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MEMORANDUM REPORT

NO. WAL 710/908
O.O. Sub-Project No. TB4-150M

Metallurgical Examination of 2", 2-1/2", and 3" Rolled Homogeneous Armor Employed in the Ballistic Evaluation of Armor Against 57 mm and 90 mm Armor-Piercing Projectiles

BY

W. P. Hatch
Phys. Science Aide

DATE 24 August 1949

WATERTOWN ARSENAL
WATERTOWN, MASS.

TITLE

Metallurgical Examination of 2", 2-1/2", and 3" Rolled Homogeneous Armor Employed in the Ballistic Evaluation of Armor Against 57 mm and 90 mm Armor-Piercing Projectiles

Report Number: 710/908

O.O. Sub-Project Number: TB4-1508

WATERTOWN ARSENAL LABORATORY

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Title of OO Sub-Project:	Comparative Evaluation of Armor for Protection Against 57 mm and 90 mm Armor-Piercing Ammunition	
WAL Project No.:	8.190	

TITLE

Metallurgical Examination of 2", 2-1/2", and 3" Rolled Homogeneous Armor Employed in the Ballistic Evaluation of Armor Against 57 mm and 90 mm Armor-Piercing Projectiles

OBJECT

To determine the metallurgical properties of rolled homogeneous armor plates of various hardnesses and thicknesses which were employed in the investigation of the performance of armor against 57 mm and 90 mm armor-piercing projectiles.

SUMMARY

A metallurgical examination including Brinell hardness surveys, fracture tests for fibre and soundness, and V-notch Charpy impact tests were made on 2", 2-1/2", and 3" thick rolled homogeneous armor. The plates were heat treated at Watertown Arsenal to hardnesses in the range of 250-400 Brinell and were ballistically tested at Aberdeen Proving Ground in order to determine the effect of thickness, hardness, and obliquity on the ballistic efficiency of rolled homogeneous armor against attack by 57 mm and 90 mm armor-piercing projectiles.

Cross-sectional Brinell hardness tests have been made on each plate and averaged for use in correlating the results of ballistic tests with hardness. At the same time, the soundness and toughness of the plates have been evaluated and found to possess adequate metallurgical properties commensurate with their hardnesses.

CONCLUSIONS

1. The results of surface hardness determinations made at Aberdeen Proving Ground and cross-sectional hardness surveys made at Watertown Arsenal are listed in Table IV. The great majority of the plates were heat treated to within 20 points Brinell of the desired hardnesses.

2. Steel soundness fracture tests showed that all plates, with but one exception, are of acceptable soundness according to the requirements of U. S. Army Specification No. 57-115-11, Amendment 2. Plate No. 3-6, having a D-2 steel soundness rating, is borderline rejectable according to the above specification.

3. Notched-bar impact tests conducted on a selected number of plates indicated that the armor responded properly to heat treatment. All plates tested met the notched-bar impact requirements of U.S. Army Specification No. 57-115-11, Amendment 2.

W. P. Hatch

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APPROVED:

J. L. MARTIN
Director of Laboratory

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INTRODUCTION

A metallurgical examination has been conducted on 2", 2-1/2", and 3" thick armor plates which had been heat treated at the Watertown Arsenal and ballistically tested at Aberdeen Proving Ground under O.O. Sub-Project TB4-150M, "Comparative Evaluation of Armor for Protection Against 57 mm and 90 mm Armor-Piercing Ammunition."

At the request of this Arsenal[1], Aberdeen Proving Ground provided 8" x 12" sections cut from a corner of each plate after the completion of the ballistic testing. The post-ballistic examination of the plates was initiated to evaluate the metallurgical properties of the subject armor in order to establish accurate data for the correlation of their metallurgical and ballistic properties. When all of the phases have been completed a final report will be written covering both the metallurgical and ballistic results.

A summary of the ballistic results obtained from the testing of the subject plates is listed in Table II to acquaint the reader with the ballistic properties of the armor. This summary was taken from Aberdeen Proving Ground Report No. AD-1115, "Report on Test to Assess the Performance of Various Types of Armor Against 57 mm and 90 mm Armor-Piercing Ammunition to Provide Armored Vehicle Design Data."

