AD NUMBER: ADA953331
CLASSIFICATION CHANGES
TO: Unclassified
FROM: Confidential
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to U.S. Defense agencies only; Test and Evaluation; 25 Mar 1944. Other requests shall be referred to Army Watertown Arseanal, Materials Tech Lab, Watertown, MA 02172
AUTHORITY
C to U: 30 Nov 1965, DoDD 5200.10, gp-4 E/4 to A/1. 28 Jun 1984, per document marking

AD NUMBER: ADA953331
CLASSIFICATION CHANGES
TO: Confidential
FROM: Restricted (Mar 1944)
AUTHORITY
5 Nov 1953, EO 10501

(1)

640/106

EXTRA COPY

2

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 640/106

WELDING OF ARMOR

Weld-Bead Tests on Samples from
Union Steel Castings Company Turret No. 3391,
Poured from a Cast Armor Heat Containing Selenium

BY

S. A. Herres
1st Lt., Ord. Dept.

DATE 25 March 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

ahk

~~RESTRICTED~~

UNCLASSIFIED

WATERTOWN ARSENAL LABORATORY
MEMORANDUM REPORT NO. WAL 640/106

Problem Number D-1.10

25 March 1944

WELDING OF ARMOR

Weld-Bead Tests on Samples from Union Steel Castings Company Turret No. 3391, Poured from a Cast Armor Heat Containing Selenium

OBJECT

To deposit weld beads on samples from subject cast armor and to examine resultant welds for defects associated with presence of selenium.

SUMMARY OF RESULTS

1. Weld-bead deposits made on subject cast armor using ferritic electrodes coated with usual commercial cellulosic type coatings show considerable porosity.

2. Weld-bead deposits made on same armor using either ferritic or austenitic electrodes with all-mineral (lime base) coatings or with uncoated mild steel electrodes are free of excessive porosity.

3. The usual type of under-bead cracking (hard cracks) in the heat-affected zone, which would be expected when depositing weld bead with ferritic electrodes, having cellulosic type coatings, on steel with the hardenability of this armor and without preheat, was not evident.

4. It is considered that the porosity of weld metal associated with the use of cellulosic coated electrodes is caused by a chemical reaction in the molten weld metal between the hydrogen from the coating and the selenium from the base metal.

5. This chemical reaction between hydrogen and selenium is believed to be sufficient to reduce the hydrogen concentration in the weld metal below that required to cause hard cracks to form in the heat-affected zone.

6. No deleterious welding effects other than porosity appear likely to result from small additions of selenium to cast armor.

E. A. Herres
1st Lt., Ord. Dept.

~~RESTRICTED~~

UNCLASSIFIED

INTRODUCTION

Union Steel Castings Company cast armor turret No. 3391, which was poured from Heat No. 374-B containing selenium, was forwarded to this arsenal for metallurgical investigation (see Basic Correspondence, Appendix A). After complete radiographic examination, two sections 12 inches square were cut out of the turret for welding tests.

Chemical composition of Union Steel Castings Heat No. 374-B is reported in the basic correspondence (Appendix A) as follows:

C	P	Mn	S	Si	Cr	Mo
.31	.036	1.77	.023	.38	.42	.35

The amount of selenium added or the specific purpose of this addition is not known. However, it may be assumed that the selenium addition was for the same general purpose as discussed in U. S. Patent No. 2,258,604, A. P. Gagnebin, assignor to the International Nickel Company, wherein claims are made that the addition of an amount to about .6% of an intensifying agent comprising alkaline earth metal and an amount to about .6% of at least one sulphur-desensitizing agent from the group consisting of selenium and tellurium to molten steel results in production of castings characterized by freedom from porosity, by freedom from chain-like sulfides, by fine grain size, and by a higher combination of strength and ductility including impact strength, than a similar steel not treated with these addition agents.

Recent tests at this laboratory* indicate that additions of selenium in amounts from .01 to .12% to a .32 C, 1.5 Mn, .35 Si, .25 Mo steel do not change the hardenability or physical properties appreciably, but lower the impact values a small amount. Selenium was added as a metal to this heat, which was made in a small acid-lined induction furnace, after deoxidation with aluminum (2 lbs./ton), and the test results do not preclude the possibility of considerable improvement in properties of either inadequately deoxidized or "over-reduced" steels by addition of calcium selenide.

