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WATERTOWN ARSENAL REPORT 710/423

Metallurgical Data on Certain Cast Armor Test Plates Tested at Aberdeen Proving Ground as a Part of the Cast Armor Low Alloy Development Program

By

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April 26, 1948

WATERTOWN ARSENAL
WATERTOWN, MASS.

Cast Armor Report No. 32

Watertown Arsenal

April 25, 1942

Metallurgical Data on Certain Cast Armor Test Plates Tested at Aberdeen Proving Ground as a Part of the Cast Armor Low Alloy Development Program

INTRODUCTION

This report incorporates the metallurgical data obtained by post-mortem examination of sections cut from twenty-eight (28) cast armor test plates submitted for ballistic tests as a part of the program to develop cast armor compositions low in strategic elements.

Samples of ballistic test plates which performed satisfactorily were forwarded from Aberdeen Proving Ground. From the samples furnished, representative sections chosen on the basis of the company which produced the plate and the composition type were selected for investigation.

METALLURGICAL DATA INCLUDED

1. Microstructure

One page of photomicrographs is devoted to each plate involving three or four prints which show the dendritic segregation, the general microstructure, and the cleanliness of the steel.

2. Macrostructure

The macrostructures of each steel are shown, and the photographs of macrosections from several plates are illustrated on one page grouped according to manufacturer.

3. The complete metallurgical and ballistic test history of each plate is shown on a data sheet facing the microstructure pages. Also shown on these sheets are the uniformity of Brinell hardness across the section, the Jominy end-quench hardenability ratings and critical cooling rates as well as the equivalent plate thicknesses which will harden completely through based upon a quench into a still water bath. The two-bead weld hardenability characteristics are included for each steel with a comparison between the hardnesses determined in the heat-affected zone by the Vickers Brinell and the Rockwell C instruments.

4. Two-Bead Weld Hardenability Chart - Rockwell C versus Vickers Brinel

This chart appears at the end of the report and consists of a plot showing the relation between the Vickers hardnesses and Rockwell C hardnesses actually obtained and the conversions to be expected.

5. Jominy Hardenability Curves

Jominy hardenability curves are plotted for each steel investigated and grouped by manufacturer.

TEST PROCEDURES

1. Jominy Hardenability Test

Jominy hardenability tests were made on the twenty-eight (28) plates examined in this report. The method of testing used is that developed by General Motors Co. and recommended by the A.S.T.M. Standard specimens (1" diameter x 3" long) were used placed in a quenching fixture ½" from a ½" nozzle. The free water head from nozzle was 2½" using a water coolant with a temperature of 70° to 75°F.

The heat treatment of specimens was that used by the company on the subject plate excepting that the maximum time was four hours including both the rise and soak. Specimens were packed in "Neutra Pack" to prevent decarburization on quenched end while heating.

Rockwell C hardness surveys were made on the quenched specimens on two longitudinal faces surface ground .015" below the surface of the round.

2. Critical Cooling Rate

The critical cooling rate was based upon information developed by Boegehold of General Motors for Jominy specimens of the type used. The Jominy hardness penetration value was taken as the average distance between full and minimum hardening or the distance which should correspond to a 50% martensitic or half-hardened product. Air hardening ability was considered to have been obtained when the Jominy bar throughout its length hardened to a value in excess of the 50% martensitic hardness for the particular carbon content of the steel.

3. Equivalent Plate Thickness

The equivalent plate thicknesses were determined arbitrarily from the Jominy hardenability data and conversion factors developed by other investigators, namely, Grossman and Battelle Memorial Institute personnel. The Grossman quenching factor was based upon a moderate or still-water quench.

4. Two-Bead Weld Hardenability Tests

Procedure on Two-Bead Weld Hardenability Test

Two-bead weld hardenability tests were conducted on all of the plates according to the method proposed for inclusion in armor plate specifications. Hardness readings were taken in each case on the zone of maximum hardness. Vickers 10 Kg impressions were made on the face of the section away from the beginning of the weld (where the specifications ask for Rockwell impressions) while Rockwell C readings were taken on the face adjacent to the beginning of the weld on the same section but in every case at least 3/4" from the beginning of the weld bead.

5. Grain Size Determinations

The grain size of each steel was determined by two methods. The actual grain size observed on the microscope was taken as one value, and the grain size revealed by the Shepherd fracture test after a heat treatment similar to that given the test plates for hardening was used as the other method.

COMMENTS AND CONCLUSIONS

1. Hardenability

The ability of a certain composition to harden completely through upon quenching in a given thickness is not a requisite for satisfactory ballistic performance. In general, however, higher ballistic efficiencies are obtained when thorough hardening results. For instance, the Mn-Mo compositions, comparatively low in manganese, (Mn - 1.30%, Mo .30-.40%) possesses satisfactory hardenability for a 1½" thick section but insufficient hardenability for a 2" section, as evidenced by the considerable amount of ferrite rejected upon quenching the 2" thickness plate. This is shown by the Symington-Gould and Pratt and Letchworth plates.

The high-copper-bearing steels submitted by Pacific Car and Foundry Co., although possessing extremely low hardenability as evidenced by the ferrite and carbide microstructure, exhibit fairly satisfactory ballistic properties. It is felt that additional alloy to promote depth hardening is required in this type of material over and above the amounts of chromium and molybdenum used in certain heats. The Jominy hardenability was not materially increased by these additions, and the microstructures indicated but a slight effect of these alloys.

The following tabulation based upon Jominy hardenability and the microstructures, indicates the thicknesses of plate in which the various compositions provide adequate hardenability for thorough hardening:

Plate Thicknesses of at Least 2"

Manufacturer	Plate No.	Heat No.	Thickness in Inches	Type
Ford Motor Co.	A5	-	2.19	Mo-Cu
Ford Motor Co.	167F	-	2.23	Mo-Cu
General Steel Castings Co.	645	5522M	2-1/4	Mn-Mo
General Steel Castings Co.	657	5531MMC	2.33	Mn-Cr-Mo
Lebanon Steel Foundry	A3	HE8935	1.0	Ni-Cr-Mo-Cu
Scullin Steel Co.	X6	3-421	2.08	Mn-Mo
Sivyer Steel Castings Co.	X7	X7	2.05	Mn-Mo
" " " "	X7X	X7	2.00	Mn-Mo
" " " "	90	5577	2.14	Ni-Cr-Mo-Cu
" " " "	90X	5577	2.11	Ni-Cr-Mo-Cu
" " " "	99	5596	2.22	Mn-Ni-Cr-Mo
" " " "	99X	5596	2.23	Mn-Ni-Cr-Mo

Plate Thicknesses of at Least 1½"

Manufacturer	Plate No.	Heat No.	Actual Thickness in Inches	Type
Continental Roll & Steel	4009-3	4009	2.18	Mn-Mo
Ford Motor Co.	167F	-	2.23	Mo-Cu
Ford Motor Co.	955	-	1.65	Cr-Mo
Pratt & Letchworth Co.	1	413	1.88	Mn-Mo
Pratt & Letchworth Co.	2	413	1.48	Mn-Mo
Scullin Steel Co.	X2	5092A	2.13	Mn-Mo
Symington-Gould Corp.	2	4552	1.49	Mn-Mo
Symington-Gould Corp.	5-2	4552	1.99	Mn-Mo
Wahr Steel Co.	A4-338	-	1.64	Ni-Cr-Mo

The balance of the steels investigated had insufficient hardenability to thorough harden in 1½" sections but sufficient for 1" sections.

2. Microstructure

In general, the size, shape, and distribution of the nonmetallic inclusions as well as the carbides have no relation to the ballistic performance in cast armor plate of the hardness range investigated, namely, 197-294 Brinell.

There was a close correlation between microstructure and Jominy hardenability, particularly as regards the deep hardening steels. The microstructures of the deep hardening steels consist of a quite uniform, spheroidised sorbite with no free ferrite present throughout the cross-section. The steels of lower hardenability contain considerable amounts of ferrite throughout the section.

In general, when ferrite rejection occurred on quenching, the amount rejected was, contrary to expectation, quite uniform throughout the cross-section. This is shown particularly well in the Symington-Gould and Pratt & Letchworth plates, where both plates submitted by each company were made from the same heat and had different amounts of ferrite rejected for each thickness of plate.

The Arnold Engineering Co. plate was evidently not tempered after the quench as the microstructure contained a considerable amount of low carbon martensite which would have been decomposed by tempering.

There was a fairly good correlation between the Shepherd fracture grain size and the A.S.T.M. microstructural grain size in all cases except one Ford plate and the Arnold Engineering Company plate. This may have been due to the grain refinement treatment of the heat treated fracture specimens.

3. Two-Bead Weldability Test

The two plates manufactured by the Scullin Steel Co. both failed the single bead weldability test in that they exceeded the maximum hardness value of 50 Rockwell C. In the Mn-Mo type of steel, the carbon content apparently should not exceed 0.30% if the manganese content is in excess of 1.00%. Confirmation of this is apparent in the following table:

Plate No.	C	Mn	Mo	Single Bead VPN	Single Bead Rc	Double Bead VPN	Double Bead Rc
Scullin X2	.36	1.46	.70	572	51.5	322	34
Scullin X6	.33	1.51	.39	585	53.5	373	36.5
General 645	.27	1.48	.51	508	48.5	327	32.5
Continental 4009-3	.32	.90	.55	542	49.5	390	37.5
Pratt & Letchworth 1	.28	1.30	.29	464	43.5	304	28.5
Pratt & Letchworth 2	.28	1.30	.29	455	42	312	29
Sivyer X7X	.27	1.24	.49	503	47.5	390	36
Sivyer 99	.31	1.06	.49	508	47	409	39
Sivyer 99X	.31	1.06	.49	519	48.5	339	34.5
Symington-Gould 2	.24	1.24	.40	514	41.5	351	34.5
Symington-Gould 5-2	.24	1.24	.40	508	48.5	354	37

Both Rockwell C and Vickers Pyramid hardness surveys were conducted on the single and double bead weldability tests as a comparison. In fifty-four surveys, the Rockwell C was found to check well with the Vickers Pyramid hardness, and in thirty cases to be from 0.5 to 7.5 Rockwell C points lower than the corresponding Vickers hardness. Thus in 55.5% of the cases investigated, the Rockwell C hardness was lower than the corresponding Vickers hardness. The conversion from Rockwell C to Vickers Pyramid hardness was based upon average values obtained from the literature.

The table at the end of the report shows the results of the comparison of the Rockwell and Vickers hardness surveys. Dividing the total range of hardness covered into three groups give the following results:

Rockwell C Range 16-30		Rockwell C Range 30-40		Rockwell C Range 40-53.5	
No. Good Correlation	No. Poor Correlation	No. Good Correlation	No. Poor Correlation	No. Good Correlation	No. Poor Correlation
0	7	7	18	17	5
100% poor correlation.		72% poor correlation.		22.7% poor correlation.	

When the base metal is on the soft side, the Rockwell survey of the weldability test specimen will have a greater tendency to be inaccurate than when the base metal of the plate is hard. This is caused by the fact that the Rockwell C impression is very much wider than the hardened zone and will overlap onto the softer metal and give a lower reading. The Rockwell is not nearly as reliable for hardness surveys of weldability test specimens as is the Vickers machine.

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P. V. Riffin

P. V. Riffin,

M. Bolotsky

M. Bolotsky,
Jr. Metallurgists.

Supervised by:

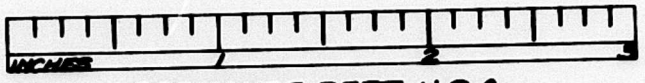
N. A. Matthews

N. A. Matthews,
Capt., Ord. Dept.,
Secretary, Subcommittee for
Cast Armor.

Key to Plates Investigated

Data Sheet No.	Manufacturer	Plate No.	Heat No.	Type
1	American Steel Foundries	HV-2	HV-2	Mn-V
2	Arnold Engineering Co.	A80	M128	Cr-Mo
3	Continental Roll&Steel Co.	4009-3	4009	Mn-Mo
4	Ford Motor Co.	A5	---	Mo-Cu
5	Ford Motor Co.	167F	---	Mo-Cu
6	Ford Motor Co.	955	---	Cr-Mo
7	General Steel Castings Corp.	645	5522M	Mn-Mo
8	General Steel Castings Corp.	657	5531MMC	Mn-Cr-Mo
9	Lebanon Steel Foundry	A3	HE8935	Ni-Cr-Mo-Cu
10	Pacific Car & Foundry Co.	2	42B105	Si-Mo-Cu
11	Pacific Car & Foundry Co.	9	42B126	Mn-Si-Cu
12	Pacific Car & Foundry Co.	10	42B127	Mn-Si-Cu
13	Pacific Car & Foundry Co.	11	42B128	Mn-Si-Cr-Cu
14	Pacific Car & Foundry Co.	12	42B129	Mn-Si-Cu
15	Pratt & Letchworth Co, Inc.	1	413	Mn-Mo
16	Pratt & Letchworth Co., Inc.	2	413	Mn-Mo
17	Scullin Steel Co.	X2	5092A	Mn-Mo
18	Scullin Steel Co.	X6	3-421	Mn-Mo
19	Sivyer Steel Castings Co.	X7	X7	Mn-Mo
20	Sivyer Steel Castings Co.	X7X	X7	Mn-Mo
21	Sivyer Steel Castings Co.	90	5577	Ni-Cr-Mo-Cu
22	Sivyer Steel Castings Co.	90X	5577	Ni-Cr-Mo-Cu
23	Sivyer Steel Castings Co.	99	5596	Mn-Ni-Cr-Mo
24	Sivyer Steel Castings Co.	99X	5596	Mn-Ni-Cr-Mo
25	Symington-Gould Corp.	2	4552	Mn-Mo
26	Symington-Gould Corp.	5-2	4552	Mn-Mo
27	Wehr Steel Co.	A4-336	---	Ni-Cr-Mo
28	Wehr Steel Co.	W2-332	---	Ni-Cr-Mo

HV2
AMERICAN STEEL FOUNDRIES



ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

A80
ARNOLD ENGINEERING CO. CAST ARMOR PLATE
APRIL 18 1942 W.A.710-1807

DATA SHEET

American Steel Foundries

Heat - HV-2 Plate - HV-2 Thickness - 1-5/8" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V	Deoxidizer
.29	1.52	.41	.035	.034	--	--	--	--	.09	2# HC Fe Ti 3# Ca Si

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1825	-	8	Air
1525	-	2	Water
1175	-	4	Air

Physical Properties

T.S. - 104,750
Y.P. - 85,500
% Elong. - 21.5
% R.A. - 52.8
Izod - 44-45
Brinell - 226

Ballistic Properties

B.L. - 37MM M51AP - 1490(+142) PTP - 2½x2½ Shock: 75MM T12AP. PP (on companion Plate HV1). Passed.

Brinell Hardness - Cross-Section

Outside- 210 Midwall- 223 Center- 217

Jominy Hardenability

Hardness Penetration) 7/16" Critical Cooling Rate - 35°F/Sec Equivalent Plate Thickness) 1½"

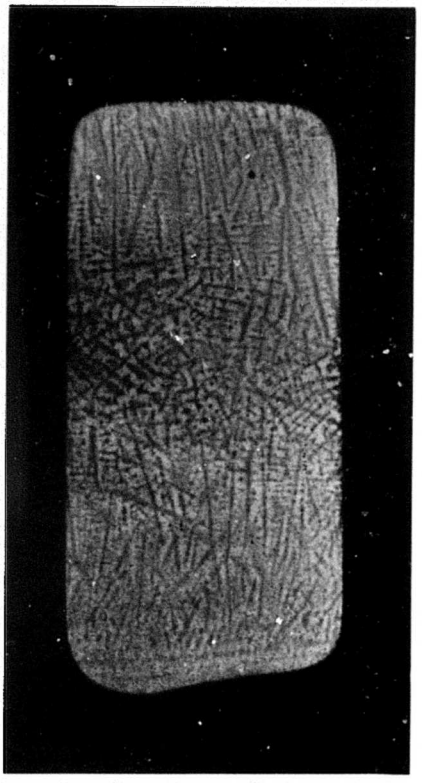
Two Bead Weldability

Single Bead VPN - 488, Rc - 45.5 Double Bead VPN - 333, Rc - 33

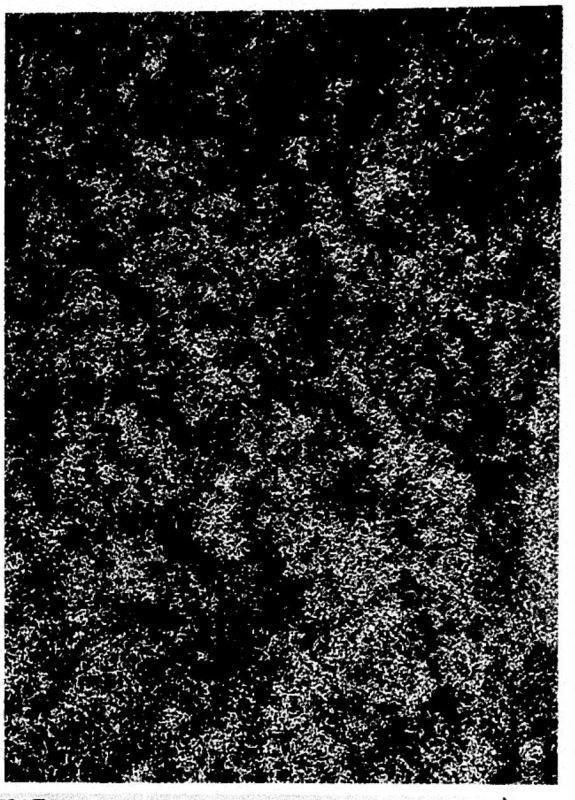
Microstructure and Remarks

Spheroidized sorbite with approximately 15% ferrite rejected upon the quench, indicating somewhat low hardenability for this section size. Very little dendritic segregation is revealed with a nital etch at a magnification of X25. The steel is fairly clean. A.S.T.M. Grain Size No. 7-8.

American Steel Foundries
Plate No. HV2



X2 MA-4202
Oberhoffer Etch



X25 MA-4197
Nital Etch

X1000 MA-4183
Murakami etch. Random distribution of carbides.

X1000 Nital and Picral Etch MA-4183

W.A.639-4034

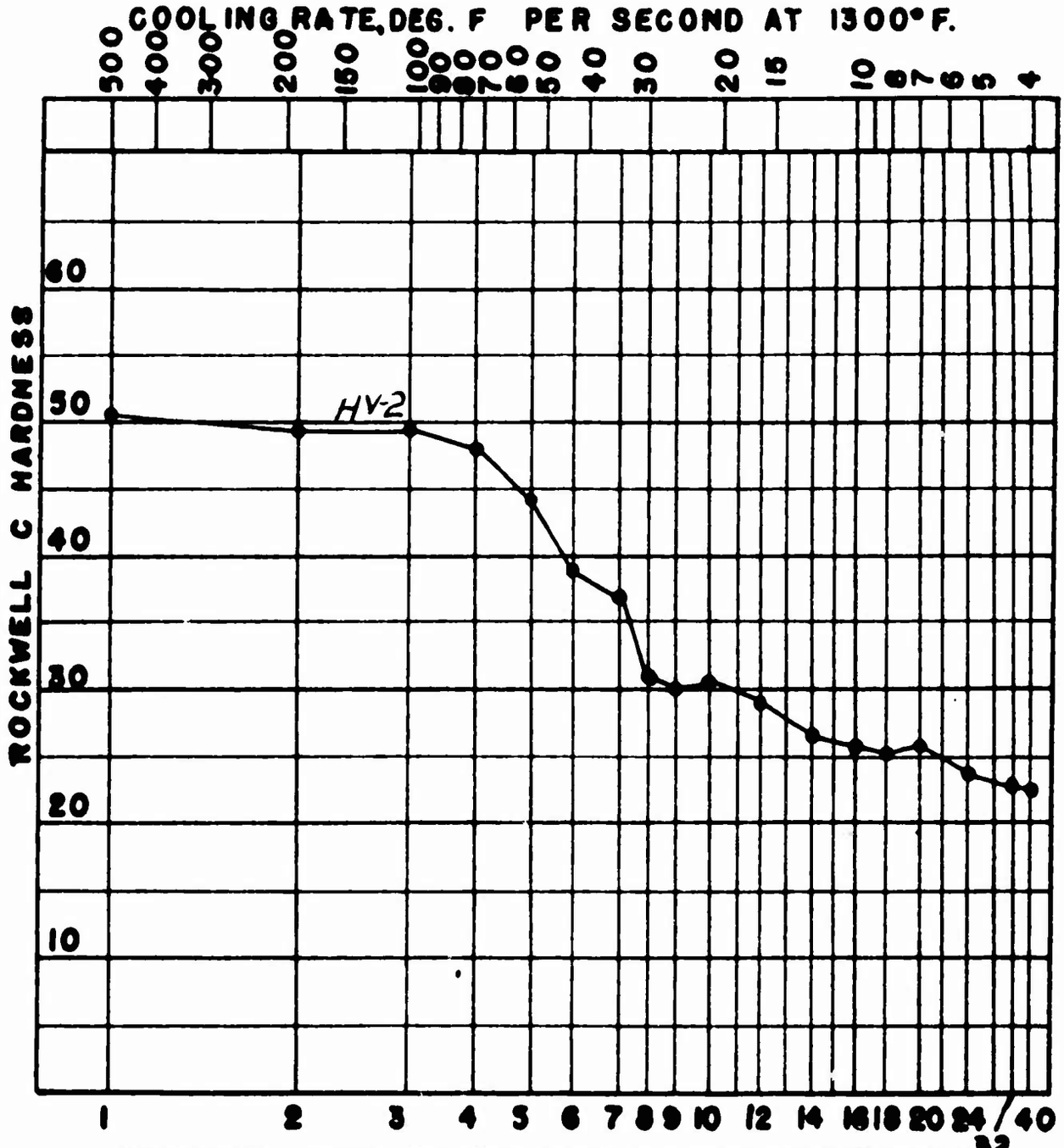


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	V	DEOX.	QUENCH TEMP	QUENCH TIME	G.S.
• HV2	HV-2	.29	1.52	.41	.035	.034	—	—	—	.09	2# HCA.T. 3# Ca Si	1525	2 hr.	7
			AMERICAN				STEEL		FOUNDRIES					

DATA SHEET

Arnold Engineering Co.

Heat - M128 Plate - A80 Thickness - 1.08"

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.17	.56	.24	.010	.014	—	1.26	.83	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1850	1	2	Air
1525	1	1	Water

Tempered to 300-340 Brinell.

Physical Properties

T.S. - 149,775
Y.P. - 91,210
% Elong. - 9.0
% R.A. - 16.3
Izod - 19
Brinell - 321-340

Ballistic Properties

B.L. - Cal..50 M2 AP - 2360 f/s 37MM M51 AP - CP - 1-5/8"x1-5/8".
37 MM M51 AP (25°) CP - CIP - BS 1-1/4x2". Passed.

Brinell Hardness - Cross-Section

Outside- 289 Midwall- 289 Center- 285

Jominy Hardenability

Hardness Penetration) 7/16" Critical Cooling Rate - 35°F/Sec Equivalent Plate Thickness) 1½"

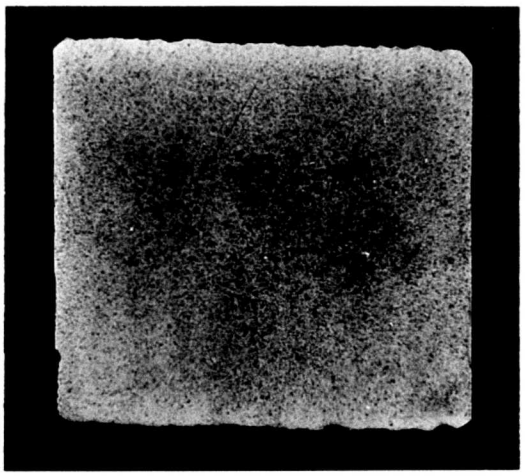
Two Bead Weldability

Single Bead VPN - 437, Rc - 42.5 Double Bead VPN 360, Rc - 36

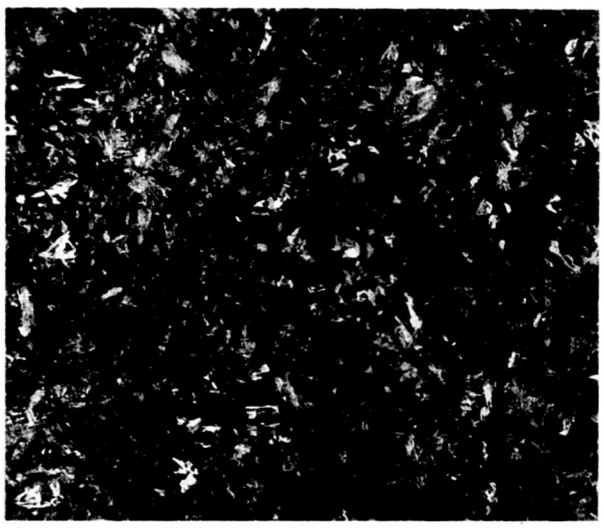
Microstructure and Remarks

Microstructure consists of patches of low carbon martensite and large ferrite grains containing islands of martensite aligned in cleavage planes. Due to the low carbon content it is impossible to quench this steel to a uniform martensitic structure. The steel has apparently not been tempered since it was impossible to obtain the desired hardness on the quench. Very little dendritic segregation is present. A.S.T.M. Grain Size No. 3.

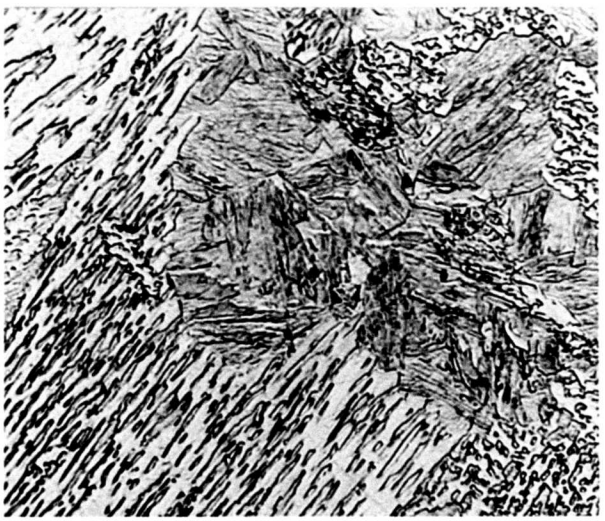
Arnold Engineering Company
Plate No. A80



X2 Oberhoffer Etch MA-4171



X25 Nital Etch MA-4165



X1000 Nital and Picral Etch MA-4158

W.A.639-4039

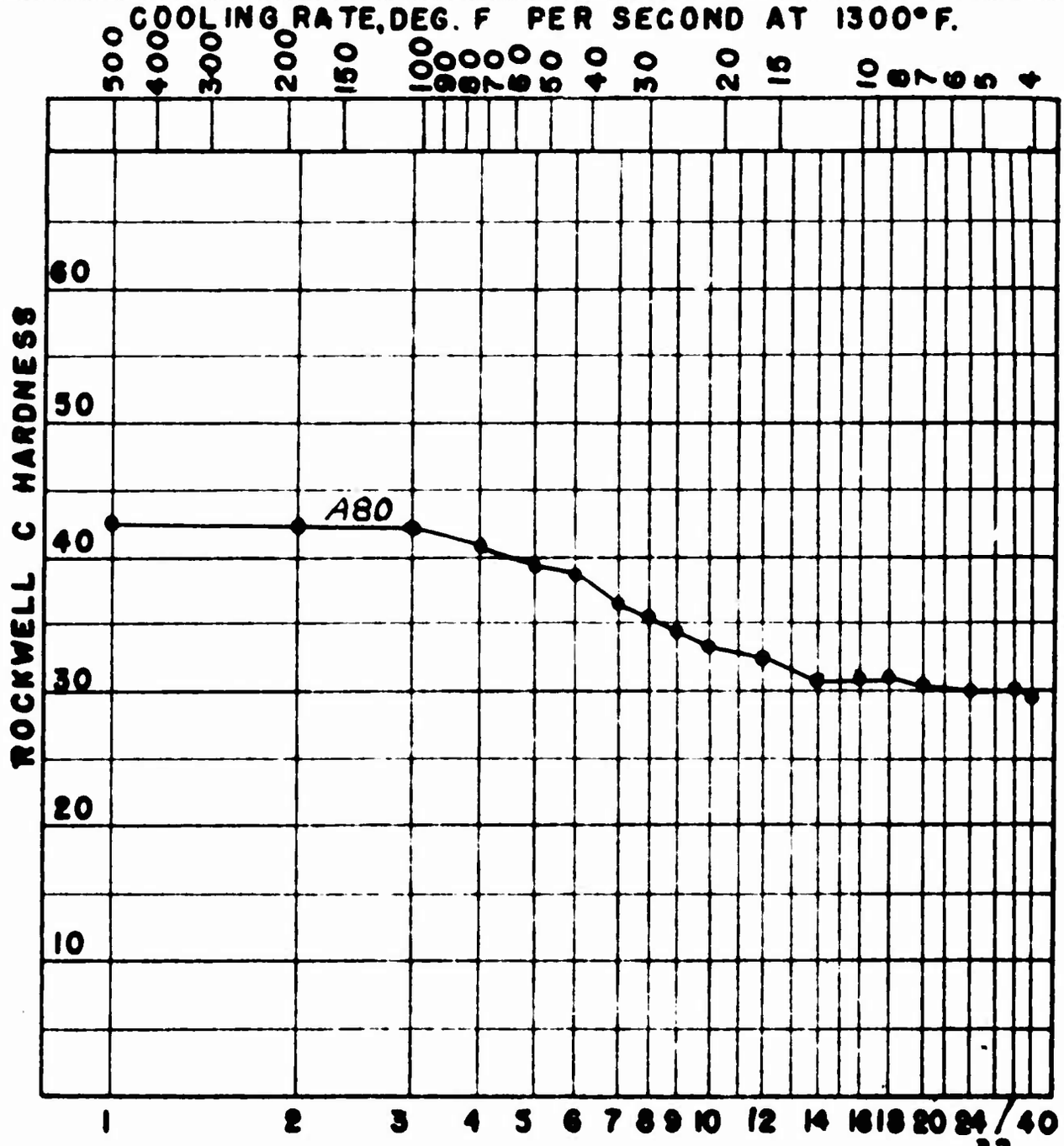
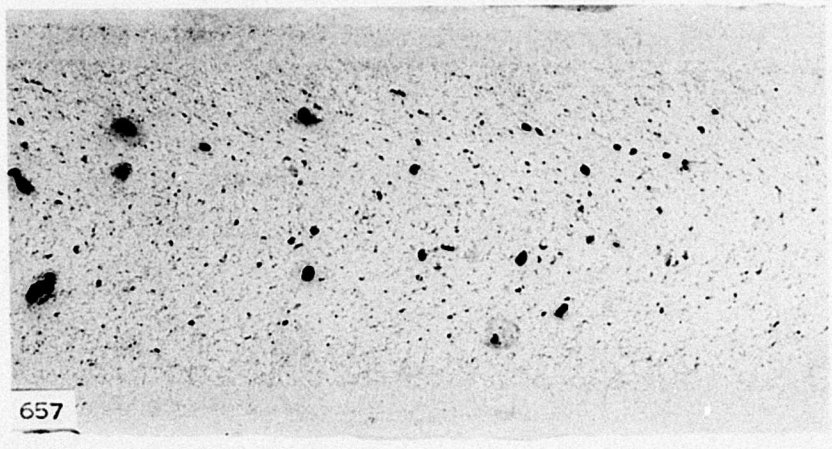
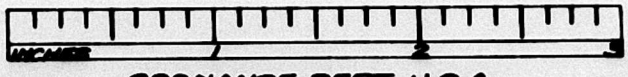


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
A80●	M128	.17	.56	.24	.010	.014	–	1.28	.83			1525	2 HRS.	7
			ARNOLD ENGINEERING Co.											

