



Development of a Ballistic Specification for Magnesium Alloy AZ31B

by Tyrone L. Jones and Richard D. DeLorme

ARL-TR-4664

December 2008

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5069

ARL-TR-4664**December 2008**

Development of a Ballistic Specification for Magnesium Alloy AZ31B

Tyrone L. Jones

Weapons and Materials Research Directorate, ARL

Richard D. DeLorme

Magnesium Elektron North America, Inc.

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE		3. DATES COVERED (From - To)	
December 2008		Final		June 2007–July 2008	
4. TITLE AND SUBTITLE Development of a Ballistic Specification for Magnesium Alloy AZ31B				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Tyrone L. Jones and Richard D. DeLorme*				5d. PROJECT NUMBER	
				1L162618AH80	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: AMSRD-ARL-WM-TA Aberdeen Proving Ground, MD 21005-5069				8. PERFORMING ORGANIZATION REPORT NUMBER ARL-TR-4664	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES *Magnesium Elektron North America, Inc., 1001 College St., Madison, IL 62060					
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					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Tyrone L. Jones
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL	52	19b. TELEPHONE NUMBER (Include area code) 410-278-6223

Contents

List of Figures	iv
List of Tables	v
Acknowledgments	vi
1. Background	1
2. Chemical Composition	1
3. Mechanical Properties	2
4. Terminal Ballistic Evaluation	5
5. Experimental Results	5
6. Discussion and Conclusion	11
7. References	12
Appendix A. Post-Ballistic Pictures	13
Appendix B. Fragment-Simulating Projectile (FSP) Data for Post-Ballistic Pictures	21
Appendix C. APM2 Projectile Data for Post-Ballistic Pictures	27
Distribution List	34

List of Figures

Figure 1. UTS – AZ31B-H24 vs. 5083-H131.....	3
Figure 2. TYS – AZ31B-H24 vs. 5083-H131.....	3
Figure 3. Percent elongation – AZ31B-H24 vs. 5083-H131.	3
Figure 4. Specific UTS – AZ31B-H24 vs. 5083-H131.	4
Figure 5. Specific TYS – AZ31B-H24 vs. 5083-H131.	5
Figure 6. Diagrams of 0.30-cal. APM2 projectile (upper) and 0.50-cal. APM2 projectile (lower).....	6
Figure 7. Diagram of 0.50-cal. FSP and 20-mm FSP.	6
Figure 8. A 0.30-cal. APM2 performance comparison by areal density.	7
Figure 9. A 0.50-cal. APM2 performance comparison by areal density.	7
Figure 10. A 0.50-cal. FSP performance comparison by areal density.	8
Figure 11. A 20-mm FSP performance comparison by areal density.....	8
Figure 12. A 0.30-cal. APM2 performance comparison by plate thickness.	9
Figure 13. A 0.50-cal. APM2 performance comparison by plate thickness.	9
Figure 14. A 0.50-cal. FSP performance comparison by plate thickness.	10
Figure 15. A 20-mm FSP performance comparison by plate thickness.	10
Figure A-1. The 1-in AZ31B-H24.	14
Figure A-2. The 1.5-in AZ31B-H24.	15
Figure A-3. The 2.0-in AZ31B-H24.	16
Figure A-4. The 2.5-in AZ31B-H24.	17
Figure A-5. The 3.0-in AZ31B-H24: 0.50-cal. APM2 impacts.....	18
Figure A-6. The 3.5- and 4.0-in AZ31B-H24: 0.50-cal. APM2 impacts.....	19

List of Tables

Table 1. Magnesium alloy AZ31B chemical composition limits (weight-percent).....	1
Table 2. Aluminum alloy 5083 chemical composition limits (weight-percent).	1
Table 3. Typical Mg AZ31B-H24 plate tensile properties.	2
Table 4. Typical Al 5083-H131 plate tensile properties.	2
Table 5. Typical Mg AZ31B-H24 plate specific strength.	4
Table 6. Typical Al 5083-H131 plate specific strength.	4

Acknowledgments

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 ($\sim 1.77 \text{ g/cm}^3$) is $\sim 35\%$ lower than aluminum ($\sim 2.68 \text{ g/cm}^3$) and $\sim 77\%$ lower than steel (1).

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).

	Al	Zn	Mn	Si	Cu	Ca	Fe	Ni	Others Each	Others Total	Mg
Max.	3.5	1.3	—	0.05	0.05	0.04	0.005	0.005	0.10	0.30	Balance
Min.	2.5	0.7	0.20	—	—	—	—	—	—	—	

Table 2. Aluminum alloy 5083 chemical composition limits (weight-percent).

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others Each	Others Total	Al
Max.	0.40	0.40	0.10	1.2	4.9	0.25	0.25	0.15	0.05	0.15	Balance
Min.	—	—	—	0.40	4.0	0.05	—	—	—	—	

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.

Thickness Range	Ultimate Tensile Strength (ksi)	Tensile Yield Strength (ksi)	Elongation (%)
0.376–0.500	39.2	25.6	14.4
0.501–0.750	38.6	24.4	13.5
0.751–1.000	38.4	24.0	13.1
1.001–1.500	38.2	24.3	12.5
1.501–2.500	38.3	24.6	11.9
2.501–3.500	37.9	24.0	11.1

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

Thickness Range	Ultimate Tensile Strength (ksi)	Tensile Yield Strength (ksi)	Elongation (%)
0.376–0.500	50.4	42.5	13.4
0.501–0.750	51.2	42.6	12.7
0.751–1.000	51.5	45.0	10.1
1.001–1.500	50.9	43.9	10.1
1.501–2.500	50.2	42.5	10.9
2.501–3.500	48.1	39.1	13.8

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.

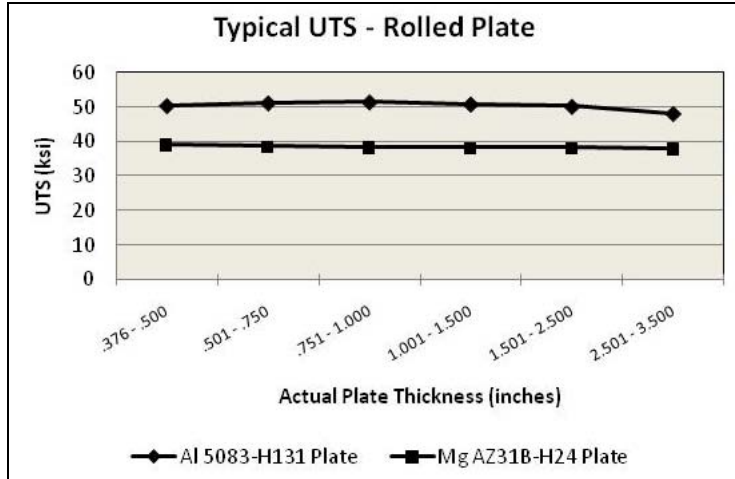


Figure 1. UTS – AZ31B-H24 vs. 5083-H131.

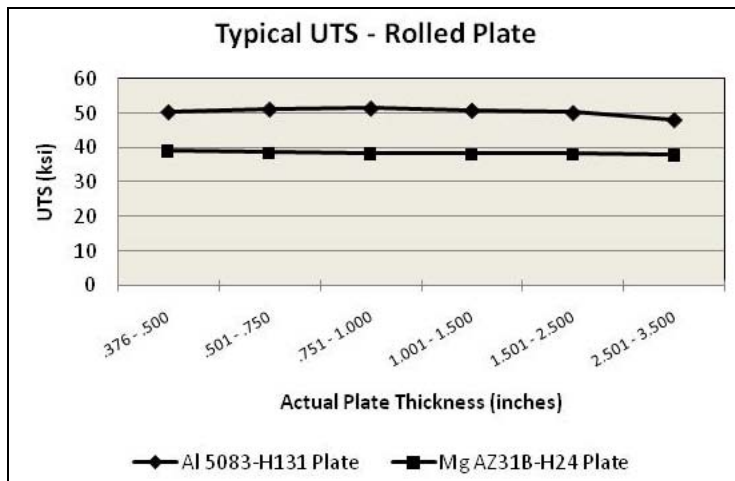


Figure 2. TYS – AZ31B-H24 vs. 5083-H131.

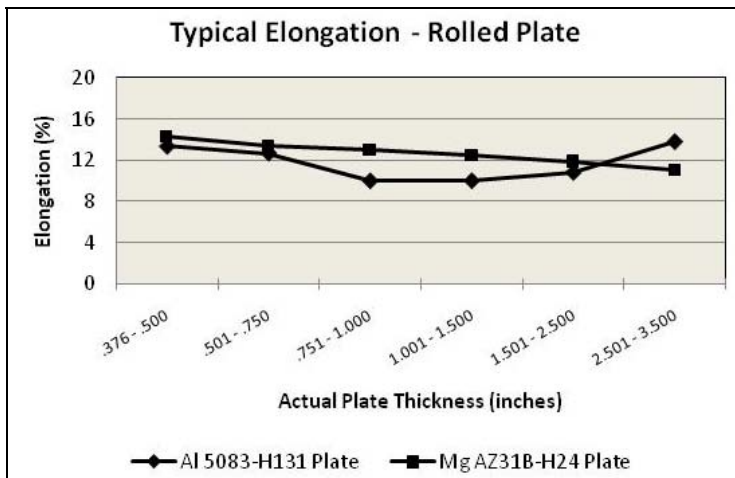


Figure 3. Percent elongation – AZ31B-H24 vs. 5083-H131.

Table 5. Typical Mg AZ31B-H24 plate specific strength.

