5 June 1941 NRL Report No. M-1747

NAVY DEPARTMENT

Report
on

Welding and Properties of Welded Tubing of the SAE x4130 Composition

FR-1747

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Number of Pages: Text - 2 Tables - 2 Plates - 3

Authorization: BuAero. Project Order No. 34/40 of 29 June 1939.

Date of Test: April 15, 1941 to June 1, 1941

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Distribution: BuAero (5)

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APPENDICES

AUTHORIZATION

1. This problem was authorized by Bureau of Aeronautics Project Order No. 34/40 of 29 June 1939. See also Bureau of Aeronautics letter Aero-E-257-HY-C-61544 of 18 September 1940.

OBJECT OF TEST

2. The prupost of the present report is to study the welding properties of steel tubing conforming to the SAE x 4130 composition and manufactured by the electric-resistance butt welding process.

3. The average chemical analysis of the tubing given by the manufacturer is:

Carbon	0.34 percent
Manganese	0.56
Phosphorus	0.018
Sulphur	0.017
Chromium	1.00
Molybdenum	0.22

DESCRIPTION OF MATERIAL UNDER TEST

4. Three sizes of chromium-molybdenum (SAE x 4130) steel tubing manufactured by the electric-resistance butt welding process were forwarded to this Laboratory by the National Bureau of Standards. The material was made by the Steel & Tubes Division of the Republic Steel Corporation. The nominal sizes of the tubing submitted were as follows:

3/4" O.D. x 0.035" wall thickness
1 inch O.D. x 0.035" wall thickness
1-1/2" O.D. x 0.058 wall thickness.

5. 1/16" diameter copper coated mild steel gas welding rod was used in making the welds.

METHODS OF TEST

6. All joints were made using manual oxy-acetylene welding with jigs for positioning the tubing. The torch was adusted to give a neutral flame. The welded joints were made using the tubing in the as-received condition (normalized 1650°F.)

7. The type of joint in all cases was a square butt weld. Tensile tests were made on full-size specimens of each size of tubing in the as-welded and normalized-after-welding condition. Vickers pyramidal diamond (10 kg load) and Rockweel-C hardness numbers were obtained from impressions made on the cross-sectional area of the tubing.

Weld joint hardness values (impressions spaced at 0.05 inch) in the as-welded and normalized conditions were obtained from longitudinal sections cut across the weld. Heat treating of the tubing and welded joints was done by heating for thirty minutes at 1650°F. in a controlled atmosphere electric furnace and cooling in still air.

DATA AND CONCLUSIONS

8. The results of the tensile tests and hardness tests are shown in Table 1; a summary of the welded joint data is given in Table 2.

9. In Plate 1 a reshown typical fractures occurring when the specimens were tested in the as-welded condition. It is to be noted that failure occurred in the tubing approximately 1/2 inch away from the weld bead. In plate 2 are shown typical fractures occurring when the specimens were normalized after welding. The change in type of failure is to be noted; failure occurred adjacent to the toe of the weld bead where the change in section thickness acts as a stress raiser.

10 The variations in hardness on a longitudinal section across the weld in the as-welded and normalized conditions are plotted in Plate 3. The drop in hardness at some distance from the weld in the as-welded condition is typical of the incipient spheroidized zone at the outer edge of the heat affected zone adjacent to a weld. The lower hardness of this portion indicates a lower strength. These statements are further substantiated by the fact that rupture of the as-welded tensile specimens occurred through this zone. The incipient spheroidized zone may be eliminated by re-heat treatment. A study of the hardness values on the specimen normalized after welding would predict the failure of the tensile specimens in or adjacent to the weld.

SUMMARY

11. With the welding technique used it was not possible to obtain as high values for rensile strength as were obtained on the tubing without a weld joint. The average value of the tensile strength, however, in spite of the stress raiser at the toe of the weld on the normalized specimens and the damage to the structure of the metal in the as-welded specimens, was well over 100,000 psi. The use of other welding techniques or other electrodes may increase the effeciency of the welding process.