CONTINENTAL ROLL & STEEL FOUNDRY CO





ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

GENERAL STEEL CASTINGS CORP. CAST ARMOR PLATE. APRIL 18 1942 W.A.710-1808

DATA SHEET

Continental Roll and Steel Co.

Heat - 4009 Plate - 4009-3 Thickness - 2.18" Acid O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.32	.90	.29	.035	.042	—	—	.55	—	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1650	-	8	Air
1550	-	8	Water
1150	-	10	Furnace

Physical Properties

T.S. - 120,600
Y.P. - 101,850
% Elong. - 19.5
% R.A. - 52.7
Izod - 41
Brinell - 229-248

Ballistic Properties

B.L. - 37MM M51 AP - 1953(+127) PTP - 2-1/4"x2-1/2" Shock: 75MM T12 AP. PP - SB. BS - none. 75MM MK1 Slug. CP, plate broke in 6 pieces.

Brinell Hardness - Cross-Section

Outside- 232 Midwall- 226 Center- 232

Jominy Hardenability

Hardness) Penetration) 10/16" Critical Cooling Rate - 21°F/Sec Equivalent) Plate) 2" Thickness)

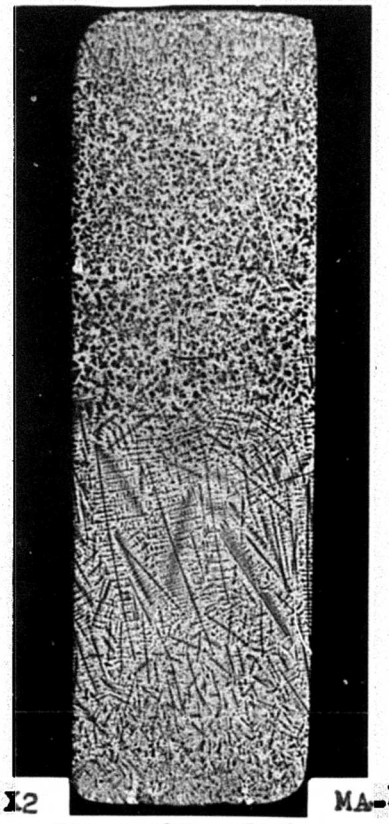
Two Bead Weldability

Single Bead VPN - 542, Rc - 49.5 Double Bead VPN - 390, Rc - 37.5

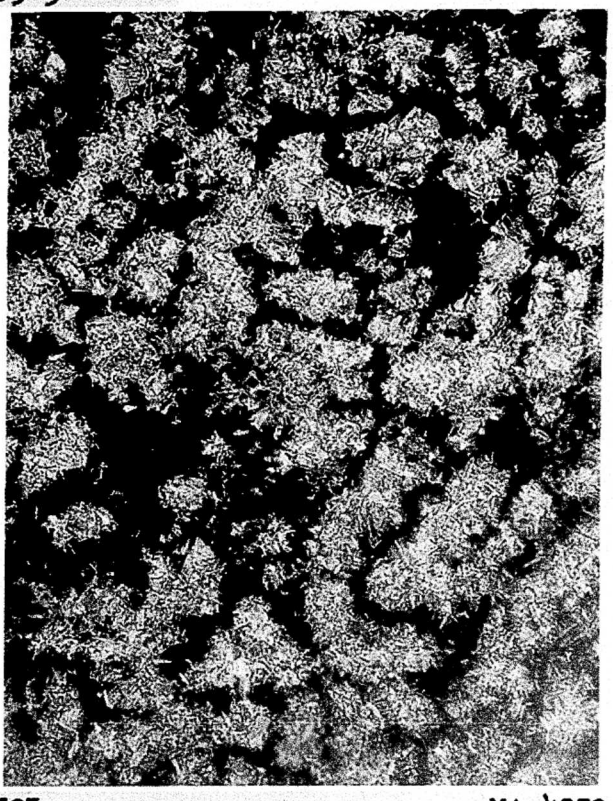
Microstructure and Remarks

Spheroidized sorbite with some ferrite rejected upon the quench, indicating somewhat low hardenability for this section size. A diffused dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 4-5.

Continental Roll and Steel Co.
Plate No. 4009-3



X2 MA-4236
Oberhoffer Etch



X25 MA-4239
Nital Etch

X25 MA-4222
Unetched. Distribution of nonmetallic inclusions.

X1000 Nital and Picral Etch MA-4246

W.A.639-4057

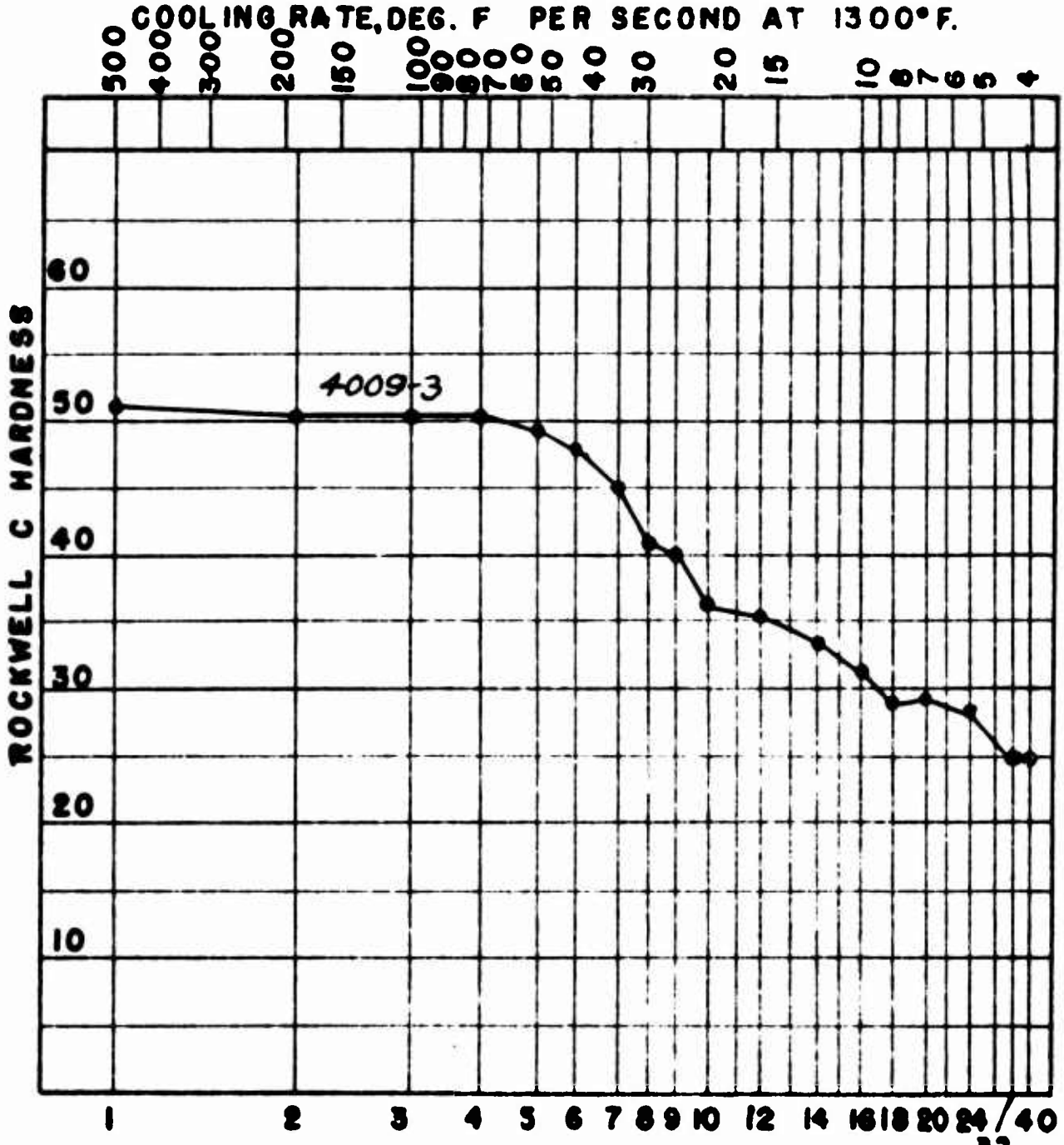
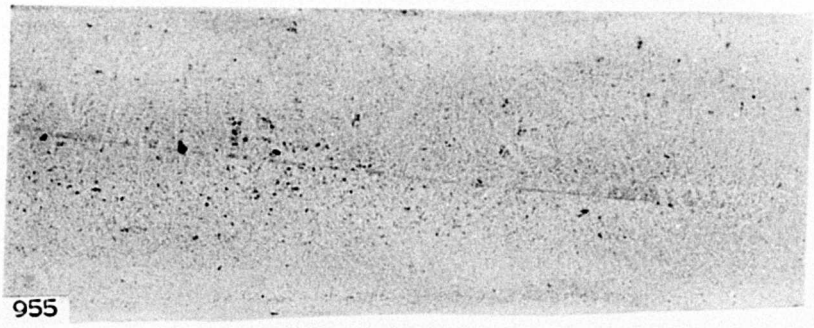
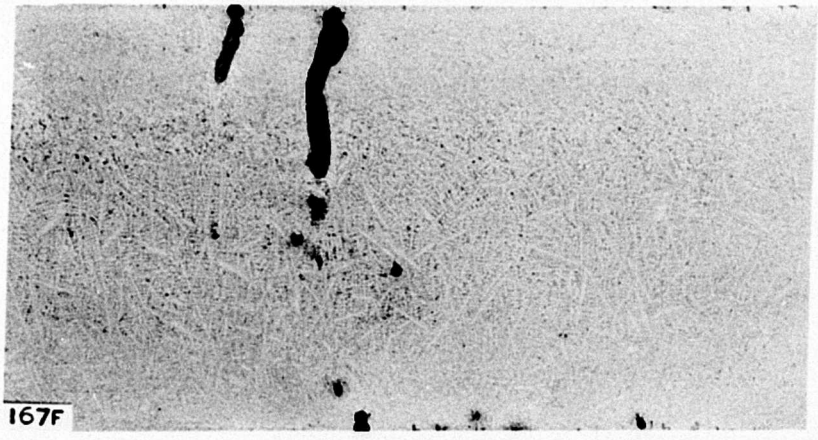
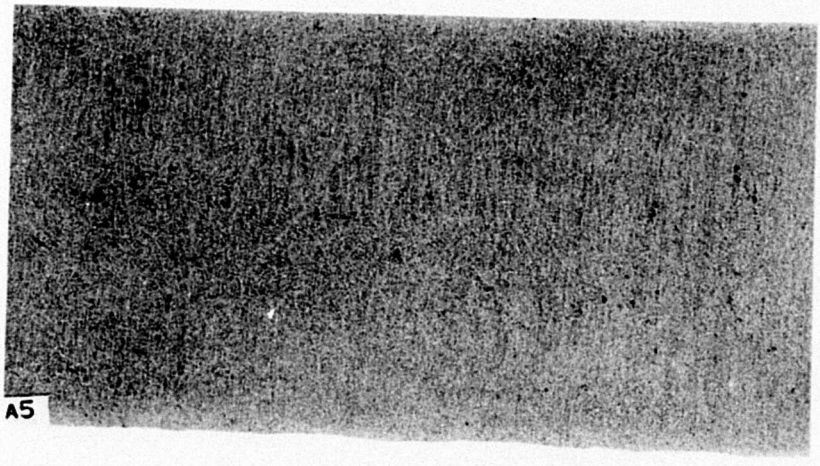
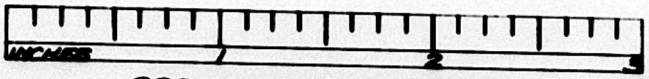


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
40093	• 4009	.32	.90	.29	.035	.042			.55			1550	4	5
		CONTINENTAL ROLL AND STEEL CO.												









ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

FORD MOTOR COMPANY CAST ARMOR PLATE
APRIL 18 1942 W.A.710-1809

DATA SHEET

Ford Motor Co.

Heat - Plate - A5 Thickness - 2.19" Basic Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.28	.79	.18	.016	.020	--	--	.52	.72	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1950	-	10	Air
1650	-	5	Caustic
1750	-	5	Caustic
1150	-	8	Air

Physical Properties

T.S. - 123,500
Y.P. - 108,500
% Elong. - 19.5
% R.A. - 52.5
Izod - 46.5
Brinell - 241

Ballistic Properties

B.L. - 37MM M51 AP - 2047(+214) PTP - 2x2-3/4" Shock: 75 MM MK1 proof slug. PP - SB. ½" bow. Passed.

Brinell Hardness - Cross-Section

Outside- 255 Midwall- 259 Center- 255

Jominy Hardenability

Hardness Penetration) 17/16" Critical Cooling Rate - 9°F/Sec Equivalent Plate Thickness) 2-3/4"

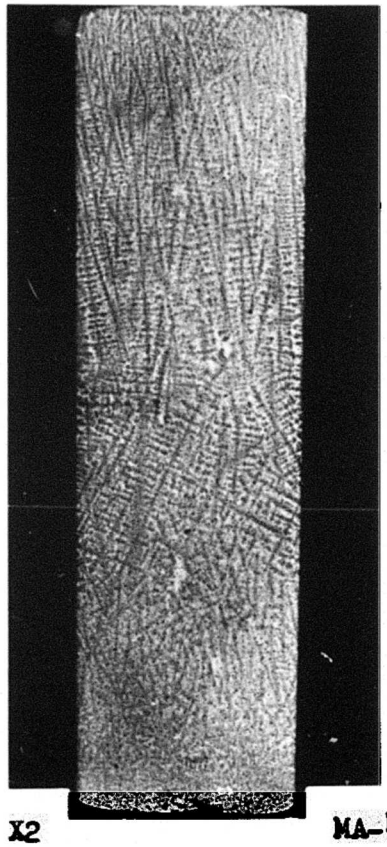
Two Bead Weldability

Single Bead VPN - 493, Rc - 47.5 Double Bead VPN - 360, Rc - 35

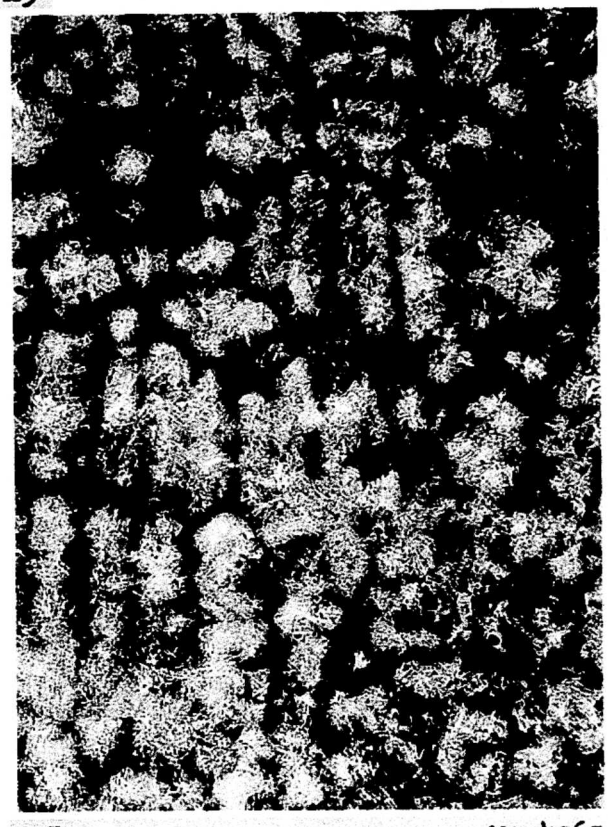
Microstructure and Remarks

Fine, uniformly spheroidized sorbite with a small amount of ferrite rejected on quenching, indicating satisfactory hardenability for this plate thickness. This steel has a considerable degree of dendritic segregation with inclusions segregated in the interdendritic fillings. A.S.T.M. Grain Size No. 2-3.

Ford Motor Co.
Plate No. A5



X2 MA-4269
Oberhoffer Etch



X25 MA-4262
Nital Etch

X25 MA-4257
Unetched. Distribution of nonmetallic inclusions. Relatively unclean steel.

X1000 Nital and Picral Etch MA-4253

W.A.639-4049

DATA SHEET

Ford Motor Co.

Heat - Plate - 167F Thickness - 2.23" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.40	.65	.24	--	--	--	--	.51	.71	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1950	-	10	Air
1750	-	5	Caustic
1150	-	8	Air

Physical Properties

T.S. - 115,000
Y.P. - 109,000
% Elong. -
% R.A. -
Izod - 23.0
Brinell - 248-262

Ballistic Properties

B.L. - 37MM M51 AP - 1879(+18) PTP - 2-3/4"x2-3/4" Shock: 75MM T12 AP. CP. SC on LB. Passed. 75MM MK1 Slug. PP. SC on LB. 7" crack on face.

Brinell Hardness - Cross-Section

Outside- 248 Midwall- 255 Center- 255

Jominy Hardenability

Hardness Penetration) 9/16" Critical Cooling Rate - 26°F/Sec Equivalent Plate Thickness) 1-3/4"

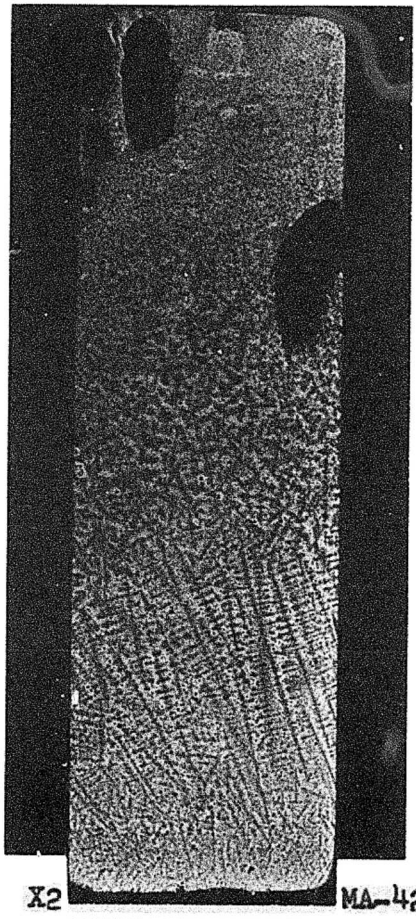
Two Bead Weldability

Single Bead VPN - 464, Rc - 44.5 Double Bead VPN - 292, Rc - 30.5

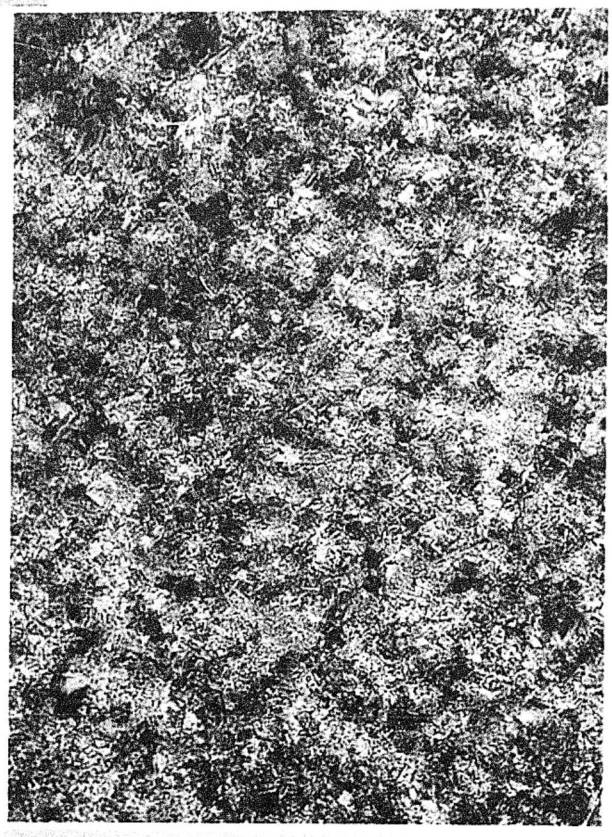
Microstructure and Remarks

Partially spheroidized acicular sorbite with a slight amount of ferrite rejected on the quench, indicating fair hardenability for this section size. The steel is relatively clean. A slight dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 6-7.

Ford Motor Co.
Plate No. 167F



X2 MA-4217
Oberhoffer Etch



X25 MA-4213
Nital Etch

X25 MA-4207
Unetched. Distribution of nonmetallic inclusions. Relatively clean steel.

X1000 Nital and Picral Etch MA-4209

W.A.639-4032

DATA SHEET

Ford Motor Co.

Heat - Plate - 955 Thickness - 1.65" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.28	.53	.23	---	---	---	.42	.79	---	---

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1950	-	10	Air
1650	-	5	Caustic
1750	-	5	Caustic
1150	-	8	Air

Physical Properties

T.S. - 114,500
Y.P. - 97,000
% Elong. - 13.0
% R.A. - 27.0
Izod - 29.0
Brinell - 241

Ballistic Properties

B.L. - 37MM M51 AP - 1516(+87) PTP - 2x2-1/4" Shock: 75MM T12 AP. CP - SC on MB. Passed. 75MM MK1 slug. PP - SB. Bow 1-1/16".

Brinell Hardness - Cross-Section

Outside- 255 Midwall- 252 Center- 241

Jominy Hardenability

Hardness Penetration 7/16" Critical Cooling Rate - 35°F/Sec Equivalent Plate Thickness 1½"

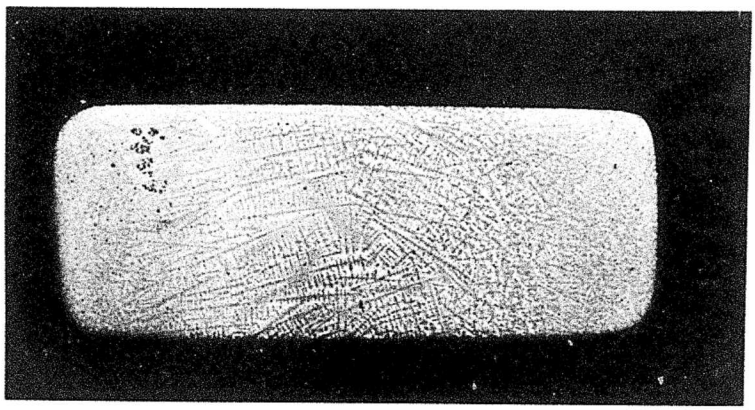
Two Bead Weldability

Single Bead VPN - 483, Rc - 42 Double Bead VPN - 336, Rc - 31.5

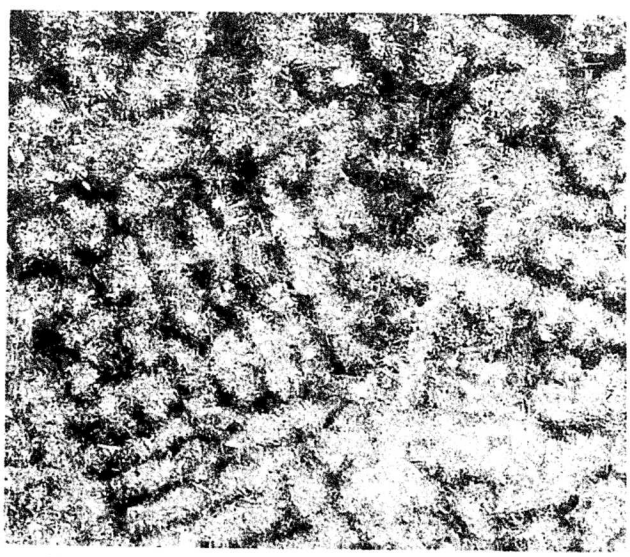
Microstructure and Remarks

Fine spheroidized sorbite with somewhat more ferrite rejected than in the case of Ford Plate No. A5. This steel possesses satisfactory hardenability for plate of this thickness, but not to the degree shown by Plate No. A5. Considerable dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 6.

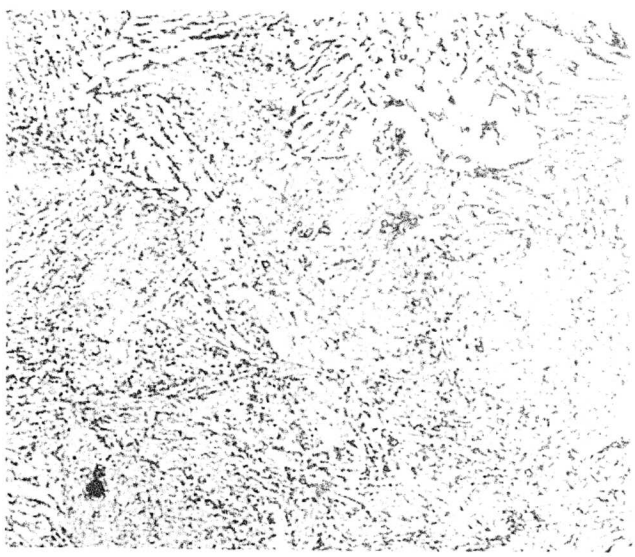
Ford Motor Co.
Plate No. 955



X2 Oberhoffer Etch MA-4267



X25 Nital Etch MA-4263



X1000 Nital and Picral Etch MA-4255

W.A.639—4060

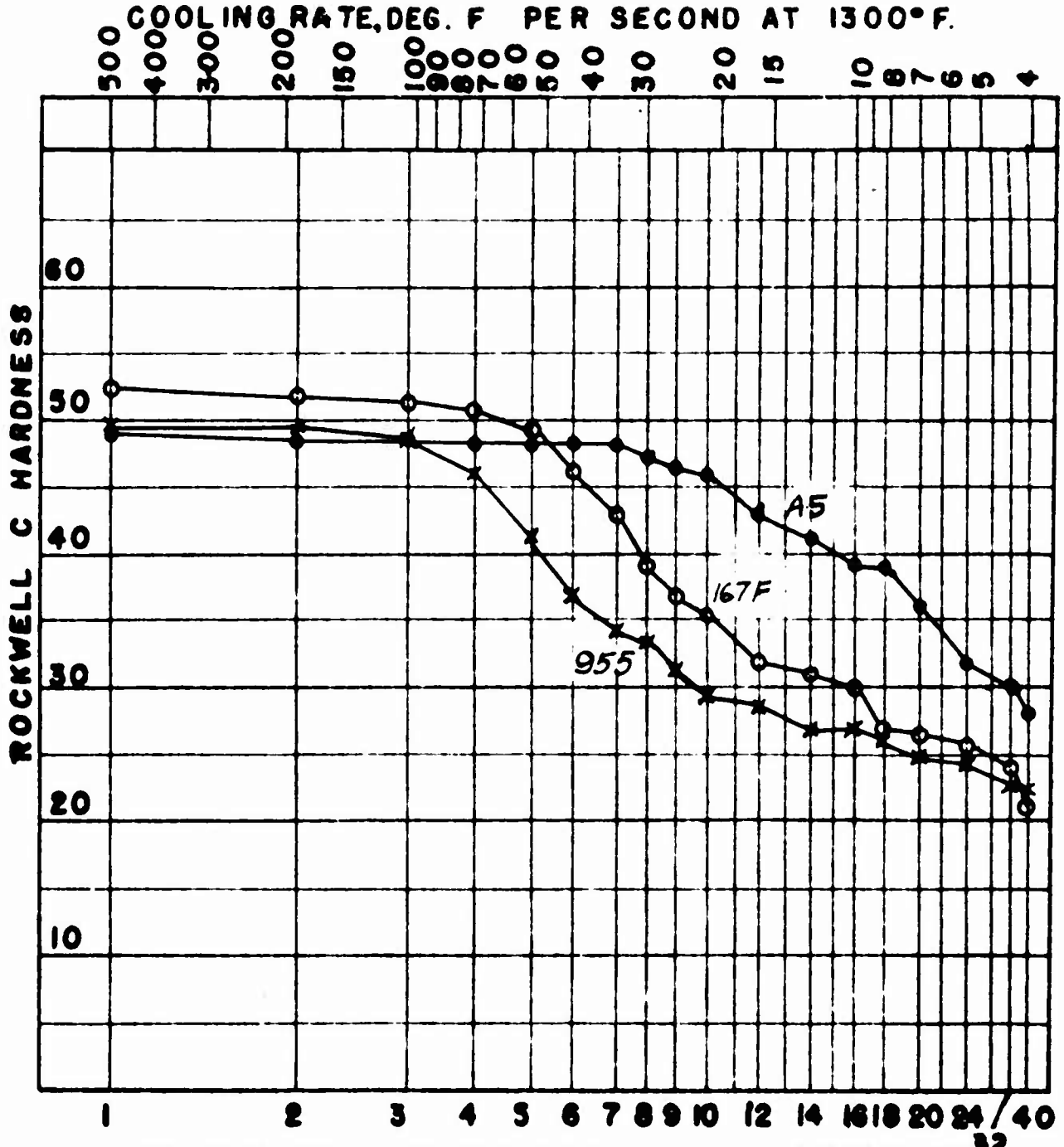


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	Cu		QUENCH TEMP	QUENCH TIME	G.S.
A5		.28	.79	.18	.016	.020	—	—	.52	.72		1750	4	6
167F		.40	.65	.24			—	—	.51	.71		1750	4	5
955X		.28	.53	.23				.42	.79			1750	4	7
		FORD		MOTOR		Co.								