It is understood that serious difficulties were encountered in arc welding of the selenium-containing cast steel. Presumably the difficulty was porosity in the weld metal which was observed during repair welding with commercial ferritic electrodes. In the absence of further information, this investigation was limited to making single bead tests with various ferritic and austenitic electrodes on samples from this armor, and examining the beads for soundness of weld deposit and hardness and susceptibility to cracking of the weld heat-affected zone of base metal.

---

* Report No. 710/495 (Watertown Arsenal Laboratory), entitled "Armor - Preliminary Study of the Effect of Several Alloying Elements and Addition Agents upon the Metallurgical Properties of Manganese-Molybdenum Steel Used in Armor."

TEST MATERIALS AND PROCEDURE

Twelve blocks, 3 x 6 x 1 inches, were obtained from Union Steel Castings turret No. 3391 after complete radiographic examination of the turret. Blocks were Blanchard ground to give smooth top and bottom surfaces.

Single weld beads, 3 inches long, were deposited along centerline of top surface of blocks using an automatic stick-feed welding head. Electrode and welding conditions used for each bead are given in Table I. The first four bead specimens were cleaned with wire brush to remove slag and scale and photographed to show porosity visible on surface. Specimens 5 through 9 were sectioned for Vickers-Brinell hardness survey, as shown by Figure 1, then macroetched for crack inspection. The tenth bead specimen was made with an uncoated electrode and examined visually for surface porosity, and for porosity after grinding bead flush with plate.

DATA AND DISCUSSION

1. Radiographic Examination of Turret

Radiographic examination showed the porosity existing in this turret to be slightly less than that in the average cast turret. Shrinkage conditions were about average as compared to other cast turrets, while hot tears were more numerous than usual.

2. Visual Inspection of Weld Bead Deposits

Figure 2 is a photograph of the top surface of weld beads deposited on subject cast armor. FW-8 and MLY (see Table I) are ferritic deposits (AWS E-2020 and E-7010 respectively) made with electrodes which have coatings containing cellulose. AW-2C and 18/8 are ferritic and austenitic deposits, respectively, made with electrodes which have lime base all-mineral type coatings. Considerable surface porosity is evident in the first two beads while the latter two appear entirely sound. A bead made with a bare low carbon electrode was examined visually for surface porosity and porosity after grinding flush with plate, and found to be free from gas holes such as are exhibited by samples FW-8 and MLY of Figure 2.

3. Hardness Surveys

Weld-hardenability curves for single weld bead deposits made with 18/8 austenitic and AW-2C and FW-8 ferritic electrodes are plotted in Figure 3. Maximum hardness and depth of heat-affected zones are entirely consistent with expectations for single bead welds on steel of the nominal chemical composition of this armor when welded under similar conditions.

4. Macroexamination

Figure 4 is a photograph of sections of single weld bead deposits used for hardness surveys after etching for 1/2 hour in hot 1-1 hydrochloric acid. Porosity is again evident in weld metal of deposit made with Fleetweld 8 electrode, while weld metal deposits made with electrodes having lime base all-mineral type coatings are sound. No weld or base metal cracking is evident. As under-bead cracking usually occurs when making single bead deposits without preheat on steel of equivalent carbon and alloy content if ferritic electrodes having cellulosic type coatings are used, additional sections were taken from the block welded with Fleetweld 8 electrode and examined for under-bead cracks. No cracks were observed.

5. General Considerations

Weld metal porosity is encountered when selenium-containing cast armor is welded with an electrode having a coating which liberates hydrogen-bearing gases during the welding cycle. A considerable volume of hydrogen is absorbed by the molten weld metal from such an atmosphere during the welding cycle and the dissolved hydrogen very possibly reacts with selenium, present in the portion of the base metal which is melted during the welding operation, generating H_2Se gas bubbles which are trapped during solidification of weld metal causing porosity. Electrodes with lime base all-mineral coatings, or uncoated electrodes, do not cause porosity apparently because much less hydrogen is available in welding atmosphere for reaction with the selenium from the melted base metal.

Under-bead cracking tendency has been related to hydrogen absorbed by the weld metal during the welding cycle.* The absence of under-bead cracks, which ordinarily would be expected to be present when single bead deposits are made using Fleetweld No. 8 electrode, without preheat, is logically associated with decrease in hydrogen concentration in the molten weld metal due to chemical reaction with selenium and diffusion of hydrogen atoms into the resultant H_2Se gas bubbles.

