

UNCLASSIFIED

AD NUMBER: ADA953524

CLASSIFICATION CHANGES

TO: Unclassified

FROM: Restricted

LIMITATION CHANGES

TO:  
Approved for public release; distribution is unlimited.

FROM:  
Distribution authorized to U.S. Defense agencies only; Test and Evaluation;  
19 Mar 1942. Other requests shall be referred to the Army Mechanics and  
Materials Research Center, Materials Tech Lab., Watertown Arsenal, MA  
02172

AUTHORITY

R to U: 31 Aug 1954, DoDD 5200.10, gp-4.  
E/4 to A/1: 18 Oct 1984, per document marking

UNCLASSIFIED

AD-A953 524

ARMOR *Plate*  
WELDING

644/5

DTIC FILE COPY

This document has been approved  
for public release and sale; its  
distribution is unlimited.

DTIC

SELECTED

OCT 18 1984

A

UNCLASSIFIED

RESTRICTED  
DECLASSIFIED

1

Report No. 644/5  
Watertown Arsenal

August 19, 1942

GAS WELDING OF ARMOR

Repair of 2" Thick Cast Armor

OBJECT

To make a complete metallurgical examination of two (?)  
2" thick cast armor plates, gas welded and ballistically tested  
at Aberdeen Proving Ground.

REFERENCES

Letter file O.O. 470.5/3436, A.P.G. 470.5/1395

This basic correspondence is included in Appendix A.

CONCLUSIONS

A large number of micro cracks was observed along fusion  
zone of welds. Some of the cracks apparently opened up under  
ballistic shock to form large longitudinal cracks. The quality  
of the welds is inferior to arc welds on cast armor which have  
been examined at this Arsenal.

W. L. Warner,  
Welding Engineer

APPROVED:

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

OCT 18 1984  
A

DECLASSIFIED  
DOD DIR 8200.9

RESTRICTED  
DECLASSIFIED

This document has been approved  
for public release and sale; its  
distribution is unlimited.

INTRODUCTION AND TEST PROCEDURE

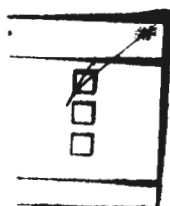
Two (2) 36" x 36" x 2" armor plates, cast by the Continental Bell and Steel Foundry Company, were welded along a longitudinal beveled slot 30" x 2" with an oxyacetylene torch and Airco No. 1 one-quarter inch welding rod at Aberdeen Proving Ground. Welding was done by a representative of Air Reduction Sales Company in connection with the program for developing oxyacetylene welding for repair of armor plate in the field. Complete welding data and welding sketch are given in Appendix B.

Welds were tested ballistically at Aberdeen Proving Ground and then submitted to this Arsenal for metallurgical examination. Visual, radiographic, macrographic, and micrographic examinations were carried out. Specimens were taken as indicated in Figure 1 for chemical analysis, hardness survey, and tensile testing.

DATA AND DISCUSSION

1. Visual Inspection

Front and back views of the two (2) plates as received after ballistic test at Aberdeen are shown in Figures 1 through 4. The crack shown in the back view of the first plate (Figure 2) did not penetrate far into the weld. The second plate (Figures 3 and 4) was cracked in such a way that it was impossible to take physical test specimens. Figure 5 is a cross section showing the extent of the crack in this plate.



|                    |                      |
|--------------------|----------------------|
| By _____           |                      |
| Distribution/      |                      |
| Availability Codes |                      |
| Dist               | Avail and/or Special |
| A                  |                      |

## 2. Nondestructive Tests

Radiographic examination of the first plate revealed some areas of cracks, lack of fusion, and lack of penetration. The second plate had very bad longitudinal cracks in the fusion zone and weld metal as disclosed in the visual examination.

## 3. Chemical Analyses

Results of chemical analyses were as follows:

|            | <u>C</u> | <u>Mn</u> | <u>Si</u> | <u>Al</u> | <u>Cr</u> | <u>Mo</u> | <u>V</u> |
|------------|----------|-----------|-----------|-----------|-----------|-----------|----------|
| Weld Metal | .10      | .28       | .12       | 1.32      | 0.10      | ---       | ---      |
| Plate      | .32      | .67       | .24       | 1.50      | 1.03      | .52       | .12      |

## 4. Macroexamination

Figure 6 is a cross section of the weld in first plate as prepared for macroexamination. Lack of fusion and small cracks in the weld metal and heat-affected zone are apparent.

## 5. Hardness Survey

Vickers Brinell hardness readings were taken across the polished cross section of the weld as prepared for macroexamination. The hardness data are plotted in Figure 7. Maximum hardness readings were as follows:

|      | <u>Base Metal</u> | <u>Heat-affected Zone</u> | <u>Weld Metal</u> |
|------|-------------------|---------------------------|-------------------|
| Face | 285               | 383                       | 246               |
| Root | 315               | 425                       | 174               |

## 6. Tensile Tests

The following results were obtained from tensile tests of specimens taken from the first plate. Location of specimens

is indicated in Figure 1. A standard .505" diameter tensile specimen was taken longitudinally in the weld metal (1) and two (2) tensile specimens of the form illustrated in Figure 8 were taken across the weld (2 and 3).

|   | <u>Tensile Strength, psi.</u> | <u>Yield Strength, psi.</u> | <u>Elongation %</u> | <u>Reduction of area %</u> | <u>Remarks</u>                  |
|---|-------------------------------|-----------------------------|---------------------|----------------------------|---------------------------------|
| 1 | 66,000                        | 50,000                      | 15.5                | 39.0                       | Porosity in weld.               |
| 2 | 68,100                        | 66,000                      | 9.0                 | ----                       | Lack of fusion.                 |
| 3 | 49,400                        | ----                        | 4.0                 | ----                       | Lack of penetration and fusion. |

#### 7. Microexamination

Figures 9 and 10 illustrate defects observed during microexamination. In Figure 9, at low magnification, cracks are shown at the boundary of the plate and weld metal. At a higher magnification, Figure 10, numerous small cracks were observed parallel to the fusion line.

