Development of a Ballistic Specification for Magnesium Alloy AZ31B

by Tyrone L. Jones and Richard D. DeLorme
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Development of a Ballistic Specification for Magnesium Alloy AZ31B

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**14. ABSTRACT**
The U.S. Army Research Laboratory (ARL) and Magnesium Elektron North America (MENA) have conducted a joint effort to develop and evaluate rolled plate in commercially available magnesium alloy-temper AZ31B-H24. MENA produced the rolled product and conducted the mechanical analysis, while ARL performed the ballistic analysis. The magnesium alloy plates were parametrically compared with the minimum performance requirements of aluminum alloy 5083-H131 temper rolled plate using various armor-piercing and fragment-simulating projectiles (FSPs). The ballistic results and comparisons are presented herein. The yield strength of AZ31B-H24 is the dominant mechanical property that will improve the performance at increased weights.

**15. SUBJECT TERMS**
magnesium, aluminum, AZ31B, 5083, ballistic performance, military specification, protection

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The development of these aluminum alloy armor solutions were performed with assistance from the following technicians: Donnie Little, Vaughn Torbert, and Shawn Thomas for the testing of these plates against armor-piercing projectiles and fragment-simulating projectiles.
1. Background

The U.S. Army is interested in providing greater ballistic protection at lower weight; thus, magnesium-based alloys are currently of interest because the density of magnesium (~1.77 g/cm³) is ~35% lower than aluminum (~2.68 g/cm³) and ~77% lower than steel (I).

In general, there is a positive correlation between tensile strength and small arms ballistic performance in metal alloys. Although the tensile strength of rolled magnesium alloys is traditionally lower than that of rolled aluminum armor alloys, magnesium may possess other unique characteristics, including superior vibration damping and differences in failure mechanisms, that could provide for improved relative ballistic performance (2).

The data generated in this manuscript will be used to develop the ballistic specification for magnesium alloy AZ31B.

2. Chemical Composition

The chemical composition limits of magnesium alloy AZ31B are listed in table 1, as specified by the commercial material specification AMS-4377H (3). The chemical composition limits of aluminum alloy 5083 are listed in table 2 per military material specification MIL-DTL-46027K (MR) (4).

Table 1. Magnesium alloy AZ31B chemical composition limits (weight-percent).

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<th></th>
<th>Al</th>
<th>Zn</th>
<th>Mn</th>
<th>Si</th>
<th>Cu</th>
<th>Ca</th>
<th>Fe</th>
<th>Ni</th>
<th>Others Each</th>
<th>Others Total</th>
<th>Mg</th>
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<tr>
<td>Max.</td>
<td>3.5</td>
<td>1.3</td>
<td>—</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.005</td>
<td>0.005</td>
<td>0.10</td>
<td>0.30</td>
<td>Balance</td>
</tr>
<tr>
<td>Min.</td>
<td>2.5</td>
<td>0.7</td>
<td>0.20</td>
<td>—</td>
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Table 2. Aluminum alloy 5083 chemical composition limits (weight-percent).

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<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
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<th>Ti</th>
<th>Others Each</th>
<th>Others Total</th>
<th>Al</th>
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<tbody>
<tr>
<td>Max.</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>1.2</td>
<td>4.9</td>
<td>0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
<td>Balance</td>
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<tr>
<td>Min.</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.40</td>
<td>4.0</td>
<td>0.05</td>
<td>—</td>
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3. Mechanical Properties

Magnesium Elektron North America provided typical tensile properties of rolled AZ31B-H24 magnesium plate and rolled 5083-H131 aluminum alloy plate. These mechanical properties were accumulated in a database of rolled plate produced at its Madison, IL, facility over a 7-year period. All plates were manufactured in accordance with ASTM-B90 (5) and/or AMS-4377 (AZ31B-H24) and MIL-A/DTL-46027K (5083-H131) (6). This historical data is presented in tabular format in tables 3 and 4 and in graphical format in figures 1–3.

Table 3. Typical Mg AZ31B-H24 plate tensile properties.

