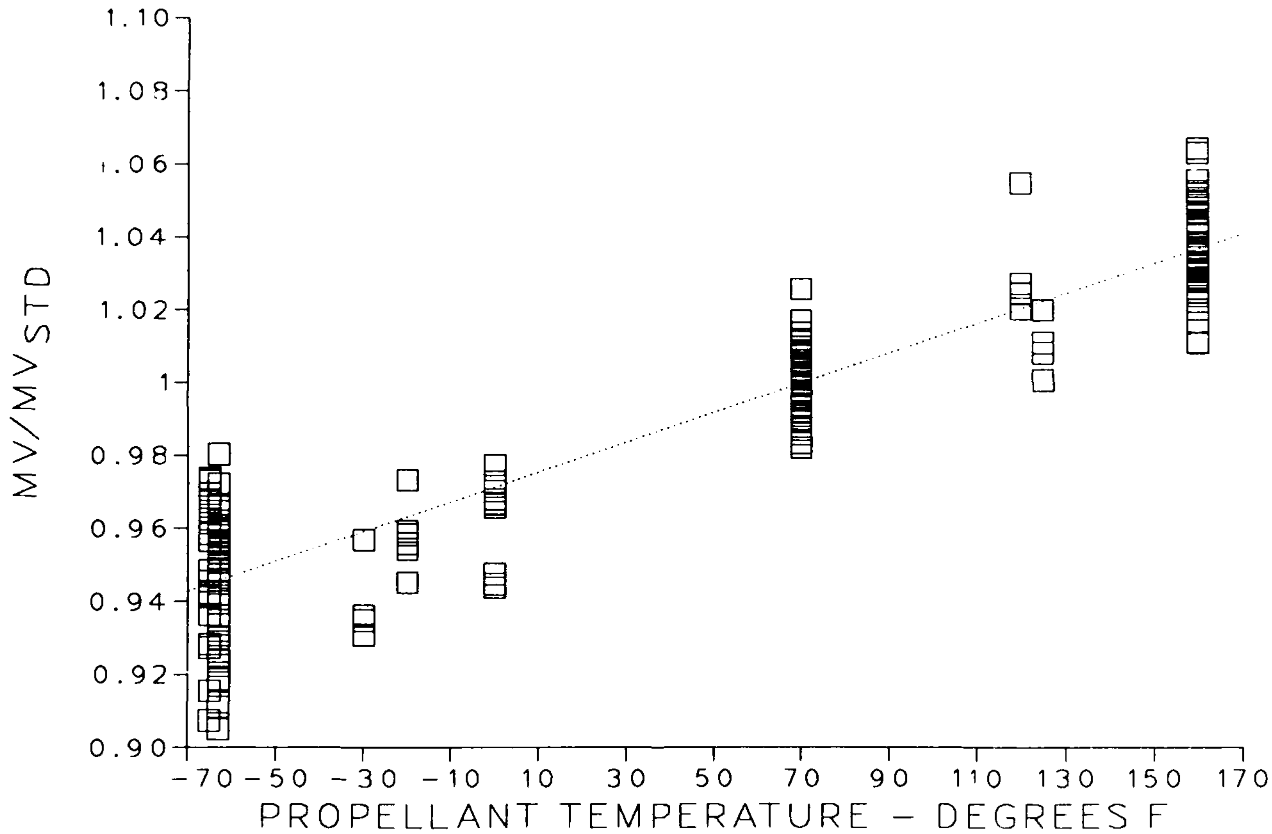

Figure 1. Muzzle velocity propellant temperature factor versus propellant temperature for Ball propellants.

