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Memorandum Report No. 542/17

ARC WELDING OF ALUMINUM

Special Bolt Failure and Hard Spotting

By

W. L. Warner
Welding Engineer

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Memorandum Report No. 642/17
Watertown Arsenal

June 5, 1942

ARC WELDING OF ARMOR

Preclad Butt Joints and Hard Facings

OBJECT

To determine, by ballistic tests, the resistance to penetration of double vee butt joints in 1" rolled homogeneous armor, machine bevelled and preclad with 25/20 stainless electrode, welded with: (1) a root pass of 25/20 stainless electrode; (2) a commercial ferritic type electrode for filler metal; (3) surface layers of various commercial hard facing electrodes.

CONCLUSIONS

1. The following ballistic limits (penetration test with .50 caliber A.P. projectiles) were obtained when a preclad double vee butt joint in 1" homogeneous armor was welded with a ferritic alloy filler and a surface layer of commercial hard facing metal:

| | | | |
|----------------------|-------------|---------------|-------------|
| Facing Electrode | Hollup #450 | Dymonhard #65 | Rollex #600 |
| Ballistic Limit, f/s | 2300 | 2150 | 2250 |

2. The tendency for this weld to crack under shock of penetration test is too great for satisfactory welding of homogeneous armor plate of the type tested.

Approved:

W. L. Warner,
Welding Engineer.

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

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INTRODUCTION AND TEST PROCEDURE

The plates used in these tests were flame cut from 36" x 36" x 1" rolled homogeneous armor of the following chemical composition: 0.49% C, 0.56% Mn, 0.23% Si, 0.019% P, 0.019% S, 1.22% Cr, 0.60% Mo, and 0.20% V.

The plates were annealed, then double vee bevels were machined on the edges to be welded. A 25/20 stainless electrode was used for buttering and the plates were heat treated according to the method described in a previous report (W.A. 648/2). A ferritic electrode was used for the filler metal, and a different type of hard facing electrode on the surface of each joint.

A cross section of each weld was taken for macroexamination and hardness survey.

The welds were ballistically tested at the Watertown Arsenal range to determine resistance to penetration by .50 caliber A.P. projectiles.

DATA AND DISCUSSION

TABLE I

Welding Data

| <u>Plate</u> | <u>Electrode</u> | <u>Size</u> | <u>No. of Passes</u> | <u>Joint</u> | <u>Amps</u> |
|--------------|------------------|-------------|----------------------|-----------------|-------------|
| No. 1 | 25/20 | 5/32" | | Buttering layer | 150 |
| | 25/20 | 5/32" | 1 front & back | | 1001 |
| | *Murex Cromansil | 5/32" | " " " " | | 215 |
| | " " | 3/16" | " " " " | | 215 |
| | Murex Cromansil | 3/16" | " " " " | | 215 |
| | Hollup #450 | 5/32" | " " " " | Surface layer | 155 |

TABLE I (cont'd.)

| Plate | Electrode | Size | No. of Passes | Joint | Amps |
|-------|-----------------|-------|----------------|------------------------------------|------|
| No. 2 | 25/20 stainless | 1/8" | 1 front & back | Buttering layer | 100 |
| | 25/20 stainless | 1/8" | " " " " | | 100 |
| | Fleetweld #8 | 5/32" | " " " " | | 155 |
| | Murex Carbon | | | | |
| | Moly #50 | 3/16" | " " " " | | 200 |
| | Murex Carbon | | | | |
| | Moly #50 | 3/16" | " " " " | | 200 |
| | *Dymonhard #65 | 3/16" | " " " " | Surface layer | 200 |
| No. 3 | 25/20 stainless | 1/8" | | Buttering layer | 100 |
| | 25/20 stainless | 1/8" | 1 front & back | | 100 |
| | Fleetweld #8 | 3/16" | " " " " | | 155 |
| | Murex Carbon | | | | |
| | Moly #50 | 3/16" | " " " " | | 200 |
| | Rollex #600 | 3/16" | " " " " | (Surface layer (straight polarity) | 200 |

*Cracks observed during welding

The method of using the 25/20 stainless electrode for buttering and root layer is apparently satisfactory as no defects were found in the heat affected zone of the plate. The sequence of welding was to alternately deposit filler metal on each side of the double vee. Some cracks occurred in the filler metal. These were ground out and repaired.

TABLE II

Hardness Data (Rockwell C)

| Plate | Weld Metal | Heat Affected Zone | Base Metal |
|--------------|------------|--------------------|------------|
| No. 1 Filler | 35 | 56 | 44 |
| Facing | 55 | | |
| No. 2 Filler | 42 | 54 | 43 |
| Facing | 52 | | |
| No. 3 Filler | 42 | 52 | 42 |
| Facing | 50 | | |

Figure 1 shows cross sections of the weld joints as prepared for macroexamination. Cracks occurred in the hard facing and extended into the weld metal. These cracks were opened up during firing tests.

