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Ballistic Testing of SSAB Ultra-High-Hardness Steel for Armor Applications

by Dwight D. Showalter, William A. Gooch, Matthew S. Burkins, and R. Stockman Koch

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14. ABSTRACT

The highest-performing U.S. steel alloys for armor-piercing (AP) bullet protection are manufactured to MIL-DTL-46100E, high-hardness armor (HHA) with a hardness range of 477–534 Brinell hardness number (BHN), and to MIL-A-46099C, dual hardness armor (DHA), which is produced by roll bonding a 601–712 BHN front plate to a 461–534 BHN back plate. While these materials still serve their intended applications, monolithic ultra-high-hardness (UHH) steels with a hardness of 600 BHN or greater have been developed. This class of steels increases AP bullet defeat, reduces armor weight, and eliminates the manufacturing difficulties inherent in DHA. Swedish Steel Oxelösund AB (SSAB) produces a number of grades of steel, which have previously been assessed against AP ammunition. However, SSAB has two UHH armor steels designated ARMOX 600T and ARMOX ADVANCE that meet this hardness criteria. ARMOX 600T is a nominal 600 BHN steel while ARMOX ADVANCE has a nominal hardness of Rockwell C58-63 (>650 BHN). This report assesses the performance of these steels against two projectiles that will be used to generate a new military specification for UHH steel armor. The performance of these UHH steels will be compared to the current HHA MIL-DTL-46100E specification.

15. SUBJECT TERMS

armor plate, steel, armor piercing, ultra-high hard

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1. Introduction

The U.S. armor community is currently engaged in accelerated efforts to deliver lightweight armor technologies that can defeat armor-piercing (AP) projectiles at reduced areal weights that are available across a large industrial base. While many of these programs involve the application of lower-density metals such as aluminum and titanium, the selection of steel alloys is still competitive for many ballistic and structural applications; the ability to fabricate armor components in both commercial and military operational areas with available equipment and personnel is a major advantage of steel solutions. To meet these requirements, the U.S. armor community has increased the availability of quenched and tempered armor steels by updating current steel military specifications—the most important has been the updated MIL-DTL-46100E specification for high-hardness armor (HHA) (*1*). This improved specification was necessary to supply the large steel demands for combat operations in Iraq and Afghanistan. This HHA specification allows modern continuous processing technologies to be used efficiently and offers a new class of auto-tempered high-hard steels.

Currently, the highest-performing U.S. steel alloys for AP bullet protection are manufactured to MIL-DTL-46100E, HHA with a hardness range of 477–534 Brinell hardness number (BHN), and to MIL-A-46099C, dual hardness armor (DHA), which is produced by roll bonding a 601–712 BHN front plate to a 461–534 BHN back plate (*2*). The roll-bonded DHA steels are complex to produce and have known production limitations. The U.S. Army Research Laboratory (ARL), in conjunction with the Institute of Metal Science of Sofia, Bulgaria, examined improved steel technologies to produce these DHA steels by electroslag remelting processes, but producing DHA steels remains difficult (*3*). While both these metal specifications serve their intended applications, considerable overseas efforts to develop monolithic ultra-high-hardness (UHH) steels with a hardness of 600 BHN or greater have been accomplished, and significant advancements in steel metallurgy have been noted in Sweden, Germany, and France. The improved ballistic resistance of steel as a function of increasing hardness is well established in the ballistic community, particularly by Rapacki et al. in the 15th Ballistics Symposium (*4*). This class of steels should increase AP bullet defeat, reduce armor weight, and eliminate the manufacturing difficulties inherent in DHA. This report will document the development of a new class of ballistic UHH steels that will be defined in a new military specification. There are additional UHH steels known or in development that could meet this specification.

Swedish Steel Oxelösund AB (SSAB) produces a number of grades of steel that have previously been assessed against AP projectiles by ARL (*5*). However, SSAB currently has available two UHH armor steels designated ARMOX 600T (*6*) and ARMOX ADVANCE (*7*) that will form the basis of this new specification. Limited evaluation of ARMOX 600T was conducted in Rapacki et al. (*4*), but this work expands upon that data. ARMOX 600T has a hardness of 570–640 BHN while ARMOX ADVANCE has a nominal hardness of Rockwell C58–63 (>650 BHN). This study assesses the performance of these steels against two projectiles that will be used to generate a new military specification for ultra hard steel with two hardness classes: class 1 (513–640 BHN) and class 2 (over 640 BHN). The performance of the ARMOX steels will be compared to the current ballistic acceptance requirements of MIL-DTL-46100E.

2. ARMOX Steels

SSAB develops, manufactures, and markets heavy steel plate and is located south of Stockholm, Sweden, on the Baltic coast. SSAB ballistic plate is manufactured under the designation ARMOX and is available in hardness ranges from rolled homogeneous armor steel (280 BHN) to UHH steel (>640 BHN). ARMOX steels are known for high toughness in relation to the hardness. ARMOX 600T has been available on the market for about 10 years and is mostly used as appliqué armor in various applications in combination with steel, aluminum, composites, or other materials. ARMOX ADVANCE is the newest member of the ARMOX family and is also intended for appliqué armor. As weight is a critical factor in many vehicle projects, the aim is to offer a higher mass efficiency.

ARMOX steels are produced from iron-ore-based metallurgy through blast furnaces, steel deoxidation in an LD converter, and vacuum treatment, thus resulting in very clean steel. The modern four-high plate mill allows the possibility to roll with large reductions, resulting in a fine-grained microstructure. Depending on the hardness/toughness requirements, the steel undergoes various heat treatments to achieve final properties. The continuous casting production flow and heat treatment line at SSAB are shown in figure 1. The chemical composition and mechanical properties of three ARMOX alloys are shown in tables 1 and 2. ARMOX 500T has a hardness and ballistic performance that meet the current MIL-DTL-46100E specification and is representative of current high-hardness steels.