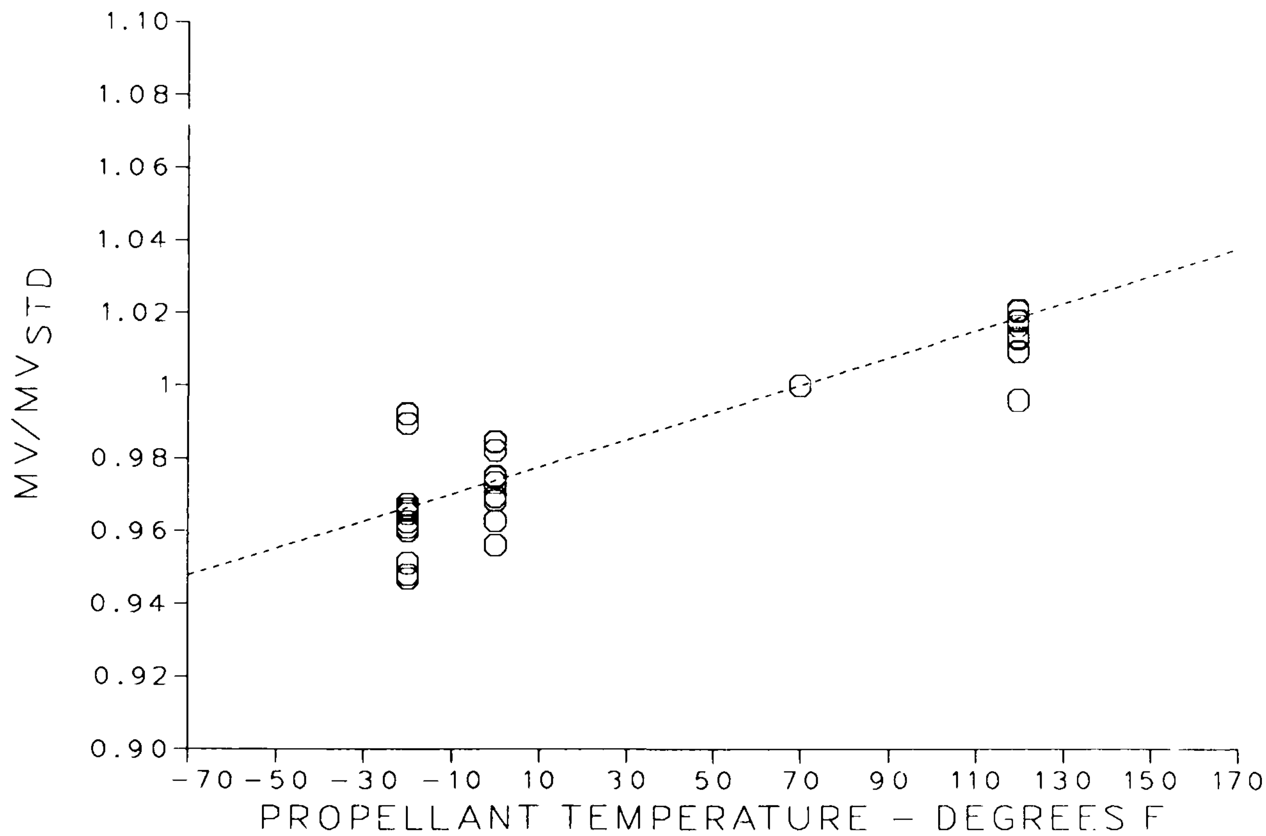

Figure 2. <u>Muzzle velocity propellant temperature factor versus propellant temperature for IMR propellants.</u>

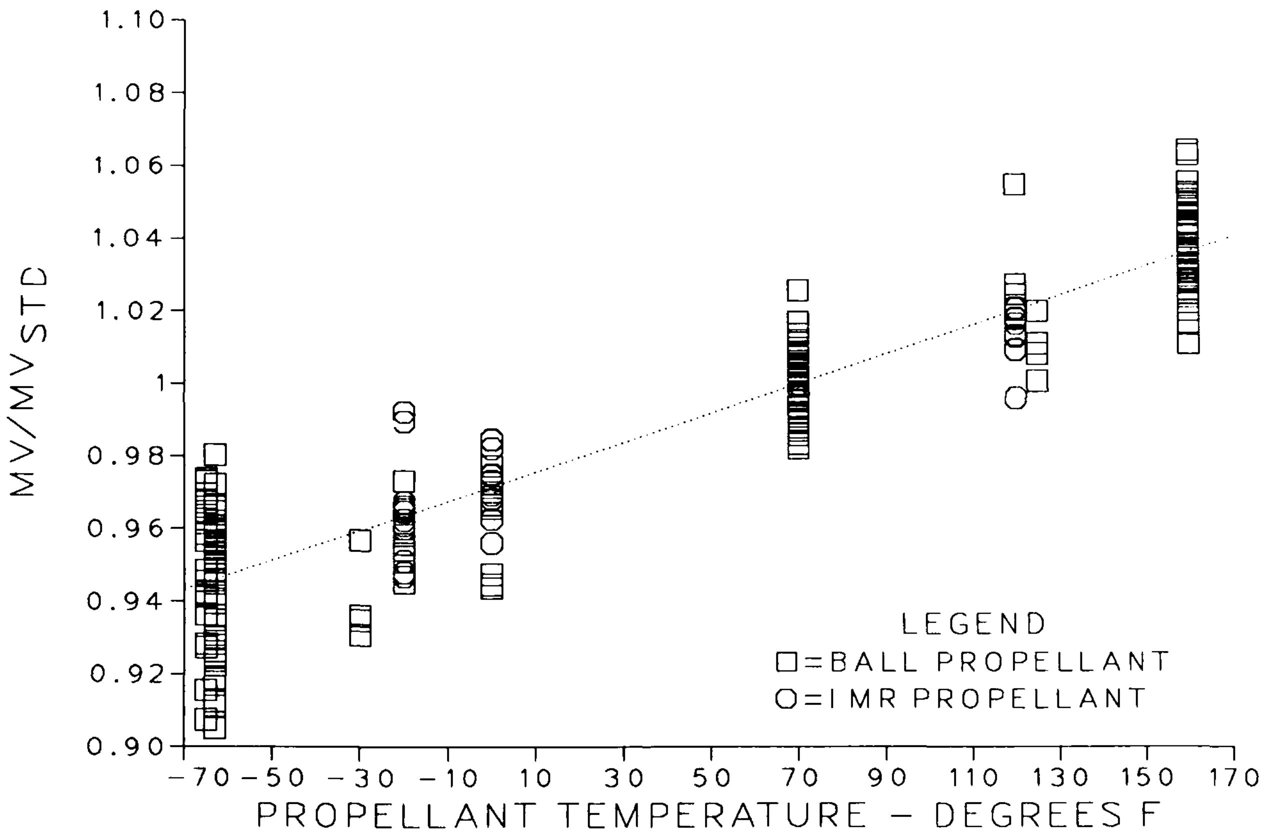

Figure 3. Muzzle velocity propellant temperature factor versus propellant temperature for Ball and IMR propellants.

