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643/19A



REPORT NO. 543/19A

MEMORANDUM FOR THE DIRECTOR

TO: THE DIRECTOR, DEPARTMENT OF DEFENSE

FROM: THE ASSISTANT SECRETARY FOR DEFENSE

SUBJECT: [Illegible]

AD-A953 316

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WATERLOO, MASS.

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Report No. 642/19A
Watertown Arsenal

September 2, 1942

ARC WELDING OF ARMOR

Rolled, Homogeneous, 7/8 Inch Thick, Armor Plate
Welded with Ferritic Electrode by the Allegheny
Ludlum Steel Corporation

OBJECT

To carry out ballistic test and metallurgical examination
of subject plate.

REFERENCES

Letter: Allegheny Ludlum Steel Corporation to
Commanding Officer, Watertown Arsenal, August 6, 1942
W.A. 470.5/5091

The portion of this correspondence relating to this
investigation is included in Appendix A.

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CONCLUSIONS

1. Ballistic limit of weld is 98% of ballistic limit of armor plate (2101 f/s. and 2145 f/s., respectively) with caliber .50 A.P. M2 projectiles in penetration test. Weld did not crack during ballistic penetration test.

2. The weld is very porous, but otherwise appears entirely satisfactory from a metallurgical standpoint.

N. A. MATTHEWS
Captain, Ordnance Department

W. L. WARNER
Welding Engineer

APPROVED:

H. H. ZORNIG
Colonel, Ordnance Department
Director of Laboratory



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INTRODUCTION AND TEST PROCEDURE

One twelve inch square of welded 7/8 inch thick homogeneous rolled armor plate was received from Allegheny Ludlum Steel Corporation. The plate had been cut into two equal parts; the two parts hardened to approximately 300 Brinell by water quenching from 1560° F. and drawing at 1150° F., then welded together from both sides by hand arc welding using a ferritic rod of very low carbon.

The plate and weld metal were tested for ballistic penetration with .50 caliber A. P. projectiles at the Watertown Arsenal test range. Plate was radiographed before and after ballistic testing and a specimen taken, as indicated in Figure 1, for metallurgical examination.

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DATA AND DISCUSSION

1. Ballistic Data

Ten rounds of .50 caliber A.P. M2 ammunition were fired at plate, three rounds striking weld. The results were as follows:

TABLE I

<u>Plate Round No.</u>	<u>Proj. Model</u>	<u>Striking Velocity</u>	<u>Result on Plate</u>
1	M2 A.P. .50 Cal.	2150 f/s	Complete Penetration, Pinhole
2	"	2179 f/s	Complete Penetration, Pinhole
3	"	2140 f/s	Partial Penetration, Slight Bulge on Back
4	"	2130 f/s	Partial Penetration, Slight Bulge on Back
5	"	2130 f/s	Partial Penetration, Slight Bulge on Back
6	"	2130 f/s	Complete Penetration, Pinhole on Weld
7	"	2075 f/s	Partial Penetration, Medium Bulge on Back
8	"	2082 f/s	Partial Penetration on Weld, Slight Bulge on Back
9	"	2120 f/s	Hit Top of Plate
10	"	2120 f/s	Complete Penetration, Pinhole on Weld

Ballistic Limit of Weld Area 2101 f/s

Ballistic Limit of Armor Plate 2145 f/s

Specified Ballistic Limit of Armor Plate 2025 f/s

2. Visual Inspection

Figures 1 and 2 are photographs of front and rear of plate.

No cracks are evident.

3. Radiographic Inspection

Figure 3 is a radiograph of plate after ballistic penetration test. Considerable porosity is apparent. One small crater crack can be seen in center of weld, but this did not open up under ballistic test.

