EXTRA COPY

(1)

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/681

Metallurgical Examination of Section from 6" Experimental M4A1E2 Assault Turret Manufactured by Union Steel Castings Division of Blaw-Knox Company

BY

P. T. RIFFIN
Asst. Metallurgist

DATE 21 July 1954

WATERTOWN ARSENAL
WATERTOWN, MASS.

UNCLASSIFIED

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 710/681

Final Report on Problem B-4.34

21 July 1944

Metallurgical Examination of Section from 6" Experimental M4A3E2 Assault Turret Manufactured by Union Steel Castings Division of Blaw-Knox Company

ABSTRACT

This report covers the investigation of a 6" thick cast sample which was evaluated by the fracture test, Charpy impact tests, microscopic examination, and hardenability tests. The results show that the casting, heat treated to 207 Brinell hardness, exhibited a mild tendency toward brittleness which probably would not be observed in ballistic tests conducted at normal temperatures.

1. As requested in a letter from the Office, Chief of Ordnance-Detroit dated 24 April 1944 (O.O.M. 470.5/Watertown Arsenal - Wtn 470.5/8101(r)), an investigation has been conducted on a sample obtained from an M4A3E2 assault turret manufactured by Union Steel Castings. The ballistic results on this turret are recorded in Armor Test Report AD-668 by the Ordnance Research Center, Aberdeen.

2. The fibre fracture test showed that the casting possesses fair toughness under normal conditions. However, the presence in the fracture of approximately 10% crystallinity and inferior Charpy impact values at -40°F indicated that there was some tendency toward brittleness. The sample possessed a uniform hardness of 212 to 201 Brinell across the thickness.

3. The metallurgical examination consisted of the following tests:

a. Chemical analysis.

b. End quench hardenability tests.

c. Brinell hardness survey.

UNCLASSIFIED

RESTRICTED

d. Fibre fracture test.

e. V-notch Charpy impact tests at 68°F and -40°F.

f. Macroetch test.

g. Microscopic examination.

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

a. Chemical analysis.

The casting was made from a medium manganese, 2.7% chromium, .5% molybdenum steel having the following analysis:

Reported by	C	Mn	Si	S	P	Ni	Cr	Mo	V
Union Steel Castings	.29	1.11	.41	.018	.035	—	3.08	.51	-
Watertown Arsenal	.29	.98	.39	.015	.021	—	2.70	.46	.06

b. Hardenability

The end quench hardenability test was conducted according to the method outlined by the A.S.T.M. The austenitizing temperature (1625°F) used by the manufacturer is insufficient to dissolve the carbides completely and consequently the hardenability is impaired. A higher austenitizing temperature (1725°F), which completely dissolves the carbides, results in a considerably higher hardenability as indicated by the hardness surveys, see Figure 1. A microscopic examination of the as quenched bar which had been austenitized at 1725°F revealed that there were no transformation constituents other than martensite present at the air cooled end.

c. Hardness

Brinell hardness readings were made every 1/2 inch across the thickness of the plate and the results are as follows:

Station	1	2	3	4	5	6	7	8	9	10	11	Ave.
BHN	212	212	207	201	207	201	201	201	207	212	212	207

The hardness of the plate is lower than is desired for 6" armor from a resistance to penetration standpoint. The manufacturer probably used a low hardness, however, in order to obtain the desired toughness.

d. Fracture and impact tests.

A section was flame notched on both sides and one face such that the unnotched area was 4"x4" and broken rapidly under a press (a forge hammer or other impact machine large enough to break the fracture bar was not available). The fracture was mainly fibrous having

a 1/4" crystalline zone at the edge of the fracture and scattered crystallinity throughout. Another bar 2" thick, whose width was the thickness of the plate, was notched in the 2" direction and broken under a forge hammer. The fracture was very much like the previous one, the 1/4" crystalline band being at the last edge to be broken. There is a tendency for this sample to exhibit brittle properties although it is not marked.

V-notched Charpy impact tests were made to supplement the results of the fracture test and the data are shown in Table I. The impact properties at the center of the plate are not appreciably different from those observed at the midwall; and, therefore, it may be assumed that the toughness across the thickness is quite uniform. The drop in impact value at -40°F reflects a tendency toward brittle properties. However, it is felt that this material possesses sufficient toughness to withstand ballistic attack conducted at normal temperatures without cracking.

Table I

V-notch Charpy Impact Data

	68°F		-40°F	
Location	Energy - Ft. Lbs.	Fracture*	Energy - Ft. Lbs.	Fracture
Center	71.0	F	48.0	Cbf 3/4
	79.0	F	47.0	Cbf 3/4
Midwall	67.5	F	48.5	Cbf 3/4
	71.5	F	28.0	Cbf 3/4

*F = Fibrous

Cbf 3/4 = bright crystalline patch with fibrous edge, 75% of the area being crystalline.