12. In no case could the failure of a tensile specimen be attributed to the process of manufacture of the tubing. The flash on the inside surface of the tubing offered no difficulty in welding.

TABLE 1.

Results of Tensile and Hardness Tests on SAE x 4130 Welded Tubing.

Test No.	Condition	Strength		Elongation	Hardness	
		Ultimate psi	Yield psi (0.2% offset)	% in 2"	Vickers	Rockwell-C
0.750" O.D. x 0.035" wall						
1.	Tubing as Received	111,000	79,000	17.5	253	21
	NBS (Average)(Note 1)	111,600	79,500	18	(101-103 R_B)	
2.	Tubing as renormalized	107,800	74,400	21.5	250	22
3	A* - W* (Note 2)	103,000	82,900	5	-	-
4	A - W	100,100	75,000	5	-	-
	Average A - W	101,500	78,900	5	253	21
5	A - W - N* (Note 3)	108,200	77,600	11.5	258	22
6	A - W - N	105,800	75,400	-	251	21
7	A - W - N	101,200	71,400	-	-	-
	Average A-W-N	105,000	74,800	11.5	254	21
1.0" O.D. x 0.035" wall						
8	Tubing as received	114,200	80,000	-	252	23
	NBS (Average)	113,900	82,900	18	(99-103 R_B)	
9	Tubing as renormalized	111,100	82,600	20.5	250	22
10	A - W	102,600	84,400	6.5	-	-
11	A - W - N	109,500	77,600	5.0	266	26
12	A - W - N	111,900	80,300	7.5	266	23
13	A - W - N	105,400	83,100	5.0	262	25
	Average A-W-N	105,400	83,100	5.0	262	25
1.5" O.D. x 0.058" wall						
14	Tubing as received	125,500	90,700	20.5	246	25
	NBS average	129,100	91,100	21	(101-104 R_B)	
15	Tubing as renormalized	118.100	84,600	26	-	-
16	A - W	103,500	89,000	5	-	-
17	A - W - N (Note 4)	96,500	81,200	4	267	25
18	A - W - N	90,500	83,400	5	-	-
19	A - W - N	110,200	81,900	11	-	-
	Average A-W-N	99,000	82,100	7	267	25

Key:

*A - as received
N - normalized - 1650°F.
W - butt welded joint

Note 1. Values reported for comparison from National Bureau of Standards Report 83/TG4145.

Note 2. A-W specimens tested as welded. All fractures in tubing approximately 1/2" from weld. See plate.

Note 3. A-W-N specimens normalized after welding. Fracture usually at toe of weld.

Note 4. Specimens numbers 17 and 18 failed in weld, with incomplete penetration.

TABLE 2.

