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C to U: 30 Nov 1965, DoDD 5200.10, gp-4.
E/4 to A/1: 27 Jun 1984, per document marking.

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INVENTORY

WAL-642/18

DOCUMENT IDENTIFICATION

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Report No. 642/18
Watertown Arsenal

August 19, 1942

ARC WELDING OF ARMOR

Welded Y Plate of Two-Inch Thick

Rolled Homogeneous Armor

OBJECT

To make a complete metallurgical examination of a 2" thick Y plate submitted by the Lincoln Electric Company and tested ballistically at Aberdeen Proving Ground.

REFERENCES

Letter File OO 470.5/7015, APG 470.5/2089
APG 470.5/2089-1, WA 470.5/3972

This basic correspondence is included in Appendix A.
Ballistic results will be found in Aberdeen Proving Ground firing record P2261, A1877 dated 11/21/41.

CONCLUSIONS

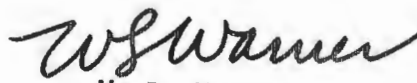
1. The plate passed ballistic test, but the joint was not entirely satisfactory as a large crack developed in the weld metal under ballistic shock.
2. The following defects were found which would materially lower the resistance to shock: (1) incomplete penetration of weld

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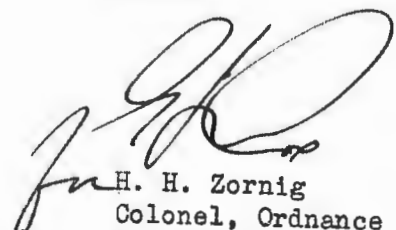
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metal between armor plate and low carbon steel strip used at root of joint; (2) small crater cracks, slag inclusions, and areas of carbide precipitation in vicinity of same steel strip.



W. L. Warner
Welding Engineer

APPROVED:



H. H. Zornig
Colonel, Ordnance Dept.
Director of Laboratory

8/31/62

INTRODUCTION AND TEST PROCEDURE

A welded Y plate 36" x 36" x 2" of homogeneous armor rolled by Carnegie Illinois Steel Corporation was received for physical and metallurgical examination. The joint was designed, welded, and submitted to Aberdeen Proving Ground for ballistic test by the Lincoln Electric Company as part of the program for the development of arc welding of armor.

The joint forming the weld was 45° double V. A low carbon steel strip was tack welded in the root for closure and a modified 18/8 stainless electrode (Lincoln Armorweld) was used in welding the joint.

Specimens for physical and metallurgical examination were taken as indicated in Figure 1 and the accompanying table. The area from which specimens were taken was not affected by the ballistic test as far as could be determined by visual examination.

DATA AND DISCUSSION

1. Visual Inspection

Figures 1 and 2 are photographs of front and rear of plate. Cracks opened up by ballistic shock are shown.

2. Nondestructive and Inspection Tests

Radiographic examination of the weld before ballistic test disclosed a lack of penetration of weld metal, between the armor plate and low carbon steel strip used at root of joint, and crater cracks in the weld metal.

3. Chemical Analysis

Results of chemical analysis were as follows:

	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>P</u>	<u>S</u>	<u>Ni</u>	<u>Cr</u>	<u>Cu</u>	<u>V</u>	<u>Mo</u>
Weld Metal	0.14	3.75	0.34	0.007	0.014	8.45	15.59	0.08	Trace	Nil
Armor Plate	0.30	0.25	----	0.025	0.025	3.11	1.25	----	-----	---

4. Macroexamination

A cross section of the weld, as prepared for macroexamination, is shown in Figure 3. Incomplete penetration of the weld metal and small weld metal cracks are evident.