Thickness Range	Specific Ultimate Tensile Strength (ksi-cu in/lb)	Specific Tensile Yield Strength (ksi-cu in/lb)
0.376–0.500	613	399
0.501–0.750	602	380
0.751–1.000	600	375
1.001–1.500	597	380
1.501–2.500	598	384
2.501–3.500	592	375

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

Thickness Range	Specific Ultimate Tensile Strength (ksi-cu in/lb)	Specific Tensile Yield Strength (ksi-cu in/lb)
0.376–0.500	520	438
0.501–0.750	528	439
0.751–1.000	530	463
1.001–1.500	524	452
1.501–2.500	517	438
2.501–3.500	495	403

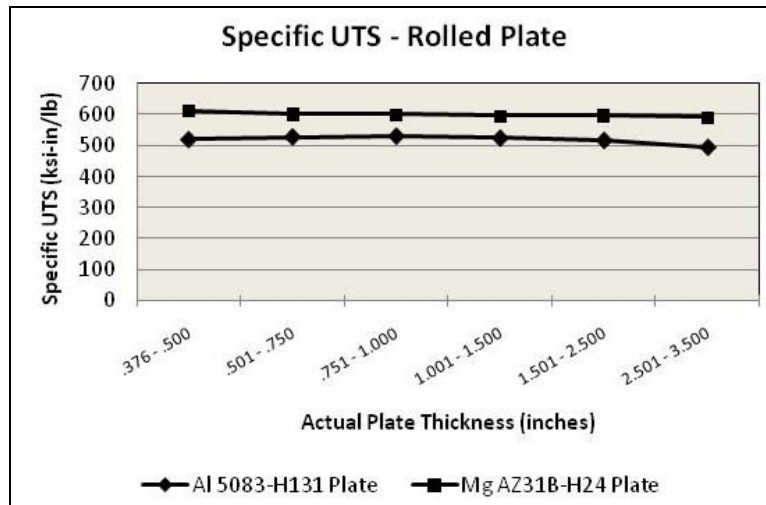


Figure 4. Specific UTS – AZ31B-H24 vs. 5083-H131.

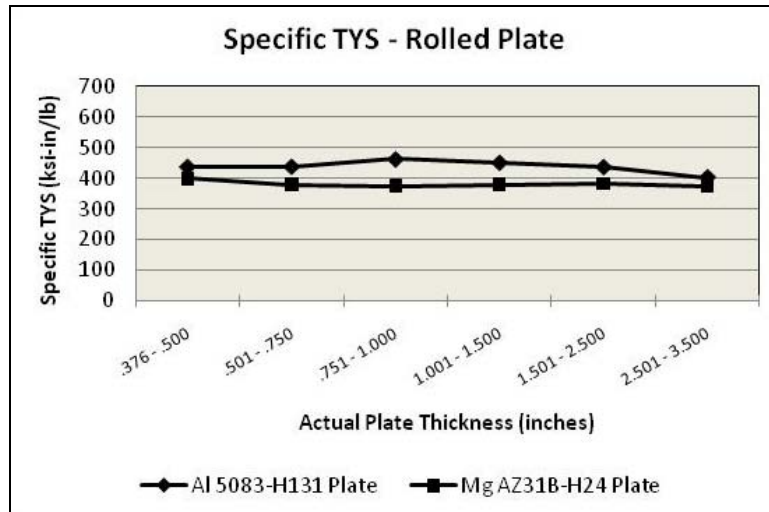


Figure 5. Specific TYS – AZ31B-H24 vs. 5083-H131.

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 V_{50} 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).

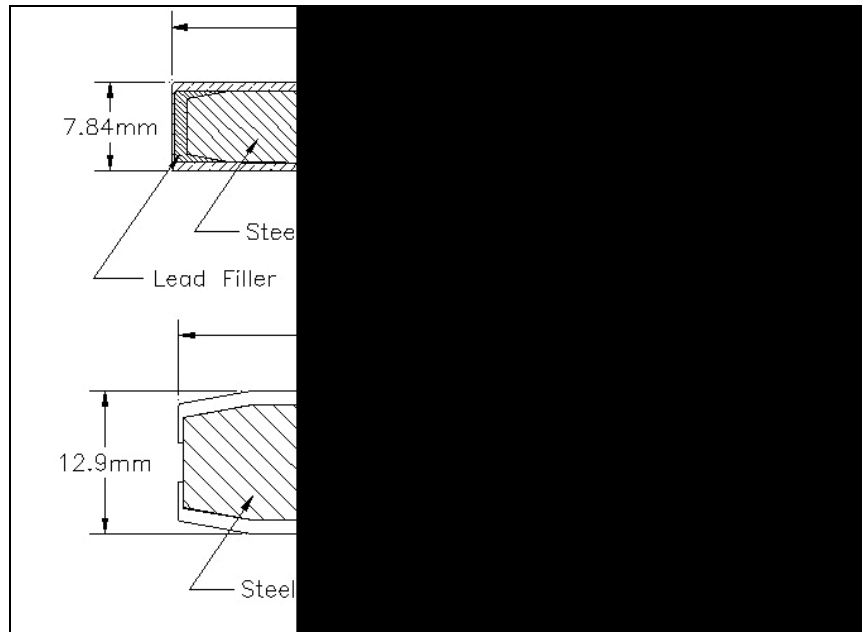


Figure 6. Diagrams of 0.30-cal. APM2 projectile (upper) and 0.50-cal. APM2 projectile (lower).

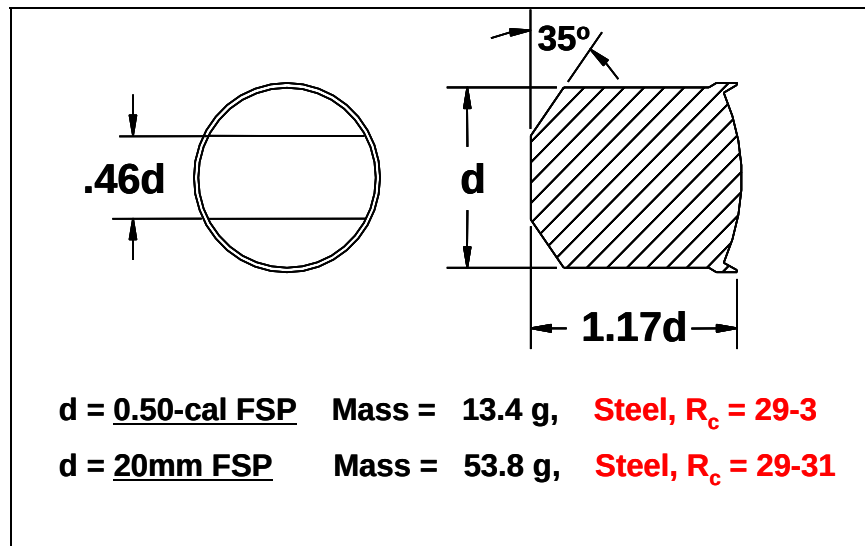


Figure 7. Diagram of 0.50-cal. FSP and 20-mm FSP.

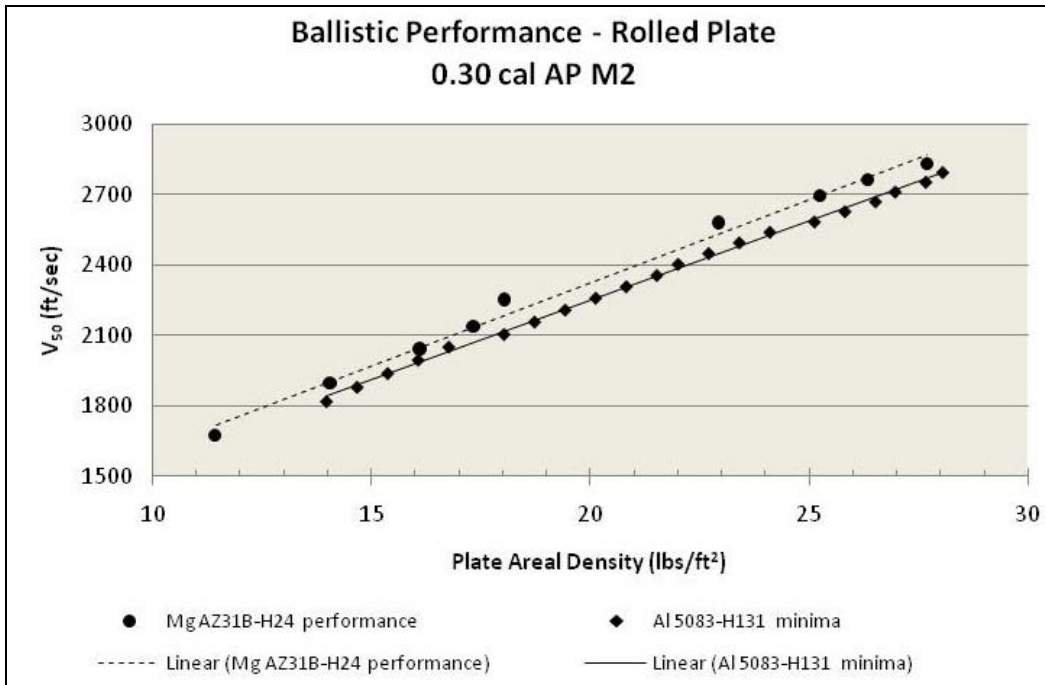


Figure 8. A 0.30-cal. APM2 performance comparison by areal density.

