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WAL 6/29/84



Memorandum Report No. 642/8

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WELDING LABORATORY
WATERTOWN ARSENAL

WELDABILITY OF ARMOR PLATE

(1st Called Homogeneous)

0.4% Carbon, Chromo-Niob-Titanium

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William L. Warner
Welding Engineer

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July 16, 1941

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**WELDING LABORATORY
WATERTOWN ARSENAL**

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Memorandum Report No. 642/8
Watertown Arsenal

July 16, 1941

WELDABILITY OF ARMOR PLATE

(1" Rolled Homogeneous)

0.50% Carbon, Chrome-Moly-Vanadium

Object

The tests described in this report include the deposition of single weld beads on the surface of the test plates together with hardness and macroexamination of certain cross sections of these weld beads.

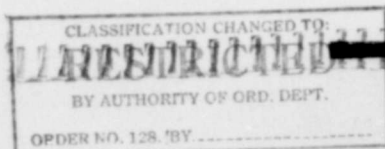
The tests were made to determine:

a. The difference in heat effect produced in the armor adjacent to the weld bead by the use of covered low carbon and austenitic stainless steel (25/20) electrodes under similar welding conditions.

b. Any difference in heat effect produced in welding annealed plate and heat treated plate without preheating.

c. The effect of low temperature (400°F) preheating of the plate, prior to welding, on the heat-affected zone of the weld bead.

d. The effect of the regular armor plate heat treatment (quench and draw) on the weld metal and heat-affected zone of the weld bead.



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Conclusions

The following conclusions are suggested by the results of the tests (see Fig. #1-4), and are considered to apply only to the high carbon homogeneous armor plate.

1. The maximum hardness produced in the heat-affected zone of the single weld bead is the same for both the covered low carbon electrode and the austenitic 25/20 stainless electrode on either the annealed or tempered armor plate. This maximum hardness is also the same for both the annealed and tempered plate when no preheating is used.

2. Cracks are produced in the heat-affected zone by the covered low carbon electrode without preheating; whereas, no cracks are produced by the austenitic stainless 25/20 electrode. These cracks occur under the weld bead and do not extend to the surface of the plate. They are considerably more extensive in the tempered plate than in the annealed plate.

3. The average depth of penetration of heat effect of the covered low carbon electrode into the armor plate is about 20% greater than that of the austenitic stainless 25/20 electrode.

4. When a 400°F preheat is used, the depth of penetration of heat effect of either electrode is increased about 25%, the maximum hardness of the heat-affected

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zone is reduced about 8%, and there are no cracks formed in the heat-affected zone.

5. The armor plate heat treatment of quench and draw (1600°F. oil quench and 1200°F. air cool) removes all trace of the heat-affected zone caused by the deposition of the weld bead, (Fig. #1 and #4).

6. The weld metal deposited by the covered low carbon electrode is approximately 40% higher in hardness than the weld metal deposited by the austenitic 25/20 stainless electrode in the "as welded" state. With the 400°F preheat this ratio may be slightly reduced. The armor plate heat treatment of quench and draw reduces the hardness of the two weld metals to approximately equal values.

7. Stress relieving at 400°F for 12 hours after welding shows no appreciable reduction in the maximum hardness of the heat-affected zone or the weld metal.

Discussion

The plate metal used was 1" thick, and of the following approximate compositions:

Carbon	0.490	Sulphur	0.019
Manganese	0.560	Chromium	1.22
Silicon	0.230	Molybdenum	0.60
Phosphorus	0.019	Vanadium	0.20

The pieces of plate used were 6" x 3" x 1", and a single weld bead approximately 3" long was laid longitudinally in the middle of the 6" x 3" plate with an



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automatic welding machine using a 3/16" diameter electrode with 200 amperes and an arc travel speed of 5" per minute. This is the standard procedure followed for the single bead weldability test at Watertown Arsenal.

The weld bead sections shown in Figures #1 to #4 are Section C taken about 1" from the start of the bead.

The following 6" x 3" x 1" plate specimens were welded:

<u>Spec. No.</u>	<u>Armor Plate</u>	<u>Electrode</u>	<u>Preheat</u>
AR-1	Annealed	Cov. Low Car.	None
AR-2	"	25/20	"
AR-3	Tempered	Cov. Low Car.	"
AR-4	"	25/20	"
AR-5	"	Cov. Low Car.	400°F
AR-6	"	25/20	"

After examining Section C from each of these weld specimens in the "as welded" condition, the following treatment was given to Section C in each case. AR-1 and AR-2 were oil quenched from 1600°F and drawn at 1200°F. AR-3, AR-4, AR-5 and AR-6 were stress relieved at 400°F for 12 hours.