<table>
<thead>
<tr>
<th>Thickness Range</th>
<th>Ultimate Tensile Strength (ksi)</th>
<th>Tensile Yield Strength (ksi)</th>
<th>Elongation (%)</th>
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</thead>
<tbody>
<tr>
<td>0.376–0.500</td>
<td>39.2</td>
<td>25.6</td>
<td>14.4</td>
</tr>
<tr>
<td>0.501–0.750</td>
<td>38.6</td>
<td>24.4</td>
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<tr>
<td>0.751–1.000</td>
<td>38.4</td>
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<tr>
<td>1.001–1.500</td>
<td>38.2</td>
<td>24.3</td>
<td>12.5</td>
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<tr>
<td>1.501–2.500</td>
<td>38.3</td>
<td>24.6</td>
<td>11.9</td>
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<tr>
<td>2.501–3.500</td>
<td>37.9</td>
<td>24.0</td>
<td>11.1</td>
</tr>
</tbody>
</table>

Table 4. Typical Al 5083-H131 plate tensile properties.

<table>
<thead>
<tr>
<th>Thickness Range</th>
<th>Ultimate Tensile Strength (ksi)</th>
<th>Tensile Yield Strength (ksi)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.376–0.500</td>
<td>50.4</td>
<td>42.5</td>
<td>13.4</td>
</tr>
<tr>
<td>0.501–0.750</td>
<td>51.2</td>
<td>42.6</td>
<td>12.7</td>
</tr>
<tr>
<td>0.751–1.000</td>
<td>51.5</td>
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<td>1.001–1.500</td>
<td>50.9</td>
<td>43.9</td>
<td>10.1</td>
</tr>
<tr>
<td>1.501–2.500</td>
<td>50.2</td>
<td>42.5</td>
<td>10.9</td>
</tr>
<tr>
<td>2.501–3.500</td>
<td>48.1</td>
<td>39.1</td>
<td>13.8</td>
</tr>
</tbody>
</table>

While the AZ31B-H24 and 5083-H131 exhibit similar ductility (% elongation), the 5083-H131 is superior in ultimate tensile strength (UTS) by 10–12 ksi (69–83 MPa) and in tensile yield strength (TYS) by 15–19 ksi (103–131 MPa). However, as shown in tables 5 and 6 and in figures 4 and 5, the specific strength of AZ31B-H24 is superior to 5083-H131 in specific UTS and approaching 5083-H131 in specific TYS. Then, based on the positive general correlation between tensile properties and ballistic performance, one might predict a similar relationship in terminal ballistic performance between rolled AZ31B-H24 plate and rolled 5083-H131 plate. Clearly, the relatively lower specific TYS may reduce fragment-simulating projectile (FSP) performance.
Figure 1. UTS – AZ31B-H24 vs. 5083-H131.

Figure 2. TYS – AZ31B-H24 vs. 5083-H131.

Figure 3. Percent elongation – AZ31B-H24 vs. 5083-H131.
Table 5. Typical Mg AZ31B-H24 plate specific strength.

<table>
<thead>
<tr>
<th>Thickness Range</th>
<th>Specific Ultimate Tensile Strength (ksi·cu in/lb)</th>
<th>Specific Tensile Yield Strength (ksi·cu in/lb)</th>
</tr>
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<tbody>
<tr>
<td>0.376–0.500</td>
<td>613</td>
<td>399</td>
</tr>
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<td>0.501–0.750</td>
<td>602</td>
<td>380</td>
</tr>
<tr>
<td>0.751–1.000</td>
<td>600</td>
<td>375</td>
</tr>
<tr>
<td>1.001–1.500</td>
<td>597</td>
<td>380</td>
</tr>
<tr>
<td>1.501–2.500</td>
<td>598</td>
<td>384</td>
</tr>
<tr>
<td>2.501–3.500</td>
<td>592</td>
<td>375</td>
</tr>
</tbody>
</table>

Table 6. Typical Al 5083-H131 plate specific strength.