4. Chemical Analysis

The results of chemical analyses of weld and plate material were as follows:

	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Cu</u>	<u>Mo</u>	<u>Va</u>
Armor Plate	.28	.87	.38	.028	.010	Trace	.59	.08	.43	Nil
Weld Metal	.26	.84	.34	.025	.014	"	.64	.07	.32	Nil

The analysis of the electrode used was reported in the reference letter from Allegheny Ludlum Steel Corporation, as follows: 0.084% C, 1.04% Mn, 0.117% Si, 0.75% Cr, and 0.25% Mo.

5. Macroexamination

Figure 4 is a photograph of cross section of the weld as prepared for macroexamination and hardness survey. Porosity of the weld metal is shown. No cracks can be observed at low magnification.

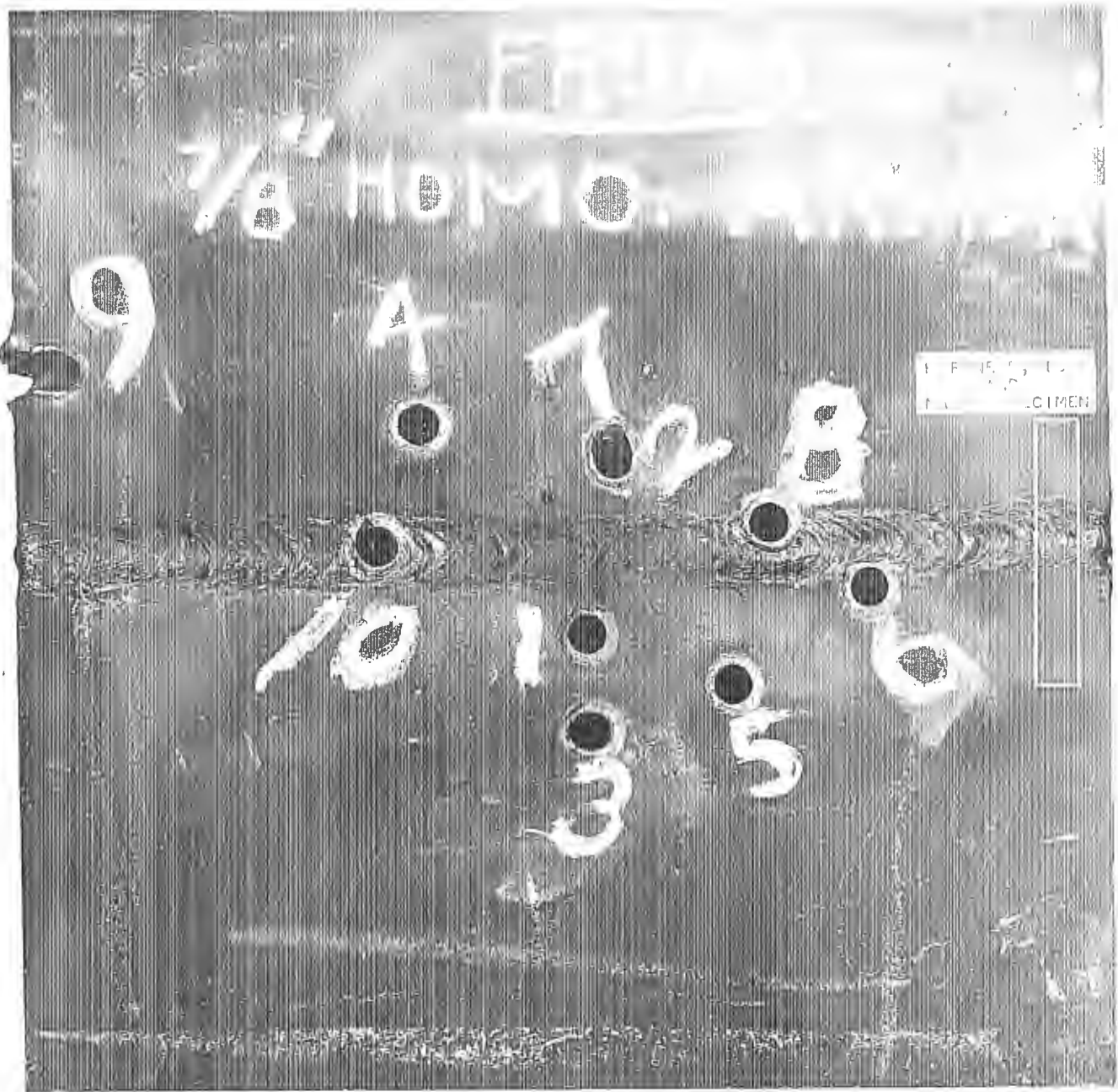
6. Hardness Survey

Vickers Brinell hardness readings across front, middle, and rear of weld cross section are plotted in Figure 5. The heat effect of weld on adjacent armor plate is rather slight

and the weld metal, itself, has a good hardness level.

7. Microexamination

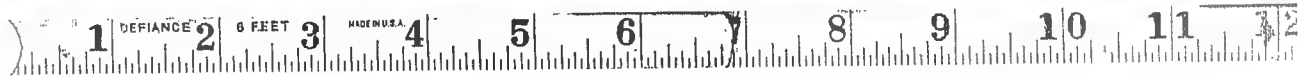
The metallographic structure runs from tempered martensite in the armor plate to ferrite with finely precipitated carbides in the weld metal. The structure is entirely consistent with chemical composition and hardness and, therefore, photomicrographs were not included. The bond between plate and weld is excellent. A few very small cracks in weld metal can be detected at 250 diameters. One comparatively large microcrack runs through, and may have been caused by, a Vickers brinell impression.



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BUTT WELD 7/8" ROLLED HOMOGENEOUS ARMOR FROM ALLEGHENY LUDLUM AFTER PENETRATION TEST WITH .50 CAL. A.P. AMMUNITION. W.A.710-1929

