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WATERTOWN ARSENAL
LABORATORY

MEMORANDUM REPORT

NO. WAL 642/126

ARC WELDING ELECTRODES

Tests of Seven (7) Commercial Brands of
Low Alloy Welding Electrodes under
Specification No. 27-203-1A

BY

Preston E. Woodward
Chief Lab. Mechanic

William L. Warner
Senior Welding Engineer

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WAL: 642/126

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DATE 23 July 1945

WATERTOWN ARSENAL
WATERTOWN, MASS.

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WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. WAL 642/126

Project D-17

25 July 1945

ARC WELDING ELECTRODES

Tests of Seven (7) Commercial Brands of
Low Alloy Welding Electrodes Under
Specification No. 57-203-1A

OBJECT

To determine operating characteristics and weld metal properties of the brands tested in order that classification requirements may be established for the respective classes under Specification 57-203-1.

REFERENCES

Correspondence relating to these tests will be found in Appendix A.

SUMMARY

1. The tests indicate that the following limits on operating characteristics are satisfactory for the WD E-7010 and WD E-8020 electrodes:

<u>Class</u>	<u>Melting Rate (Inches/Minute)</u>	<u>Deposition Rate (Oz./Hour)</u>	<u>Deposition Efficiency (Percent)</u>	<u>Penetration (Inches - 1/2" Plate)</u>
WD E-7010	9 - 11	40.0	70	.08 Minimum
WD E-8020	10 - 12	40.0	60	.10 Maximum

2. The following brands are acceptable under Class WD E-7010:

Lincoln Shield Arc #85
Hollup MLY
Champion Blue Devil #85

3. The Murex Molex is not acceptable because of unsoundness of weld metal, see Appendix C.

4. The following brands are acceptable under Class WD E-8020 for welding Class C plate:

A. O. Smith S# 76
Murex Type 90

INTRODUCTION

The tests of electrode brands covered by this report were undertaken in 1943 to obtain data for revision of Specification 57-203-1A. This issue of the specification included coverage of three classes of low carbon covered mild steel electrodes and one class of electrodes for hard facing. Low alloy covered electrodes for welding low alloy constructional steels were not included under this specification.

Since it was indicated by the Office, Chief of Ordnance, that tentative Watertown Arsenal Specification WXS-34 (Low Alloy Covered Electrodes) had to be cancelled, having been in existence over 6 months, it became necessary to add a suitable classification to Specification 57-203-1 to cover electrodes approved under WXS-34.

The desirability was also indicated by the Office, Chief of Ordnance, that Specification 57-203-1 should cover a class of electrodes suitable for welding structural alloy plate of Class C, Specification 57-114-1 (Correspondence in Appendix A), since mounts for the 155 mm. gun were being fabricated of this type of plate material at Rock Island Arsenal using two commercially available brands of electrodes which had been found acceptable.

TEST MATERIALS

The following commercial brands of welding electrodes were included in the tests covered by this report.

<u>Brand</u>	<u>Manufacturer</u>
Shield Arc #85	Lincoln Electric Co.
Murex Molex	Metal & Thermit Corp.
Sureweld MLY	Hollup Corporation
Blue Devil #85	Champion Rivet Co.
*Murex Type 90	Metal & Thermit Corp.
*SW 76	A. O. Smith Corp.
Shield Arc #100	Lincoln Electric Co.

These brands were all tested in the 5/32" diameter for operating characteristics and weld metal tensile properties except Blue Devil #85 (See Appendix C).

* These two brands were recommended for welding plate of Class C, Specification 57-114-1A, by Rock Island Arsenal (See Appendix A).

TEST PROCEDURE

These brands of electrodes were tested for respective classification under Specification 57-203-1A. Operating characteristics were determined with an automatic welding machine using 5/32" diameter electrode at 150 amperes welding current with a travel speed of 5" per minute as described in Memorandum Report No. WAL 641/12, 24 February 1945. Soundness and tension properties of weld metals were determined in accordance with paragraph F-3d, Specification 57-203-1A (See Figure 1).