<table>
<thead>
<tr>
<th>Thickness Range</th>
<th>Specific Ultimate Tensile Strength (ksi·cu in/lb)</th>
<th>Specific Tensile Yield Strength (ksi·cu in/lb)</th>
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</thead>
<tbody>
<tr>
<td>0.376–0.500</td>
<td>520</td>
<td>438</td>
</tr>
<tr>
<td>0.501–0.750</td>
<td>528</td>
<td>439</td>
</tr>
<tr>
<td>0.751–1.000</td>
<td>530</td>
<td>463</td>
</tr>
<tr>
<td>1.001–1.500</td>
<td>524</td>
<td>452</td>
</tr>
<tr>
<td>1.501–2.500</td>
<td>517</td>
<td>438</td>
</tr>
<tr>
<td>2.501–3.500</td>
<td>495</td>
<td>403</td>
</tr>
</tbody>
</table>

Figure 4. Specific UTS – AZ31B-H24 vs. 5083-H131.
4. Terminal Ballistic Evaluation

Ballistic testing of all rolled AZ31B-H24 magnesium plate samples was performed by the U.S. Army Research Laboratory (ARL) at Aberdeen Proving Ground, MD, in accordance with MIL-STD-662F (7). Ballistic results were characterized using the standard V₅₀ test methodology, also documented in MIL-STD-662F. The ballistic projectiles were selected for each nominal plate thickness as specified by the 5083-H131 armor material specification MIL-DTL-46027K (MR). The specific projectiles used to evaluate the magnesium alloy plates were the 0.30-cal. APM2 and the 0.50-cal. APM2, depicted in figure 6, and 0.50-cal. and 20-mm FSP, depicted in figure 7. The APM2 projectiles used were standard production, while the FSPs used were produced in accordance with MIL-DTL-46593B (MR) (8).

5. Experimental Results

The rolled plate of AZ31B-H24 and 5083-H131 was evaluated on an equivalent weight (i.e., areal density) basis. The AZ31B-H24 ballistic results vs. areal density are displayed in figures 8–11, and the same results vs. plate thickness are displayed in figures 12–15. See appendices A–C for AZ31B-H24 plate post-ballistic pictures and data at various thicknesses. The 5083-H131 data points in these figures are the minimum ballistic limit requirements per military material specification MIL-DTL-46027K (MR).
Figure 6. Diagrams of 0.30-cal. APM2 projectile (upper) and 0.50-cal. APM2 projectile (lower).

d = 0.50-cal FSP  Mass = 13.4 g,  Steel, R_c = 29-3

d = 20mm FSP  Mass = 53.8 g,  Steel, R_c = 29-31

Figure 7. Diagram of 0.50-cal. FSP and 20-mm FSP.
Figure 8. A 0.30-cal. APM2 performance comparison by areal density.

Figure 9. A 0.50-cal. APM2 performance comparison by areal density.
Figure 10. A 0.50-cal. FSP performance comparison by areal density.

Figure 11. A 20-mm FSP performance comparison by areal density.
Figure 12. A 0.30-cal. APM2 performance comparison by plate thickness.

Figure 13. A 0.50-cal. APM2 performance comparison by plate thickness.
Figure 14. A 0.50-cal. FSP performance comparison by plate thickness.

Figure 15. A 20-mm FSP performance comparison by plate thickness.
6. Discussion and Conclusion

On an equivalent weight basis, AZ31B-H24 plate performed just above (against the 0.30 cal.) or just below (against the 0.50 cal.) the 5083-H131 APM2 minimum ballistic performance limits, while its performance against the specified FSP was thickness-dependent (i.e., the lower thickness plate passed handily while the thicker plate fell short of the minimum requirements). These results indicate that rolled AZ31B-H24 magnesium plate may be an effective substitution for 5083-H131 against armor-piercing projectiles on an equivalent weight basis. Of course, weight-neutral AZ31B-H24 plate would be 50% thicker than the 5083-H131 it might replace, which would require consideration during the design of any armor system.

On a plate-thickness basis, the V50 AZ31B-H24 fell ~300 fps lower than the 5083-H131 minima against the armor-piercing projectiles and fell ~1000 fps short against the FSPs. This would indicate that the relatively lower TYS of AZ31B-H24 plate as compared to 5083-H131 plate might play a role in predicting the difference in terminal ballistic resistance between the materials compared. Therefore, further development of higher strength wrought magnesium alloys might reduce or close the performance gap between magnesium alloy and aluminum alloy plates.

An AZ31B-H24 armor material specification guide is expected to be completed in the near future. This guide will serve as a baseline for any future developments of magnesium alloys for armor.
7. References


3. AMS 4377H. Magnesium Alloy, Sheet and Plate 3.0Al - 1.0Zn - 020Mn (AZ31B-H24) Cold Rolled, Partially Annealed; Society of Automotive Engineers International: Warrendale, PA, 1 September 2005.