5. Hardness Survey

Results of Vickers Brinell hardness survey taken across section prepared for macroexamination are shown in Figure 4. Representative hardness readings were as follows:

	<u>Base Metal</u>	<u>Heat-affected Zone</u>	<u>Weld Metal</u>
Front	302	514	278
Rear	307	421	240

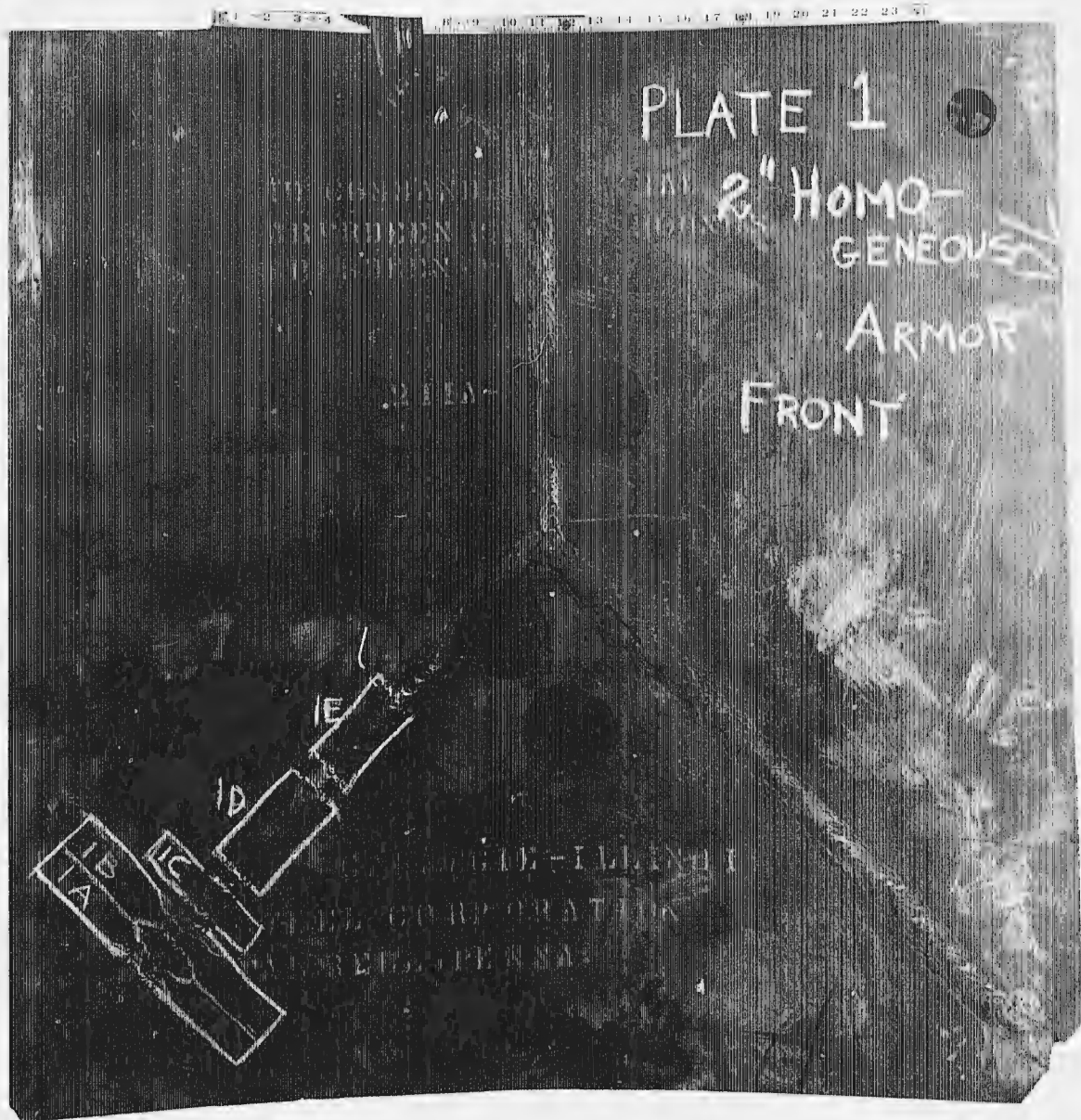
6. Tensile Tests

A standard .505" diameter tensile bar was taken longitudinally in the weld metal and two (2) flat tensile bars were taken across the joint. Figure 5 is a sketch of flat tensile bars. Results of tests were as follows:

FIGURE 1

Front view of Y joint in 2" rolled
homogeneous armor plate after ballistic test.
Specimens were marked out for the following
purposes:

- 1A for tension test of welded joint
- 1B " " " " " "
- 1C " macro, micro, and hardness survey
- 1D " tension test of weld metal
- 1E " chemical analysis of weld metal