TABLE III

Ballistic Data

| Plate | Ballistic Limit | | Specified Bal. Limit | Ballistic Efficiency in Weld |
|-------|-----------------|----------|----------------------|------------------------------|
| | On Plate | On Weld | | |
| No. 1 | 2550 f/s | 2300 f/s | 2250 f/s | 102% |
| No. 2 | 2550 f/s | 2150 f/s | 2250 f/s | 95% |
| No. 3 | 2250 f/s | 2250 f/s | 2250 f/s | 100% |

The weld metal of Plate No. 1 which had a slightly greater hardness in the facing layer also had a slightly higher ballistic efficiency.

Figures 2 through 7 are photographs of the front and rear of each weld after ballistic test. The extent of cracking and spalling of the weld metal are such that the method of welding described in this report cannot be regarded as satisfactory for homogeneous armor plate of the type tested.

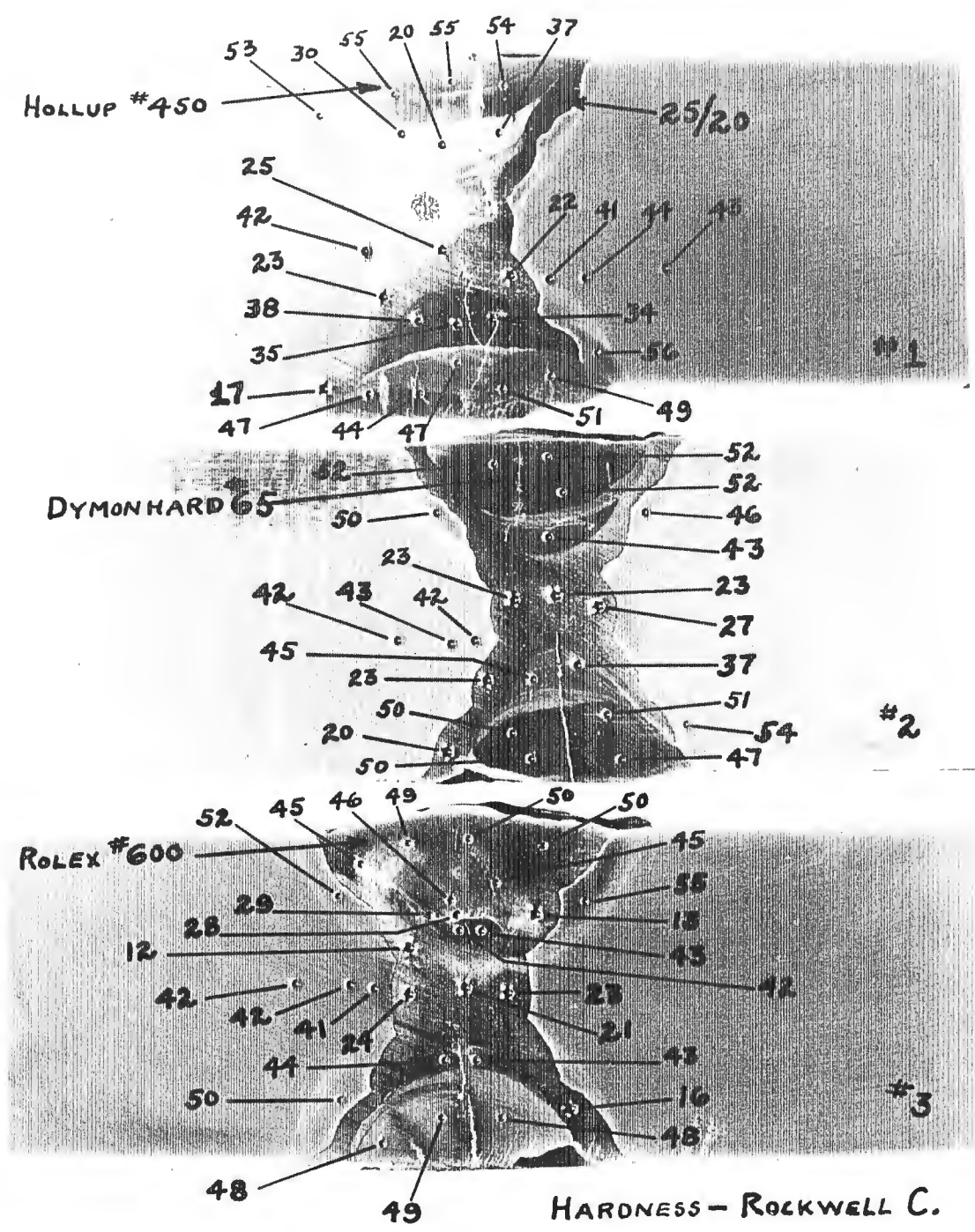


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Figure 1

Hardness Surveys and
Macroexamination of Plates.