The following maximum hardnesses were found in the heat-affected zones of the specimens examined (Section C in all cases:

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<u>Armor</u>	<u>Electrode</u>	<u>Preheat</u>	<u>Heat Treatment</u>	<u>Vickers Brinell</u>
<u>(Examined in the "as welded" condition)</u>				
Annealed	Cov. Low Car.	None	None	470 crack
"	25/20	"	"	470
Tempered	Cov. Low Car.	"	"	460 crack
"	25/20	"	"	480
"	Cov. Low Car.	400°F	"	430
"	25/20	"	"	440

(Examined after Heat Treatment specified)

Annealed	Cov. Low Car.	None	(Quench and (draw after (welding	340 crack
"	25/20	"	"	330
Tempered	Cov. Low Car.	"	(Stress Re- (lief 400°F (after welding	460 crack
"	25/20	"	"	470
"	Cov. Low Car.	400°F	(Stress Re- (lief 400°F (after welding	435
"	25/20	"	"	450

All hardness values given in this report are Vickers Brinell.

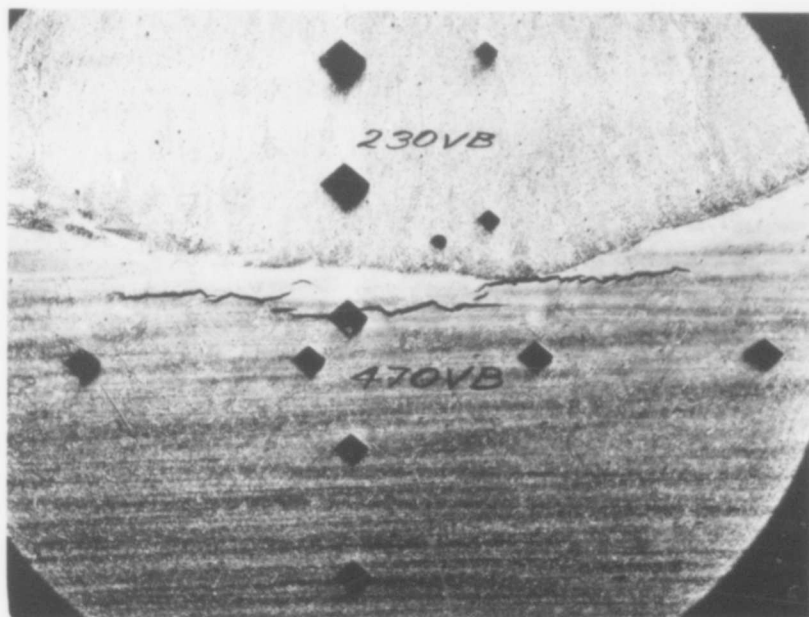
Respectfully submitted,

William L. Warner
Welding Engineer

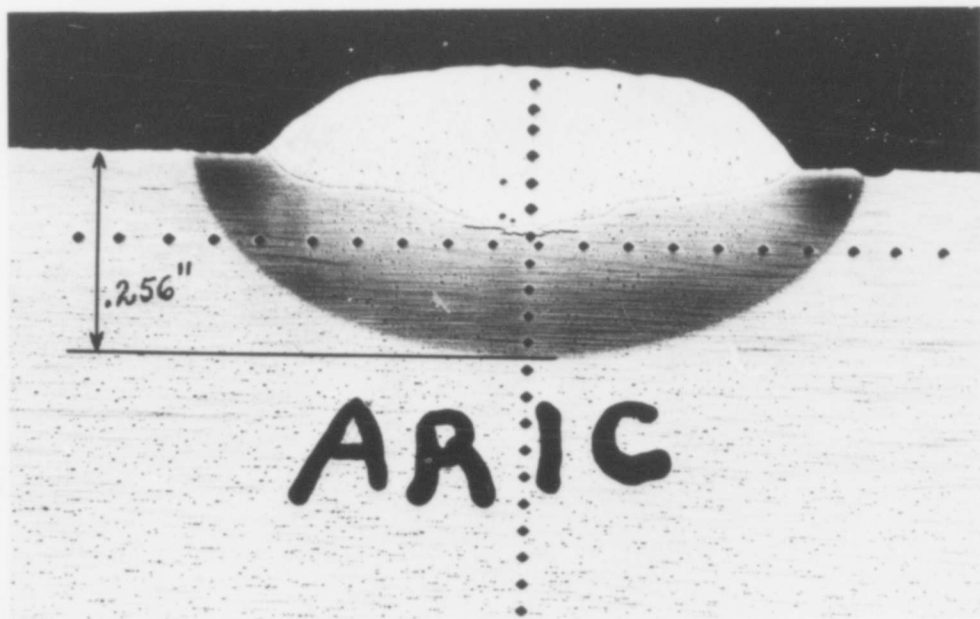
APPROVED:

S. B. Ritchie
Lt. Colonel, Ord. Dept.
Director of Laboratory

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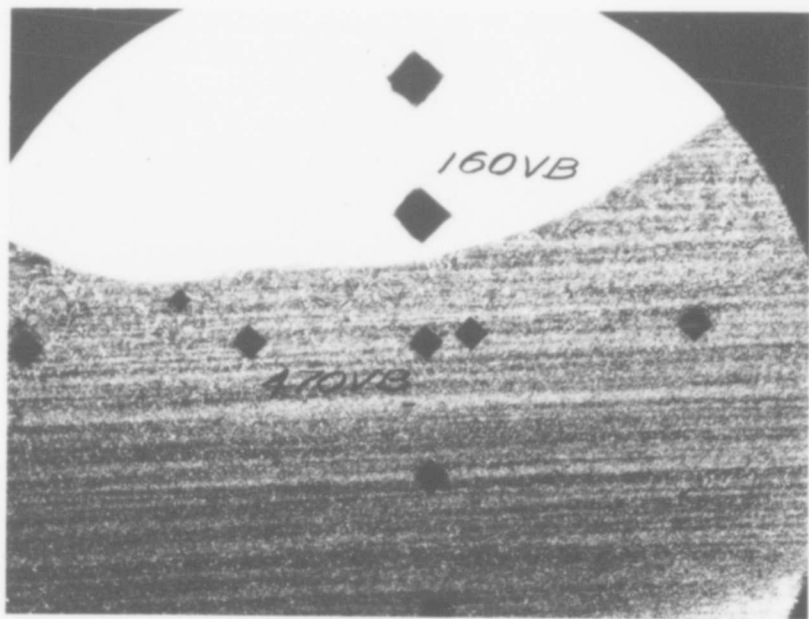
X25



X5

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FIG. 1A
ANNEALED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED.
NO PREHEAT, COVERED LOW CARBON ELECTRODE.
JULY 17, 1941 W.A. 639-3330



X25

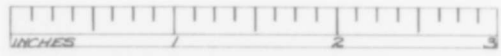
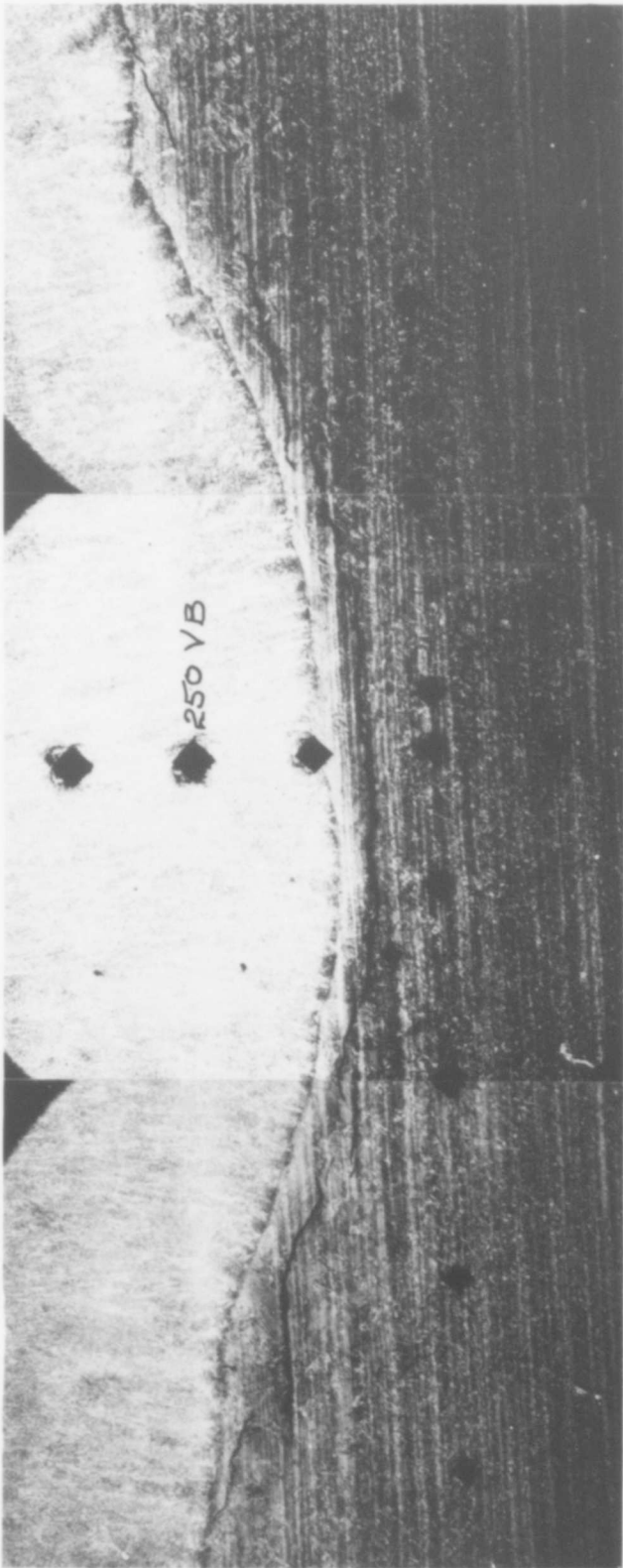