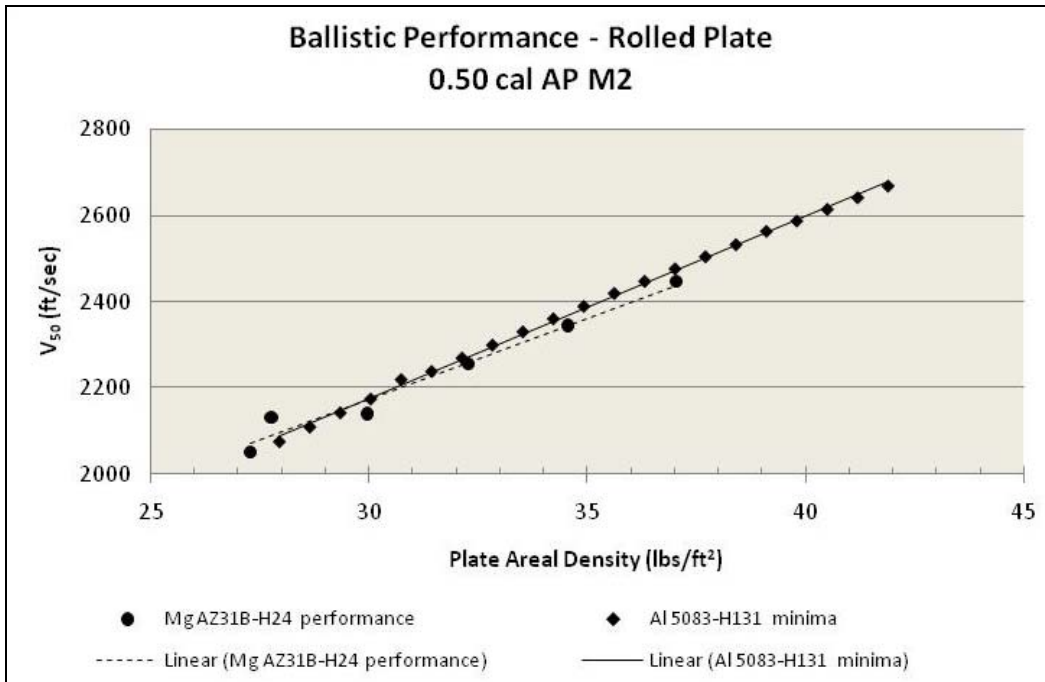


Figure 9. A 0.50-cal. APM2 performance comparison by areal density.

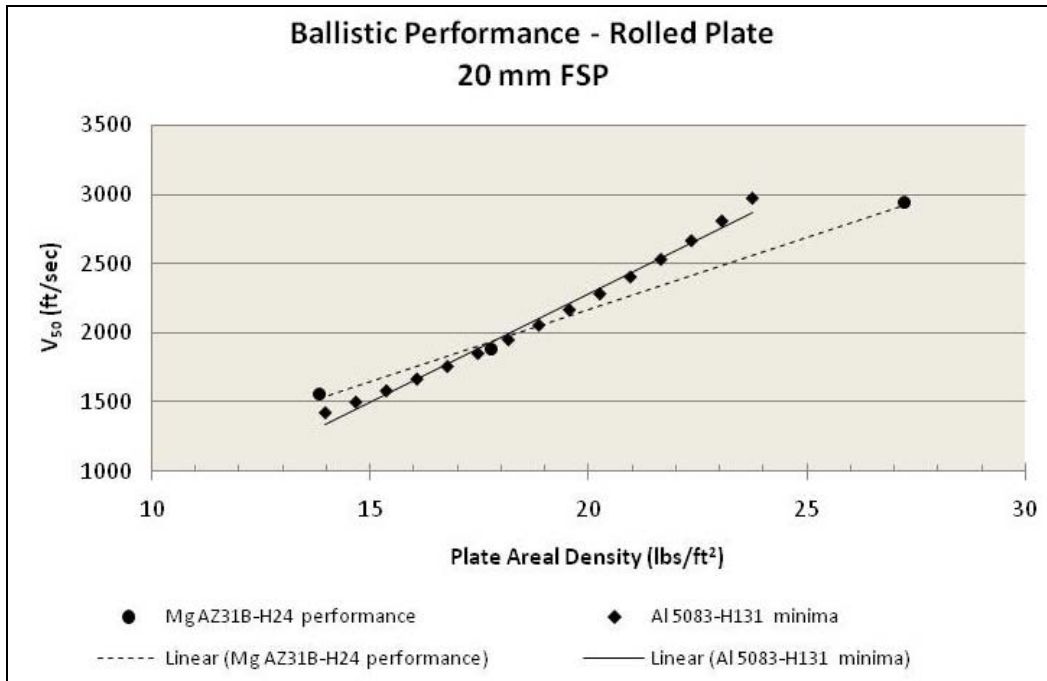


Figure 10. A 0.50-cal. FSP performance comparison by areal density.

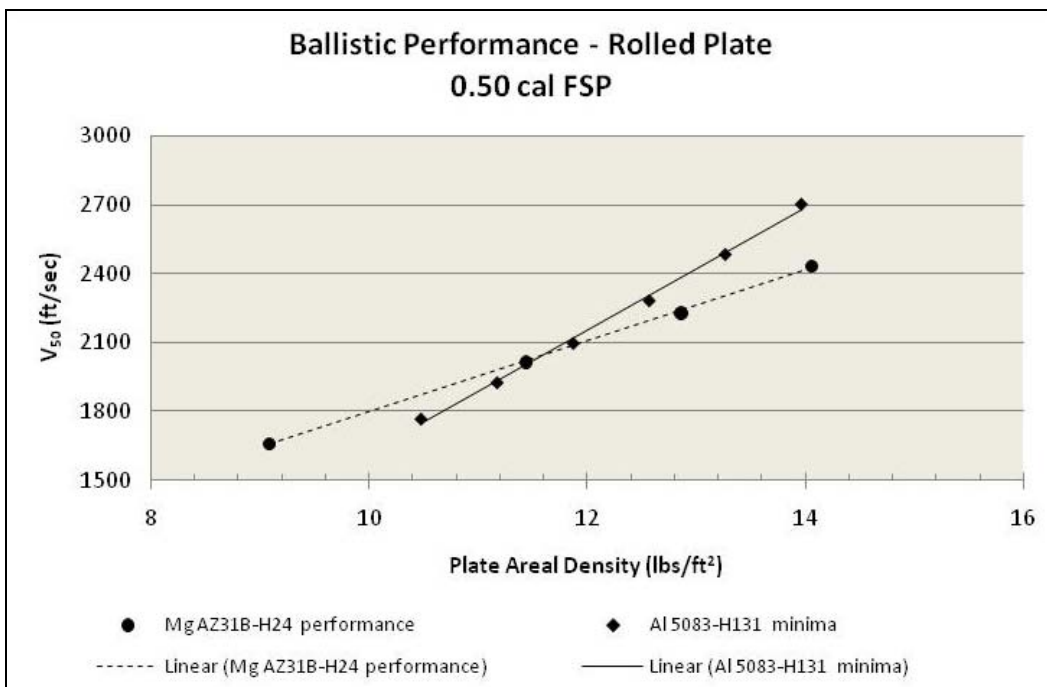


Figure 11. A 20-mm FSP performance comparison by areal density.

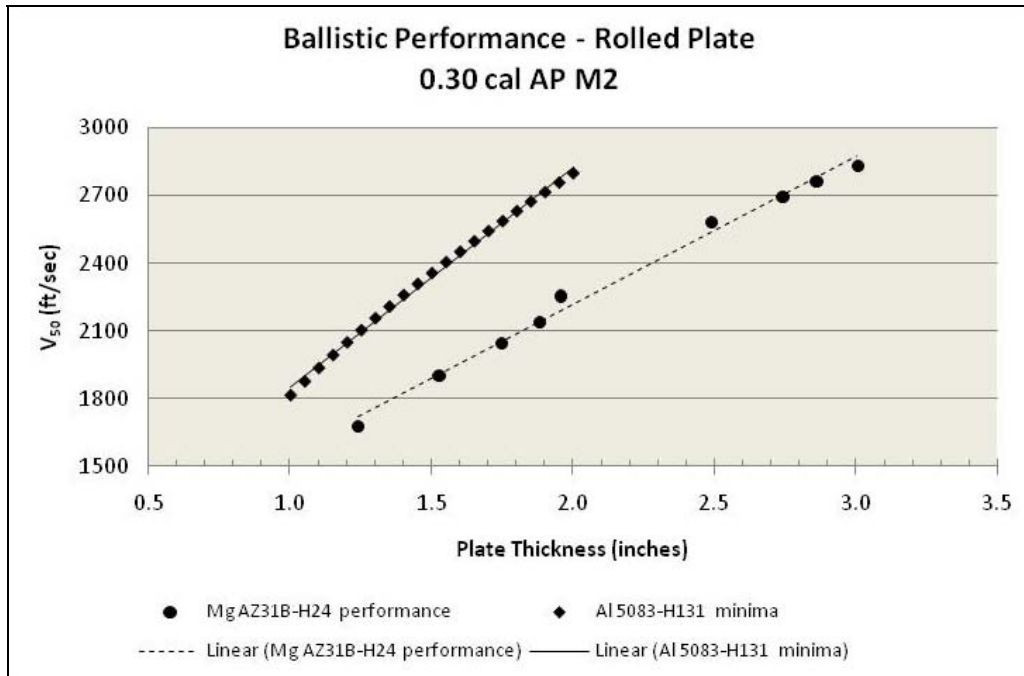


Figure 12. A 0.30-cal. APM2 performance comparison by plate thickness.

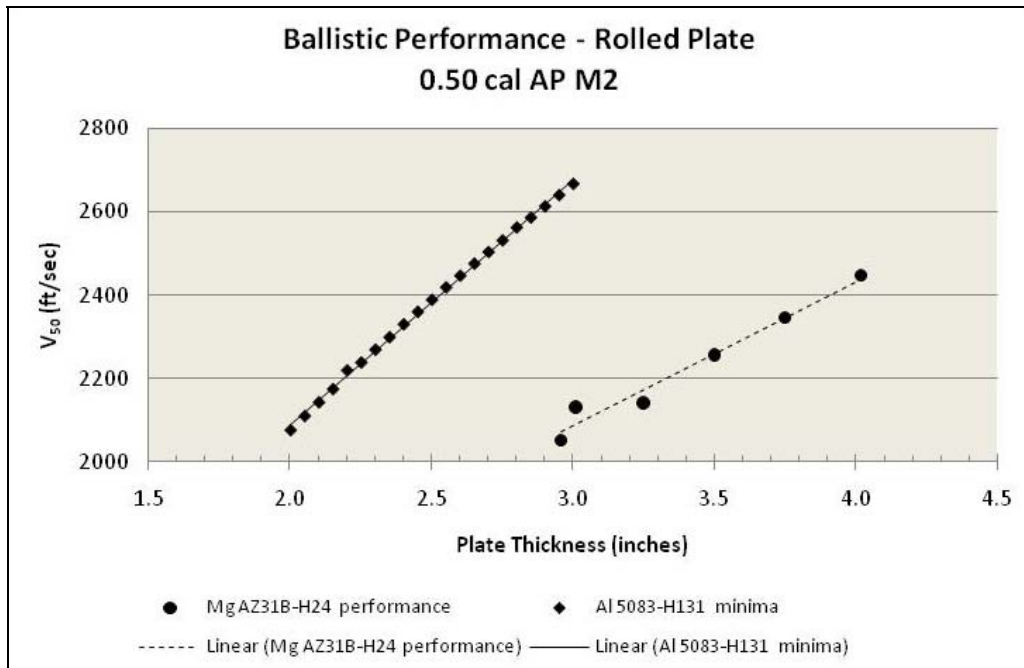


Figure 13. A 0.50-cal. APM2 performance comparison by plate thickness.

