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AD-A953 685

W. H. No. 750/452

EXPERIMENTAL SEATS OF LAST TYPE

UNDER CONSIDERATION FOR USE IN ARMY PLATE

By

L. H. Jones
Military Motor Car Division
General Motors Corporation

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RESEARCH LABORATORIES DIVISION
GENERAL MOTORS CORPORATION
DETROIT, MICHIGAN

NO. M 1295

OBSERVER F. J. Webber

DATE SUBMITTED _____

APPROVED A. L. Houghshead

DATE REPORTED 8-30-42

SUBJECT Experimental Heats of Cast Steel Under Consideration for use in Armor Plate by Cadillac Motor Car Division, per Mr. L. A. Danse.

INVESTIGATION REQUIRED: Determination of physical properties of seven heats of cast steel made by Climax Molybdenum Company of different compositions and with various methods of deoxidation.

Determination of physical properties of seven heats made by Research Laboratories Division of General Motors Corporation.

IDENTIFICATION: W. O. 11822

This investigation was made to determine the minimum amount of alloy additions necessary to produce physical properties comparable to those of the present specified composition and also whether or not it might be possible to elinain to the specified diffusion or homogenizing treatment and substitute a conventional normalizing treatment.

DISCUSSION: Seven heats of steel were cast by the Climax Molybdenum Company of Michigan laboratory in a dry sand mold of a double keel block which has been designed to yield two test bars 1 x 7/8 x 11" of sound metal. These were melted and alloyed in a 30% silica-lined, coreless high frequency induction furnace. (See Climax Laboratory report No. 2496, dated 7-27-42). The heats which varied in composition and method of deoxidation were calculated to give the following chemical compositions:

Composition No. Climax Heat No.	1 2632	2 2633	3 2634	4 2636	5 2637	6 2638	7 2639
Carbon	.29	.29	.29	.29	.29	.29	.29
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Silicon	.50	1.00	1.00	1.00	1.00	.50	1.00
Molybdenum	.50	.50	.50	.20	-	.20	.20
Chromium	-	-	-	.50	.50	.50	.50
Boron added				.005	.005	.005	
Aluminum added	1.5#/ton	1.5#/ton	1.5#/ton	1.5#/ton	1.5#/ton	1.5#/ton	1.5#/ton
Ferro Titanium (Hi C)	-	-	3#/ton	-	-	-	-

Seven compositions were also cast by G. M. Research Laboratories Division in a dry sand mold of a single keel block which yields a test block of 1-1/8 x 3 x 11-1/2". These were of different compositions and different methods of deoxidation. One heat #C-270 was to replace No. 3 of the Climax Molybdenum Company heats which was found to be badly checked on the surface after heat treatments. Another #C-277 was to duplicate, except for the homogenizing treatment, No. 7 of the Climax heats which showed the best combination of physical properties.

The intended composition of these seven heats was as follows:

Heat No.	C-270	C-271	C-273	C-274	C-275	C-276	C-277
Carbon	.29	.28	.28	.29	.29	.29	.29
Manganese	1.50	1.50	1.00	.90	1.50	1.50	1.50
Silicon	1.00	.45	.45	.45	.45	.45	.95
Chromium	-	.35	.35	.65	.65	.65	.50
Molybdenum	.50	.35	.35	.23	.35	.35	.23
Boron added			.005	.005	.005		
Zirconium added				.14			
Aluminum added	1.5#/ton	1.5#/ton	1.5#/ton	-	1.5#/ton	1.5#/ton	1.5#/ton

These compositions were also melted in 30# Coreless high frequency induction furnace using a magnesia crucible.

Actual Chemical Analysis:

Heat No.	C	Mn	Si	Cr	Mo
Climax 2632	.25	1.41	.65	.12	.45
" 2633	.28	1.52	1.21	-	.33
" 2634	not analyzed since cracked				
" 2636	.28	1.48	1.15	.51	.21
" 2637	.29	1.48	1.17	.52	-
" 2638	.29	1.45	.65	.53	.23
" 2639	.30	1.51	1.18	.54	.24
GMC-270	.30	1.60	.80	-	.46
"C-271	.31	1.46	.36	.33	.41
"C-273	.29	1.06	.50	.35	.39
"C-274	.27	1.01	.80	.57	.30
"C-275	.28	1.45	.49	.56	.37
"C-276	.31	1.45	.49	.56	.35
"C-277	.29	1.45	1.02	.39	.34

HEAT TREATMENT:

Both keels were cut from the Climax blocks so as to give a bar 1" x 7/8" x 11". Two 1-1/4 x 1-1/8 x 11-1/2" bars were also taken from the Research cast keel block, bar A being from the bottom end of the keel while bar B was located nearer the gate.

The bars from the seven Climax heats and G.M.R./C-270 were then homogenized and heat treated as follows:

Heated to 1950°F in six hours. Held at heat 10 hours. Cooled in still air to room temperature. Reheated to 1650°F in 5 hours and held at heat one hour. Quenched in water down to a temperature of 500-600°F (20 seconds required as determined by experiment.)

Tempered to 321-351, three hours up to heat, 6 hours at heat and cooled in air. Tempering temperature 850°F.

The bars representing the remaining six heats made by the Research Laboratories were heated to 1700°F in 1-1/2 hours and held for four hours, transferred to a furnace at 1000°F, held one hour and cooled in air. They were subsequently hardened in the same manner as the Climax made bars.

As stated previously the bars from Climax heat No. 2634 were found to be badly checked, particularly on the bottom face. The extent of these cracks is shown in a photograph included in this report. A micrograph taken in the region of one of the cracks is also included. This shows oxide at the edges of the crack and practically complete decarburization in the adjacent zone, indicating that the cracks were present at the time the samples were homogenized. The bars were then machined into test bars of standard Cadillac dimensions as shown in the attached sketch.

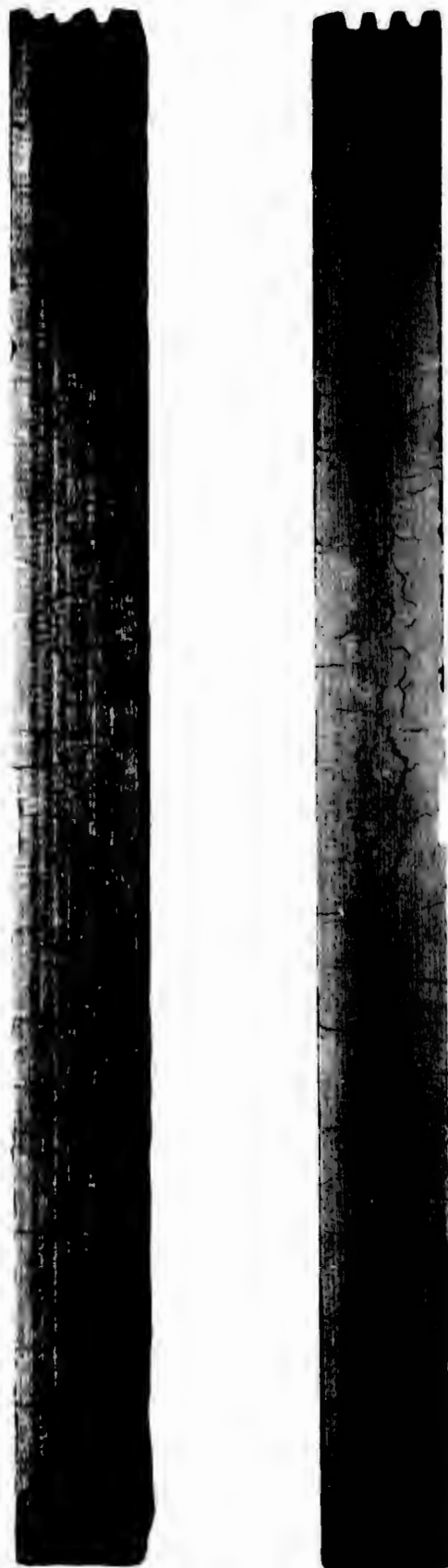
PHYSICAL PROPERTIES:

BAR NO.	HEAT NO.	BRINELL HARDNESS	ULTIMATE STRENGTH PSI	YIELD STRENGTH (JOHNSON'S) PSI	MODULUS OF RUPTURE PSI	ELONGATION IN 2" %	REDUCTION OF AREA (APPROX.) %
1-A	2632	352	169,000	145,000	196,000	15.0	27.2
1-B	2632	341	169,000	150,000	206,000	14.5	29.0
2-A	2633	352	176,000	135,000	218,000	13.2	30.0
2-B	2633	363	175,000	135,000	215,000	13.5	25.6
	C-270	363	168,000	133,000	182,500	10.0	13.9
	C-270	352	178,400	142,000	197,500	10.2	14.9
4-A	2636	363	170,000	125,000	205,000	15	26.0
4-B	2636	352	170,000	126,000	-	16.5	27.4
5-A	2637	352	161,000	120,000	202,000	19.8	33.0
5-B	2637	331	160,800	126,000	203,000	19.5	33.0
6-A	2638	352	166,000	127,000	204,000	16.1	28.4
6-B	2638	352	166,000	132,000	208,000	13.6	27.8
7-A	2639	363	176,000	125,000	227,000	15.0	31.4
7-B	2639	352	176,000	145,000	233,000	15.2	32.4
	C-271A	341	148,000	110,000	176,000	14.5	33.3
	C-271B	352	158,000	130,000	179,500	9.4	18.2
	C-273A	352	156,600	125,000	186,000	14.5	34.7
	C-273B	341	158,000	122,000	173,000	10.4	20.1
	C-274A	311	150,800	105,000	154,000	11.3	8.5
	C-274B	375	146,400	108,000	163,500	7.0	16.8
	C-275A	363	176,400	146,000	201,000	13.8	18.4
	C-275B	375	176,000	136,000	203,000	10.0	16.2
	C-276A	321	155,400	104,000	177,000	13.2	20.8
	C-276B	375	177,800	146,000	204,000	8.8	17.6
	C-277A	352	162,300	106,000	182,000	11.5	22.2
	C-277B	363	177,200	130,000	205,000	10.5	20.2

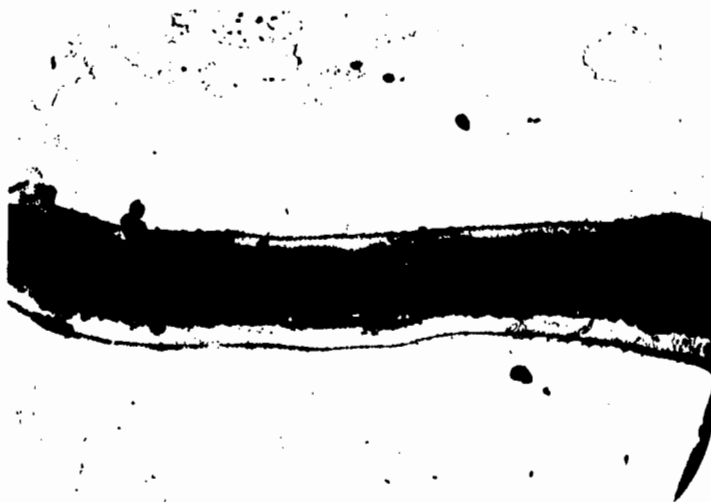
HARDENABILITY:

Hardenability bars were then machined from the heavy end of one tensile bar of the Climax heats and Research Heat C-273 and from a 1-1/8" dia. test ring cast in a cast iron mold of the other Research Laboratories heats.

FCK curves showing the hardenability of these various heats are also included in this report.



**Network surface cracks on bottom
faces of hardened keel blocks from Climax
Heat No. 2634.**



M 1295-1 4% Nital 100 X

Micrograph showing oxide in crack and extent of decarburisation of adjacent metal in section from bar of Climax heat No. 3 which was badly checked on surface.

SUMMARY:

The best combination of physical properties was obtained from composition No. 7 of the Climax Molybdenum laboratory heats which was given a homogenizing treatment prior to hardening and tempering. No. C-277 of the Research Laboratory heats was intended to be of the same composition and was made to determine the advantages, if any, of the homogenizing treatment. The composition of these two heats and the resultant properties were as follows:

Source Composition Heat No.	Climax Molybdenum No. 7 2639	G.M. Research Lab. No. 7 C-277
Carbon	.30	.29
Manganese	1.51	1.45
Silicon	1.18	1.02
Chromium	.54	.39
Molybdenum	.24	.34
Aluminum added	1.5#/ton	1.5#/ton
	Homogenized	Not Homogenized
Hardness Brinell	352 - 363	352 - 363
Ultimate Strength psi	176,000-176,000	162,300-177,200
Yield Strength psi	125,000-145,000	106,000-130,000
Mod. of Rupture psi	227,000-233,000	188,000-205,000
Elongation in 2" %	15.0 - 15.2	11.5 - 10.5
Red. of Area (approx.) %	31.4 - 32.4	22.2 - 20.2
Hardenability Rockwell c max.	50	53
Distance from water cooled end Rockwell c-50	4/16"	6/16"
Distance from water cooled end Rockwell c-45	18/16"	10/16"
Distance from water cooled end Rockwell c-40	32/16"	15/16"

The better agreement of the physical test results obtained on the above homogenized test bars together with the consistently higher values indicate that there is a definite advantage to be derived from a 10 hour homogenizing treatment at 1950°F.

Research heat C-275 which was similar in composition to C-277 except for .49 silicon content compared to 1.02% and the addition of .005% boron to the melt showed comparatively high physical properties without homogenizing. This appears to be a composition which merits further investigation.

Ultimate strength and ductility were in general higher for the several lots of homogenized bars than for those bars which were given only a normalizing treatment prior to hardening.

The cracking which was experienced with the test bars from Climax heat No. 2634 made with a high carbon ferro-titanium addition and the low ductility of Research heat C-270 of similar composition and deoxidation practice suggests that the addition of ferro-titanium is detrimental rather than beneficial in connection with a high manganese high silicon composition.

H. C. MOUGHEY, DIRECTOR - RESEARCH LABORATORIES DIVISION, DETROIT

SAE HARDENABILITY CHARTS

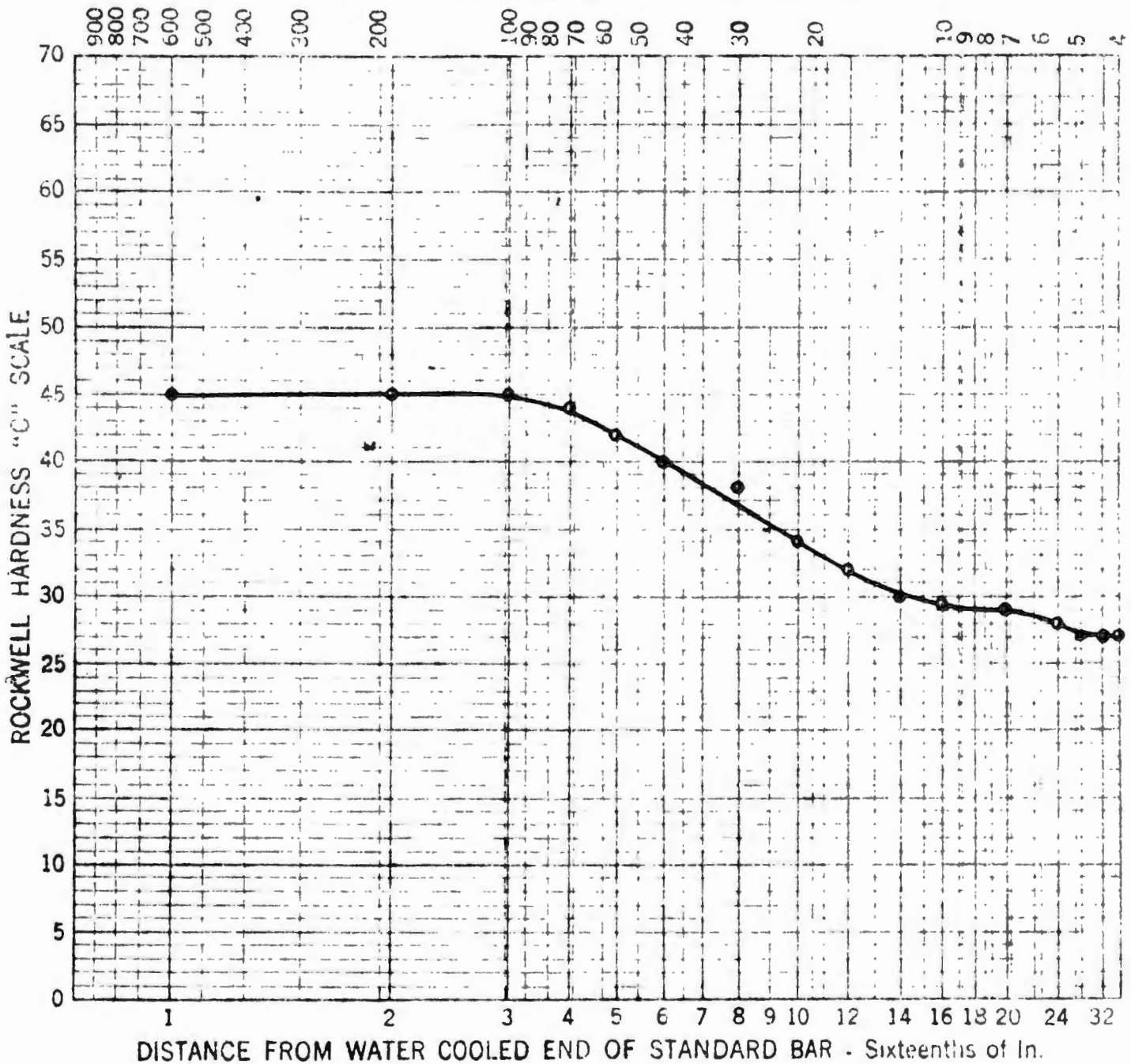
END-QUENCH TEST

Form 1

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.
29 WEST 39 ST., NEW YORK CITY