DATA SHEET

General Steel Castings Corp.

Heat - 5522M Plate - 645 Thickness - 2-1/4" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.27	1.48	.40	.017	.022	--	--	.51	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
2000	-	10	Air
1250	-	4	Air
1675	-	4	Water
1175	-	4	Air

Physical Properties

T.S.	- 125,000
Y.P.	- 107,500
% Elong.	- 17.0
% R.A.	- 38.2
Izod	- 56.3
Brinell	- 252

Ballistic Properties

B.L.(Companion Plate No. 646) 37MM M51 AP - 1936(+61)
PTP - 2-3/8x2-7/16"
Shock(Plate No. 645) - 75MM T12 AP - PP, SB. Passed.

Brinell Hardness - Cross-Section

Outside- 255 Midwall- 252 Center- 245

Jominy Hardenability

Hardness Penetration) 14/16" Critical Cooling Rate - 12°F/Sec Equivalent Plate Thickness) 2-1/4"

Two Bead Weldability

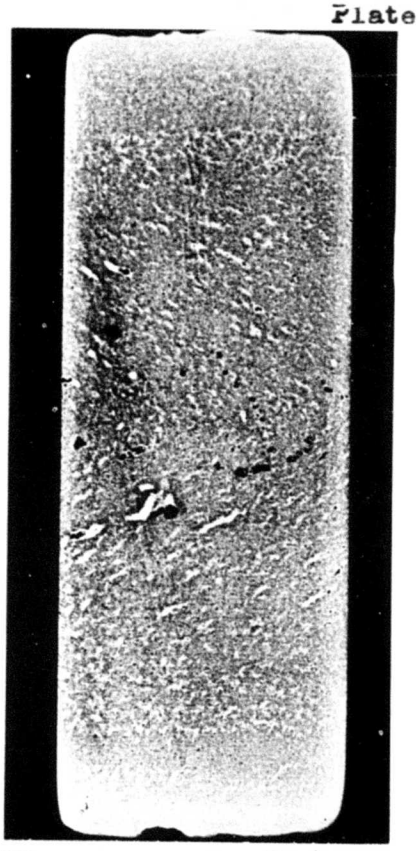
Single Bead VPN - 508, Rc - 48.5 Double Bead VPN - 327, Rc - 32.5

Microstructure and Remarks

Somewhat spheroidized acicular sorbite with occasional patches of ferrite rejected on quenching, indicating satisfactory hardenability for this section size. Considerable dendritic segregation is revealed with a nital etch at a magnification of X25. The steel is fairly dirty with considerable shrinkage porosity in the middle of the cross-section. A.S.T.M. Grain Size No. 6-7.

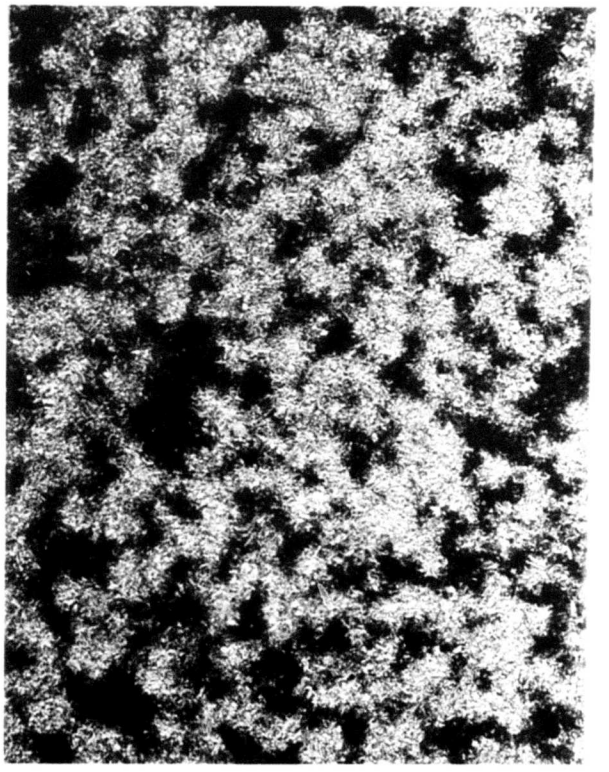
General Steel Castings Corp.

Plate No. 645



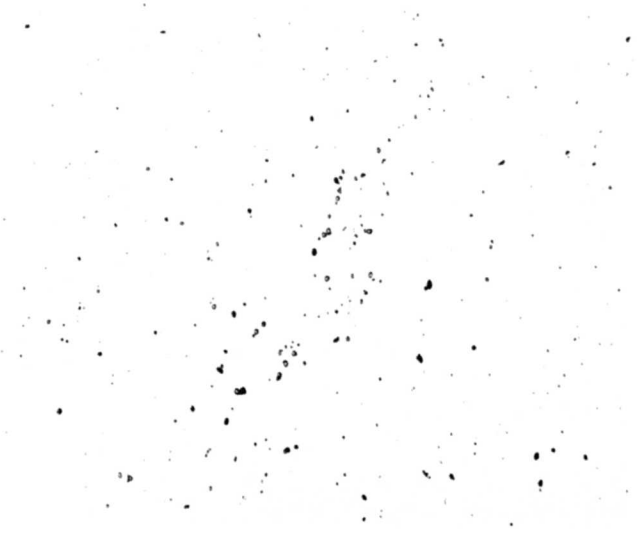
X2 MA-4172

Oberhoffer Etch



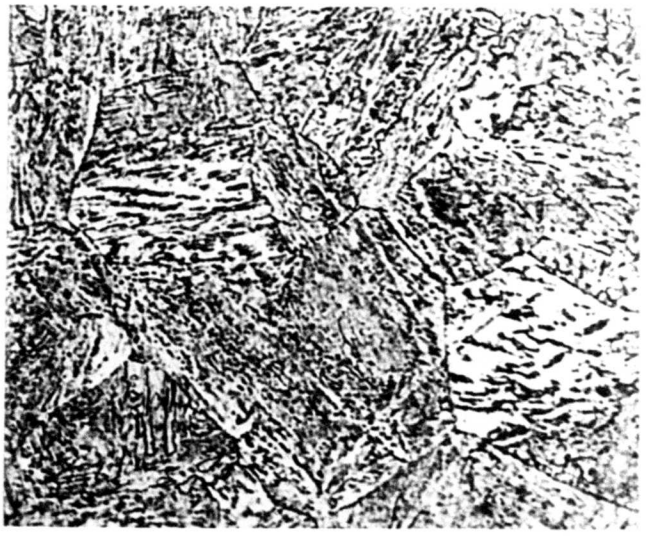
X25 MA-4169

Nital Etch



X25 MA-4155

Unetched. Distribution of nonmetallic inclusions.



X1000 MA-4163

Nital and Picral Etch

W.A.639—4038

DATA SHEET

General Steel Casting Co.

Heat - 5531MMC Plate - 657 Thickness - 2.33" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.28	1.58	.40	.017	.020	—	.71	.52	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
2000	-	10	Air
1250	-	4	Air
1675	-	4	Water
1175	-	4	Air
1250	-	4	Air

Physical Properties

T.S. - 107,000
Y.P. - 76,000
% Elong. - 18.0
% R.A. - 30.5
Izod - 51.3
Brinell - 244

Ballistic Properties

B.L. - 37MM M51 AP - 1979(+69) PTP - 2-3/8x2-5/8" Shock: 75MM T12 AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 212 Midwall- 220 Center- 223

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

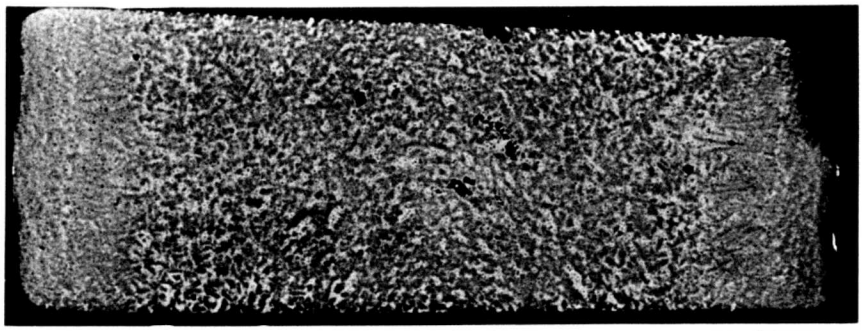
Two Bead Weldability

Single Bead VPN - 530, Rc - 50.5 Double Bead VPN - 417, Rc - 39.5

Microstructure and Remarks

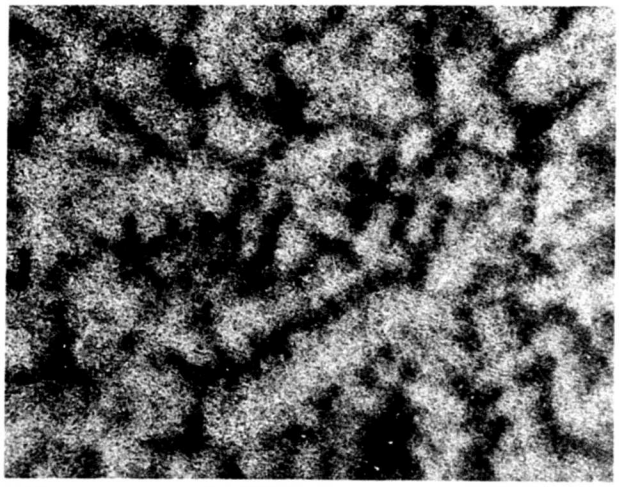
Extremely uniform spheroidized sorbite indicating excellent hardenability. No ferrite present in the microstructure. A somewhat diffused dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size is finer than No. 8.

General Steel Castings Co.
Plate No. 657



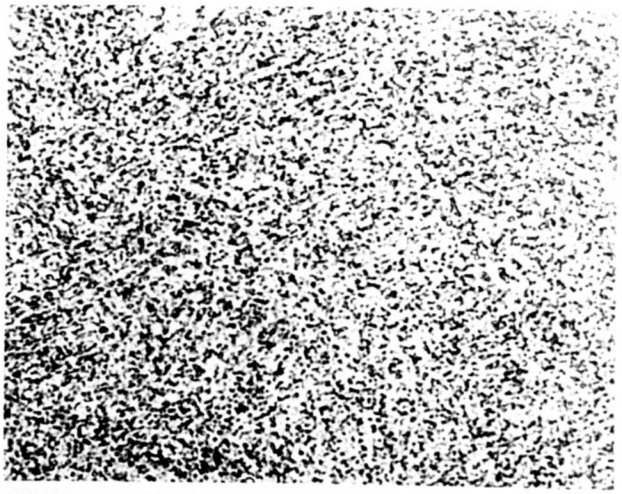
X2 Oberhoffer Etch MA-4235

X25 MA-4223
Unetched. Distribution of nonmetallic inclusions in interdendritic fillings.



X25 Nital Etch MA-4237

X1000 MA-4227
Murakami etch. Carbide distribution.



X1000 MA-4247
Nital and Picral Etch

W.A.639—4053

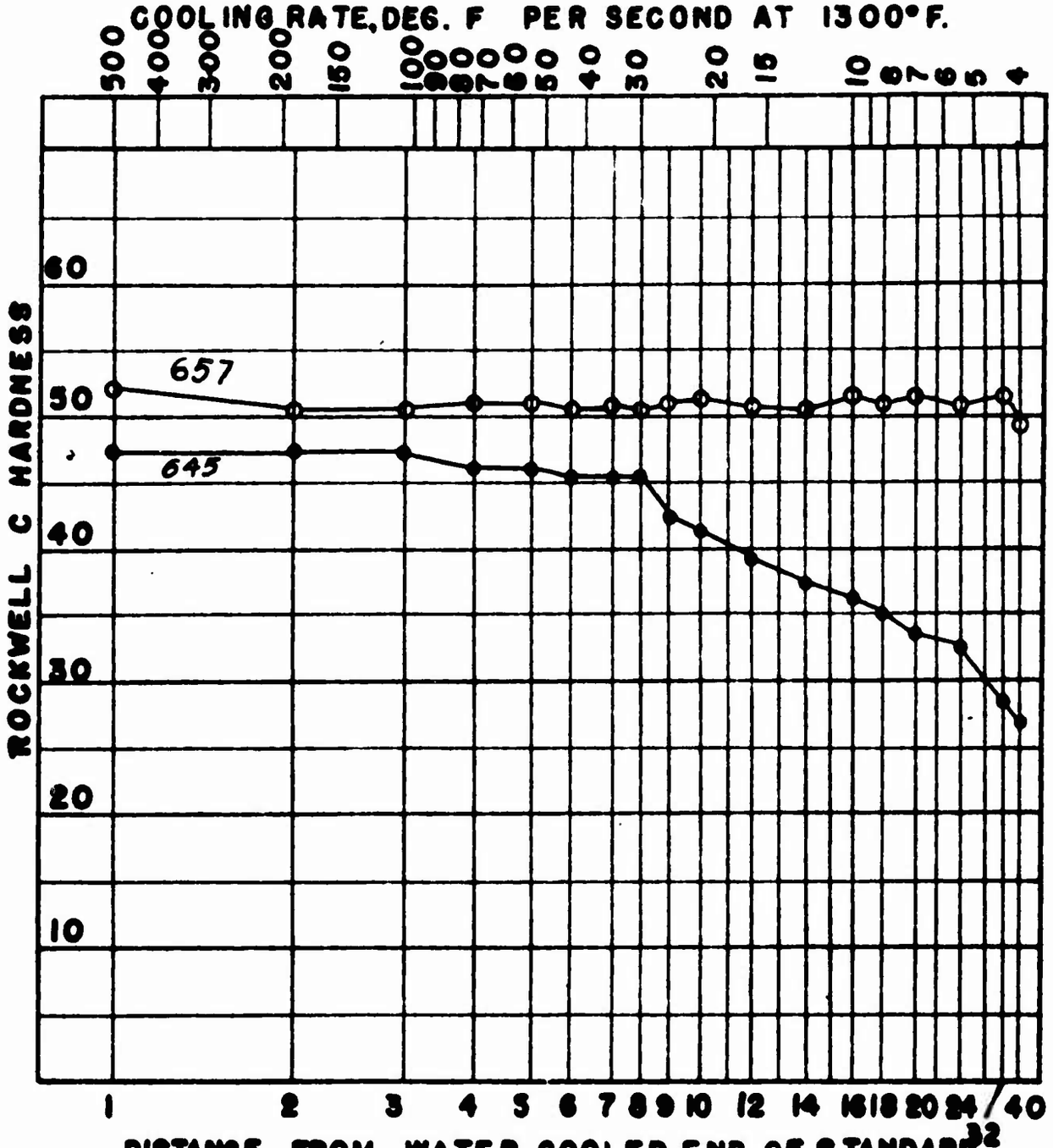
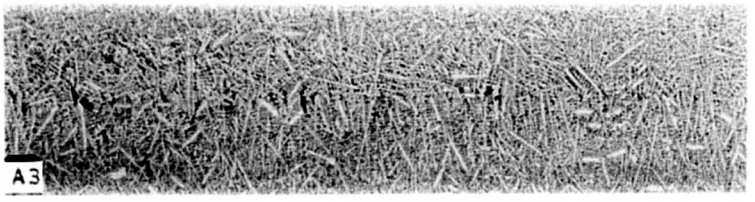
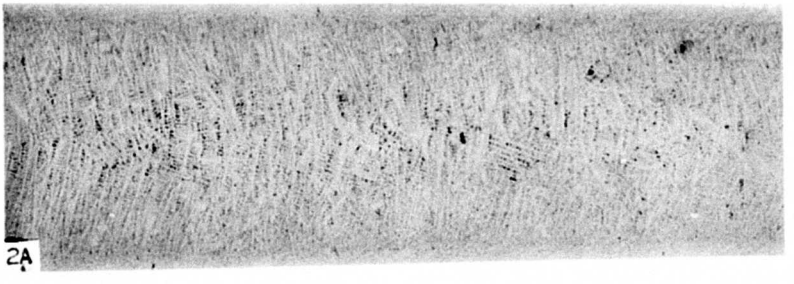
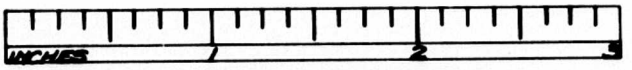


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
645	•552211	.27	1.46	.40	.017	.022	-	-	.51			1675	4	7
657	0559IM	.28	1.58	.40	.017	.020	-	.71	.52			1675	4	7
		GENERAL STEEL CASTING CO.												



LEBANON STEEL FOUNDRY





ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

PRATT & LETCHWORTH CO. INC. CAST ARMOR PLATE. APRIL 18 1942 W.A.710-1811

DATA SHEET

Lebanon Steel Foundry

Heat - HE8935 Plate - A3 Thickness - 1" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.19	.95	.48	.020	.035	.67	.66	.65	1.03	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1900	-	5	Air to 1700
1700	-	-	Water
1575	-	4	Water
1075	-	5	Water

Physical Properties

T.S. - 142,000
Y.P. - 105,000
% Elong. - 9.0
% R.A. - 32.1
Izod - 12.0
Brinell - 302

Ballistic Properties

B.L. Cal. .50 AP M1 - 2223(+23) 37MM M51AP - 1-11/16"x1-13/16"
37MM M51AP(25°) - PP. SC on LB. Passed.

Brinell Hardness - Cross-Section

Outside- 281 Midwall- 285 Center- 285

Jominy Hardenability

Hardness Penetration) 13/16" Critical Cooling Rate - 14°F/Sec Equivalent Plate Thickness) 2-1/4"

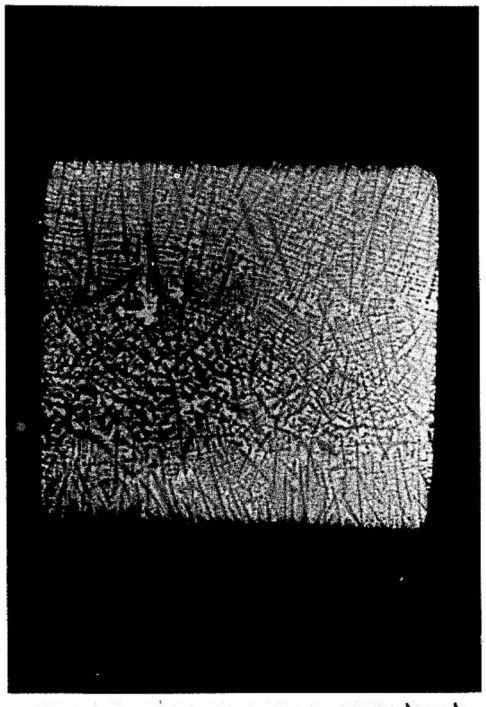
Two Bead Weldability

Single Bead VPN - 468, Rc - 44 Double Bead VPN - 373, Rc - 37

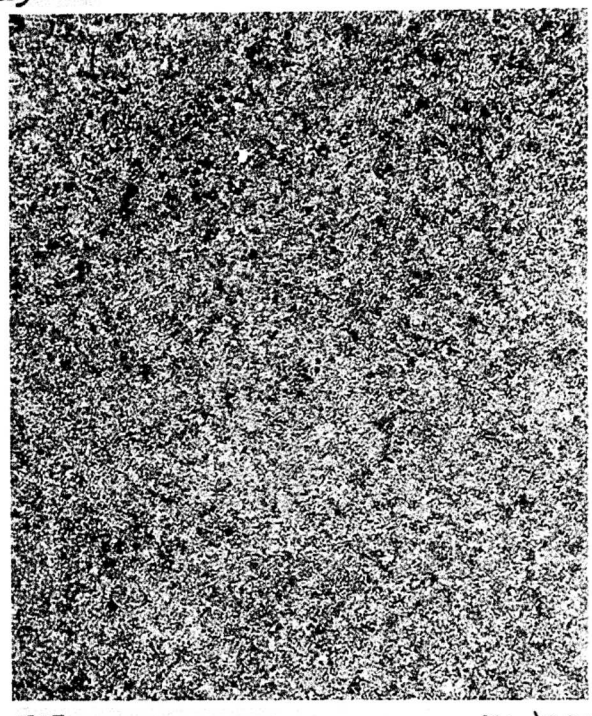
Microstructure and Remarks

Acicular sorbite with no ferrite present, indicating excellent hardenability for this section size. The Murakami etch shows very fine carbides with a tendency to outline grain boundaries. A very homogeneous structure is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 7.

Lebanon Steel Foundry
Plate No. A3

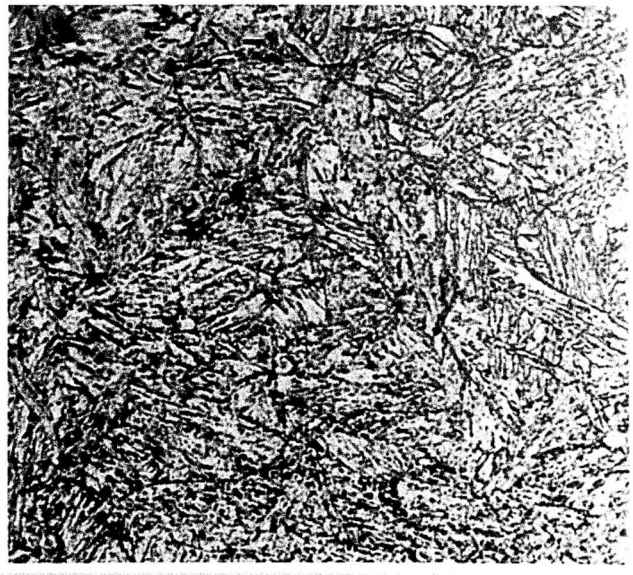


X2 MA-4204
Oberhoffer Etch



X25 MA-4198
Nital Etch

X1000 MA-4187
Murakami etch. Fine carbides with tendency to outline grain boundaries.



X1000 Nital and Picral Etch MA-4186

W.A.639—4030

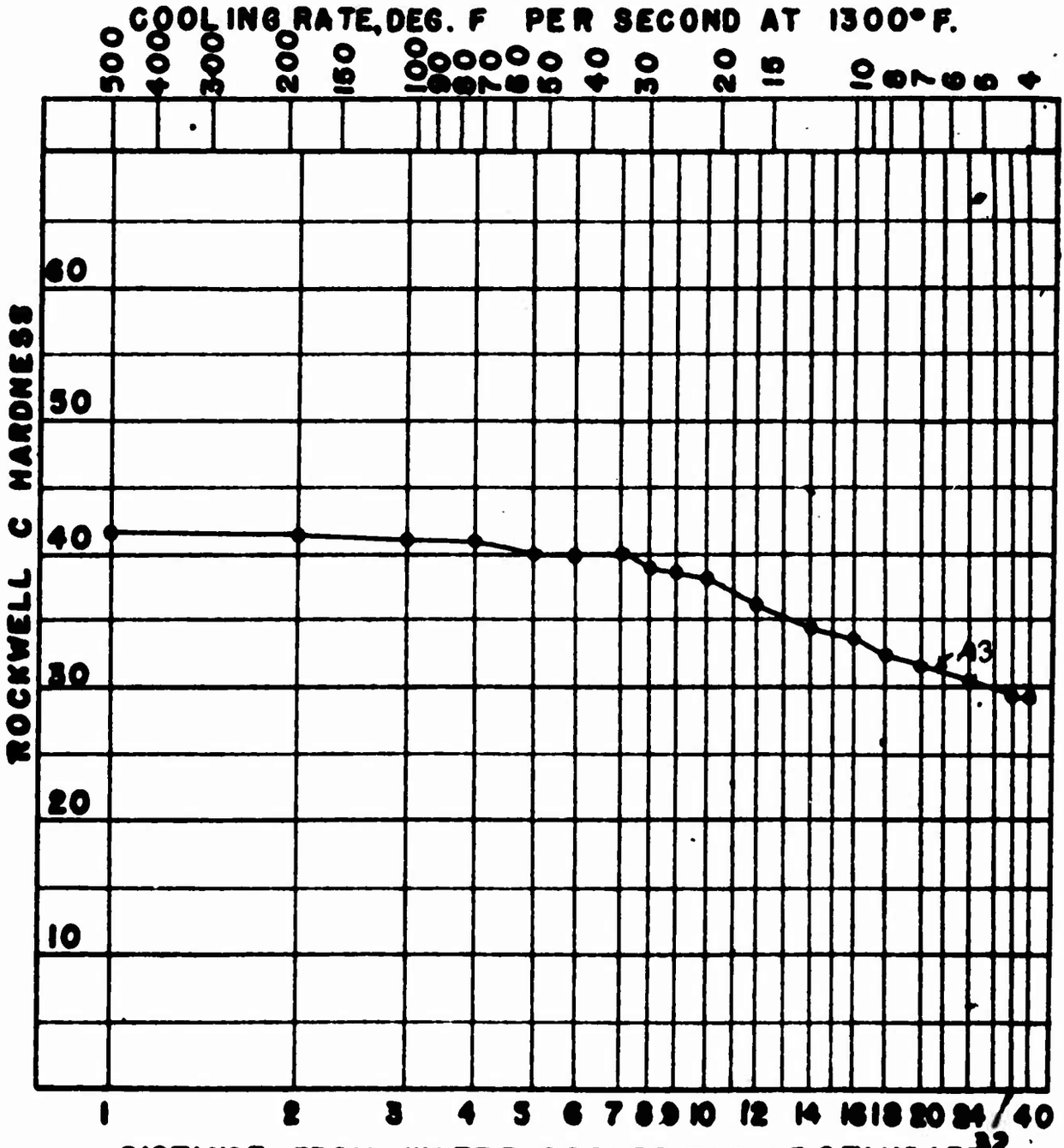
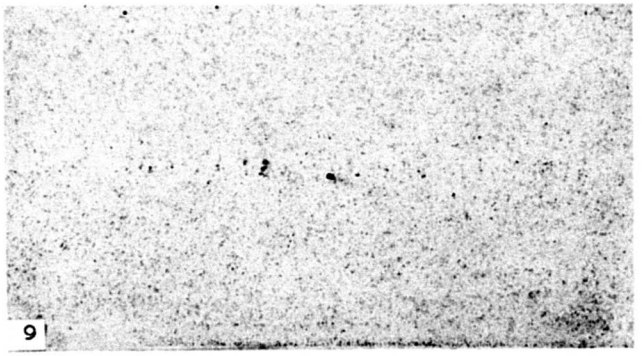
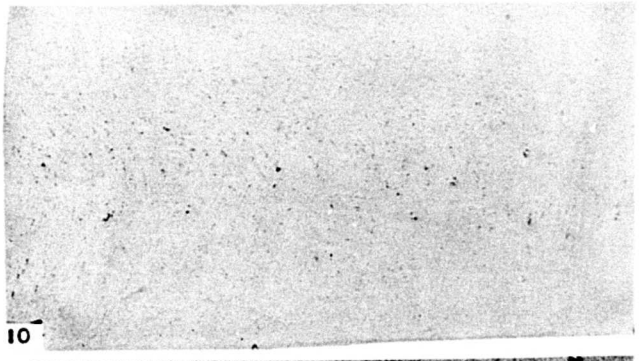


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	CU		QUENCH TEMP	QUENCH TIME	G.S.
A3	• 8935	.19	.95	.48	.020	.035	.67	.66	.65	1.03		1575	4	6

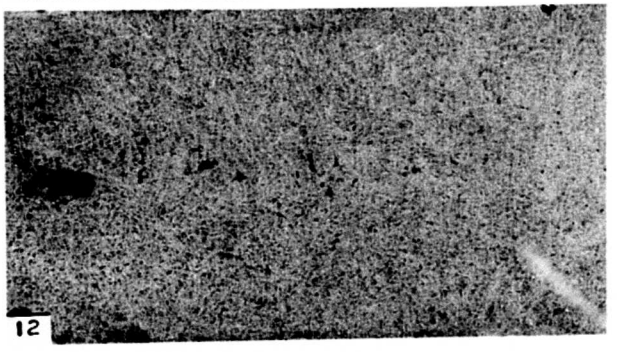


9



10

11



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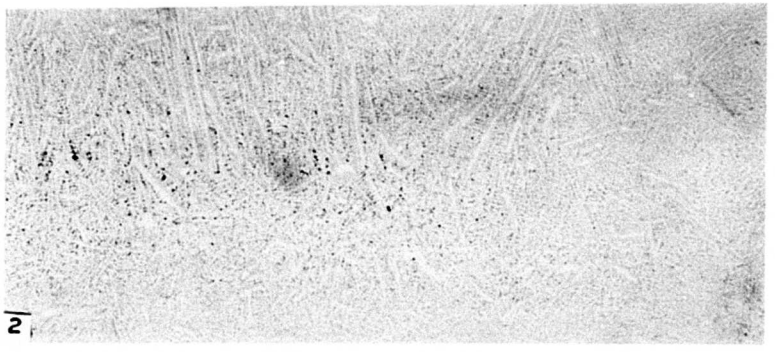
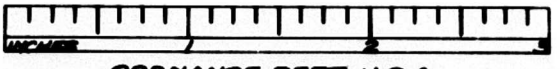


2



ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

PACIFIC CAR & FOUNDRY CO. CAST ARMOR PLATE
APRIL 18 1942 W.A.710-1810

DATA SHEET

Pacific Car & Foundry Co.