DATA AND DISCUSSION

Operating Characteristics

Data on operating characteristics of the 5/32" electrode tested are given in Appendix B. The average values are as follows:

<u>Electrode</u>	<u>Melting Rate (In./Min.)</u>	<u>Deposition Rate (Oz./Hr.)</u>	<u>Deposition Efficiency (%)</u>	<u>Penetration (Inches - 1/2" Plate)</u>
SA-85	10.8	48.1	75.6	.096
Molex	10.8	49.9	78.9	.082
MLY	9.4	41.3	72.2	.112
BD-85	10.2	44.6	73.7	.112
Type 90	11.2	47.5	62.3	.080
SW-76	10.8	43.1	64.0	.096
SA-100	11.3	49.4	74.1	.094

Soundness and Composition

Data on soundness and chemical composition of the welds in the 3/4" mild steel plate from which tensile properties were determined are given in Appendix C. There was no particular difficulty in obtaining Standard I soundness (Specification AXS-476, Appendix I) with all the electrodes tested except Molex. With this electrode Standard II was the best which could be obtained.

Chemical analysis of the weld metals indicates that all contain molybdenum, usually not less than 0.50%, except the SW-76 and Blue Devil #85. The Type 90 is the only one containing nickel and an appreciable amount of chromium. The SA-100 is of the moly-vanadium type.

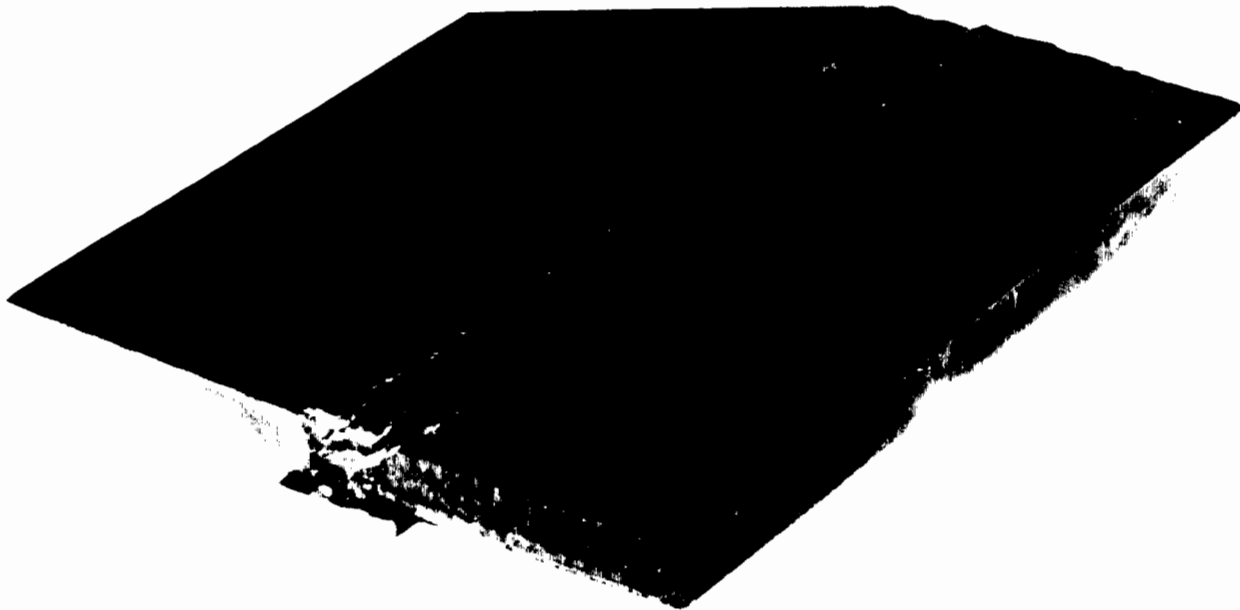
Tensile Properties

Tensile properties of weld metals are given in Appendix D. Two stress relieving temperatures were used (1000°F and 1150°F). The former is prescribed for Class C plate and the latter for Class B plate by Specification 57-114-1. Minimum tensile values are given below. In each case the first value is "as welded", the second and third being "stress relieved" at 1000°F and 1150°F, respectively. Test specimens were prepared as shown by Figure 1.