Further experiments have demonstrated that the same effects may be observed when welds are deposited on steels of relatively high sulphur content. Porosity in this case may be a result of formation of H_2S.

Other than porosity, which may be eliminated by use of electrodes with all-mineral type coatings, no deleterious welding effects due to small additions of selenium to cast armor, either through increased cracking tendencies or impairment of mechanical properties of weld metal or heat-affected zone, appear likely.

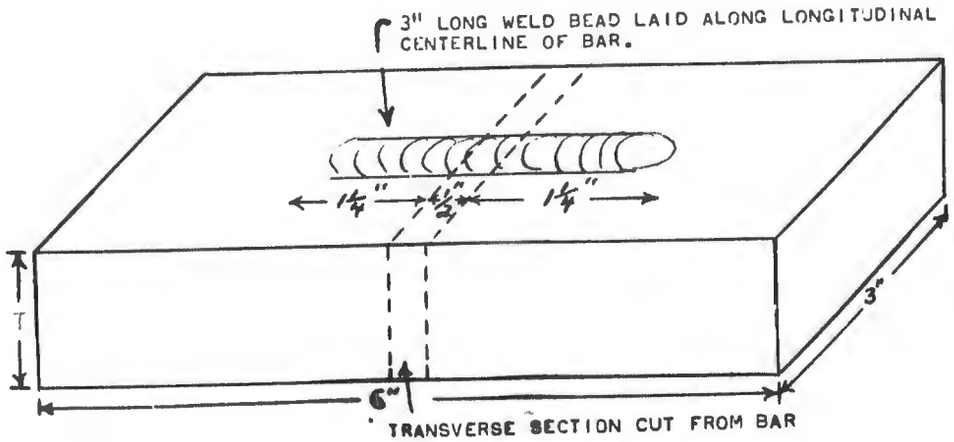
---

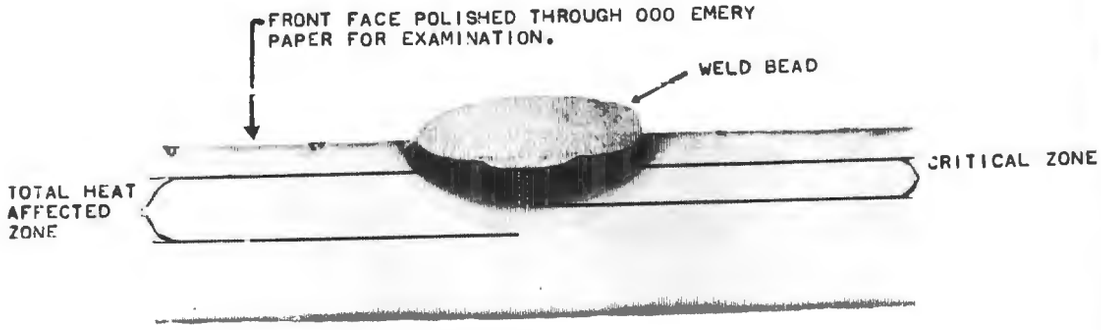
* Watertown Arsenal Laboratory Report No. 642/115, entitled "Arc Welding of Alloy Steels - Study of Base Metal Cracks Associated with Effects of Arc Welding Process."

TABLE I

Welding Data for Single Bead Tests

Spec. No.	Electrode	Amperes	Arc Volts	Polarity	Travel Speed	Type of Bead
1	3/16" dia. Lincoln Fleetweld #8	195	24	Reverse	5"/Min.	Stringer
2	3/16" dia. Hollup Sureweld MLY	195	24	Reverse	5"/Min.	Stringer
3	3/16" dia. Harnischfeger AW2C	195	24	Reverse	5"/Min.	Stringer
4	3/16" dia. Crucible Rezistal 18/8	195	24	Reverse	5"/Min.	Stringer
5	3/16" dia. Crucible Rezistal 18/8	195	24	Reverse	5"/Min	Stringer 9/16" wide
6	3/16" dia. Crucible Rezistal 18/8	195	24	Reverse	5"/Min.	Weave 11/16" wide
7	3/16" dia. Harnischfeger AW2C	200	26	Reverse	5"/Min.	Stringer 9/16" wide
8	3/16" dia. Harnischfeger AW2C	200	26	Reverse	5"/Min.	Weave 11/16" wide
9	3/16" dia. Lincoln Fleetweld #8	195	24	Reverse	5"/Min.	Stringer
10	5/32" dia. Uncoated Mild Steel Electrode	190	18	Straight	5"/Min.	Stringer