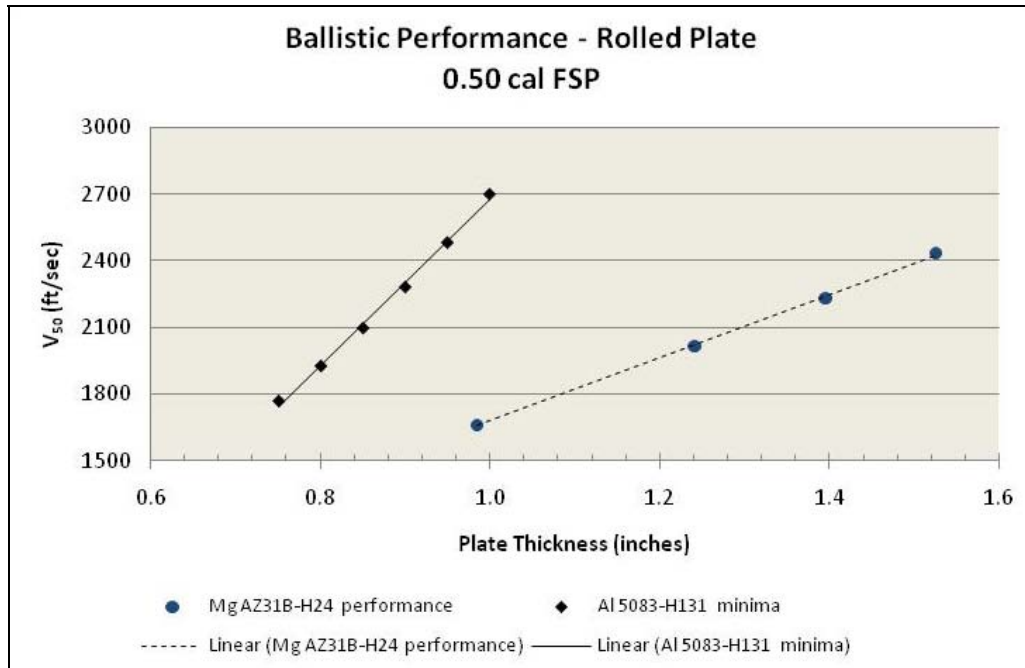


Figure 14. A 0.50-cal. FSP performance comparison by plate thickness.

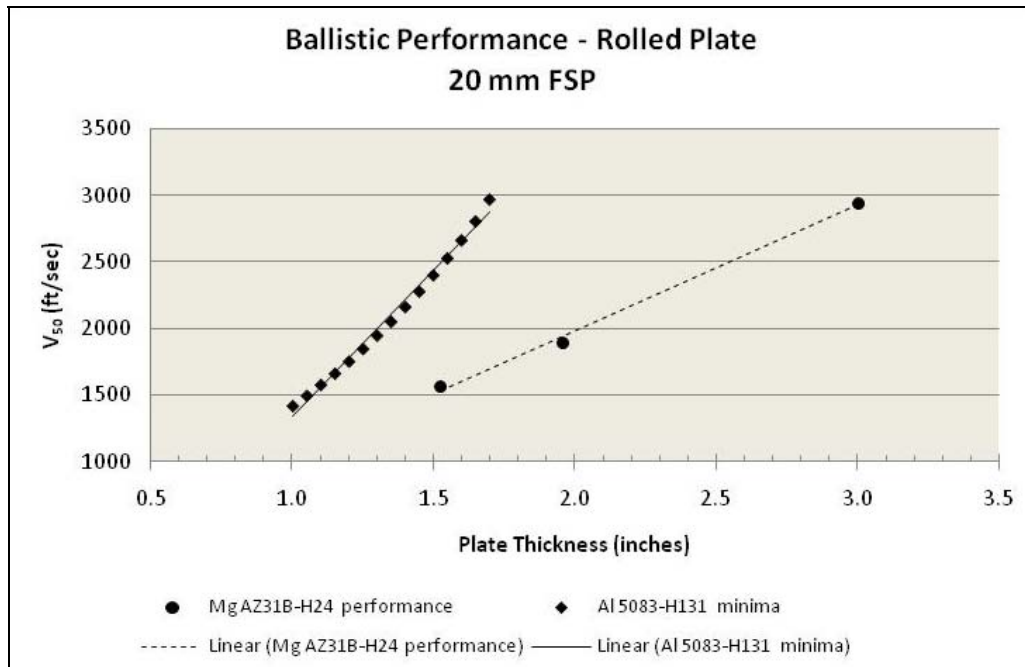


Figure 15. A 20-mm FSP performance comparison by plate thickness.

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 V_{50} 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

1. Jones, T. L.; DeLorme, R. D.; Burkins, M. S.; Gooch, W. A. *Ballistic Evaluation of Magnesium Alloy AZ31B*; ARL-TR-4077; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, April 2007.
2. Jones, T. L.; DeLorme, R. D.; Burkins, M. S.; Gooch, W. A. Ballistic Performance of the Magnesium Alloy AZ31B. *Proceedings of the 23rd International Symposium on Ballistics*, Tarragona, Spain, 16–20 April 2007.
3. AMS 4377H. Magnesium Alloy, Sheet and Plate 3.0Al - 1.0Zn - 0.20Mn (AZ31B-H24) Cold Rolled, Partially Annealed; Society of Automotive Engineers International: Warrendale, PA, 1 September 2005.
4. MIL-DTL-46027K (MR). *Armor Plate, Aluminum Alloys. Weldable 5083 and 5456* **1998**.
5. ASTM B90/B90M-07. Standard Specification for Magnesium-Alloy Sheet and Plate; American Society for Testing and Materials. *Annu. Book ASTM Stand.* **2007**.
6. Magnesium Elektron North America, Inc. Tensile Properties Lot Acceptance Database for 5083-H131 plate and AZ31B-H24 plate, 1999–2006.
7. MIL-STD-662F. *V50 Ballistic Test for Armor* **1997**.
8. MIL-DTL-46593B (MR). *Projectile, Calibers 0.22, 0.30, 0.50, and 20 MM Fragment-Simulating* **2006**.

Appendix A. Post-Ballistic Pictures

Front



Back



Figure A-1. The 1-in AZ31B-H24.

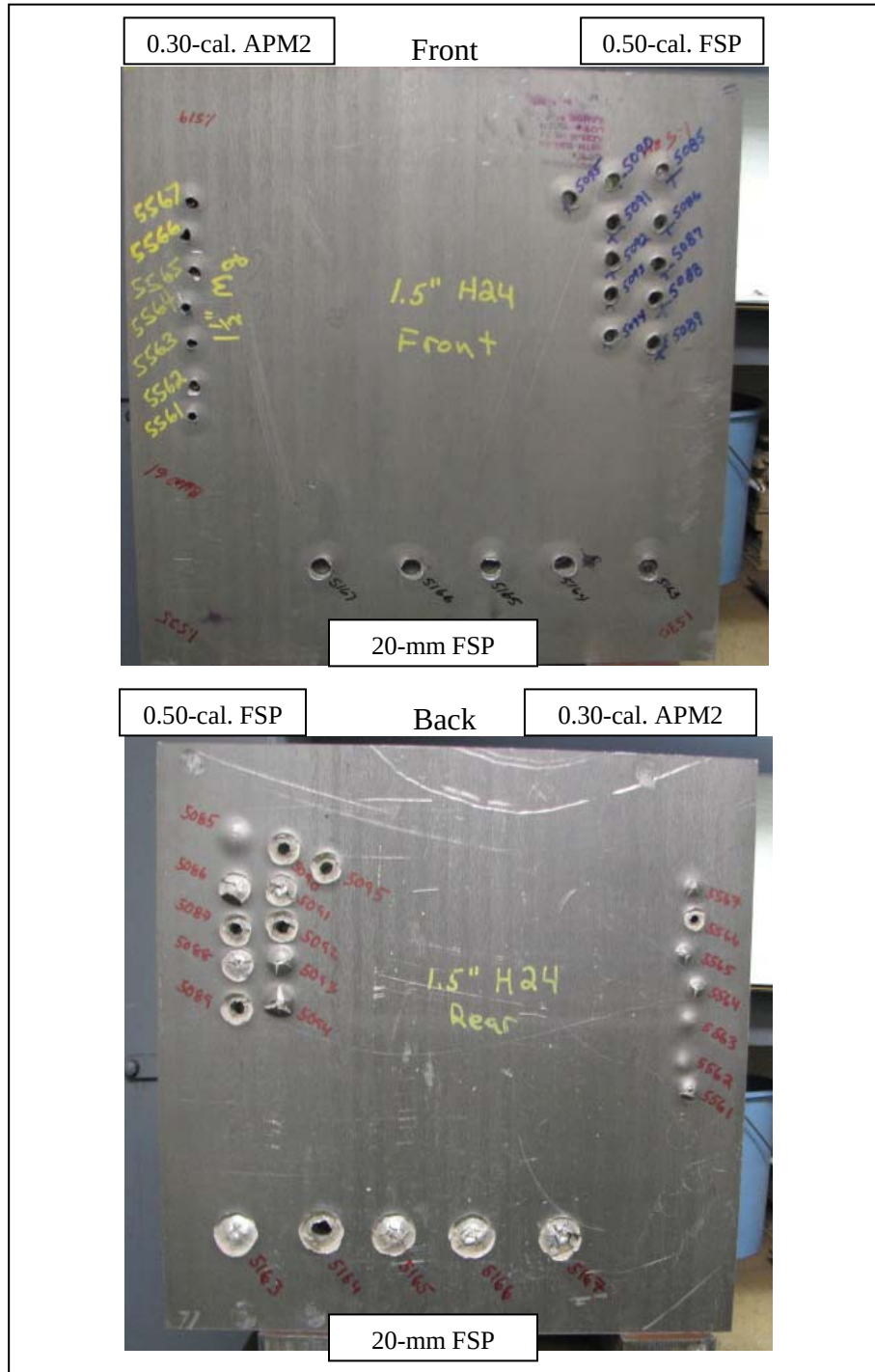


Figure A-2. The 1.5-in AZ31B-H24.