Test No.
Sheet No.
Date *AUG. 12, 1942*

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel *EXPERIMENTAL HEAT* Source *CLIMAX MOLYBDENUM CO.*
Notes

Signed *J.E.C.*

STEEL ANALYSES AND QUENCHES

Bar No.	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
<i>1A</i>	<i>.25</i>	<i>1.41</i>			<i>.65</i>		<i>.12</i>	<i>.45</i>	<i>1650°F.</i>		<i>2632</i>
	<i>ADDED</i>		<i>.075</i>	<i>Al</i>							

END-QUENCH TEST

Date AUG. 12, 1942.....

DISTANCE FROM WATER COOLED END OF STANDARD BAR - Sixteenths of In

Signed JEC.

[illegible]

SAE HARDENABILITY CHARTS

END-QUENCH TEST

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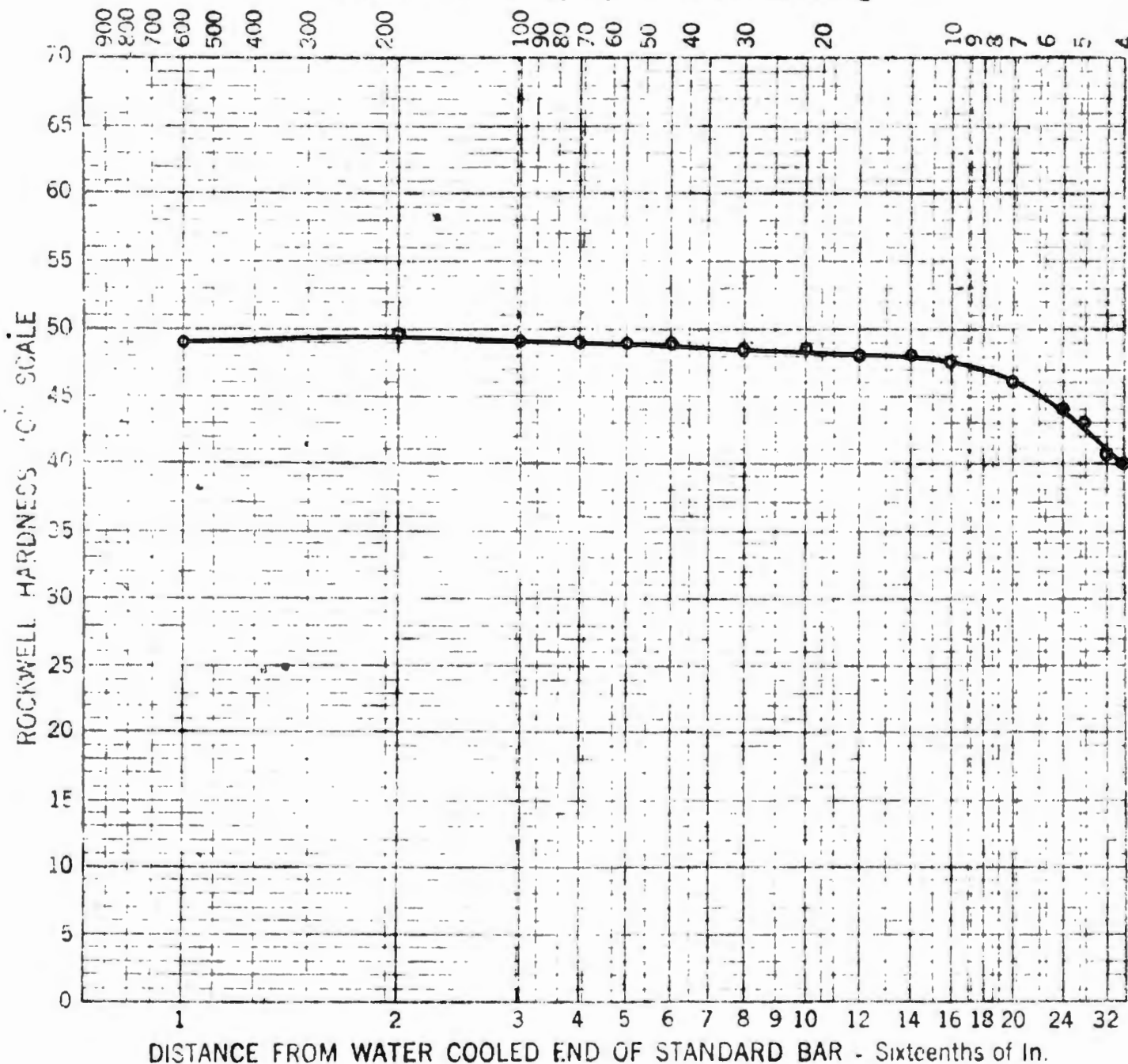
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29 WEST 39 ST., NEW YORK CITY

Test No.

Sheet No.

Date *AUG. 12, 1942*

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel *EXPERIMENTAL HEAT*

Source *CLIMAX MOLYBDENUM CO.*

Notes:

Signed *J.E.C.*

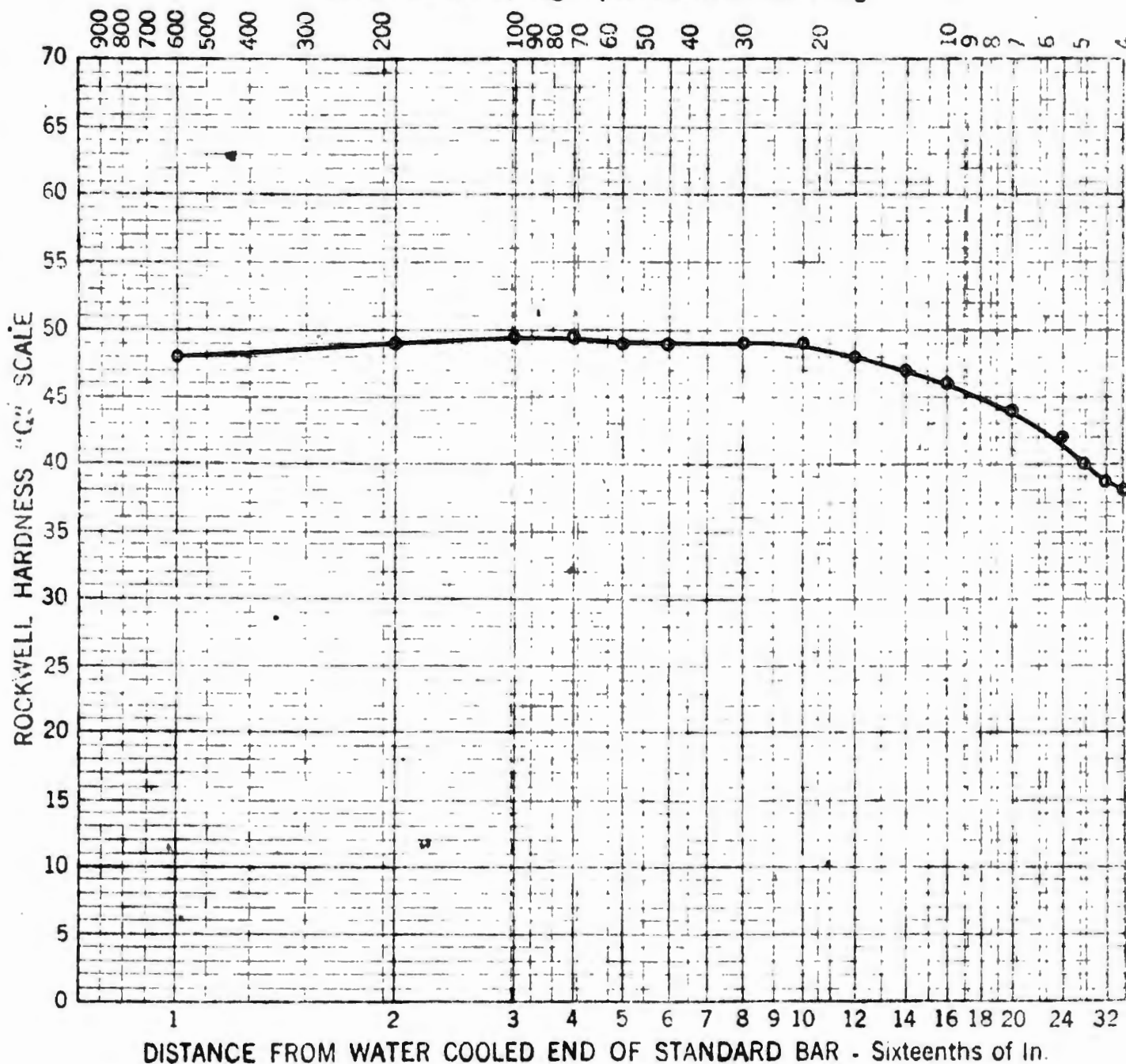
STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
<i>4A</i>	<i>.28</i>	<i>1.48</i>			<i>1.15</i>		<i>.51</i>	<i>.21</i>	<i>1650°F.</i>		<i>2636</i>
	<i>ADDED .075 Al, .005 B</i>										