MATERIALS AND TEST PROCEDURE

The plates used in this investigation were of the following compositions:[2]

Thickness of Plate	Chemical Analysis				
	C	Mn	Ni	Cr	Mo
2"	.31	1.4	.05	.55	.44
2-1/2"	.29	1.84	.05	--	.51
3"	.29	1.49	.72	.75	.41

The identification and sizes of the ballistic test plates are as follows:

Plate No.	Thickness	Size
2-1 to 2-10	2"	51" x 52"
25-1 to 25-16	2-1/2"	40" x 52"
3-1 to 3-27 and 3-34	3"	54" x 68

[1] Letter file WTN 400.112/4969, dated 12 January 1949, Appendix A.
[2] Data taken from APG report No. AD-1115.

Prior to heat treating the ballistic test plates, a series of preliminary heat treatments had been conducted on relatively small coupons (3 to 4 sq. ft. in area) cut from some of the excess 2", 2-1/2", and 3" thick plates. After the proper heat-treating cycles had been satisfactorily determined so that it was possible to obtain desired hardnesses in the range of 250-400 Brinell, the ballistic test plates were heat treated and shipped to Aberdeen Proving Ground. Details of the heat-treating cycles are given in Table I.

After the ballistic testing was completed, 8" x 12" sections were flame-cut from the corners of the plates and were shipped to Watertown Arsenal for metallurgical examination.

The metallurgical examination of these plates consisted of the following tests:

a. Cross-sectional Brinell hardness surveys on all plates.
b. Steel soundness and fibre fracture tests on all plates.
c. V-notch Charpy impact tests at -40° F. on selected plates.

DATA AND DISCUSSION

Fracture Tests

The 8" x 12" samples received from Aberdeen Proving Ground were notched by flame-cutting in from the middle of the two long sides leaving a cross-section approximately T x T* in area to be fractured. The 2" thick samples were fractured by impact under a forge hammer while the 2-1/2" and 3" thick samples were broken by a falling weight mechanism. The fractured surfaces of all samples were rated both for fibre and steel soundness; the steel soundness ratings being made only in those cases where the fractures were completely fibrous. It is not possible to obtain an accurate steel soundness rating on completely or partially brittle (crystalline) fractures because the laminations do not open up when the fracture proceeds with low energy absorption as is the case in brittle fracture.

The results of the fibre and steel soundness ratings are given in Table III. As shown by the results of the fracture test for steel soundness, the steels used for the subject plates are of acceptable soundness under the requirements of U. S. Army Specification No. 57-115-11, Amendment 2, with the exception of Plate No. 3-6. The D-2 steel soundness rating of this plate is considered borderline rejectable.

The 2" thick plates showed essentially fibrous fractures up to hardnesses of approximately 310 Brinell while at higher hardnesses the fractures of the 2" thick plates showed increasing amounts of crystallinity.

* T = thickness

The 2-1/2" and 3" thick plates showed essentially fibrous fractures up to hardnesses of approximately 360 Brinell. The plates having hardnesses in the range of 360-400 Brinell have more or less completely crystalline fractures (low toughness) which is to be expected at this high hardness range.

Brinell Hardness Surveys

A slice was cut from each fracture specimen. Three Brinell impressions were taken on a cross section of the 2-inch samples and five Brinell impressions were taken on a cross-section of the 2-1/2" and 3" thick samples. The results of the hardness survey are given in Table IV. The hardnesses at the center of the samples are, in general, somewhat lower than the surface hardnesses; the greatest variation occurring in plates 2-6, 2-8, 2-9, 25-5 and 25-6 which exhibit a difference of about 30 to 40 points Brinell. The difference between the aim hardness and the actual hardness of individual plates is sufficient to require individual plate hardness in correlating hardness and ballistic results. In most cases, however, the average cross-sectional hardnesses of the plates were within 20 points Brinell of the aim hardnesses.

