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Report No. 640/60

ARMOR PLATE - WELDING

Adaptability of Four Procedures for Welding Pistol Port Splash Beads

by
P. V. Riffin
Asst. Metallurgist

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January 26, 1943

WATERTOWN ARSENAL
WATERTOWN, MASS.

Report No. 640/60
Watertown Arsenal
Problem B-23

January 26, 1943

ARMOR PLATE - WELDING

Adaptability of Four Procedures for Welding Pistol Port Splash Beads

OBJECT

To determine the characteristics of four procedures proposed for welding pistol port splash beads.

SUMMARY OF RESULTS

1. The procedure employing a manganese modified 18-8 stainless steel electrode in all passes was completely satisfactory.

2. The procedure employing a manganese modified 18-8 stainless steel electrode for the three buttering passes followed by reversed polarity mild steel deposits formed cracks in the mild steel beads adjacent to the buttering passes.

3. The procedure employing a bare mild steel electrode for the three buttering passes formed porosity in the first three weld beads, but no cracking was observed in the heat affected zones or the weld metal.

4. The procedure employing reversed polarity mild steel electrodes throughout was unsatisfactory since cracks were formed in the base metal heat affected zones. Some of these cracks formed perpendicular to the line of fusion, an extremely undesirable condition in armor plate.

P. V. RIFFIN
Asst. Metallurgist

APPROVED:

H. H. ZORNIG
Colonel, Ord. Dept.
Director of Laboratory

INTRODUCTION

Upon request of the Tank-Automotive Center,* a study was conducted to evaluate preliminary tests of special procedures employing ferritic electrodes for the welding of pistol port splash beads on tank turrets and hulls. As a basis for comparison, one sample was welded throughout with an austenitic modified 18% chromium - 8% nickel electrode. The four welded samples were prepared at the Ordnance School at Aberdeen Proving Ground using four 1½"x8"x14" sections of Great Lakes Steel Corporation armor. A complete description of the procedures used in preparing the welded samples is contained in an inclosure with the basic letter as Appendix A.**

The Ordnance School forwarded to this arsenal six consecutive transverse sections from each of the four welded samples. The transverse sections were approximately 1" in thickness.

A letter report recording preliminary results has been forwarded to the Tank-Automotive Center.***

In Figure 1 is shown the position and sequence of the deposition of the weld beads. The types of electrodes used in each individual sample are given below:

1. Sample A - Passes 1, 2, and 3 were welded with 5/32" diameter manganese modified 18-8 stainless steel electrode. The weld was completed in seven (7) passes with 3/16" diameter reverse polarity mild steel electrode.

2. Sample B - Passes 1, 2, and 3 were welded with 5/32" diameter bare mild steel electrode. The weld was completed in seven (7) passes with 3/16" diameter reverse polarity mild steel electrode.

3. Sample C - Passes 1, 2, and 3 were welded with 5/32" diameter reverse polarity mild steel electrode. The weld was completed with 7 passes 3/16" diameter reverse polarity mild steel electrodes.

4. Sample D - Passes 1, 2, and 3 were welded with 5/32" diameter manganese modified 18-8 stainless steel electrode. The weld was completed in seven (7) passes with 3/16" diameter manganese modified 18-8 stainless steel electrode.

TEST PROCEDURE

The following tests were conducted on the six 1" thick transverse sections cut from each of the four welded samples:

---

*OOM #400.273/5, W.A. #400.273/609, see Appendix A.
**Fourth Ind. of O.O. #451.25/2255, O.T.C. #470.8/4, see Appendix A.
***1st Ind. O.O.M. #400.273/5, W.A. #400.273/609, January 11, 1943.

1. Sections 2 and 5 (see Appendix A) were ground to a uniform thickness of .865" and fractured between the jaws of a tensile testing machine as shown in Figure 1. The specimen and fixtures were rigidly supported so that the forces acted to stress the weld deposit in shear.

2. Section 3 was macroetched in hot hydrochloric acid.

3. Sections 1 and 4 were examined microscopically and then Vickers Brinell hardness surveys were conducted upon them. Position of hardness surveys is shown in Figure 1. A chemical analysis was made on the armor of Section C-1.

RESULTS AND DISCUSSION

1. Physical Test

The physical test (shown in Figure 1) was conducted in order to determine the plane of maximum weakness and the relative shear strength of the four welding procedures. The results are indicative inasmuch as they reveal the plane of weakness at the fusion zone of Sample C (ferritic deposit on the armor plate) and the tendency toward cracking in zones 4 and 5 (between ferritic and austenitic deposits) of Sample A.

Reference to Figure 2, which shows the fractured test pieces, shows the failure in Sample A which progressed along the crack formation which developed in this procedure due to the formation of a hard zone in the boundary deposits between ferritic and austenitic passes. The porosity in the first three bare wire passes of Sample B is reflected in the somewhat lower strength of the sections from this weldment.

The breaking load of the sections tested is as follows:

Sample	Section 2	Section 5
A	38,900 lbs.	42,900 lbs.
B	30,640 lbs.	27,900 lbs.
C	*19,440 lbs.	29,400 lbs.
D	37,320 lbs.	32,250 lbs.

*Lack of fusion under Bead 1.

2. Macroetched Structure

The macroetching revealed that the armor was straight-away rolled, (difference in etching characteristics in the longitudinal and transverse directions) and contained some undesirable nonmetallic segregations. It will be noted by referring to Figure 3 that

Samples A, B, and D were welded perpendicular to the rolling direction, whereas Sample C was welded parallel to the rolling direction.

