WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/723

Metallurgical Examination of Eighteen Pieces of 25/64" Thick Rolled Homogeneous Armor

BY

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Final Report on Problem B-4.67

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ABSTRACT

Metallurgical examination of 18 pieces of armor plate 25/64" x 2" x 8" cut from heat SCN219-1, rolled by Ford Motor Company and heat treated by Standard Steel Spring Company has been completed. This material spalled badly when tested with cal. .50APM2 ammunition under requirements of AXS-495. The results of this investigation indicate that spalling was due to the presence of segregations of elongated silicate nonmetallic inclusions in the material. This condition was revealed by the torsion test, microscopic examination, and also by "woodiness" in the fracture test for steel soundness. Directional properties are evident in the material as revealed by macroscopic examination and "woodiness" in the fracture test. A "woody" condition in rolled armor is indicative of poor quality plate and therefore, is not desirable in good quality plate.

1. At the request of the Office of the Chief of Ordnance-Detroit[1], a metallurgical examination to determine the cause for spalling has been conducted on 18 pieces of armor plate 25/64"x2"x8" cut from heat SCN219-1, rolled by Ford Motor Company and heat treated by Standard Steel Spring Company. This material spalled badly when tested with cal. .50APM2 ammunition under the requirements of AXS-495.

2. The samples under investigation are listed below: 18 fracture samples 25/64"x2"x8" cut from heat SCN219-1 as follows:

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1. OOM 470.5/Watertown Arsenal, 29 Nov. 1944 - Wtn 470.5/108, 29 Nov. 1944

From N219-1T1

3 - transverse direction
3 - longitudinal direction

From N219-1M1

3 - transverse direction
3 - longitudinal direction

From N219-1B1

3 - transverse direction
3 - longitudinal direction

3. Metallurgical examination included the following tests:

a. Brinell hardness survey.

b. Fracture test for steel soundness.

c. Macroetch tests.

d. Torsion tests.

e. Chemical analysis.

f. Microscopic examination.

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

a. Brinell Hardness Survey.

One sample was cut from each of the fractured sections of heat SCN219-1 namely, 1T1, 1M1, 1B1 and properly surface ground to remove any traces of decarburization. Brinell hardness readings were taken on the surface of the samples and the average hardness was obtained from four readings taken at equally spaced intervals. The values were fairly uniform across the sections. Results are summarized below in Table I.

TABLE I

Brinell Hardness Survey

Sample No.	Surface Hardnesses	
	Range	Average
N219-1T1	363	363
N219-1M1	352-363	359
N219-1B1	341	341

b. Fracture test for steel soundness.

Sections, 25/64"x2"x8" were notched and then broken slowly with a Baldwin Southwark hydraulic testing machine. Samples, taken from each section and in both directions were fractured in the "as-received" condition (BHN 341-363) whereas the remaining samples were first tempered at 1050°F. to reduce the hardness uniformly to approximately 300 Brinell and then notched and fractured in like manner. The specimens for steel soundness were rated in accordance with the standards of specification 488, revision 2. The results of the tests are shown below in Table II.

TABLE II

Fracture Test for Steel Soundness

"As-Received"

Sample No.	Longitudinal	Transverse
N219-1T1	*C - woody	*C
N219-1M1	*C - woody	*C
N219-1B1	C - woody	*C

Tempered

Sample No.	Set 1 Longitudinal	Set 2 Longitudinal	Set 1 Transverse	Set 2 Transverse
N219-1T1	B - woody	C - woody	*C	D
N219-1M1	*C - woody	*C - woody	*C	*C
N219-1B1	B - woody	*C - woody	*C	B

*Indication of shelving in fracture.

The fracture test revealed "woodiness" only in the longitudinal direction of rolling.

c. Macroetch tests.

Macroetching of a sample from each section revealed no pronounced laminations, see Figure 1. Directional properties in the samples were revealed in the macroscopic examination in that the transverse sections etched more deeply than the longitudinal sections. A fairly good correlation was established between the "woody" condition and the macrostructure.

d. Torsion tests.

A torsion test for revealing laminations in steel[1] was conducted on the samples investigated in this report. Sections $\frac{1}{8}$"x3"xT(thickness) were cut

1. WAL 710/321.

adjacent to the macroetch test bar, clamped in a vise, and twisted with a wrench at an angle of approximately 180°. The deformed bars revealed varying degrees of centerline laminations, and in some cases evidence of shearing was noticed. It is evident from the data reviewed thus far, that the top and middle sections show pronounced laminations of silicate stringers, whereas the bottom seems to have the least amount of segregation. See Figure 2 for photomicrograph illustrating results of the torsion tests.

e. Chemical analysis.

