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METALLURGICAL EXAMINATION OF FORD MOTOR COMPANY 1" CAST ARMOR TEST PLATES

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by

H. A. Matthews  
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Oct. 18, 1943

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(2). Plate 2627B. Completely crystalline fracture indicating poor quenching practice.

(3). Plate 2735A. Mixed fracture (50% crystalline) and showing fine shrinkage porosity in central third of the section.

(4). Plate 2735B. Mixed fracture (40% crystalline) considerable shrinkage at center of section and small amounts of the conchoidal type fracture.

(5). Plate 2642B. Essentially fibrous, showing slight traces of crystallinity at center of section, scattered fine porosity and traces of the conchoidal type of fracture.

(6). Plate 2663. As fractured the plate appeared essentially fibrous but because of the high hardness (375 Brinell) was difficult to interpret. After retempering to 321 Brinell an essentially completely fibrous fracture was obtained.

Of the six plates, only number 2663 had been adequately quench hardened. Plates 2627B, 2735A and 2735B had been poorly quenched. The conchoidal condition observed to a slight extent in several of the plates is associated with poor melting and deoxidation practices, but is not considered harmful unless existing in greater amounts than observed in these samples.

b. Brinell Hardnesses. Surface Brinell hardnesses and hardnesses across the section were obtained on each plate as shown below.

<u>Plate Number</u>	<u>Surface BHN</u>	<u>Cross Sectional BHN</u>	
		<u>Range</u>	<u>Average</u>
2627	338	321-341	331
2627B	341	321-352	335
2735A	255	262-293	274
2735B	285	277-285	281
2642B	341	331-352	348
2663	384	363-388	375

The above values are, in general, considerably higher than those reported by the manufacturer. This is because of the considerable surface decarburization on the plates. It was necessary to grind to a 1/8" depth to get accurate surface Brinell readings. The surface hardness readings are the average of four (4) impressions whereas the cross-sectional averages are the mean of six (6) determinations at equi-spaced intervals across the thickness.

c. Microexamination. Micro specimens across the thickness of each plate were examined for steel cleanliness, grain size, extent of

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decarburization, and microstructure. The results on each plate are shown below. Examples of the microstructures are illustrated in Figure 2.

(1). Plate 2627. Non-metallic inclusions well distributed. Average cleanliness. Decarburization, .04" on one face, .02" on opposite face, average .03". Grain size 6-7. Microstructure consists of tempered martensite plus considerable amounts of high temperature transformation products including ferrite.

(2). Plate 2627S. Non-metallic inclusions well distributed. Average cleanliness. Decarburization .02" on both faces. Microstructure consists of large amounts of high temperature transformation products including ferrite plus tempered martensite. (See Figure 2.) Grain size 6-7. Shrinkage voids at center of specimen.

(3). Plate 2735A. Non-metallic inclusions well distributed. Average cleanliness. Grain size 6-7. Decarburization .02" on each face. Microstructure comparable to plate 2627S.

(4). Plate 2735B. Similar to 2735A in all respects, except considerable centerline porosity visible.

(5). Plate 2642B. Non-metallic inclusions well distributed. Some large silicate inclusions visible, average cleanliness. Shrinkage voids at center of section. Decarburization .035" and .03". Microstructure consists essentially of tempered martensite with slight traces of ferrite.

(6). Plate 2663. Average non-metallic condition. Shrinkage porosity at center of section. Decarburization .020" and .03", average .025". Grain size 6-7. Microstructure essentially tempered martensite with small amounts of high temperature transformation products including ferrite.

The steels are satisfactory with respect to cleanliness. The microstructure of plates 2627, 2627S, 2735A and 2735B is such as would result in poor shock properties. These plates had not been properly quench hardened, as evidenced by the large amounts of high temperature transformation products.

d. Chemistry and Jominy Hardenability. Chemical analyses and Jominy hardenabilities were obtained on plates 2627 and 2735B. The results follow:

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<u>Plate No.</u>	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Cu</u>	<u>Al</u>
2627	.28	1.14	.51	.019	.023	.15	.53	.22	.11	.05
2735B	.29	1.00	.39	.018	.027	.16	.49	.21	.15	.06

These analyses check closely with those reported by the manufacturer. The high residual aluminum contents are probably somewhat responsible for the conchoidal fracture tendencies. The Battelle Memorial Institute has associated the conchoidal fracture with either high aluminum or nitrogen contents or more usually a combination of these elements. The Jominy hardenability curves are shown in Figure 3. Heat 2627 retains 42 Rockwell C at 8/16 inches from the bar end, which is approximately equivalent to a 1½" thick plate quenched in still water at 70°F. Under this same criterion, heat 2735B should quench out in still water in plate thicknesses up to 1.2" thickness. It is evident, therefore, that the wide differences in degree of quench hardening of the six plates are the result of a variable quenching practice.