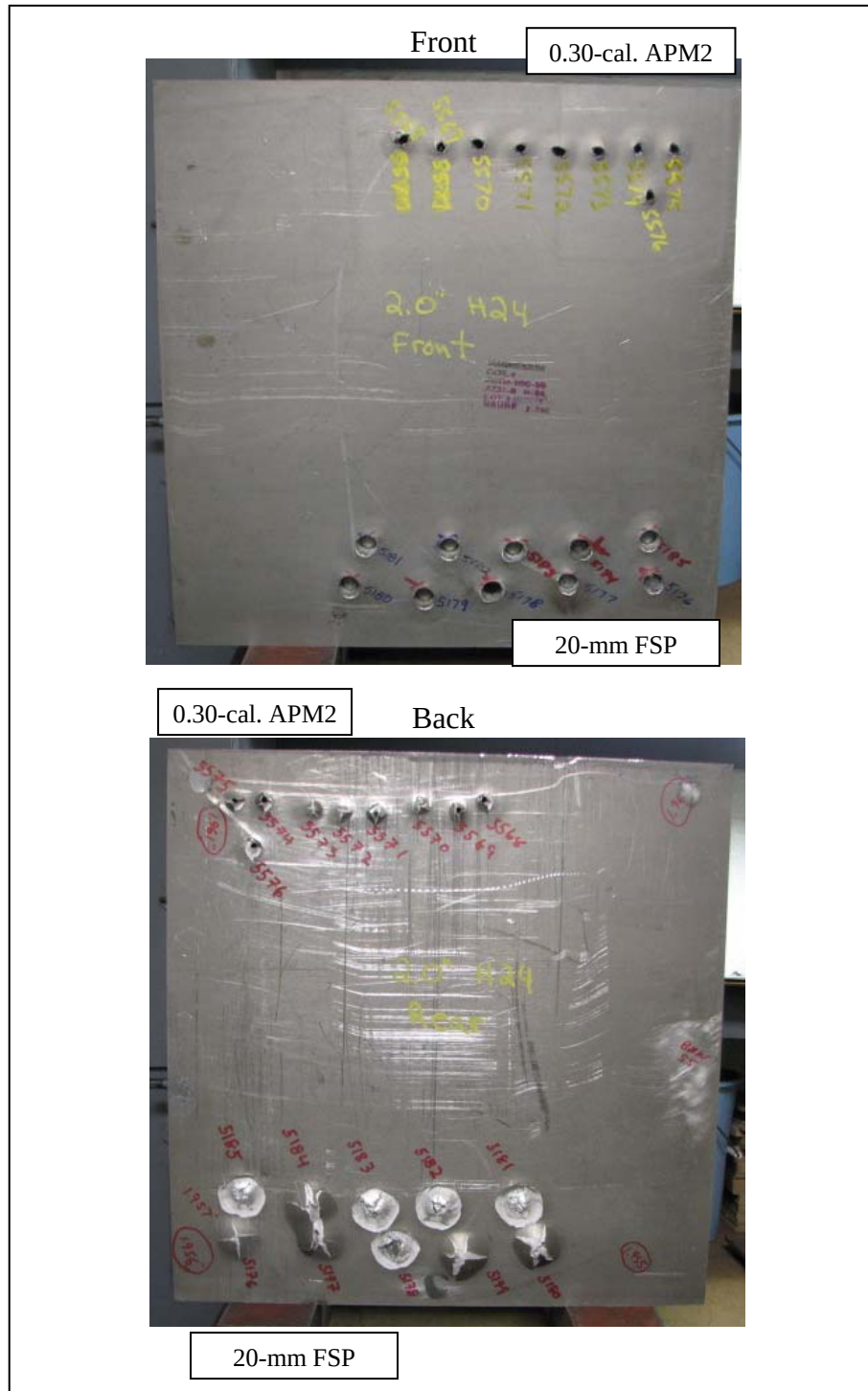


Figure A-3. The 2.0-in AZ31B-H24.

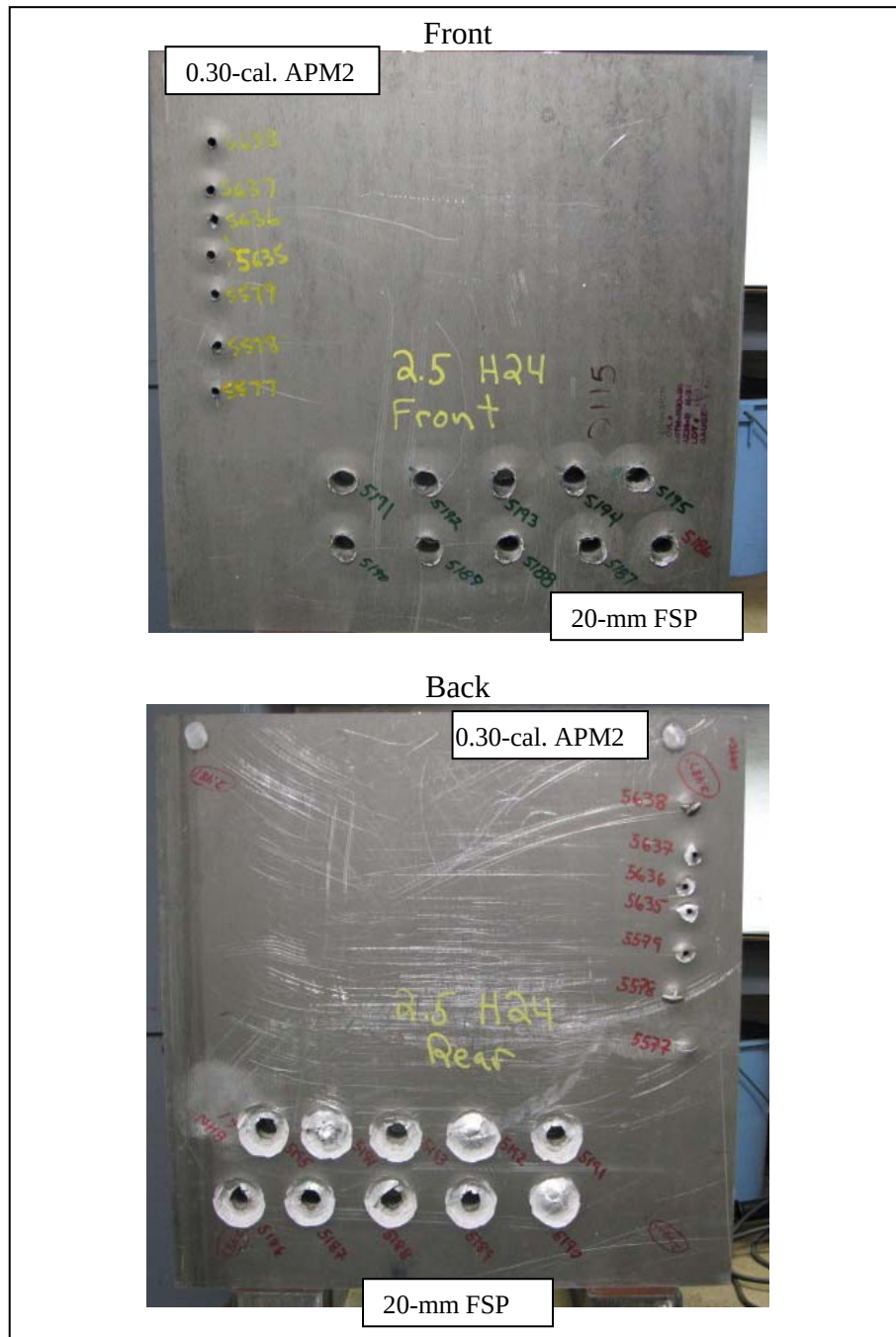


Figure A-4. The 2.5-in AZ31B-H24.

Front

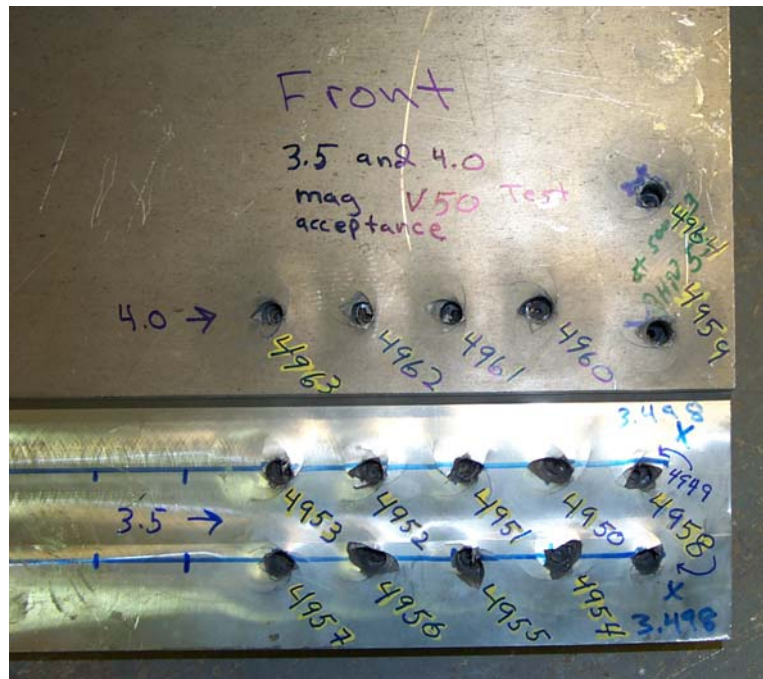


Back



Figure A-5. The 3.0-in AZ31B-H24: 0.50-cal. APM2 impacts.