Although the preheat and postheat treatments were sufficient to prevent a high hardness in the heat-affected zone, the ductility of the low carbon ferritic electrode was insufficient to prevent excessive cracking of the welded joint.

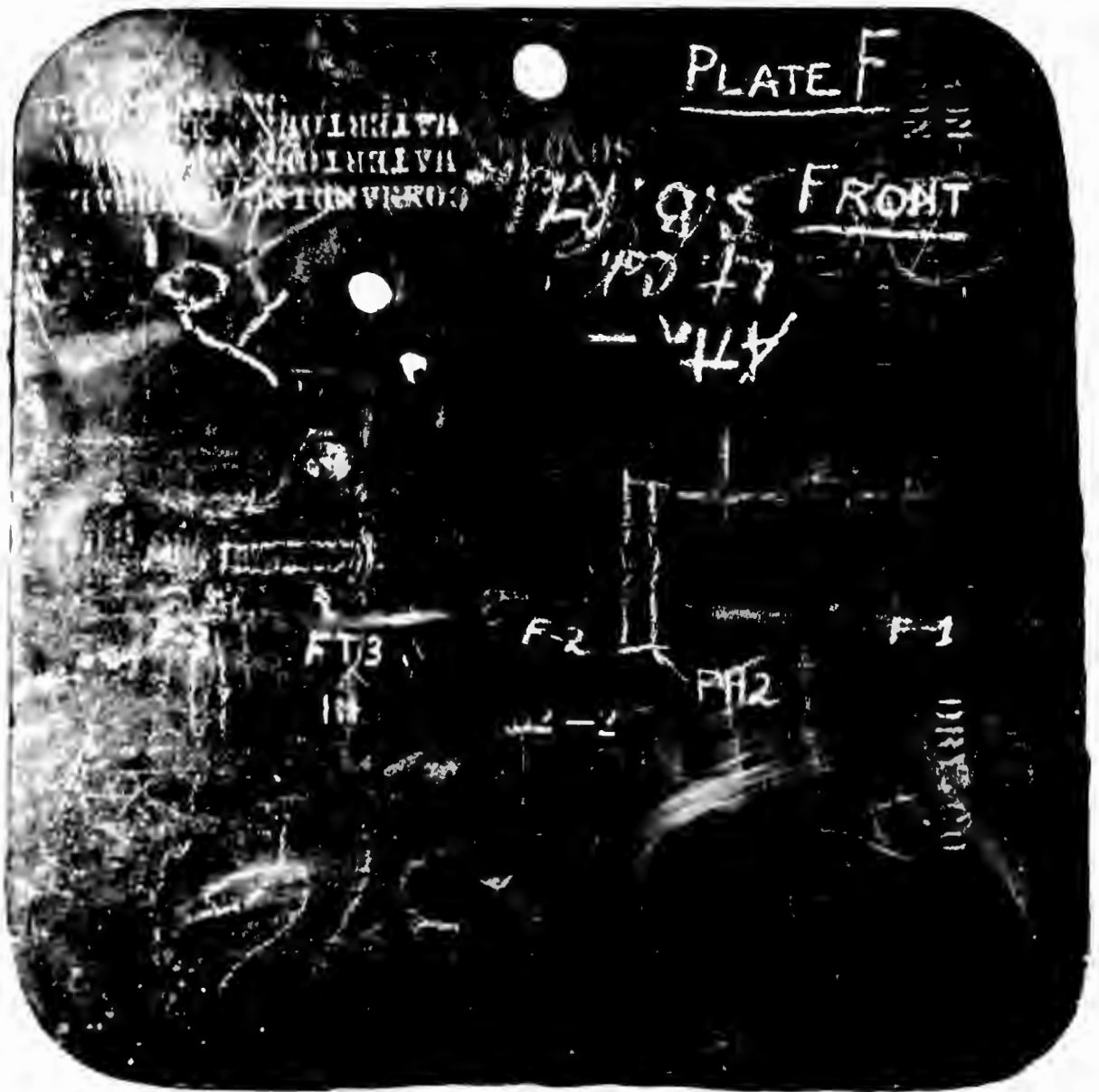




WATERTOWN ARSENAL

2" CAST ARMOR 36" X 36". GAS WELD IN GROOVE. AIRCO #1 ROD  
OCTOBER 1, 1941 W.A. 710-1445

FIGURE 2



WATERTOWN ARSENAL

2" CAST ARMOR 36" X 36". GAS WELD IN GROOVE. AIRCO #1 ROD  