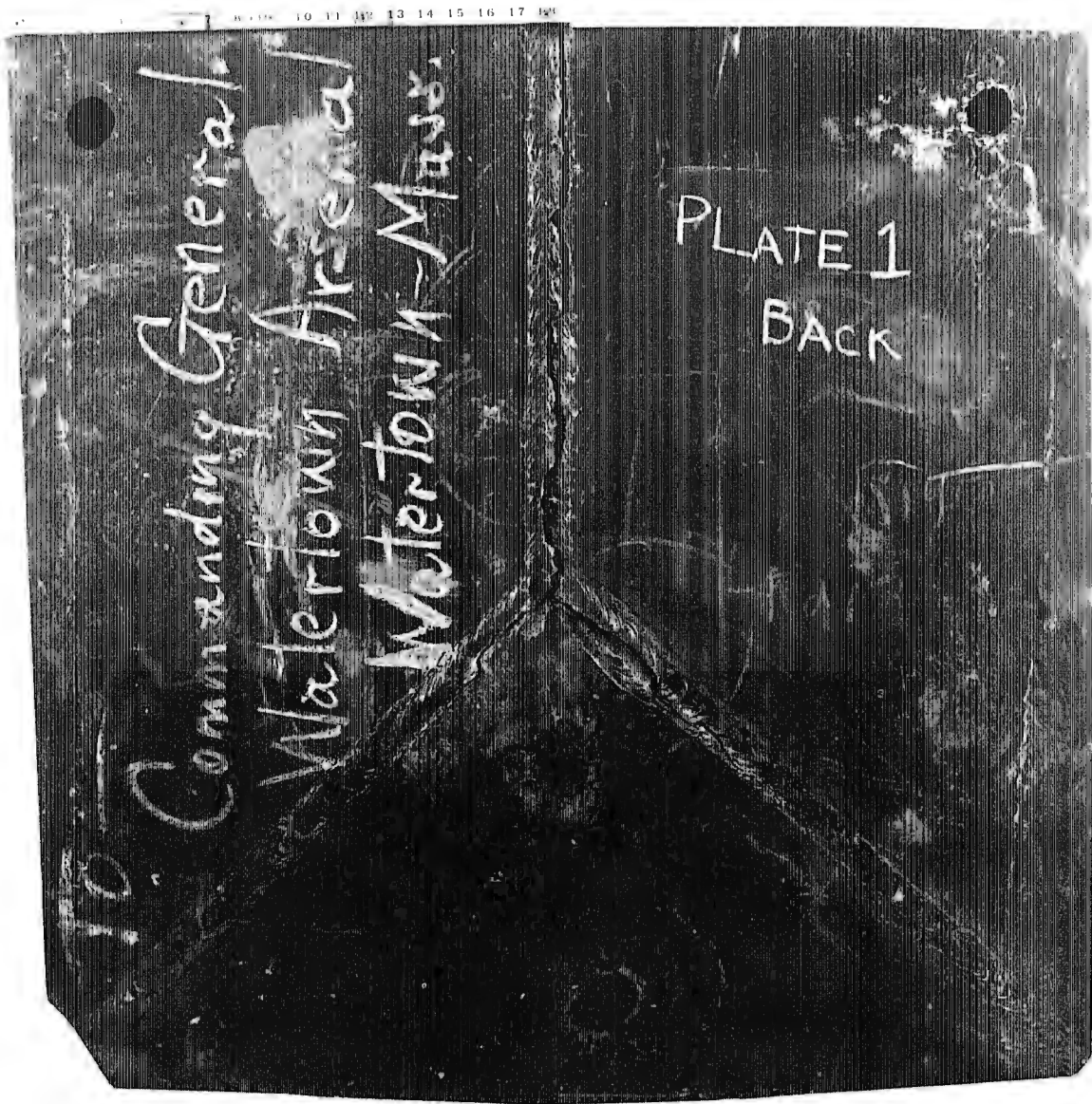
WATERTOWN ARSENAL

2" ROLLED HOMOGENEOUS ARMOR 36" x 36". "Y" JOINT
OF LINCOLN ARMORWELD. FLAME CUT EDGES
FEBRUARY 18 1942 FRONT W.A.710-1749

FIGURE 1

FIGURE 2

Rear view of Y joint in 2" rolled
homogeneous armor plate after ballistic
test.