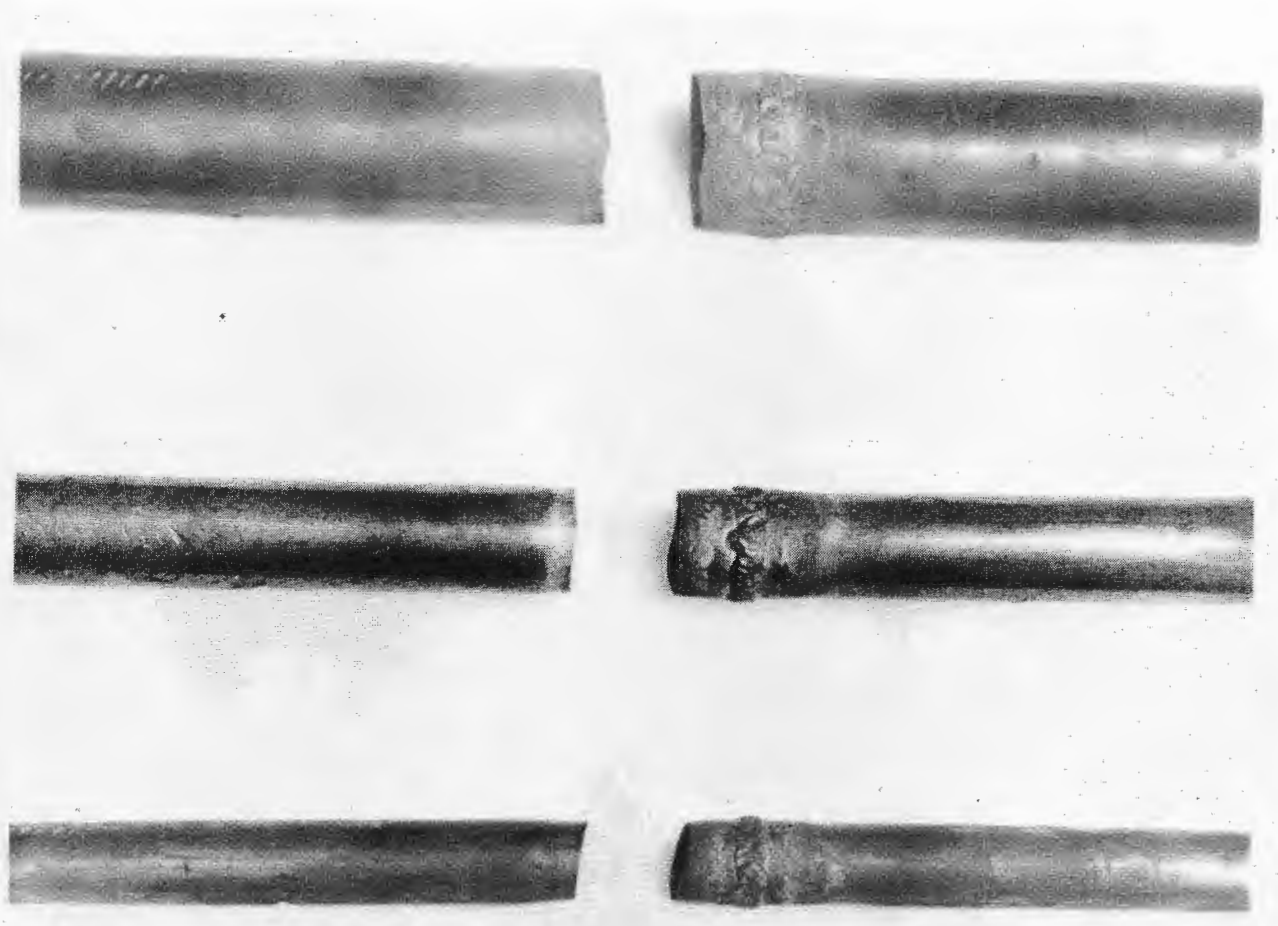
Summary of Tensile and Hardness Tests on SAE X 4130 Welded Tubing.

Average of all specimens tested as welded (all sizes):

Ultimate strength	102,000 psi	
Yield strength	82,800 psi	
Elongation	5.3%	
	Minimum	Maximum
Weld joint hardness, Vickers - (See Plate 3)	181	287