END-QUENCH TEST

Date. AUG 12, 1942

COOLING RATE, deg. f. per second at 1300 deg.



Source...CLIMAX MOLYBDENUM CO.

Notes.

Signed... J.E.C.

STEEL ANALYSES AND QUENCHES

[illegible]

SAE HARDENABILITY CHARTS

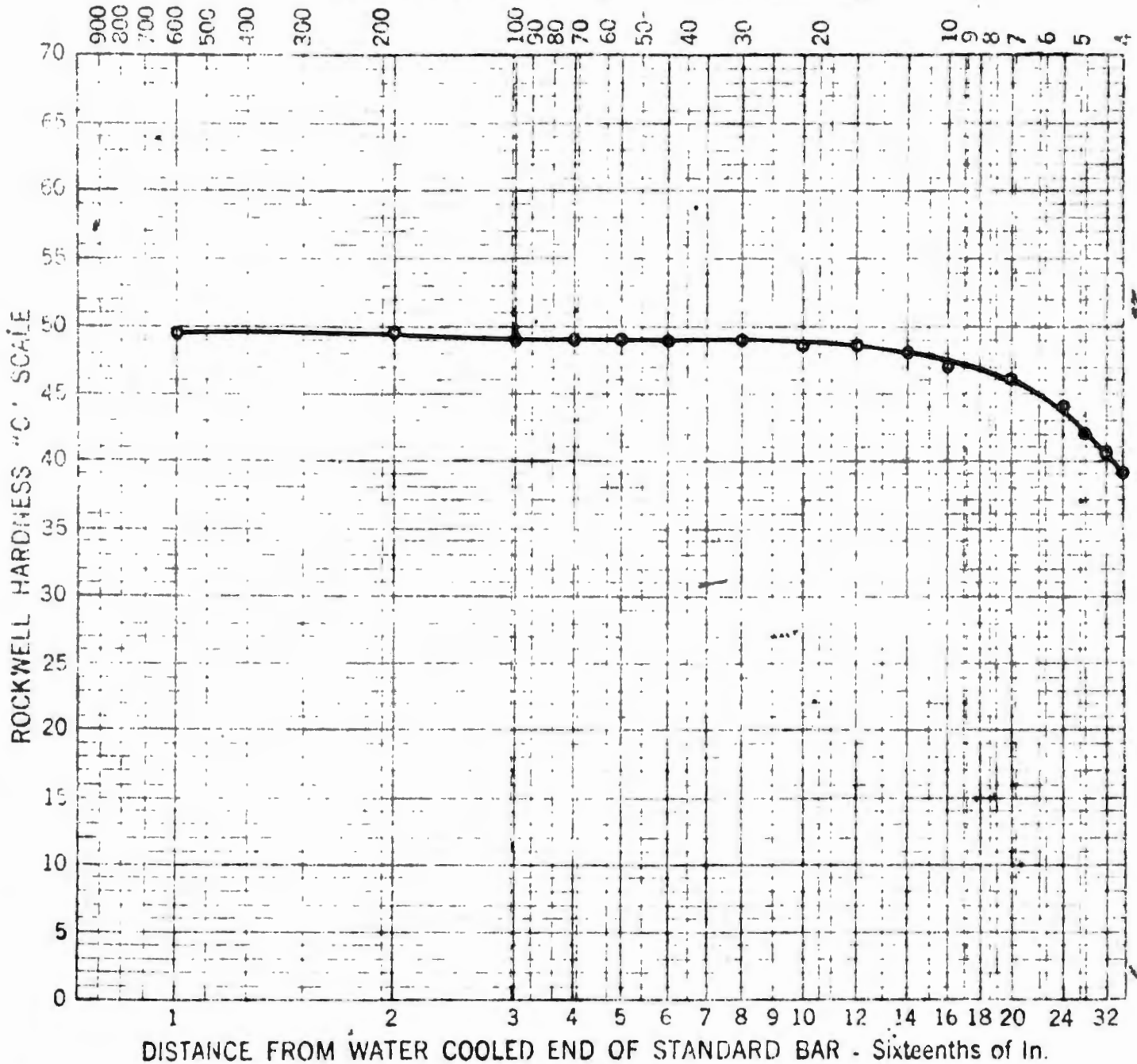
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29 WEST 39 ST. NEW YORK CITY

Test No.
Sheet No.
Date Aug 12, 1942

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel EXPERIMENTAL HEAT
Notes

Source CLIMAX MOLYBDENUM CO.

Signed J.E.C.

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
6A	.29	1.45			.65		.53	.23	1650°F.		2638
	ADDED		.075 Al, .005 B								

SAE HARDENABILITY CHARTS

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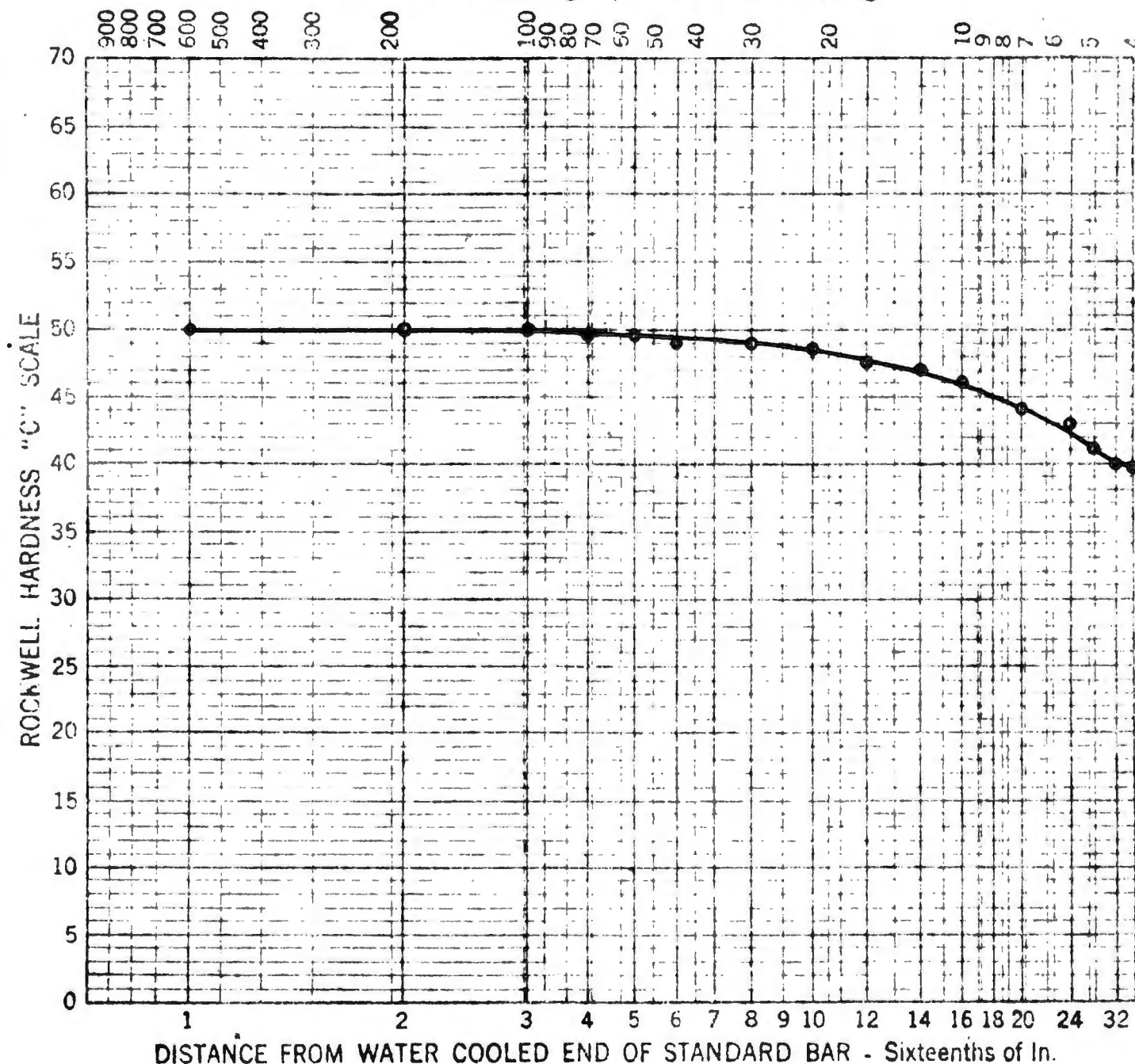
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29 WEST 39 ST., NEW YORK CITY

Test No.