3. Microscopic Examination

Sample A. The first three passes made with a stainless steel electrode formed a good bond with the base metal and the structure was austenitic. The remaining passes (4 to 10)were made with a reverse polarity mild steel electrode. Passes 4 and 5 dissolved some alloy from the high alloy weld beads and formed a martensitic structure in which an interdendritic type of cracking was observed. The crack system is clearly shown in Section A-4 of Figure 4. A detail of the interdendritic type of cracking formed is shown in Sample A-1 of Figure 6.

Sample B. The first three passes made with a bare mild steel electrode formed an excessive amount of porosity, but the weld metal formed a good bond with the base metal. The remaining passes made with reverse polarity mild steel electrode formed a heterogeneous structure of ferrite and pearlite. No cracking was observed in either the heat affected zone of the base metal or in the weld metal. The porosity in passes 1 to 3 is clearly shown in Sections B-1 and B-4 of Figure 4.

Sample C. All passes were made with a reverse polarity mild steel electrode which formed a heterogeneous microstructure of ferrite and pearlite. In the heat affected zone of the armor plate, cracking was observed parallel to the line of fusion and perpendicular to it. See Sections C-1 and C-4 of Figures 5 and 6. A cracking condition of this type is extremely undesirable since any cracking perpendicular to the plate surface may weaken the armor and initiate a ballistic failure. The cause of this cracking was probably associated with the shrinkage which occurs during the solidification of the weld metal, but it should be noted that this sample would be more susceptible toward cracking since the welding was conducted parallel to the rolling direction whereas welding of the other three samples was conducted perpendicular to the rolling direction of the armor. This factor is significant in straight-away rolled Great Lakes armor which is susceptible toward cracking during welding fabrication.

Sample D. In this weldment a manganese modified 18-8 stainless steel electrode was employed, and the weld metal, which was completely austenitic, formed a good bond with the base metal. No defects were observed and the weldment is considered to be completely satisfactory. See Sections D-1 and D-4 of Figure 5.

4. Vickers Hardness Surveys

Results of the Vickers hardness surveys taken every .02" across the heat affected and unaffected zones of the armor, and in the weld metal are given in Table I listing maximum hardnesses.

The location of the maximum hardnesses is shown in Figures 7 and 8. Some high hardnesses were developed in the heat affected zones especially under Pass 3, but no excessive hardnesses were observed. High hardnesses of 390-425 Vickers in Beads 4 and 5 of Sample A were associated with the cracks and martensitic structure which were found in the microspecimens.

TABLE I

Maximum Vickers Hardness Values in Weld Samples

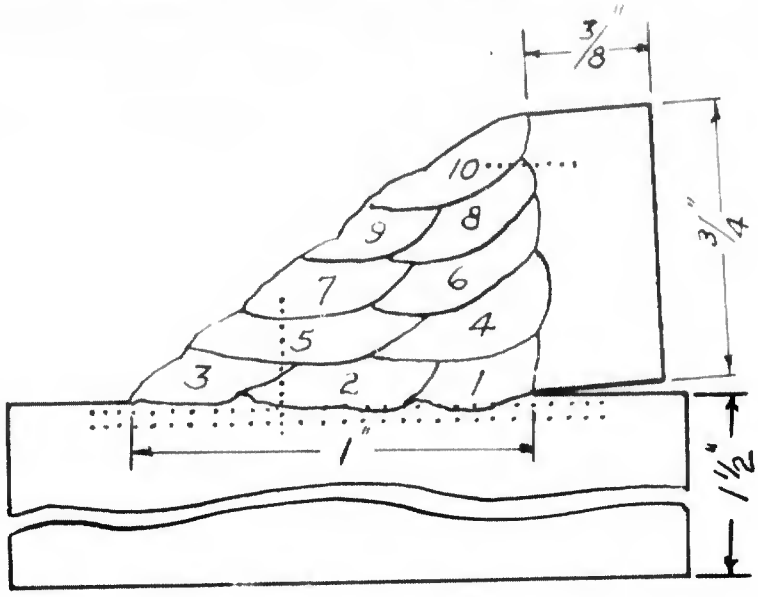
Section	Base Metal	Heat Affected Zone	Austenitic Weld Metal	Ferritic Weld Metal
A-1	289	488	224	425
A-4	294	459	192	390
B-1	281	459	-	247
B-4	279	429	-	258
C-1	287	421	-	202
C-4	285	425	-	198
D-1	297	433	270	-
D-4	281	468	242	-

5. Chemical Analysis

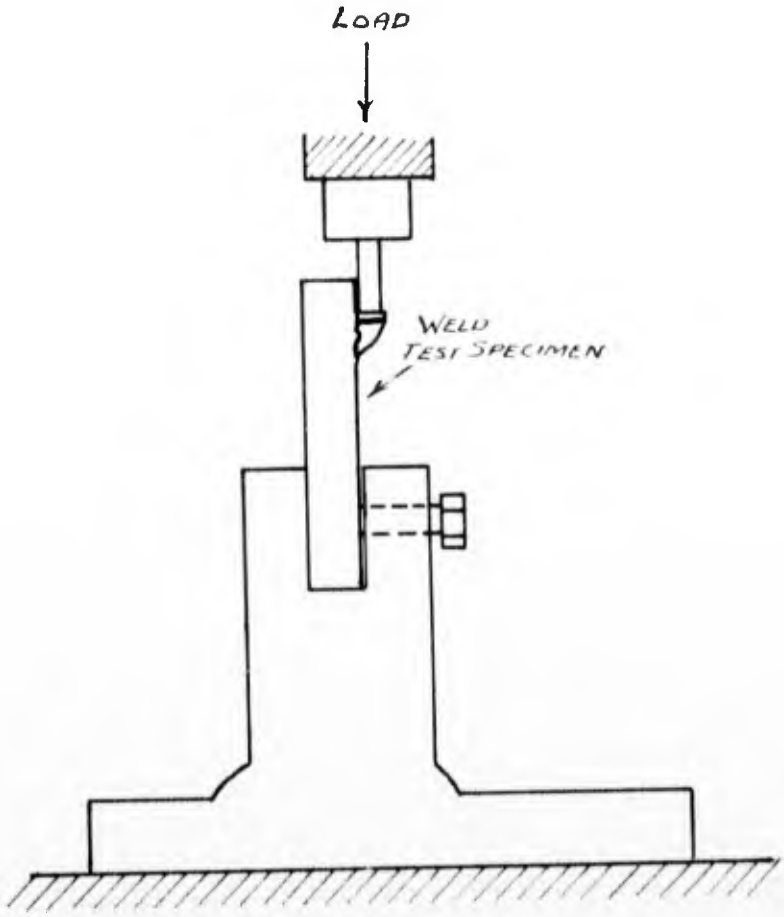
A chemical analysis of the armor was obtained from Sample C, Section 1 and the results are as follows:

Sample	C	Mn	Si	S	P	Cr	Mo	Zr
C-1	.31	.88	.74	.021	.009	.63	.21	.16

The analysis of this armor is similar to that of other Great Lakes Steel Corporation armor which is considered to be suitable for welding fabrication.



ORDER OF DEPOSITION OF WELD PASSES.
DOTS INDICATE VICKERS PYRAMID
HARDNESS READINGS.



METHOD OF FRACTURING WELDS.

FIGURE 1.

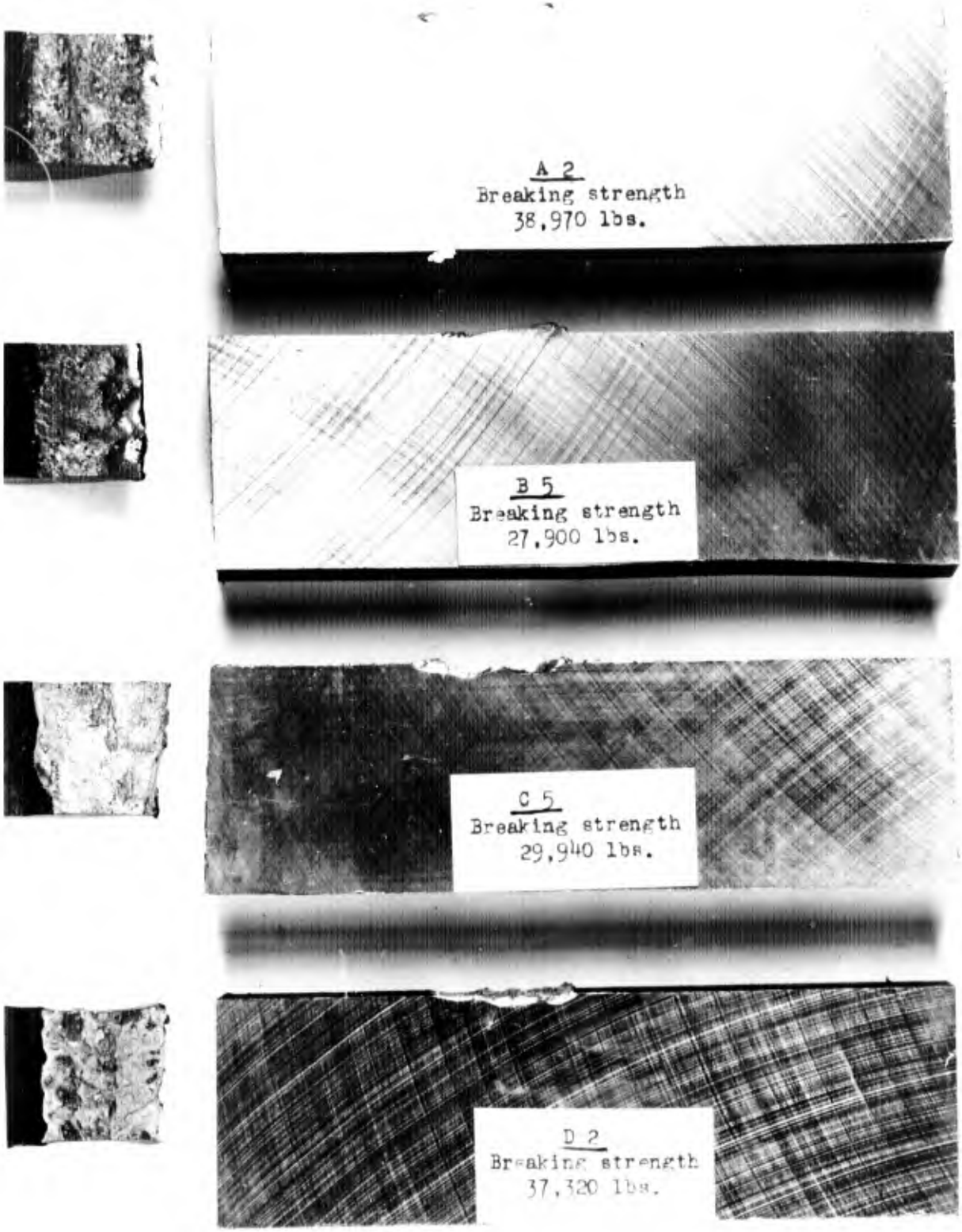
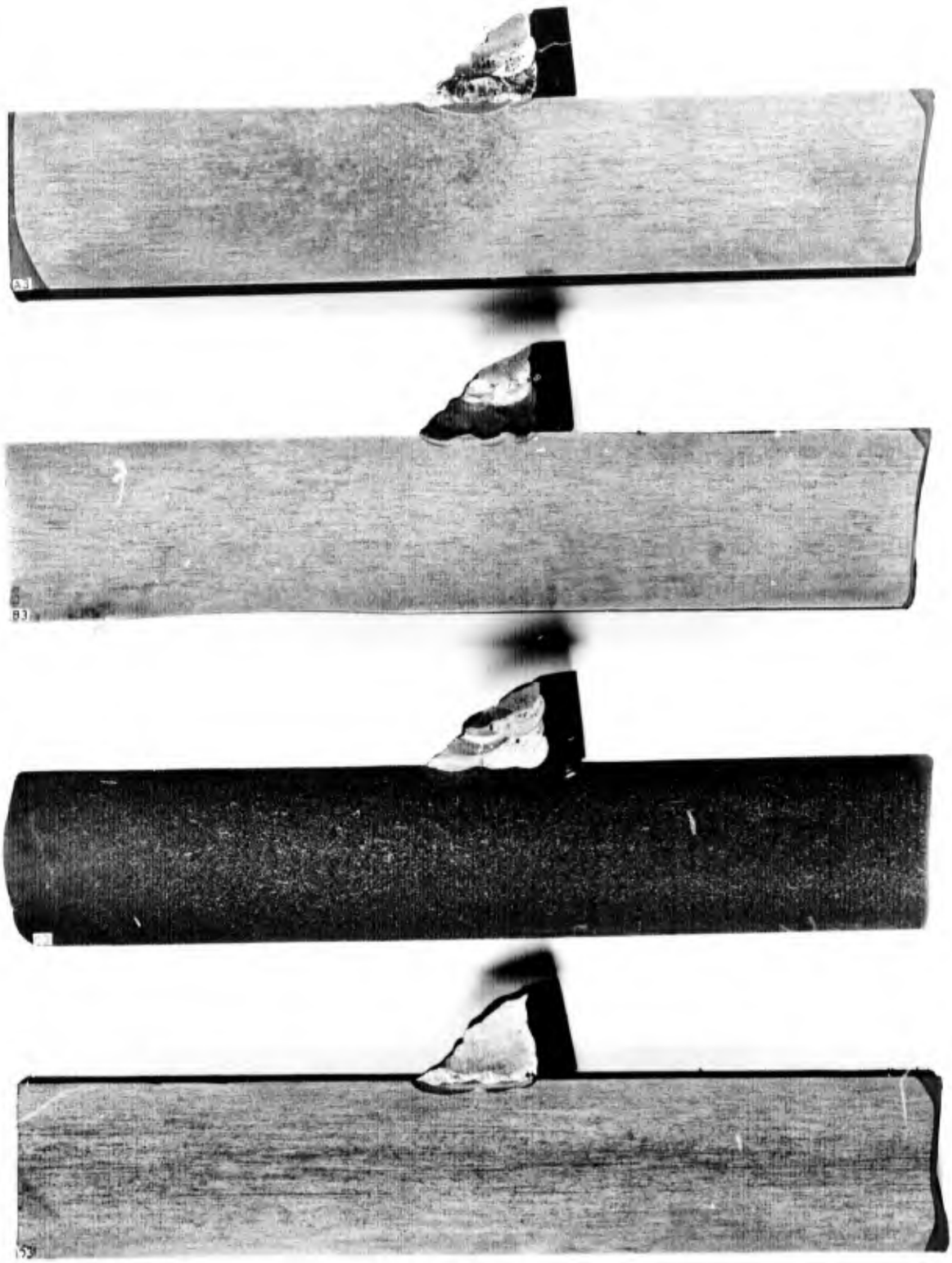