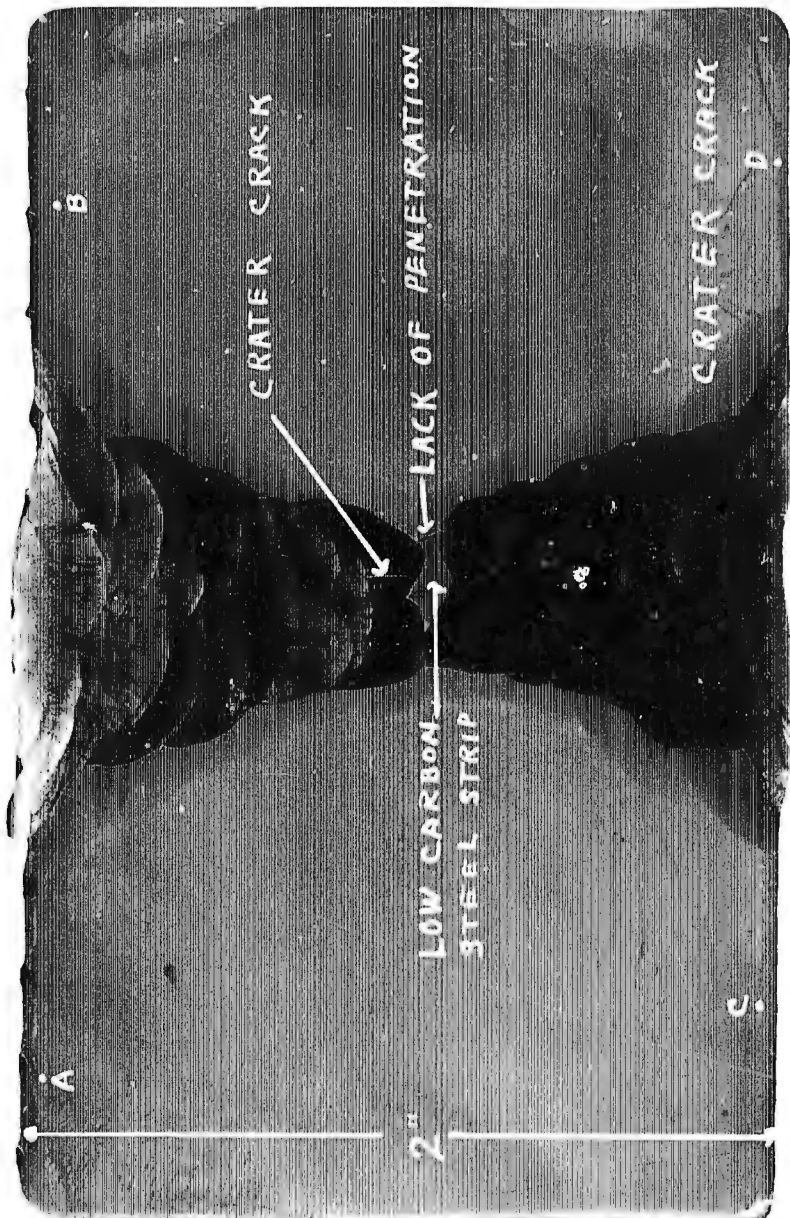
WATERTOWN ARSENAL

2" ROLLED HOMOGENEOUS ARMOR 36" X 36". "Y" JOINT
OF LINCOLN WELD ARMOR. FLAME CUT EDGES
FEBRUARY 18 1942 BACK W.A. 710-1750

FIGURE 2

FIGURE 3

Cross section of weld as prepared
for macroexamination. Area of incomplete
weld metal penetration and cracks are
indicated by arrows.