3. Experimental Procedure

The ballistic performance of ARMOX 600T and ARMOX ADVANCE steel plates was determined by obtaining the V_{50} ballistic limit for each plate thickness against the corresponding specified test projectile. The test methodology is described in detail in the MIL-STD-662F (*8*). The V_{50} ballistic limit is the velocity at which an equal number of fair impact complete penetration (target is defeated) and partial penetration (target is not defeated) velocities are attained using the up-and-down firing method. Fair impact is defined as occurring when a projectile with an acceptable yaw strikes the target at a distance of at least two projectile

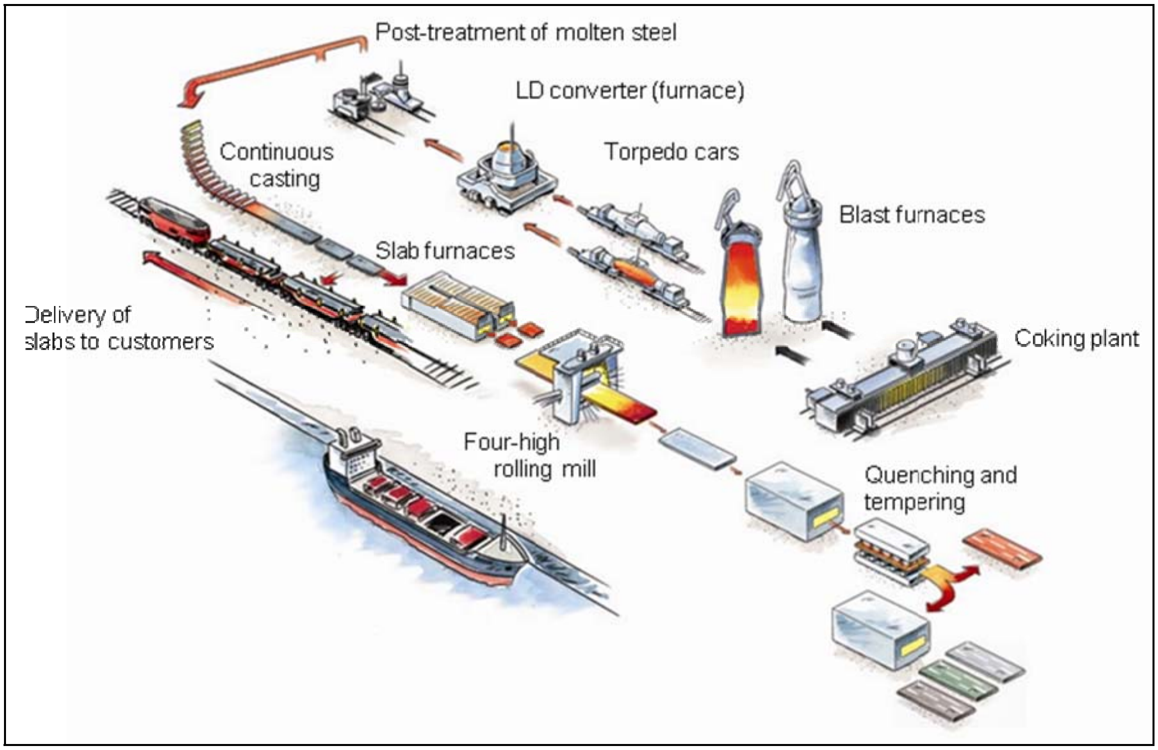

Figure 1. Production flow diagram at SSAB for ARMOX steel plate manufacture.

Table 1. Chemical composition of ARMOX plate.

Grade	C max (%)	Si (%)	Mn max (%)	P max (%)	S max (%)	Cr max (%)	Ni max (%)	Mo max (%)	B max (%)
ARMOX 500T	0.32	0.1–0.4	1.2	0.015	0.010	1.0	1.8	0.7	0.005
ARMOX 600T	0.47	0.1–0.7	1.0	0.010	0.005	1.5	3.0	0.7	0.005
ARMOX ADVANCE	0.47	0.1–0.7	1.0	0.010	0.005	1.5	3.0	0.7	0.005

Table 2. Mechanical properties of ARMOX plate.

Grade	Hardness (BHN)	Charpy-V –40 °C 10 × 10 mm (J)	0.2%Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%)
ARMOX 500T	480–540	Minimum 25	Minimum 1250	1450–1750	Minimum 8
ARMOX 600T	570–640	Minimum 12	1500[a]	2000[a]	7[a]
ARMOX ADVANCE	RC58-63	14[a]	1600[a]	2250[a]	9[a]

[a]Typical values.

diameters from a previously damaged impact area or edge of plate. A complete penetration is determined by placing a 0.5-mm (0.020-in) 2024T3 aluminum witness plate 152.6 mm (6.00 in) behind and parallel to the target. If any penetrator or target fragment strikes this witness plate with sufficient energy to create a hole through which light passes, the result is considered a complete penetration. A partial penetration is any impact that is not a complete penetration. For the MIL-DTL-46100E (MR) specification, the V_{50} ballistic limit is defined as the average of six fair impact velocities comprising the three lowest velocities resulting in complete penetration and the three highest velocities resulting in partial penetration. A maximum spread of 45.7 m/s (150 fps) shall be permitted between the lowest and highest velocities employed in determining ballistic limits. The data for the two ARMOX steels are compared to the baseline data of MIL-DTL-46100E.