The surface hardness of the plates had been measured at Aberdeen Proving Ground by means of a portable Brinell tester, reference APG Report AD-1115, Appendix B. The portable Brinell tester does not, however, yield results as reliable as those obtained by the standard Brinell machine, in addition to which surface hardness readings may often be in error due to surface decarburization. Since the ballistic performance of armor is influenced by hardness, and since projectiles, in penetrating armor, pass completely through the thickness of the plate, it is believed that the average cross-sectional hardness of the armor should be employed when attempting to correlate the ballistic and mechanical properties of armor. Table IV presents data covering the surface hardness tests conducted at Aberdeen Proving Ground and the cross-sectional hardness tests conducted at the Watertown Arsenal. It is recommended that the latter hardness values be used in assessing the ballistic performance of rolled homogeneous armor as a function of hardness.

V-Notch Charpy Impact Tests

Notched-bar impact tests were conducted on samples cut from the center of the cross-section of selected plates of various thicknesses and hardnesses. The tests were conducted at -40° F. in accordance with the impact test requirements of U. S. Army Specification No. 57-115-11, Amendment 2, and the results are presented in Table VI. Table VI also includes the results of Rockwell C hardness tests conducted on the Charpy impact test specimen, the conversion of the Rc hardnesses to Brinell, the pertinent impact energy requirements of the above specification, and the ratings of the fractures of the impact test specimens.

The results of the V-notch Charpy impact tests indicate an acceptable response to heat treatment in these plates. Rated in accordance with Table IV of U. S. Army Specification No. 57-115-11, Amendment 2, for rolled homogeneous steel armor plate, all of the samples exceeded the minimum specification requirements. The low impact values obtained on the samples in the hardness range of 360-400 Brinell are consistent with the results of the fibre fracture test in which the materials fractured in a brittle manner. However, it should be noted that the energy values for these high hardness plates exceeded the specification values required for lighter gage plate of these hardnesses.

GENERAL CONSIDERATIONS

The subject armor was found to be of acceptable metallurgical quality except for one plate of borderline rejectable steel soundness. If this one plate did not back-spall because of poor soundness during ballistic testing, it may be concluded that the ballistic properties of all the subject armor plates accurately reflect the ballistic performance of good quality armor of the various thicknesses and hardnesses employed for the investigation being undertaken under O.O. Sub-Project TB4-150M.

TABLE I

Heat Treatment of 2", 2-1/2", and 3" Armor

Plate No.	Aim Hardness BHN	Austenitizing Temp.°F.	Austenitizing Time (hrs.)	Austenitizing Coolant	Tempering Temp.°F.	Tempering Time (hrs.)*	Tempering Coolant
2-1 2-2 2-3 2-4 2-5	320	1650	2	H_2O	1100	2	H_2O
2-6 2-7 2-8 2-9 2-10	360	1650	2	H_2O	1000	2	H_2O
25-1 25-2 25-3 25-4 25-5	320	1650	2	H_2O	1100	2-1/2	H_2O
25-6 25-7 25-8 25-9 25-10	360	1650	2	H_2O	1000	2-1/4	H_2O
25-11 25-12 25-13	320	1650	2	H_2O	1100	2-1/2	H_2O
25-14 25-15 25-16	360	1650	2	H_2O	1000	2-1/4	H_2O

* All plates charged into hot furnaces except as noted by ** and held in furnaces for total time indicated.

TABLE I (cont.)

Heat Treatment of 2", 2-1/2", and 3" Armor

Plate No.	Aim Hardness BHN	Austenitizing Temp. °F.	Austenitizing Time (hrs.)	Cool-ant	Tempering Temp. °F.	Tempering Time (hrs.)*	Cool-ant
3-1 3-2 3-3 3-4 3-5 3-6 3-7	280	1650	2	H_2O	1125	4**	H_2O
3-8 3-9 3-10 3-11 3-12 3-13 3-14	320	1650	2	H_2O	1100	2-1/2	H_2O
3-15 3-16 3-17 3-18 3-19	360	1650	2	H_2O	1000	2-1/2	H_2O
3-20 3-21 3-22 3-23 3-24	400	1650	2	H_2O	900	2-1/2	H_2O
3-25	280	1650	2	H_2O	1125	4**	H_2O
3-26	320	1650	2	H_2O	1100	2-1/2	H_2O
3-27	360	1650	2	H_2O	1000	2-1/2	H_2O
3-34	400	1650	2	H_2O	900	2-1/2	H_2O

** Plates charged into cold furnace, time represents total time plate was at tempering heat. Plates required approximately 2 hrs. to reach tempering temperature.