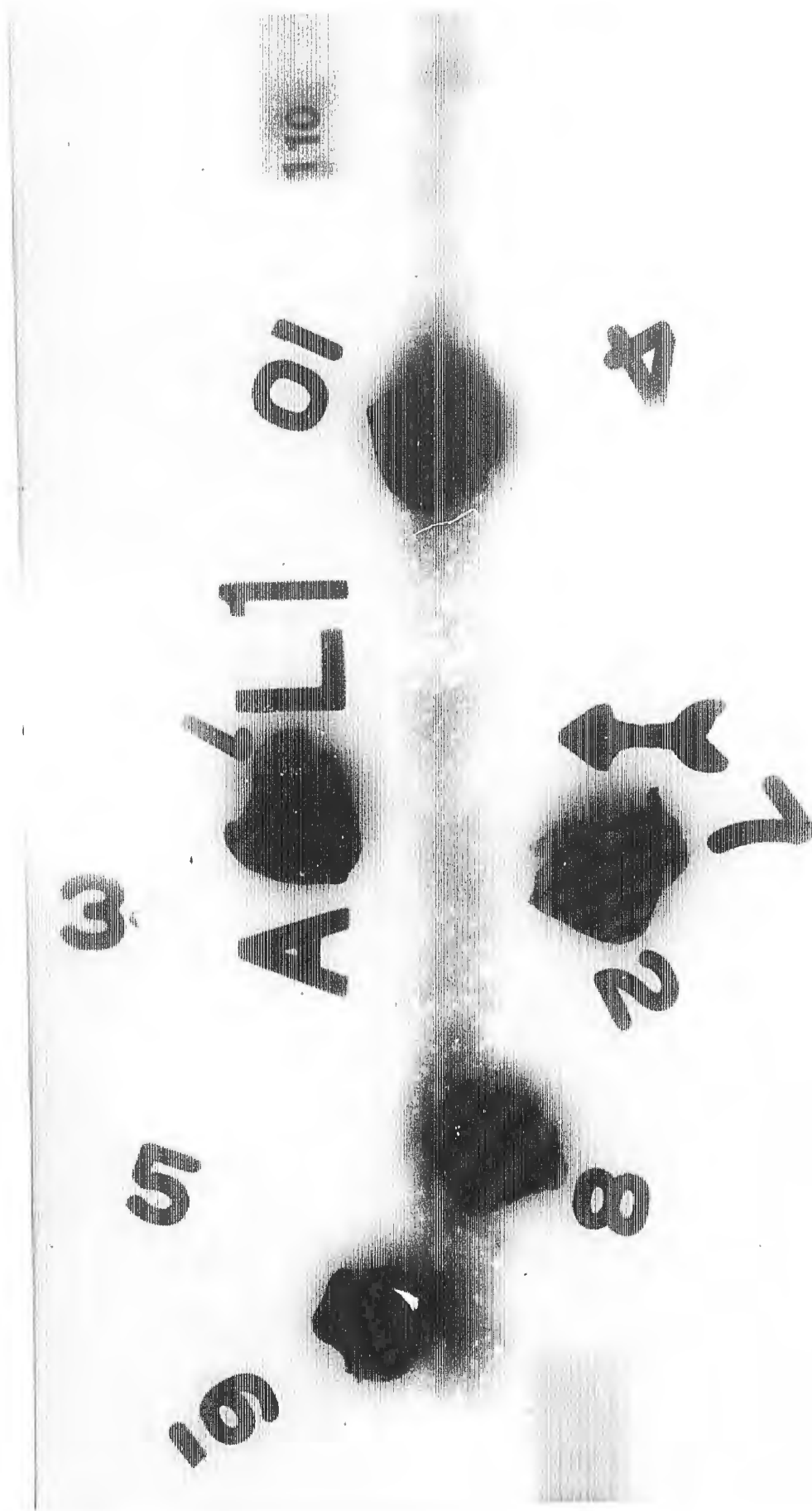
FIGURE 1



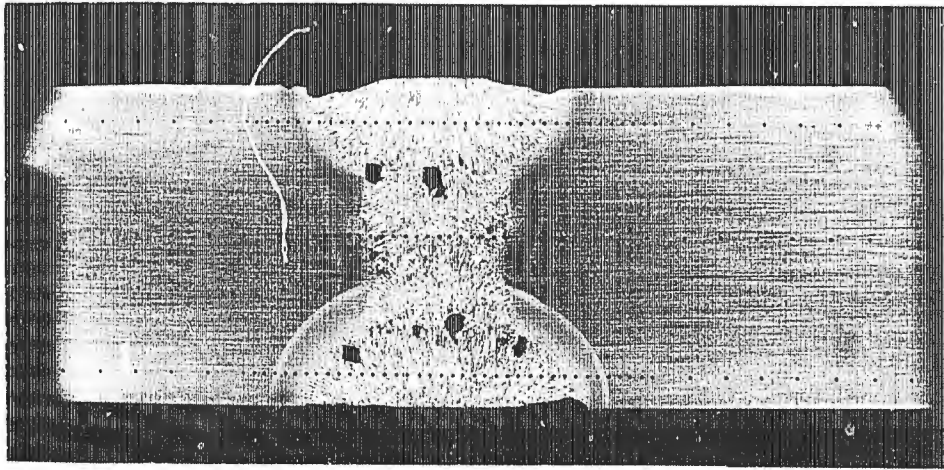
WATERTOWN ARSENAL

BUTT WELD 7/8" ROLLED HOMOGENEOUS ARMOR FROM ALLEGHENY LUDLUM AFTER PENETRATION TEST WITH .50 CAL. A.P. AMMUNITION. W.A.710-1928