Front



Back



Figure A-6. The 3.5- and 4.0-in AZ31B-H24: 0.50-cal. APM2 impacts.

INTENTIONALLY LEFT BLANK.

Appendix B. Fragment-Simulating Projectile (FSP) Data for Post-Ballistic Pictures*

List of Definitions and Abbreviations

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

*The charts in this appendix appear in their original form, without editorial change.

Target: **Magnesium AZ31B-H24** **8-May-06**
 Plate #: **--** **EF108**
 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")**

V50:	507	m/s	#	shots:	6
Std Dev:	11	m/s	Spread:	24	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
639	--	--	CP	No	--	5070
519	--	--	CP	Yes	--	5071
417	--	--	PP	No	--	5072
479	--	--	PP	No	--	5073
511	--	--	CP	Yes	--	5074
456	--	--	PP	No	--	5075
448	--	--	PP	No	--	5076
495	--	--	PP	Yes	--	5077
441	--	--	PP	No	--	5078
498	--	--	PP	Yes	--	5081
470	--	--	PP	No	--	5082
498	--	--	PP	Yes	--	5083
518	--	--	CP	Yes	--	5084

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")**

V50:	742	m/s	#	shots:	6
Std Dev:	9	m/s	Spread:	27	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
630	--	--	PP	No	--	5085
729	--	--	PP	No	--	5086
764	--	--	CP	No	--	5087
738	--	--	PP	Yes	--	5088
762	--	--	CP	No	--	5089
746	--	--	CP	Yes	--	5090
738	--	--	PP	Yes	--	5091
757	--	--	CP	Yes	--	5092
720	--	--	PP	No	--	5093
730	--	--	PP	Yes	--	5094
745	--	--	CP	Yes	--	5095

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")

V50:	477	m/s	#	shots:	4
Std Dev:	6	m/s	Spread:	13	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
773	--	--	PP	No	--	5163
485	--	--	CP	Yes	--	5164
472	--	--	PP	Yes	--	5165
476	--	--	PP	Yes	--	5166
476	--	--	CP	Yes	--	5167

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")

V50:	576	m/s	# shots:	4
Std Dev:	7	m/s	Spread:	15 m/s
ZMR:	4			

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
540	--	--	PP	No	--	5176
549	--	--	PP	No	--	5177
585	--	--	CP	Yes	--	5178
569	--	--	PP	No	--	5179
567	--	--	PP	No	--	5180
574	--	--	PP	Yes	--	5181
573	--	--	PP	Yes	--	5182
572	--	--	PP	No	--	5183
569	--	--	PP	No	--	5184
570	--	--	CP	Yes	--	5185

Target: **Magnesium 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")-AL 2024(0.020")**

V50:	735	m/s	#	shots:	4
Std Dev:	4	m/s	Spread:	9	m/s
ZMR:	3				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
834	--	--	CP	No	--	5186
816	--	--	CP	No	--	5187
806	--	--	CP	No	--	5188
768	--	--	CP	No	--	5189
714	--	--	PP	No	--	5190
731	--	--	CP	Yes	--	5191
723	--	--	PP	No	--	5192
734	--	--	PP	Yes	--	5193
733	--	--	PP	Yes	--	5194
740	--	--	CP	Yes	--	5195

Appendix C. APM2 Projectile Data for Post-Ballistic Pictures*

List of Definitions and Abbreviations

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

*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")**

V50:	579	m/s	#	shots:	4
Std Dev:	6	m/s	Spread:	11	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
584	--	--	CP	Yes	--	5561
543	--	--	PP	No	medium bulge	5562
550	--	--	PP	No	medium bulge with crack	5563
564	--	--	PP	No	large bulge with cracks: PIP, TP	5564
					large bulge with cracks:	
574	--	--	PP	Yes	PIP, TP	5565
584	--	--	CP	Yes	--	5566
573	--	--	PP	Yes	PP, TP	5567

Target: **Magnesium AZ31B-H24** **24-Apr-06**
Plate #: **--** **EF106**
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")**

V50:	687	m/s	#	shots:	4
Std Dev:	8	m/s	Spread:	18	m/s
ZMR:	9				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
729	--	--	CP	No	--	5568
698	--	--	CP	No	--	5569
658	--	--	PP	No	PIP, TP	5570
665	--	--	PP	No	PIP, TP	5571
662	--	--	PP	No	large bulge with cracks	5572
676	--	--	PP	Yes	large bulge with cracks	5573
684	--	--	CP	Yes	--	5574
693	--	--	PP	Yes	Hole in target; dent in witness	5575
694	--	--	CP	Yes	--	5576

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")**

V50:	787	m/s	#	shots:	4
Std Dev:	7	m/s	Spread:	15	m/s
ZMR:	3				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
757	--	--	PP	No	medium bulge with cracks	5577
792	--	--	PP	Yes	large bulge with cracks	5578
805	--	--	CP	No	--	5579
804	--	--	CP	No	--	5635
789	--	--	CP	Yes	--	5636
791	--	--	CP	Yes	--	5637
777	--	--	PP	Yes	PP, TP	5638

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")**

V50:	650	m/s	#	shots:	4
Std Dev:	5	m/s	Spread:	10	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
621	--	--	PP	No	Med. bulge w/crack	3605
696	--	--	CP	No	--	3606
661	--	--	CP	No	--	3607
655	--	--	CP	Yes	--	3608
647	--	--	PP	Yes	Lg. bulge; star break	3609
653	--	--	CP	Yes	--	3610
629	--	--	PP	No	Lg. bulge w/cracks	3611
645	--	--	PP	Yes	Lg. bulge; star break	3612

Target: **Magnesium AZ31B-H24** **2-Apr-07**
Plate #: **--** **EF108**
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")**

V50:	688	m/s	#	shots:	6
Std Dev:	9	m/s	Spread:	25	m/s
ZMR:	0				

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
714	--	--	CP	No	--	4949
706	--	--	CP	No	--	4950
650	--	--	PP	No	--	4951
661	--	--	PP	No	--	4952
697	--	--	CP	Yes	--	4953
672	--	--	PP	Yes	--	4954
687	--	--	PP	Yes	--	4955
694	--	--	CP	Yes	--	4956
692	--	--	CP	Yes	--	4957
684	--	--	PP	Yes	--	4958

Target:
Plate #:
Lot#:
Thickness:

Magnesium AZ31B-H24
--
--
102.03mm 4.017 "

2-Apr-07
EF108

Hardness:
Obliquity:
Projectile:
Setup:

55 BHN on 500kg scale
0°
.50 cal AP M2
Mg-Air(6")-AL 2024(0.020")

V50:
Std Dev:
ZMR:

746
7
0

m/s
m/s

#
shots:
Spread:

4
15

m/s

Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V50	Comments	Shot #
769	--	--	CP	No	--	4959
--	--	--	--	--	uncaptured data	4960
755	--	--	CP	Yes	--	4961
740	--	--	PP	Yes	--	4962
740	--	--	PP	Yes	--	4963
748	--	--	CP	Yes	--	4964