<u>Electrode</u>	<u>Minimum Tensile Properties (0.505" Bar)</u>			<u>Reduction of Area</u>
	<u>Yield Strength (0.1% Offset)</u>	<u>Tensile Strength</u>	<u>Elongation %</u>	
SA-85	68,000	83,500	18.5	46.9
	73,500	89,000	22.5	62.3
	67,000	81,900	23.5	62.0
Molex	61,500	78,300	15.5	37.2
	68,500	84,800	22.5	49.9
	66,500	79,700	18.5	50.2

<u>Electrode</u>	<u>Minimum Tensile Properties (0.505" Bar)</u>			<u>Reduction of Area</u>
	<u>Yield Strength (0.1% Offset)</u>	<u>Tensile Strength</u>	<u>Elongation %</u>	
Hollup MLY	73,500	89,800	18.5	36.9
	77,000	91,800	17.0	31.0
	75,500	88,900	21.0	54.6
BD-85	70,000	81,200	19.3	39.8
	70,000	79,750	21.0	49.1
	70,620	82,000	17.0	32.7
Type 90	76,500	93,200	17.5	38.4
	86,000	99,500	22.5	52.4
	81,000	93,100	16.5	50.2
SW-76	70,500	91,750	20.0	39.0
	89,000	103,700	15.5	29.4
	84,500	98,600	18.5	45.1
SA-100	96,500	112,100	14.5	37.2
	97,500	111,500	15.5	49.6
	105,000	118,200	14.0	43.3

It should be noted that the Hollup MLY indicates some possibility because of its high yield strength for use with Class C plate material. The Shield Arc #100 develops a very high yield strength in the "as welded" condition and this property is not impaired by stress relieving. This electrode should have possibilities for higher yield strengths by a post-welding quench and temper treatment.



A - COMPLETED BUTT WELD



B - LONGITUDINAL COUPONS CUT OUT AND MARKED FOR ROUGH TURNING



C - ROUGH TURNED ALL WELD-METAL TENSION SPECIMENS READY FOR STRESS RELIEVING



D - ALL WELD-METAL TENSION SPECIMENS FINISH MACHINED

TYPICAL OPERATIONS FOR OBTAINING ALL WELD-METAL TENSION SPECIMENS FROM BUTT WELDS
WTN.639-6561

APPENDIX A

Correspondence

Relating to Tests of Commercial
Brands of Welding Electrodes
for Specification 57-203-1

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON

HOLLADY/fsm

O.O. No. 470.1/22816
Attn: SPOTB-Specs. Unit

March 29, 1943
Rec'd.
R.I.A.
470.14/3021
April 1, 1943

Subject: Specification for Alloy Steel Welding Electrodes.

To: Commanding General
Rock Island Arsenal
Rock Island, Illinois

1. It has come to the attention of this office that a considerable quantity of alloy steel electrodes is being used by Rock Island Arsenal and certain commercial manufacturers in the welding of high-tensile steel plate. It is considered necessary to establish a specification for such electrodes to assist in the conservation of critical materials and to enable those agencies responsible for the control of materials to determine what alloys are required for this purpose.

2. It is requested that information with regard to the chemical composition and other essential characteristics of alloy electrodes be furnished this office as soon as practicable, together with your recommendation with regard to the development of a specification.

By order of the Chief of Ordnance:

(s/t) Edward L. Hollady
Assistant

O.O. 470.1/22816
Attn: SPOTB-Specs. Unit
R.I.A. 470.14/3021

1st Ind.

Hoppe/dn

Rock Island Arsenal, Rock Island, Ill., April 7, 1943.

To: Chief of Ordnance, War Department, Washington, D. C.
Attn: Technical Division, Service Branch, Specifications Unit.

1. Alloy steel electrodes are being used at this Arsenal for welding steels meeting requirements of Specification 57-114-1A, Class C, and WD steels having yield strengths of approximately 70,000 psi.

2. Electrodes have been purchased with the requirement that deposited weld metal shall have a minimum yield strength of 70,000 psi. and a minimum elongation of 20% in 2" after stress relieving for one hour at 1100°F.

3. Electrodes meeting these requirements have been A. O. Smith S1476 and Murex Cromansil. Approximate analyses of metal deposited by these electrodes are as follows:

O.O. 470.1/22816
Attn: SPOTB-Specs. Unit
R.I.A. 470.14/3021

1st Ind. (Continued)

April 7, 1943

	<u>SW-76</u>	<u>Cromansil</u>
Carbon	.10	.14
Manganese	.56	.65
Silicon	.20	.15
Chromium	--	.31
Nickel	--	1.00
Molybdenum	.70	.80
Vanadium	.06	--

4. It is suggested that the specification for alloy steel electrodes be similar to Specification 57-203-1A and that they be separated into classes in accordance with physical properties as in A.S.T.M.-A.W.S. Specification A233-42T.

