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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/344

Metallurgical Examination of Fourteen 3/4 Inch
Rolled Homogeneous Armor Plates Manufactured by
Great Lakes Steel Corporation

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BY
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MEMORANDUM REPORT NO. WAL 710/344

Final Report on Problem B-4.61

14 November 1944

Metallurgical Examination of Fourteen 3/4 Inch

Rolled Homogeneous Armor Plates Manufactured by

Great Lakes Steel Corporation

armor
1. Metallurgical examination, including Brinell hardness surveys, fracture tests for steel soundness and fibre was conducted on each of the fourteen plates furnished by Great Lakes Steel Corporation. Microscopic and macroscopic examinations and chemical analyses were made of selected samples. All the samples except four (^{APG}fractures) were satisfactory with respect to steel soundness. Thirteen of the samples responded to heat treatment satisfactorily as revealed by the fibrous manner in which they fractured. Sample 57 with a Brinell hardness of 388 revealed a mixed fracture.

1. As requested by the Ordnance Research Center¹, metallurgical examination has been completed on sections from fourteen (14), 3/4 inch rolled homogeneous armor plates manufactured by the Great Lakes Steel Corporation and tested at Aberdeen as a part of the effect of hardness program.

2. Metallurgical examination on representative samples included the following tests:

- a. Surface and cross sectional Brinell hardness surveys.
- b. Fracture tests for steel soundness and fibre fracture tests for revealing response to heat treatment.
- c. Chemical analyses.
- d. Macroscopic examination.
- e. Microscopic examination.

1. APG 470.5/740 - Wtn 400.112/3208(r) dated 10 October 1944.

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3. The results of the metallurgical examination are as follows:

a. Brinell hardness. On carefully ground surfaces and cross sections Brinell hardness tests were made. The values reported are based upon the average of five surface and five cross sectional readings, equidistantly spaced through the section. The results are given in Table I. In all cases, the samples were heat treated to a fairly uniform hardness along their respective surfaces and cross sections.

b. Fracture tests for steel soundness and fibre fracture tests for revealing response to heat treatment. On sections $3/4 \times 8 \times 10$ " fracture tests were made on the properly notched sections and then rated with respect to steel soundness and heat treated condition (See Table II for results of tests). With the exception of sample Nos. 70, 169, 171 and 172, the balance of the samples had satisfactory fractures with respect to steel soundness. Completely fibrous fractures were noted in all samples except No. 57 which revealed a mixed fracture.

c. Chemical analyses. The chemical analyses obtained of samples were as follows:

Sample No.	Chemical Composition											
	C	Mn	Si	S	P	Ni	Cr	Mo	Va	Cu	Al	B
68	.30	1.55	.29	.021	.020	N11	.49	.21	Trace	.13	.06	.004
70	.29	1.56	.27	.021	.020	N11	.48	.20	Trace	.12	.06	.004

d. Macroscopic examination. Sections were cut from samples and macroetched in a hot acid solution (50% HCl + 50% H₂O) for fifteen minutes. Sections 63 and 65 were free from nonmetallic inclusions while No. 70 showed evidence of centerline stringer laminations. Nos. 59 and 172 were comparatively clean with some centerline segregation. No. 169 revealed a few scattered nonmetallic inclusions and also exhibited evidence of ingotism.

e. Microscopic examination. Metallographic samples cut from sections of selected plates were examined for nonmetallic inclusion distribution and microstructure. Of those examined No. 172 revealed the highest sulphide nonmetallic inclusion distribution, and some of the stringer type. Near the surface was an alumina stringer. Whereas, in Nos. 70 and 169 which also were comparatively high in nonmetallic inclusion content, the sulphides were smaller although evenly distributed throughout the area. No. 57 was fairly clean.

With the exception of No. 57, the microstructure was an acicular tempered martensite. Sample 57 revealed a finer tempered martensite with evidence of some carbides. (See Figure 1 for typical microstructures).