AR2C

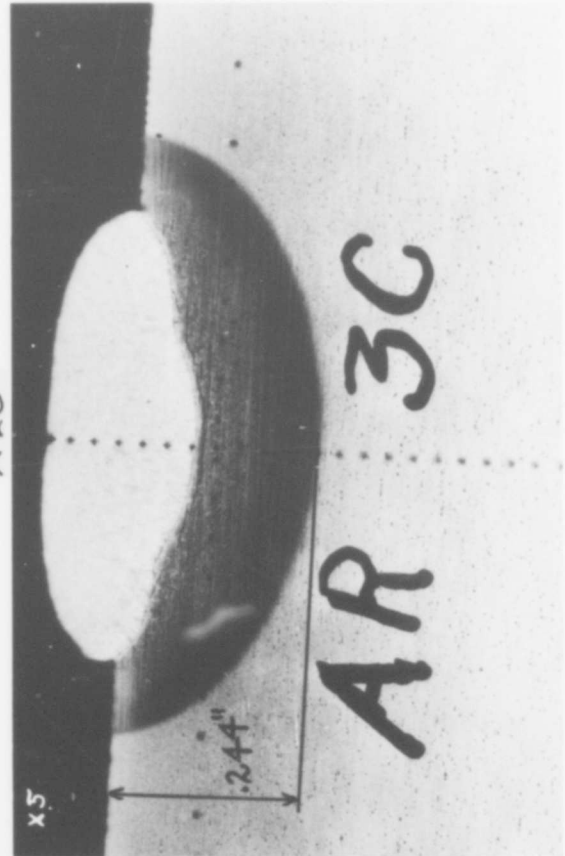
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WATERTOWN ARSENAL

FIG. 1B
ANNEALED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED.
NO PREHEAT. STAINLESS 25/20 ELECTRODE.
JULY 17, 1941 W.A.639-3331



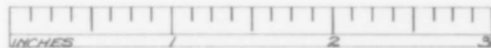
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WATERTOWN ARSENAL



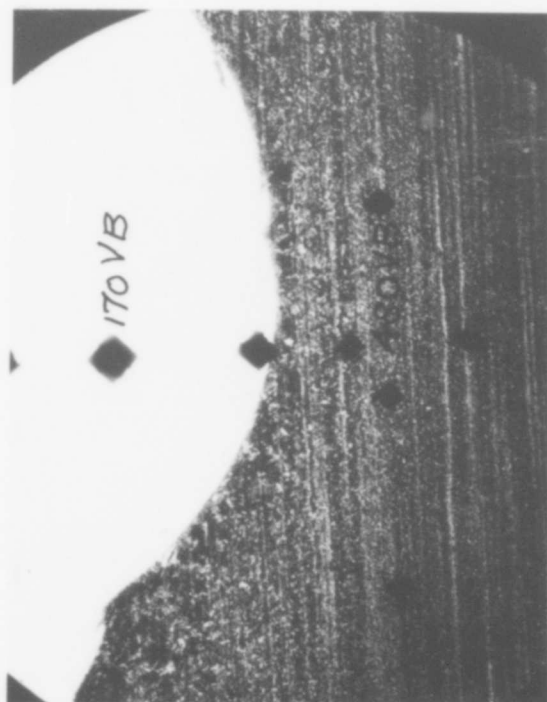
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FIG. 2A