4. Test Projectiles

The ARMOX plate samples for this report ranged in thickness (nominal) from 0.189 in (4.8 mm) up to 0.472 in (12 mm). The corresponding test projectiles and plate obliquities required for each thickness under MIL-DTL-46100E are listed in table 3. The 0.30-cal. APM2 steel core weighs 5.2 g; with the copper jacket and lead filler, the total projectile weight is 10.6 g. The total length of the projectile is 35.6 mm (1.4 in). This projectile is shown in figure 2. The 0.50-cal. APM2 also has a steel core along with a copper jacket and lead filler. The steel core weighs 25.4 g with a total weight of 44.9 g. The total length is 57.5 mm (2.26 in). Figure 2 also shows this projectile in detail.

5. Results and Discussion

The V_{50} ballistic limits and standard deviation, σ, for each plate thickness against the 0.30-cal. APM2 were determined experimentally for both the ARMOX 600T and ARMOX ADVANCE plates; the data is shown in table 4. Figure 3 plots the V_{50} velocities vs. the plate thickness for the ARMOX 600T and ARMOX ADVANCE plates, as well as the velocity specification

Table 3. Projectile and obliquity requirements for ordered thicknesses.

Ordered Thickness Nominal mm (in)	**Projectile**[a]	**Angle of Obliquity (°)**
4.8 (0.189)–8.00 (0.315)	0.30-cal. AP	30
8.00(0.315)–12.0 (0.472)	0.50-cal. AP	30

[a]Two types of projectiles are required for the nominal thickness 8 mm (0.315 in).

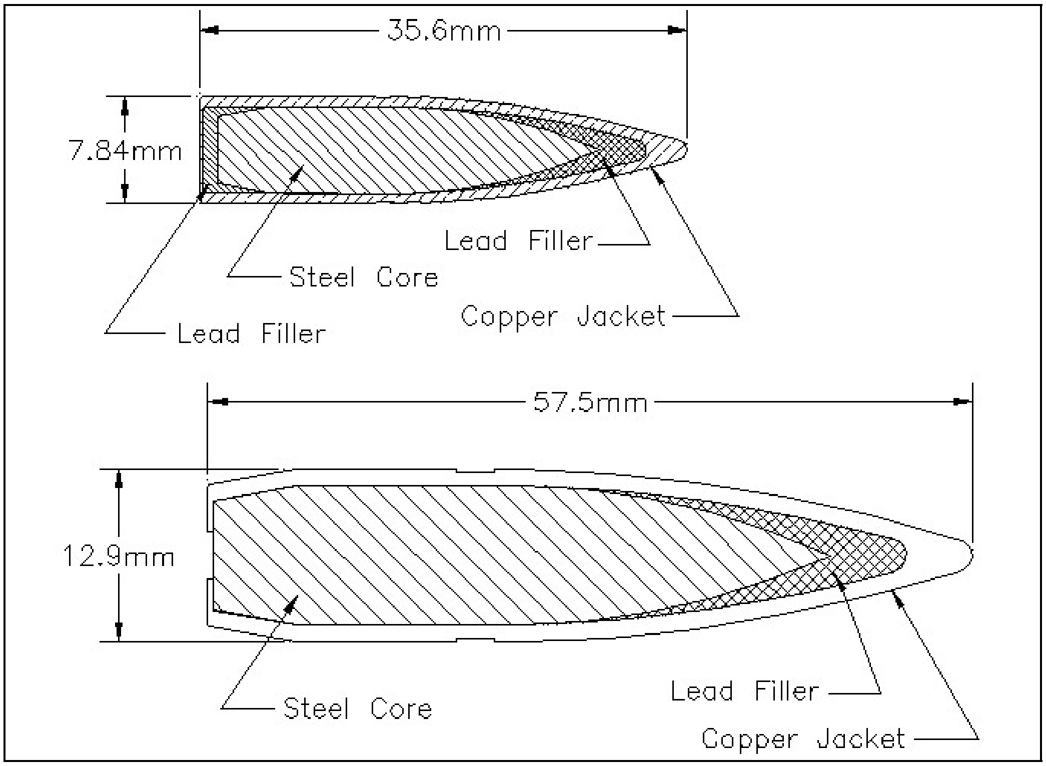

Figure 2. The 0.30-cal. APM2 and 0.50-cal. APM2 test projectiles.

Table 4. ARMOX 600T and ARMOX ADVANCE plate vs. the 0.30-cal. APM2 projectile at 30° obliquity.

Steel	Nominal Thickness (mm)	Actual Thickness mm (in)	Obliquity Angle (°)	V_{50} m/s (ft/s)	Standard Deviation m/s (ft/s)
600T	4.8	4.52 (0.178)	30	723.0 (2372)	13.4 (44)
600T	5	5.46 (0.215)	30	760.1 (2494)	15.2 (50)
600T	6	6.32 (0.249)	30	781.8 (2565)	10.1 (33)
600T	7	7.42 (0.292)	30	863.2 (2832)	15.2 (50)
600T	8	8.36 (0.329)	30	891.5 (2925)	14.3 (47)
Advance	4.8	4.52 (0.178)	30	666.6 (2187)	14.0 (46)
Advance	5	5.38 (0.212)	30	819.0 (2687)	17.4 (57)
Advance	6	6.40 (0.252)	30	859.5 (2820)	13.4 (44)
Advance	7	7.34 (0.289)	30	905.5 (2971)	17.1 (56)
Advance	8	8.33 (0.328)	30	892.4 (2928)	12.2 (40)