TABLE II

Ballistic Results of 2", 2-1/2", and 3" Armor
Against 57 mm and 90 mm Projectiles

Plate No.	Thickness Inches	Obliquity Degrees	Brinell Hardness*	Low B.L.** Army ft/sec	Projectile Condition***
Tests Against 57 mm APC M86 Projectiles					
2-2	2.01	50	285	2526	I
2-4	2.03	50	315	2616	I
2-5	2.01	50	277	2450	I
2-6	2.02	50	328	2483	I
2-8	2.01	50	331	2473	I
25-3	2.49	50	321	2696 HP	I
25-3	2.49	45	321	2695 HP	I
25-6	2.54	45	331	2692 HP	S
25-1	2.48	40	327	2558	I
25-2	2.49	40	321	2590	I
25-6	2.54	40	331	2565	S
25-9	2.53	40	341	2580	I
25-13	2.53	40	309	2426	I
25-14	2.52	40	331	2521	S
3-7	3.02	40	300	2735 HP	I
3-19	3.03	40	363	2779 HP	S
3-24	[illegible]	40	391	2718	S

* - Average cross section hardness obtained at Watertown Arsenal as result of subject investigation.

** - Low Ballistic Limit is the mean between the lowest complete penetration and the highest partial penetration below this complete. Three partial penetrations within 50 ft/sec below the low complete penetration were obtained to confirm this value.

*** - I = Intact
S = Shattered.

HP - High Partial Penetration, ballistic limit above muzzle velocity of gun.

TABLE II (cont.)

Ballistic Results of 2", 2-1/2", and 3" Armor
Against 57 mm and 90 mm Projectiles

Plate No.	Thickness Inches	Obliquity Degrees	Brinell Hardness*	Low B.L.** Army ft/sec	Projectile Condition***
Tests Against 57 mm APC M86 Projectiles (cont.)					
3-6	3.02	35	288	2679	I
3-7	3.02	35	300	2702	I
3-8	3.04	35	319	2779 HP	S
3-11	2.97	35	304	2688	I
3-16	3.01	35	363	2812 HP	S
3-19	3.03	35	363	2718 HP	S
3-20	3.02	35	391	2592	S
3-24	3.01	35	391	2634	S
3-26	3.01	35	311	2707	I
3-27	3.02	35	363	2737	S
3-4	3.00	30	283	2399	I
3-6	3.02	30	288	2385	I
3-8	3.04	30	319	2526	I
3-11	2.97	30	304	2446	I
3-15	3.00	30	363	2609	S
3-16	3.01	30	363	2697	S
3-20	3.02	30	391	2464	S
3-22	3.03	30	388	2515	S
3-26	3.01	30	311	2562	I
3-27	3.02	30	363	2607	S
Tests Against 57 mm AP M70 Projectiles					
2-1	2.02	50	302	2357	S
2-3	2.02	50	305	2417	S
2-7	2.01	50	338	2328	S
2-9	2.02	50	325	2159	S
2-10	2.01	50	324	2226	S
25-1	2.48	50	327	2612	S
25-4	2.50	50	317	2713	S
25-7	2.50	50	363	2693	S
25-8	2 52	50	361	2595	S
25-4	2.50	40	317	2239	S
25-5	2.53	40	312	2254	S
25-7	2.50	40	363	2264	S
25-10	2.52	40	339	2227	S

TABLE II (cont.)