WATERTOWN ARSENAL

CROSS SECTION OF 2" 1/4" ROLLED HOMOGENEOUS ARMOR PLATE
 WELDED WITH A MODIFIED 18/8 ELECTRODE. NOTE MILD STEEL
 STRIP AT THE ROOT OF JOINT. 3-25-42 W.A.710-1794

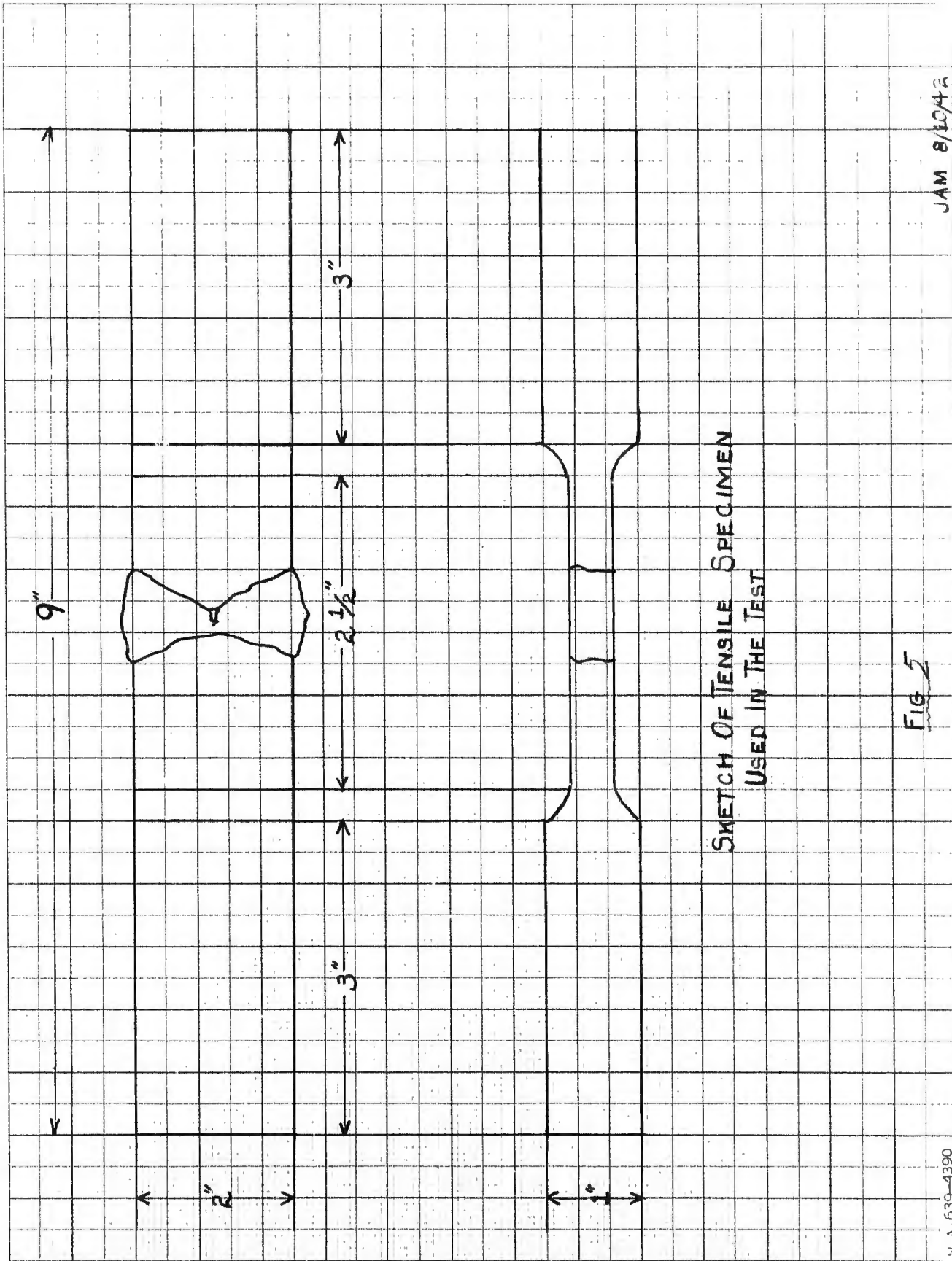
FIGURE 3

FIGURE 4

Vickers Brinell hardness survey as
taken on same weld cross section prepared
for macroexamination.

FIGURE 5

Type of tensile test specimen
taken across weld joint.