8. MIL-DTL-46593B (MR). *Projectile, Calibers 0.22, 0.30, 0.50, and 20 MM Fragment-Simulating* 2006.
Appendix A. Post-Ballistic Pictures
Figure A-1. The 1-in AZ31B-H24.
Figure A-2. The 1.5-in AZ31B-H24.
Figure A-3. The 2.0-in AZ31B-H24.
Figure A-4. The 2.5-in AZ31B-H24.
Figure A-5. The 3.0-in AZ31B-H24: 0.50-cal. APM2 impacts.
Figure A-6. The 3.5- and 4.0-in AZ31B-H24: 0.50-cal. APM2 impacts.
Appendix B. Fragment-Simulating Projectile (FSP) Data for Post-Ballistic Pictures*

List of Definitions and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>CP</td>
<td>Complete penetration; penetrator/target material exits rear surface of target.</td>
</tr>
<tr>
<td>PIP</td>
<td>Penetrator in plate; penetrator lodged in impact crater.</td>
</tr>
<tr>
<td>Pitch</td>
<td>Attitude of projectile in the vertical direction.</td>
</tr>
<tr>
<td>PP</td>
<td>Partial penetration; the penetrator is defeated by the target.</td>
</tr>
<tr>
<td>Plug</td>
<td>Target material ejected off rear of the plate.</td>
</tr>
<tr>
<td>Result</td>
<td>Result of shot; CP or PP.</td>
</tr>
<tr>
<td>Striking Velocity</td>
<td>Velocity of the projectile just before it impacts the target.</td>
</tr>
<tr>
<td>TP</td>
<td>Tip protruding out the back of the target.</td>
</tr>
<tr>
<td>Yaw</td>
<td>Attitude of projectile in the horizontal direction.</td>
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*The charts in this appendix appear in their original form, without editorial change.
Target: Magnesium AZ31B-H24
Plate #: --
Lot#: --
Thickness: 25.019mm 0.985"

Hardness: 57 BHN on 500kg scale
Obliquity: 0°
Projectile: .50 cal FSP

Setup: Mg-Air(6")-AL 2024(0.020")

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<td>518</td>
<td>--</td>
<td>--</td>
<td>CP</td>
<td>Yes</td>
<td>--</td>
<td>5084</td>
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</table>
Target: Magnesium AZ31B-H24 9-May-06
Plate #: --  EF108
Lot#: --
Thickness: 38.735mm 1.525 "

Hardness: 61 BHN on 500kg scale
Obliquity: 0°
Projectile: .50 cal FSP

Setup: Mg-Air(6")-AL 2024(0.020")

<table>
<thead>
<tr>
<th>V50: 742 m/s</th>
<th># shots: 6</th>
<th>Std Dev: 9 m/s</th>
<th>Spread: 27 m/s</th>
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<p>| Striking Pitch Yaw Result Used Comments Shot |
|----------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Velocity (m/s)</th>
<th>(deg)</th>
<th>(deg)</th>
<th>(PP/CP)</th>
<th>for V50</th>
<th>#</th>
</tr>
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<tbody>
<tr>
<td>630</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>No</td>
<td>--</td>
</tr>
<tr>
<td>729</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>No</td>
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<td>762</td>
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<tr>
<td>720</td>
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<td>745</td>
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Target: Magnesium AZ31B-H24 4-Jun-07
Plate #: ASTM B90-98 EF108
Lot#: --
Thickness: 38.74mm 1.525 "

Hardness: 61 BHN on 500kg scale
Obliquity: 0°
Projectile: 20mm FSP

Setup: Mg-Air(6")-AL 2024(0.020")

<table>
<thead>
<tr>
<th>Striking Velocity (m/s)</th>
<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
<th>Result</th>
<th>Used for V50</th>
<th>Comments</th>
<th>Shot</th>
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<tr>
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<td>485</td>
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<td>472</td>
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<td>476</td>
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<td>476</td>
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<td>--</td>
<td>CP</td>
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<td>--</td>
<td>5167</td>
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V50: 477 m/s shots: 4
Std Dev: 6 m/s Spread: 13 m/s
ZMR: 0