Ballistic Results of 2", 2-1/2", and 3" Armor
Against 57 mm and 90 mm Projectiles

Plate No.	Thickness Inches	Obliquity Degrees	Brinell Hardness*	Low B.L.** Army ft/sec	Projectile Condition***
Tests Against 57 mm AP M70 Projectiles (cont.)					
3-1	3.03	40	288	2963 HP	S
3-10	3.00	40	297	2888	S
3-17	3.03	40	385	2581	S
3-21	3.02	40	388	2583	S
3-25	3.02	40	295	3003 HP	S
3-26	3.01	40	311	2951 HP	S
3-27	3.02	40	363	2703	S
3-34	3.00	40	412	2566	S
3-1	3.03	35	288	2866	S
3-4	3.00	35	283	2884	S
3-10	3.00	35	297	2647	S
3-11	2.97	35	304	2746	S
3-18	3.03	35	370	2479	S
3-19	3.03	35	363	2511	S
3-21	3.02	35	388	2525	S
3-23	3.00	35	388	2466	S
3-1	3.03	30	288	2654	S
3-4	3.00	30	283	2764	S
3-8	3.04	30	319	2651	S
3-12	2.98	30	308	2524	S
3-18	3.03	30	370	2463	S
3-19	3.03	30	363	2480	S
3-21	3.02	30	388	2443	S
3-23	3.00	30	388	2333	S
3-25	3.02	30	295	2757	S
3-26	3.01	30	311	2699	S
3-34	3.00	30	412	2334	S
Tests Against 90 mm APC T39 Projectiles					
3-2	3.01	55	290	2638	S
3-3	3.00	55	300	2639	S
3-5	3.01	55	295	2709	S
3-9	3.02	55	309	2531	S
3-13	3.00	55	306	2494	S
3-14	3.00	55	329	2529	S

TABLE III

Results of Fracture Tests for Fibre and Steel Soundness

Plate No.	Average Cross-Sectional Hardness — BHN	Fibre Rating	Steel Soundness Rating
2-1	302	Fc 10	B-woody
2-2	285	F	B
2-3	305	Fc trace	C
2-4	315	Fc 40	Indeterminate
2-5	277	Fc 20	C-woody
2-6	328	Fc 50	Indeterminate
2-7	338	Fc 80	Indeterminate
2-8	331	Cfc	Indeterminate
2-9	325	Fc 50	C-woody
2-10	324	Fc 80	Indeterminate
25-1	327	F	C
25-2	321	F	B
25-3	321	F	C
25-4	317	F	C
25-5	312	F	C
25-6	331	F	D-1
25-7	363	F	D-1
25-8	361	F	D-1
25-9	341	F	C
25-10	339	F	C
25-11	335	F	C
25-12	300	F	C
25-13	309	F	C
25-14	331	Fc 50	Indeterminate
25-15	370	Cfc	Indeterminate
25-16	363	Fc 50	Indeterminate
3-1	288	F	C
3-2	290	F	C
3-3	300	F	B
3-4	283	F	B
3-5	295	F	C

TABLE III (cont.)

Results of Fracture Tests for Fibre and Steel Soundness

Plate No.	Average Cross-Sectional Hardness — BHN	Fibre Rating	Steel Soundness Rating
3-6	288	F	B-2
3-7	300	F	B
3-8	319	F	B
3-9	309	F	C
3-10	297	F	C
3-11	304	F	B
3-12	308	F	B
3-13	306	F	B
3-14	329	F	B
3-15	363	Fc trace	B
3-16	363	Fc trace	B
3-17	385	Cfe (D)	Indeterminate
3-18	370	Cfe (D)	Indeterminate
3-19	363	Cfe (D)	Indeterminate
3-20	391	Cfe	Indeterminate
3-21	388	Cfe	Indeterminate
3-22	388	Cfe	Indeterminate
3-23	388	Cfe	Indeterminate
3-24	391	Cfe	Indeterminate
3-25	295	F	B
3-26	311	F	B
3-27	363	Cfe	Indeterminate
3-34	412	C	Indeterminate

F - Fibrous
C - Crystalline
Fc - Mixed fibrous and crystalline
Cfe - Crystalline center and fibrous edge
D - Dull crystalline
Numbers after fracture rating refer to per cent of fracture area which is crystalline.