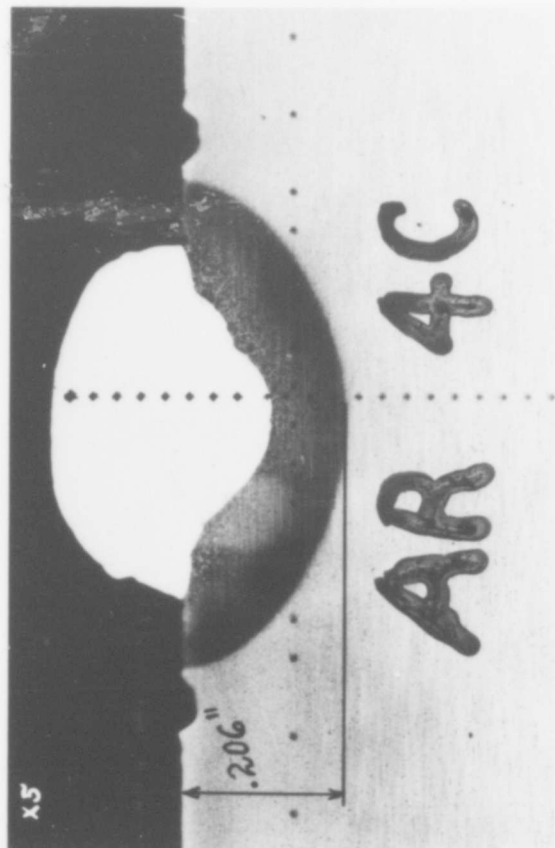
HEAT TREATED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED.
NO PREHEAT.
COVERED LOW CARBON ELECTRODE
JULY 17, 1941 W.A. 639-3332



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WATERTOWN ARSENAL.



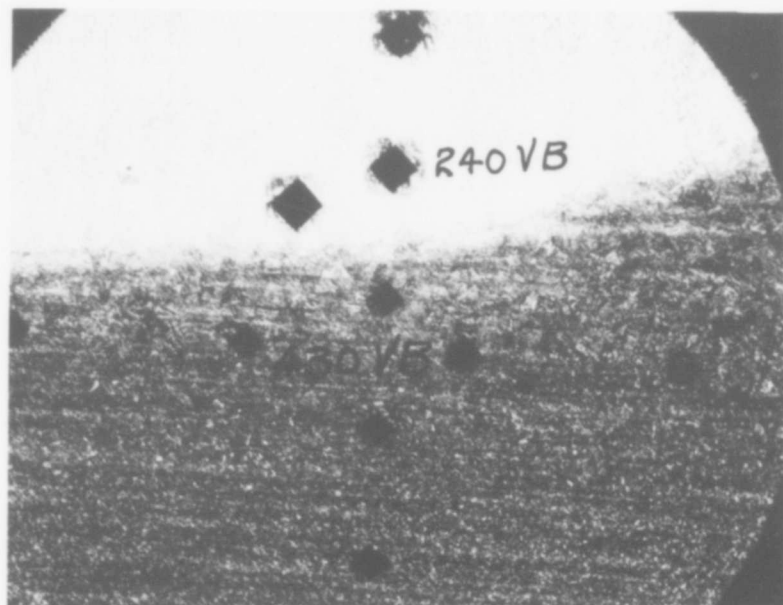
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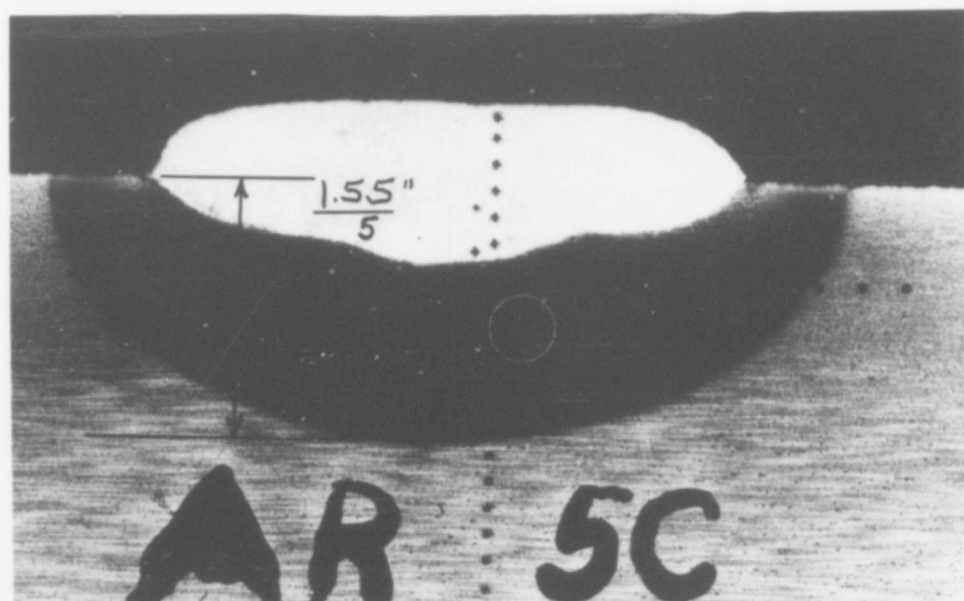
WATERTOWN ARSENAL