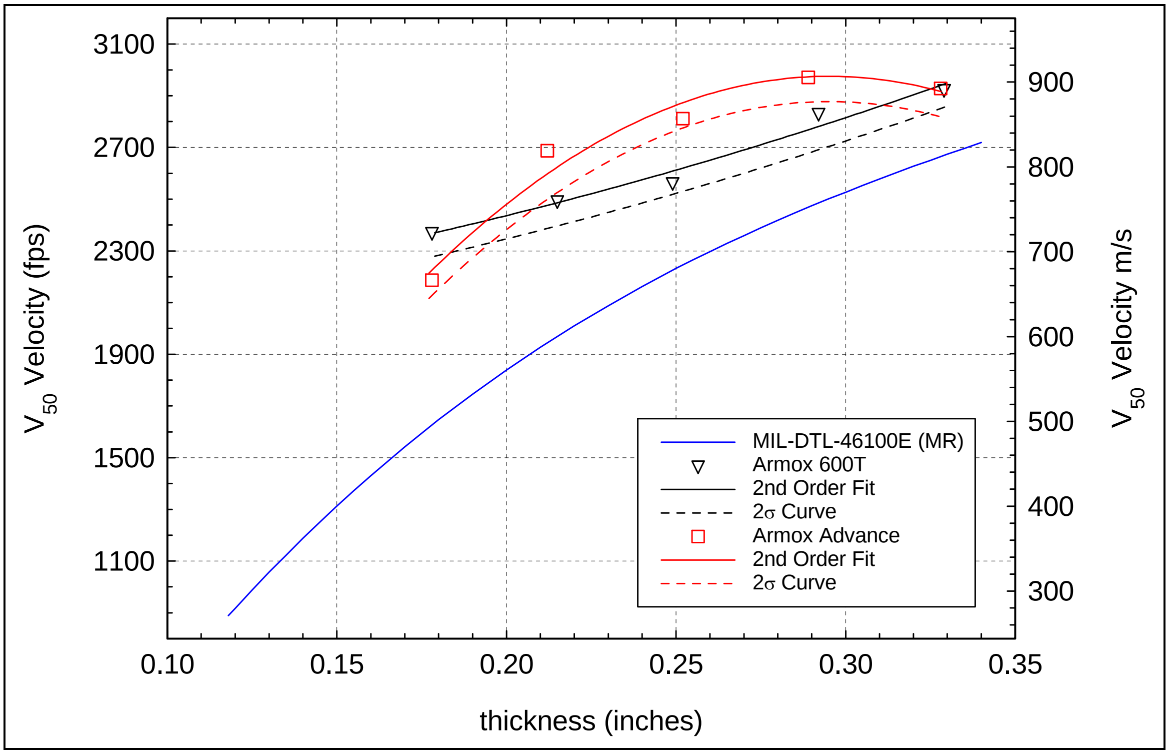

Figure 3. ARMOX 600T and ARMOX ADVANCE plate thickness vs. V_{50} velocity for the 0.30-cal. APM2 at 30° obliquity.

requirements for high-hard steel (MIL-DTL-46100E). The 2σ curve ($V_{50} - 2\sigma$) is also plotted for each steel; this curve accounts for the fact that the V_{50} only provides the velocity at which the armor defeats the penetrator 50% of the time. Subtracting 2σ from the V_{50} velocity provides the statistical velocity at which the armor will defeat the penetrator 98% of the time. The V_{50} ballistic limits and σ for each plate thickness against the 0.50-cal. APM2 for ARMOX 600T and ARMOX ADVANCE plates are shown in table 5. Figure 4 plots the V_{50} vs. the plate thickness for the ARMOX 600T and ARMOX ADVANCE plates, as well as the specification requirements for high-hard steel (MIL-DTL-46100E).

Table 5. ARMOX 600T and ARMOX ADVANCE plate vs. 0.50-cal. APM2 at 30° obliquity.

Steel	**Nominal Thickness (mm)**	**Actual Thickness mm (in)**	**Obliquity Angle (°)**	**V_{50} m/s (ft/s)**	**Standard Deviation m/s (ft/s)**
600T	8	8.36 (0.329)	30	691.9 (2270)	6.5 (28)
600T	10	10.41 (0.410)	30	754.3 (2475)	13.1 (43)
600T	12	12.25 (0.482)	30	826.0 (2710)	14.3 (47)
Advance	8	8.33 (0.328)	30	725.7 (2381)	11.0 (36)
Advance	10	10.29 (0.405)	30	788.2 (2586)	14.3 (47)
Advance	12	12.24 (0.482)	30	824.7 (2706)	13.4 (44)