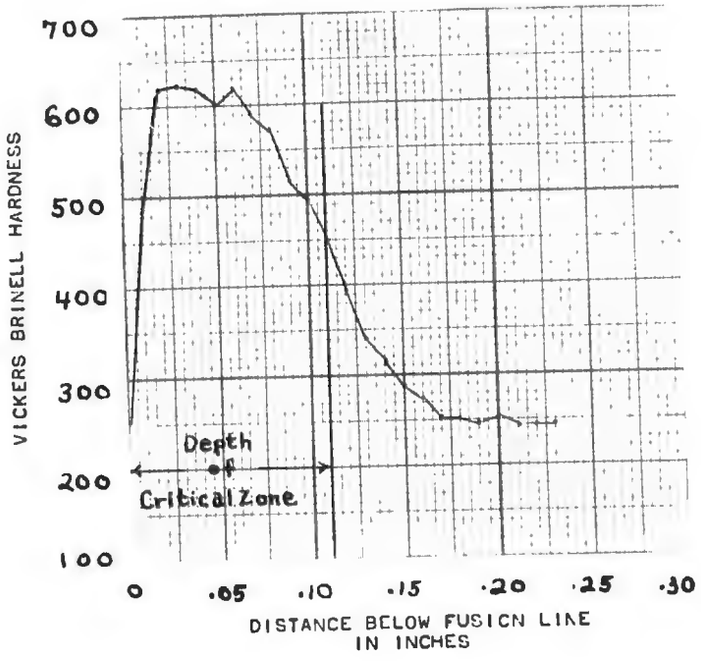




x2

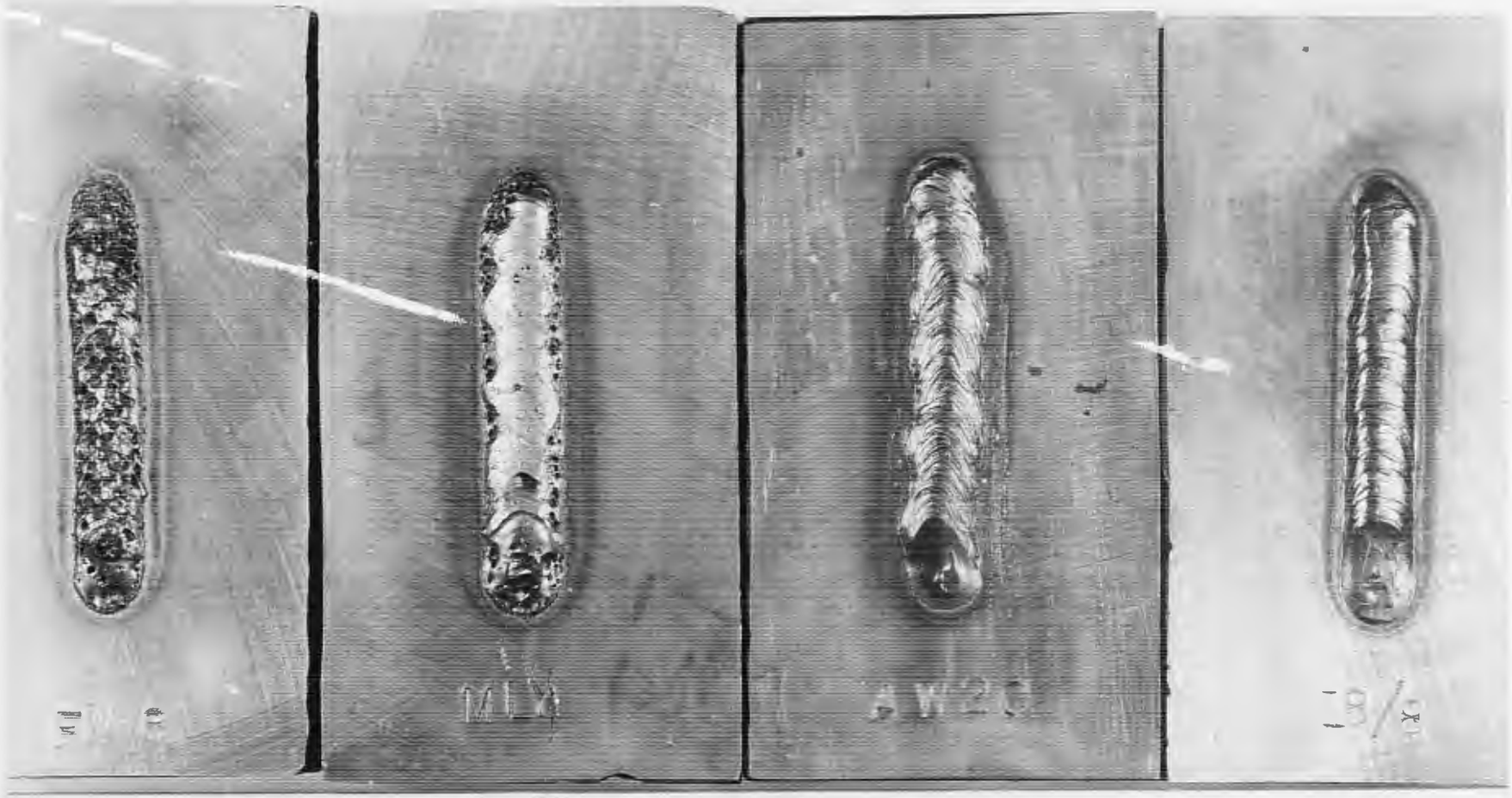
NITAL PICRAL ETCH

VICKERS BRINELL (10 KG. LOAD) IMPRESSIONS TAKEN IN TWO STAGGERED ROWS TO GIVE VERTICAL INTERVAL OF .01 INCHES



WTN.639-5188

FIGURE 1 METHOD OF TAKING WELD-HARDENABILITY SURVEY



ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

FIGURE 2 WELD BEADS DEPOSITED ON CAST HOMOGENEOUS ARMOR CONTAINING SELENIUM. 12 FEB 1944 WTN.121-533

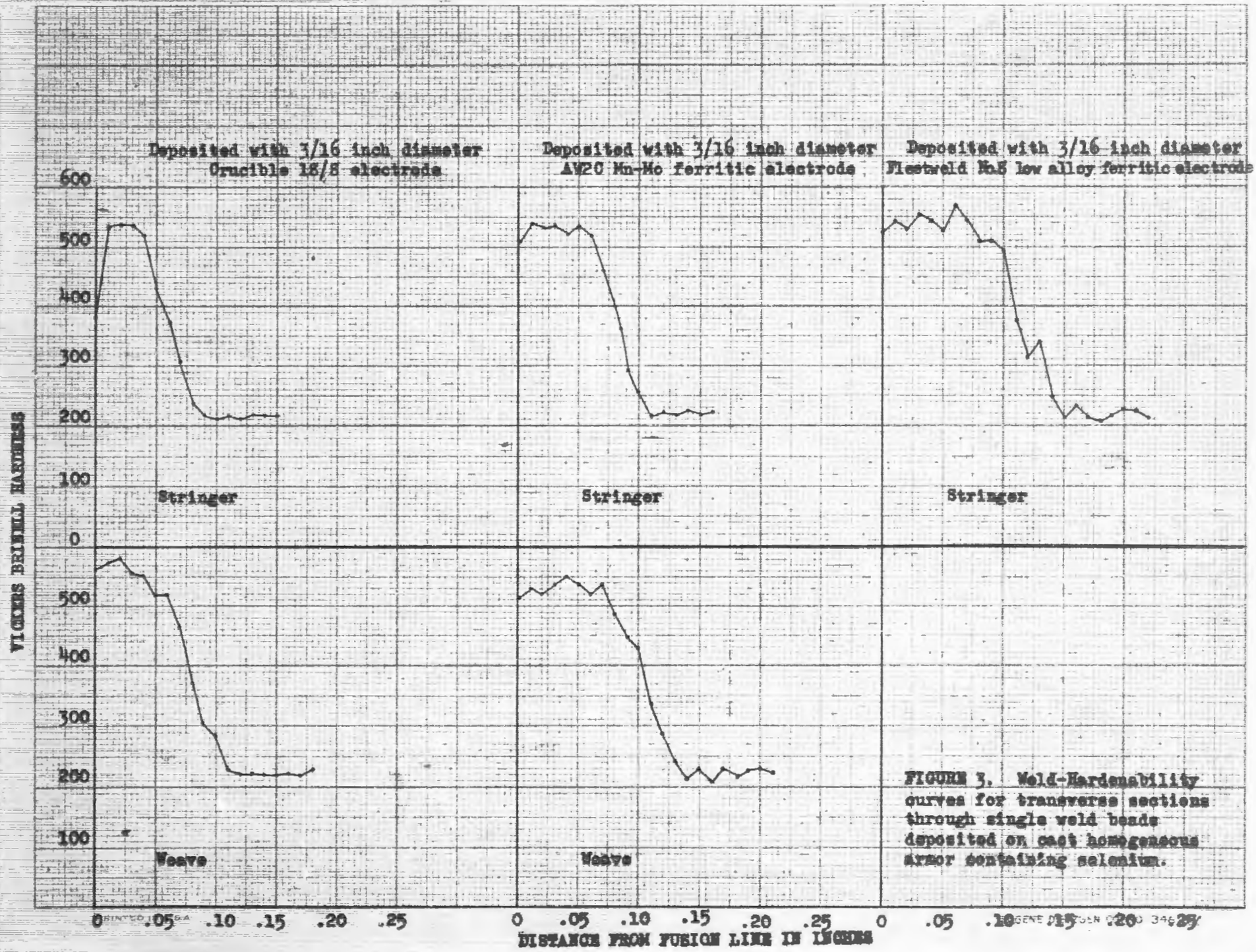
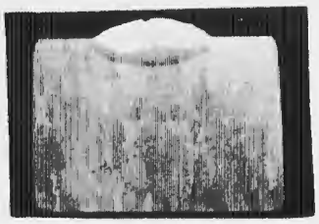


