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CGI/447



# WATERTOWN ARSENAL LABORATORY

## MEMORANDUM REPORT

NO. WAL 640/153

WELDING OF ARMOR

Examination of Samples from "H" Welded Ballistic Test Plates  
Three Submitted by Chrysler Plymouth Corporation and One by  
General American Transportation Company

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JUN 29 1984

BY

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1st Lt., Ord. Dept.

**B**

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DATE 15 March 1945

**WATERTOWN ARSENAL**  
**WATERTOWN, MASS.**

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 640/153

Problem Numbers D-16.5 and D-16.6

15 March 1945

WELDING OF ARMOR

Examination of Samples from "H" Welded Ballistic Test Plates  
3 Submitted by Chrysler Plymouth Corporation and 1 by  
General American Transportation Company

OBJECT

To carry out examination of subject samples in accordance with instructions from SPOTZ-F.

SUMMARY

1. Nick-break and bend fracture tests were made for the four weld joint samples.

2. Crystallinity of the cast armor was observed in the nick-break fracture test for plate CP-72 which developed excessive base metal cracking during ballistic shock testing. Bend fracture test bars from plates CP-65, CP-72 and GAT-28 failed in the weld metal next to the fusion line after slight plastic deformation. The bend fracture test from plate CP-73 failed in a similar manner after appreciable plastic deformation.

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## INTRODUCTION

Samples from four ballistically tested "H" welded 1-1/2 inch thick homogeneous armor plates were subjected to laboratory fracture tests in accordance with instructions from SPOTZ-F (see basic correspondence Appendix B).

## TEST MATERIALS AND TEST PROCEDURE

Samples approximately 12 inches x 12 inches x thickness of plate were flame-cut from a portion of undamaged weld of the plates as follows:

<u>Plate No.</u>	<u>Location of Sample</u>
CP-65	Upper right leg
CP-72	" " "
CP-73	" " "
GAT-28	----

Firing record data including fabricator, armor composition and manufacturer, electrode composition and manufacturer, joint preparation, welding procedure, and ballistic test results have been abstracted from Aberdeen Proving Ground Armor Test Reports AR-15264 and AR-15387 and tabulated on the charts of Appendix A.

Samples were notched and broken as indicated in Figure 1 to develop fibre characteristics of the plate metal, heat affected zone and weld metal on fractured surface through weld joint. From one half of the fractured specimens, bend bars one inch wide were taken transversely through the weld joint. Bend bars were broken as shown in Figure 2 with slow rate of loading at approximately +70°F. One half of the broken bar was ground and macroetched to show path of fracture.

## TEST RESULTS

### Nick-Break Fracture Tests:

Photographs of the fractured surfaces are shown in Figure 3. Crystallinity of the unaffected cast armor was observed through the thickness of plate CP-72 and in patches through the thickness of plate CP-65. Subsurface porosity in plate CP-65 and centerline shrinkage of all three plates, but most pronounced in plate CP-73, were evident. Weld metal and heat affected zone fractures were fibrous.

### Bend Fracture Tests:

Photographs of macroetched sections and bend bar fractures are shown in Figure 4. Failure was almost entirely through the austenitic weld metal adjacent to the fusion line. A few small patches of fine crystalline appearance indicate some failure at the fusion line or plate metal adjacent

to fusion line. At the root of plate CP-73 a portion of the fracture runs along the heat-affected zone and plate metal through centerline shrinkage cavities.

GENERAL COMMENTS

Excessive ballistic cracking in the base metal of plate CP-72 correlates with the observation of crystallinity of the cast armor in the nick-break test. Ballistic failure of the weld joints in plates CP-65, CP-72, and GAT-28 with fracture in the weld metal next to the fusion line would be expected since the failure of bend fracture test bars occurred in this manner with little deformation. The bend fracture of plate CP-73 while largely of the same fusion zone type did not occur until the bar had plastically deformed appreciably. This may indicate that a higher velocity impact would be required to start ballistic cracking in this plate than that used for testing this plate.