NO. OF
COPIES ORGANIZATION

1 DEFENSE TECHNICAL
 (PDF INFORMATION CTR
 only) DTIC OCA
 8725 JOHN J KINGMAN RD
 STE 0944
 FORT BELVOIR VA 22060-6218

1 DIRECTOR
 US ARMY RESEARCH LAB
 IMNE ALC IMS
 2800 POWDER MILL RD
 ADELPHI MD 20783-1197

1 DIRECTOR
 US ARMY RESEARCH LAB
 AMSRD ARL CI OK TL
 2800 POWDER MILL RD
 ADELPHI MD 20783-1197

1 DIRECTOR
 US ARMY RESEARCH LAB
 AMSRD ARL CI OK PE
 2800 POWDER MILL RD
 ADELPHI MD 20783-1197

ABERDEEN PROVING GROUND

1 DIR USARL
 AMSRD ARL CI OK TP (BLDG 4600)

NO. OF
COPIES ORGANIZATION

3 CDR US ARMY TACOM
AMSTA TR S
T FURMANIAK
L FRANKS
D TEMPLETON
MS 263
WARREN MI 48397-5000

1 CDR US ARMY TACOM
AMSTA TR R
D HANSEN
WARREN MI 48397-5000

1 PM
SFAE GCSS HBCTS
J ROWE
MS 325
WARREN MI 48397-5000

2 NATL GROUND INTLLGNC CTR
J CRIDER
W GSTATTENBAUER
2055 BOULDERS RD
CHARLOTTESVILLE VA 22091-5391

1 CRUSADER OPM
SFAE GCSS CR E
B ROOPCHAND
BLDG 171A
PICATINNY ARSENAL NJ 07806-5000

1 DIRECTOR
DARPA
3701 N FAIRFAX DR
ARLINGTON VA 22203-1714

1 PM BFVS
ATTN SFAE GCSS W BV S
M KING
WARREN MI 48397-5000

1 NVL SURFC WARFARE CTR
CARDEROCK DIV
R PETERSON CODE 28
9500 MACARTHUR BLVD
WEST BETHESDA MD 20817-5700

2 LAWRENCE LIVERMORE NATL LAB
R LANDINGHAM L372
J REAUGH L282
PO BOX 808
LIVERMORE CA 94550

NO. OF
COPIES ORGANIZATION

2 LOS ALAMOS NATL LAB
F ADDESSIO
M BURKETT
PO BOX 1663
LOS ALAMOS NM 87545

3 SANDIA NATL LAB
J ASAY MS 1811
L CHHABILDAS MS 1811
D CRAWFORD MS 0836 9116
PO BOX 5800
ALBUQUERQUE NM 87185-0307

1 AIR FORCE ARMAMENT LAB
AFATL DLJW
W COOK
EGLIN AFB FL 32542

4 UNIV OF TEXAS
INST FOR ADVNCD TECH
S BLESS
H FAIR
J HODGE
R SUBRAMANIAN
3925 W BRAKER LN
AUSTIN TX 78759-5316

1 UNIV OF DAYTON RSRCH INST
N BRAR KLA 14
300 COLLEGE PARK
DAYTON OH 45469-0182

3 SOUTHWEST RSCH INST
C ANDERSON
J RIEGEL
J WALKER
6220 CULEBRA RD
SAN ANTONIO TX 78238

4 US DEPT OF ENERGY
ALBANY RSCH CTR
J HANSEN (2 CPS)
P TURNER (2 CPS)
1450 QUEEN AVE SW
ALBANY OR 97321-2198

1 BROWN UNIV
DIV OF ENGRG
R CLIFTON
PROVIDENCE RI 02912

NO. OF
COPIES ORGANIZATION

2 UNIV OF CA SAN DIEGO
DEPT OF APPL MECH & ENGR
SVC RO11
S NEMAT NASSER
M MEYERS
LA JOLLA CA 92093-0411

2 AERONAUTICAL RSRCH ASSN
R CONTILIANO
J WALKER
PO BOX 2229
50 WASHINGTON RD
PRINCETON NJ 08540

1 ALLIANT TECHSYSTEMS
G JOHNSON
5050 LINCOLN DR
EDINA MN 55340-1097

1 APPLIED RSRCH ASSN INC
D GRADY
4300 SAN MATEO BLVD NE STE A
ALBUQUERQUE NM 87110

1 BRIGGS COMPANY
ATTN J BACKOFEN
2668 PETERSBOROUGH ST
HERNDON VA 222071-2443

3 CERCOM
R PALICKA
G NELSON
B CHEN
1960 WATSON WAY
VISTA CA 92083

1 CYPRESS INTERNTL
A CAPONECCHI
1201 E ABINGDON DR
ALEXANDRIA VA 22314

1 EPSTEIN AND ASSN
K EPSTEIN
2716 WEMBERLY DR
BELMONT CA 94002

1 GEN RSRCH CORP
PO BOX 6770
SANTA BARBARA CA 93160-6770

1 INTERNATL RSRCH ASSN
D ORPHAL
4450 BLACK AVE
PLEASANTON CA 94566

NO. OF
COPIES ORGANIZATION

3 GDLS
W BURKE MZ436 21 24
G CAMPBELL MZ436 30 44
D DEBUSSCHER MZ436 20 29
38500 MOUND RD
STERLING HTS MI 48310-3200

3 GDLS
J ERIDON MZ436 21 24
W HERMAN MZ435 01 24
S PENTESCU MZ436 21 24
38500 MOUND RD
STERLING HTS MI 48310-3200

1 JET PROPULSION LAB
IMPACT PHYSICS GRP
M ADAMS
4800 OAK GROVE DR
PASADENA CA 91109-8099

3 OGARA HESS & EISENHARDT
G ALLEN
D MALONE
T RUSSELL
9113 LE SAINT DR
FAIRFIELD OH 45014

2 ALLVAC OREMET FACLT
J KOSIN
B MAHONEY
530 34TH AVE SW
PO BOX 460
ALBANY OR 97321

4 POULTER LAB
SRI INTRNTL
D CURRAN
R KLOOP
L SEAMAN
D SHOCKEY
333 RAVENSWOOD AVE
MENLO PARK CA 94025

6 RMI TITANIUM CO
J BENNETT
E CHRIST
F JANOWSKI
W PALLANTE
S ROBERTSON
O YU
1000 WARREN AVE
NILES OH 44446

NO. OF
COPIES ORGANIZATION

1 TIMET
J FANNING
PO BOX 2128
HENDERSON NV 89009

1 SIMULA INC
R WOLFFE
10016 SOUTH 51ST ST
PHOENIX AZ 85044

3 UNITED DEFNS LIMITED PARTNERS
GROUND SYS DIV
E BRADY
R JENKINS
K STRITTMATTER
PO BOX 15512
YORK PA 17405-1512

1 PENN STATE UNIV
APPLIED RSRCH LAB
ACOUSTICS PRGM
D SWANSON
504L APPLIED SCI BLDG
UNIVERSITY PK PA 16803

5 MENA
R DeLORME
1001 COLLEGE ST
PO BOX 258
MADISON IL 62060

1 CENTRAL 7
R JONES
80 PALISADE AVE
WHITE PLAINS NY 10607

1 PACIFIC NORTHWEST NATL LAB
E NYBERG
MSIN P7-82
902 BATTELLE BLVD
RICHLAND WA 99352

1 UNIV OF VIRGINIA
DEPT OF MTRLS SCI & ENG
SCHOOL OF ENG & APPL SCI
H WADLEY
B214 THORNTON HALL
116 ENGINEERS WAY
CHARLOTTESVILLE VA 22903

1 CELLULAR MTRLS INTRNTL INC
Y MURTY
2 BOARS HEAD LN
CHARLOTTESVILLE VA 22903

NO. OF
COPIES ORGANIZATION

1 EMBASSY OF AUSTRALIA
COUNSELLOR DEFNC SCI
1601 MASSACHUSETTS AVE NW
WASHINGTON DC 20036-2273

1 FORCE PROTECTION INDUST INC
V JOYNT
9801 HWY 78
LADSON SC 29456

2 US ARMY RSRCH DEV & ENGRG CTR
AMSRD NSC IPD B
P CUNNIFF
J WARD
KANSAS ST
NATICK MA 01760-5019

1 NVL SURFC WARFARE CTR
CARDEROCK DIV
R PETERSON CODE 28
9500 MACARTHUR BLVD
WEST BETHESDA MD 20817-5700

1 THE AIR FORCE RSRCH LAB
AFRL/MLLMP
T TURNER
BLDG 655 RM 115
2230 TENTH ST
WRIGHT-PATTERSON AFB OH
45433-7817

1 PRATT & WHITNEY ROCKETDYNE
A PANDEY
PO BOX 109600 MS 702-06
WEST PALM BEACH FL 33410-9600

1 GEN MOTORS CORP
P CREPEAU
MAIL CODE 483-730-472
823 JOSLYN RD
PONTIAC MI 48340

1 CHRYSLER CORP
R BEALS
CIMS 481-01-41
800 CHRYSLER DR
AUBURN HILLS MI 48326-2757

1 BMW OF NORTH AMERICA LLC
A KHALILI
555 HAMILTON AVE STE 300
PALO ALTO CA 94301

NO. OF
COPIES ORGANIZATION

1 MISSOURI UNIV OF SCI & TECHLGY
R MISHRA
B37 MCNUTT HALL
ROLLA MO 65409-0340

1 THIXOMAT
S LEBREAU
620 TECHNLOGY DR
ANN ARBOR MI 48108

1 US INFANTRY CTR
MTRLS LOG NCO – SCI TECHNLOGY
ADVISOR
SOLDIER DIV
S VAKERICS
6731 CONSTITUTION LOOP STE 319
FORT BENNING GA 31905

3 NATL GROUND INTLLGNC CTR
D EPPERLY
T SHAVER
T WATERBURY
2055 BOULDERS RD
CHARLOTTESVILLE VA 22911-8318

3 PROG EXECUTIVE OFC – SOLDIER
US ARMY DIR TECH MGMT
PROJ MGR - SOLDIER EQUIP
K MASTERS
C PERRITT
J ZHENG
15395 JOHN MARSHALL HWY
HAYMARKET VA 20169

1 CERADYNE INC
M NORMANDIA
3169 RED HILL AVE
COSTA MESA CA 92626

2 SOUTHWEST RSRCH INST
C ANDERSON
J WALKER
6220 CULEBRA RD
PO DRAWER 28510
SAN ANTONIO TX 78228

2 FOSTER-MILLER
J REIGEL
R SYKES
195 BEAR HILL RD
WALTHAM MA 02451

NO. OF
COPIES ORGANIZATION

2 SOUTHWEST RSRCH INST
T HOLMQUIST
G JOHNSON
5353 WAYZATA BLVD STE 607
MINNEAPOLIS MN 55416

1 US ARMY RAPID EQUIPPING FORCE
R TURNER
10236 BURBECK RD
BLDG 361T
FORT BELVOIR VA 22060-5806

1 MAGNESIUM TECH RESRCS LLC
S ERICKSON
4241 AUGUSTA CT
HOWELL MI 48843

2 LETTERKENNY ARMY DEPOT
PRODUCTION ENGRNG DIV
AMSAM LE MO E S
K HERSHEY
J FRIDAY
1 OVERCASH AVE
CHAMBERSBURG PA 17201-4150

1 TIMMINCO CORP
DIR BUS DEV
S SHOOK
3595 MOLINE ST
AURORA CO 80010

1 MINE SAFETY APPLIANCES CO
T MOYNIHAN
PO BOX 439
PITTSBURGH PA 15230-0439

1 NATL TECH SYS
S DETRUIT
3070 SW CAPTIVA CT
PALM CITY FL 34990

1 SAINT GOBAIN
D MCELWEE
9 RENEE CT
NORTHGATE COMMONS
NEWARK DE 19711

1 CIVILIAN HUMAN RESRC AGCY
B ANDERSON
200 OAK LEAF CIR
ABINGDON MD 21009

NO. OF
COPIES ORGANIZATION

1 DIR US ARMY RSRCH LAB
AMSRD ARL D
J MILLER
V WEISS
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIR US ARMY RSRCH LAB
AMSRD ARL SE SA
N SROUR
2800 POWDER MILL RD
ADELPHI MD 20783-1197

ABERDEEN PROVING GROUND

1 DIR USA EBCC
SCBRD RT
5183 BLACKHAWK RD
APG EA MD 21010-5424

1 CDR USA SBCCOM
AMSCB CII
5183 BLACKHAWK RD
APG EA MD 21010-5424

1 DIR USAMSAA
AMSRD AMS D
BLDG 392

1 CDR USATEC
STEAC LI LV
E SANDERSON
BLDG 400

1 CDR US ARMY DTC
CSTE DTC TT T
M SIMON
RYAN BLDG

83 DIR USARL
AMSRD ARL SL
R COATES
AMSRD ARL SL B
R BOWEN
AMSRD ARL SL BE
A DIETRICH
AMSRD ARL SL BW
W BRUCHEY
L ROACH
AMSRD ARL VT UV
S WILKERSON