4. The results of these tests indicate that ten of the samples were satisfactory with respect to steel soundness and all but one, at a Brinell hardness of 388, fractured in a fibrous manner which is indicative of proper heat treatment.

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APPROVED:

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Acting Chief, Armor Section

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TABLE IBrinell Hardness Survey

<u>Sample No.</u>	<u>Surface Hardness, BHN</u>		<u>Cross Section Hardness, BHN</u>	
	<u>Range</u>	<u>Average</u>	<u>Range</u>	<u>Average</u>
57	388-388	388	388-388	388
59	375-388	385	388-401	391
61	363-375	368	375-375	375
63	341-352	350	352-363	359
65	341-341	341	341-341	341
68	321-331	325	321-331	329
69	341-341	341	341-341	341
70	321-331	329	302-331	323
167	285-293	290	293-302	295
168	269-277	275	269-277	272
169	285-293	287	269-285	285
170	269-285	282	285-285	285
171	302-302	302	293-302	297
172	302-302	302	311-311	311

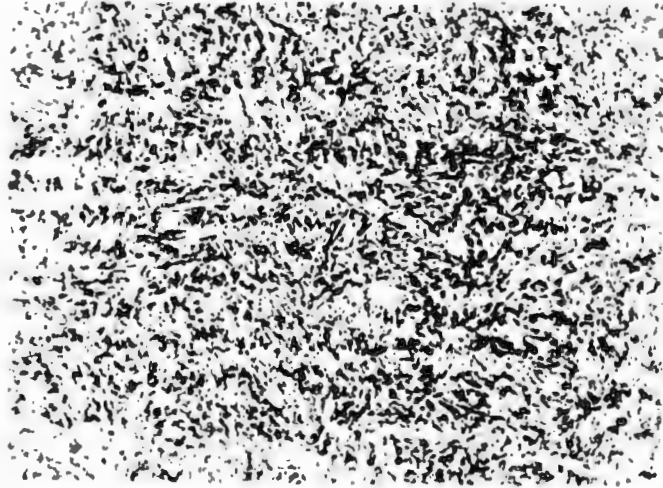
TABLE II

Fracture Test Results

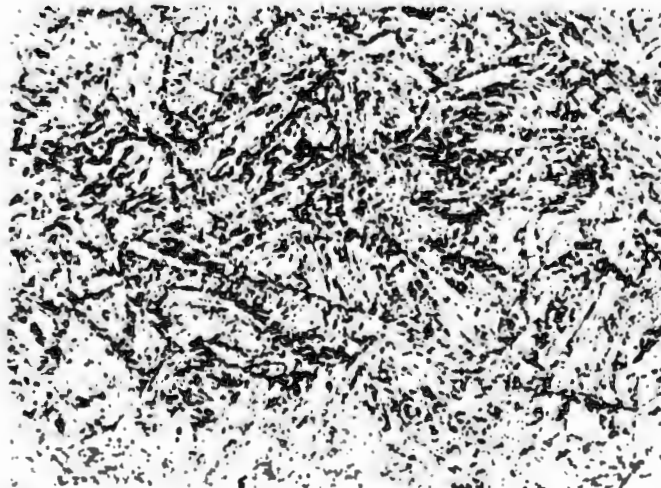
<u>Sample No.</u>	<u>Steel Soundness</u>	<u>Fibre Fracture Test</u>
57	B	Mixed
59	B	Fibrous
61	B	Fibrous
63	B	Fibrous
65	B	Fibrous
68	C	Fibrous
69	B	Fibrous
70	D	Fibrous
167	B	Fibrous
168	B	Fibrous
169	D	Fibrous
170	B	Fibrous
171	D	Fibrous
172	D	Fibrous

Republic Steel Corporation - 3/4 Inch Rolled Armor Plate

Typical Microstructures



X1000 No. 57 Picral
Tempered martensite with evidence of fine
carbides.



X1000 No. 172 Picral
Acicular tempered martensite.