# shots: 4

Std Dev: 6 m/s Spread: 13 m/s
Target: Magnesium AZ31B-H24  5-Jun-07
Plate #: ASTM B90-98  EF108
Lot#:  --
Thickness: 49.73mm  1.958 "

Hardness: 55 BHN on 500kg scale
Obliquity: 0°
Projectile: 20mm FSP

Setup: Mg-Air(6")-AL 2024(0.020")

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<th># shots:</th>
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<td>Spread:</td>
<td>15 m/s</td>
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<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
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<th>Used for V50</th>
<th>Comments</th>
<th>Shot #</th>
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<tr>
<td>540</td>
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<td>--</td>
<td>PP</td>
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<td>5176</td>
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<tr>
<td>549</td>
<td>--</td>
<td>--</td>
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<td>5177</td>
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<tr>
<td><strong>585</strong></td>
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<td><strong>5178</strong></td>
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<td>--</td>
<td>5179</td>
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<td><strong>574</strong></td>
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<td><strong>5181</strong></td>
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<td>--</td>
<td><strong>5182</strong></td>
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<td>PP</td>
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<td><strong>570</strong></td>
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<td>--</td>
<td>CP</td>
<td>Yes</td>
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<td><strong>5185</strong></td>
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Target: Magnetesium AZ31B-H24  11-Jun-07  
Plate #: ASTM B90-98  EF108  
Lot#:  
Thickness: 63.119mm  2.485 "  

Hardness: 61 BHN on 500kg scale  
Obliquity: 0°  
Projectile: 20mm FSP  
Setup: Mg-Air(6")-AL2024(0.020")  

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<table>
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<th>Velocity (m/s)</th>
<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
<th>Result (PP/CP)</th>
<th>Shot #</th>
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</thead>
<tbody>
<tr>
<td>834 -- -- CP No -- 5186</td>
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<td>--</td>
<td>--</td>
<td>CP</td>
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<td>816 -- -- CP No -- 5187</td>
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<td>CP</td>
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<td>806 -- -- CP No -- 5188</td>
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<td>--</td>
<td>CP</td>
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</tr>
<tr>
<td>768 -- -- CP No -- 5189</td>
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<td>--</td>
<td>CP</td>
<td>No</td>
</tr>
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<td>714 -- -- PP No -- 5190</td>
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<td>--</td>
<td>PP</td>
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</tr>
<tr>
<td>731 -- -- CP Yes -- 5191</td>
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<td>--</td>
<td>CP</td>
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<td>723 -- -- PP No -- 5192</td>
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<td>--</td>
<td>PP</td>
<td>No</td>
</tr>
<tr>
<td>734 -- -- PP Yes -- 5193</td>
<td>734</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>Yes</td>
</tr>
<tr>
<td>733 -- -- PP Yes -- 5194</td>
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<td>--</td>
<td>--</td>
<td>PP</td>
<td>Yes</td>
</tr>
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<td>740 -- -- CP Yes -- 5195</td>
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<td>CP</td>
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Appendix C. APM2 Projectile Data for Post-Ballistic Pictures*

List of Definitions and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>Complete penetration; penetrator/target material exits rear surface of target.</td>
</tr>
<tr>
<td>PIP</td>
<td>Penetrator in plate; penetrator lodged in impact crater.</td>
</tr>
<tr>
<td>Pitch</td>
<td>Attitude of projectile in the vertical direction.</td>
</tr>
<tr>
<td>PP</td>
<td>Partial penetration; the penetrator is defeated by the target.</td>
</tr>
<tr>
<td>Plug</td>
<td>Target material ejected off rear of the plate.</td>
</tr>
<tr>
<td>Result</td>
<td>Result of shot; CP or PP.</td>
</tr>
<tr>
<td>Striking Velocity</td>
<td>Velocity of the projectile just before it impacts the target.</td>
</tr>
<tr>
<td>TP</td>
<td>Tip protruding out the back of the target.</td>
</tr>
<tr>
<td>Yaw</td>
<td>Attitude of projectile in the horizontal direction.</td>
</tr>
</tbody>
</table>

*The charts in this appendix appear in their original form, without editorial change.
Target: Magnesium AZ31B-H24  20-Apr-06
Plate #: --  EF106
Lot#: --
Thickness: 38.74mm  1.525 "

