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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/669

Metallurgical Examination of Six 1/2 Inch Rolled Homogeneous Armor Plates Manufactured by Great Lakes Steel Corporation

BY

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Asst. Phy. Sci. Aide

DATE 1 July 1944

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/669

Final Report on Problem B-4.37

1 July 1944

Metallurgical Examination of Six 1/2 Inch Rolled Homogeneous Armor Plates Manufactured by Great Lakes Steel Corporation

ABSTRACT

Metallurgical examination, including Brinell hardness surveys, fracture tests for steel soundness and fibre, and macroetch tests, was conducted on each of the six plates furnished by Great Lakes Steel Corporation. Microscopic examination was made on two plates and a chemical analysis taken of one. All plates were satisfactory with respect to steel soundness. The plates at hardnesses of 388 Brinell and above developed some crystallinity in the fibre fracture test. Crystallinity in this material is attributed to temper embrittlement.

1. As requested by the Ordnance Research Center, (APG 470.5/5864 - Wtn 470.5/8121(r)), metallurgical examination has been completed on sections from six (6) 1/2 inch rolled homogeneous plates manufactured by the Great Lakes Steel Corporation and tested at Aberdeen as a part of the effect of hardness program. Ballistic test results will be reported in Armor Test Report AD-515 of the Ordnance Research Center, Armor Branch.

2. Metallurgical examination included the following tests:

a. Brinell hardness surveys.

b. Fracture test for steel soundness.

c. Fracture test for response to heat treatment.

d. Macroetch tests.

e. Chemical analysis.

f. Microscopic examination.

3. Results and Discussion. Results of the metallurgical examination are as follows:

a. Brinell hardness.

A surface and cross section of each plate was Blanchard ground to a depth of 1/16 inch to remove any traces of decarburization. Brinell hardness readings were then taken on each section; the average hardness was obtained from four readings taken at equally spaced intervals. Results are listed below in Table I.

Table I

Plate No.	Average Hardnesses, BHN	
	Surface	Cross Section
43	415	415
45	388	388
47	388	388
50	388	388
51	363	363
53	363	352

b. Fracture test for steel soundness.

Sections, approximately 6" in length and 3" wide were cut from each sample in both directions, notched transversely, tempered at 1050°F to reduce the hardness uniformly to approximately 300 Brinell, and then broken slowly under a Baldwin Southwork hydraulic testing machine. The results are summarized in Table II.

c. Fracture test for response to heat treatment.

Sections the same size as above were notched transversely to a depth of 1/2 inch from each side and broken rapidly under a drop weight mechanism. The sample broken in one direction was as-received, whereas the second sample, taken in the opposite rolling direction, was tempered at 1050°F. Because of efficient cross rolling, it was difficult to distinguish the directional properties.

Table II

Plate No.	Steel Soundness Tests		Fibre Test	
	Longitudinal	Transverse	Tempered	As-Received
43	C	B	Fibrous	Mixed, crystalline along centerline.
45	C	B	Fibrous	Mixed, mainly fibrous
47	B	B	Fibrous	Fibrous
50	B	B	Fibrous	Mixed, slight crystallinity
51	C	B	Fibrous	Fibrous
53	B	B	Fibrous	Fibrous

Reference to Table I will show that crystallinity develops to a small degree in this steel at hardnesses of 388 Brinell and above. Temper embrittlement is considered the cause.

d. Macroetch tests.

Macroetching of a section from each plate revealed pronounced centerline segregation in plate 51 and uniformly distributed segregation in plate 43, 45, and 47. Plates 50 and 53 exhibited no pronounced segregation. Photographic results are shown in Figure 1.

e. Chemical analysis.

The chemical analysis obtained of plate 45 was as follows:

C	Mn	Si	S	P	Ni	Cr	Mo	V
.32	1.50	.31	.019	.022	Trace	.50	.28	Nil

f. Microscopic examination.

A section from plates 43 and 51 was examined for nonmetallic inclusion distribution and microstructure. Both plates were fairly dirty with a high content of silicate-oxide nonmetallic inclusions and some sulphides. Plate 43 had occasional stringers of aluminum oxides. The microstructure of both plates was a tempered martensite, decarburization was negligible. See Figure 2 for photomicrographs of typical microstructures.

4. Since all plates were fibrous or essentially fibrous it may be assumed that the plates were thoroughly quenched, thus indicative of proper heat treatment. The fracture test for steel soundness revealed that the plates were satisfactory with respect to steel soundness.

Therefore, ballistic behavior will probably be attributable to the respective hardnesses of each plate.