SKETCH OF TENSILE SPECIMEN
USED IN THE TEST

FIG 2

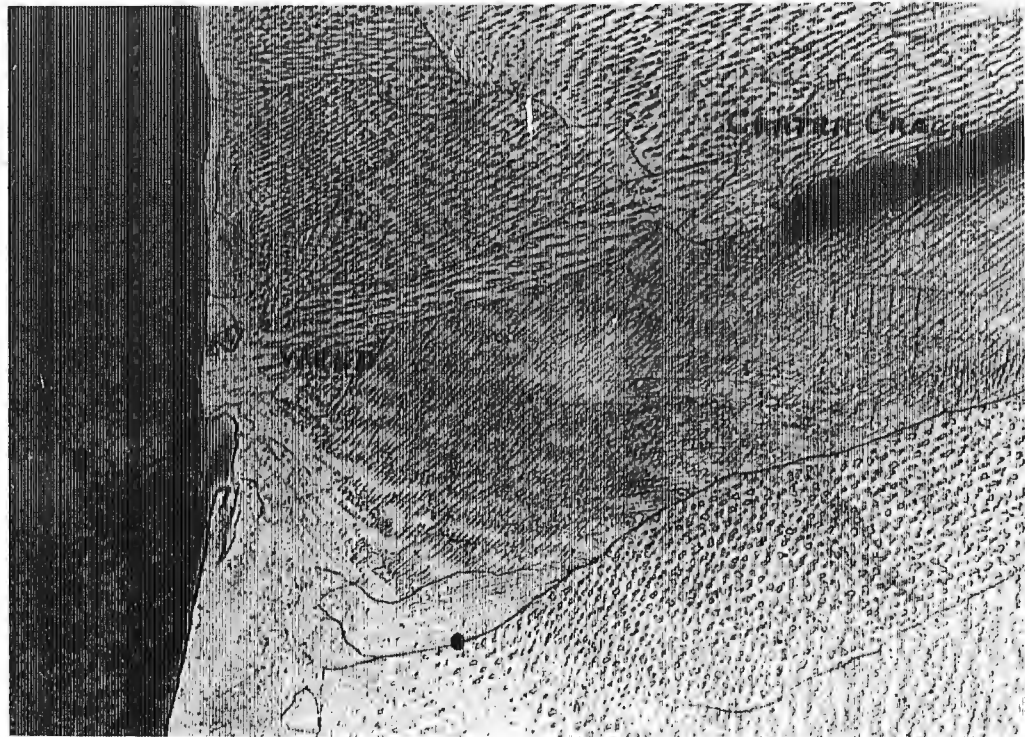
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U.S. 639-4390

FIGURE 6

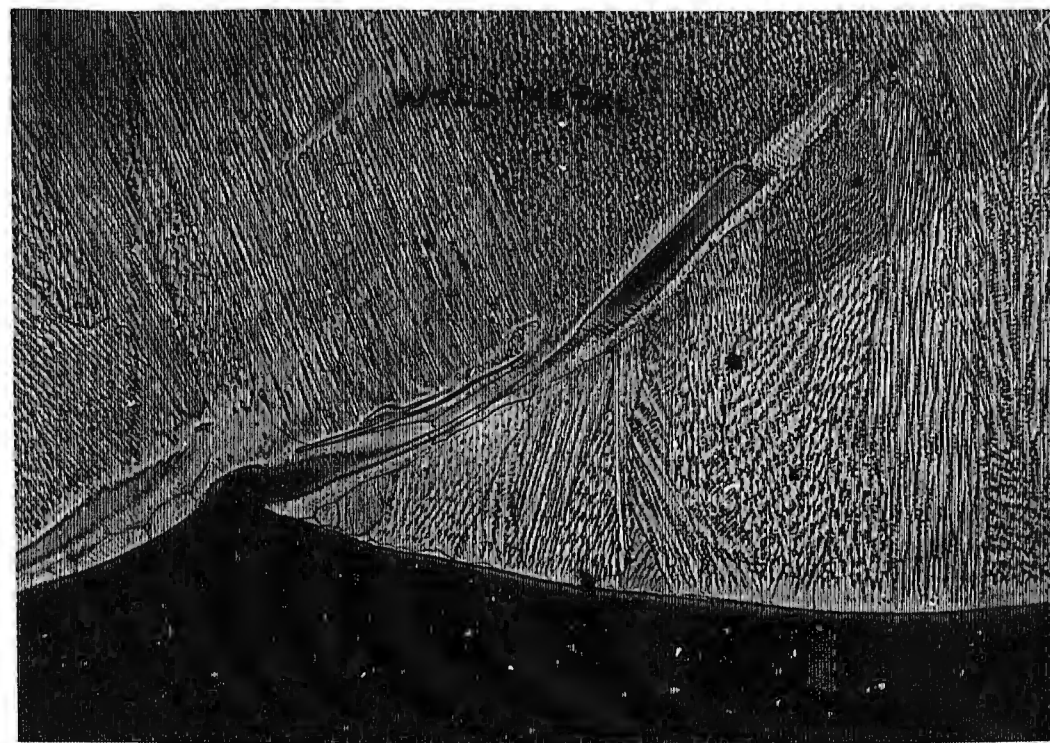
A. Boundary of 18/8 weld metal
and mild steel strip.