OCTOBER 1, 1941 W.A. 710-1441

FIGURE 3



WATERTOWN ARSENAL

2" CAST ARMOR 36" X 36". GAS WELD IN GROOVE. AIRCO #1 ROD  
OCTOBER 1, 1941 W.A. 710-1446

FIGURE 4



WATERTOWN ARSENAL  
CROSS SECTION OF CAST ARMOR SHOWING CRACKS  
APRIL 8 1942 (MAG. X2) W.A.710-1806

FIGURE 5



x5

MACROPHOTO OF GAS WELD IN 2" CAST ARMOR  
NOTE LACK OF FUSION AND TRANSVERSE CRACK

FIGURE 6

W.A.639-4021

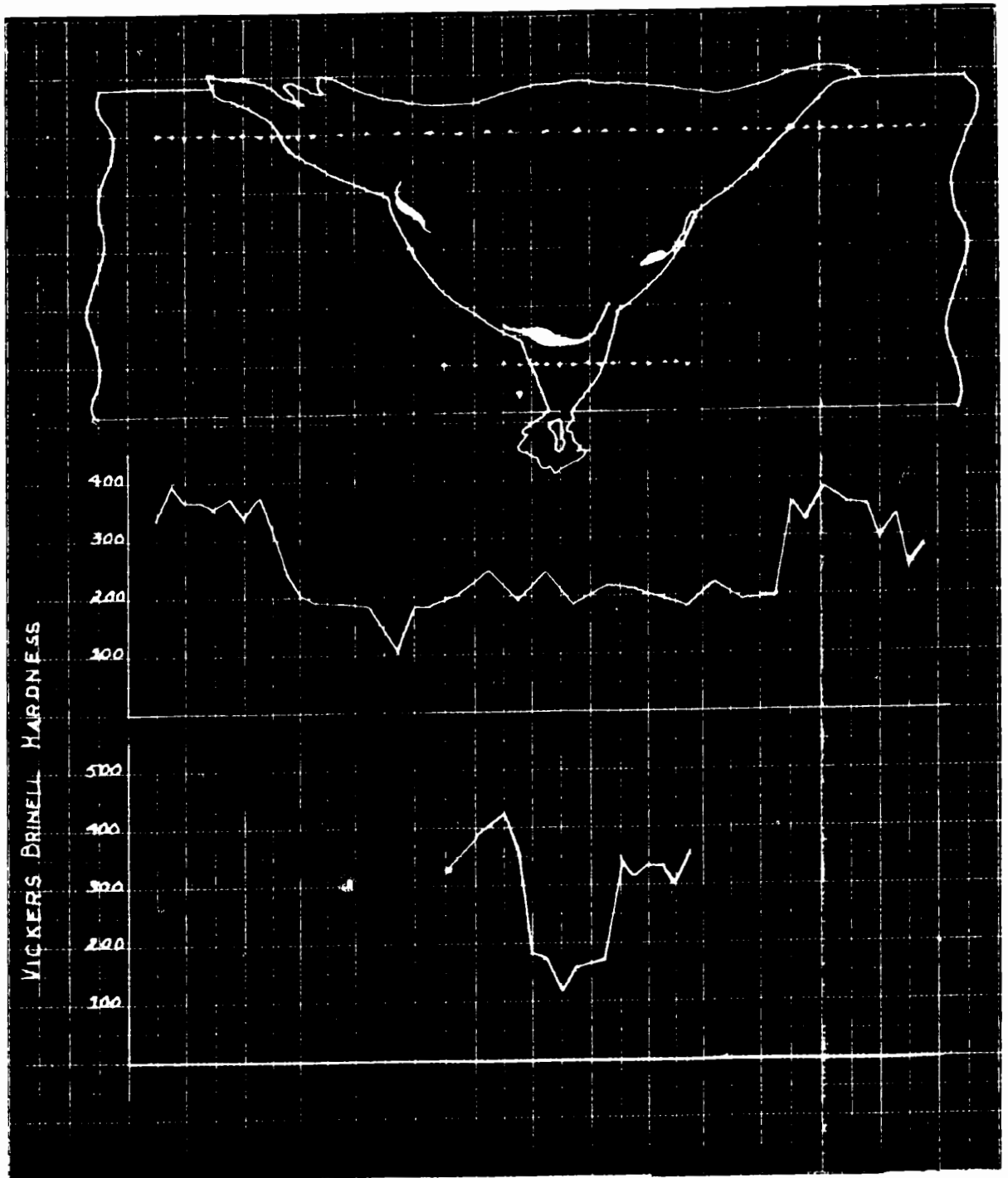
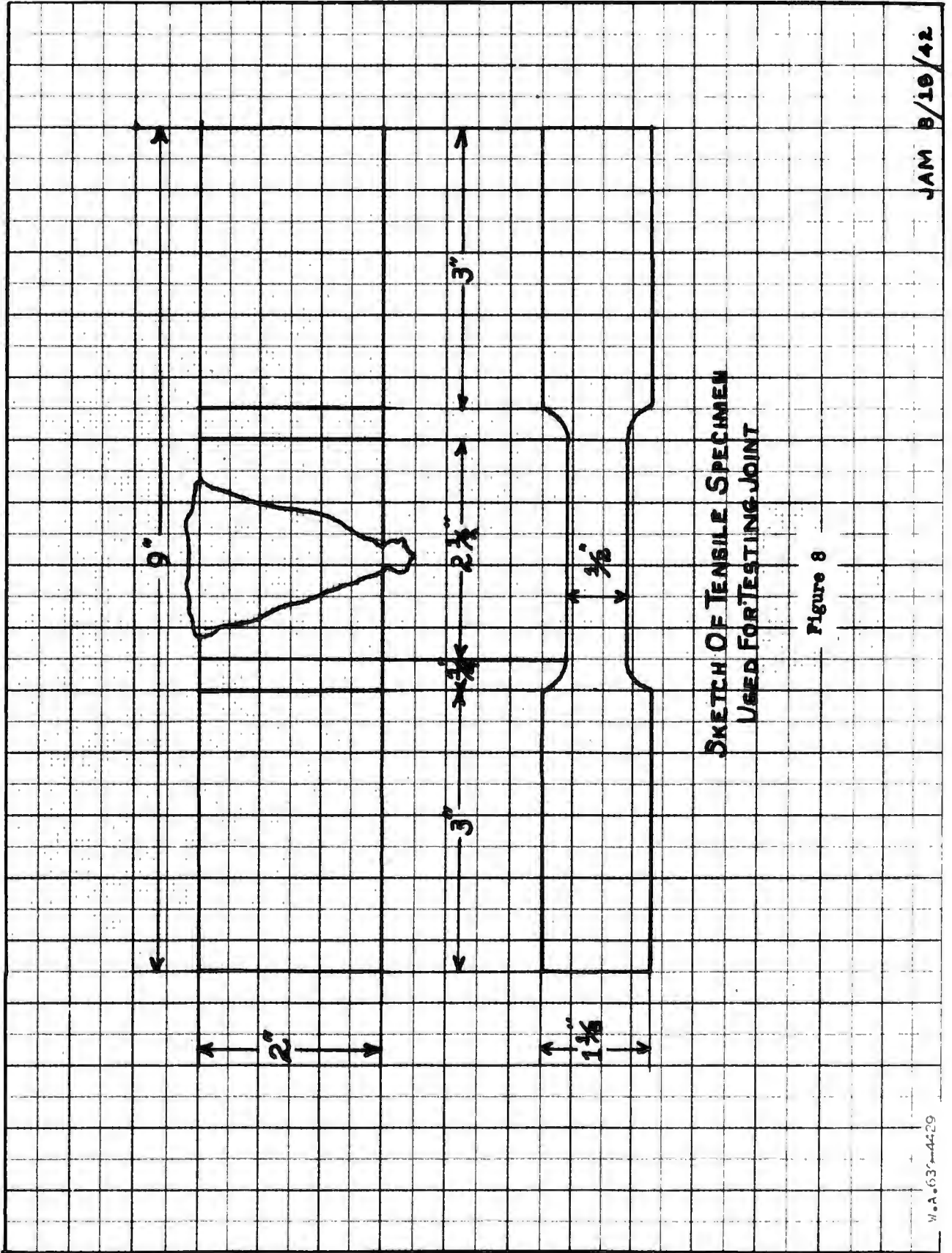