Load-deflection measurements on bend bars, which may permit determination of the energy required to start and to propagate failure are being studied. Specimens have been obtained from plates CP-72 and CP-73 for study of fusion zone microstructures and results of these tests will be given in a report on causes of fusion zone failures.

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APPENDIX A

1. Key to tabulation method and symbols.
2. Tabulation charts of firing record data.

## Key to Tabulation Method and Symbols

### Armor Data

A.O.H. - acid open hearth.  
Elec. - electric  
B.O.H. - basic open hearth.  
B. Elec. - basic electric

### Joint Design

DV - double vee

### Deposition Types

Figure 1 shows how the weld is broken up into root, body and crown types. Passes are divided into two kinds: (a) layer, if pass bridges the gap, and (b) bead, if the pass does not bridge the gap.


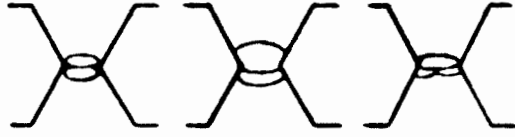
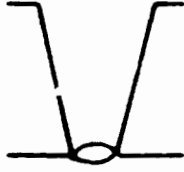
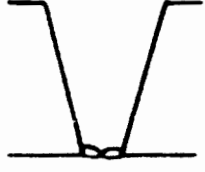
### Ballistic Results

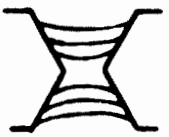

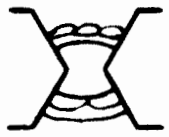
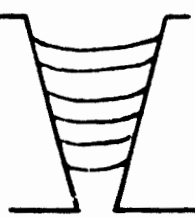
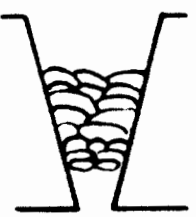
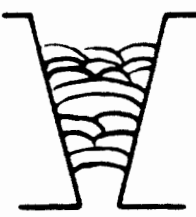
H - hit  
F/S - feet per second  
L.L. - left leg  
R.L. - right leg  
CB. - crossbar  
LOC. - location  
R - right of  
L - left of  
X - on weld  
U - above  
D - below  
IMP - running from or through impact  
O - not running from or through impact

### Cracking Types

I - weld (includes weld, fusion zone, and heat-affected zone cracking within 1/8 inch from weld)  
IV - star plate cracking  
V - linear plate cracking

Cracking is measured on the back of the plate.

Root types	Type I	Type II
Double V bevel	 Single root bead in center of root	 etc. More than one bead at root
Single V bevel	 Single bead bridging root gap	 etc. More than one bead bridging root gap

Body types	Type I	Type II	Type III	Type IV	Type V
Double V bevel	 Layers only	 Beads only	 Layers & beads	Unionmelt	Special
Single V bevel	 Layers only	 Beads only	 Layers & beads	Unionmelt	Special


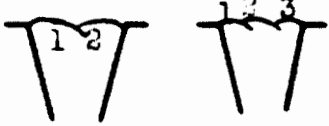
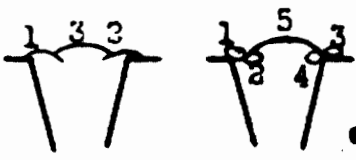
Crown types	Type I	Type II	Type III
Double V & Single V bevel	 Single Crown Single pass bridges gap	 Multiple Crown Last bead touches parent metal	 etc. Multiple Crown Last bead does not touch parent metal