Sheet No.

Date *Aug. 12, 1942*

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel *EXPERIMENTAL HEAT* Source *CLIMAX MOLYBDENUM CO.*
Notes

Signed *J.E.C.*

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
<i>7A</i>	<i>.30</i>	<i>1.51</i>			<i>1.18</i>		<i>.54</i>	<i>.24</i>	<i>1650°F.</i>		<i>2639</i>
	<i>ADDED</i>		<i>.075 Al</i>								

SAE HARDENABILITY CHARTS

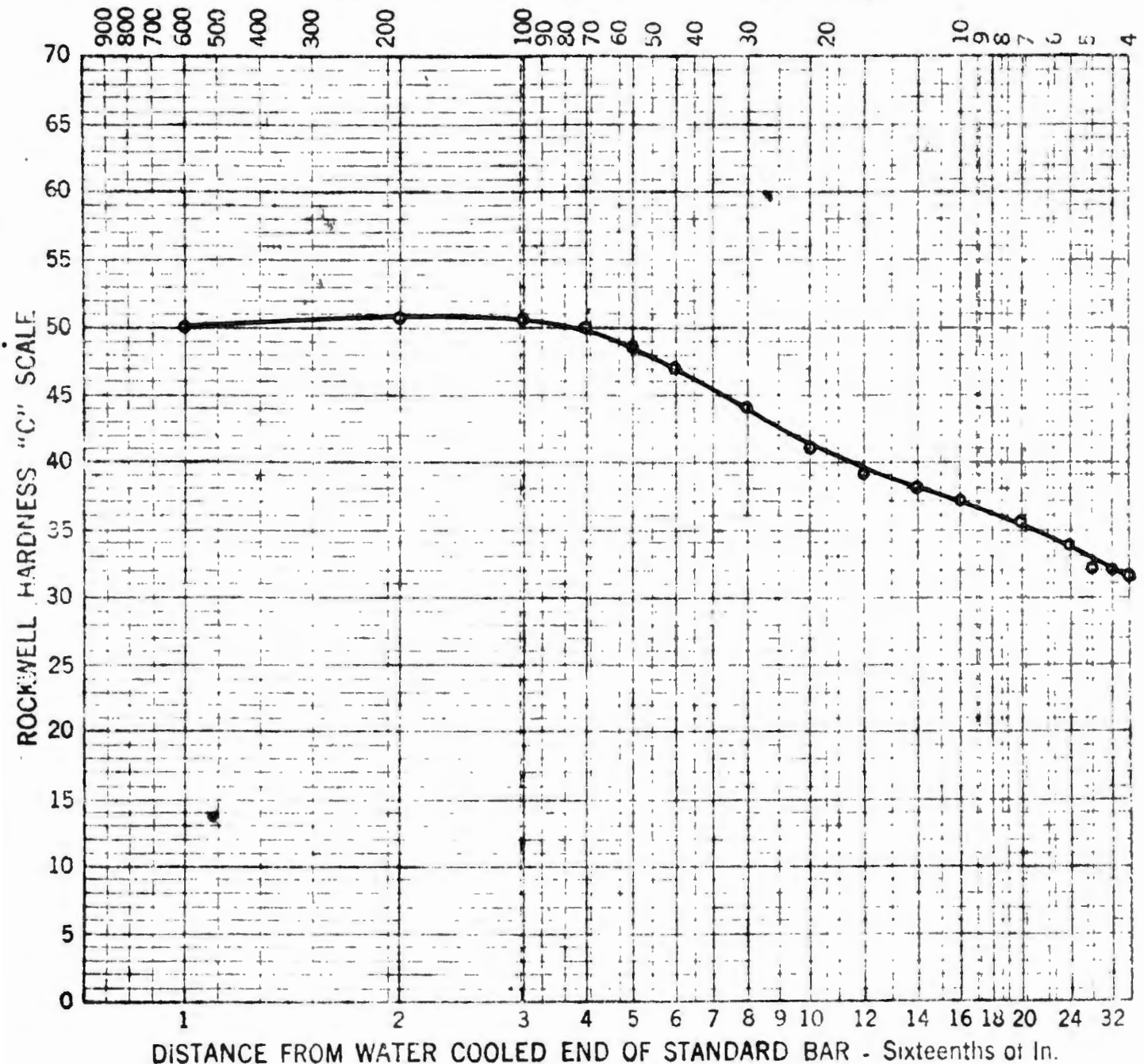
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29 WEST 39 ST., NEW YORK CITY

Test No.
Sheet No.
Date Aug. 14, 1942

COOLING RATE, deg. f. per second at 1300 deg.



DISTANCE FROM WATER COOLED END OF STANDARD BAR - Sixteenths of in.

Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH
Notes

Signed JEC

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Added	Quenching Temperature	Grain Size	Heat Number
	.30	1.60			.80			.46	1.5% Al 3% FeTi	1650°F		C-270

SAE HARDENABILITY CHARTS

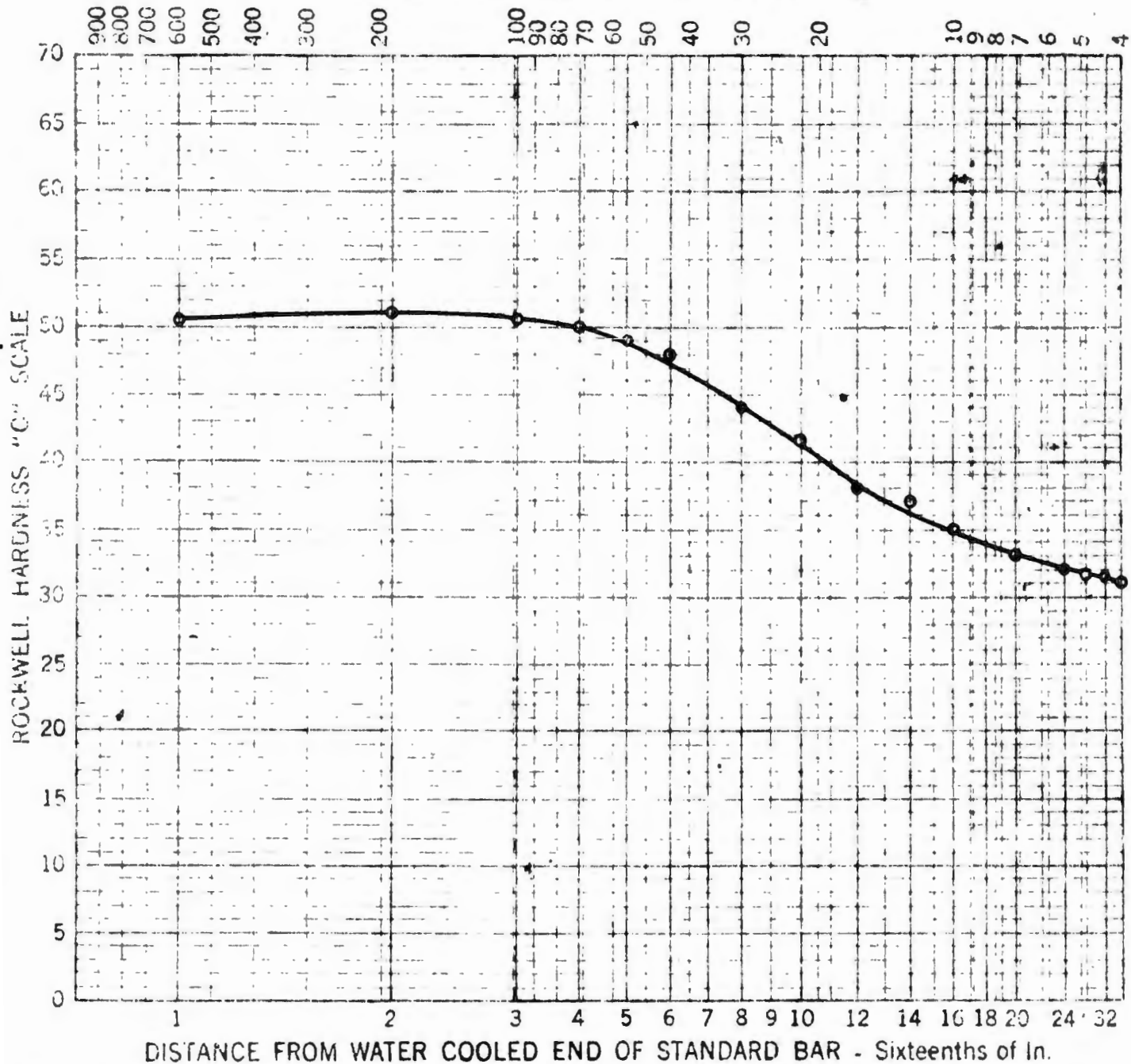
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COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH
Notes:

Signed J.E.C.

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Added	Quenching Temperature	Grain Size	Heat Number
	.31	1.46			.36		.33	.41	1.5% Al	1650°F.		C-271

SAE HARDENABILITY CHARTS

END-QUENCH TEST

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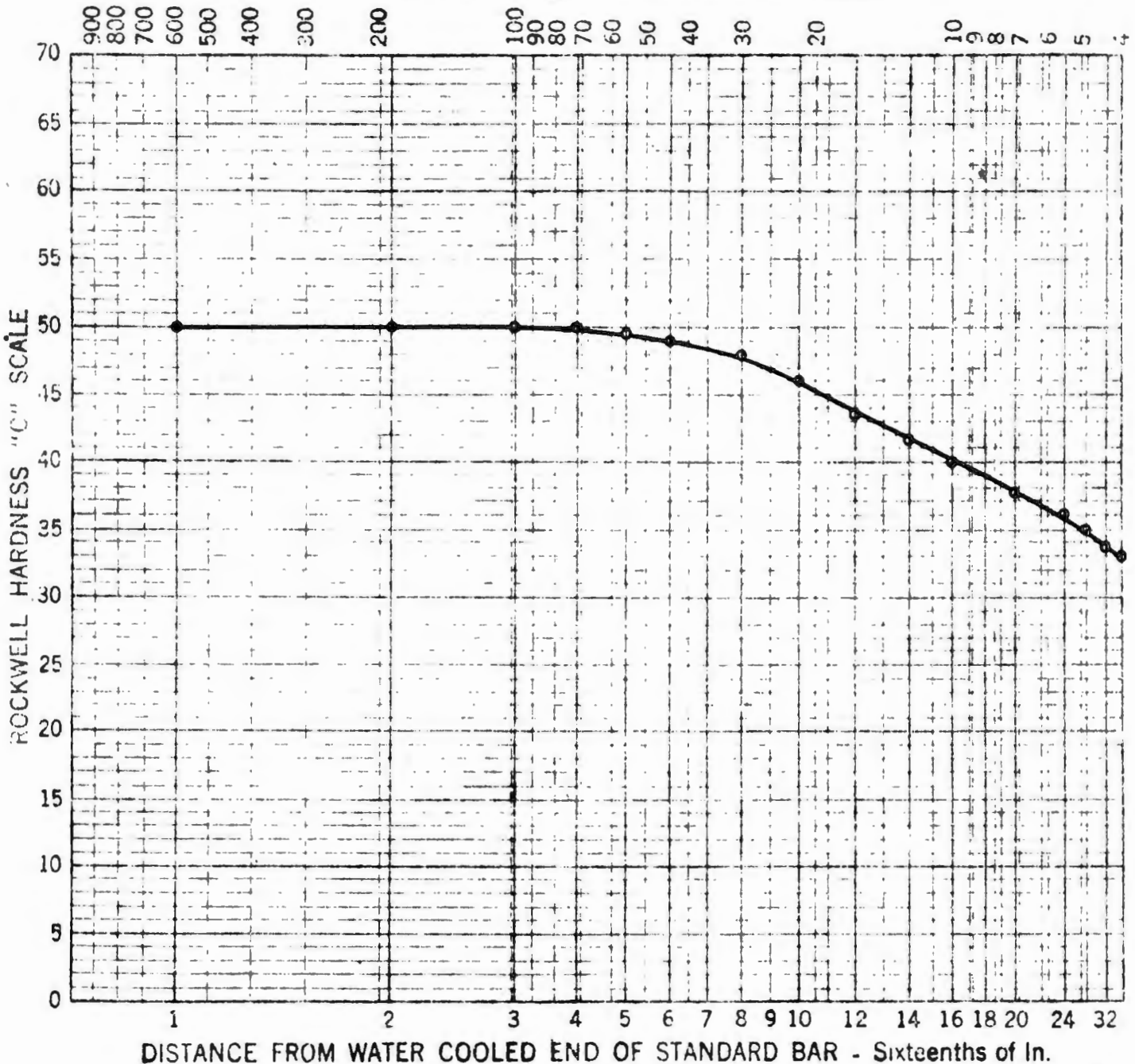
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29 WEST 39 ST, NEW YORK CITY

Test No.

Sheet No.

Date AUG. 15, 1942

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH
Notes

Signed J.E.C.

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
	.29	1.06			.50		.35	.39	1650°F		C-273
	ADDED 1.5% T. Al, .5% T. FeB										

SAE HARDENABILITY CHARTS

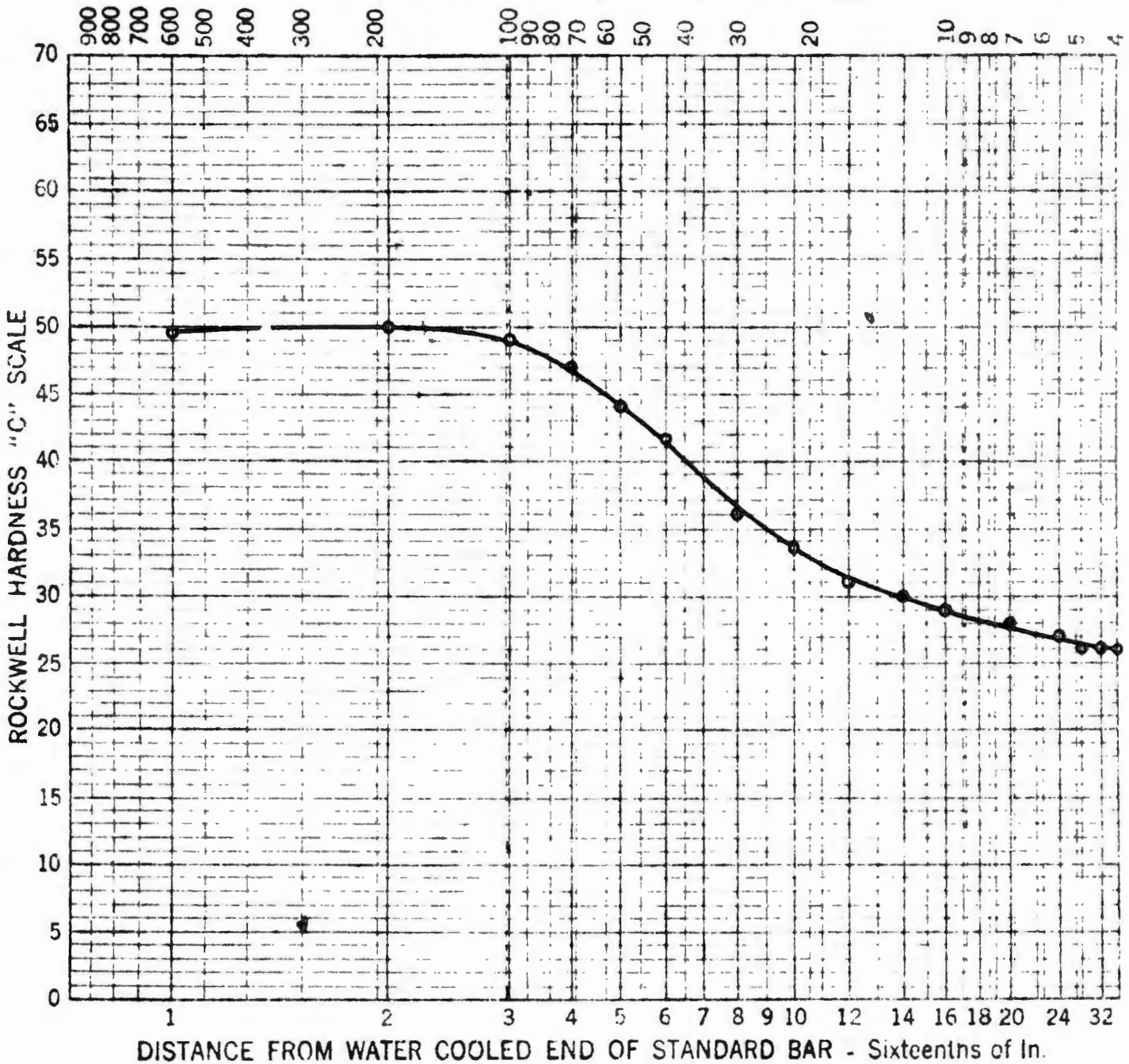
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29 WEST 39 ST., NEW YORK CITY

Test No.
Sheet No.
Date AUG. 14, 1942

COOLING RATE, deg. f. per second at 1300 deg.