For the Commanding General:

(s/t) ELMER C. GOEBERT
Colonel, Ord. Dept.
Assistant

O.O. 470.1/22816
Attn: SPOTB-Spec. Unit
R.I.A. 470.14/3021

2nd Ind.

WHITE/ds

War Department, Ordnance Office, Washington, D. C., April 10, 1943.

To: Commanding Officer, Watertown Arsenal, Watertown, Mass.
Attn: Ordnance Laboratory.

1. The recommendations of your Arsenal are requested relative to the preparation of a specification as proposed above.

2. As indicated in the first indorsement, it is desirable to have the class or classes of electrodes selected to meet the requirements corresponding to A.S.T.M./A.W.S. classifications in Specification A233-42T. At the same time, the class or classes should include the electrodes already found suitable for the purpose by Rock Island Arsenal.

3. It appears that the additional classes required could be added by amendment or revision to U. S. Army Specification No. 57-203-1A, thus eliminating the need for the preparation of a separate specification. If this course is considered practicable, comments are desired as to any changes necessary in 57-203-1A.

By order of the Chief of Ordnance:

(s/t) Edward L. Hollady
Assistant

O.O. 470.1/22816
Attn: SPOTB-Spec. Unit
R.I.A. 470.14/3021
W.A. 400.273/802

3rd Ind.

AJF/eac

Watertown Arsenal, Watertown, Massachusetts, April 28, 1943

To: Chief of Ordnance, Pentagon Building, Washington, D. C.
Attn: SPOTB-Specification Section

1. It is the opinion of this Arsenal that the addition of a class to U. S. Army Specification 57-203-1A which would include the electrodes referred to in the first indorsement is desirable. It is believed that a class meeting the requirements of class E3020 of the A.S.T.M./A.W.S. Specification would be adequate for this purpose.

2. If it is considered desirable by his office, it is suggested that Rock Island be instructed to furnish this Arsenal with ten pounds of 5/32" or 3/16" diameter electrodes of each of the types referred to in the 1st indorsement, in order that tests may be made on this material to determine whether they will meet the requirements of class E3020.

3. This Arsenal concurs in the proposal to add this class to 57-203-1A rather than issuing a new specification. No changes other than the addition of the proposed class will be required in the present specifications.

For the Commanding Officer:

(s/t) H. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

O.O. 470.1/22816
Attn: SPOTB-Specs. Unit
RIA 470.14/3021
W.A. 400.273/802

4th Ind.

WHITE/fsm

War Department, Ordnance Office, Washington, D. C. May 15, 1943.

To: Commanding General, Rock Island Arsenal, Rock Island, Illinois.

1. In order to make specification No. 57-203-1A suitable for the purchase of alloy steel electrodes, it is proposed, in accordance with the recommendation in the third indorsement, to add a Class E to the specification with requirements corresponding to A.W.S./A.S.T.M. Grade E3020. Suitable reference will be made to proposed Class E throughout the specification wherever applicable. However, in paragraph E-4a, E-4b and F-3d(1), steel plate in accordance with specification No. 57-114-1, Class C, will be prescribed for use with Class E electrodes.

2. The attention of your arsenal is directed to paragraph 2 of the third indorsement.

3. Comment or concurrence in the above proposal is requested.

By order of the Chief of Ordnance:

(s/t) Edward L. Hollady
Assistant

O.O. 470.1/22816
Attn: SPOTB-Specs. Unit
R.I.A. 470.14/3021

5th Ind.

Hoppe/dn

Rock Island Arsenal, Rock Island, Illinois, May 31, 1943

To: Chief of Ordnance, War Dept., Washington, D. C.
Attn: Technical Division, Service Branch, Specifications Unit

1. This Arsenal concurs in the change in Specification No. 57-203-1A proposed in the 4th Indorsement.

2. There is being shipped to Watertown Arsenal for test 10 pounds each of the electrodes referred to in 1st Indorsement as suggested in paragraph 2 of 3rd Indorsement. Contact should be made by his office with Watertown Arsenal for results of the test prior to revision of the specification.