FIGURE 7

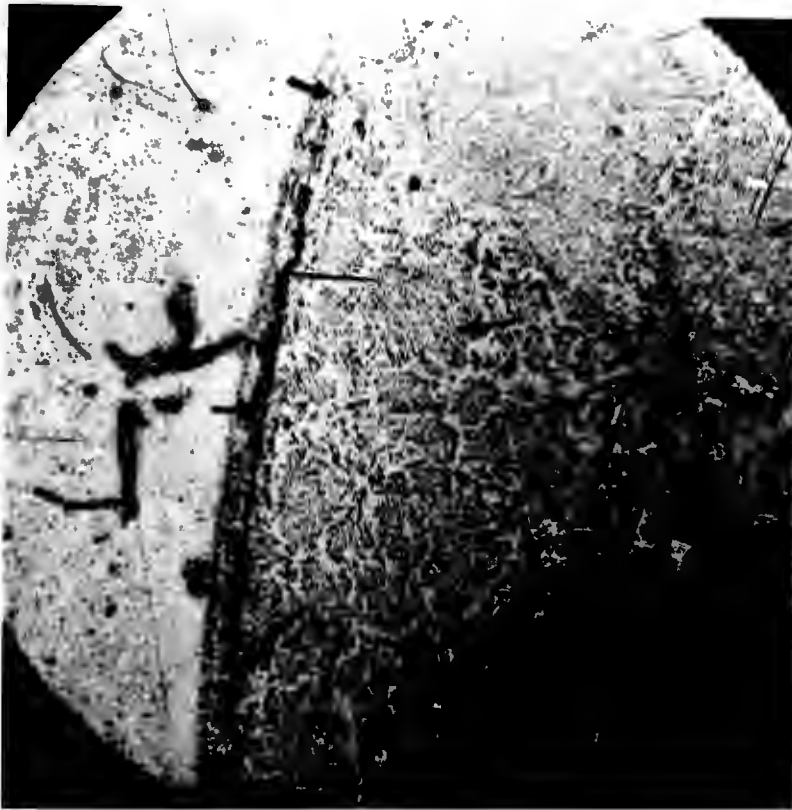
HARDNESS SURVEY OF CROSS SECTION GAS WELD IN 2" CAST ARMOR