FIGURE 2

FRACTURED PISTOL PART SPLASH BEAD SECTIONS, NOTE POROSITY IN B-5 AND LACK OF FUSION IN C-5 DECEMBER 28 1943 WTN 121-512

FIGURE 2



ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

MACROETCHED TRANSVERSE SECTIONS OF SAMPLE SPLASH BEAD WELDS
SUBMITTED BY ORDNANCE SCHOOL.
DECEMBER 22 1942

MAG. X 3/4
WTN. 121-511

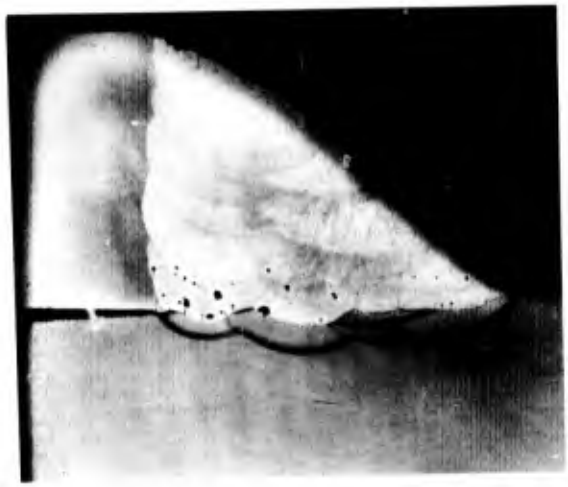
FIGURE 3

FIGURE 3

Section A-1

Section A-4

Passes 1,2,3, - 5/32"D Mn modified 18-8 stainless steel electrode, passes 4-10 - 3/16"D reversed polarity mild steel electrode. Cracks observed in passes 4 and 5 of both specimens resulted from alloy pick-up.