FIGURE 3. Weld-Hardenability curves for transverse sections through single weld beads deposited on cast homogeneous armor containing selenium.

stringer

weave



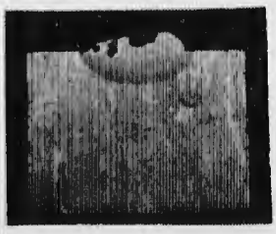
Deposited with 3/16 inch diameter Crucible 18/8 electrode

stringer

weave

Deposited with 3/16 inch diameter AW2C Mn-Mo ferritic electrode

stringer



Deposited with 3/16 inch diameter Fleetweld No. 8 low alloy ferritic electrode

FIGURE 4 PHOTOMACROGRAPHS OF TRANSVERSE SECTIONS THROUGH SINGLE WELD BEADS DEPOSITED ON CAST HOMOGENECUS ARMOR CONTAINING SELENIUM

WTN.639-6156

APPENDIX A

Basic Correspondence

COPY - 15 March 1944 - ahk

TANK-AUTOMOTIVE CENTER
Fisher Building
Detroit, Michigan

Goud/fmc
Ext. 396

29 May 1943

SPOME-EP

Subject: Union Steel Casting No. 374-B, Containing Selenium

To: Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. This office has been notified by the Union Steel Casting Company, Pittsburgh, Pa., that they have shipped turret No. 3391 which was poured from heat No. 374-B containing selenium to your station for metallurgical investigation.

2. This turret is being forwarded to your station in order that a very careful check may be made on the welding qualities of such steel. If any further assistance in regard to this problem can be offered by the Union Steel Casting Company, they have signified that they will furnish any information available.

3. The above turret was shipped on P R waybill No. 34356 in car BTE-91422.

By Order of the Chief of Ordnance:

D. C. PIPPEL
Major, Ord. Dept.
Assistant

Wtn. 472.81/27932
T.A.C. 470.4/177
Attn: SPOME-EP

1st Ind.

Warner/ahk

C.O., Watertown Arsenal, Watertown 72, Mass. 1 November 1943.

To: Chief, Tank-Automotive Center, Union Guardian Bldg., Detroit 26, Michigan.

1. Subject casting has been radiographed.

2. Two sections, each about 12 inches square, have been cut out for welding tests of this casting. Information as to composition of this turret casting is desired.

3. Disposition of remainder of casting as scrap is requested.

For the Commanding Officer:

H. H. Zornig
Colonel, Ord. Dept.
Assistant

TAC 470.4/177
Attn: SPOME-EE
Wtn. 472.81/27932 2nd Ind. Kahl-dw
2996-24th Fl.