4. The reported Brinell hardnesses of these plates are in error in most cases. These hardnesses were used in the plotting of the curves in report AD-380. The errors probably resulted because of severe decarburization of the plate surfaces. The ballistic shock results on this series of plates should not be taken as representative of satisfactory cast armor since the plates were not satisfactorily quench hardened in the majority of cases. Such pearlitic microstructures are known to produce inferior shock resistance.

*H. A. Matthews*  
H. A. MATTHEWS,  
Major, Ord. Dept.



2627



26278



2735A



27358



26428



2663

WATERTOWN ARSENAL

FORD MOTOR CAR COMPANY - 1" CAST PLATES OF VARYING HARDNESSES  
FRACTURE TESTS.  
30 SEPTEMBER 1943

MAG. X 1 1/2  
WTN.710-2152

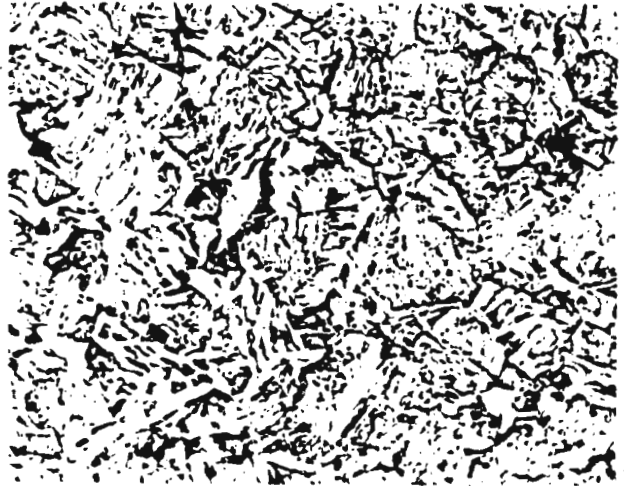
FIGURE 1

TYPICAL MICROSTRUCTURES

FORD 1<sup>st</sup> CAST ARMOR TEST PLATES

(Photomicrographs at Center of Section)

Incompletely quench hardened.  
Tempered martensite with  
considerable amounts of high  
temperature transformation  
products including ferrite.  
Plates 2735 A and B similar.  
Plate 2627 somewhat less ferrite  
evident.

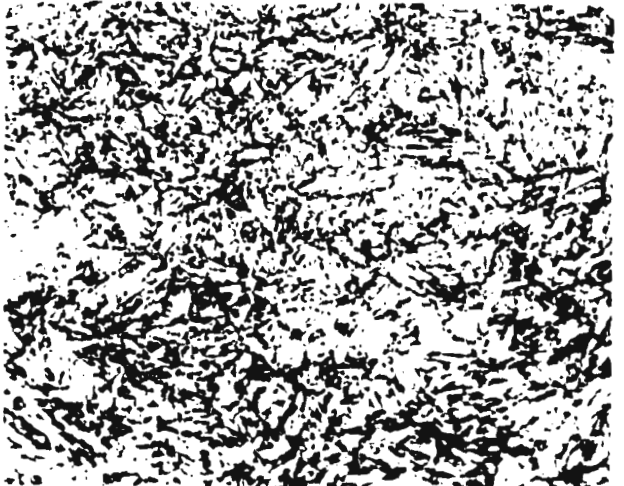


X1000

26278

Pical-Nital

Essentially tempered martensite.  
Slight amounts of ferrite and  
carbide segregates visible.

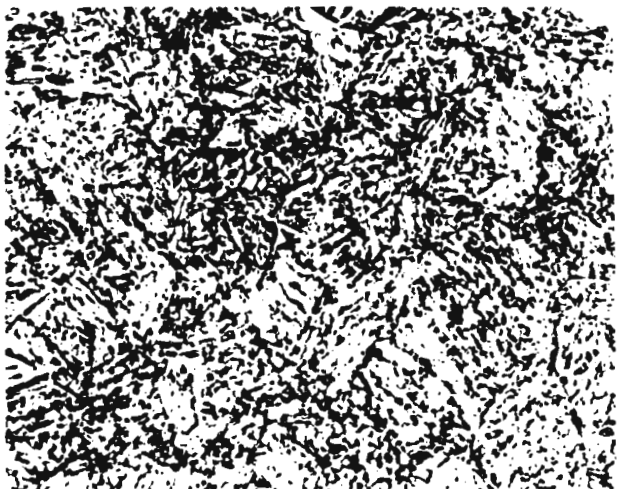


X1000

2642B

Pical-Nital

Essentially tempered martensite.  
Slight amounts of ferrite and  
other high temperature transforma-  
tion products visible.