TABLE IV

Brinell Hardnesses Obtained on Cross-Section of Fracture Blocks

Plate No.	Aim Hardness BHN	Brinell Hardness 3/8" below surface	3/4" below surface	Center of Cross-Section	3/4" below surface	3/8" below surface
2-1	320	302	---	302	---	302
2-2	320	285	---	285	---	285
2-3	320	302	---	302	---	311
2-4	320	321	---	302	---	321
2-5	320	293	---	269	---	269
2-6	360	341	---	302	---	341
2-7	360	341	---	331	---	341
2-8	360	341	---	311	---	341
2-9	360	331	---	302	---	341
2-10	360	331	---	321	---	321
25-1	320	321	331	321	331	331
25-2	320	321	321	321	321	321
25-3	320	321	321	321	321	321
25-4	320	321	321	302	321	321
25-5	320	321	311	285	321	321
25-6	360	331	341	302	341	341
25-7	360	363	363	363	363	363
25-8	360	352	363	363	363	363
25-9	360	341	341	341	341	341
25-10	360	341	341	341	331	341
25-11	320	331	331	331	341	341
25-12	320	302	302	302	293	302
25-13	320	311	311	302	311	311
25-14	360	331	331	321	331	341
25-15	360	363	375	363	375	375
25-16	360	363	363	363	363	363
3-1	280	285	293	285	293	285
3-2	280	302	285	285	285	293
3-3	280	302	302	302	302	293
3-4	280	293	285	269	285	285
3-5	280	285	302	302	302	285
3-6	280	285	293	302	302	293
3-7	280	302	302	293	302	302

TABLE IV (cont.)

Brinell Hardnesses Obtained on Cross-Section of Fracture Blocks

Plate No.	Aim Hardness BHN	Brinell Hardness				
		3/8" below surface	3/4" below surface	Center of Cross-Section	3/4" below surface	3/8" below surface
3-8	320	321	321	311	321	321
3-9	320	311	311	302	311	311
3-10	320	302	293	285	302	302
3-11	320	302	302	311	302	302
3-12	320	302	302	302	321	311
3-13	320	285	302	321	321	302
3-14	320	331	341	331	321	321
3-15	360	363	363	363	363	363
3-16	360	363	363	363	363	363
3-17	360	375	388	388	388	388
3-18	360	363	375	375	375	363
3-19	360	363	363	363	363	363
3-20	400	388	388	400	388	388
3-21	400	388	388	388	388	388
3-22	400	388	388	388	388	388
3-23	400	388	388	388	388	388
3-24	400	388	388	401	388	388
3-25	280	293	293	302	293	293
3-26	320	302	311	321	311	311
3-27	360	363	363	363	363	363
3-34	400	415	415	415	415	401

TABLE V

Results of Hardness Surveys at
Aberdeen Proving Ground and at Watertown Arsenal

Plate No.	Aim Hardness BHN	Average Surface Hardness Determined by APG (Portable BHN)*	Average Cross-Sectional Hardness Determined by Watertown Arsenal BHN
2-1	320	328	302
2-2	320	315	285
2-3	320	308	305
2-4	320	309	315
2-5	320	317	277
2-6	360	339	328
2-7	360	324	338
2-8	360	360	331
2-9	360	333	325
2-10	360	345	324
25-1	320	328	327
25-2	320	326	321
25-3	320	325	321
25-4	320	325	317
25-5	320	324	312
25-6	360	351	331
25-7	360	343	363
25-8	360	347	361
25-9	360	347	341
25-10	360	340	339
25-11	320	326	335
25-12	320	310	300
25-13	320	306	309
25-14	360	320	331
25-15	360	349	370
25-16	360	353	363

* Data from APG Report No. AD-1115.

TABLE V (cont.)