B. Boundary of 18/8 weld metal
and armor plate.



X100

ETCH: 10% CHROMIC
1% NITAL



X100

ETCH: 10% CHROMIC
1% NITAL

Fig 6

W.A. 639-4391

FIGURE 7

Areas where weld metal failed to
penetrate between mild steel strip and
armor plate.

<u>Location</u>	<u>Yield Strength psi(0.1% ext.)</u>	<u>Tensile Strength psi</u>	<u>Elongation % (1" gage)</u>	<u>Remarks</u>
Across joint 1 A	76,900	84,500	20	Break occurred in weld metal at center of joint.
Across joint 1 B	69,200	70,200	17	Break occurred in weld metal & showed slag inclusions at edge of steel strip.
Longitudinally in weld metal	70,000	94,700	33	Break occurred in middle third of specimen & showed a large slag inclusion.

7. Microexamination

Figures 6, 7, and 8 are photomicrographs of the weld section. Figure 6 shows boundaries of weld metal and low carbon steel strip and of weld metal and armor plate. Figure 7 shows area where weld metal did not penetrate between armor plate and low carbon steel strip. Figure 8 shows a crater crack and an area of weld metal near the steel strip in which carbides have precipitated. The weld defects of Figures 7 and 8 are regarded as deleterious to the resistance to ballistic shock of this type joint.



X100

A.

ETCH: 10% CHROMIC
AND 1% NITAL



X100

B.