The result of the chemical analysis of sample N219-1M1 obtained was as follows:

C	Mn	Si	S	P	Ni	Cr	Zr	V	Cu	Al	Mo	Ti	B
.30	1.40	.25	.016	.020	.15	.66	Nil	Nil	.10	.02	.28	.03	.0009

f. Microscopic examination.

A sample from each section was examined microscopically. The nonmetallic content of 1T1 and 1M1 was fairly high with stringers of silicate nonmetallic inclusions evenly distributed throughout the areas examined. The nonmetallic inclusion content of 1B1 was considerably lower, with occasional stringers of silicate inclusions. A streak of alumina oxide was observed in 1B1. The nonmetallic inclusion content distribution obeerved in the unetched areas of the microspecimens correlated fairly well with both the torsion test and the "woodiness" revealed by the fracture test for steel soundness. The microstructure of the top, middle and bottom samples was a tempered martensite. For typical photomicrographs, see Figure 2.

5. The results of these tests indicated that the spalling condition of the material exhibited when subjected to impacts with cal. .50 APM2 projectiles may be attributed to the segregation of silicate nonmetallic inclusion stringers revealed by the torsion and microscopic investigations. The material possessed directional properties as revealed by macroscopic examination and the fracture test.

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APPROVED:

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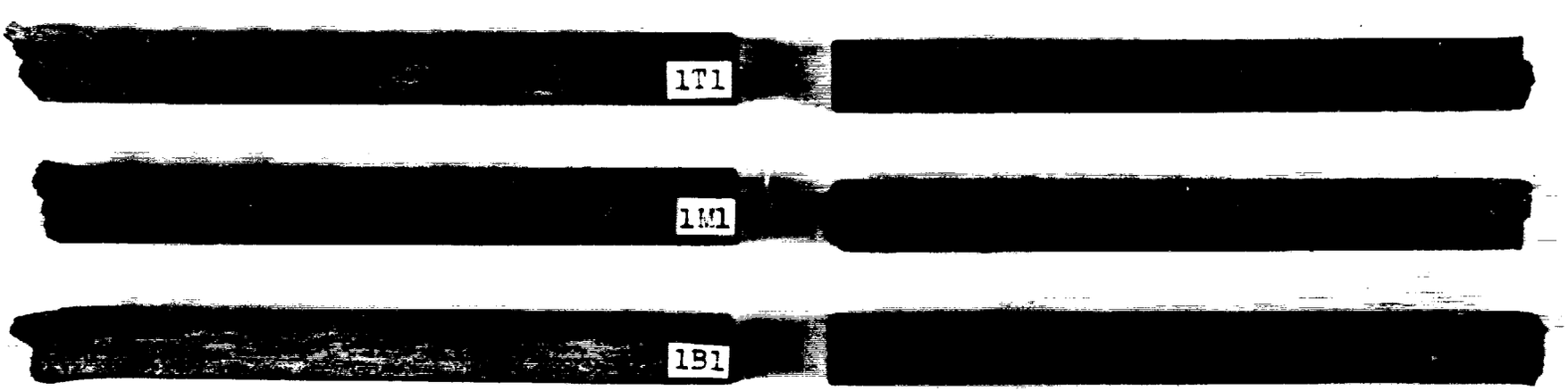
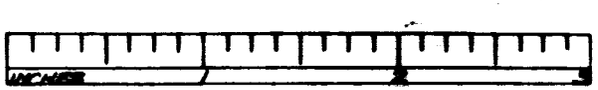
LONGITUDINAL TRANSVERSE





MACROSTRUCTURE OF 25/64" THICK ROLLED HOMOGENEOUS ARMOR PLATE MANUFACTURED BY FORD MOTOR COMPANY. 30 DEC 1944 WTN. 710-2356

Figure 1

Typical Microstructure of 25/64" Thick Rolled Homogeneous Armor

X1 N219

Typical laminations revealed by torsion test.

X100 N219-111 Unetched

Typical silicate nonmetallic inclusion distribution in 111 and 1M1.

X100 N219-131 Unetched

Segregated streak of alumina inclusion. Some silicates evident.

X1000 N219-111 Picral

Tempered martensite. Typical of 1M1 and 131.

FIGURE 2