Army Service Forces, Office of the Chief of Ordnance, Tank-Automotive Center, Union Guardian Bldg., Detroit 26, Michigan. 16 November 1943

To: District Chief, Pittsburgh Ordnance District, 1202 Chamber of Commerce Bldg., Pittsburgh 19, Pennsylvania.

1. It is requested that the information requested in Para. 2 of first indorsement relative to chemical composition of this melt be furnished Watertown Arsenal.

2. Authorization to dispose of the remainder of this casting as scrap should be made by your office.

By order of the Chief of Ordnance

(s/t) D. C. PIPPEL
Major, Ord. Dept.
Assistant

Pit. 400.163/660
TAC 470.4/177
Attn: SPOME-EE
Wtn. 472.81/27932 3rd Ind. Cutshall/mrw

Army Service Forces, Office of the Chief of Ordnance, Pittsburgh Ordnance District, 1202 Chamber of Commerce Building, Pittsburgh 19, Penna. 18 November 1943.

To: Commanding Officer, Watertown Arsenal, Watertown 72, Mass.

1. As requested in 2nd Indorsement, chemical composition of Ht. 374-B is furnished herewith, i.e. --

C	P	Mn	S	Si	Cr	Mo
.31	.036	1.77	.023	.38	.42	.35

2. With regard to the disposition of the remainder of the casting, the Union Steel Castings Company has requested that it be returned to them.

3. For his information and necessary action.

For the District Chief:

HAROLD G. GARVIS
Major, Ord. Dept.
Assistant

Wtn. 472.81/27932
TAC 470.4/177
Attn: SPOME-ME
PIT 400.163/660 4th Ind. Matthews/amv

C.O., Army Service Forces, Ordnance Department, Watertown Arsenal, Watertown 72, Massachusetts. 29 November 1943

To: Chief, Tank-Automotive Center, Army Service Forces, Union Guardian Bldg., Detroit 26, Michigan. Attn: SPOME-ME

1. Reference 3rd indorsement, it is regretted that the subject casting has been scrapped during a recent drive to clean up salvaged items at this arsenal. If the Union Steel Castings Company wishes to have samples of the material for experimental tests, it is probable that these can be made available from the two 12" x 12" sections which were removed from the turret and are being used for welding experiments at this arsenal.

For the Commanding Officer:

H. H. Zornig
Colonel, Ord. Dept.
Assistant

War Department
PITTSBURGH ORDNANCE DISTRICT
1202 Chamber of Commerce Building
Pittsburgh, Pa.

Outshall/mrw

PIT 400.163/1765
Attn: Inspection Section
Tank & Mtr. Transport Branch

27 December 1943

Subject: Union Steel Castings Company Turret No. 3391, Ht. No. 374-B, Containing Selenium

To: Chief, Tank-Automotive Center
Union Guardian Building
Detroit, Michigan

Attn: SPOMB-EE

1. Reference is made to letter from your office dated 29 May 1943, File No. TAC 470.4/177 and subsequent indorsements from Watertown Arsenal, File No. Wtn. 472.81/27932 and from this office, File No. PIT 400.163/660, regarding the disposition of scrap material from Union Steel Castings Company under Ht. No. 374-B, containing selenium.

2. Subject company has advised this office they do not require samples of the two 12 x 12 pieces remaining from this casting, but have requested information as to any results obtained from welding experiments conducted.

3. For his information.

For the District Chief:

(s/t) G. B. Hoffman
Capt., Ord. Dept.
Assistant

OOM 470.4/Pgh.Ord.Dist (27 Dec 43)
Attn: SPOMB-EE
PIT 400.163/1765
Wtn. 472.81/67 1st Ind. Kahl/ms
Ext.2996 - 24 Fl.

Army Service Forces, Office, Chief of Ordnance, Tank-Automotive Center, Union Guardian Bldg., Detroit 26, Mich., 31 December 1943.

To: Commanding Officer, Watertown Arsenal, Watertown, Mass.

1. Attention is invited to Paragraph 2 of basic communication.

2. It is requested that information obtained from welding experiments conducted at your station be made available to Pittsburgh Ordnance District.

By order of the Chief of Ordnance:

(s/t) D. C. PIPPEL
Major, Ord. Dept.
Assistant