X1000

2663

Pical-Nital

Figure 2

COOLING RATE, DEG. F PER SECOND AT 1300°F.

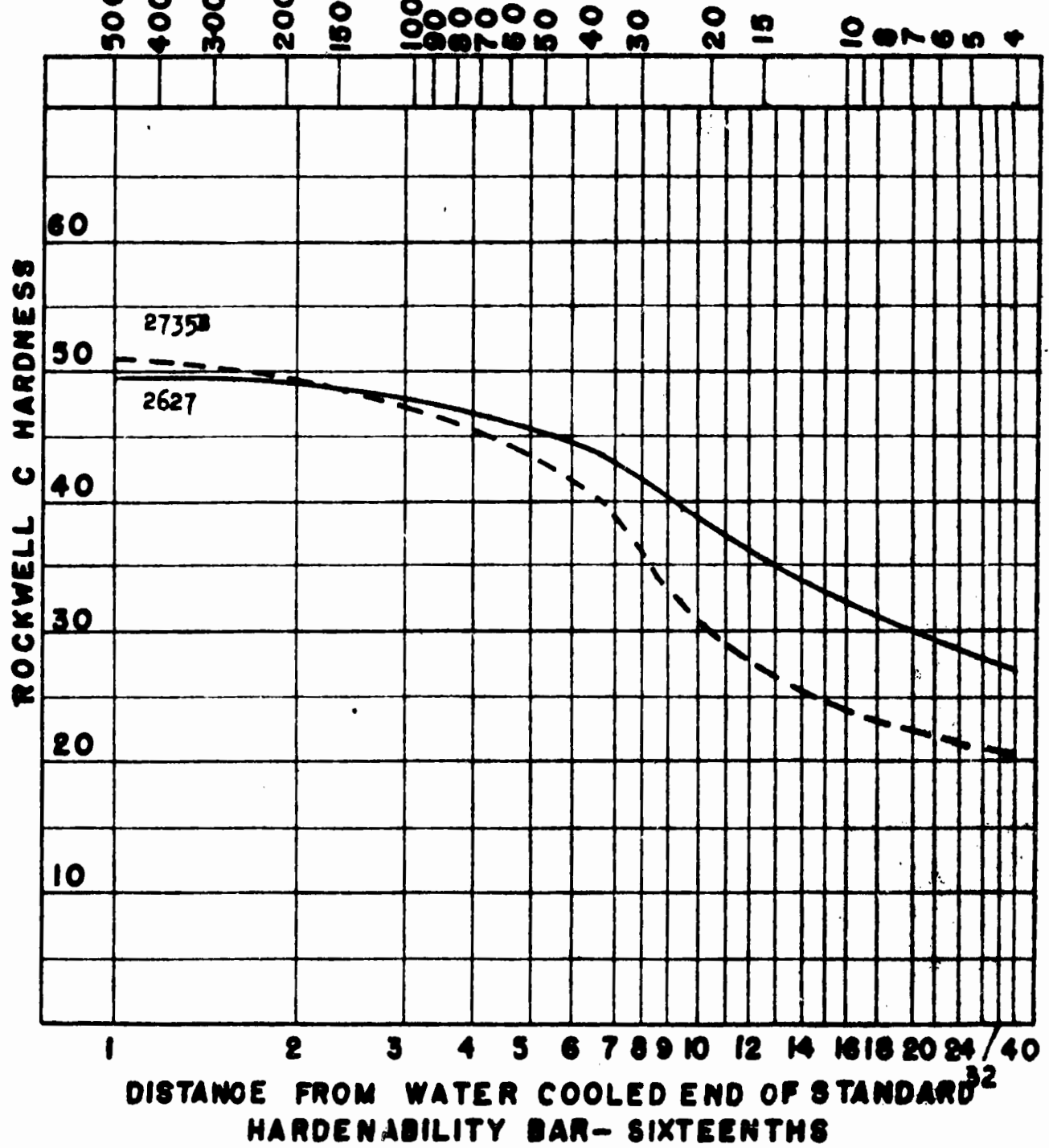


PLATE NO.	HEAT NO.	C	Mn	Si	S	P	Ni	Cr	Mo	V	Cu	Al	QUENCH	
													TEMP	TIME G.S.
2627	—	.29	1.14	.51	.019	.023	.15	.53	.22	Tr	.11	.05	1700	2hrs
2735B	—	.29	1.00	.39	.018	.027	.16	.49	.21	Tr	.15	.06	1700	2hrs

FIGURE 3.