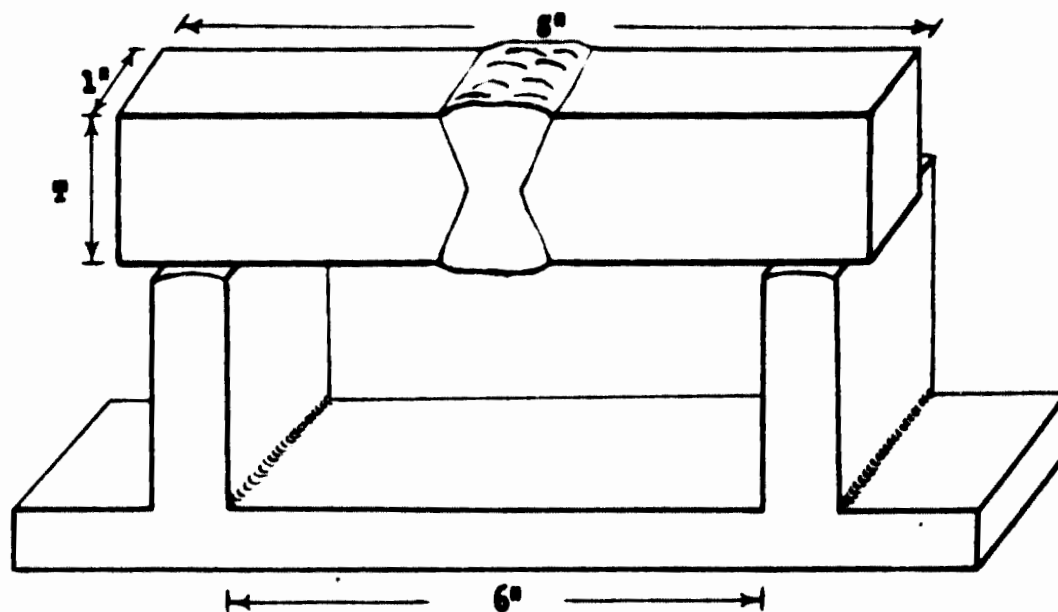
Fig. 1 Weld Metal Deposition Types



IDENTIFICATION	ANNEAL DATA	ELECTRODE DATA	JOINT DESIGN	WELDING PROCEDURE	HEAT	BALLISTIC RESULTS								RESULTS OF CRACKING	
						#	VEL.	LOCATION OF D.			CRACKING		RADIOGRAPHIC RESULTS, ETC.		
A. DESIGN NUMBER NO. B. DATE OF TEST C. PLATE NO. D. ANNEAL MANUFACTURER E. ELECTRODE MFG. F. ANNEAL PARTICULARS	A. PLATE THICKNESS B. TYPE C. CARBON CONTENT D. SIZE E. PROCESS F. HEAT TREATMENT TEMP. TIME SOURCE G. Nr.	A. TYPE B. TRACE MARK C. COATING D. CURRENT & POLARITY	A. GROOVE, INCLUDED ANGLE, ROOT FACE B. ROOT GAP C. PLATE PREPARATION	A. SECTION B. DEPOSITION SIZE EL. NO. TYPE AND V. 1. ROOT TYPE 2. ROOT TYPE 3. GORDEL TYPE C. TOTAL WELDING TIME & INTER PASS TEMPERATURE D. REMARKS	A. PRE B. POST		V/S	L.L.	R.L.	C.B.	LOC.	TYPE	LEN		
A. AR-10507 B. 12/22/44 C. G.A.T. 20-B D. Carnegie-Illi- sols E. Crucible McKay F. General American Transportation	A. 14" B. Rolled 1.25% Mn, .22% Si .012% P, .012% S .88% Cr, .75% Ni, .37% Cu. C. 0.25 D. Face 200 Back 202 E. Elec. F. rise soak 1500 1 1/2 H <sub>2</sub> O 1070 1 1/2 H <sub>2</sub> O	A. Automatic Crucible: .15C S. 81% Ni, .41% Si 19.0% Cr, 9.5% Ni, 1.0% Mn McKay: .15C, 4.25% Mn, .80% Si, 19.0% Cr, 9.75% Ni, .60% Cu. B. Armco C. Crucible: TiO <sub>2</sub> McKay: Lime D. DC; Rev.	A. 45° DV B. 3/16" C. Machining	A. Copper B. 1. I 3/16" McKay 1 a 180 22 2. II 3/16" McKay 1 a 200 22 4 b 200 22 1/4" Crucible 3 a 275/280 22 4 b 275 22 B. II 1/4" Crucible 4, b 275 22 C. _____; 100-100° F. D.	A. None B. None	1	1104	1/4" R			7 1/2"	U	I	26"	Passed radiographic inspection.
															7 in Free projectile 731