W.A.639-4430



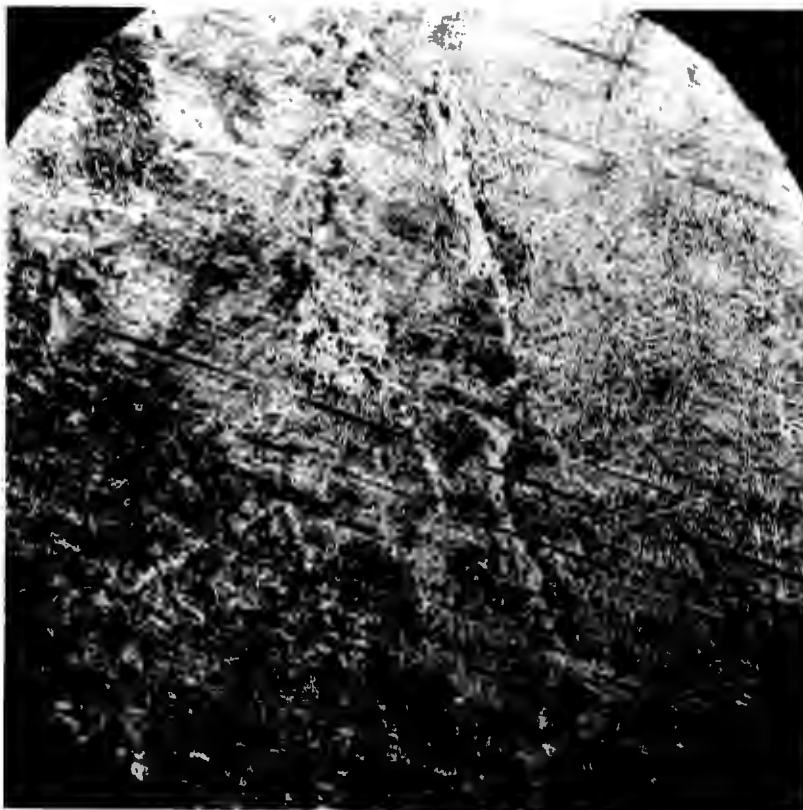
SKETCH OF TENSILE SPECIMEN  
USED FOR TESTING JOINT

Figure 8



**A** JUNCTION OF FILLER METAL AND ARMOR. NOTE CRACKS AND DENDRITIC STRUCTURE.

x25



**B** BOUNDARY OF TWO LAYERS OF WELD METAL. NOTE DENDRITIC STRUCTURE.

x 25

FIGURE 9

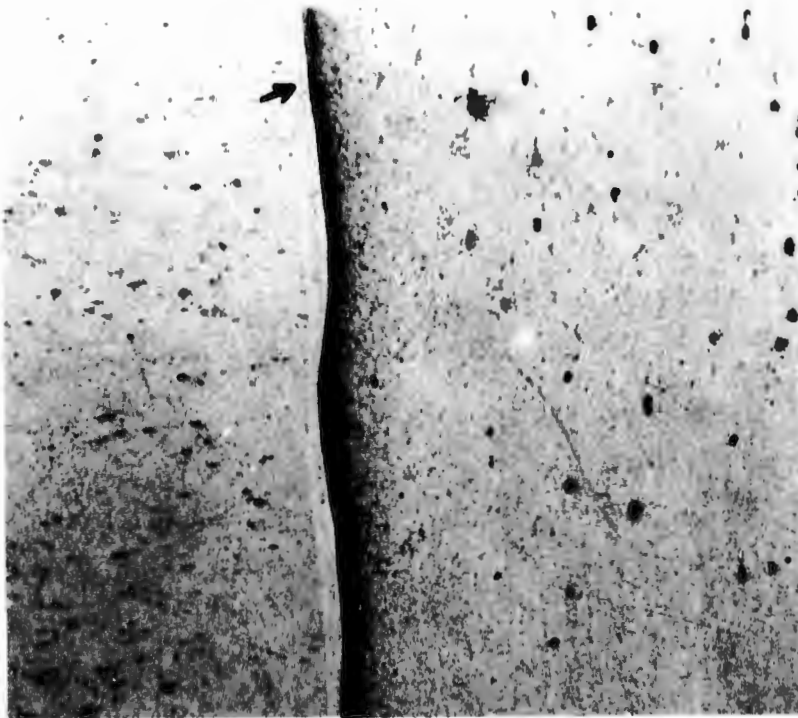
W.A.639-3922



A

X100

JUNCTION OF PLATE METAL  
AND FILLER METAL. NOTE  
ARROWS SHOW FINE CRACKS  
AND LACK OF FUSION.



B

X100

FIGURE 10

W.A.639-3921

APPENDIX A

**Basic Correspondence**

WAR DEPARTMENT  
OFFICE OF THE CHIEF OF ORDNANCEAttention of  
Arty. Div., Tech. Staff

WASHINGTON

June 6, 1941

SUBJECT: Welded Joints, and Weld Repair of Cracks and Penetrations  
in Cast ArmorTO: The Commanding General  
Aberdeen Proving Ground  
Maryland

1. In order to investigate the feasibility of making joints and repairing penetrations and cracks in cast armor under field conditions of welding, preliminary tests are proposed at Aberdeen Proving Ground.
2. All welding of rolled or cast armor investigated to date in the War and Navy Departments has been performed by the electric arc process. The use of the oxyacetylene method has not been investigated because the present development of this art is believed to produce results inferior to those obtained by the metallic arc. Under field conditions, it is anticipated that electric power may not always be available, or for other reasons the use of oxyacetylene welding equipment may be desirable or necessary in place of electric welding apparatus. One of the objections to gas welding is excessive heating of the base metal, and the consequent danger of destroying its ballistic resistance, yet the smaller temperature differential between the gas welding flame and the work as compared to that between the electric arc and the work may be in favor of the former. In spite of arguments against the use of gas welding, it is believed advisable to conduct ballistic tests and metallurgical examinations of gas welded cast plates of which the ballistic characteristics are known. The program outlined here is devised to prove whether the Linde or Airco processes of gas welding are satisfactory for making welds for repair of cracks and penetrations in cast armor. These processes are the same and were developed for speed welding of pipe lines. The technique of back hand welding with a low melting point, low nickel gas welding rod limits the degree to which the parent metal is heated. Though 25 chromium-20 nickel gas welding rods have not been used with these processes, they are included in this program.
3. A paragraph in all cast armor specifications forbids the use of flame treatment without specific authority of the Contracting Officer. Since the final tempering temperature for all but face hardened armor is approximately 1000°F, it is believed that preheating cast armor below