References

1. Piddington, M.J., "Comparison of the Exterior Ballistics of the M193 Projectiles When Launched From 1:12 in. and 1:14 in Twist Rifles," BRL-MR-1943, US Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, October 1968 (AD 844934).

2. Hagel, B., "Game Loads and Practical Ballistics for the American Hunter," Alfred A. Knopp, Inc., New York.

3. Private communication between Mr. Charles Abel, US Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland and Mr. William Chase, US Army Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland in 1982 concerning Qualification Test of 30mm, M789, HEDP Ammunition at Yuma Proving Ground, Yuma, Arizona.

4. G. Steier, "First Partial Report Preproduction Test (PPT)of 25-MM, Ammunition, Second Source," Material Testing Directorate, Aberdeen Proving Ground, Maryland, APG -MT-5997 (VOLUME I), July 1984.

5. R.J. Carey, "Vol I Final Report Preproduction Test - Government (PPT-G) of 25-mm, M790 Series Ammunition, Third Source," Material Testing Directorate, Aberdeen Proving Ground, Maryland, APG -MT-5997 (VOLUME I), July 1984.

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List of Symbols

Symbol	Definition	Unit
a	Muzzle velocity propellant temperature coefficient	$1/^\circ F$
ΔMV	Change in muzzle velocity	m/s
MV	Muzzle velocity at a given propellant temperature	m/s
MV_{STD}	Standard muzzle velocity at a temperature of 70° F	m/s
$\frac{\delta MV}{\delta PT}$	Change in muzzle velocity with respect to propellant temperature	$m/s/^\circ$ F
PT	Propellant temperature	° F

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APPENDIX

APPLICATIONS

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APPENDIX. APPLICATIONS

The muzzle velocity for a given projectile is determined in the following manner:

Given:

Cartridge	30mm, HEDP, M789
MV_{STD}	805 m/s
Propellant temperature	160° F

From equation [3], Section II, the change in muzzle velocity with respect to propellant temperature $\left(\frac{\delta MV}{\delta PT}\right)$ is determined by:

$$\left(\frac{\delta MV}{\delta PT}\right) = a\,MV_{STD}$$

$$= 0.000405 * 805$$

$$= .326$$

therefore,

$$\Delta MV = .326 * (PT - 70°F)$$

$$= .326 * (160 - 70)$$

$$= +29.3\,m/s$$

where ΔMV is the change in muzzle velocity due to a propellant temperature of 160° F.

$$MV_{160°F} = 805 + 29.3$$

$$= 834.3\,m/s$$

Or, by substituting directly into equation [2], Section II:

$$MV_{160°F} = [1 + 0.000405 * (160 - 70)] * 805$$

$$= 834.3\, m/s$$

Muzzle velocity correction factors for various propellant temperatures are provided in Table A-1. These tabular values are obtained by solving equation [1] Section II, for the propellant temperature of interest. Using this table, muzzle velocity for a given cartridge can be determined as follows:

Given:

Cartridge	30mm, HEDP, M789
MV_{STD}	805 m/s
Propellant temperature	160° F

From Table 1, the muzzle velocity correction factor for a propellant temperature of 160° F is 1.0364, implying a 3.64% increase over the muzzle velocity at 70° F.

$$MV_{160°F} = 1.0364 * MV_{STD}$$

$$= 1.0364 * 805$$

$$= 834.3\, m/s$$

Table A-1. Ball and IMR Propellant Muzzle Velocity Correction Factors for Propellant Temperature

TEMPERATURE OF PROPELLANT ° F	MUZZLE VELOCITY CORRECTION FACTOR	TEMPERATURE OF PROPELLANT ° C
-70	.9433	-56.7
-60	.9474	-51.1
-50	.9514	-45.6
-40	.9554	-40.0
-30	.9595	-34.4
-20	.9636	-28.9
-10	.9676	-23.3
0	.9716	-17.8
10	.9757	-12.2
20	.9798	-6.7
30	.9838	-1.1
40	.9878	4.4
50	.9919	10.0
60	.9960	15.6
70	1.0000	21.1
80	1.0040	26.7
90	1.0081	32.2
100	1.0122	37.8
110	1.0162	43.3
120	1.0202	48.9
130	1.0243	54.4
140	1.0284	60.0
150	1.0324	65.6
160	1.0364	71.1
170	1.0405	76.7

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