Load applied to center of weld



Supported on six-inch span; bars of 1 inch and 1 1/2 inch thickness broken in a steam press; bars of lesser thickness broken with one blow of drop weight

Figure 2. Bend Fracture Test of Weld Joint

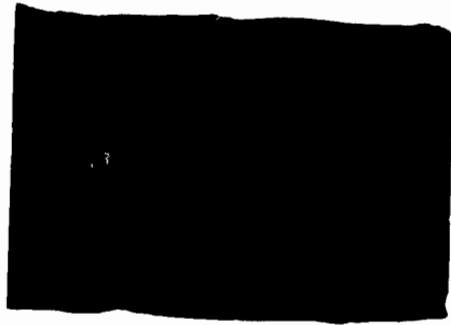


Plate  
CP-65



Plate  
CP-72

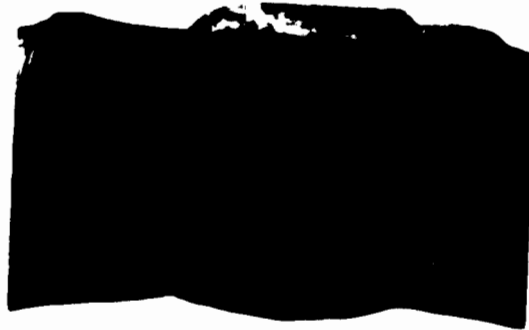


Plate  
CP-73

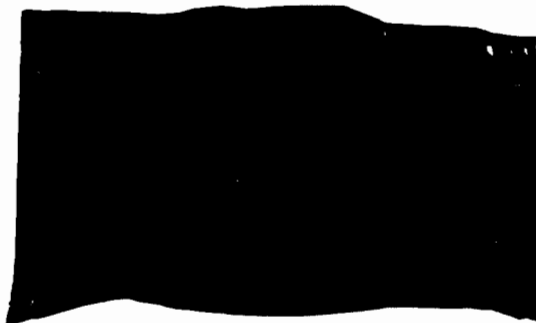


Plate  
GAT-28

WTN.639-7741

Weld Joint Nick-Break Fractures

Figure 3



Plate CP-65

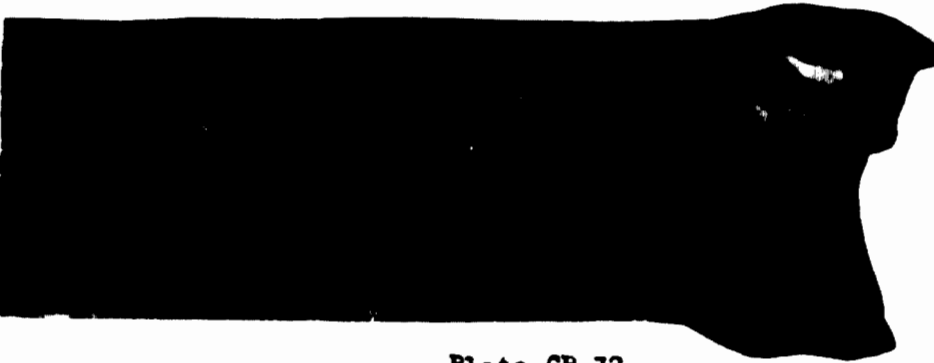


Plate CP-72

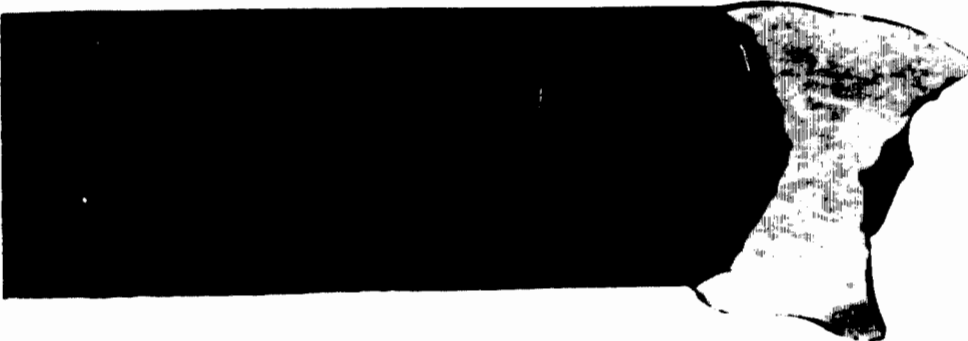


Plate CP-73



Plate GAT-28

WTN.639-7742

Weld Joint Bend Fractures

Figure 4

**APPENDIX B**

**Basic Correspondence**

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ARMY SERVICE FORCES  
ORDNANCE DEPARTMENT  
ABERDEEN PROVING GROUND  
MARYLAND

18 December 1944

SPOTZ-F

Subject: Nick Break and Bend Test of Weldments

To: Commanding Officer  
Watertown Arsenal  
Watertown, Massachusetts

Attention: Laboratory

1. In accordance with previous agreements in regard to "Nick Break and Bend Tests of Weldments", this installation has shipped to Watertown Arsenal three samples of cast homogeneous welded plates 12"x12"x1-1/2" which may be identified as follows:

<u>Sample No.</u>	<u>Fabricator</u>	<u>Plate No.</u>	<u>Location of Sample Area</u>	<u>Armor Test Report</u>
CP-65	Chrysler-Plymouth	CP-65	Upper Right Leg	Ar-15264
CP-72	" " "	CP-72	Upper Right Leg	Ar-15264
CP-73	" " "	CP-73	Upper Right Leg	Ar-15264