It was considered that the low impact strength might be associated with temper brittleness which was not completely eliminated in water quenching the 6" casting from the tempering temperature. A small section (1"x3"x3") was retempered at 1250°F for 3 hours and water quenched. V-notch Charpy tests at -40°F yielded values of 50.5 and 54.5 Ft. Lbs. These values are not significantly higher than those obtained from the as-received material, and, therefore, the inferior toughness cannot be altogether attributed to temper brittleness.

e. Macroetch test.

A section was macroetched in hot acid to reveal the nonmetallic segregation and porosity, see Figure 2A. The section possessed a small amount of segregation and porosity throughout the cross section. This condition is consistent with the scattered porosity observed in the fracture.

f. Microscopic examination.

No unusual distributions of nonmetallic inclusions were observed in the specimens examined. The microstructure consisted, for the most part, of spheroidized carbides randomly oriented in the ferrite matrix, see Figures 2B and C. A small amount of free ferrite and chain formations of carbides were observed throughout the section. There was no noticeable difference between the structure at the midwall and at the center. Occasional segregations of undissolved carbides were observed indicating incomplete carbide solution prior to quenching.

From the tempered microstructure it is difficult to evaluate the constituents formed upon quenching, but it is known that a considerable quantity of nonmartensitic transformation structures are formed upon quenching a 6" thick section of the subject analysis after an austenization treatment such as that employed by the manufacturer.

5. The properties of this casting are satisfactory to meet present ballistic requirements. Nevertheless, it possessed a hardness (207 Brinell) lower than that desired for optimum resistance to penetration. It is considered that increasing the hardness of this material would impair its shock resistance appreciably since brittleness is accentuated at the higher hardnesses when tempered martensitic structures are not obtained. The presence of intermediate transformation structures formed upon quenching, which are responsible for the inferior impact strength, may be decreased by austenitizing at a higher temperature (1725°F) to dissolve the alloy carbides more completely.

P. V. Riffin

P. V. RIFFIN
Asst. Metallurgist

APPROVED:

N. A. Matthews

N. A. MATTHEWS
Major, Ordnance Dept.
Chief, Armor Section

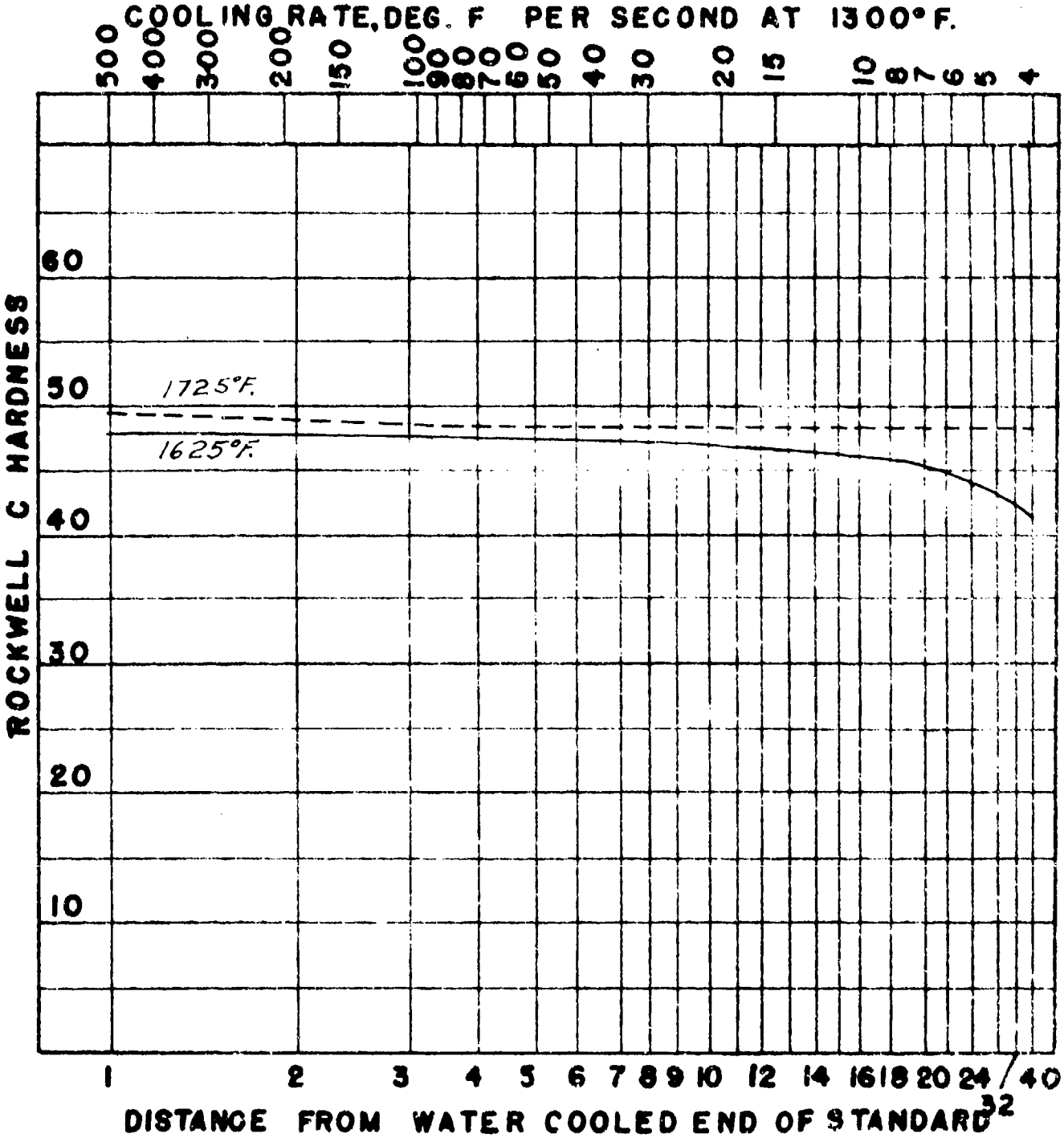
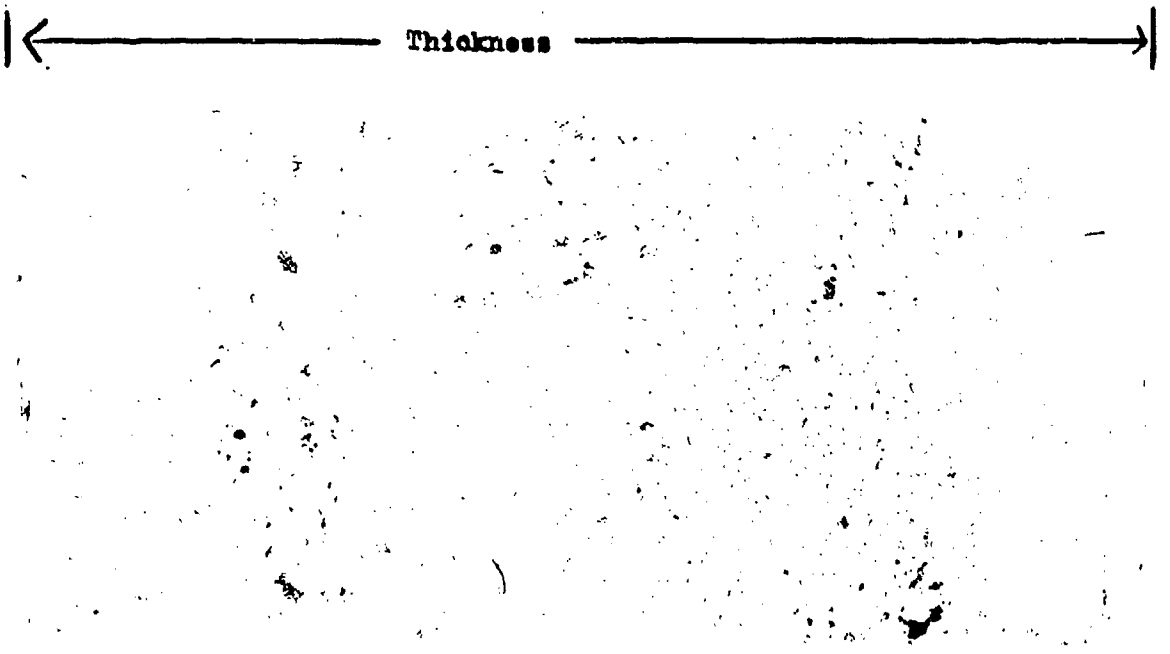


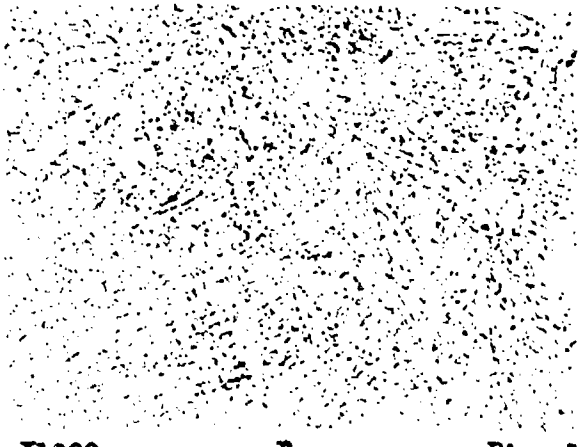
PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	V		QUENCH TEMP	QUENCH TIME	G.S.
	———	.29	.98	.39	.015	.021		2.70	.46	.06		1625	3 Hrs.	
	- - - -	"	"	"	"	"		"	"	"		1725	3 Hrs.	
		6"	M4	A3	E2	ASSAULT		TURRET						

FIGURE 1

Structure of 6" M4A3E2 Assault Turret
Manufactured by Union Steel Castings



X1 Macrostructure A Hot Acid Etch



X1000 B Picral
Midwall - Tempered martensite and bainite.

X1000 C Picral
Center - Tempered martensite and bainite with a small amount of free ferrite.

Microstructure

FIGURE 2.