Section B-1

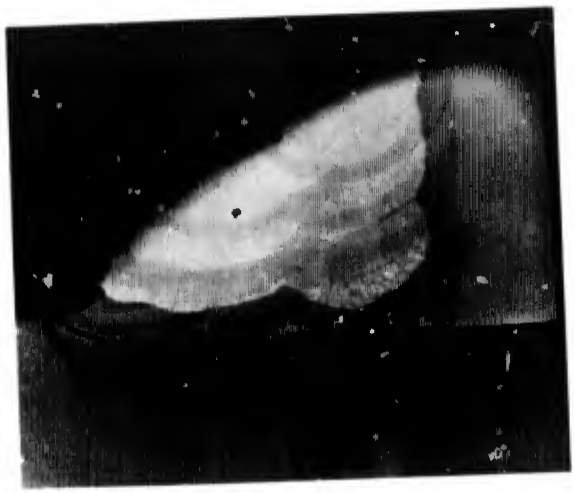
Section B-4

Passes 1,2,3, - 5/32"D bare mild steel electrode, passes 4-10 - 3/16"D reversed polarity mild steel electrode. Excessive porosity was observed in passes 1,2, and 3 of both sections.

CROSS SECTION OF PISTOL SPLASH PORT BEADS
ETCHES IN VILELLA'S REAGENT
Mag. x2

WTN.639-4914

Figure 4



Section C-1

Section C-4

Passes 1,2,3, - 5/32"D reversed polarity mild steel electrode, passes 4-10 3/16"D reversed polarity mild steel electrode. Note cracking in heat affected zones under pass 3 and 1 in section C1 and under passes 2 and 3 in section C4.

Section D-1

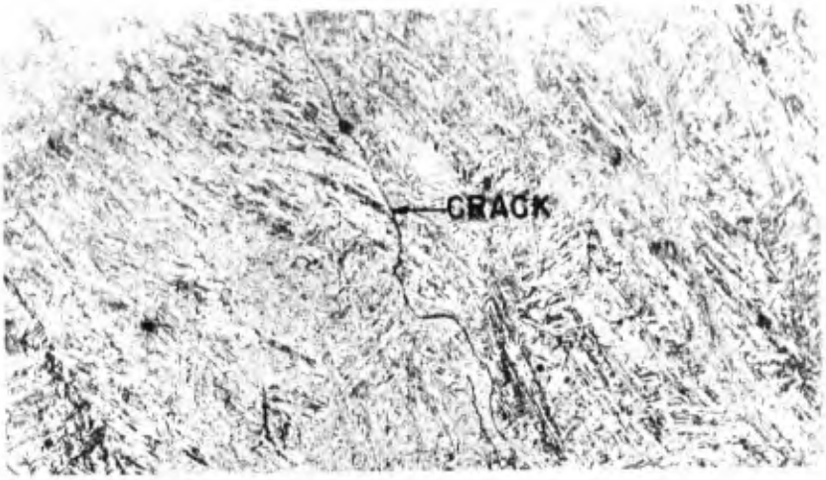
Section D-4

Passes 1,2,3, - 5/32"D Mn modified 18-8 stainless steel electrode, passes 4-10 - 3/16"D Mn modified 18-8 stainless steel electrode. Oblique illumination used in section D4 to reveal grain structure in the weld metal.

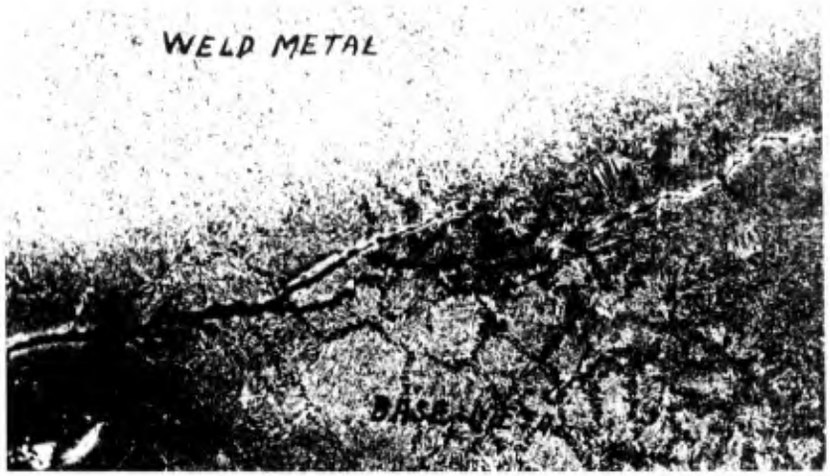
CROSS SECTION OF PISTOL SPLASH PORT
BEADS ETCHED IN VILELLA'S REAGENT
Mag. x2

Figure 5

WTN.639-4915



X100 Sample A-1 Nital-picral
Interdendritic type cracking observed in passes 4 and 5 (mild steel). Martensitic microstructure.