Heat - 42B105 Plate - 2 Thickness - 2-1/16"

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.20	.89	.70	.017	.019	—	—	.43	1.44	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1850	-	7	Air
1625	-	2	Water
1250	-	2½	Furnace

Physical Properties

T.S. - 102,350
Y.P. - 88,520
% Elong. - 24.0
% R.A. - 56.0
Izod -
Brinell - 217

Ballistic Properties

B.L. - 37MM M51 AP - 1795(+51) PTP - 2-5/8"x2-1/8" Shock: 75MM T12 AP. PP. Passed.

Brinell Hardness - Cross-Section

Outside- 202 Midwall- 207 Center- 207

Jominy Hardenability

Hardness Penetration 6/16" Critical Cooling Rate - 43°F/Sec Equivalent Plate Thickness 1-1/4"

Two Bead Weldability

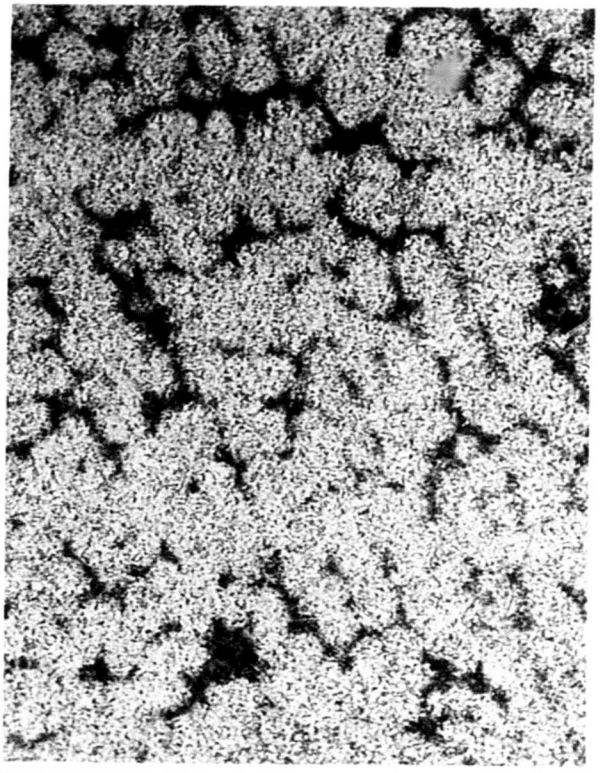
Single Bead VPN - 384, Rc - 34.5 Double Bead VPN - 302, Rc - 25

Microstructure and Remarks

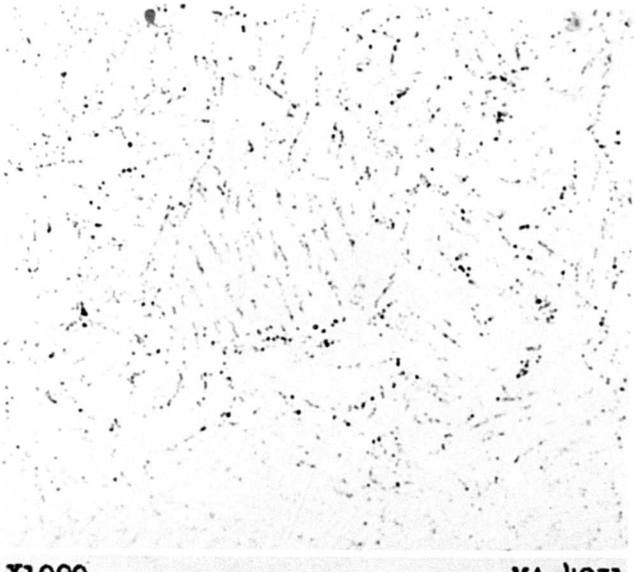
Spheroidized sorbite with approximately 50% ferrite, indicating very low hardenability for this section size. The Murakami etch shows a tendency for carbides to outline the grain boundaries. The steel is relatively clean and has a pronounced dendritic segregation revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size finer than No. 8.

Pacific Car and Foundry Co.
Plate No. 2

X2 MA-4232
Oberhoffer Etch



X25 MA-4131
Nital Etch



X1000 MA-4231
Murakami etch. Some tendency for carbides to outline grain boundaries.

X1000 Nital and Picral Etch MA-4129

W.A.639—4058

DATA SHEET

Pacific Car & Foundry Co.

Heat - 42B126 Plate - 9 Thickness - 2.14"

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.20	1.02	.82	.024	.018	--	--	--	1.75

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1850	-	6	Air
1000	-	2	Air
1625	-	2	Water
925	-	2	Air

Physical Properties

T.S. - 118,750
Y.P. - 105,850
% Elong. - 20.0
% R.A. - 36.3
Izod -
Brinell - 252

Ballistic Properties

B.L. - 37MM M51 AP - 1889(+90) PTP - 2-3/8x3" Shock: 75MM T12 AP.
FP - S3. Passed.

Brinell Hardness - Cross-Section

Outside- 241 Midwall- 235 Center- 229

Jominy Hardenability

Hardness Penetration) 3/16" Critical Cooling Rate - 106°F/sec. Equivalent Plate Thickness) 3/4"

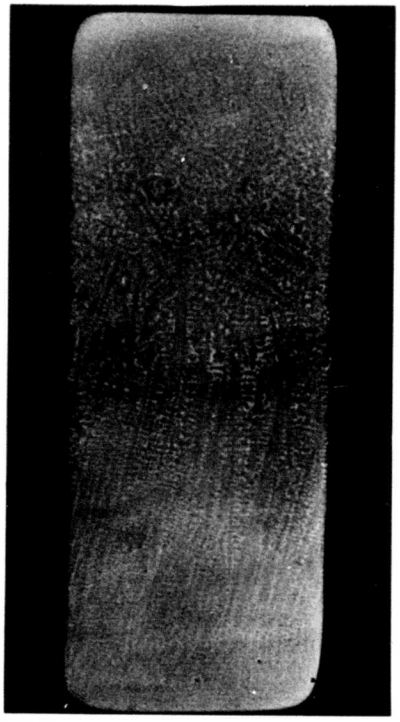
Two Bead Weldability

Single Bead VPN - 285, Rc - 19.5 Double Bead VPN - 233, Rc - 14.5

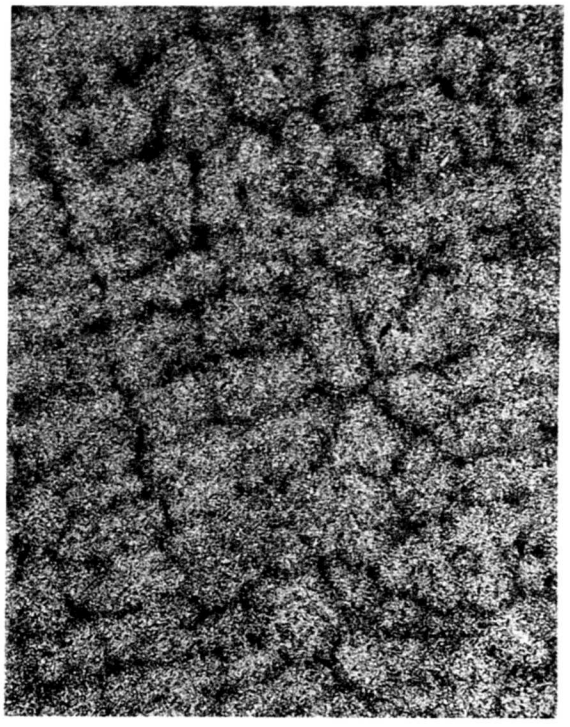
Microstructure and Remarks

Small patches of sorbite and approximately 80% ferrite rejected upon the quench, indicating very poor hardenability for this section size. A slight amount of dendritic segregation is revealed with a nital etch at a magnification of X25. A very pronounced segregation of nonmetallic inclusions occurs in the interdendritic fillings. A.S.T.M. Grain Size No. 8-9.

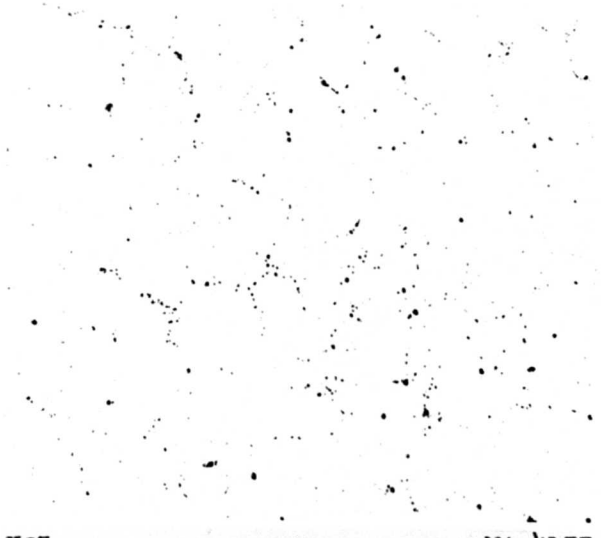
Pacific Car and Foundry Co.
Plate No. 9



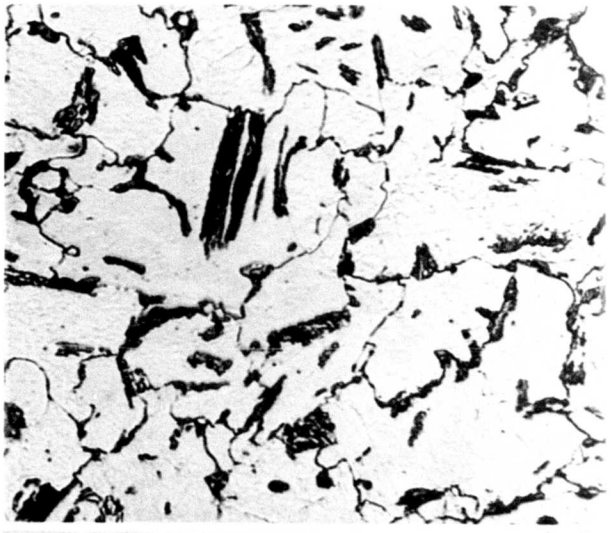
X2 MA-4174
Oberhoffer Etch



X25 Nital Etch MA-4170



X25 MA-4157
Unetched. Distribution of nonmetallic inclusions in interdendritic fillings.



X1000 Nital and Picral Etch MA-4161

W.A.639-4041

DATA SHEET

Pacific Car & Foundry Co.

Heat - 42B127 Plate - 10 Thickness - 2.20"

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.21	1.09	.82	.011	.019	--	--	--	1.61

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1650	-	6	Air
1000	-	2	Air
1625	-	2	Water
1125	-	2	Air

Physical Properties

T.S. - 134,860
Y.P. - 127,450
% Elong. - 16.0
% R.A. - 36.9
Izod -
Brinell - 290

Ballistic Properties

B.L. - 37MM M51 AP - 1976(+138) PTP - 2-5/8x2-5/8" Shock: 75MM T12 AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 294 Midwall- 269 Center- 269

Jominy Hardenability

Hardness Penetration) 6/16" Critical Cooling Rate - 43°F/Sec Equivalent Plate Thickness) 1-1/4"

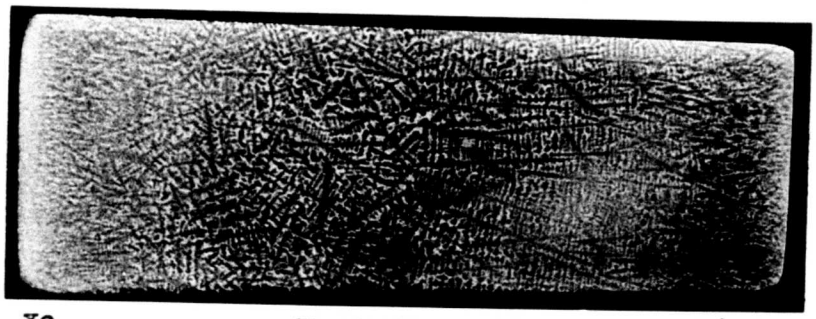
Two Bead Weldability

Single Bead VPN - 405, Rc - 38 Double Bead VPN - 306, Rc 29

Microstructure and Remarks

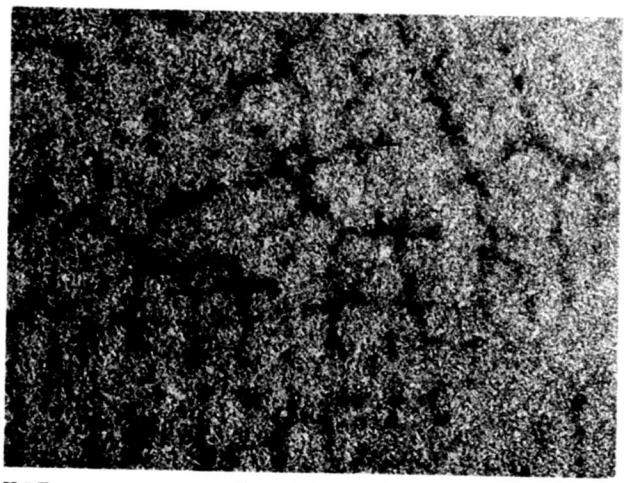
Acicular sorbite with approximately 40% ferrite rejected on the quench, indicating low hardenability for this section size. The Murakami etch shows some tendency for the carbides to outline the grain boundaries. There is a pronounced segregation of inclusions in the interdendritic fillings of a slightly segregated dendritic structure. A.S.T.M. Grain Size finer than No. 8.

Pacific Car and Foundry Co.
Plate No. 10

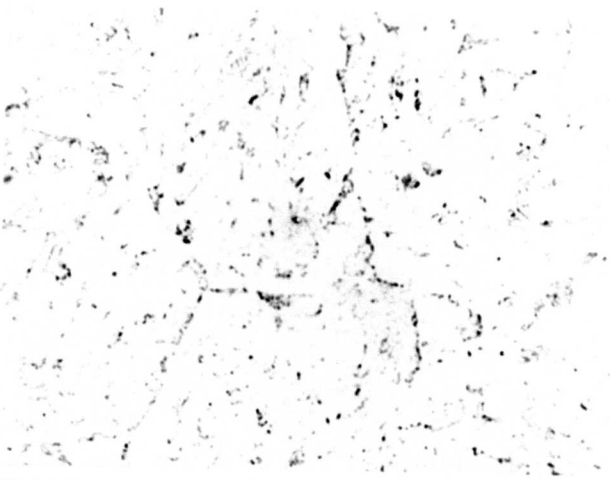


X2 Oberhoffer Etch MA-4175

X25 MA-4153
Unetched. Distribution of nonmetallic inclusions in interdendritic fillings.



X25 Nital Etch MA-4168



X1000 MA-4179
Murakami etch. Carbide distribution.

X1000 Nital and Picral Etch MA-4160

W.A.639-40-42

DATA SHEET

Pacific Car & Foundry Co.

Heat - 42B128 Plate - 11 Thickness - 1.87"

CHEMISTRY

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.20	1.05	.79	.017	.013	—	.65	—	1.62	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1650	-	6	Air
1000	-	2	Air
1625	-	2	Water
1125	-	2	Air

Physical Properties

T.S. - 108,750
Y.P. - 97,550
% Elong. - 22.0
% R.A. - 50.5
Izod - -
Brinell - 252

Ballistic Properties

B.L. - 37MM M51 AP - 1608(+12) PTP - 2½x2-3/4 Shock: 75MM T12 AP. PP - MB. Passed.

Brinell Hardness - Cross-Section

Outside- 204 Midwall- 197 Center- 201

Jominy Hardenability

Hardness Penetration) 6/16" Critical Cooling Rate - 43°F/Sec Equivalent Plate Thickness) 1-1/4"

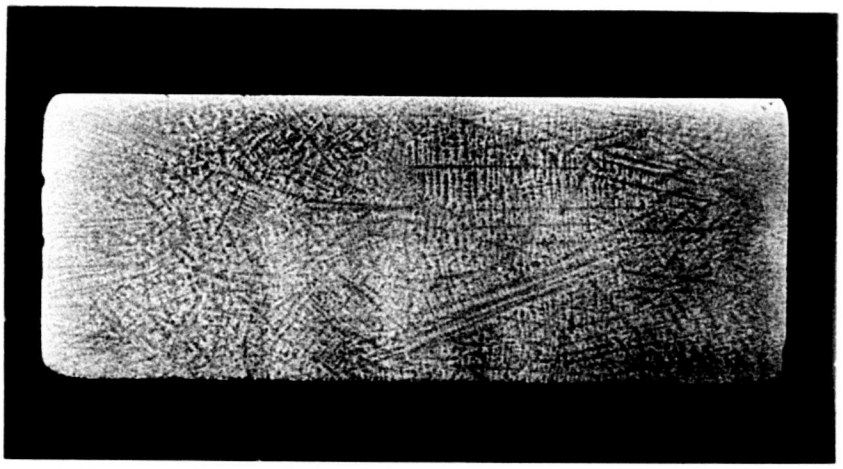
Two Bead Weldability

Single Bead VPN - 376, Rc - 33 Double Bead VPN - 279, Rc - 25.5

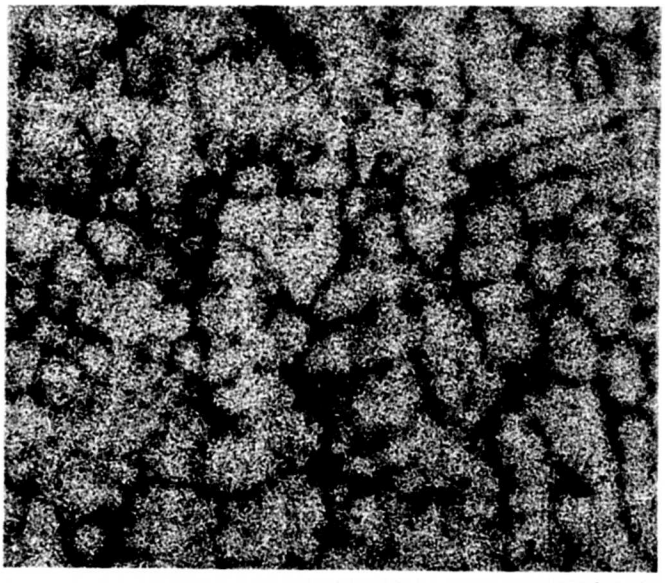
Microstructure and Remarks

Spheroidized sorbite with approximately 50% ferrite rejected upon quenching, indicating too low hardenability for this section size. A somewhat diffused dendritic segregation is revealed with a nital etch at a magnification of X25. Fairly clean steel. A.S.T.M. Grain Size finer than No. 8.

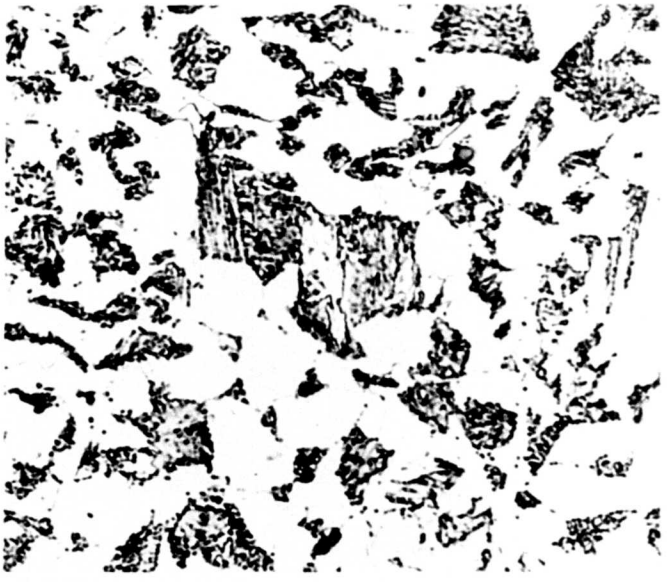
Pacific Car and Foundry Co.
Plate No. 11



X2 Oberhoffer Etch MA-4176



X25 Nital Etch MA-4167



X1000 Nital and Picral Etch MA-4164

W.A.639—4040

DATA SHEET

Pacific Car & Foundry Co.

Heat - 42B129 Plate - 12 Thickness - 1.89"

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.24	1.08	.86	.023	.008	--	--	--	1.76	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1750	-	4	Air
925	-	1½	Air

Physical Properties

T.S. - 109,700
Y.P. - 94.600
% Elong. - 20.5
% R.A. - 42.1
Izod - -
Brinell - 252

Ballistic Properties

B.L. - 37MM M51 AP - 1667(+56) PTP - 2-1/8x2-3/4" Shock: 75MM T12 AP. PP - MB. Passed.

Brinell Hardness - Cross Section

Outside- 199 Midwall- 207 Center- 210

Jominy Hardenability

Hardness Penetration) 5/16" Critical Cooling Rate - 54°F/sec. Equivalent Plate Thickness) 1-1/4"

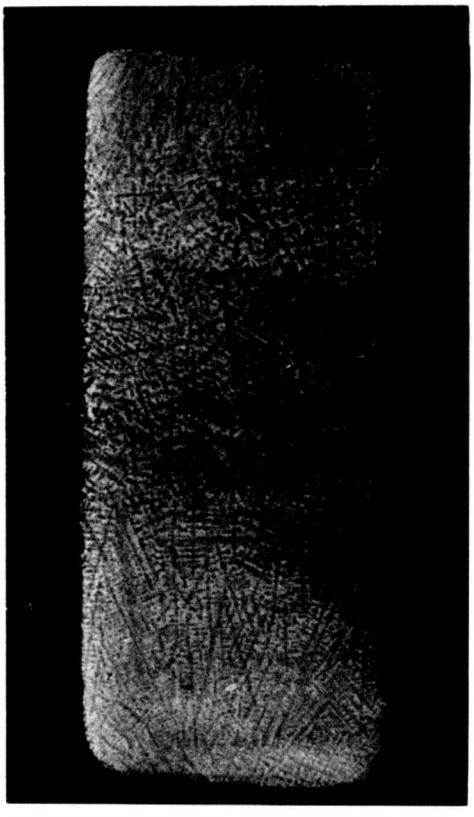
Two Bead Weldability

Single Bead VPN - 387, Rc - 35.5 Double Bead VPN - 283, Rc - 23.5

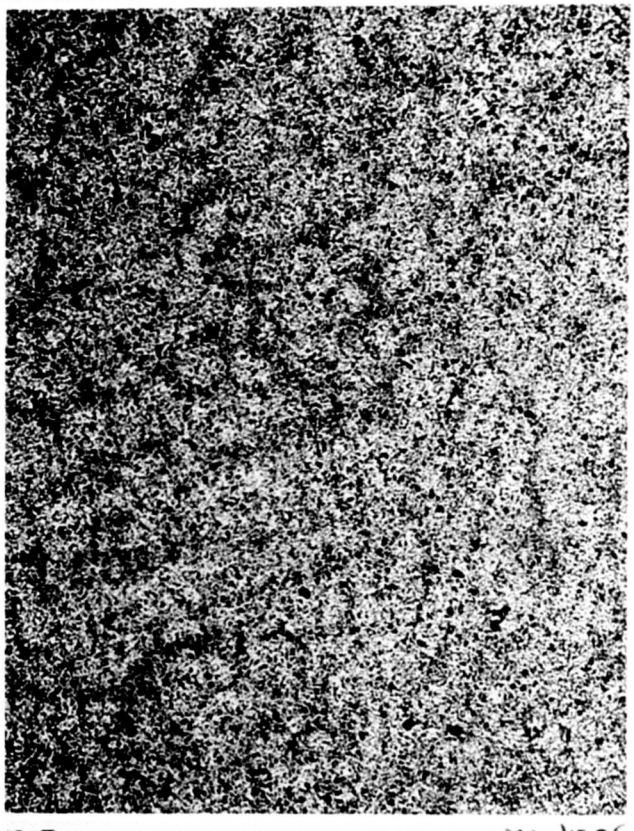
Microstructure and Remarks

Patches of fine pearlite and approximately 60% ferrite, indicating very poor hardenability for this section size particularly upon air cooling. The Murakami etch duplicates the nital and picral etch. A very homogeneous structure is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 8.

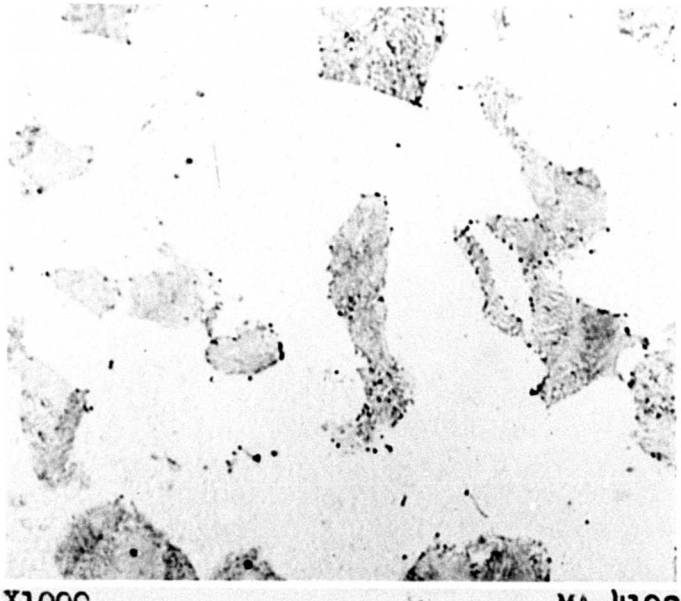
Pacific Car and Foundry Co.
Plate No. 12



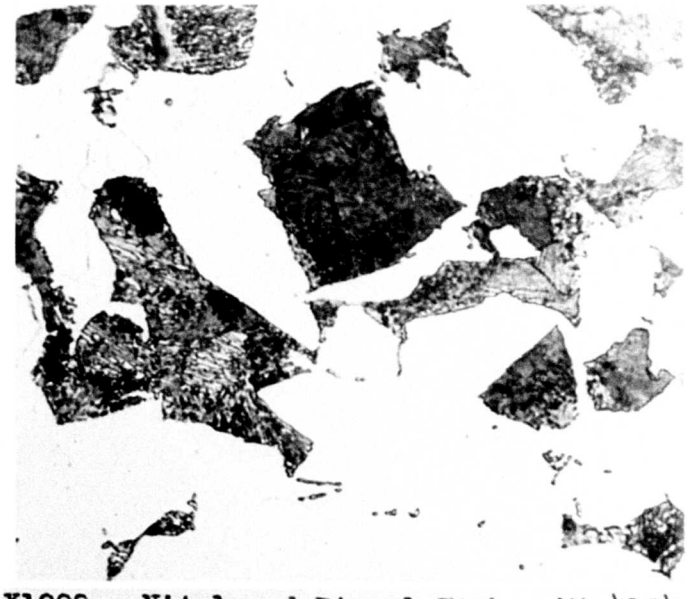
X2 MA-4203
Oberhoffer Etch



X25 MA-4196
Nital Etch



X1000 MA-4192
Murakami etch. Carbide distribution.



X1000 Nital and Picral Etch MA-4184

W.A.639-4036

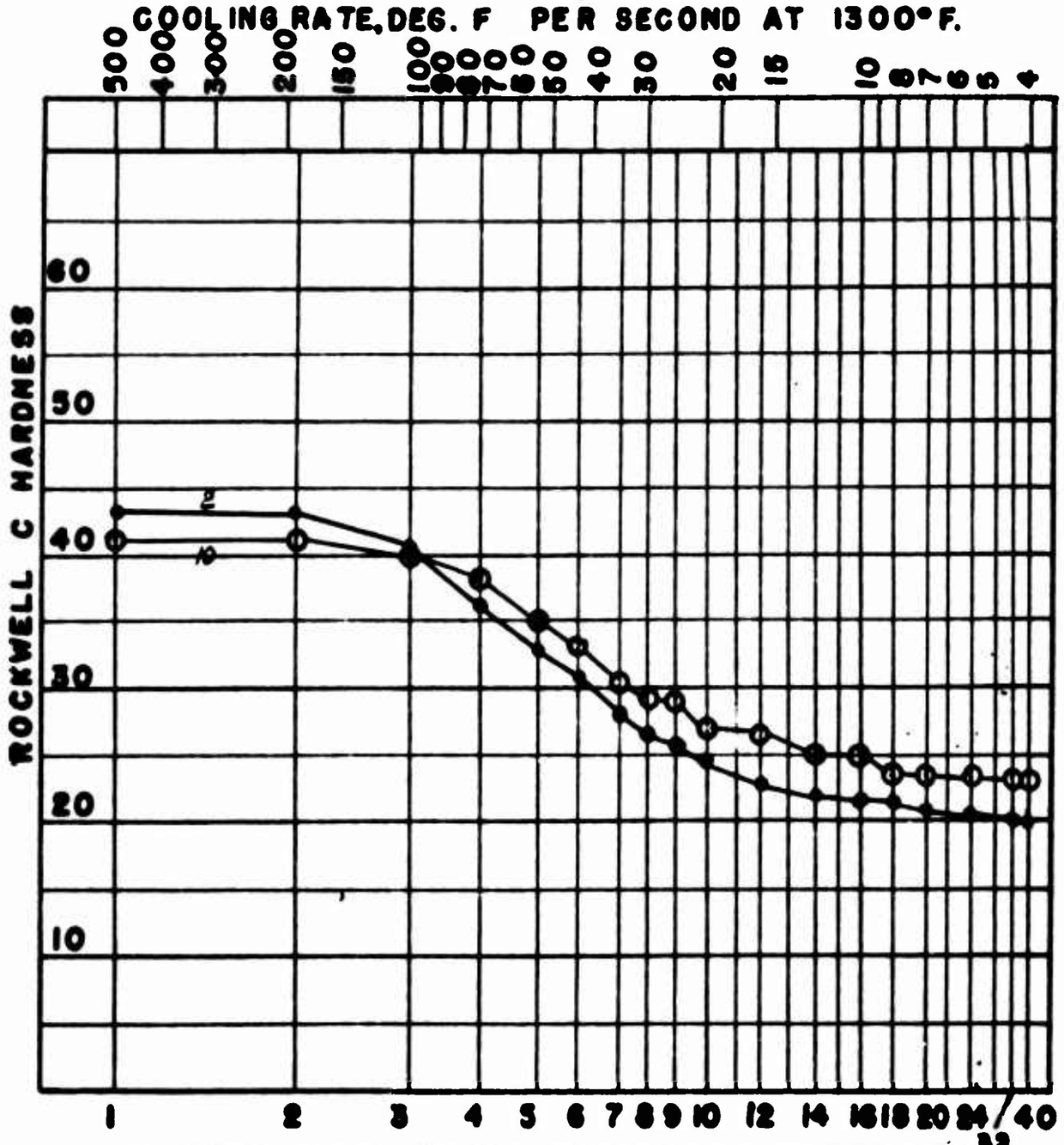


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	CU		QUENCH TEMP	QUENCH TIME	G.S.
2	● 428105	.20	.89	.70	.017	.019			.43	1.44		1625	2	8
10	○ 428127	.21	1.09	.82	.011	.019				1.61		1625	2	8
				PACIFIC CAR AND FOUNDRY CO.										