DISTANCE FROM WATER COOLED END OF STANDARD BAR - Sixteenths of In.

Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH
Notes

Signed JEC

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
	.27	1.01			.80		.57	.30	1650°F		C-274
	ADDED 1/2% T. FeB, .14Zr										

SAE HARDENABILITY CHARTS

END-QUENCH TEST

Form 1

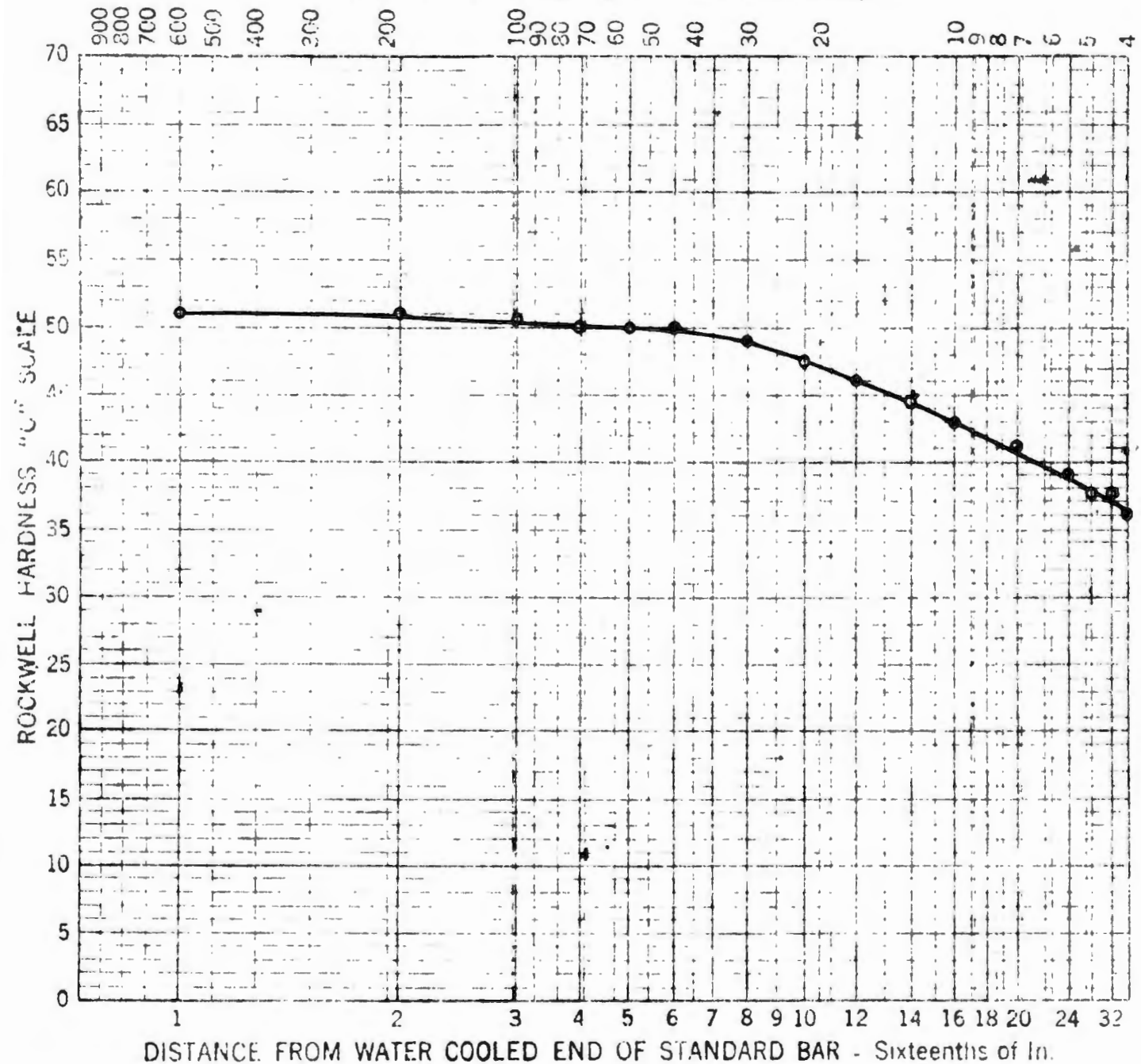
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29 WEST 39 ST., NEW YORK CITY

Test No.

Sheet No.

Date. AUG. 14, 1942

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel EXPERIMENTAL HEAT

Source. GENERAL MOTORS RESEARCH

Notes

Signed J.E.C.

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
	.28	1.45			.49		.56	.37	1650°F.		C-275
	ADDED 1.5%/T. Al, .5%/T. FeB										

SAE HARDENABILITY CHARTS

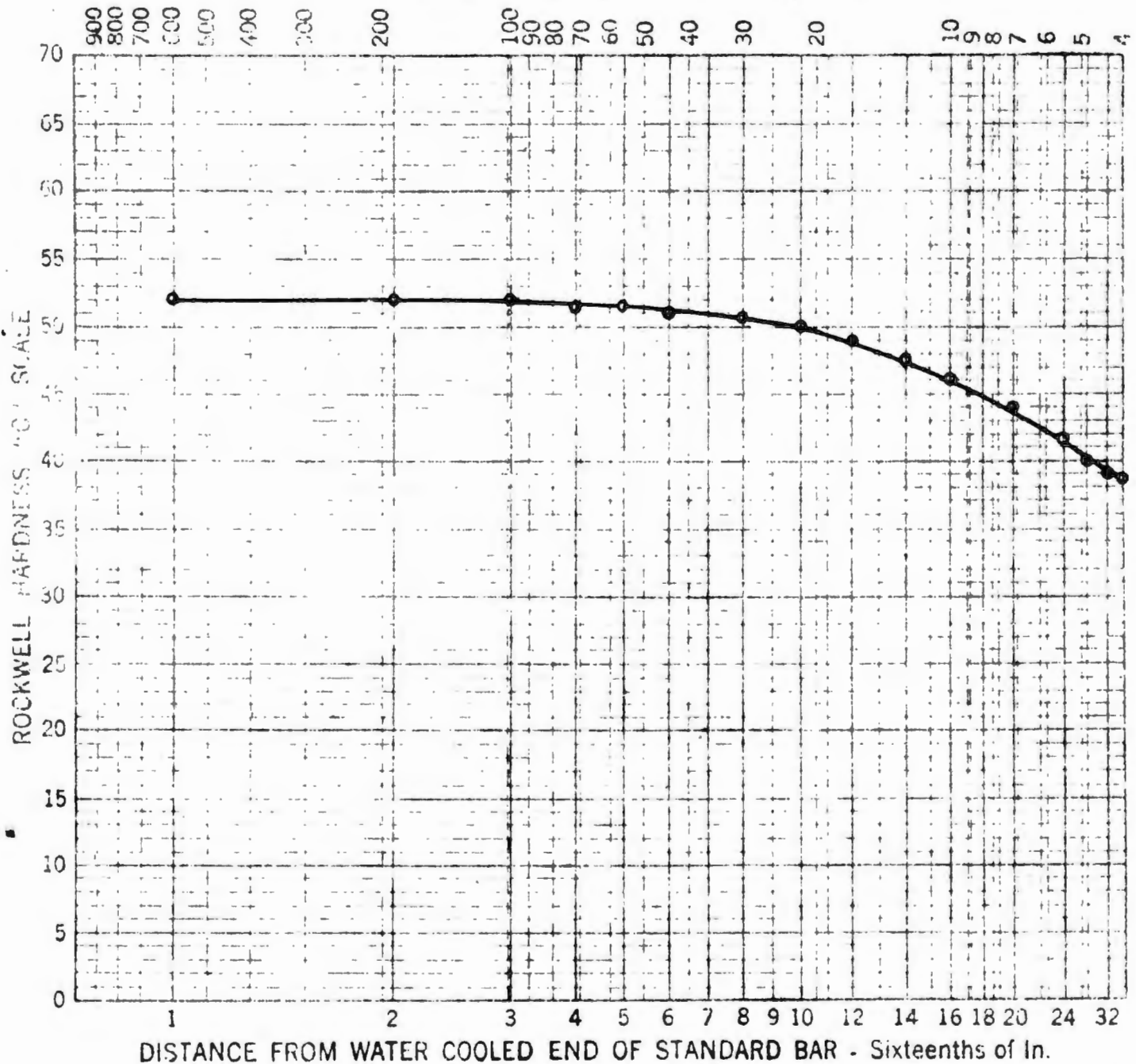
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29 WEST 39 ST., NEW YORK CITY