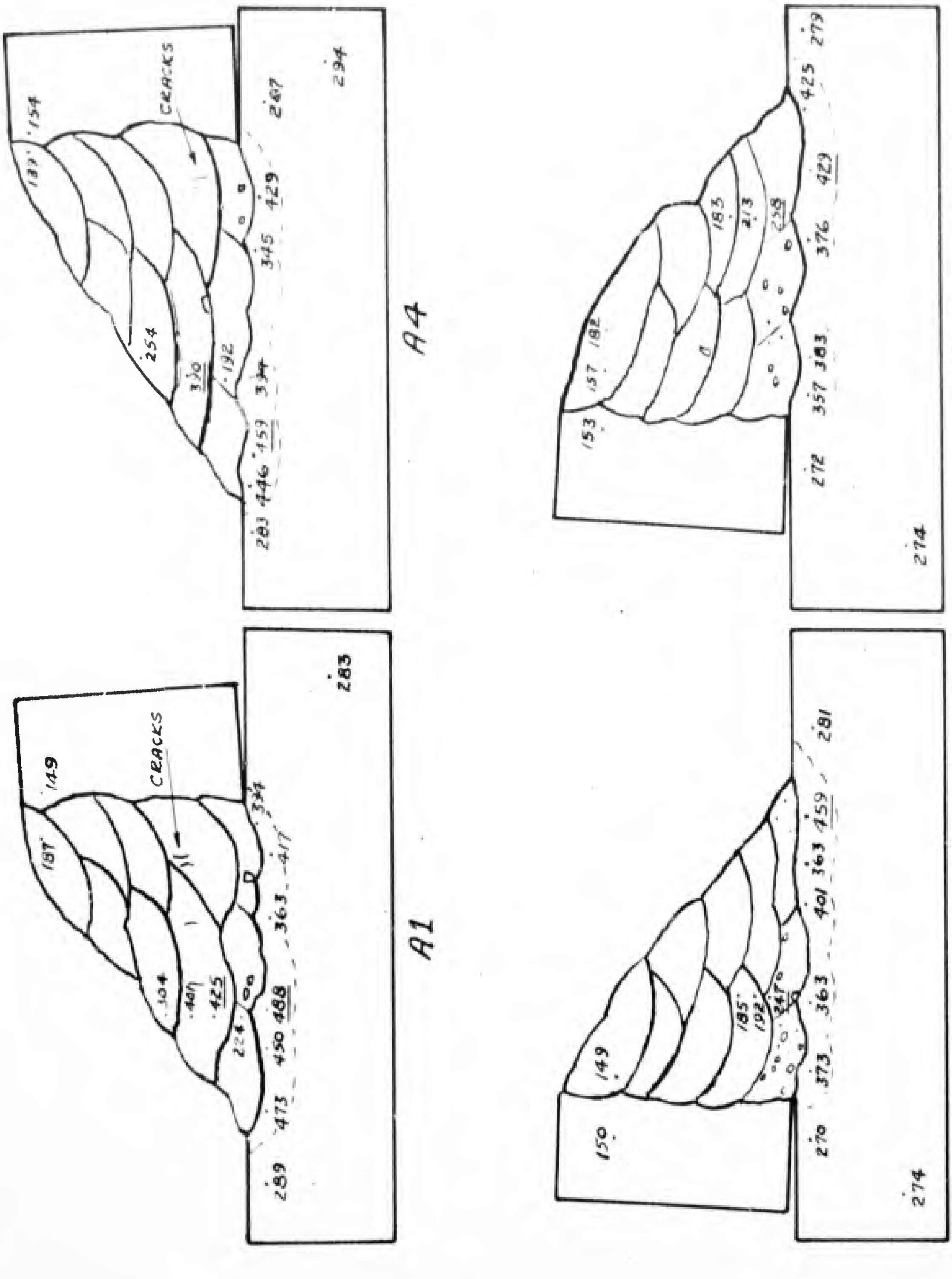


X100 Sample C-1 Nital-picral
Structure of crack systems observed in the heat affected zone adjacent to pass 3.

X7 Sample C-4 Ammonium persulfate
Crack systems observed in this sample at the line of fusion.