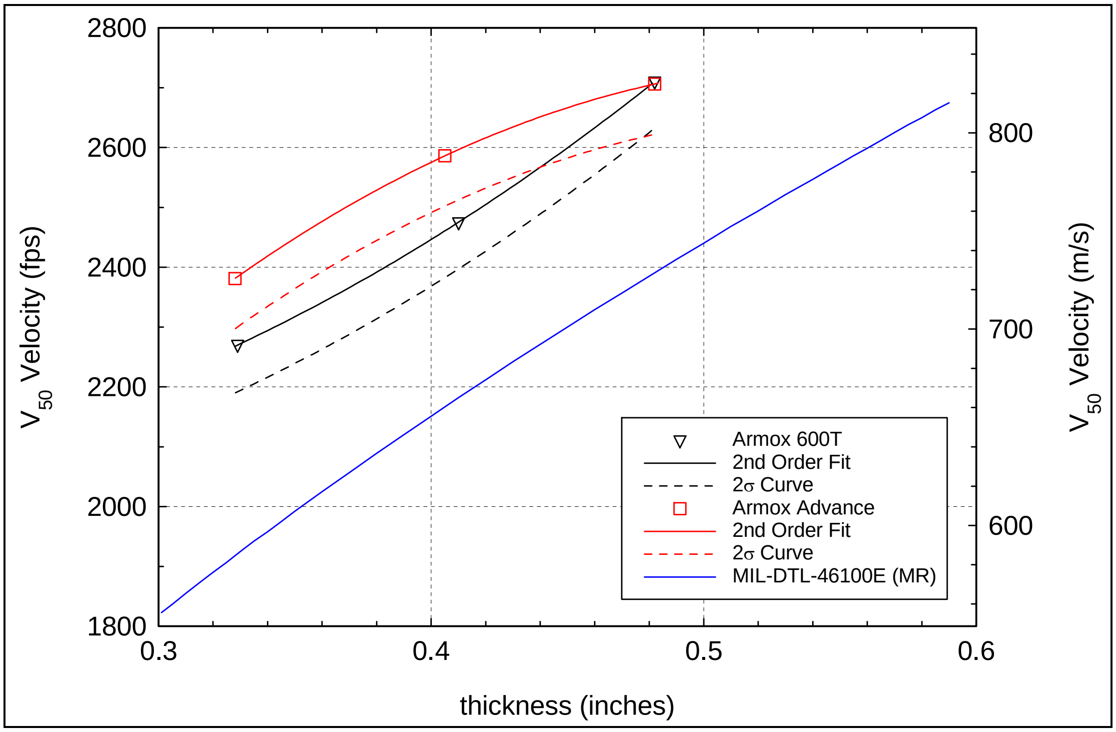

Figure 4. ARMOX 600T and ARMOX ADVANCE plate thickness vs. V_{50} velocity for the 0.50-cal. APM2 at 30° obliquity.

The ballistic advantage of increased hardness can be seen in figures 3 and 4 where both the ARMOX 600T and ARMOX ADVANCE are significantly better-performing steels than standard high-hard steels. The data points for each thickness are plotted, and a second order fit to the data is shown in the solid lines. The solid lines at the bottom of the graphs are also second order fits that define the acceptance velocities under MIL-DTL-46100E for the respective thickness. These lines already incorporate ~2σ reduction, which provides an acceptable variance to allow the high-hard plate to meet the specification. Therefore, the best direct comparisons to the baseline high-hard acceptance lines are the dashed 2σ lines of the ARMOX 600T and ARMOX ADVANCE plates over the thickness range tested.

The 0.30-cal. data for both ARMOX steels of figure 3 show a performance inflection in the data at the 4.8-mm thickness and equivalent performance at 8-mm thicknesses. The 4.8-mm data point probably results from projectile diameter/thickness effects on the plugging mechanism, and the equivalent performance at 8 mm probably results from a minimum hardness needed to stop the projectile when the projectile diameter and plate thickness are similar. The ARMOX ADVANCE is statistically better than the ARMOX 600T in the thickness range of 5, 6, and 7 mm. The ARMOX ADVANCE exhibited some cracking during testing, but the test plates were only 305 mm (12 in) wide, and cracking originated from the cut edges.

The 0.50-cal. data of figure 4 consisted of only three thicknesses and showed the same equivalence at the 12-mm thickness where the projectile diameter approaches the plate thickness.

Both showed significant increased performance over the baseline MIL-DTL-46100 high-hard steel. Some cracking was also noted from the 305-mm (12-in)-wide test plates; this can be eliminated by proper edge treatment after cutting.

6. Conclusions

This report has documented the increased performance that results from increased plate hardness. Both the ARMOX 600T and ARMOX ADVANCE plates showed significant ballistic performance increases in the thickness range tested over standard MIL-DTL-46100E high-hardness plate. This data will form part of the ballistic data that will be used to create a new US steel specification for UHH steel plate. The specification will include two classes of hardness that will cover the hardness range from 513 to over 650 BHN. This new class of ultra-hard steel plates will increase the metallic armor technologies available to armor designers.

7. References

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6. SSAB Data Sheet, ARMOX 600T, Version 2007-10-1. Swedish Steel Oxelösund AB, Sweden, 2007.

7. SSAB Data Sheet, ARMOX ADVANCE, Version 2007-10-1. Swedish Steel Oxelösund AB, Sweden, 2007.

8. MIL-STD-662F. *V50 Ballistic Test for Armor* **1997**.

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Appendix A. ARMOX ADVANCE Photographs

(a) (b)

Figure A-1. ARMOX ADVANCE (0.30 cal.): 4.8 mm (a) front and (b) back.

(a) (b)

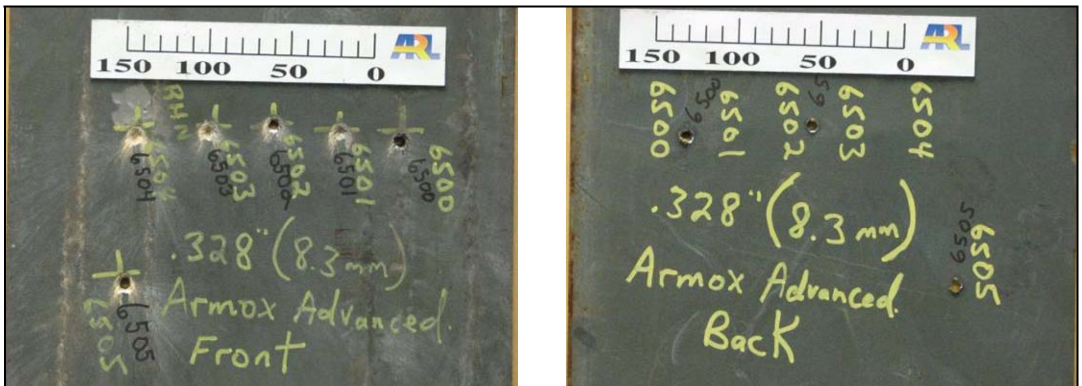
Figure A-2. ARMOX ADVANCE (0.30 cal.): 5 mm (a) front and (b) back.