ETCH: 10% CHROMIC
17% NITAL

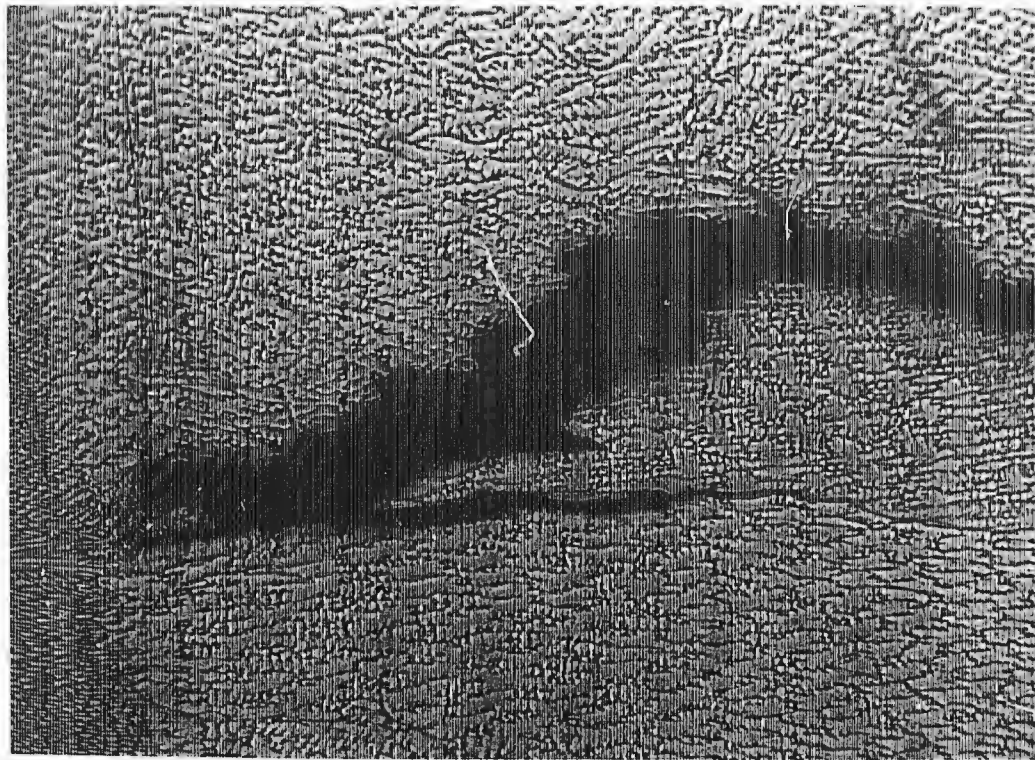
FIG 7

W.A.639-4392

FIGURE 8

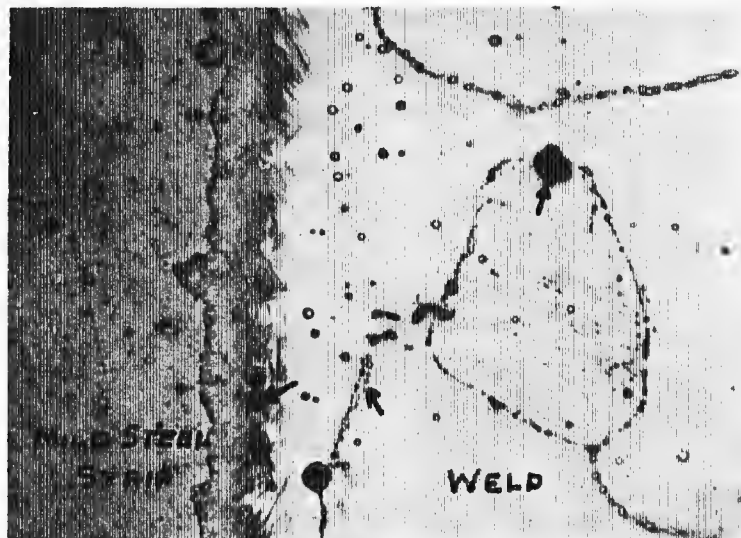
A. Crater crack in weld metal.

B. Area of carbide precipitation in
weld metal at boundary of mild steel strip
and weld metal.



X 100

ETCH: 10% CHROMIC
1% NITAL



X1500

ETCH: 10% CHROMIC
1% NITAL

FIG 8

W.A. 639-4393

APPENDIX A

Basic Correspondence

COPY - mlc

Brooker/mbg

WAR DEPARTMENT

O.O. 470.5/7015

OFFICE OF THE CHIEF OF ORDNANCE

Attention of
Ind.Serv-Tank Div.

WASHINGTON

APG 470.5/2039

December 15, 1941

Subject: 2" Thick Y Plate Welded by the Lincoln
Electric Company - F. R. P2261 A1877
dated November 21, 1941

To: Commanding General
Aberdeen Proving Ground
Maryland

1. It is requested that the plate used for the
subject shock test be sent to Watertown Arsenal for
metallurgical examination.

2. A separate letter will be sent to the Arsenal
requesting this work.

By order of the Chief of Ordnance:

s/t

JOHN L. ATKINS
Major, Ordnance Dept.
Assistant

OO 470.5/7015
APG 470.5/2039

1st. Ind.

Lt. Ellis/rn

Commanding General, Aberdeen Proving Ground, Md.
December 20, 1941. To: Commanding General, Watertown
Arsenal, Watertown, Massachusetts.

1. As requested in paragraph one basic letter,
subject plate has been sent to your arsenal.

For the Commanding General:

s/t G. G. Eddy,
Lt. Col., Ord. Dept.,
Assistant

COPY - mlc

COPY - 6/23/42 - ahk

WAR DEPARTMENT
ABERDEEN PROVING GROUND
MARYLAND

Lt. Ellis/rn

January 3, 1942.

A.P.G. 470.5/2089-1
W.A. 470.5/3972

Subject: Re 2" Y Welded Plate Submitted by Lincoln Electric Co.

To: The Commanding General
Watertown Arsenal
Watertown, Massachusetts.

1. It is requested that subject plate be examined metallurgically by your arsenal upon arrival.
2. Ballistic results will be found on Aberdeen Proving Ground firing record P2261, A1877 dated 11/21/41.

For the Commanding General:

(s/t) G. G. Eddy,
Lt. Col., Ord. Dept.,
Assistant