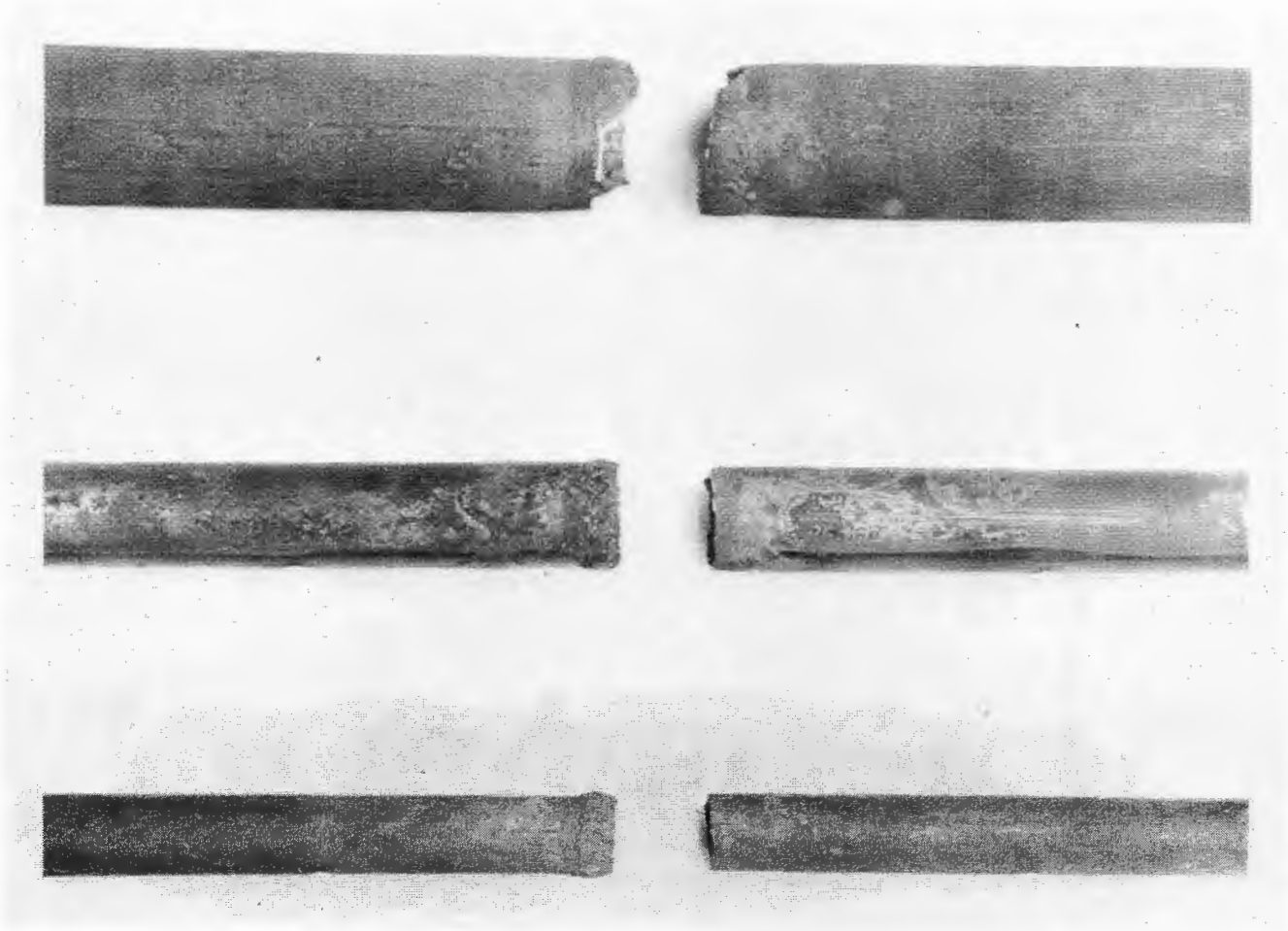
Average of all specimens tested re-normalized from 1650°F. after welding (all sizes):

Ultimate strength	104,400 psi	
Yield strength	79,100 psi	
Elongation	7.0%	
Hardness, Vickers, 10 kg	261	
	Minimum	Maximum
Weld joint hardness, Vickers, 10 kg (See Plate 3)	124	278



Typical Fractures Occurring when the Specimens were tested in as-welded condition.

PLATE I



Typical Fractures Occurring when the Specimens were tested as normalized after welding.