(a) (b)

Figure A-3. ARMOX ADVANCE (0.30 cal.): 6 mm (a) front and (b) back.

(a) (b)

Figure A-4. ARMOX ADVANCE (0.30 cal.): 7 mm (a) front and (b) back.

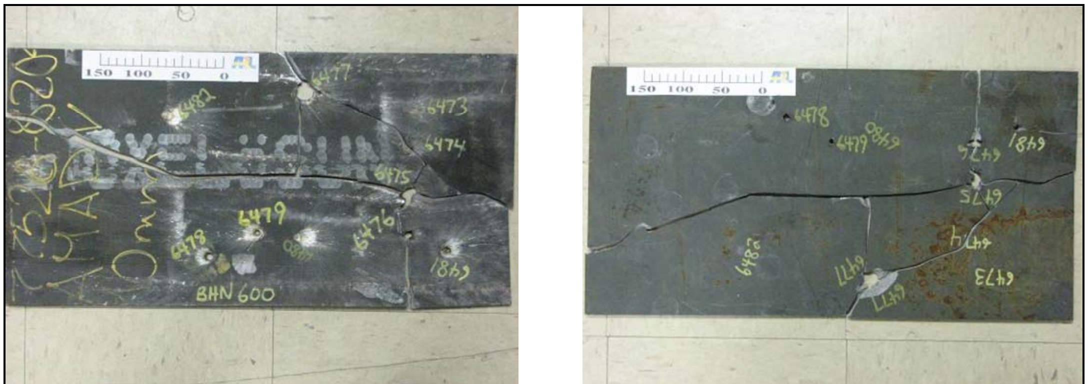


(a) (b)

Figure A-5. ARMOX ADVANCE (0.30 cal.): 8 mm (a) front and (b) back.

(a) (b)

Figure A-6. ARMOX ADVANCE (0.50 cal.): 8 mm (a) front and (b) back.



(a) (b)

Figure A-7. ARMOX ADVANCE (0.50 cal.): 10 mm (a) front and (b) back.

(a) (b)

Figure A-8. ARMOX ADVANCE (0.50 cal.): 12 mm (a) front and (b) back.

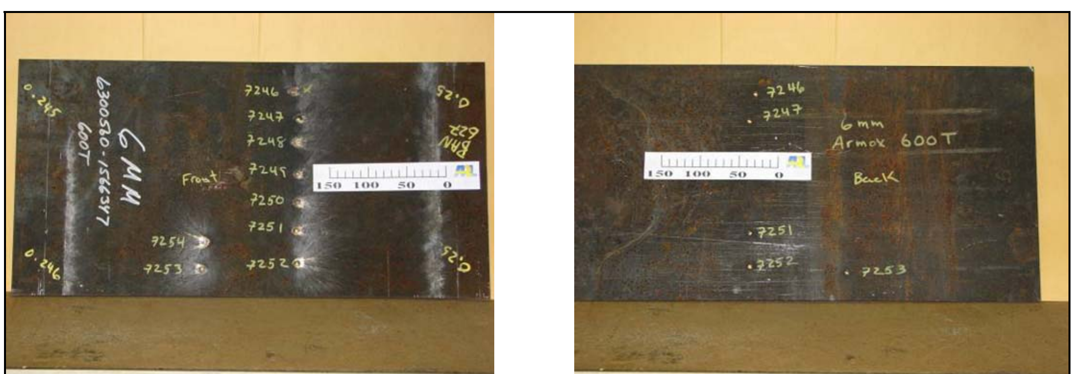
Appendix B. ARMOX 600T Photographs

(a) (b)

Figure B-1. ARMOX 600T (0.30 cal.): 4.8 mm (a) front and (b) back.

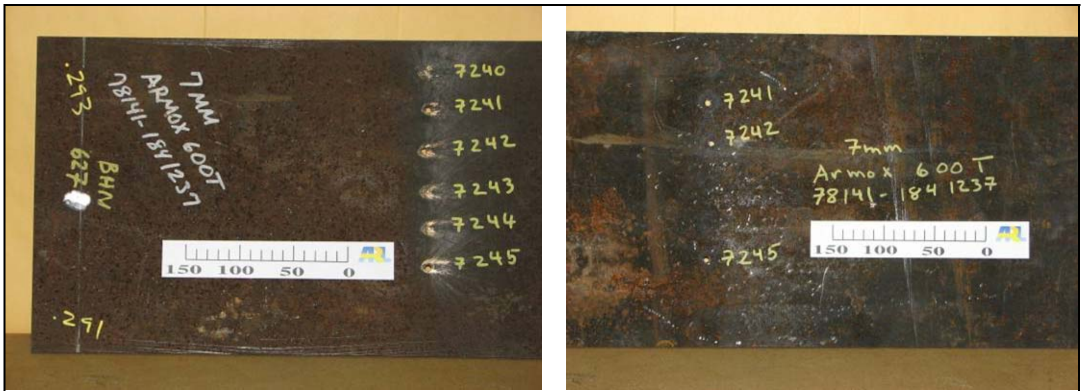
(a) (b)

Figure B-2. ARMOX 600T (0.30 cal.): 5 mm (a) front and (b) back.