FIG. 2B

HEAT TREATED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED.
NO PREHEAT. STAINLESS 25/20 ELECTRODE.
JULY 17, 1941 W.A.639-3333



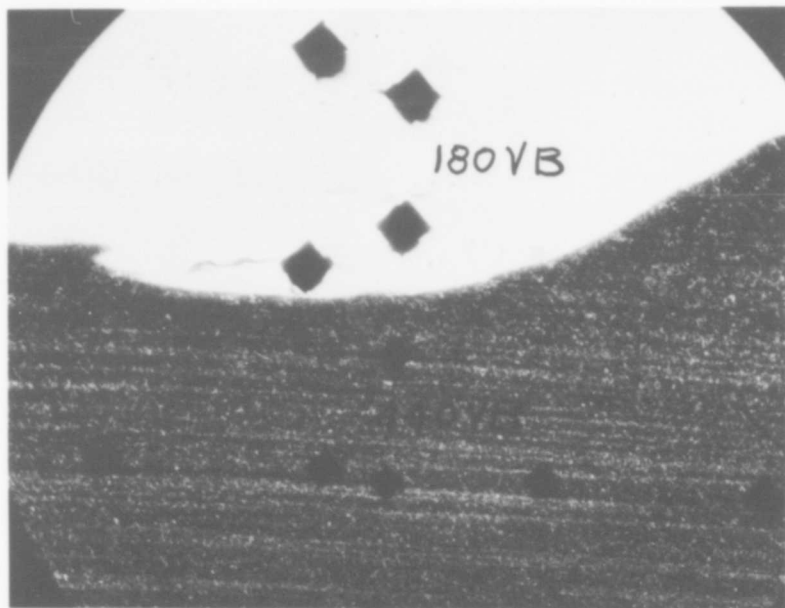
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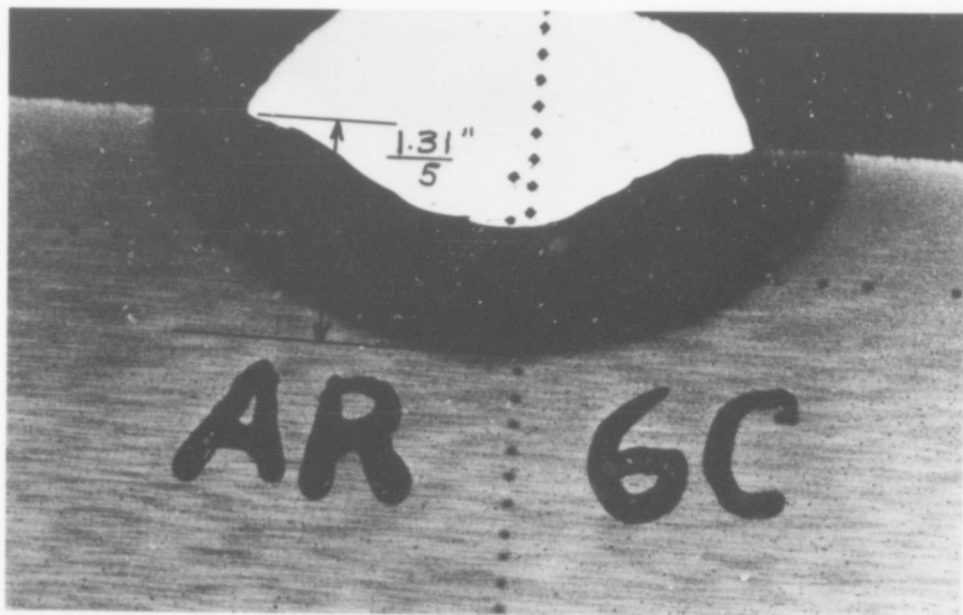
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FIG. 3A
HEAT TREATED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED,
400°F PREHEAT. COVERED LOW CARBON ELECTRODE,
JULY 17, 1941 W.A. 639-3334