PLATE 2

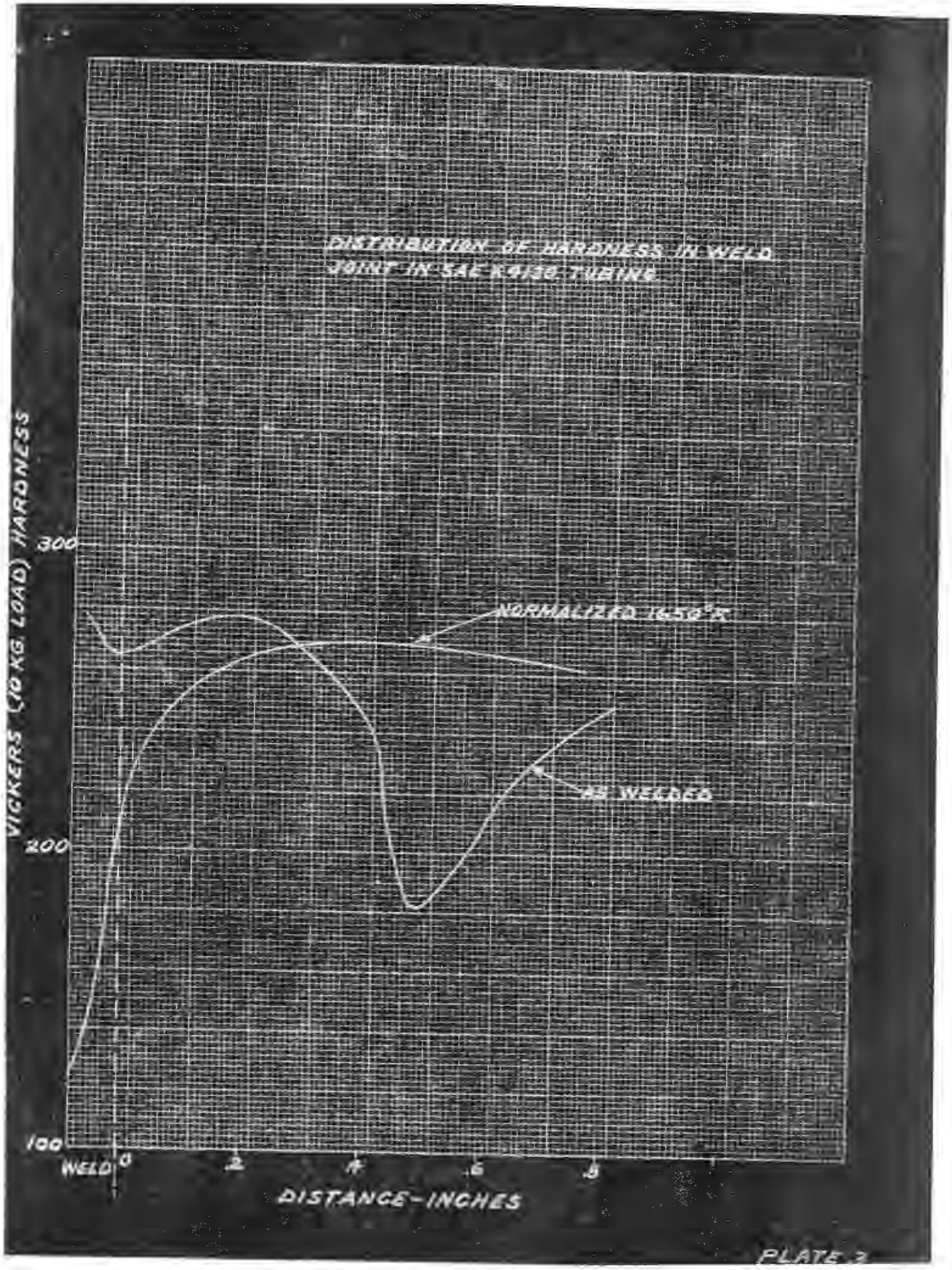

DISTRIBUTION OF HARDNESS IN WELD JOINT IN S.A.E. K4130 TUBING
VICKERS (10 KG. LOAD) HARDNESS
300
200
100
NORMALIZED 1650°F.
AS WELDED
WELD
0
.2
.4
.6
.8
DISTANCE - INCHES

PLATE 2