NO. OF
COPIES ORGANIZATION

AMSRD ARL WM
J MCCAULEY
P PLOSTINS
J SMITH
T WRIGHT
AMSRD ARL WM B
M ZOLTOSKI
AMSRD ARL WM BC
R ANDERSON
AMSRD ARL WM BD
D LOWRY
AMSRD ARL WM M
J BEATTY
B DOWDING
S MCKNIGHT
AMSRD ARL WM MB
R CARTER
L KECSKES
S MATHAUDHU
D SNOHA
AMSRD ARL WM MC
W ROY
R SQUILLACIOTI
AMSRD ARL WM MD
E CHIN
B CHEESEMAN
K CHO
J MONTGOMERY
B SCOTT
S WALSH
AMSRD ARL WM SG
T ROSENBERGER
AMSRD ARL WM T
P BAKER
B BURNS
N GNIAZDOWSKI
AMSRD ARL WM TA
M BURKINS (5 CPS)
W GOOCH (5 CPS)
D HACKBARTH
T HAVEL
C HOPPEL
E HORWATH
T JONES (5 CPS)
D KLEPONIS
C KRAUTHAUSER
B LEAVY
D LITTLE
H MEYER
J RUNYEON
S SCHOENFELD

NO. OF
COPIES ORGANIZATION

AMSRD ARL WM TB
R BANTON
R GUPTA

AMSRD ARL WM TC
T FARRAND
K KIMSEY
L MAGNESS
R MUDD
D SCHEFFLER
S SCHRAML
S SEGLETES
R SUMMERS
W WALTERS

AMSRD ARL WM TD
S BILYK
T BJERKE
D CASEM
J CLAYTON
D DANDEKAR
M GREENFIELD
Y HUANG
B LOVE
M RAFTENBERG
E RAPACKI
M SCHEIDLER
T WEERASOORIYA

AMSRD ARL WM TE
C HUMMER
B RINGERS

NO. OF
COPIES ORGANIZATION

- 3 AERONAUTICAL & MARITIME
RSCH LAB
N MURMAN
S CIMPOERU
D PAUL
PO BOX 4331
MELBOURNE VIC 3001
AUSTRALIA
- 1 ARMSCOR
L DU PLESSIS
PRIVATE BAG X337
PRETORIA 0001
SOUTH AFRICA
- 1 CARLOS III UNIV OF MADRID
C NAVARRO
ESCUELA POLTEENICA SUPERIOR
C/BUTARQUE 15
28911 LEGANES MADRID
SPAIN
- 1 CELIUS MATERIAL TEKNIK
KARLSKOOGA AB
L HELLNER
S 69180 KARLSKOOGA
SWEDEN
- 3 CENTRE D'ETUDES GRAMAT
J CAGNOUX
C GALLIC
J TRANCHET
GRAMAT 46500
FRANCE
- 1 MINISTRY OF DEFENCE
DGA DSP STTC
G BRAULT
4 RUE DE LA PORTE D'ISSY
00460 ARMEES
F 75015 PARIS
FRANCE
- 1 CONDAT PROJEKT GMBH
ATTN J KIERMEIR
MAXIMILIANSTR 28
SCHEYERN 85298
GERMANY

NO. OF
COPIES ORGANIZATION

- 1 OSAKA UNIVERSITY
JOINING & WELDING RSCH INST
DR KATSUYOSHI KONDOH
11-1 MIHOGAOKA IBARAKI
OSAKA 567-0047 JAPAN
- 2 DEFENCE PROCUREMENT AGCY
G LAUBE
W ODERMATT
BALLISTICS WPNS & COMBAT
VEHICLE TEST CTR
CH 3602 THUN
SWITZERLAND
- 1 TDW EADS
ATTN M HELD
PO BOX 1340
SCHROBENHAUSEN D 86523
GERMANY
- 4 DEFENSE RESEARCH AGENCY
ATTN W CARSON
ATTN T HAWKINS
ATTN B JAMES
ATTN B SHRUBSALL
PORTON DOWN
SALISBURY WTTTS SP04 OJQ
UNITED KINGDOM
- 1 DEFENCE RESEARCH AND
DEVELOPMENT-VALCARTIER
ATTN R DELAGRAVE
2459 PIE XI NORTH
VAL-BELAIR QC G3J 1X5
CANADA
- 2 DEUTSCH FRANZOSISCHES
FORSCHUNGSINSTITUT ST LOUIS
H ERNST
H LERR
CEDEX 5 RUE DU
GENERAL CASSAGNOU
F 68301 SAINT LOUIS
FRANCE
- 1 DIEHL GMBH AND CO
M SCHILDKNECHT
FISCHBACHSTRASSE 16
D 90552 ROTBENBACH AD
PEGNITZ
GERMANY

NO. OF
COPIES ORGANIZATION

- 1 DYNAMEC RSCH AB
A PERSSON
PARADESGRND7
SODERTALJE S151 36
SWEDEN
- 2 ETBS DSTI
P BARNIER
M SALLES
ROUTE DE GUERAY
BOITE POSTALE 712
18015 BOURGES CEDEX
FRANCE
- 1 FEDERAL MINISTRY OF DEFENCE
DIR OF EQPT & TECH LAND
RUV 2
D HAUG
POSTFACH 1328
53003 BONN
GERMANY
- 4 FRANHOFER INSTITUT FUR
KURZZEITDYNAMIK
ERNST MACH INSTITUT
V HOHLER
E STRASSBURGER
R TRAM
K THOMA
ECKERSTRASSE4
D 79 104 FREIBURG
GERMANY
- 1 MINISTRY OF DEFENCE
DGA/SPART
C CANNAVO
10 PLACE GEORGES CLEMENCEAU
BP 19
F 92211 SAINT CLOUD CEDEX
FRANCE
- 2 HIGH ENERGY DENSITY RSCH CTR
V FORTOV
G KANEL
IZHORSKAY STR 13/19
MOSCOW 127412
RUSSIAN REPUBLIC
- 1 INGENIEURBURO DEISENROTH
F DEISENROTH
AUF DE HARDT 33 35
D 5204 LOHMAR 1
GERMANY

NO. OF
COPIES ORGANIZATION

- 1 INST OF CHEMICAL PHYSICS
S RAZORENOV
142432 CHERNOGOLOVKA
MOSCOW REGION
RUSSIAN REPUBLIC
- 7 INST FOR PROBLEMS IN MATLS SCI
S FIRSTOV
B GALANOV
O GRIGORIEV
V KARTUZOV
V KOVTUN
Y MILMAN
V TREFILOV
3 KRHYZHANOVSKY STR
252142 KIEV 142
UKRAINE
- 1 INST FOR PROBLEMS
OF STRENGTH
G STEPANOV
TIMIRY AZEVSKAYA STR 2
252014 KIEV
UKRAINE
- 3 INST OF MECH ENGR PROBLEMS
V BULATOV
D INDEITSEV
Y MESCHERYAKOV
BOLSHOY 61 VO
ST PETERSBURG 199178
RUSSIAN REPUBLIC
- 2 IOFFE PHYSICO TECH INST
E DROBYSHEVSKI
A KOZHUSHKO
ST PETERSBURG 194021
RUSSIAN REPUBLIC
- 1 R OGORKIEWICZ
18 TEMPLE SHEEN
LONDON SW 14 7RP
UNITED KINGDOM
- 2 NATL DEFENCE HDQRTRS
PMO MRCV MAJ PACEY
PMO LAV A HODAK
OTTOWA ONTARIO KIA OK2
CANADA

NO. OF
COPIES ORGANIZATION

1	OTO BRED M GUALCO VIA VALDIOCCHI 15 119136 LA SPEZIA ITALY
1	ROYAL NETHERLANDS ARMY JHOENEVELD V D BURCHLAAN 31 PO BOX 90822 2509 LS THE HAGUE NETHERLANDS
1	DEFENCE MATERIEL ADMIN WEAPONS DIRECTORATE A BERG S 11588 STOCKHOLM SWEDEN
1	SINGAPORE INST OF MFG TECHLGY RSRCH SCIENTIST FORMING TECHNLGY M CHANDRASEKARAN 71 NANYANG DR SINGAPORE 638075
1	ACERAM TECHLGY INC DIRECTOR PROD DEV V LUCATA 102 FRASER ST KINGSTON ON K7K 2J2 CANADA
1	AMERICAN EMBASSY SINGAPORE E STIERNA PO BOX ODC FPO AP 96507
1	ADVNCED DEF MTRLs LTD G ROBERSON SIR FRANK WHITTLE BUSINESS CENTRE GREAT CENTRAL WAY RUGBY WARWICKSHIRE ENGLAND CV21 3XH
1	NATL INST FOR MTRLs SCI MAGNETIC MTRLs CTR NANOSTRUCTURE ANALYS GR C MENDIS 1-2-1 SENGEN TSUKUBA IBARAKI 305-0047 JAPAN

NO. OF
COPIES ORGANIZATION

1	TNO SCIENCE AND INDUST W SILLEKENS DE RONDON 1 PO BOX 6235 5600 HE EINDHOVEN THE NETHERLANDS
1	BISALLOYS STEELS PTY LTD W PANG 18 RESOLUTION DR UNANDERRA NSW 2526 AUSTRALIA
1	TNO DEFENCE SEC AND SAFETY F T M VAN WEGEN LANGE KLEIWEG 137 PO BOX 45 2280 AA RIJSWIJK THE NETHERLANDS
1	USA ITC-PAC J P SINGH 7-23-17 ROPPONGI MINATO-KU TOKYO JAPAN 106-0032
1	OSAKA UNIV JOINING AND WELDING RSRCH INST K KONDOH 11-1 MIHOGAOKA IBARAKI 567-0047 OSAKA JAPAN

INTENTIONALLY LEFT BLANK.