FIGURE 2

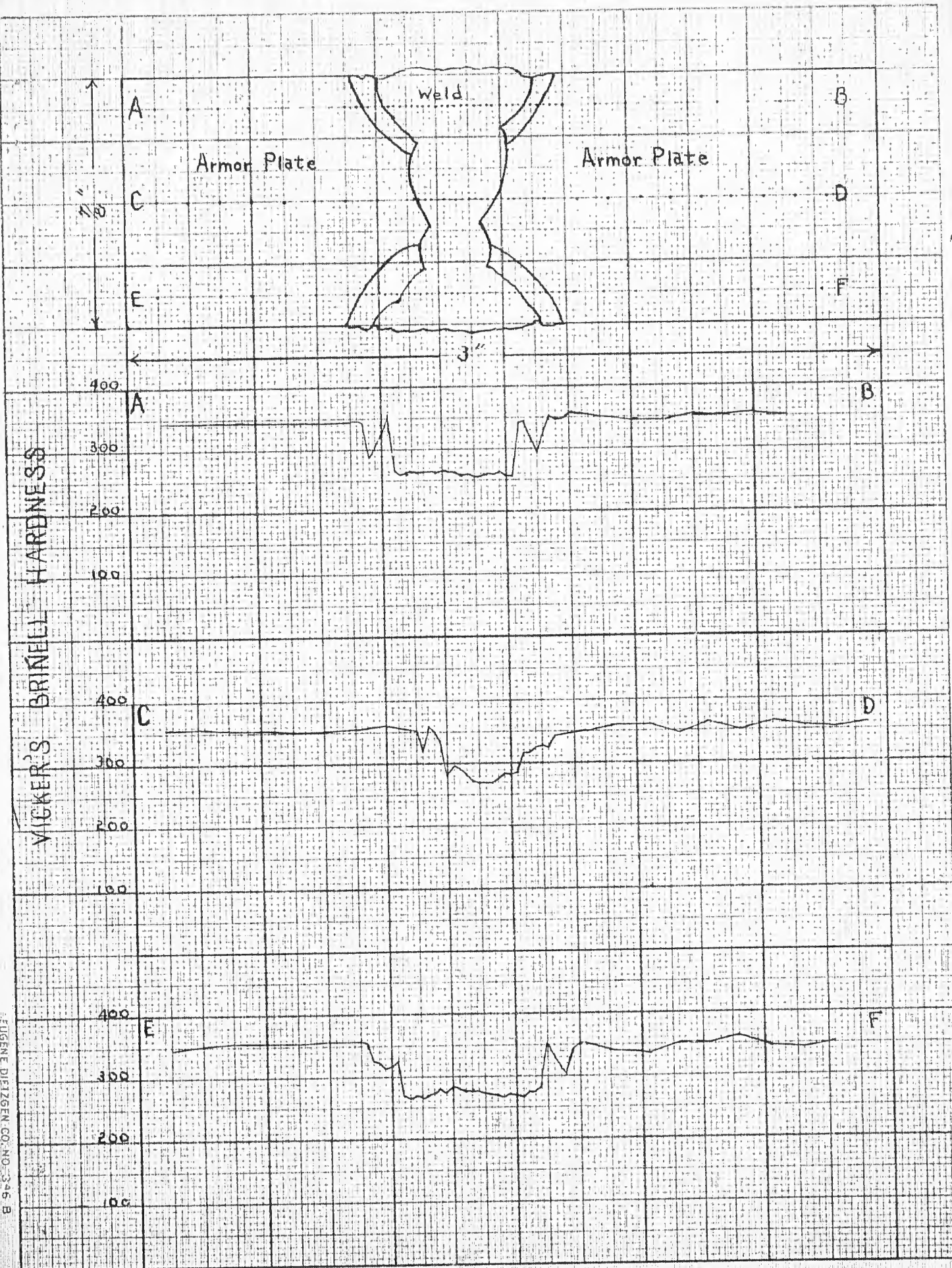


RADIOGRAPH OF LONGITUDINAL WELD SECTION AFTER BALLISTIC TEST
FIG. 3



MACRO-ETCHED WELD CROSS SECTION
DARK AREAS ARE POROSITY CAVITIES
FIG. 4

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VICKER'S BRINELL HARDNESS

Fig. 5 HARDNESS SURVEY

EUGENE DIEZGEN CO. NO. 346 B

APPENDIX A

Basic Correspondence