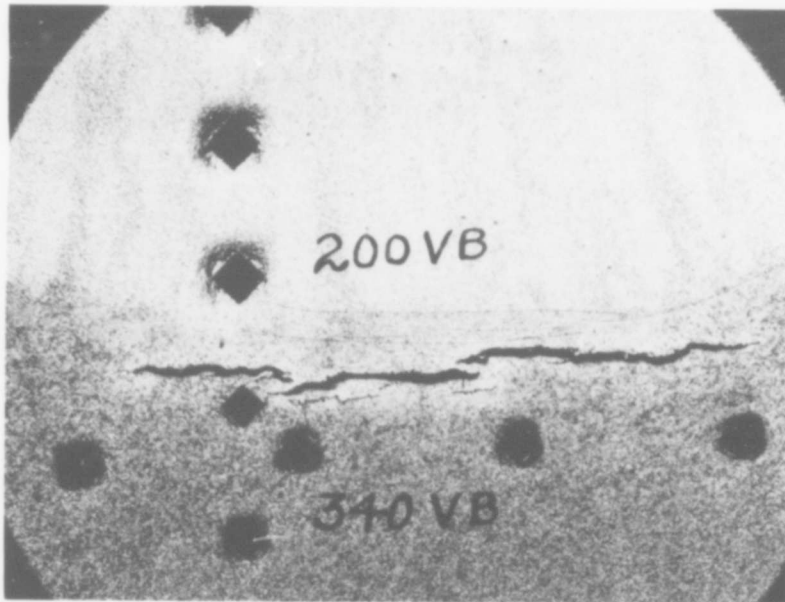
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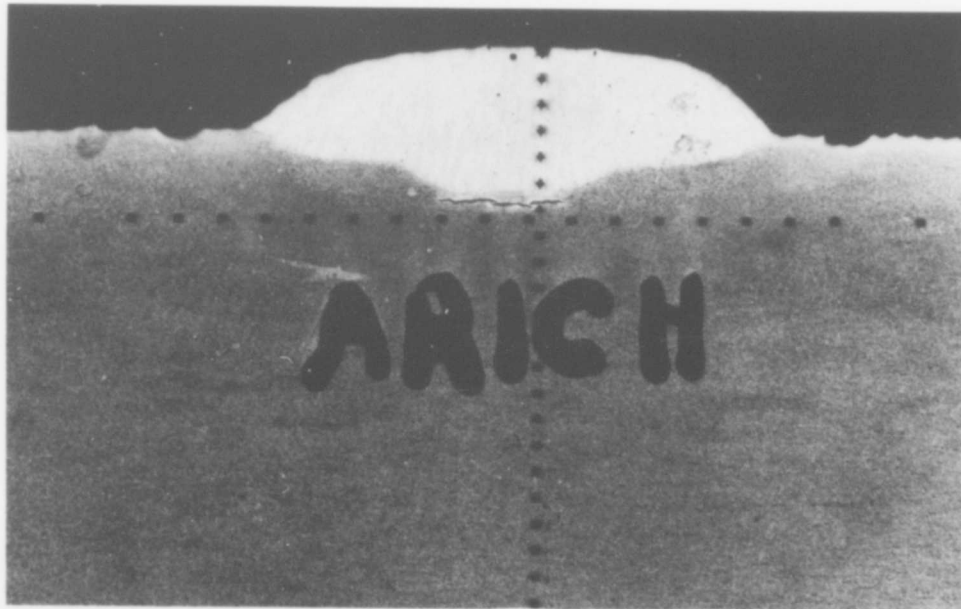
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WATERTOWN ARSENAL