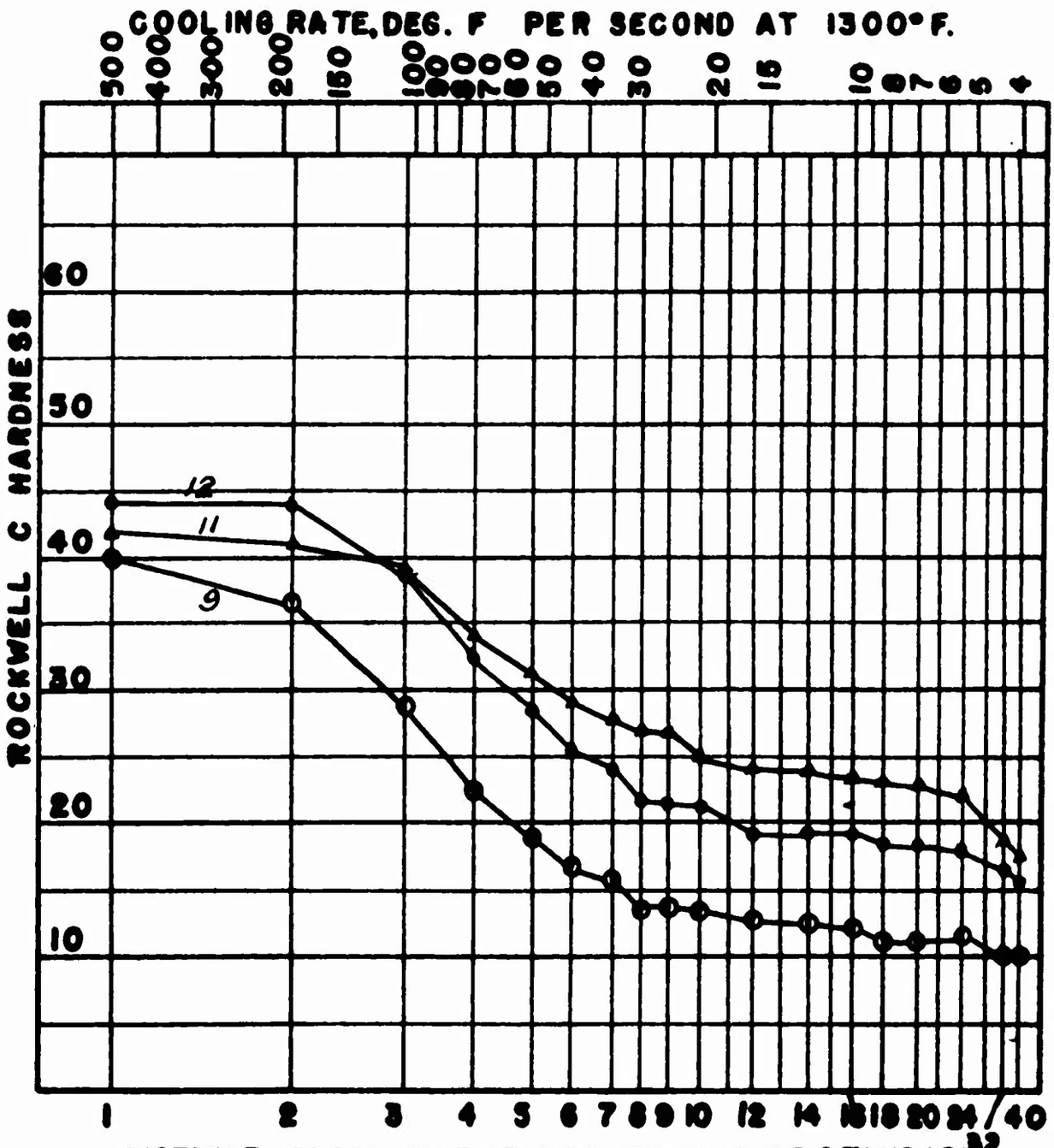


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	CU		QUENCH TEMP	QUENCH TIME	G.S.
9	042B126	.20	1.02	.82	.024	.018				1.75		1625	2	8
11	▲ 42B128	.20	1.05	.79	.019	.013		.65		1.62		1625	2	7
12	● 42B129	.24	1.08	.86	.023	.008				1.76		1625	2	7
			PACIFIC CAR AND FOUNDRY Co.											

DATA SHEET

Pratt & Letchworth Co., Inc.

Heat - 413 Plate - 1 Thickness - 1.88" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.28	1.30	.46	.016	.020	--	--	.29	--	-

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1725	-	4	Air
1610	-	4	Water
1025	-	5	Air

Physical Properties

T. S. - 122,500
Y.P. - 107,550
% Elong. - 18.0
% R.A. - 43.5
Izod - 55.6
Brinell - 248

Ballistic Properties

P.L. - 37MM M51AP - 1750(+146) PTF - 2½x2-3/4" Shock: 75 MM T12 AP PP, MB. Passed. 75 MM MK1 slug. CP, broke in two pieces.

Brinell Hardness - Cross-Section

Outside- 248 Midwall- 241 Center- 238

Jominy Hardenability

Hardness Penetration 7/16" Critical Cooling Rate - 35°F/Sec Equivalent Plate Thickness 1½"

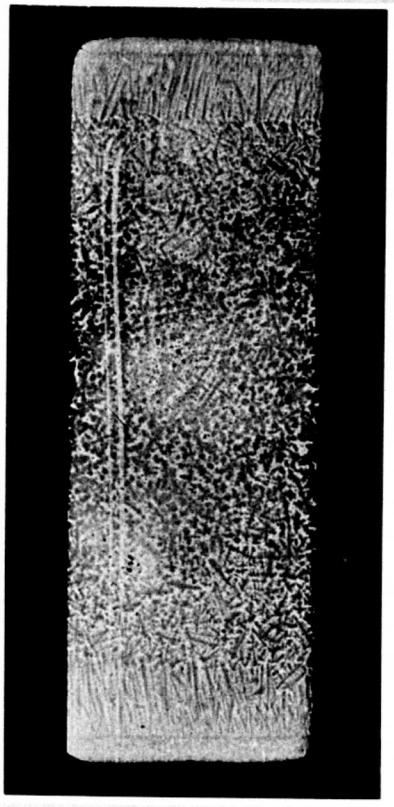
Two Bead Weldability

Single Bead VPN - 464, Rc - 43.5 Double Bead VPN - 304, Rc - 28.5

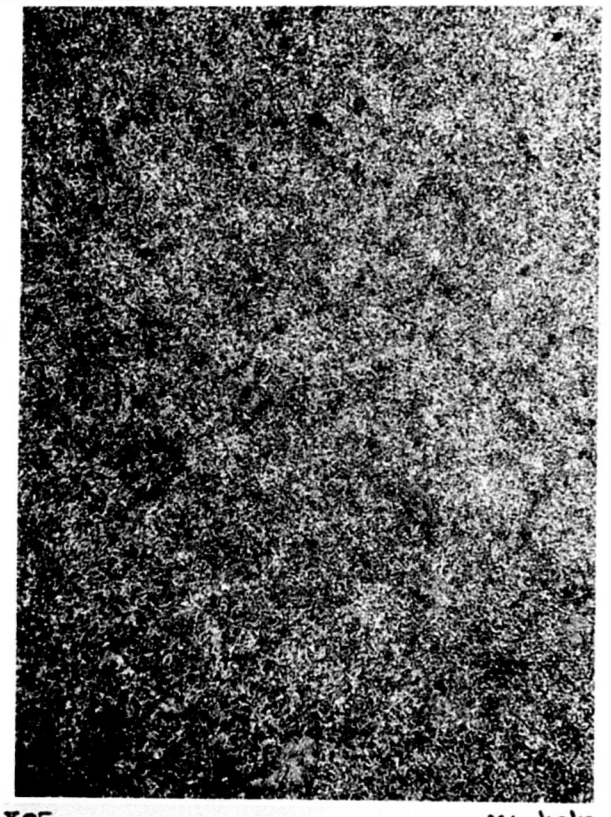
Microstructure and Remarks

Spheroidized sorbite with considerable ferrite rejected upon quenching, indicating insufficient hardenability for this section size. This plate shows practically no dendritic segregation revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 7.

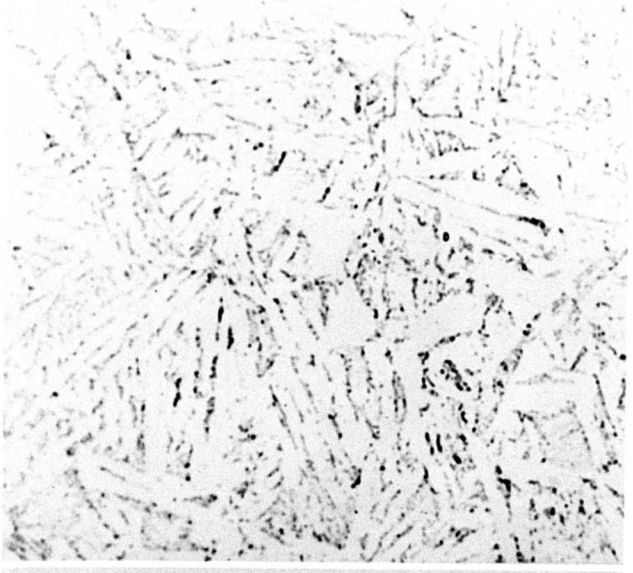
Pratt and Letchworth Co., Inc.
Plate No. 1



X2 MA-4231
Oberhoffer Etch



X25 MA-4241
Nital Etch



X1000 MA-4228
Murakami etch. Carbide distribution same as that revealed by nital and picral etch.

X1000 Nital and Picral Etch MA-4249

W.A.639-4056

Data Sheet

Pratt & Letchworth Co., Inc.

Heat - 413 Plate - 2 Thickness - 1.48" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.28	1.30	.46	.016	.020	--	--	.29	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1725	-	4	Air
1610	-	4	Water
1025	-	5	Air

Physical Properties

T.S. - 121,150
Y.P. - 106,050
% Elong. - 20.0
% R.A. - 52.0
Izod - 54.5
Brinell - 252

Ballistic Properties

B.L. - 37MM M51 AP - 1491(+203) PTP - 2-1/4"x2-1/4" Shock: 75MM T12 AP CP. 4" crack on LB. 75MM MK1 slug. CP. Broke in 2 pieces.

Brinell Hardness - Cross-Section

Outside- 255 Midwall- 255 Center- 248

Jominy Hardenability

Hardness Penetration) 3/16" Critical Cooling Rate - 30°F/Sec Equivalent Plate Thickness) 1½"

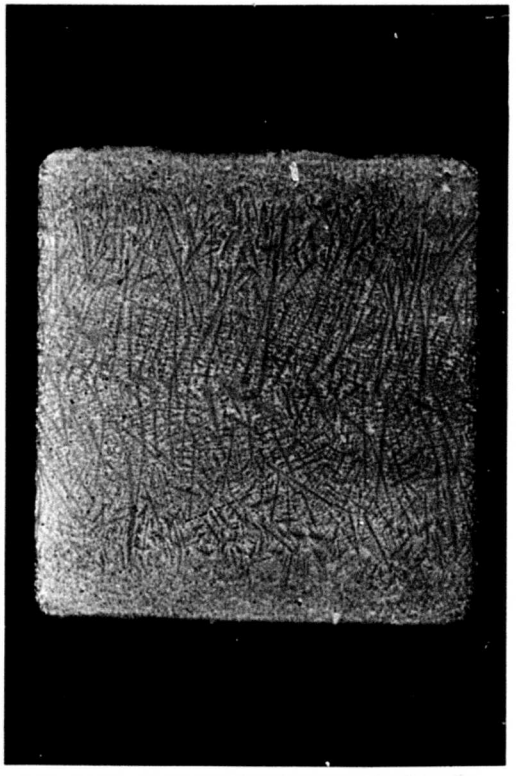
Two Bead Weldability

Single Bead VPN - 455, Rc - 42 Double Bead VPN - 312, Rc - 29

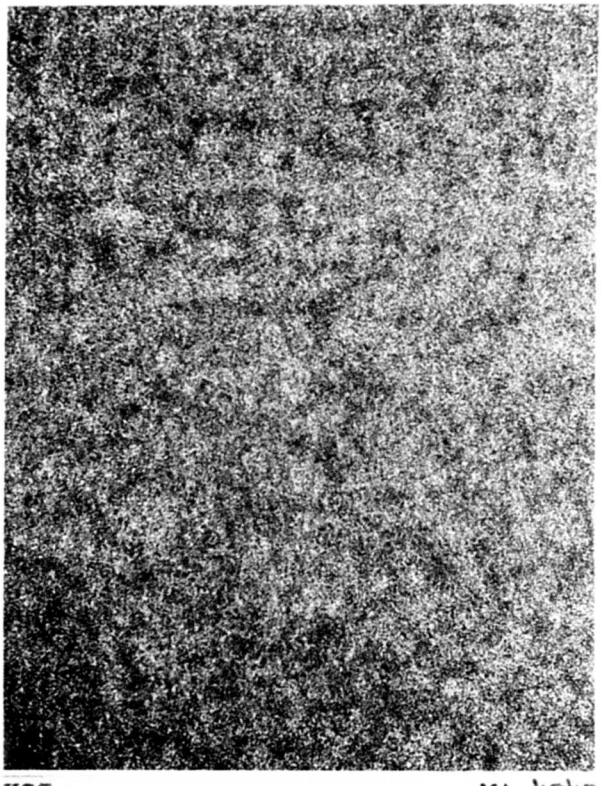
Microstructure and Remarks

Spheroidized sorbite with much less ferrite rejected on the quench then in the case of Pratt and Letchworth Plate No. 1. Plate No. 2 possesses fairly satisfactory hardenability for its section size. Plates No. 1 and No. 2 illustrate the effect of mass on the hardening ability of this composition; the thinner plate possessing the more satisfactory microstructure although both plates of this steel have the same hardenability. A.S.T.M. Grain Size No. 7.

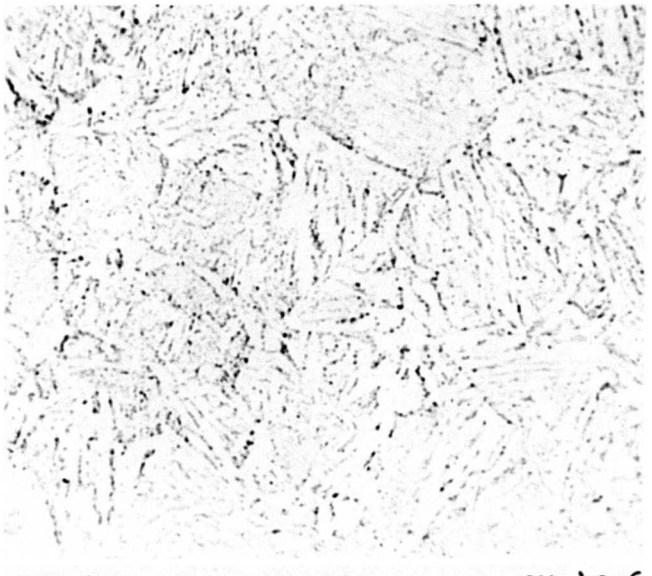
Pratt and Letchworth Co., Inc.
Plate No. 2



X2 MA-4229
Oberhoffer Etch



X25 MA-4243
Nital Etch



X1000 MA-4226
Murakami etch. Carbide distribution same as that revealed by nital and picral etch.

X1000 Nital and Picral Etch MA-4250

W.A.639-4061

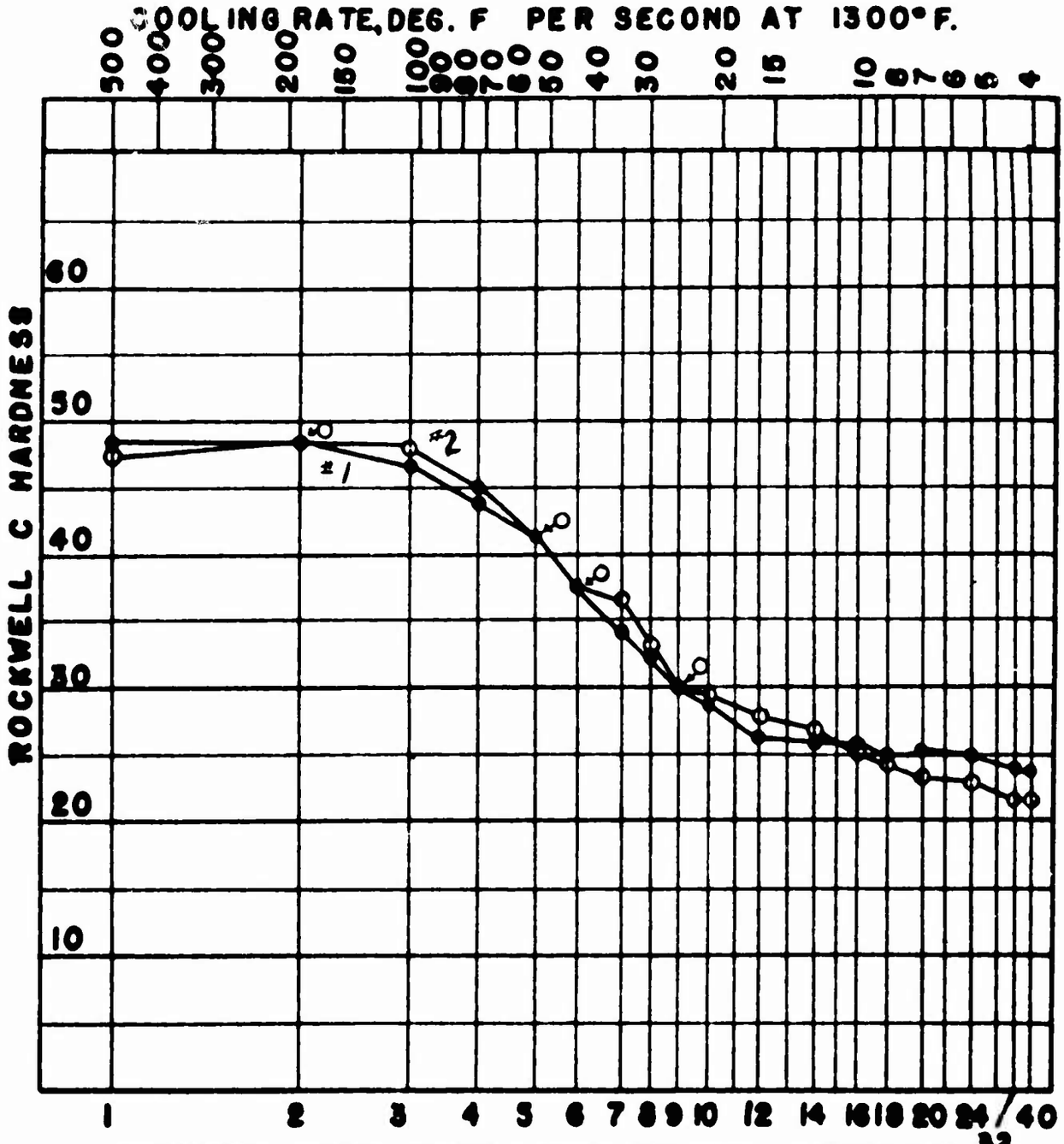
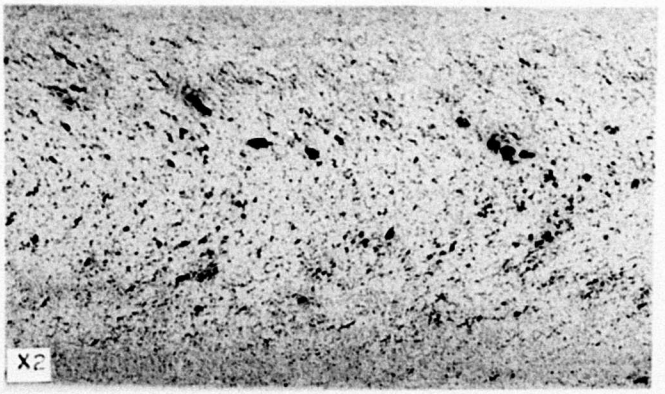
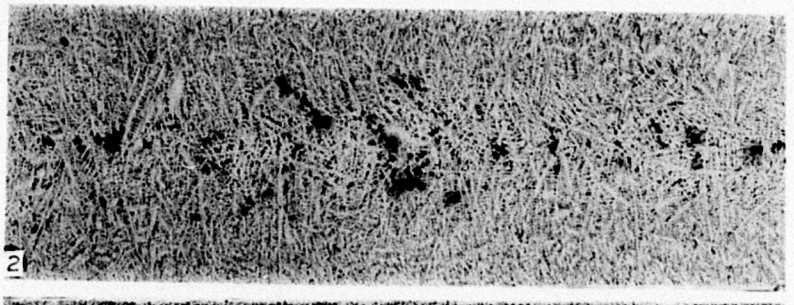
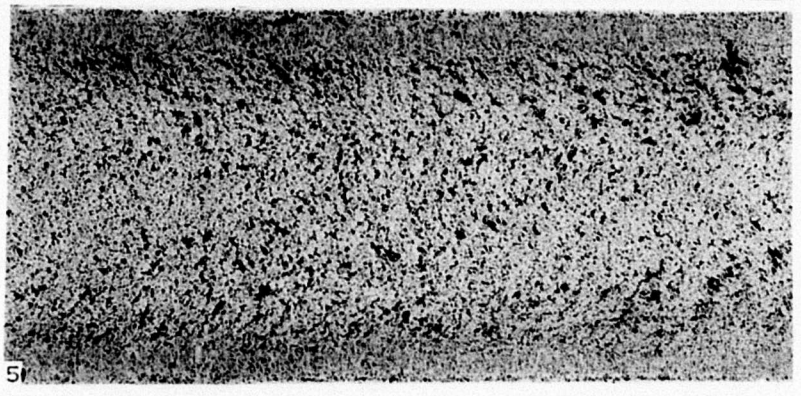


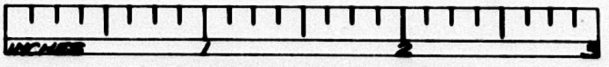
PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
1	• 413	.28	1.30	.46	.016	.020	–	–	.29			1610	4	7
2	o 413	.28	1.30	.46	.016	.020	–	–	.29			1610	4	7
		PRATT AND LETCH WORTH CO. INC.												



SCULLIN STEEL CO







ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

SYMINGTON – GOULD CORP. CAST ARMOR PLATE. APRIL 18 1942 W.A.710–1813

DATA SHEET

Scullin Ste[illegible]

Heat - 5092A Plate - X2 Thickness - 2.13" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.36	1.46	.45	.015	.030	--	--	.70	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1750	-	5	Air
1100	-	3	Air
1580	-	3	Water
1000	-	7	Air

Physical Properties

T.S.	- 136,500
Y.P.	- 120,000
% Elong.	- 15.0
% R.A.	- 37.6
Izod	- 40.0
Brinell	- 269

Ballistic Properties

B.L. - 37MM. M51 AP - 1938(+150) PTP - 2-3/4"x2-7/8" Shock: 75MM T12 AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 281 Midwall- 266 Center- 245

Jominy Hardenability

Hardness Penetration) 9/16" Critical Cooling Rate - 26°F/Sec Equivalent Plate Thickness) 1-3/4"

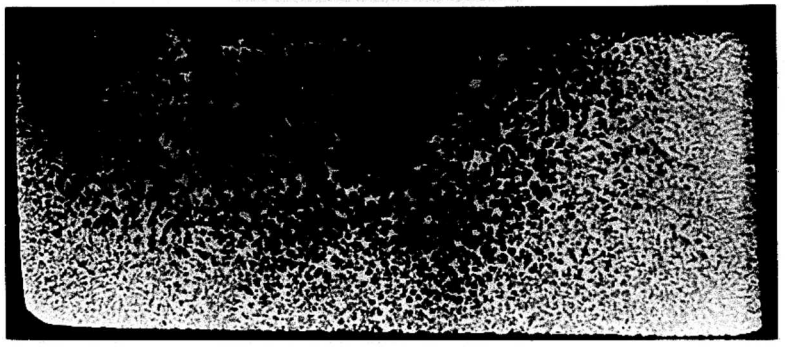
Two Bead Weldability

Single Bead VPN - 572, Rc - 51.5 Double Bead VPN - 322, Rc -34

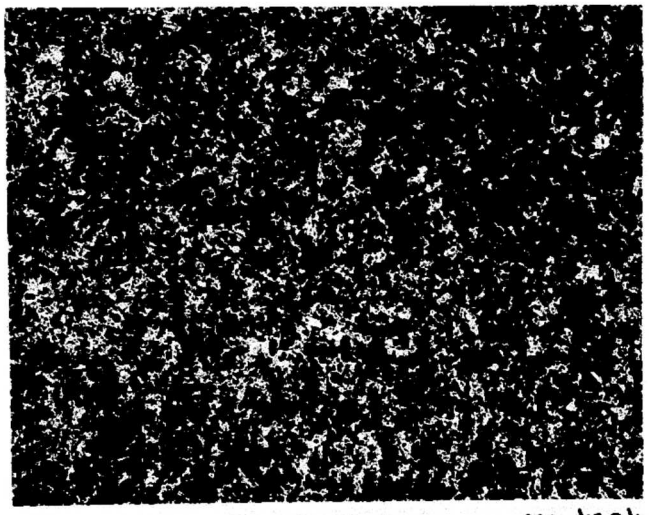
Microstructure and Remarks

Acicular sorbite with approximately 20% pro-eutectoid ferrite, indicating low hardenability for this section size. The outer thirds of the cross-section showed no segregation with a nital etch at a magnification of X25, while the middle of the cross-section contained some fairly well diffused dendritic segregation. A.S.T.M. Grain Size finer than No. 8.

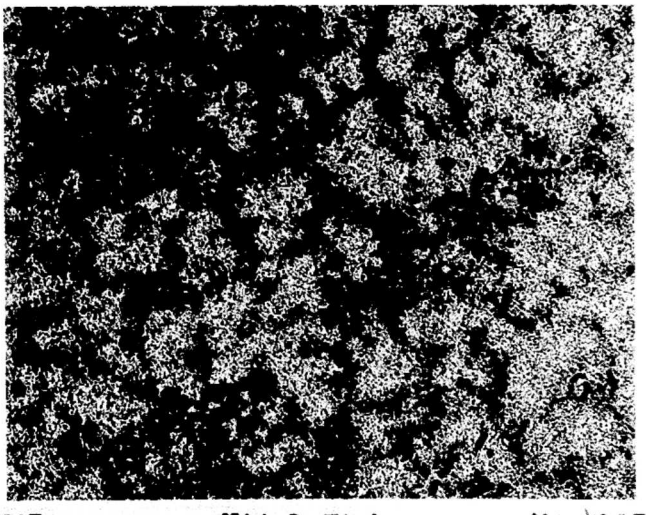
Scullin Steel Co.
Plate No. X2



X2 Oberhoffer Etch MA-4201



X25 Nital Etch MA-4194
No segregation at outer regions of cross-section.



X25 Nital Etch MA-4195
Segregation in middle of cross-section.

X1000 MA-4190
Murakami etch. Distribution of carbides same as that revealed by nital and picral etch.

X1000 Nital and Picral Etch MA-4185

W.A.639—4033

DATA SHEET

Scullin Steel Co.

Heat - 3-421 Plate - X6 Thickness - 2.08" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu
.33	1.51	.68	.014	.016	--	--	.39	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1750	-	7	Air
1580	-	3½	Water
1220	-	7	Air

Physical Properties

T.S. - 109,000
Y.P. - 87,000
% Elong. - 22.0
% R.A. - 44.0
Izod - 43-45
Brinell - 235-240

Ballistic Properties

B.L. - 37MM M51 AP - 1774(+18) PTP - 2⅝x2½" Shock: 75MM T12 AP.
PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 232 Midwall- 229 Center- 217

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

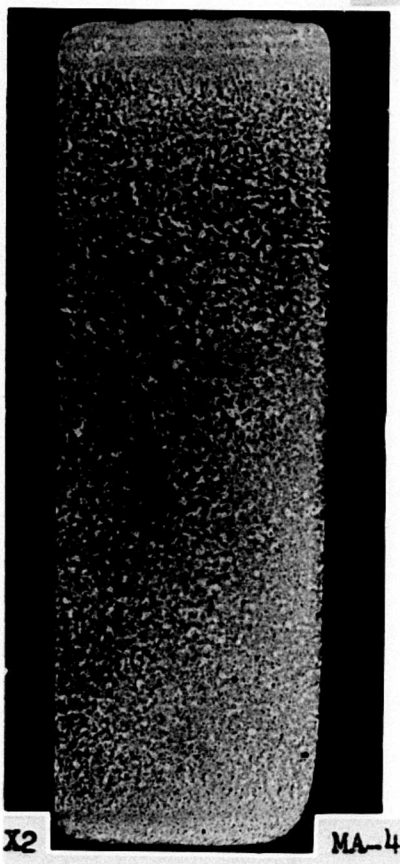
Two Bead Weldability

Single Bead VPN - 585, Rc - 53.5 Double Bead VPN - 373, Rc - 36.5

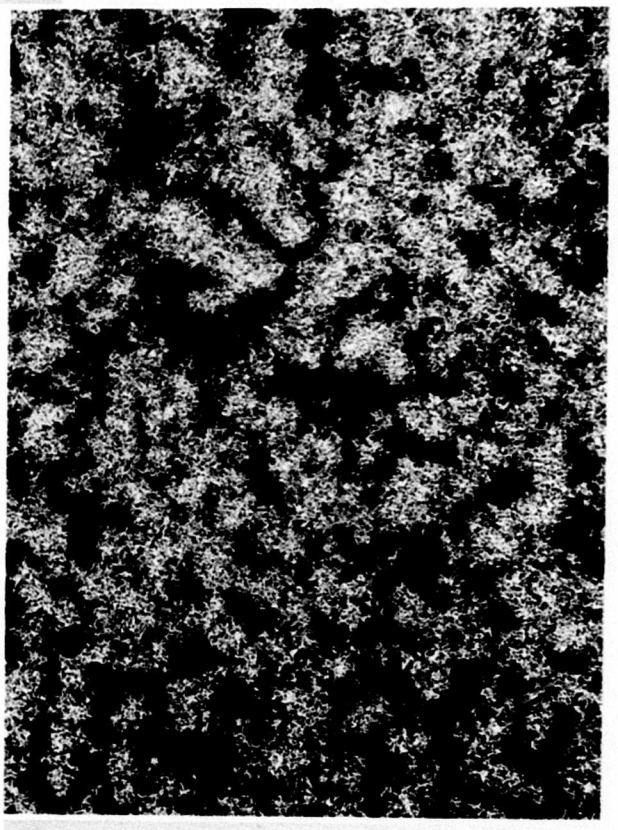
Microstructure and Remarks

Very uniform, spheroidized sorbite with no free ferrite, indicating excellent hardenability for this section size. A fairly pronounced dendritic segregation is revealed with a nital etch at a magnification of X25. The steel is relatively clean. A.S.T.M. Grain Size finer than No. 8.