**SUBJECT: Welded Joints, and Weld Repair of Cracks and Penetrations  
in Cast Armor (Continued)**

this temperature, say to 300°F, will not be injurious to ballistic properties. Electrical strip heaters are regularly used by the Navy for welding rolled homogeneous armor. These are not now available in ordnance field welding equipment, hence gas preheating and postheating will be used.

4. Oxyacetylene welding of work thicker than 1/2" is an art not commonly possessed by welders, hence arrangements have been made for a demonstrator of the Air Reduction Sales Company to be present at the Proving Ground to perform the welding. Though a departure from "field" conditions, this service afforded by a supplier of gas and electric welding equipment is valuable in that it will give a fair trial to gas welding. Welding instructors at the Aberdeen Training Center will be able to make observations and obtain instructions from the Air Reduction Sales Company's demonstrator. A complete description of the welding technique will be reported.

5. Details of welded joints to be made are given on Welding Sketch 500 inclosed herewith. Materials required are as follows:

a. One restraining plate of mild steel, homogeneous armor or any other weldable steel, 3" thick. (If rolled plate is not available for this, it will be possible to devise a restrainer from other material available at the Proving Ground.)

b. Twelve cast armor plates 2" x 36" x 36" containing a minimum of penetrations, from which ballistic limits are known. These twelve are to be considered as six pairs. Of each pair, one plate is for gas welding followed by ballistic test and the other plate is for gas welding followed by metallurgical examination at Watertown Arsenal. A disturbing feature of this test is the variance in composition and heat treatment used by the various suppliers of cast armor. Weld tests of plates from each supplier are impractical, hence, an effort will be made to obtain matching plates from one supplier. In this way, a better comparison between results of metallurgical examination and ballistic tests of weldments will be possible.

c. Gas Welding Rods -

- (1) 3/16" Airco #1 - 25 pounds
- (2) 1/4" Airco #1 - 100 pounds
- (3) 3/16" 25-20 Cr-Ni--25 pounds ) electrodes with coating
- (4) 1/4" 25-20 Cr-Ni--100 pounds ) partially removed.

d. Standard welding torch with #10 and #12 tips.  
Standard cutting torch.

e. Twelve base metal thermocouples equally distributed along weld and fastened with K-E-File silver solder.

f. Portable pyrometer for above.

g. Twelve point selector switch.

h. Asbestos board or pulp insulation for covering both sides of plate to be welded.

**SUBJECT: Welded Joints, and Weld Repair of Cracks and Penetrations  
in Cast Armor (Continued)**

**6. PROCEDURE:**

a. Prepare cast armor plates by gas scarfing, attach thermocouples and weld each successively to the restrainer as shown on sketch attached. Mark and orient in position as shown in Table I. Preheat slowly with a gas torch to 300°F, - 400°F (50-50 solder melts at 437°F and leaves a brown heat tint.) Complete the longitudinal gas weld and weld the penetrations making temperature measurements at regular time intervals. Postheat slowly, cooling to room temperature in approximately one-half hour. Determine ballistic limits of welded plates. With these ballistic data as a basis, all or part of the remaining plates will be sent to Watertown Arsenal for metallurgical examination. Further details are given in Table I, as shown on page 4.

**SUBJECT: Welded Joints, and Weld Repair of Cracks and Penetrations  
in Cast Armor (Continued)**

TABLE I

| <u>Plates<br/>Marked</u>                  | <u>Position of<br/>Welding</u> | <u>Welded<br/>by</u>           | <u>Disposal of<br/>Welded Plate</u> |
|---|--------------------------------|--------------------------------|-------------------------------------|
| <u>Welded with Airco #1 Gas Rod:</u>      |                                |                                |                                     |
| 500-1-1-B                                 | Vertical                       | Air Reduction<br>Sales Company | Ballistic test                      |
| 500-1-1-M                                 | Vertical                       | Aberdeen<br>Proving Ground     | Metallurgical<br>examination        |
| 500-2-1-B                                 | Horizontal<br>(plate vertical) | Aberdeen<br>Proving Ground     | Ballistic<br>test                   |
| 500-2-1-M                                 | Horizontal<br>(plate vertical) | Air Reduction<br>Sales Company | Metallurgical<br>examination        |
| 500-3-1-B                                 | Flat                           | Air Reduction<br>Sales Company | Ballistic test                      |
| 500-3-1-M                                 | Flat                           | Aberdeen<br>Proving Ground     | Metallurgical<br>examination        |
| <u>Welded with 25-20 Gr - W1 Gas Rod:</u> |                                |                                |                                     |
| 500-1-2-B                                 | Vertical                       | Air Reduction<br>Sales Company | Ballistic test                      |
| 500-1-2-M                                 | Vertical                       | Aberdeen<br>Proving Ground     | Metallurgical<br>examination        |
| 500-2-2-B                                 | Horizontal                     | Aberdeen<br>Proving Ground     | Ballistic test                      |
| 500-2-2-M                                 | Horizontal                     | Air Reduction<br>Sales Company | Metallurgical<br>examination        |
| 500-3-2-B                                 | Flat                           | Air Reduction<br>Sales Company | Ballistic test                      |
| 500-3-2-M                                 | Flat                           | Aberdeen<br>Proving Ground     | Metallurgical<br>examination        |