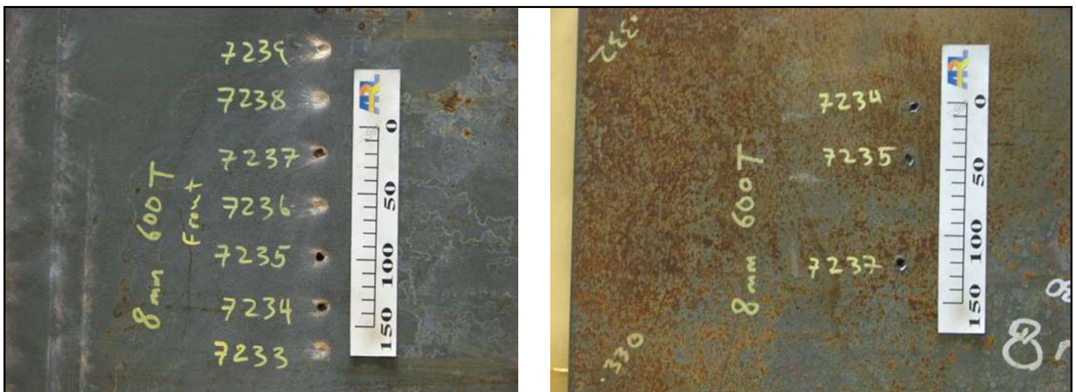
(a) (b)

Figure B-3. ARMOX 600T (0.30 cal.): 6 mm (a) front and (b) back.



(a) (b)

Figure B-4. ARMOX 600T (0.30 cal.): 7 mm (a) front and (b) back.



(a) (b)

Figure B-5. ARMOX 600T (0.30 cal.): 8 mm (a) front and (b) back.

(a) (b)

Figure B-6. ARMOX 600T (0.50 cal.): 8 mm (a) front and (b) back.

(a) (b)

Figure B-7. ARMOX 600T (0.50 cal.): 10 mm (a) front and (b) back.

(a) (b)

Figure B-8. ARMOX 600T (0.50 cal.): 12 mm (a) front and (b) back.

Appendix C. Data Sheets

This appendix appears in its original form, without editorial change.

Plate Type:	Armox Advance
Nominal Thickness (mm)	4.8
Nominal Thickness (in)	0.189
Measured Thick. (in)	0.178
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	14-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6490	1916	584	PP
6491	2033	620	PP+
6492	2128	649	CP
6493	2091	638	PP-
6494	2161	659	PP
6495	2139	652	PP-
6496	2169	661	PP+
6497	2249	686	CP-
6498	2180	665	PP
6499	2232	680	PP

Low CP	2128
High PP	2180

	(ft/s)	m/s
V50	2187	667
Std Dev	46	14
Vel Spread	121	37
ZMR	52	16

Plate Type:	Armox Advance
Nominal Thickness (mm)	5
Nominal Thickness (in)	0.197
Measured Thick. (in)	0.212
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	15-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6506	2222	677	PP
6507	2366	721	PP
6508	2470	753	PP
6509	2592	790	PP-
6510	2726	831	CP+
6511	2679	817	PP-
6512	2726	831	CP+
6513	2741	836	CP+
6514	2655	809	PP-

Low CP	2726
High PP	2679

	(ft/s)	m/s
V50	2687	819
Std Dev	57	17
Vel Spread	149	45
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	6
Nominal Thickness (in)	0.236
Measured Thick. (in)	0.252
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	16-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6523	2778	847	PP-
6524	2880	878	CP+
6525	2843	867	CP+
6526	2820	860	CP+
6527	2780	848	PP-
6528	2769	844	PP-

Low CP	2820
High PP	2780

	(ft/s)	m/s
V50	2812	857
Std Dev	44	13
Vel Spread	111	34
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	7
Nominal Thickness (in)	0.276
Measured Thick. (in)	0.289
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	19-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6529	2893	882	PP-
6530	2920	890	PP-
6532	2971	906	PP-
6532	3040	927	CP+
6533	3013	919	CP+
6534	2990	912	CP+

Low CP	2990
High PP	2971

	(ft/s)	m/s
V50	2971	906
Std Dev	56	17
Vel Spread	147	45
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	8
Nominal Thickness (in)	0.315
Measured Thick. (in)	0.328
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	15-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6500	2990	912	CP +
6501	2871	875	PP -
6502	2926	892	CP +
6503	2910	887	PP -
6504	2918	890	PP -
6505	2953	900	CP +

Low CP	2926
High PP	2918

	(ft/s)	m/s
V50	2928	893
Std Dev	40	12
Vel Spread	119	36
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	8
Nominal Thickness (in)	0.315
Measured Thick. (in)	0.328
BHN	578
Penetrator:	.50 AP M2
Obliquity:	30
Date:	6-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6456	2188	667	PP
6457	2369	722	PP-
6458	2509	765	CP
6459	2409	734	CP+
6460	2389	728	PP-
6461	2415	736	CP+
6462	2391	729	CP+
6463	2315	706	PP-

Low CP	2391
High PP	2389

	(ft/s)	m/s
V50	2381	726
Std Dev	36	11
Vel Spread	100	30
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	10
Nominal Thickness (in)	0.394
Measured Thick. (in)	0.405
BHN	600
Penetrator:	.50 AP M2
Obliquity:	30
Date:	12-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6473	2507	764	PP
6474	2582	787	PP-
6475	2741	836	CP
6476	2709	826	CP
6477	2665	813	CP
6478	2662	812	CP+
6479	2596	791	CP+
6480	2552	778	PP-
6481	2598	792	CP+
6482	2523	769	PP-