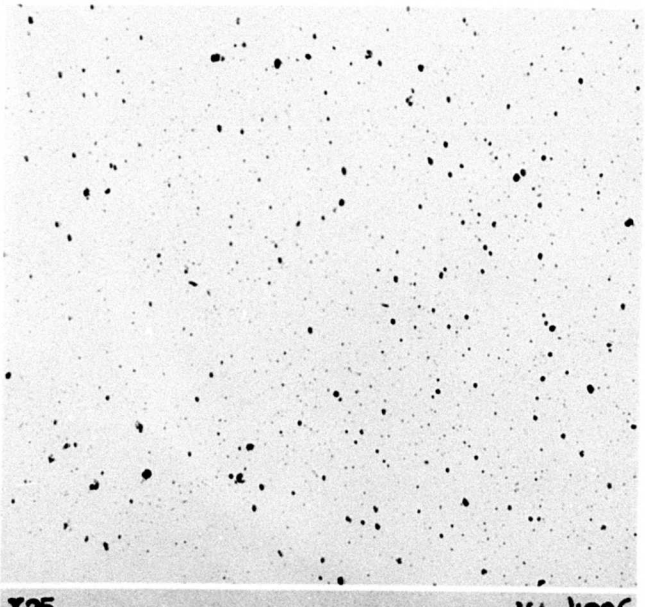
Scullin Steel Co.
Plate No. X6



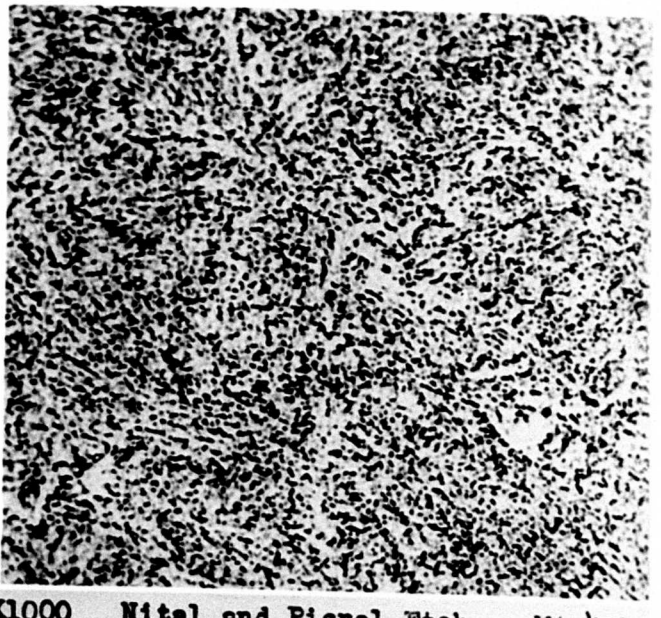
X2 MA-4220
Oberhoffer Etch



X25 MA-4216
Nital Etch



X25 MA-4206
Unetched. Distribution of nonmetallic inclusions.



X1000 Nital and Picral Etch MA-4212

W.A.639-4031

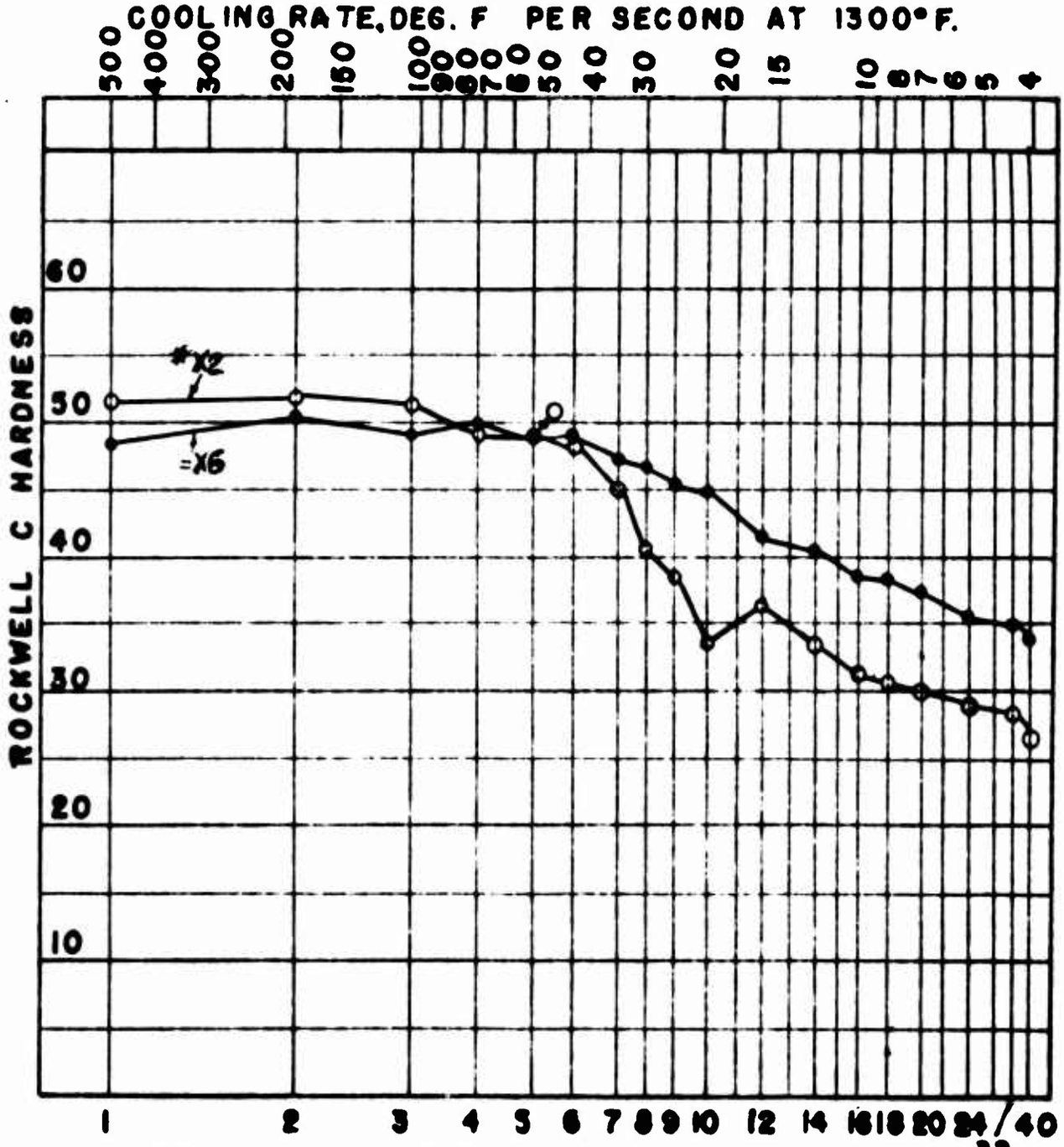
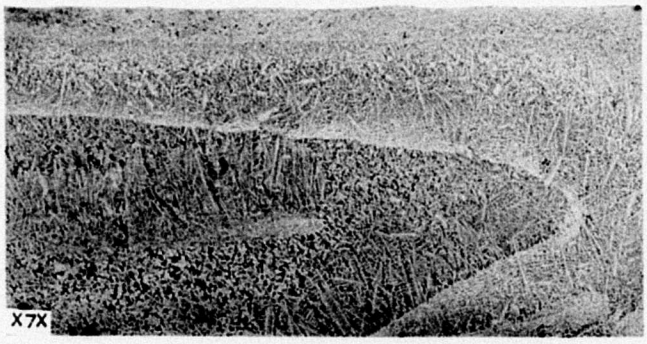
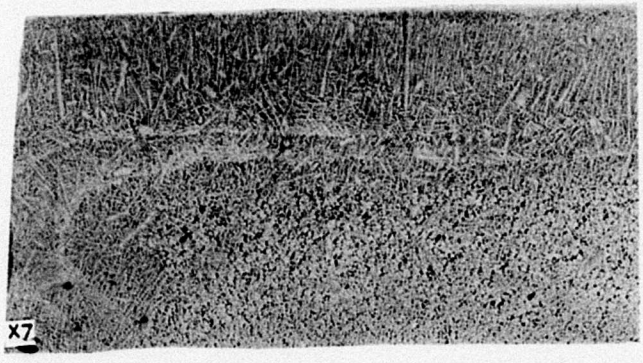
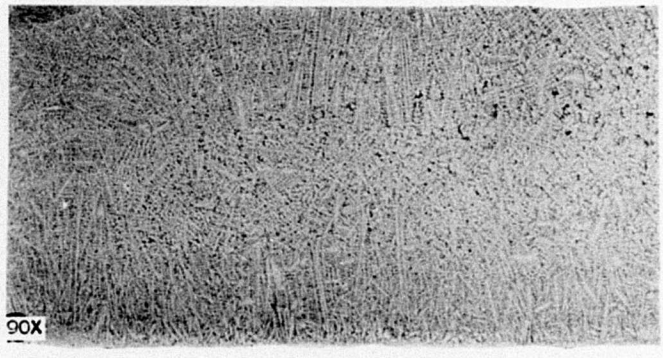
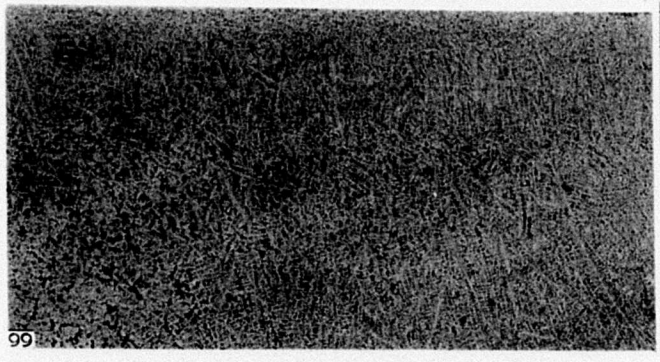


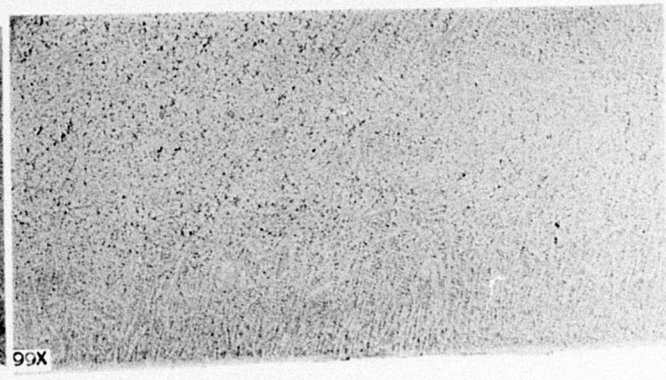
PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
X2	o 5092A	.36	1.46	.45	.015	.030	–	–	.70			1580	3	7
X6	• 3-421	.33	1.51	.68	.014	.026	–	–	.39			1580	3	7
		SCULLEN STEEL Co.												











ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL

SIVYER STEEL CASTINGS CO. CAST ARMOR PLATE. APRIL 18 1942 W.A.710-1812

DATA SHEET

Sivyer Steel Castings Co.

Heat - X7 Plate - X7 Thickness - 2.05" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.27	1.24	.33	.036	.022	--	--	.49	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1900	6	8	Air
1300	2	3	Air
1575	4	4	Water
1200	4	4	Furnace

Physical Properties

T.S. - 110,000
Y.P. - 89,300
% Elong. - 22.5
% R.A. - 55.5
Brinell - 248

Ballistic Properties

B.L. - 37MM M51 AP - 1735(+0) PTP - 2½x2½" Shock: 75MM T12 AP. PP - MB. Passed. 75MM MK1 Slug. CP. SC on LB.

Brinell Hardness - Cross-Section

Outside- 229 Midwall- 229 Center- 223

Jominy Hardenability

Hardness Penetration) 12/16" Critical Cooling Rate - 16°F/Sec Equivalent Plate Thickness) 2-1/4"

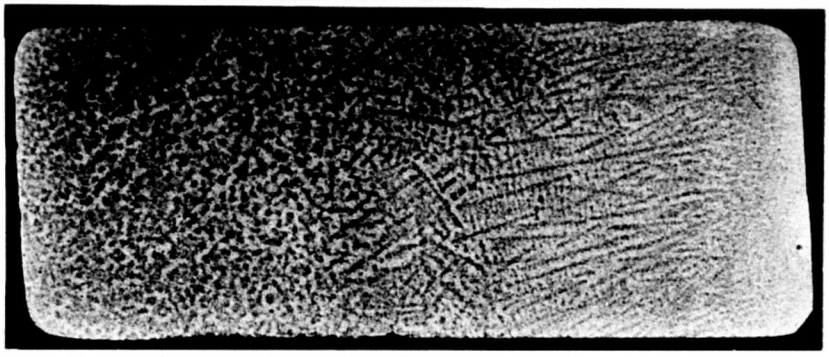
Two Bead Weldability

Single Bead VPN - 542, Rc - 47.5 Double Bead VPN - 366, Rc - 35.5

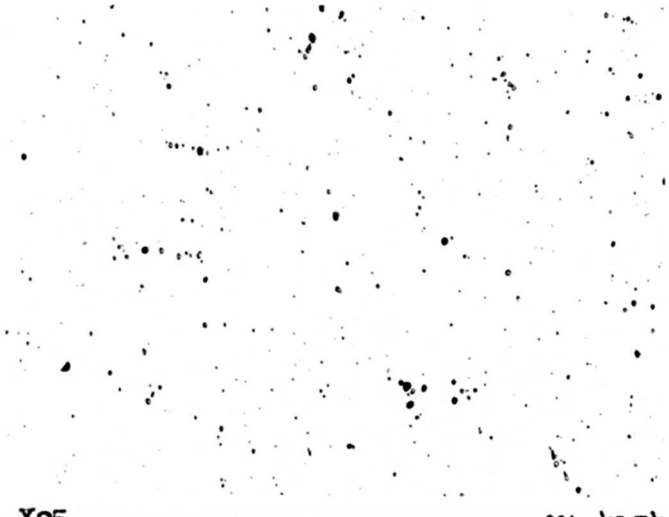
Microstructure and Remarks

The microstructure consists of a coarse, partially spheroidized acicular sorbite with very little pro-eutectoid ferrite present, indicating satisfactory hardenability for this section size. There is a pronounced tendency for the carbides to outline the grain boundaries. The inclusions are distributed in the interdendritic fillings of a pronounced dendritic segregation. A.S.T.M. Grain Size No. 6.

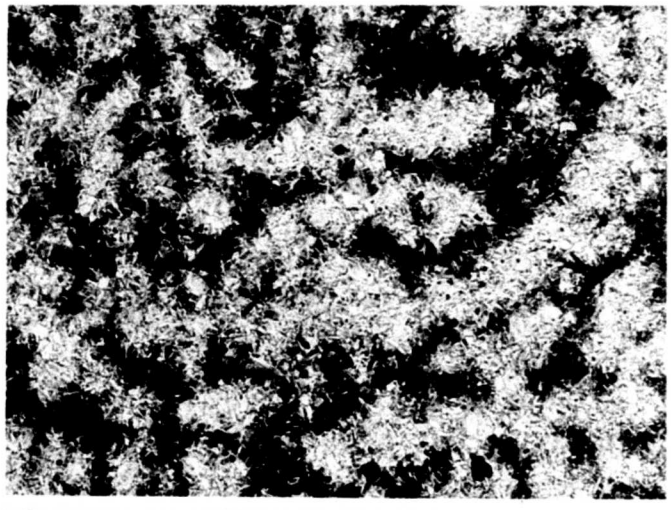
Sivyer Steel Castings Co.
Plate No. X7



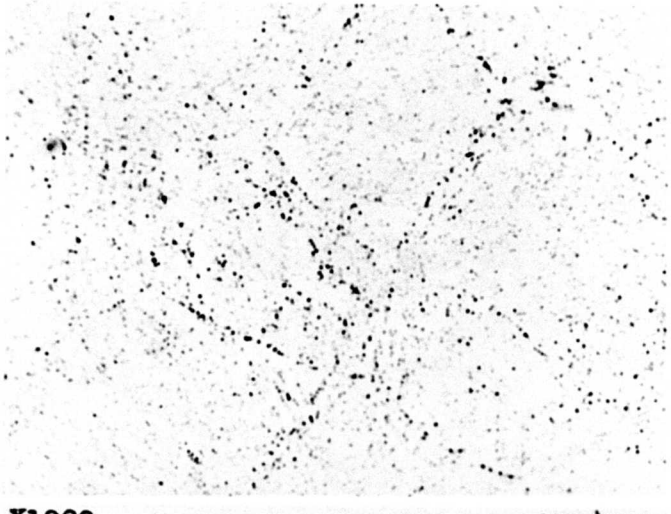
X2 Oberhoffer Etch MA-4173



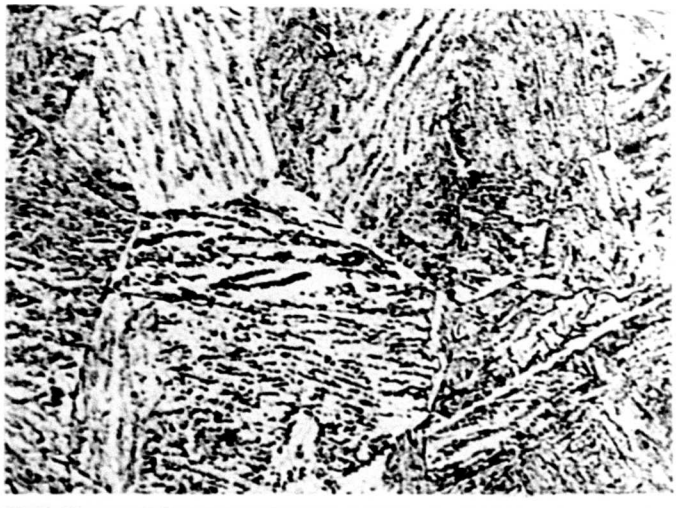
X25 MA-4154
Unetched. Distribution of nonmetallic inclusions.



X25 Nital Etch MA-4166



X1000 MA-4178
Murakami etch. Tendency for carbide segregation at grain boundaries.



X1000 Nital and Picral Etch MA-4162

W.A.639-4043

DATA SHEET

Sivyer Steel Castings Co.

Heat - X7 Plate - X7X Thickness - 2.00" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.27	1.24	.33	.036	.022	—	—	.49	—	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1700	6	4	Air
1300	2	3	Air
1575	4	4	Water
1200	4	4	Furnace

Physical Properties

T.S. - 109,710
Y.P. - 88,420
% Elong. - 20.5
% R.A. - 52.4
Izod -
Brinell - 248

Ballistic Properties

B.L. - 37MM M51AP - 1778(+78) PTP - 2-1/4"x2-5/8" Shock: 75MM T12AP. PP - MB. Passed. 75MM MK1 Slug. PP - SC on LB. Bow - 1-1/16".

Brinell Hardness - Cross-Section

Outside- 232 Midwall- 223 Center- 226

Jominy Hardenability

Hardness Penetration - 12/16" Critical Cooling Rate - 16°F/sec. Equivalent Plate Thickness - 2-1/4"

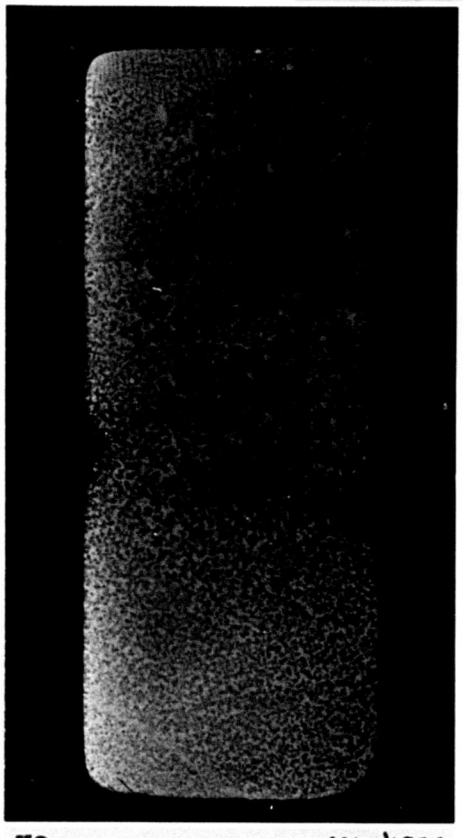
Two Bead Weldability

Single Bead VPN - 503, Rc - 47.5 Double Bead VPN - 390, Rc - 36

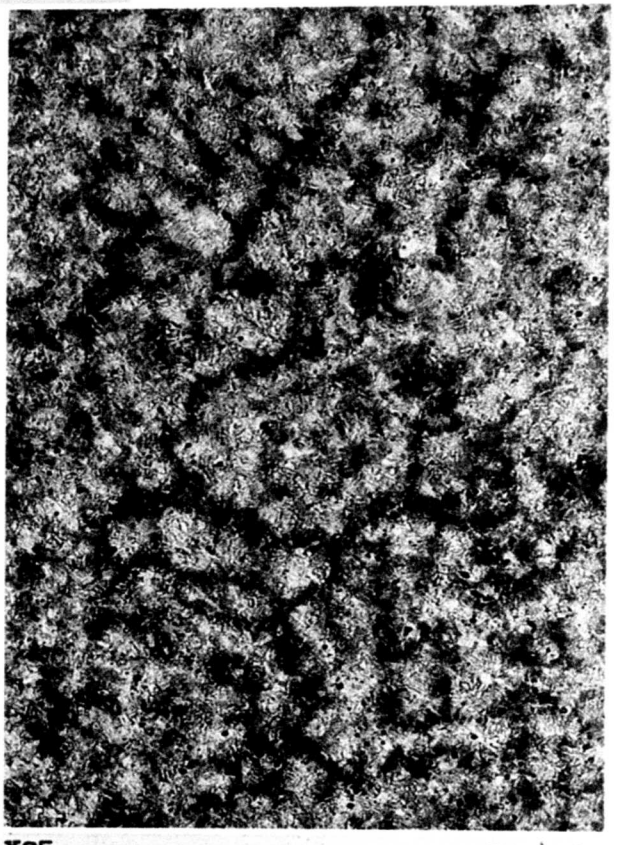
Microstructure and Remarks

Fairly coarse spheroidized sorbite with no pro-eutectoid ferrite, indicating excellent hardenability for this section size. A well diffused dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 5.

Sivyer Steel Castings Co.
Plate No. X7X



X2 MA-4200
Oberhoffer Etch



X25 MA-4193
Nital Etch

X1000 MA-4191
Murakami Etch - Random carbide distribution.

X1000 Nital and Picral Etch MA-4182

W.A.639-4035

DATA SHEET

Sivyer Steel Castings Co.

Heat - 5577 Plate - 90 Thickness - 2.14" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.23	.95	.23	.036	.018	.54	.71	.51	1.01	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1900	6	8	Air
1300	2	3	Air
1550	4	4	Water
1175	6	8	Air

Physical Properties

T.S. - 125,050
Y.P. - 108,150
% Elong. - 19.5
% R.A. - 55.5
Charpy - 28.8
Brinell - 262-269

Ballistic Properties

B.L. - 37MM M51AP - 2023(+179) PTP - 2"x2" Shock: 75MM T12AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 273 Midwall- 277 Center- 277

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

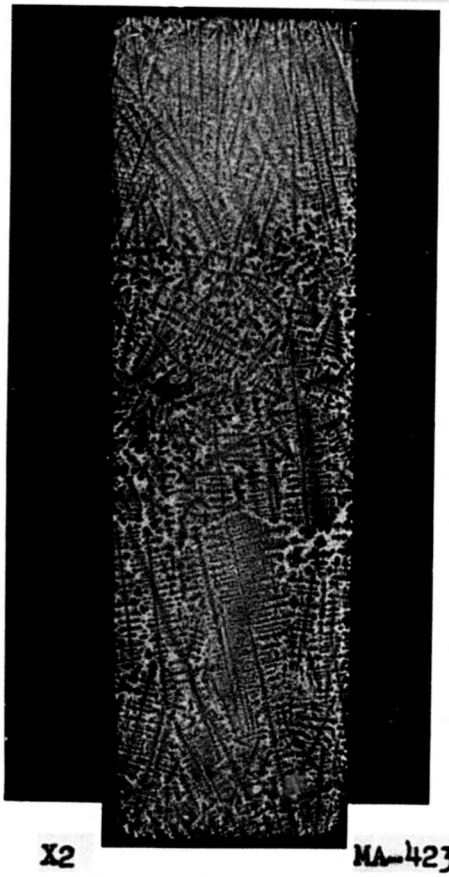
Two Bead Weldability

Single Bead VPN - 493, Rc - 47 Double Bead VPN - 401, Rc - 35.5

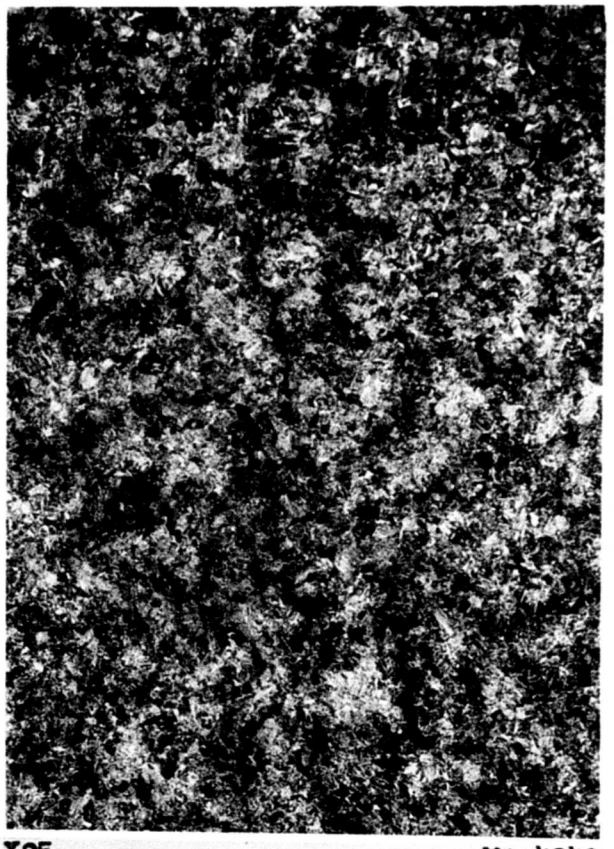
Microstructure and Remarks

Partially spheroidized acicular sorbite with no pro-eutectoid ferrite, indicating excellent hardenability. The nonmetallic inclusions are segregated in the interdendritic fillings of a very well diffused dendritic segregation revealed by a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 5-6.

Sivyer Steel Castings Co.
Plate No. 90

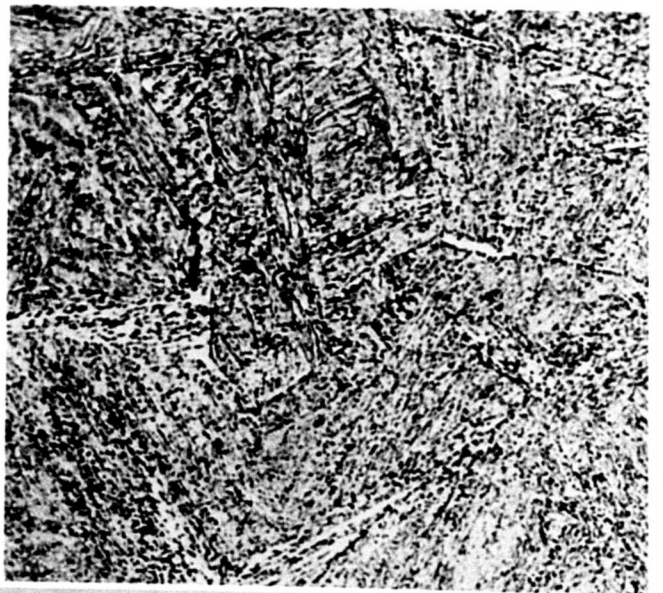


X2 MA-4234
Oberhoffer Etch



X25 MA-4240
Nital Etch

X25 MA-4224
Unetched. Distribution of nonmetallic inclusions in interdendritic fillings.



X1000 Nital and Picral Etch MA-4248

W.A.639-4050

DATA SHEET

Sivyer Steel Castings Co.