**SUBJECT: Welded Joints, and Weld Repair of Cracks and Penetrations  
in Cast Armor (Continued)**

7. Arrangements will be made through the Industrial Service and cast armor makers to have the cast plates set aside for the subject tests. It is requested that these plates be prepared and welded at Aberdeen Proving Ground as a project of the Automotive Test and Research Division using the facilities, cooperation and assistance of the Welding School at the Training Center. In this way the School will obtain experience for instruction of field welders. As soon as all preliminary arrangements can be made, this office should be notified so as to obtain the services of the Air Reduction Sales Company's demonstrator. This demonstrator will remain only two days at the Proving Ground, hence, it is desirable that complete preparations can be made in advance and the first plate to be welded, be set up ready for welding.

By order of the Chief of Ordnance:

s/t

F. J. ATWOOD  
Lt. Colonel, Ordnance Dept.  
Assistant

Incl.-  
One Welding Sketch 500 (in dup.)

O.O. 470.5/3436  
APG. 470.5/1395

1st Ind.

WBR/SHS/jla

Aberdeen Proving Ground, Maryland. August 30, 1941. To: The Commanding General, Watertown Arsenal, Watertown, Massachusetts. Attention: Lt. Colonel S. B. Ritchie.

1. Two Continental Roll & Steel Foundry cast plates are being shipped by freight prepaid to Watertown. These plates are gas welded with Aircro No. 1 rod.

2. In addition, there are included in the shipment three Henry Disston plates which are arc welded.

3. The Disston plates were welded under letter file O.O. 470.5/4536. It is requested that all 5 plates be submitted to the same comparable metallurgical examination as specified in O.O. 470.5/3436.

4. It is further requested that this file be returned to Aberdeen Proving Ground.

For the Commanding General:

s/t

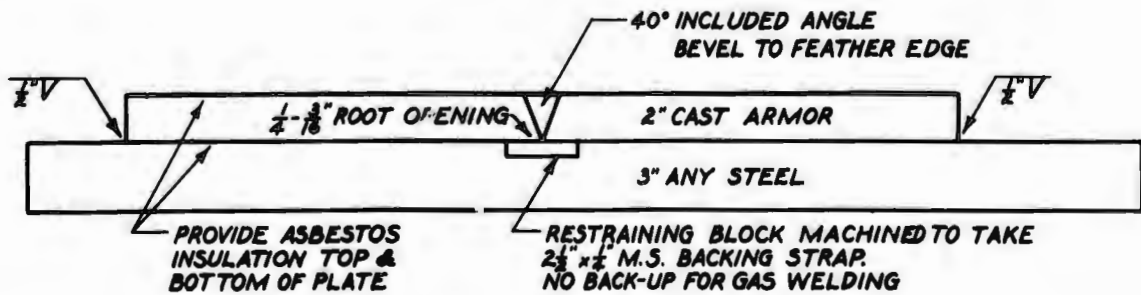
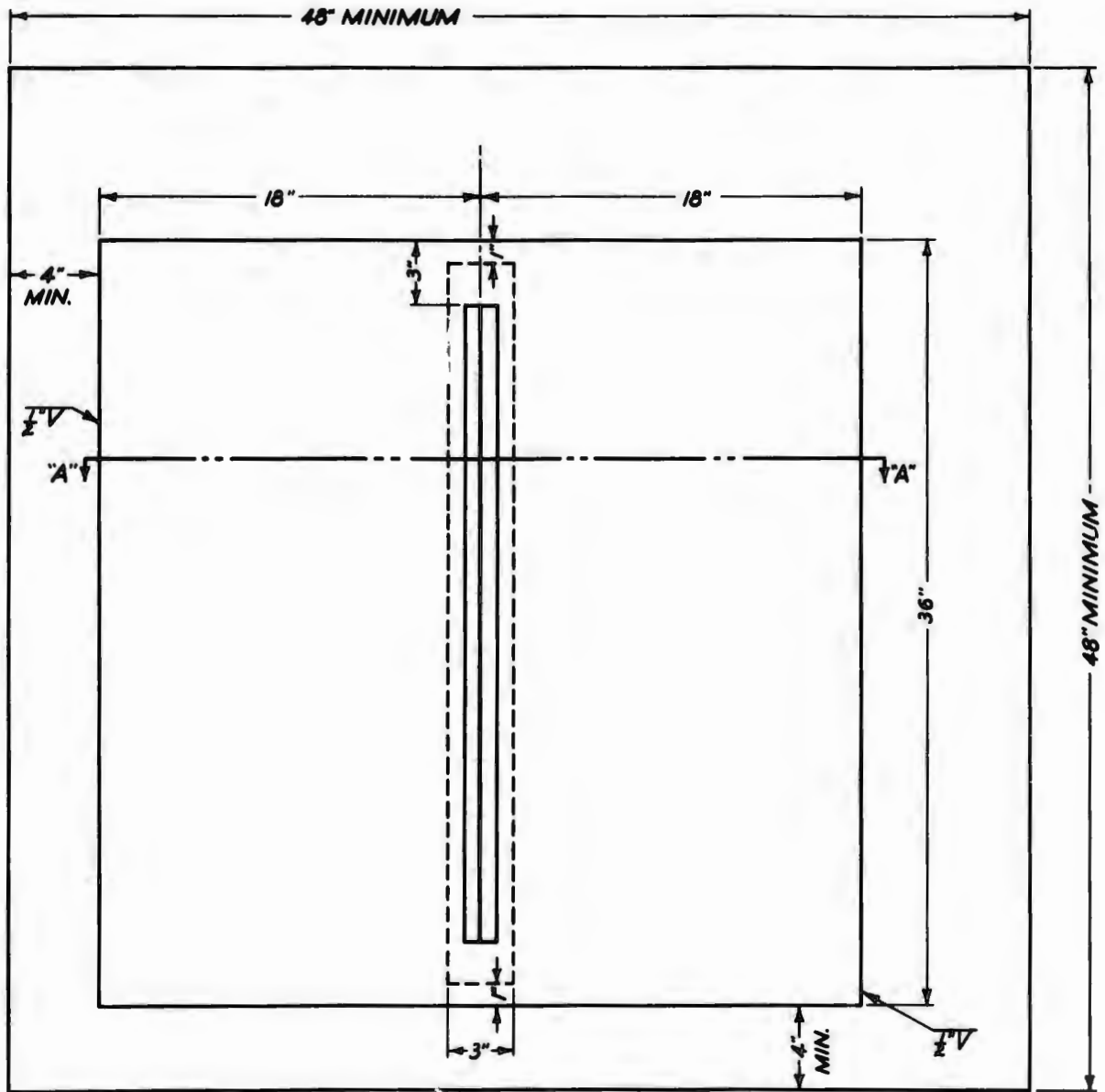
J. E. McInerney  
Major, Ord. Dept.  
Assistant (per H. G. McLean  
2nd Lt. Ord. Dept.)