2. Attention is called to the fact that these samples were cut from the plates so as to include the edge of the plate. Hence, it is suggested that the part of the sample to be used in the bend tests be taken from an area not too close to this edge. Also, it should be noted that the samples were cut from that leg weld which upon the ballistic test developed cracking which was mainly of one type.

3. It will be appreciated if your installation will perform the nick break and bend tests on these samples. It is requested that the test specimens be returned to this installation and that, if possible, the results be furnished this office by indorsement as soon as they are available.

For the Commanding General:

(s/s) S. G. JUNE  
Col., Ord. Dept.  
Director

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WAR DEPARTMENT  
ABERDEEN PROVING GROUND  
MARYLAND

3 January 1945

SPOTZ-F

Subject: Sample from Plate GAT28

To: Commanding Officer  
Watertown Arsenal  
Watertown, Massachusetts

Attention: Laboratory  
Lt. Herres

1. In accordance with a previous agreement with Watertown Arsenal with regard to the development of the "Nick Break" and "Bend" tests for welded armor this installation has shipped one sample 1-1/2"x5"x10" marked No. 28 from Plate No. 28 submitted by General American Transportation Company. Report of the ballistic test has been submitted in Armor Test Report No. AR-15387.

2. It is requested that after all desirable tests have been completed on it this sample be returned to this installation to be used in acquainting the personnel of this installation with the characteristics of interpretation of the test.

For the Commanding General:

(s/t) G. G. HEDY  
Colonel, Ord. Dept.  
Director  
Ord. Res. & Dev. Center

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