FIG. 3B
HEAT TREATED 1" HOMOGENEOUS ROLLED ARMOR, AS WELDED,
400°F PREHEAT, STAINLESS 25/20 ELECTRODE,
JULY 17, 1941 W.A.639-3335



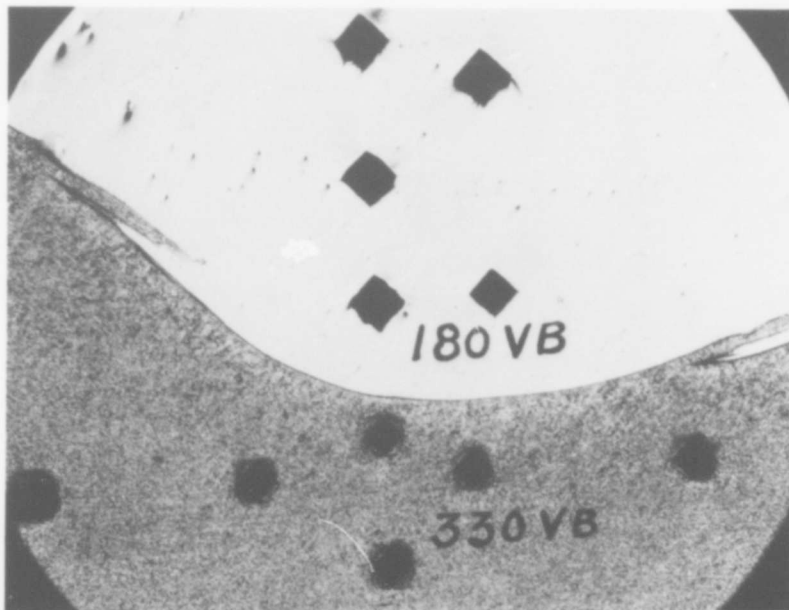
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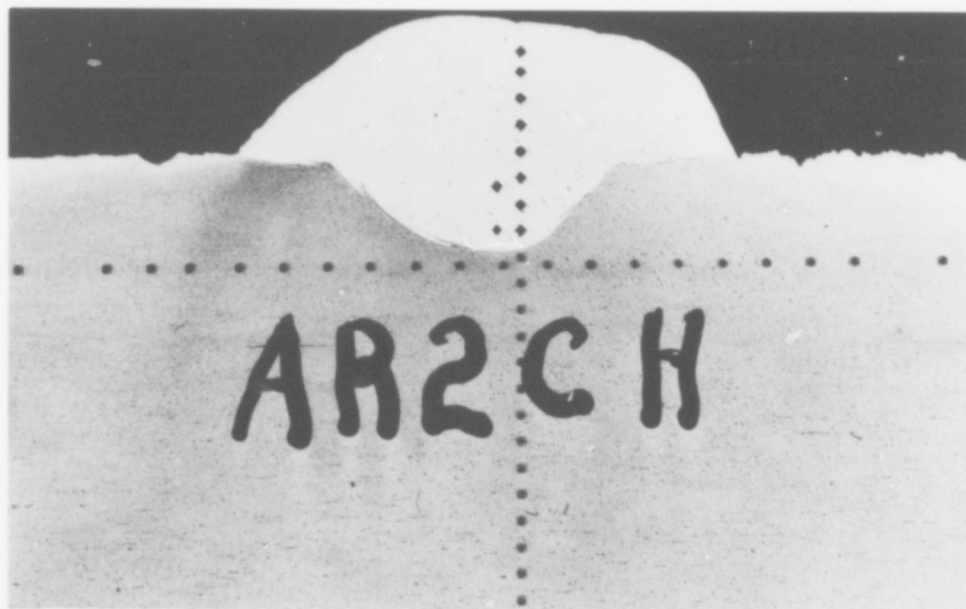
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FIG. 4A
1" HOMOGENEOUS RODLED ARMOR, WELDED, ANNEALED AND NO
PREHEAT. HEAT TREATED AFTER WELDING. COVERED LOW
CARBON ELECTRODE. JULY 17, 1941 W.A. 639-3336



X25



X5

WATERTOWN ARSENAL

FIG. 4B

1" HOMOGENEOUS ROLLED ARMOR, WELDED, ANNEALED AND NO PREHEAT. HEAT TREATED AFTER WELDING. STAINLESS 25/20 ELECTRODE. JULY 17, 1941 W.A.639-3337