5 Encls.  
Armor Welding Data Sheets

**APPENDIX B**

**Welding Sketch**

**Welding Data Sheets**



SECTION "A-A"

DIMENSIONS OF TEST PLATE FOR  
RESTRAINED WELD IN ARMOR  
(COPIED FROM ORDNANCE DEPT. TECHNICAL STAFF WELDING SKETCH NO. 500)

ARMOR WELDING DATA SHEET

Air Reduction  
Welded by Sales Co.

Ordinance  
Dept. Specification O.O. 470.5/3436

Location A.P.G.

Object: Experimental X

Date 7/25/41

Qualification \_\_\_\_\_

ARMOR:

Manufacturer Continental Roll & Steel Foundry

Type - Rolled Cast

Preheat 540 °F

F. H.

Postheat 1200 °F

Homo.

Heat Numbers:

Plate Numbers:

Thickness:

2982

2

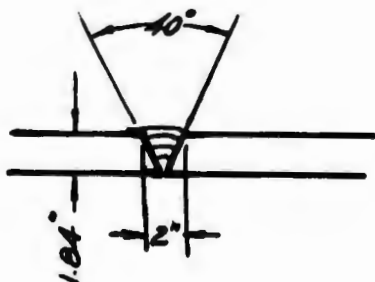
1.84

ELECTRODE:

Air Reduction Grade  
Manufacturer Sales Co. Name Airco Size 1/4"

Welding current ~~AC~~ Oxyacetylene

JOINT PREPARATION: machined, flame cut, ground, flame softened. Dimensioned sketch showing layers of weld metal, order of welding, peening, etc.



Weld cross section - 30" in length

REMARKS: To be analyzed as to sketch in O.O. 470.5/3436.

*Stanley H Simmons*  
Stanley H Simmons  
Und. Engr Aide

ARMOR WELDING DATA SHEET

Welded by Air Reduction Sales Co.

Ordnance Dept. Specification O.O. 470.5/3436

Location A.P.G.

Object: Experimental X

Date 8/4/41

Qualification \_\_\_\_\_

ARMOR:

Manufacturer Continental Roll & Steel Foundry

Type - Rolled Cast X

Preheat 531.86°F

F. H.

Postheat 1200 °F

Homo. Cast X

Heat Numbers:

Plate Numbers:

Thickness:

2771

3

1.93 around weld

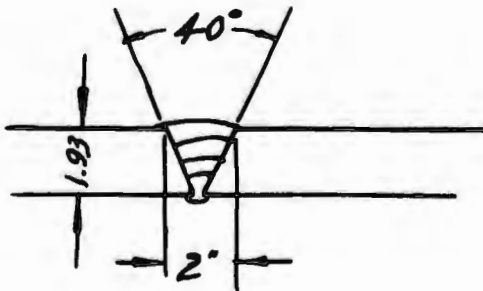
1.71 at plate corners

ELECTRODE:

Manufacturer Air Reduction Trade Sales Co. Name Airco Size 1/4"

Welding current ~~AC~~ Oxyacetylene

JOINT PREPARATION: machined, flame cut, ground, flame softened. Dimensioned sketch showing layers of weld metal, order of welding, peening, etc.



Weld Cross Section - 30" in length

REMARKS: This plate to be analyzed as to sketch in O.O. 470.5/3436.

*Stanley H. Simmons*  
Stanley H. Simmons  
Und. Engr. Aide