Heat - 5577 Plate - 90X Thickness - 2.11" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.23	.95	.23	.036	.018	.54	.71	.51	1.01	—

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1650	3	4	Air
1300	2	3	Air
1550	4	4	Water
1175	6	8	Air

Physical Properties

T.S. - 121,800
Y.P. - 105,000
% Elong. - 19.0
% R.A. - 54.7
Charpy - 30.4
Brinell - 262-269

Ballistic Properties

B.L. - 37MM M51AP - 1910(+144) PTP - 1⅛"x2" Shock: 75MM T12AP.
PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 277 Midwall- 269 Center- 269

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

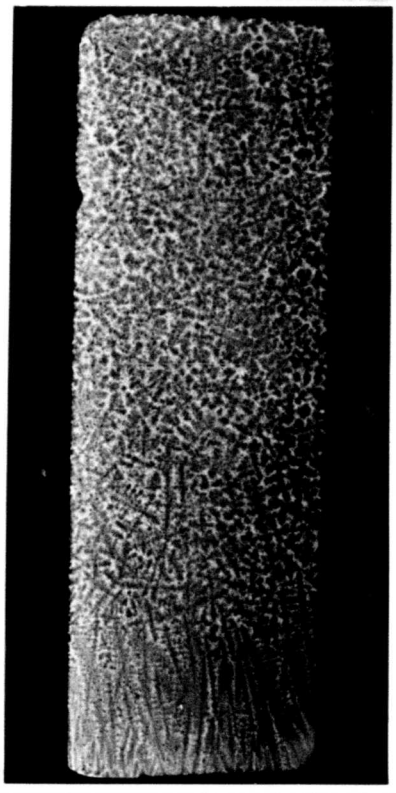
Two Bead Weldability

Single Bead VPN - 488, Rc - 46.5 Double Bead VPN - 351, Rc - 33.5

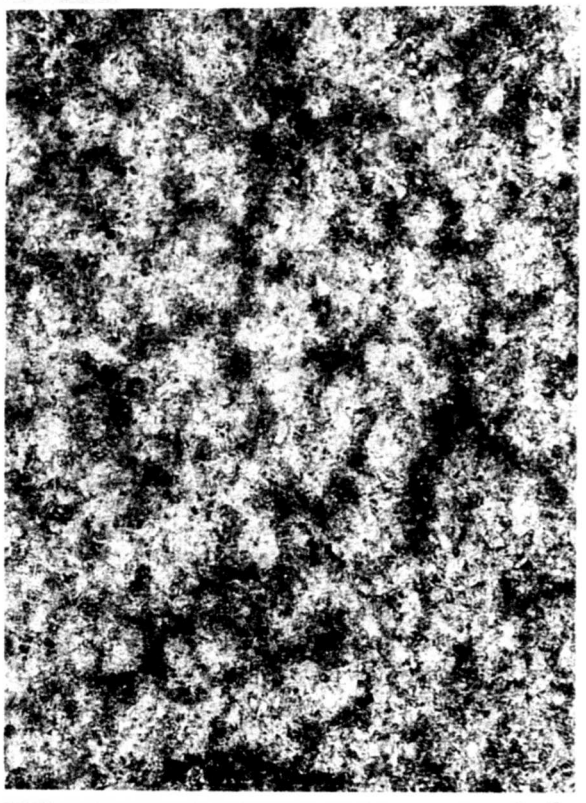
Microstructure and Remarks

Somewhat nonuniform sorbite partially spheroidized and no pro-eutectoid ferrite present, indicating excellent hardenability. The nonmetallic inclusions are segregated in the interdendritic fillings of a diffuse dendritic segregation revealed by a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 6.

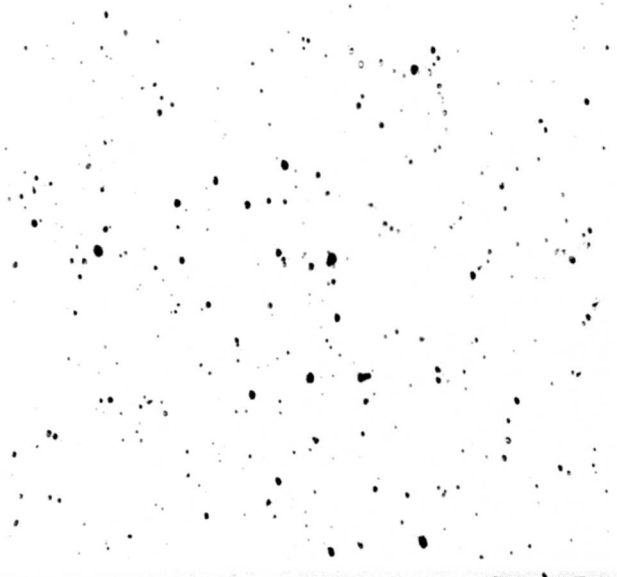
Sivyer Steel Castings Co.
Plate No. 90X



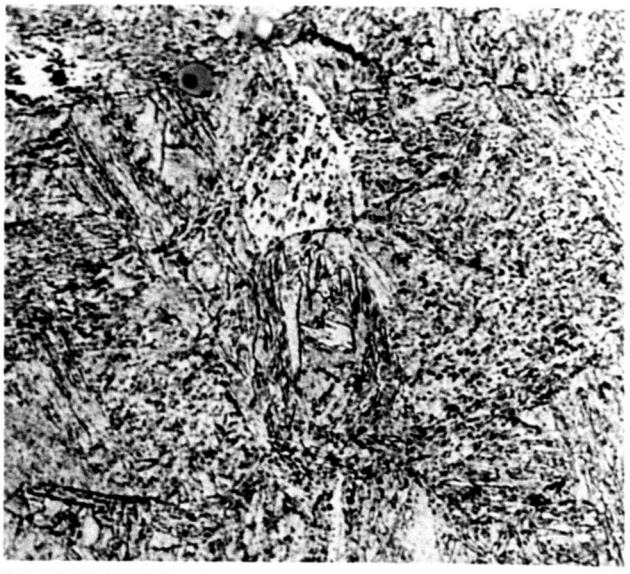
X2 MA-4268
Oberhoffer Etch



X25 MA-4261
Nital Etch



X25 MA-4258
Unetched. Distribution of nonmetallic inclusions in the interdendritic fillings.



X1000 Nital and Picral Etch MA-4254

W.A.639-4052

DATA SHEET

Sivyer Steel Castings Co.

Heat - 5596 Plate - 99 Thickness - 2.22" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.31	1.06	.25	.038	.019	.47	.59	.49	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1900	6	8	Air
1300	2	3	Air
1550	4	4	Water
1200	6	8	Air

Physical Properties

T.S. - 118,350
Y.P. - 97,250
% Elong. - 21.5
% R.A. - 57.8
Charpy - 33.5
Brinell - 248-255

Ballistic Properties

B.L. - 37MM M51AP - 1944(+112) PTP - 1½x2" Shock: 75MM T12AP.
PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 241 Midwall- 241 Center- 241

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

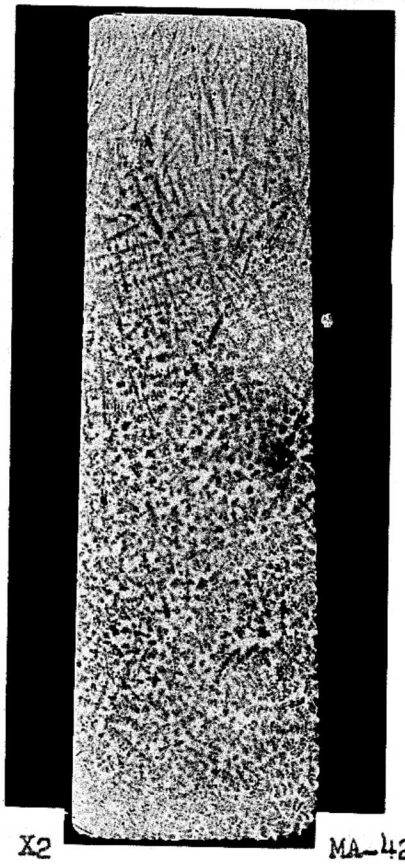
Two Bead Weldability

Single Bead VPN - 508, Rc - 47 Double Bead VPN - 409, Rc - 39

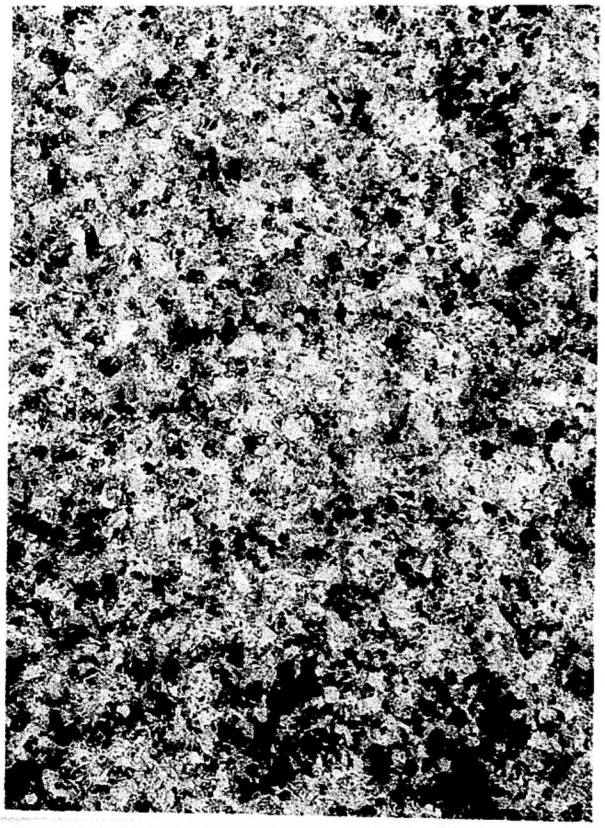
Microstructure and Remarks

Finely spheroidized sorbite with no ferrite present, indicating excellent hardenability for this section size. A very well diffused structure is revealed with a nital etch at a magnification of X25. The nonmetallic inclusions are segregated in the interdendritic fillings. A.S.T.M. Grain Size No. 7.

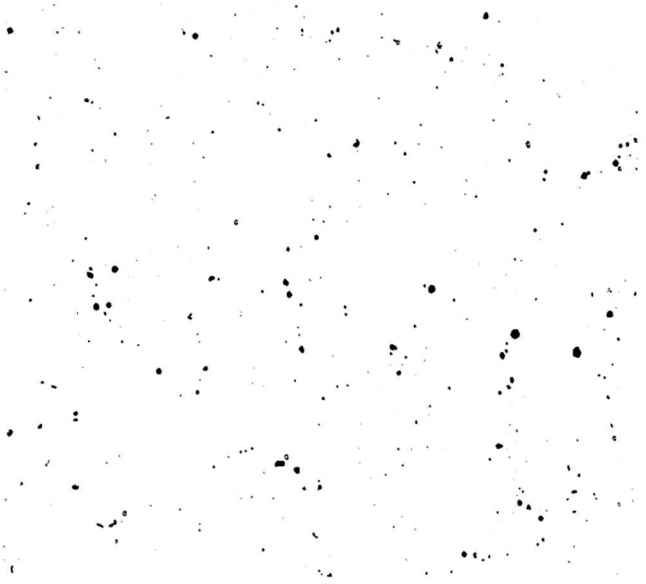
Sivyer Steel Castings Co.
Plate No. 99



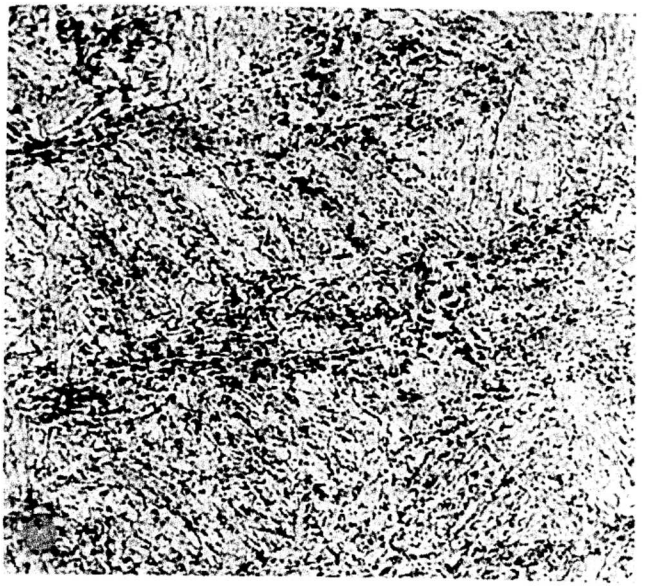
X2 MA-4219
Oberhoffer Etch



X25 MA-4214
Nital Etch



X25 MA-4208
Unetched. Nonmetallic inclusions distributed in interdendritic fillings.



X1000 Nital and Picral Etch MA-4211

W.A.639—4029

DATA SHEET

Sivyer Steel Castings Co.

Heat - 5596 Plate - 99X Thickness - 2.23" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.31	1.06	.25	.038	.019	.47	.59	.49	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1650	3	4	Air
1300	2	3	Air
1550	4	4	Water
1200	6	8	Air

Physical Properties

T.S. - 116,900
Y.P. - 96,650
% Elong. - 23.0
% R.A. - 57.8
Charpy - 33.5
Brinell - 248-255

Ballistic Properties

B.L. - 37MM M51AP - 1988(+150) PTP - 1-7/8x2-1/4" Shock: 75MM T12AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 238 Midwall- 245 Center- 245

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

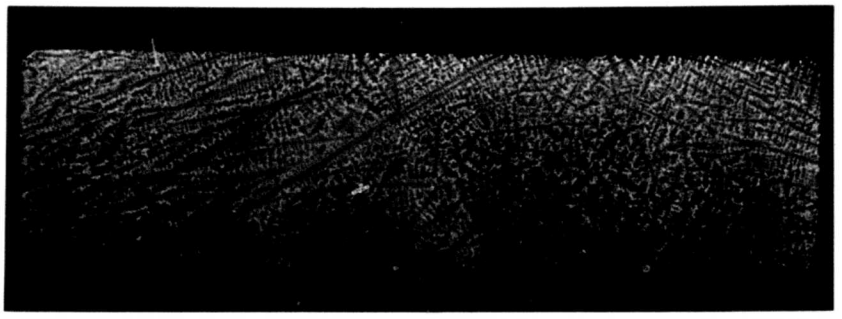
Two Bead Weldability

Single Bead VPN - 519, Rc 48.5 Double Bead VPN - 339, Rc - 34.5

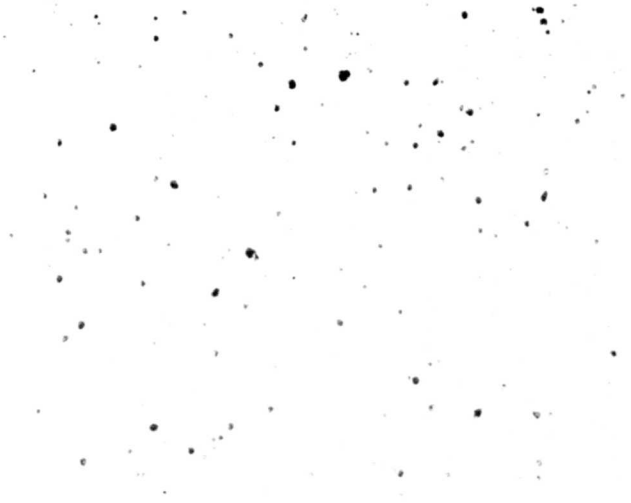
Microstructure and Remarks

Fine uniformly spheroidized sorbite with no ferrite present, indicating excellent hardenability. The Murakami etch shows a tendency for the carbides to outline grain boundaries. A fairly well diffused dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 6.

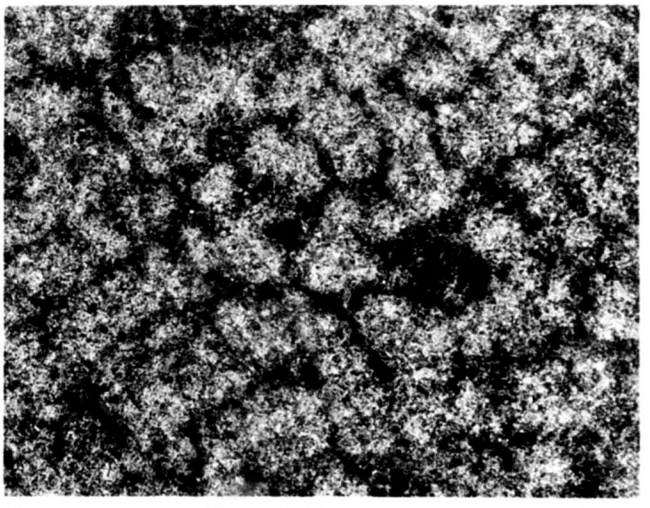
Sivyer Steel Castings Co.
Plate No. 99X



X2 Oberhoffer Etch MA-4270

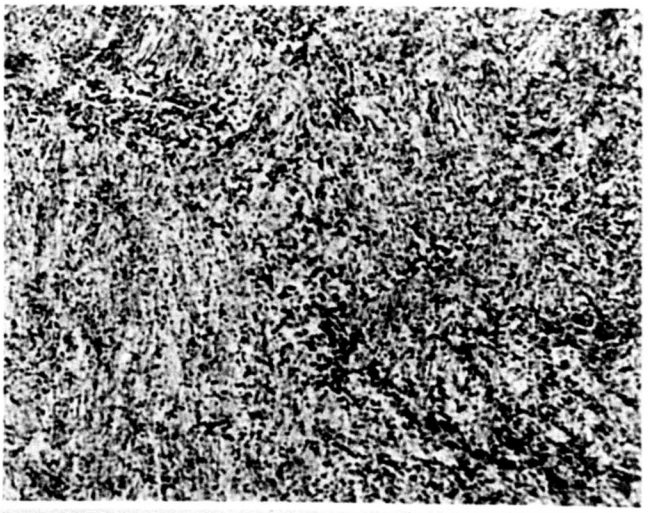


X25 Unetched MA-4259



X25 Nital Etch MA-4264

X1000 MA-4265
Murakami etch. Some tendency for carbides to outline grain boundaries.



X1000 Nital and Picral Etch MA-4251

W.A.639-4051

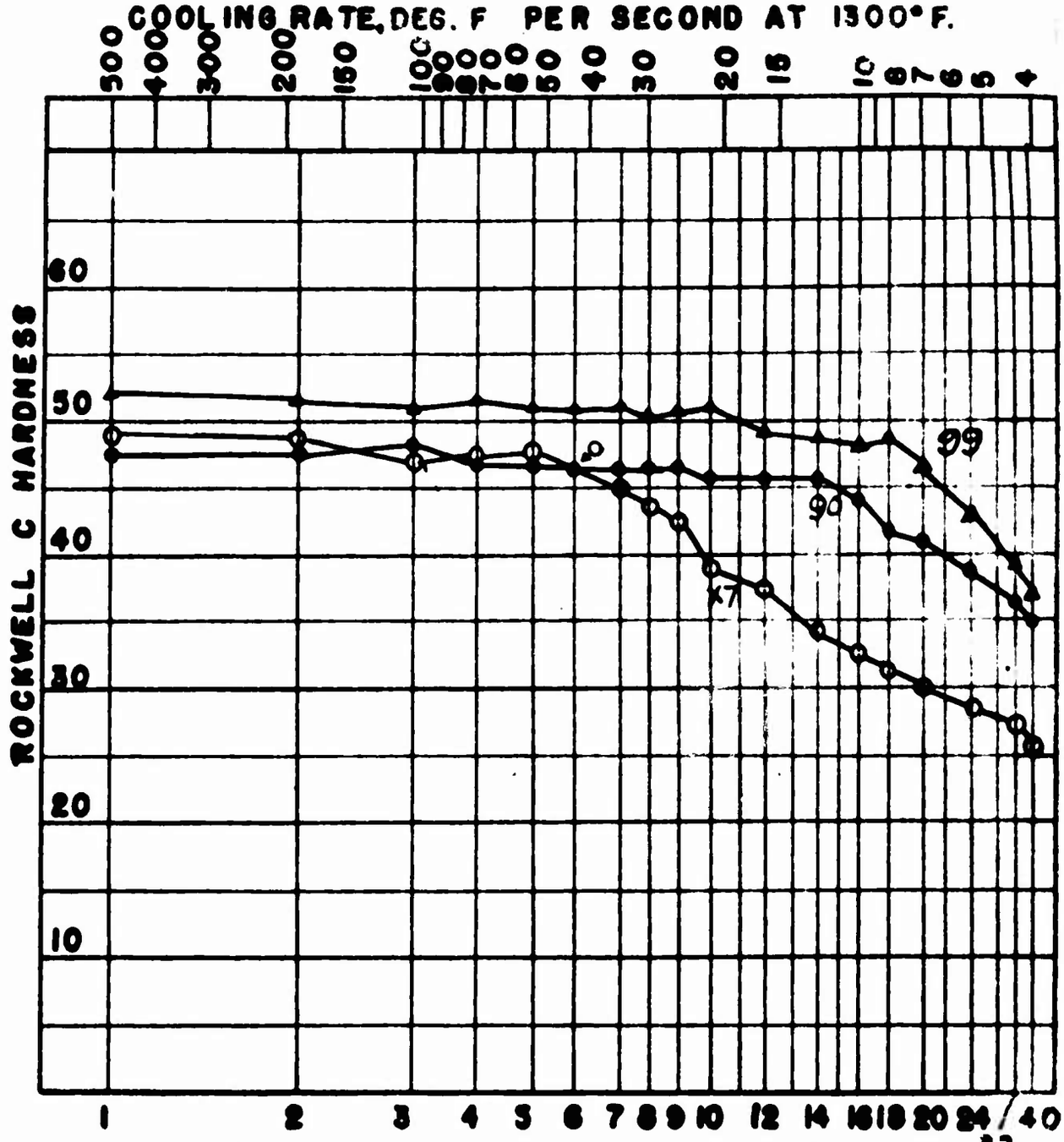


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	CU		QUENCH TEMP	QUENCH TIME	G.S.
X7	o X7	.27	1.24	.33	.036	.022	-	-	.49			1575	4	5
90	•5577	.23	.95	.23	.036	.018	.54	.71	.51	1.01		1550	4	6
99	▲5596	.31	1.06	.25	.038	.019	.47	.58	.49			1550	4	6
		SIVYER		STEEL		CASTINGS			Co					

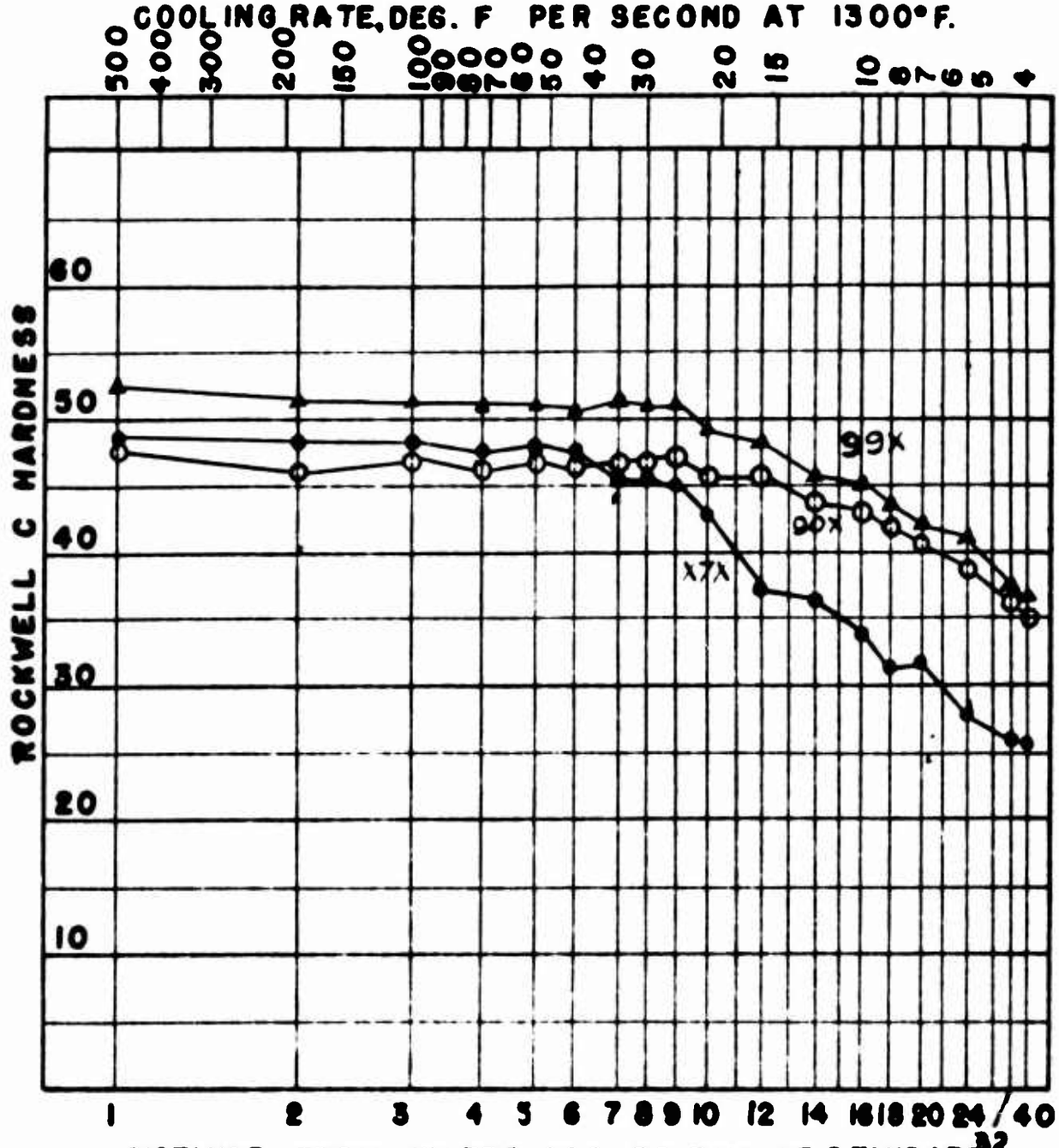


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO	CU		QUENCH TEMP	QUENCH TIME	G.S.
X7X	● 7X	.27	1.24	.33	.036	.022	–	–	.49			1575	4	5
90X	○ 5577	.23	.95	.23	.036	.018	.54	.71	.51	1.01		1550	4	6
99X	▲ 5596	.31	1.06	.25	.038	.019	.47	.59	.49			1550	4	6-7
		SIVIEA STEEL CASTING CO.												

DATA SHEET

Symington-Gould Corp.

Heat - 4552 Plate - 2 Thickness - 1.49" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.24	1.24	.38	.014	.024	--	--	.40	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1700	-	4	Air
1600	-	4	Water
1200	-	4	Air

Physical Properties

T.S. - 137,700
Y.P. - 99,500
% Elong. - 13.0
% R.A. - 36.6
Izod - 48 - 50 - 58
Brinell - 237-244

Ballistic Properties

B.L. - 37MM M51AP - 1495(+201) PTP - 2-1/4x2-5/8" Shock: 75MM T12AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 273 Midwall- 273 Center- 266

Jominy Hardenability

Hardness Penetration 10/16" Critical Cooling Rate - 21°F/Sec Equivalent Plate Thickness 2"

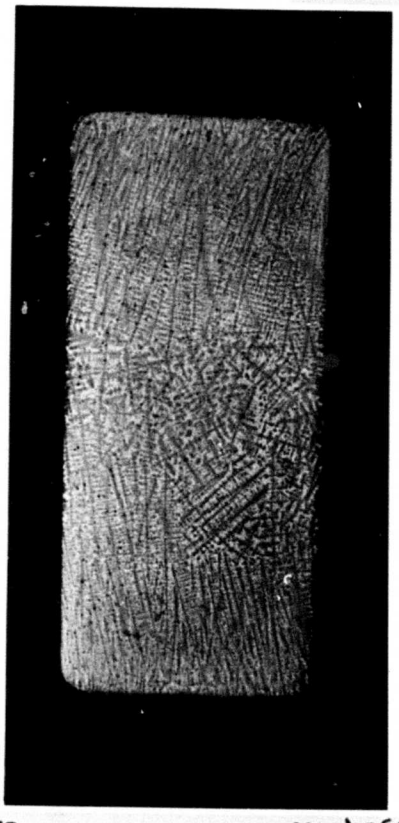
Two Bead Weldability

Single Bead VPN - 514, Rc - 41.5 Double Bead VPN - 351, Rc - 34.5

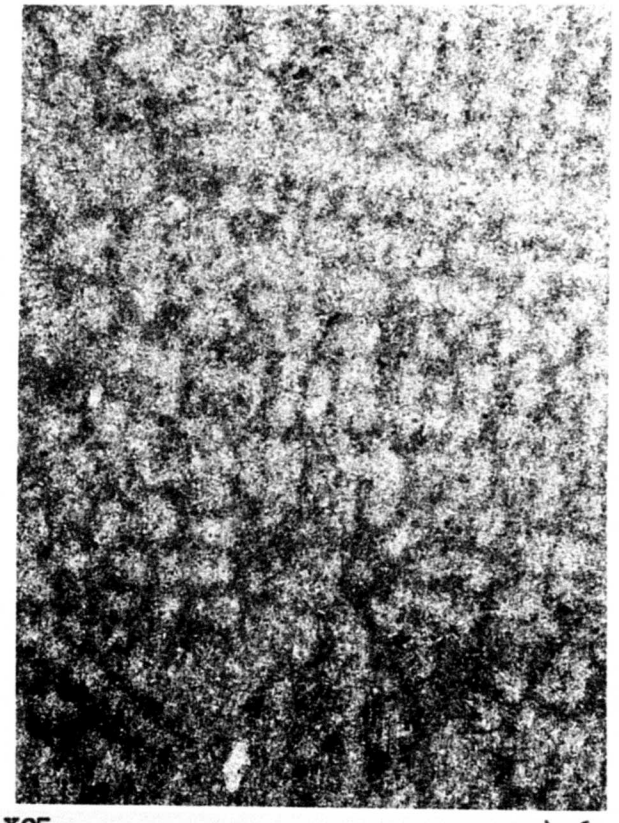
Microstructure and Remarks

Uniform, finely spheroidized sorbite with very little free ferrite, indicating excellent hardenability for this section size. A very slight degree of dendritic segregation is revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 7-8.