Low CP	2596
High PP	2582

	(ft/s)	m/s
V50	2586	788
Std Dev	47	14
Vel Spread	139	42
ZMR	0	0

Plate Type:	Armox Advance
Nominal Thickness (mm)	12
Nominal Thickness (in)	0.472
Measured Thick. (in)	0.482
BHN	600
Penetrator:	.50 AP M2
Obliquity:	30
Date:	2-May-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6448	2497	761	PP
6449	2640	805	PP-
6450	2840	866	CP
6451	2729	832	CP+
6452	2697	822	PP-
6453	2730	832	CP+
6454	2677	816	PP-
6455	2762	842	CP+

Low CP	2596
High PP	2582

	(ft/s)	m/s
V50	2586	788
Std Dev	47	14
Vel Spread	139	42
ZMR	0	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	6
Nominal Thickness (in)	0.236
Measured Thick. (in)	0.249
BHN	627
Penetrator:	.30 AP M2
Obliquity:	30
Date:	1-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
7246	2712	827	CP
7247	2620	799	CP
7248	2440	744	PP
7249	2540	774	PP-
7250	2586	788	PP-
7251	2603	794	CP+
7252	2594	791	CP+
7253	2540	774	CP+
7254	2527	770	PP-

Low CP	2540
High PP	2586

	(ft/s)	m/s
V50	2565	782
Std Dev	33	10
Vel Spread	76	23
ZMR	46	14

Plate Type:	Armox 600T
Nominal Thickness (mm)	4.8
Nominal Thickness (in)	0.189
Measured Thick. (in)	0.178
BHN	627
Penetrator:	.30 AP M2
Obliquity:	30
Date:	6-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
7261	2333	711	PP-
7262	2437	743	CP+
7263	2384	727	CP+
7264	2320	707	PP-
7265	2355	718	PP-
7266	2402	732	CP+

Low CP	2384
High PP	2355

	(ft/s)	m/s
V50	2372	723
Std Dev	44	13
Vel Spread	117	36
ZMR	0	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	5
Nominal Thickness (in)	0.197
Measured Thick. (in)	0.215
BHN	627
Penetrator:	.30 AP M2
Obliquity:	30
Date:	7-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
7255	2439	744	PP-
7256	2481	756	PP-
7257	2573	784	CP+
7258	2523	769	CP+
7259	2501	763	CP+
7260	2449	747	PP-

Low CP	2501	
High PP	2481	
	(ft/s)	m/s
V50	2494	760
Std Dev	50	15
Vel Spread	134	41
ZMR	0	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	7
Nominal Thickness (in)	0.276
Measured Thick. (in)	0.292
BHN	627
Penetrator:	.30 AP M2
Obliquity:	30
Date:	1-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
7240	2770	845	PP-
7241	2911	888	CP+
7242	2864	873	CP+
7243	2801	854	PP-
7244	2808	856	PP-
7245	2840	866	CP+

Low CP	2840
High PP	2808

	(ft/s)	m/s
V50	2832	863
Std Dev	50	15
Vel Spread	141	43
ZMR	0	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	8
Nominal Thickness (in)	0.315
Measured Thick. (in)	0.329
BHN	600
Penetrator:	.30 AP M2
Obliquity:	30
Date:	30-Jun-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
7233	2790	851	PP
7234	2991	912	CP+
7235	2961	903	CP+
7236	2879	878	PP-
7237	2927	892	CP+
7238	2928	893	PP-
7239	2866	874	PP-

Low CP	2927	
High PP	2928	
	(ft/s)	m/s
V50	2925	892
Std Dev	47	14
Vel Spread	125	38
ZMR	1	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	8
Nominal Thickness (in)	0.315
Measured Thick. (in)	0.329
BHN	600
Penetrator:	.50 AP M2
Obliquity:	30
Date:	1-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6765	2227	679	PP-
6766	2273	693	CP+
6767	2247	685	PP-
6768	2303	702	CP+
6769	2280	695	PP-
6770	2291	698	CP+

Low CP	2273
High PP	2280

	(ft/s)	m/s
V50	2270	692
Std Dev	28	9
Vel Spread	76	23
ZMR	7	2

Plate Type:	Armox 600T
Nominal Thickness (mm)	10
Nominal Thickness (in)	0.394
Measured Thick. (in)	0.41
BHN	600
Penetrator:	.50 AP M2
Obliquity:	30
Date:	1-Jul-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6759	2425	739	PP-
6760	2540	774	CP+
6761	2508	765	CP+
6762	2465	752	PP-
6763	2473	754	CP+
6764	2441	744	PP-

BHN	600
Low CP	2473
High PP	2465

	(ft/s)	m/s
V50	2475	755
Std Dev	43	13
Vel Spread	115	35
ZMR	0	0

Plate Type:	Armox 600T
Nominal Thickness (mm)	12
Nominal Thickness (in)	0.472
Measured Thick. (in)	0.482
BHN	578
Penetrator:	.50 AP M2
Obliquity:	30
Date:	19-Jun-08

Shot #	Velocity (ft/s)	Velocity (m/s)	Result
6708	2735	834	CP+
6709	2633	803	PP-
6710	2682	818	PP-
6711	2713	827	PP-
6712	2768	844	CP+
6713	2729	832	CP+

Low CP	2729
High PP	2713

	(ft/s)	m/s
V50	2710	826
Std Dev	47	14
Vel Spread	135	41
ZMR	0	0

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