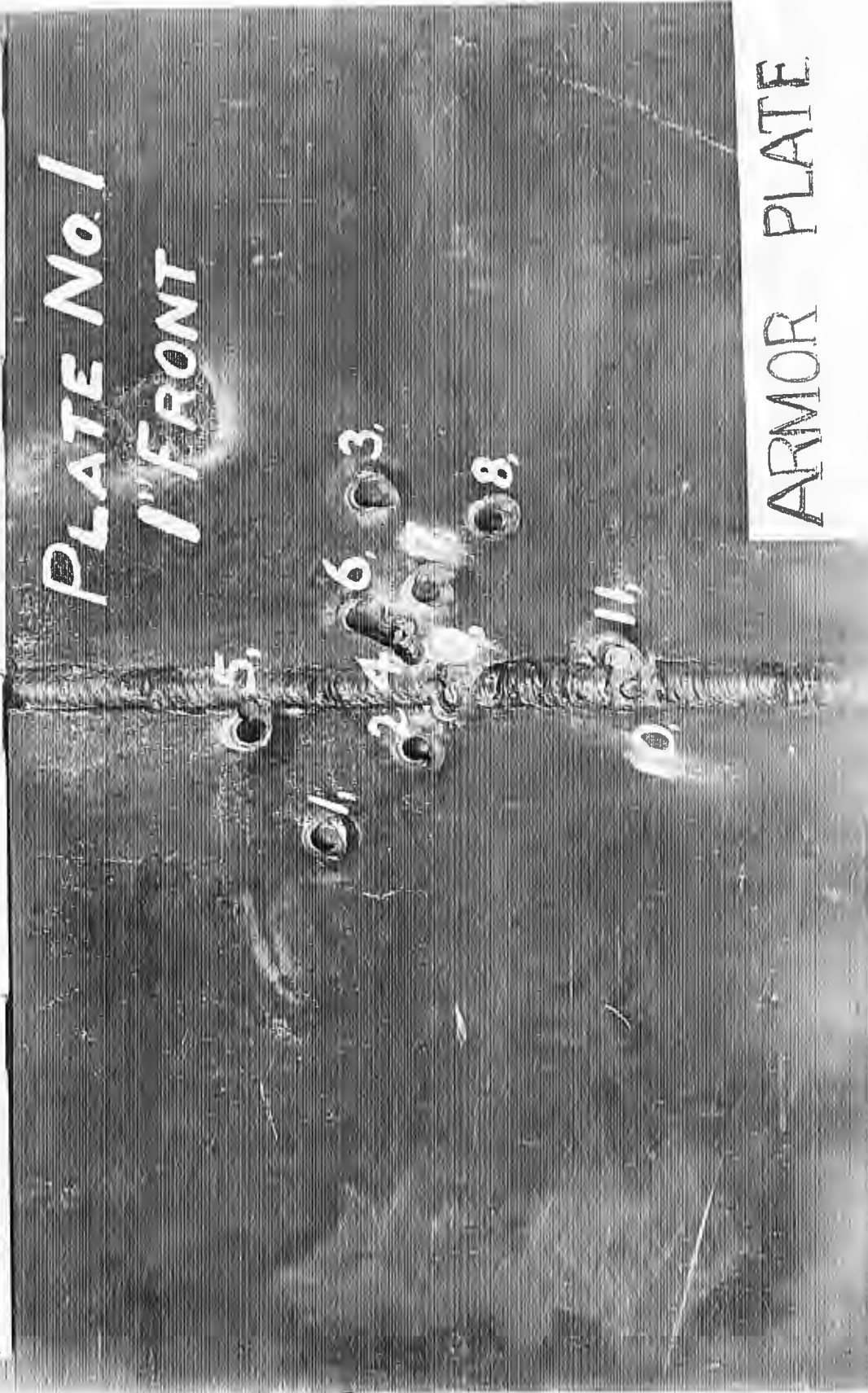
BUTT WELDS, 1" HOMOGENEOUS ARMOR PLATE.
 January 16, 1941 W.A. 639-2806

Figure 2

Front of Plate No. 1. Spalling of Weld
Metal.

14 15 16 17 18 19 20 21 22 23

PLATE No. 1
1" FRONT



ARMOR PLATE

1/4 V/

1" DOL = LE V, 30° BEVEL, HP

Figure 3

Back of Plate No. 1.

Weld crack starting at weld metal spall.

PLATE NO 1
1" BACK

ARMOR PLATE



1" DOUBLE V. 30° BEVEL, HARDENED

Figure 4

Front of Plate No. 2.

Spalling of weld metal.

17 18 19 20 21 22 23

PLATE No. 2
FRONT

ARMOR PLATE



1" D₀₁ - LF V, 30° BEVEL, H₁ - S₁

Figure 5

Back of Plate No. 2.

Spalling of weld metal.

13 11 15 16 17 18 19 20 21 22 23

PLATE NO. 2
1" BACK

6
2
1
3
10
9
8

ARMOR PLATE

1" DOUBLE V, 30° BEVEL, H₁ SURFACING

1/4" W/1.1 2.1



Figure 6

Front of Plate No. 3.

Weld crack and spalling.

7 8 9 10 11 13 14 15 16 17 18 19 20 21 22 23 24

PLATE No. 3
1" FRONT



ARMOR PLATE

1" DOUBLE V, 30° BEVEL, HARDENED

7A

Figure 7

Back of Plate No. 3.

Weld crack and spalling.

7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

PLATE NO. 3
1" BACK



ARMOR PLATE

11A7

1" DOUBLE V, 30° BEVEL, H.A. CURRIC