WTN.639-4916

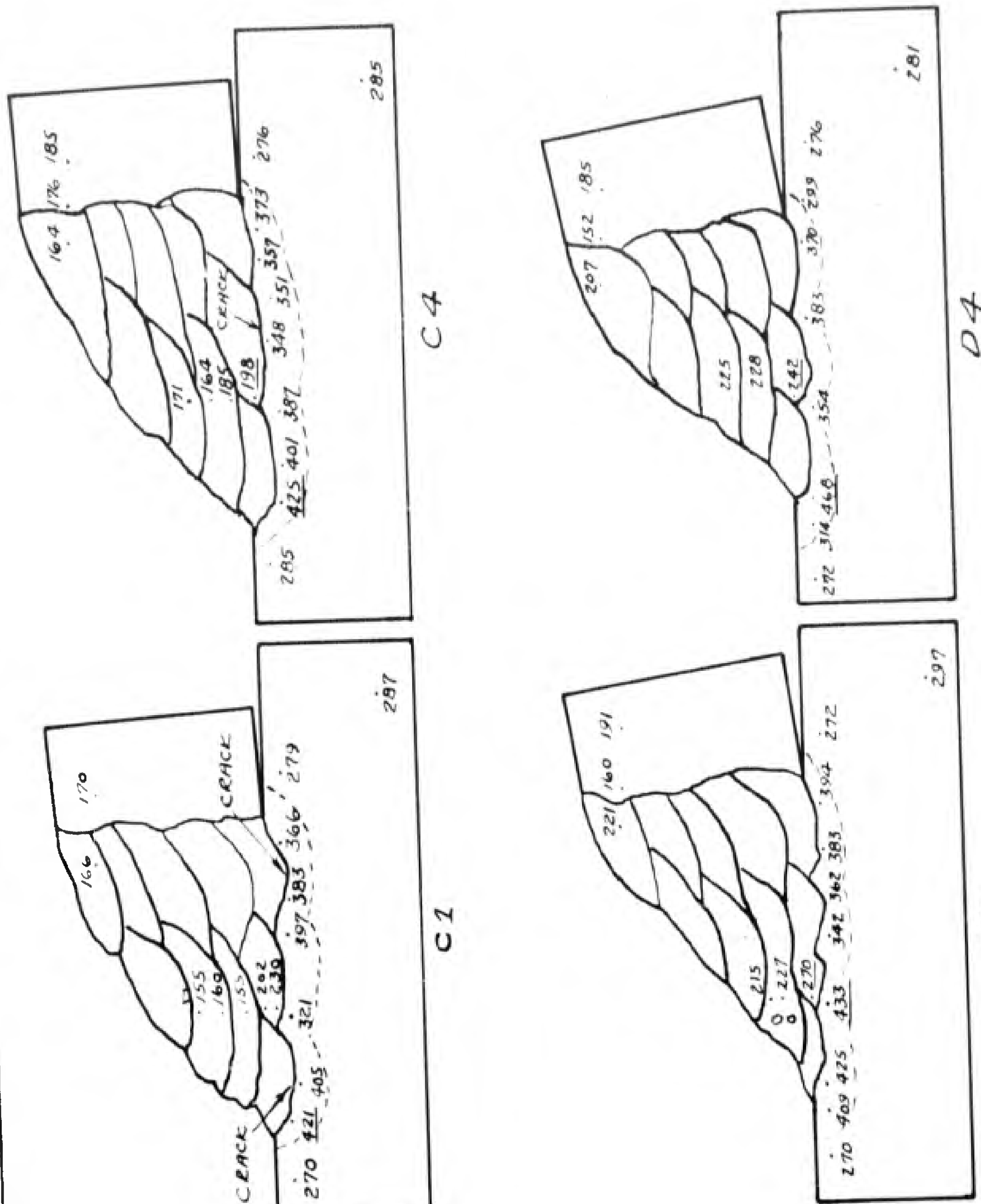
STRUCTURE OF CRACKS OBSERVED Figure 6



VICKERS PYRAMID HARDNESS SURVEYS
OF PISTOL PORT SPLASH BEAD WELDS.

MAXIMUM OBSERVED VALUES UNDERLINED.

FIGURE 7



VICKERS PYRAMID HARDNESS SURVEYS OF PISTOL PORT SPLASH BEAD WELDS.

MAXIMUM OBSERVED VALUES UNDERLINED.

FIGURE 8

APPENDIX A

RESTRICTED

C O P Y

WAR DEPARTMENT

TANK AND AUTOMOTIVE CENTER

UNION GUARDIAN BUILDING

DETROIT, MICH.

RANDALL/dmf
Ext. 2641 - 2642

O.O.M. #400.273/5
Attn.: SPOMT - Armor & Welding
W.A. # 400.273/609

October 24, 1942

Subject: Welding of Pistol Port Splash Beads.

To: Commanding Officer
Watertown Arsenal
Watertown, Massachusetts

Attention: Director of Laboratories

1. Upon numerous occasions this office has been requested to permit the use of special procedures employing ferritic electrodes for the welding of pistol port splash beads on tank turrets. As a preliminary step in investigating this matter, the Ordnance School at Aberdeen Proving Ground has prepared a series of samples. A description of the samples and their methods of preparation is contained in the inclosures to this letter.

2. The Ordnance School has been requested to send to your laboratory, samples A1 to A6, B1 to B6, C1 to C6 and D1 to D6 inclusive. It is requested that when these are received they be examined metallurgically and, subjected to hardness surveys and such other methods of test as you may select. This office would like to have the recommendations of your station as to the desirability of permitting the use of any of the procedures described in the inclosures for the production of pistol port splash beads.

3. It will be noted that the Ordnance School used a step back and skip welding procedure and also that the various beads were peened while hot. It is recognized that this procedure would not prove practical for shop production work, and depending upon the outcome of your investigation, it will probably prove necessary to have additional samples welded by normal procedures before a definite decision can be reached.

By order of the Deputy Chief of Ordnance:

4 Inclosures
1 - sketch
2 - sketch
3 - data sheets (4)
4 - copy of 4th Ind.

(signed) J. V. Coombe, Major
for DONALD C. PIPPEL
Major, Ord. Dept.,
Assistant.

RESTRICTED

RESTRICTED

INCLOSURE 4

COPY OF 4TH IND.

O.O. 451.25/2255 (R)
OTC 470.8/4
SPONT
Os 451/78 4th Ind. SYLVESTER/mmd

Headquarters, The Ordnance School, Aberdeen Proving Ground, Maryland. October 9, 1942, To: The Chief of Ordnance, War Department, Washington, D.C. ATTN.: SPOIT, Armor & Material.

1. In compliance with the third indorsement, the welding Section of the Ordnance School has completed four sample splash bead welds as shown in submitted sketch No. 1 and each has been sawed into strips transverse to the weld as directed in par. 8 thereof.

2. Strips of mild steel 3/8" x 3/4" x 14" were welded to 1-1/2" x 8" x 14" sections of Great Lakes Steel Corporation armor containing approximately 0.34 percent carbon. Each of the welded samples has been stamped and is identified as follows:

Sample -A- Passes 1, 2, and 3 were welded with 5/32" diameter manganese modified 18-8 stainless steel electrode. The remainder of the weld was completed with 3/16" diameter reverse polarity mild steel electrode.

Sample -B- Passes 1, 2, and 3 were welded with 5/32" diameter bare mild steel electrode. The remainder of the weld was completed with 3/16" diameter reverse polarity mild steel electrode.

Sample -C- Passes 1, 2, and 3 were welded with 5/32" diameter reverse polarity mild steel electrode. The remainder of the weld was completed with 3/16" diameter reverse polarity mild steel electrode.

Sample -D- Passes 1, 2, and 3 were welded with 5/32" diameter manganese modified 18-8 stainless steel electrode. The remainder of the weld was completed with 3/16" diameter manganese modified 18-8 stainless steel electrode.