Symington-Gould Corp.
Plate No. 2

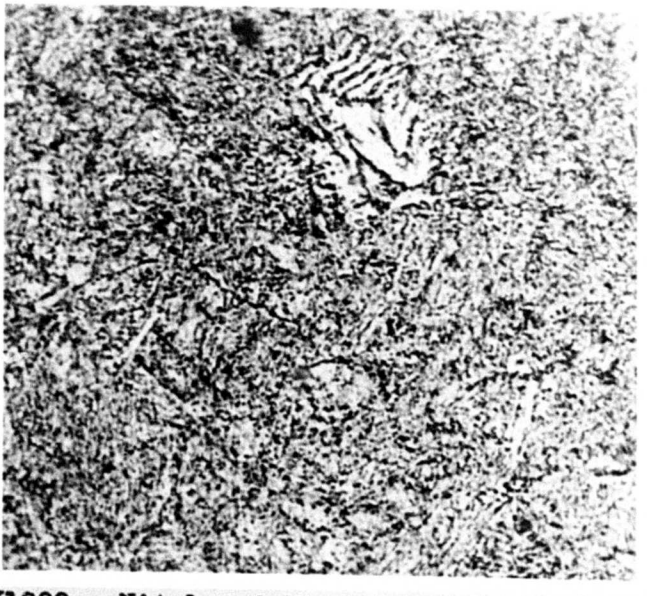


X2 MA-4266
Oberhoffer Etch



X25 MA-4260
Nital Etch

X25 MA-4256
Unetched. Distribution of nonmetallic inclusions.



X1000 Nital and Picral Etch MA-4252

W.A.630-4054

DATA SHEET

Symington-Gould Corp.

Heat - 4552 Plate - 5-2 Thickness - 1.99" Basic O.H.

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.24	1.24	.38	.014	.024	--	--	.40	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1700	-	4	Air
1600	-	4	Water
1200	-	5	Air

Physical Properties

T.S. - 149,050
Y.P. - 136,750
% Elong. - 11.0
% R.A. - 31.1
Izod - --
Brinell - 229-269

Ballistic Properties

B.L. - 37MM M51 AP - 1846(+154) PTP - 2-1/4"x2-3/4" Shock: 75MM T12 AP. PP - SB. Passed.

Brinell Hardness - Cross-Section

Outside- 277 Midwall- 262 Center- 255

Jominy Hardenability

Hardness Penetration) 9/16" Critical Cooling Rate - 26°F/Sec Equivalent Plate Thickness) 1-3/4"

Two Bead Weldability

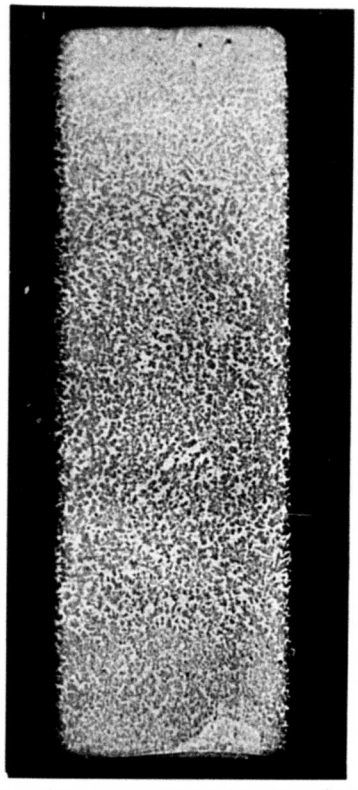
Single Bead VPN - 508, Rc - 48.5 Double Bead VPN - 354, Rc - 37

Microstructure and Remarks

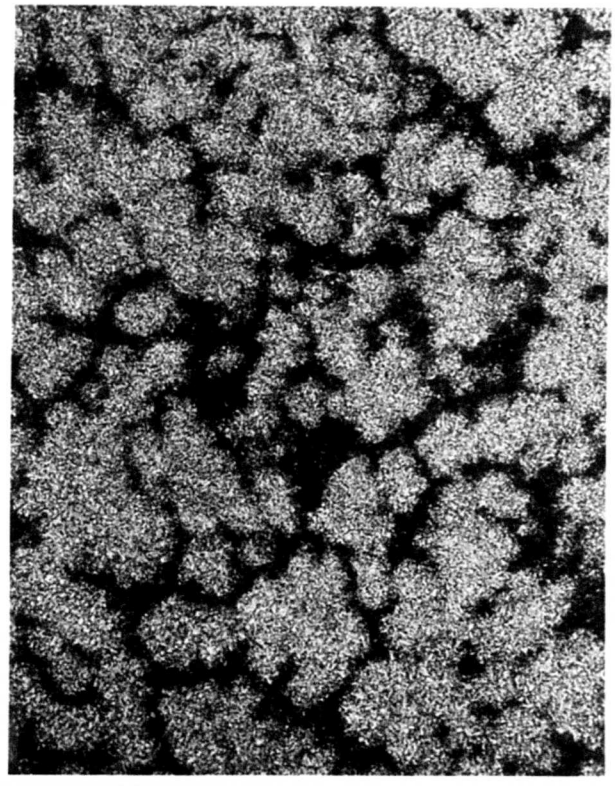
Spheroidized sorbite with approximately 20% ferrite, indicating insufficient hardenability for this section size. The inclusions are distributed in the interdendritic fillings of a pronounced dendritic structure revealed with a nital etch at a magnification of X25. A.S.T.M. Grain Size No. 7.

Symington-Gould Plates No. 2 and No. 5-2 indicate the effect of mass on the hardening ability of steel. The thinner plate has the more satisfactory microstructure because of the more effective hardening of the smaller section.

Symington-Gould Corp.
Plate No. 5-2



X2 MA-4233
Oberhoffer Etch



X25 MA-4238
Nital Etch

X25 MA-4221
Unetched. Distribution of nonmetallic inclusions in interdendritic fillings.

X1000 Nital and Picral Etch MA-4245

W.A.639-4059

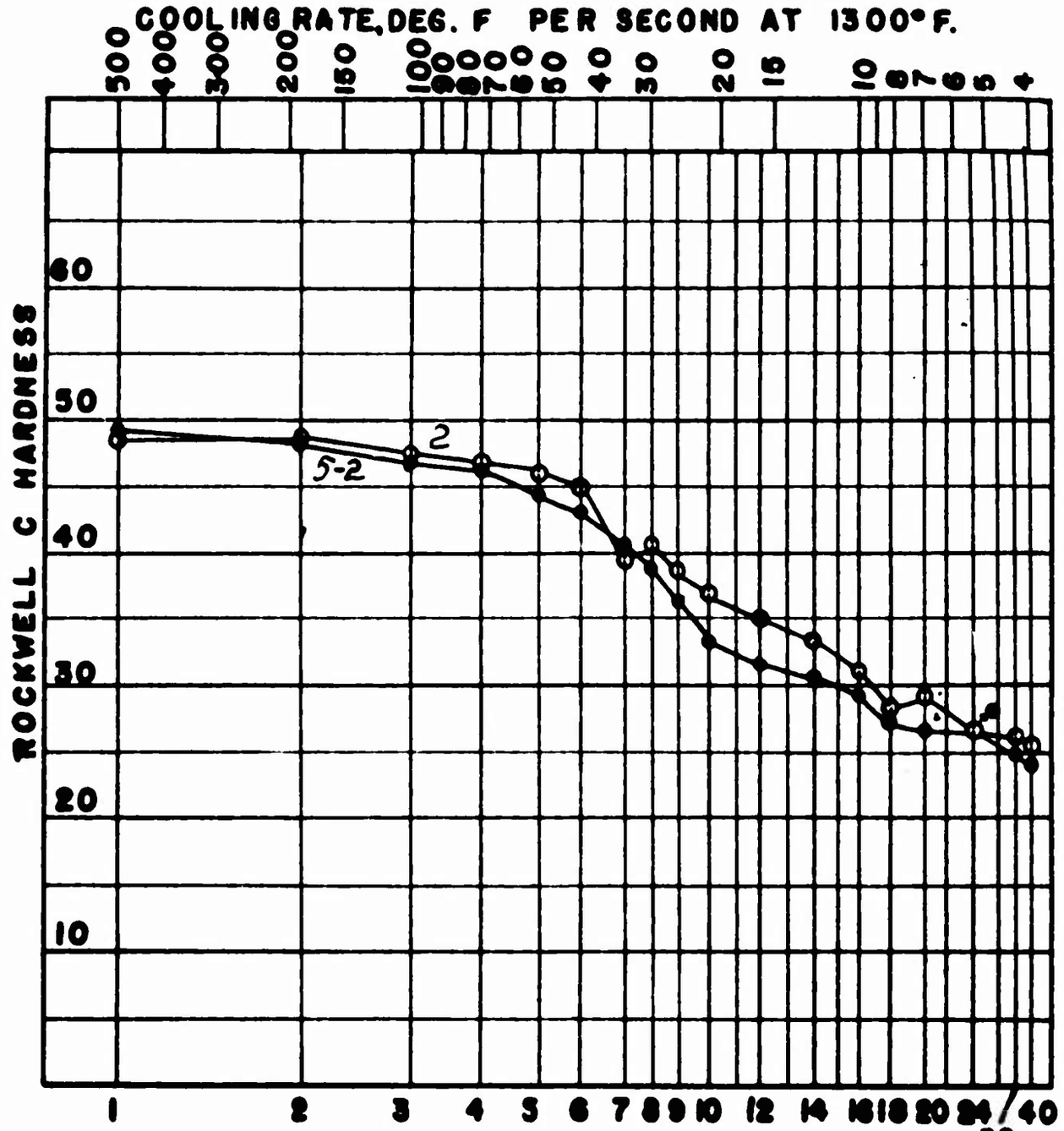
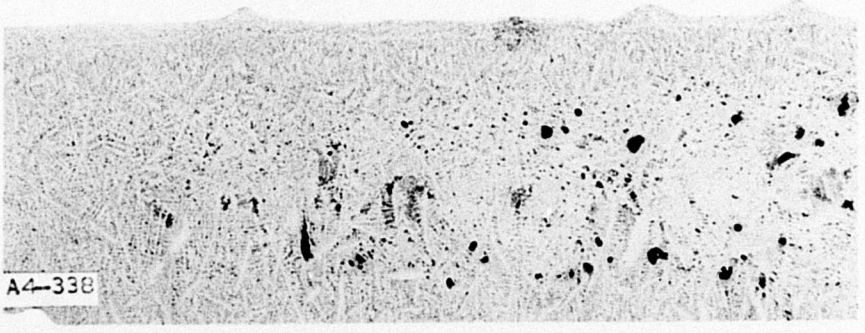
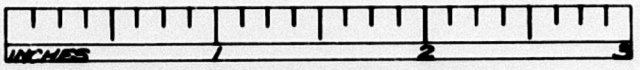


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO			QUENCH TEMP	QUENCH TIME	G.S.
2	○ 4552	.24	1.24	.38	.014	.024	–	–	.40			1600	4	8
5-2	● 4552	.24	1.24	.38	.014	.024	–	–	.40			1600	4	7-8
		SYMINGTON-GOULD CORP.												





ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL.

WEHR STEEL CO. CAST ARMOR PLATE
APRIL 19 1942 W.A.710-1814

DATA SHEET

Wehr Steel Co.

Heat - Plate - A4-338 Thickness - 1.64" Acid Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V
.30	.98	.50	.032	.030	.96	.48	.34	--	--

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1825	-	6	Air
1650	-	4	Water
1200	-	8	Fce to 1100 Water

Physical Properties

T.S. - 114,000
Y.P. - 93,500
% Elong. - 18.0
% R.A. - 31.6
Izod - 35 - 41
Brinell - 255

Ballistic Properties

B.L. - 37MM M51AP - 1611(+199) PTP - 2½x2-15/16" Shock: 75MM T12AP. PP - SC on MB. Passed. 75MM MK1 slug. PP - SC on MB.

Brinell Hardness - Cross-Section

Outside- 238 Midwall- 232 Center- 232

Jominy Hardenability

Hardness Penetration	Critical Cooling Rate	Equivalent Plate Thickness
Air Hardening Steel	-	-

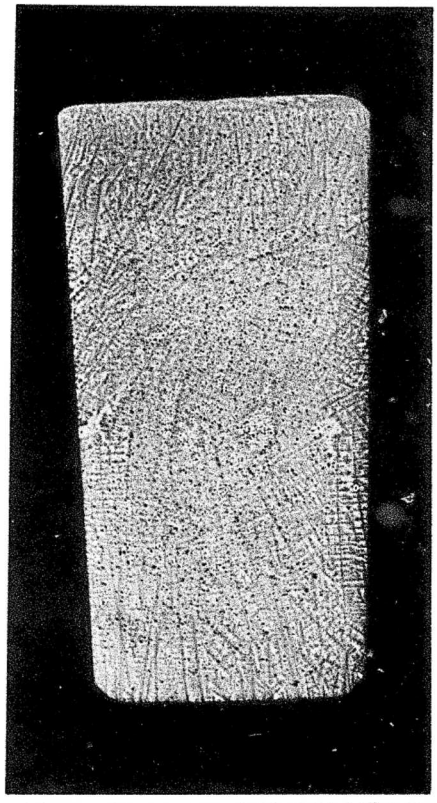
Two Bead Weldability

Single Bead VPN - 530 Rc - 50.5 Double Bead VPN - 360, Rc - 37.5

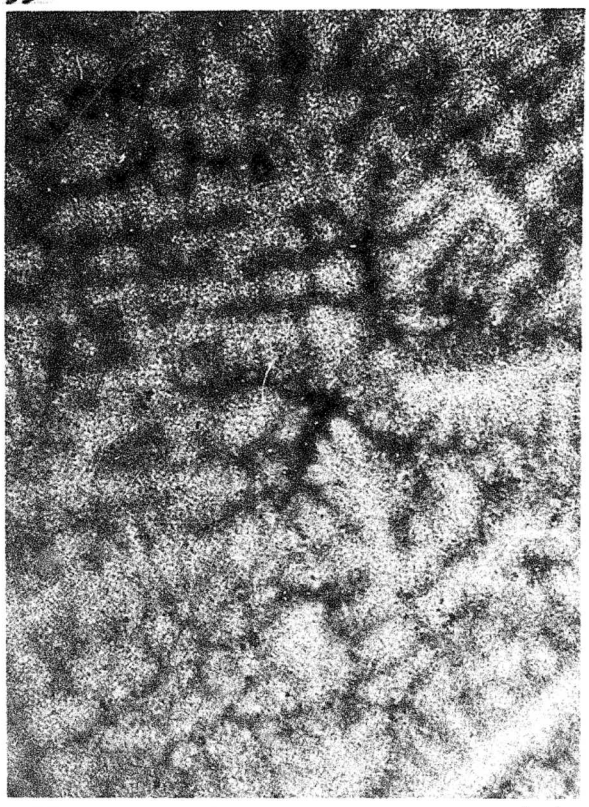
Microstructure and Remarks

Somewhat nonuniform spheroidized sorbite with no pro-eutectoid ferrite, indicating excellent hardenability for this section size. The nonmetallic inclusions are segregated in the interdendritic fillings of a well diffused dendritic segregation. A.S.T.M. Grain Size No. 8.

Wehr Steel Co.
Plate No. A4-338

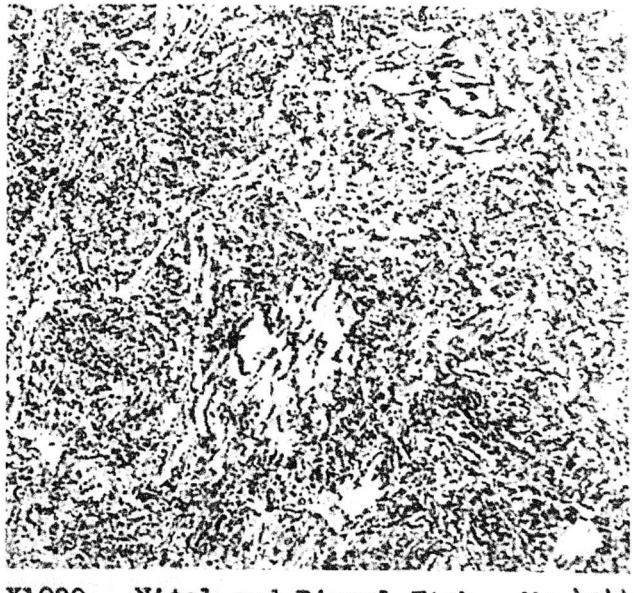


X2 MA-4230
Oberhoffer Etch



X25 MA-4242
Nital Etch

X25 MA-4225
Unetched. Distribution of nonmetallics in interdendritic fillings.



X1000 Nital and Picral Etch MA-4244

W.A.639-4055

DATA SHEET

Wehr Steel Co.

Heat - Plate - W2-332 Thickness - 1.49" Electric

Chemistry

C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Deoxidizer
.27	.78	.35	.033	.035	1.00	.51	.40	--	2# Al

Heat Treatment

Temp.	Hrs. Rise	Hrs. Soak	Coolant
1825	-	6	Air
1575	-	4	Water
1550	-	4	Water
1100	-	6	Air

Physical Properties

T.S. - 131,500
Y.P. - 114,000
% Elong. - 12.0
% R.A. - 22.7
Izod - 19.0
Brinell - 277

Ballistic Properties

B.L. - 37MM M51AP - 1448(+148) PTP - 2-3/8x2-3/8 Shock: 75MM T12AP. PP. Passed.

Brinell Hardness - Cross-Section

Outside- 269 Midwall- 252 Center- 245

Jominy Hardenability

Hardness Penetration) 8/16" Critical Cooling Rate - 30°F/Sec Equivalent Plate Thickness) $1\frac{1}{2}$"

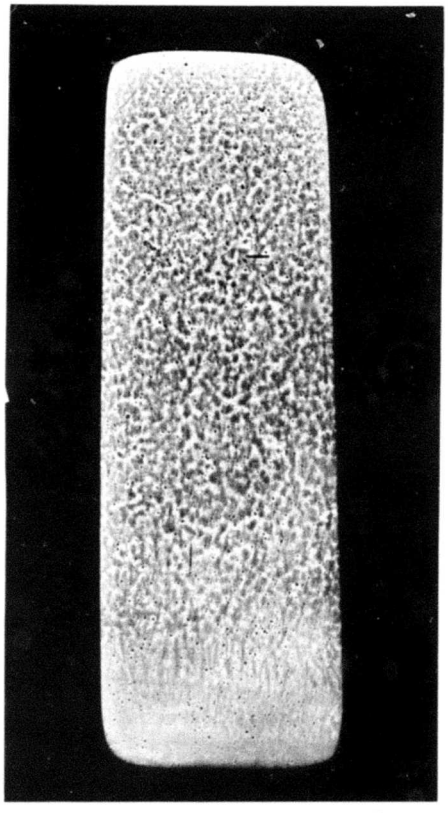
Two Bead Weldability

Single Bead VPN - 459, Rc - 44.5 Double Bead VPN - 325, Rc - 32.5

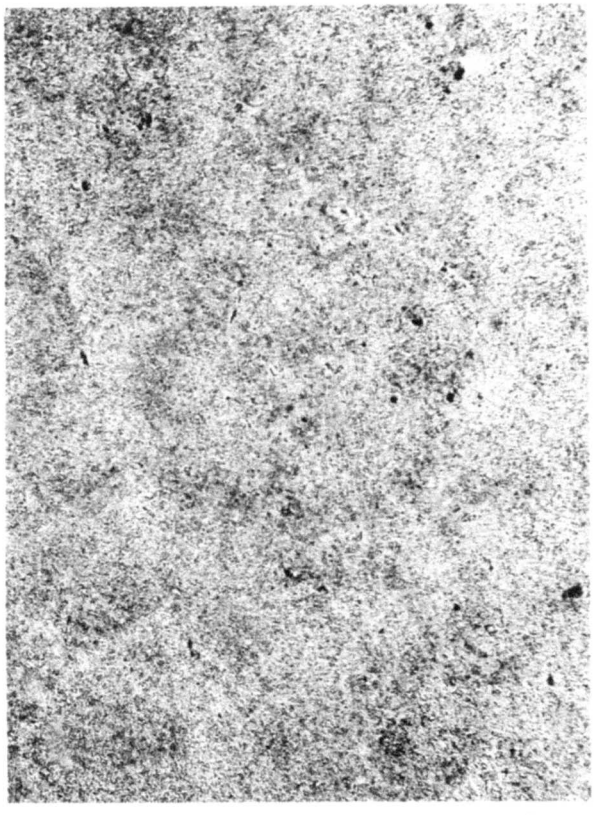
Microstructure and Remarks

Spheroidized sorbite with patches of acicular ferrite, indicating rather low hardenability for this section size. A very homogeneous structure is revealed with a nital etch at a magnification of X25. There is a very pronounced segregation of the inclusions in the interdendritic fillings. A.S.T.M. Grain Size No. 8.

Wehr Steel Co.
Plate No. W2-332



X2 MA-4218
Oberhoffer Etch



X25 MA-4215
Nital Etch

X25 MA-4208
Unetched. Nonmetallic inclusions distributed in interdendritic fillings.

X1000 Nital and Picral Etch MA-4210

W.A.639-4037

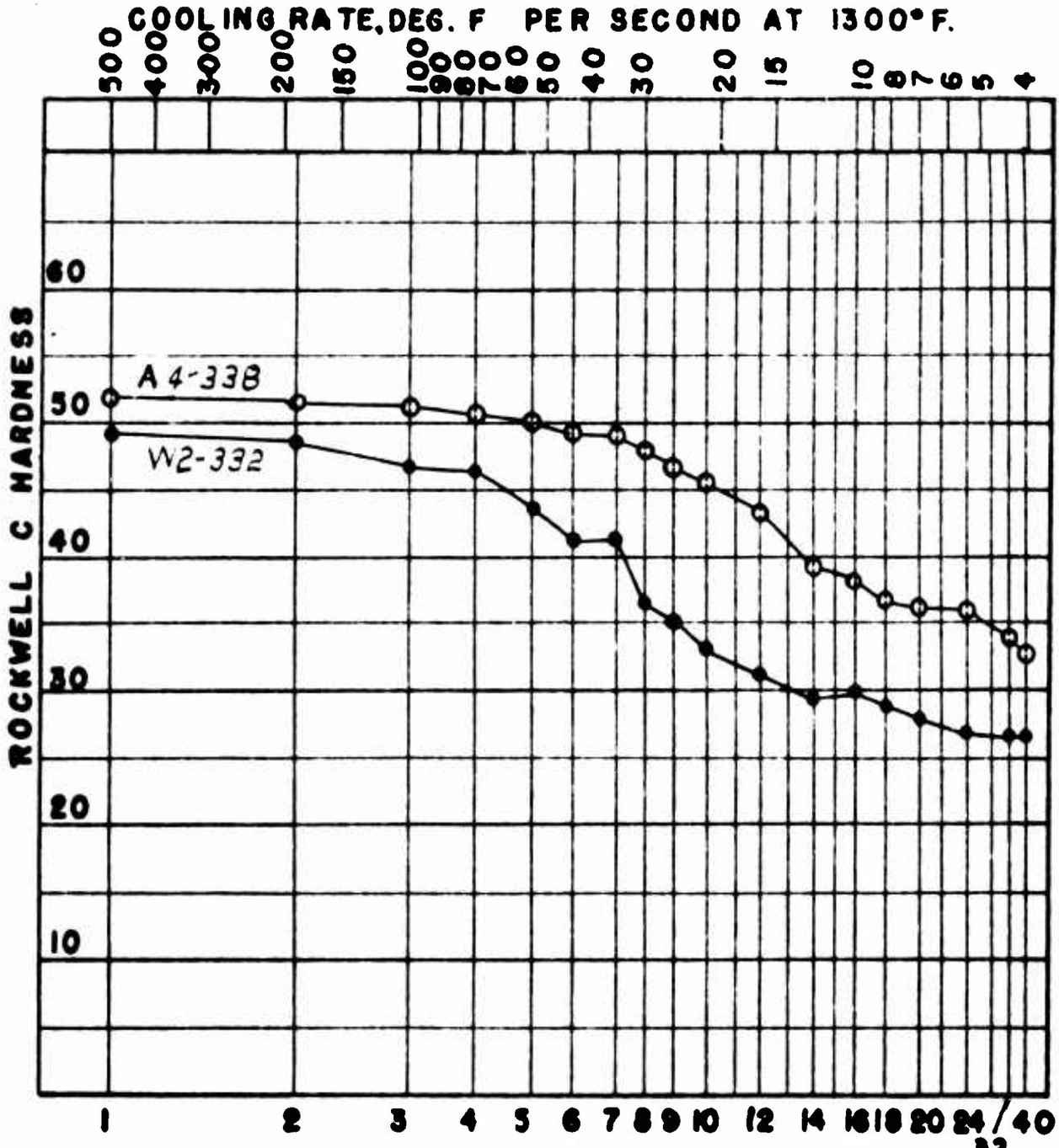
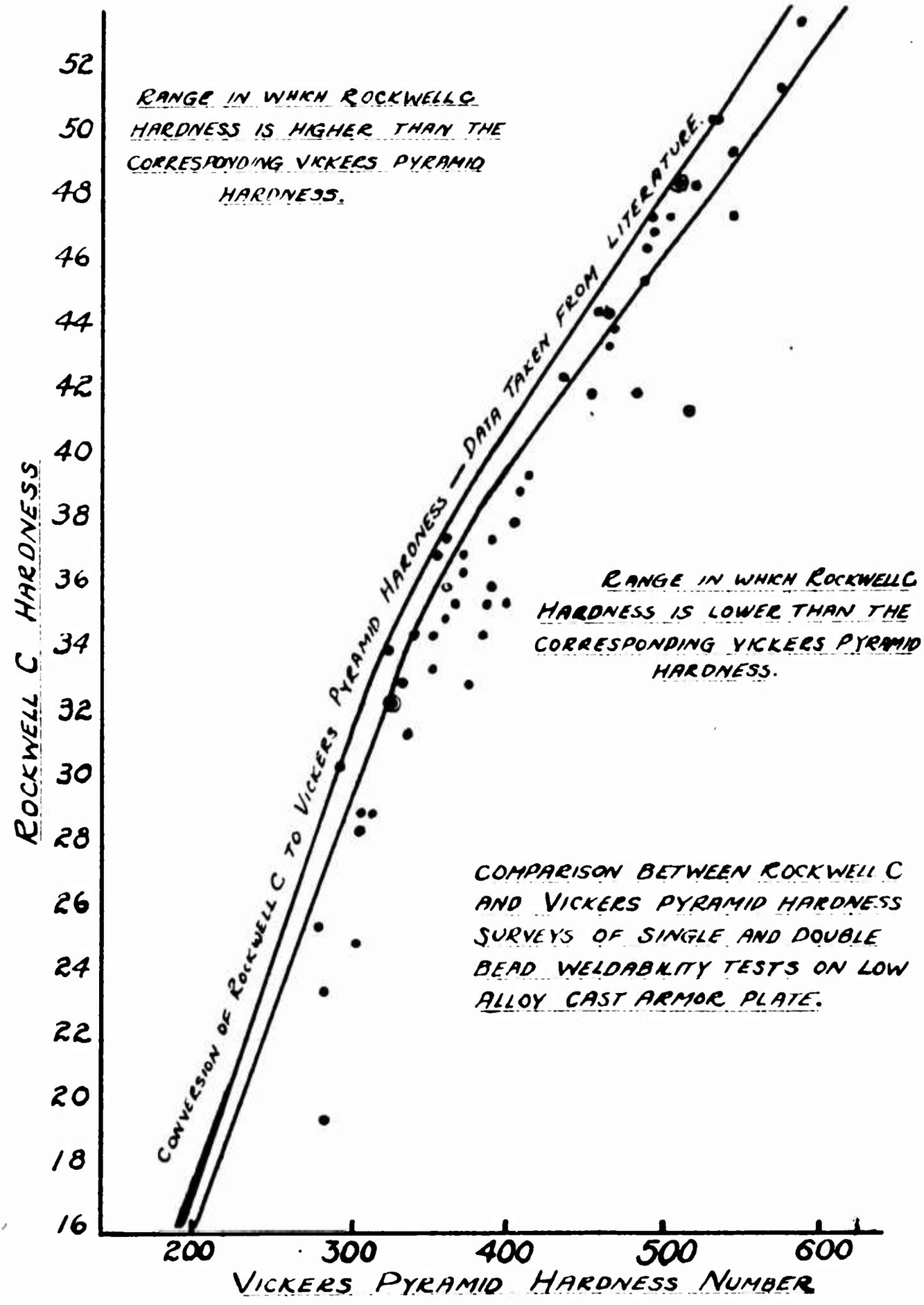


PLATE NO.	HEAT NO.	C	MN	SI	S	P	NI	CR	MO		Deox	QUENCH TEMP	QUENCH TIME	G.S.
A4-338	○	.30	.98	.50	.032	.030	.98	.48	.34			1650	4	6-8
W2-332	●	.27	.78	.35	.033	.035	1.00	.51	.40		2nd AL	1550	4	7-8
				WEHA	STEEL		Co.							


RANGE IN WHICH ROCKWELL C HARDNESS IS HIGHER THAN THE CORRESPONDING VICKERS PYRAMID HARDNESS.
CONVERSION OF ROCKWELL C TO VICKERS PYRAMID HARDNESS — DATA TAKEN FROM LITERATURE.
RANGE IN WHICH ROCKWELL C HARDNESS IS LOWER THAN THE CORRESPONDING VICKERS PYRAMID HARDNESS.
COMPARISON BETWEEN ROCKWELL C AND VICKERS PYRAMID HARDNESS SURVEYS OF SINGLE AND DOUBLE BEAD WELDABILITY TESTS ON LOW ALLOY CAST ARMOR PLATE.
ROCKWELL C HARDNESS
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
200
300
400
500
600
VICKERS PYRAMID HARDNESS NUMBER