Results of Hardness Surveys at
Aberdeen Proving Ground and at Watertown Arsenal

Plate No.	Aim Hardness BHN	Average Surface Hardness Determined by APG (Portable BHN)*	Average Cross-Sectional Hardness Determined by Watertown Arsenal BHN
3-1	280	289	288
3-2	280	288	290
3-3	280	288	300
3-4	280	302	283
3-5	280	296	295
3-6	280	304	288
3-7	280	297	300
3-8	320	323	319
3-9	320	320	309
3-10	320	315	297
3-11	320	334	304
3-12	320	316	308
3-13	320	315	306
3-14	320	318	329
3-15	360	359	363
3-16	360	351	363
3-17	360	357	355
3-18	360	355	370
3-19	360	372	363
3-20	400	387	391
3-21	400	385	388
3-22	400	388	388
3-23	400	385	388
3-24	400	388	391
3-25	280	283	295
3-26	320	320	311
3-27	360	326	363
3-34	400	405	412

TABLE VI

Results of V-Notch Charpy Impact Tests

Plate No.	Average Plate Hardness BHN	Average Hardness on Charpy Bar Rc	Rockwell* Hardness on Charpy Bars Converted to BHN	Impact Energy ft-lbs	Minimum** Impact Required ft-lbs	Fracture*** Rating % Fibrous
25-2	321	35	337	35.6	20	Fc 20
25-5	312	33	319	48.5	24	Fc 20
25-6	331	33	319	28.1	24	Fc 50
25-7	363	39	375	16.6	14	Fc 55
25-15	370	39	375	16.9	14	Fc 30
3-1	288	28	278	54.1	35	F
3-4	283	27	271	60.7	35	F
3-8	319	31	302	47.7	27	Fc 10
3-10	297	29	286	53.0	35	F
3-15	363	39	375	14.3	14	Fc 85
3-17	385	41	394	13.3	12	Fc 85
3-20	391	42	405	13.6	12	Fc 90
3-21	388	41	394	14.5	12	Fc 85
3-34	412	43	415	13.0	12	Fc 90

* - Conversion from Ordnance Inspection Handbook on Metals, dated 25 July 1947.
** - U.S. Army Specification 57-115-11, Amend. 2, dated 19 Nov 1945.
*** - Mixed fracture; number refers to per cent crystalline.

APPENDIX A

Letter file WTH 400.112/4969

COPY - 24 August 1949 - ahk

War Department
WATERTOWN ARSENAL
Watertown 72, Mass.

RECORD
AHurlich/gt/537

WTN No. 400.112/4969
Attn: Laboratory

12 January 1949

SUBJECT: Hardness Tests on Armor Tested Under O.O. Project TB4-150M

TO: Commanding General
Aberdeen Proving Ground
Aberdeen, Maryland

ATTN: Armor Branch, Mr. H. Rouse

1. It is requested that your station provide this Arsenal with one 12" x 8" section of plate flame-cut from a corner of each of the ballistic test plates which have been employed for the testing scheduled under O.O. Sub-Project TB4-150M.

2. Cross-sectional Brinell hardness tests and other metallurgical tests considered desirable will be performed on these sections in order to accumulate metallurgical data for correlation with the ballistic test results being obtained at your station. These data will be forwarded to your station for inclusion in the reports on the subject program.

FOR THE COMMANDING OFFICER:

(s/t) J. L. MARTIN
Assistant

CC: OCO, ORDTB-Mat'ls

APG 470.5/4
ATTN: ORDBG-DPD
Wtn 400.112/4969

1st Ind

RECORD
Creamer/hlc/5192

Ord Dept, Development & Proof Services, Aberdeen Proving Ground, Maryland, 28 January 1949

TO: Commanding Officer, Watertown Arsenal, Watertown 72, Massachusetts
ATTN: Laboratory

A 12"x8" corner section from each of the twenty-seven 3", sixteen 2-1/2", and ten 2" homogeneous steel plates being tested under Project TB4-150M was shipped to your Arsenal 26 January 1949.

FOR THE COMMANDING GENERAL:

(s) W. M. Tisdale, Lt Col, Ord Dept
(t) for T. F. COLEMAN
Director
Development & Proof Services