Test No.
Sheet No.
Date AUG. 14, 1942

COOLING RATE, deg. f. per second at 1300 deg.



Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH
Notes

Signed JEC

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
	.31	1.45			.49		.56	.35	1650°F.		C-276
	ADDED		1.5% T. Al								

SAE HARDENABILITY CHARTS

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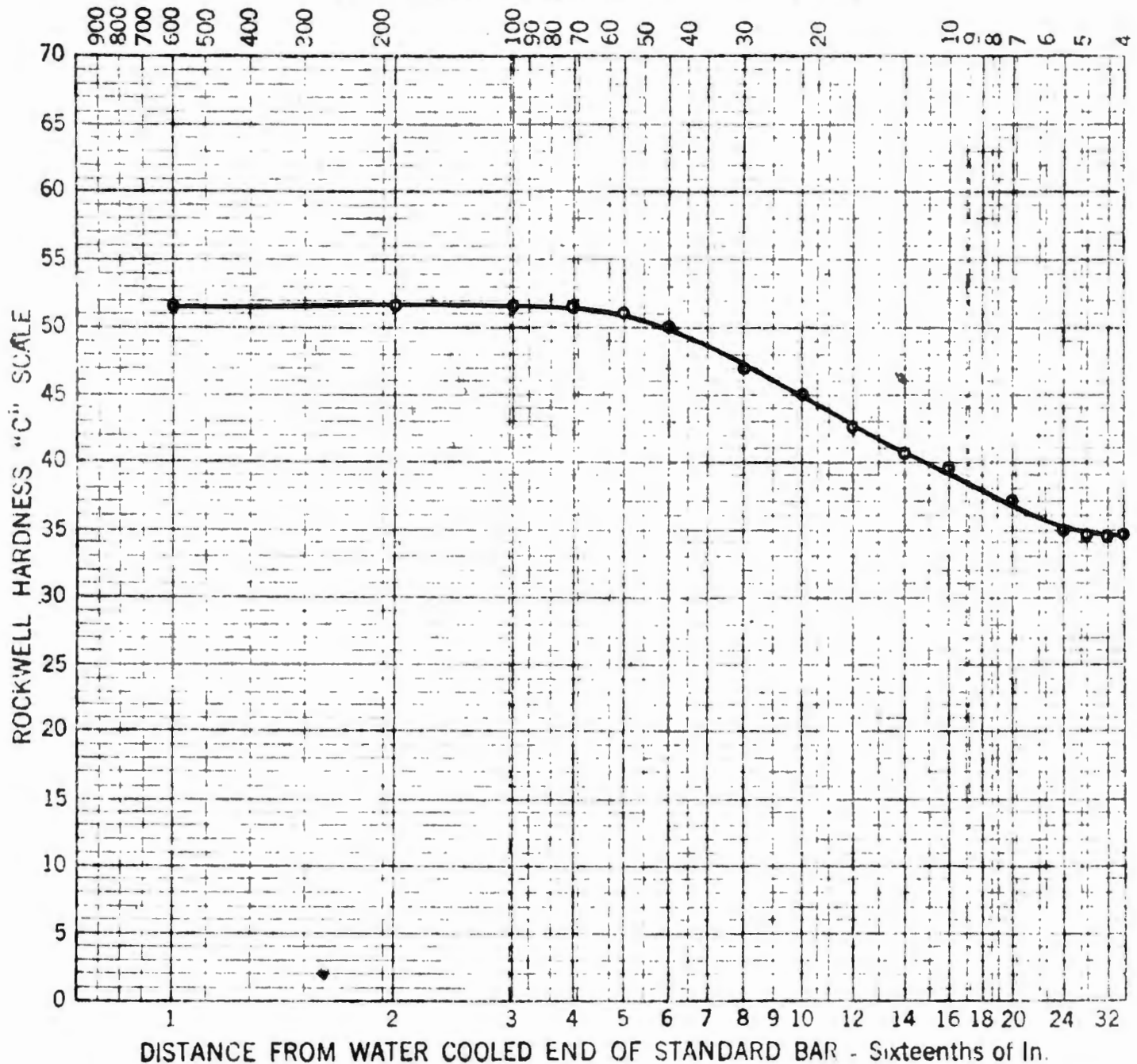
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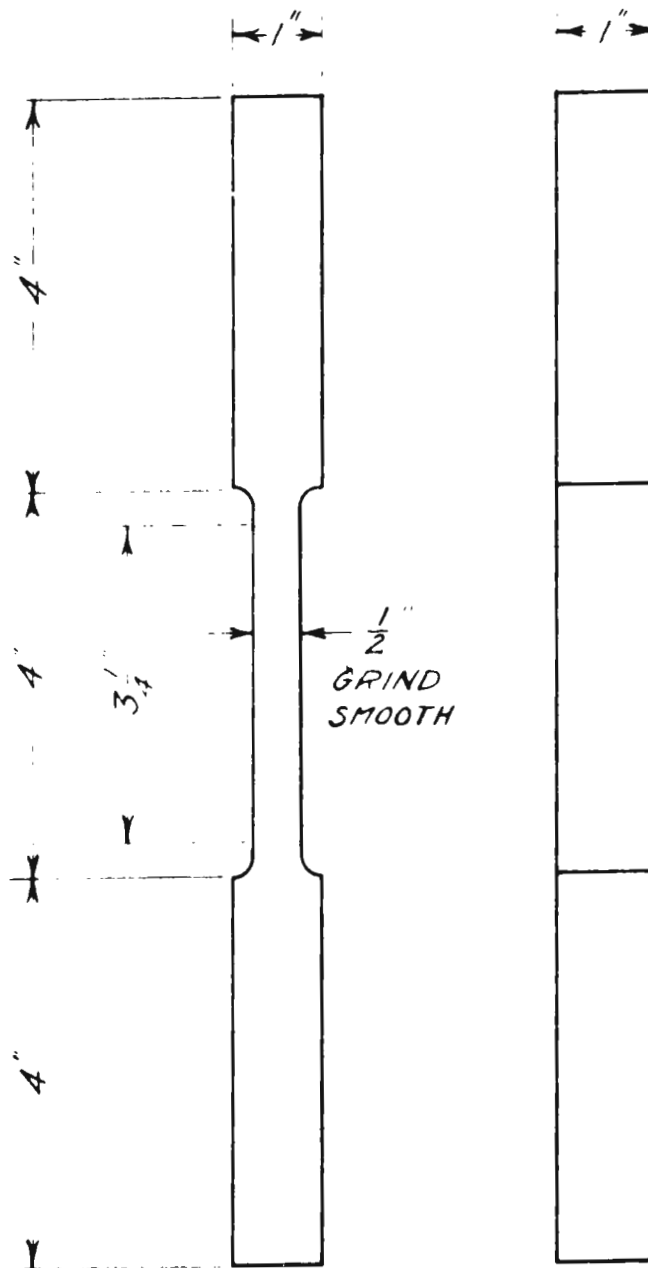


Type of Steel EXPERIMENTAL HEAT Source GENERAL MOTORS RESEARCH

Notes: Signed JEG

STEEL ANALYSES AND QUENCHES

Steel	C	Mn	P	S	Si	Ni	Cr	Mo	Quenching Temperature	Grain Size	Heat Number
	.29	1.44			1.02		.39	.34	1650°F.		C-277
	ADDED		1.5% T. Al								



$\frac{1}{2}$ SIZE

STANDARD ARMOR PLATE
TENSILE SPECIMEN