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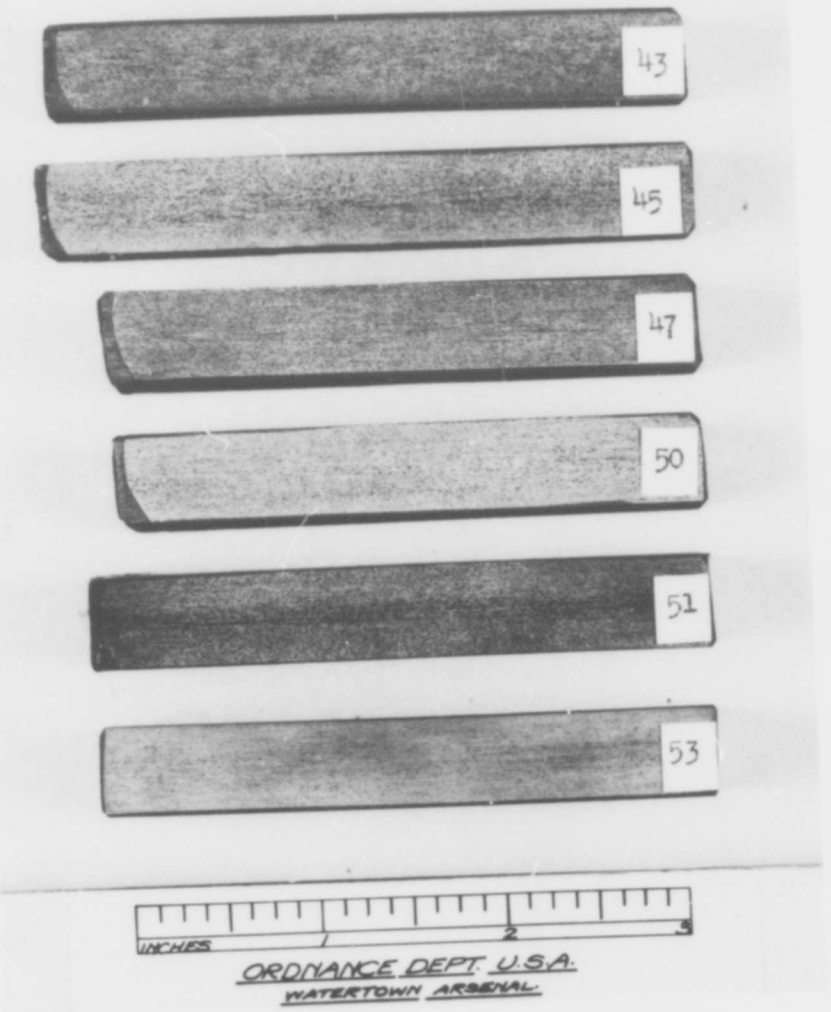

GREAT LAKES STEEL CORPORATION ½ INCH ROLLED ARMOR PLATE
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Figure 1

Great Lakes Steel Corporation 1/2 Inch Rolled Armor Plate

Typical Microstructures

X100 Unetched X1000 Picral

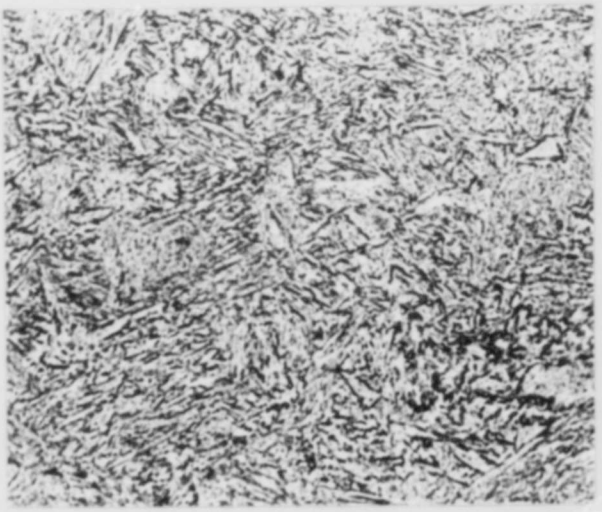

Plate 43

Silicate-oxide and some sulphide non-metallic inclusions. Occasional alumina oxide stringers.

Tempered martensite with a Brinell hardness of 415.

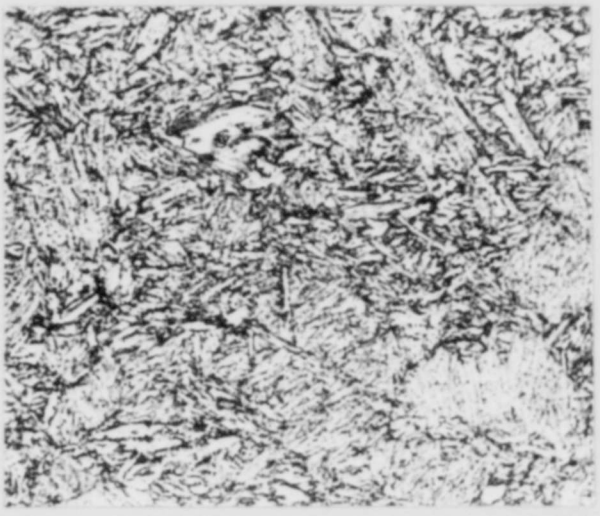

Plate 51

Silicate-oxide and some sulphide non-metallic inclusions.

Tempered martensite with a Brinell hardness of 363.

FIGURE 2.