Hardness: 61 BHN on 500kg scale
Obliquity: 0°
Projectile: .30 cal APM2

Setup: Mg-Air(6")-AL 2024(0.020")

<table>
<thead>
<tr>
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<th>shots:</th>
<th># shots</th>
</tr>
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<tbody>
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<td>579</td>
<td>4</td>
<td></td>
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<table>
<thead>
<tr>
<th>Std Dev: (m/s)</th>
<th>Spread: (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>11</td>
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</table>

ZMR: 0

<table>
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<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
<th>Result</th>
<th>Used for V50</th>
<th>Comments</th>
<th>Shot #</th>
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<tbody>
<tr>
<td>584</td>
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<td>--</td>
<td>CP</td>
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<td>--</td>
<td>5561</td>
</tr>
<tr>
<td>543</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>No medium bulge</td>
<td>5562</td>
<td></td>
</tr>
<tr>
<td>550</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>No medium bulge with crack</td>
<td>5563</td>
<td></td>
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<tr>
<td>564</td>
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<td>--</td>
<td>PP</td>
<td>No large bulge with cracks: PIP, TP</td>
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<td></td>
</tr>
<tr>
<td>574</td>
<td>--</td>
<td>--</td>
<td>PP</td>
<td>Yes PIP, TP</td>
<td>5565</td>
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<td>584</td>
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<td>--</td>
<td>CP</td>
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<td>5566</td>
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<td>--</td>
<td>PP</td>
<td>Yes PP, TP</td>
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</table>
Target: Magnesium AZ31B-H24  
Plate #: --  
Lot#: --  
Thickness: 49.73mm 1.958 "

Hardness: 61 BHN on 500kg scale
Obliquity: 0°
Projectile: .30 cal APM2

Setup: Mg-Air(6")-AL 2024(0.020")

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<th>Striking Velocity (m/s)</th>
<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
<th>Result</th>
<th>Used for V50</th>
<th>Comments</th>
<th>Shot</th>
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<td>--</td>
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<td>698</td>
<td>--</td>
<td>--</td>
<td>CP</td>
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<td>--</td>
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<td>658</td>
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<td>PIP, TP</td>
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<td>684</td>
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<td>Yes</td>
<td>Hole in target; dent in witness</td>
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Target: Magnesium AZ31B-H24  25-Apr-06
Plate #: --  EF106
Lot#: --
Thickness: 63.5mm  2.485 "

Hardness: 61 BHN on 500kg scale
Obliquity: 0°
Projectile: .30 cal APM2

Setup: Mg-Air(6")-AL 2024(0.020")

<table>
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<th>Pitch (deg)</th>
<th>Yaw (deg)</th>
<th>Result (PP/CP)</th>
<th>Used for V50</th>
<th>Comments</th>
<th>Shot #</th>
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V50: 787 m/s
Std Dev: 7 m/s
ZMR: 3

# shots: 4
Spread: 15 m/s
Std Dev: 7 m/s
ZMR: 3
Target: Magnesium AZ31B-H24 3-Apr-06  
Plate #: -- EF108  
Lot#: --  
Thickness: 76.48mm 3.011"  

Hardness: 61 BHN on 500kg scale  
Obliquity: 0°  
Projectile: .50 cal AP M2  

Setup: Mg-Air(6")-AL 2024(0.020")

<table>
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<tr>
<th>Striking Velocity (m/s)</th>
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<th>Yaw (deg)</th>
<th>Result</th>
<th>Used for V50</th>
<th>Comments</th>
<th>Shot #</th>
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Target: Magnesium AZ31B-H24  
Plate #: --  
Lot#: --  
Thickness: 88.93mm 3.501"  

Hardness: 55 BHN on 500kg scale  
Obliquity: 0°  
Projectile: .50 cal AP M2  

Setup: Mg-Air(6")-AL 2024(0.020")

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V50: 688 m/s  
Std Dev: 9 m/s  
Spread: 25 m/s  

# shots: 6  
ZMR: 0  

2-Apr-07  
EF108  

Target: Magnesium AZ31B-H24  2-Apr-07  
Plate #: --  EF108  
Lot#: --  
Thickness: 102.03mm  4.017 "  

Hardness: 55 BHN on 500kg scale  
Obliquity: 0°  
Projectile: .50 cal AP M2  

Setup: Mg-Air(6")-AL 2024(0.020")

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