3. The welding operating variables for each sample weld are noted on attached welding procedure data sheets. This information is specified for each welding pass and includes the pass number, the length and width of each bead in a given welding pass, the size and type of electrode, the welding voltage, amperage and polarity settings, angle of electrode, the type of electrode weaving motion and extent of weave in multiples of electrode diameter, the characteristics of the arc, the deviation from normal of the vertical welded strip, and specifications as to peening, quenching, and times of welding.

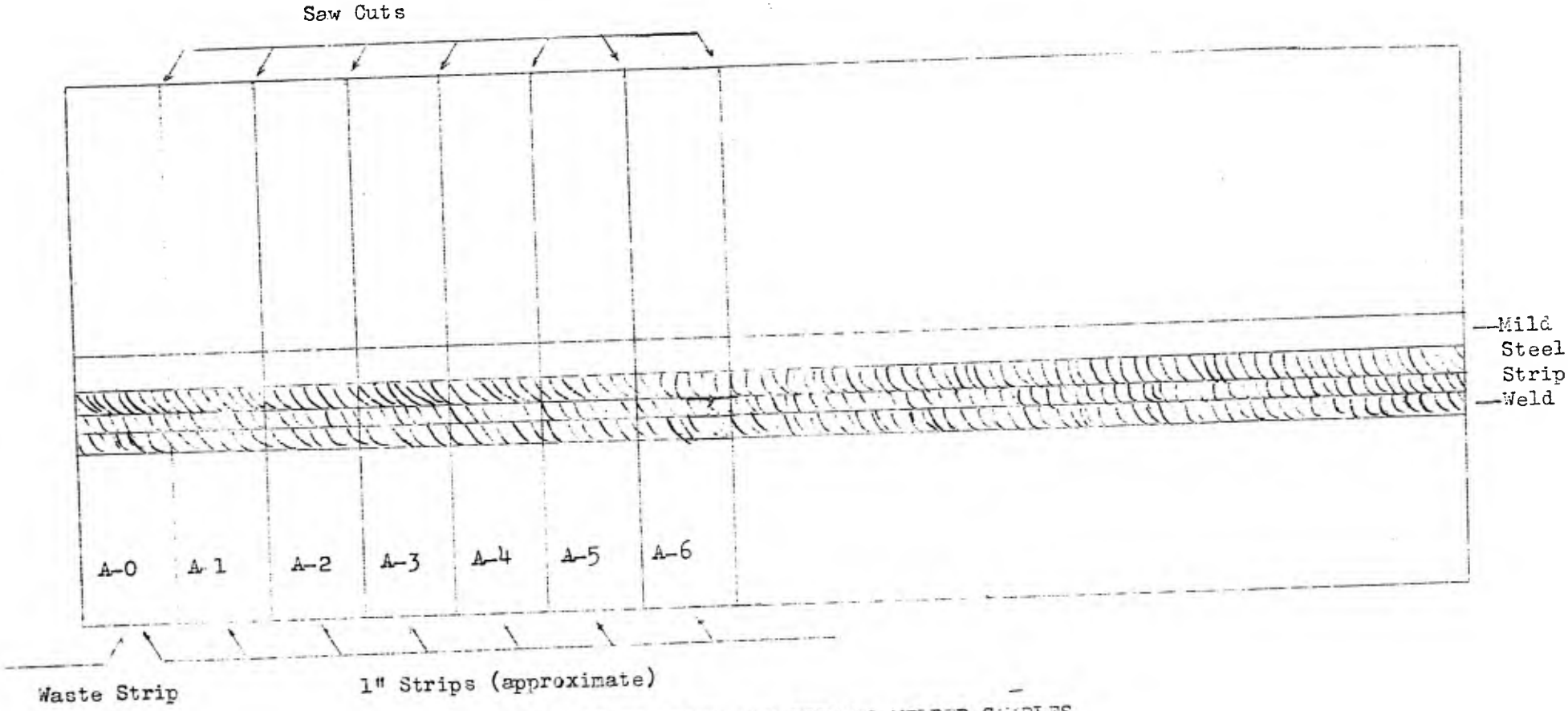
4. The mild steel strip was located normal to the armor plate and fixed in place by three 1/2" tack welds located at the ends and center on the side to be welded. The step back and skip weld procedure was used for each pass to control the longitudinal warpage in the weldment. Each of the beads in a given pass were peened while hot to minimize transverse contraction, bead cracking, and deviation from normal of the vertical strip. Each pass was cooled to below 100°F when completed and thoroughly cleaned by chipping and wire brushing before additional weld metal was deposited. This precaution was taken to eliminate oxide and slag inclusions in the weld metal. The current, voltage, and polarity settings used were those established for good weldability by tests on trial samples. The angle of electrode (B) used was consistent with good weld metal deposition and elimination of arc blow whereas the angle of electrode (A) and the weaving motion indicated was used to obtain good sidewall fusion and to control the flow of the deposited metal to within the required dimensional limits. The craters at the end of each bead weld were filled by an electrode hesitation and drawback technique to eliminate any crater cracking.

5. Deviation from normal of the mild steel strip was measured at the ends noted under (a) and (c) on data sheets and at the center (b) of the strips after each pass. Presetting of the vertical mild steel strip to obviate deviation did not produce the results desired in trial tests and is accordingly not recommended.

For the COMMANDANT:

JOHN D. BILLINGSLEY,
Lt. Col., Ord. Dept.,
Assistant Commandant.

8 Inclosures
1 - Sketch
2 - Sketch . . . . . .)Not
3 - 6 Incl. - Data Sheets . .)Included
7 - Letter to Aberdeen (copy).)in
8 - Sketch . . . . . .)Report



METHOD OF STAMPING AND CUTTING WELDED SAMPLES

Test Sample A - Stamped as shown
Test Samples B,C, and D stamped as shown above except that B,C, and D have been substituted respectively for the letter A.