For the Commanding General:

(s/t) ELMER C. GOEBERT
Colonel, Ord. Dept.
Assistant

O.O. 470.1/22816
Attn: SPOTB-Spec. Unit
R.I.A. 470.14/3021
W.A. 400.273/802

6th Ind.

WHITE/ds

War Department, Ordnance Office, Washington, D. C., 23 June 1943.

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

1. In view of the recommendation made in paragraph 2 of the fifth indorsement, revision of Specification No. 57-203-1A to include alloy steel electrodes is being withheld pending receipt of information from your arsenal relative to the tests being conducted on the samples submitted by Rock Island Arsenal. Such data should be furnished as soon as practicable,

By order of the Chief of Ordnance:

(t) Edward L. Hollady
Assistant

4 November 1943

Laboratory (MLW)

Subject: Class E Electrode, Spec. 57-203-1

To: Chief of Ordnance, U.S.A.
Pentagon Building
Washington 25, D. C.

Attn: SPOTB - Spec. Unit

1. With reference to Class E welding electrodes under subject specification for welding Class C structural alloy steels of Specification 57-114-1, there is inclosed a copy of WAL Test Report No. 641/2, 13 October 1943, giving tensile properties of weld metal deposited by three commercial brands:

A. O. Smith Corporation - SW-76
Metal & Thermit Corporation - Type 90
Lincoln Electric Company - Shield-Arc #100

2. The properties were obtained from pad deposits, as shown in Figure #1, and not from butt joint specimens as specified in Specification A7S-ASTM A233-42T. Also a tensile specimen of 0.357" diameter was used instead of a 0.505" diameter specimen. The data should be comparable however.

3. It will be noted that the minimum yield and tensile strengths of SW-76 and Type 90 after stress-relieving are well above the 67,000 lbs. per sq. in. and 80,000 lbs. per sq. inch minimum respectively prescribed for Class E-8020 in Specification A233-42T. The Lincoln Shield-Arc #100 appears to be E10010 because of tensile properties shown and by reason of its inability to be used on straight polarity D.C.

4. Further tests are being made to determine the response of these weld metals to stress-relieving at 1000°F for 4 hours as prescribed for Class C material in Specification 57-114-1.

For the Commanding Officer:

1 Incl.
W.A.L. Test Rpt. 641/2(s/t) G. L. COX
Lt. Colonel, Ord. Dept.
Assistantcc Rock Island Arsenal
Attn: Laboratory

UUB14

WA35

BWA V WAO C7 WD

FROM BARNES, C. OF ORDINANCE, ASF, WASHINGTON, D. C. 072231Z MAR 44
TO WATERTOWN ARSENAL, WATERTOWN, MASS.

GR NC

ATTN: LABORATORY

RE YOUR FOURTH INDORSEMENT WTN. 400.273/1064 WHEN CAN OPERATING CHARACTER-
ISTICS CLASS B ELECTRODES BE EXPECTED AT THIS OFFICE FOR SPECIFICATION
57-203-1B. END. CITE SPOTB MATERIAL SEC. WEBSTER.

080012Z

WTN. 400.273/1110

X

LABORATORY

9 MARCH 1944

WLW/ahk

CHIEF OF ORDINANCE, U.S.A.

PENTAGON BUILDING, WASHINGTON 25, D. C.

SPOTB, MATERIAL SECTION

REURTT 072231Z MAR 44, SPOTB MATERIAL SEC WEBSTER, ELECTRODE DATA TO BE
FORWARDED BY LETTER NEXT WEEK. TESTS OF WELD METALS FOR CLASSIFICATION OF
BRANDS NEARLY COMPLETED. END. CITE WARNER LABORATORY.

MATHER, WATERTOWN ARSENAL

G. L. COX
LT. COL., ORD. DEPT.
ASSISTANT

16 March 1944

Laboratory (CMS)

Subject: Specification 57-203-1, Welding Electrodes, Steel Arc

To: Chief of Ordnance, U.S.A.
Pentagon Building
Washington 25, D. C.

Attn: SPOTB - Spec. Unit

1. Reference TT 072231Z, March 44, Webster, the following data on electrode operating characteristics for Class E and F material are submitted herewith for inclusion in paragraph H-10 of subject specification.

	<u>Class E</u>	<u>Class F</u>
Melting rate	9 - 11	10.5 - 12.5
Deposition rate min.	40	40
Deposition efficiency min.	70	60
Penetration	0.08" min.	0.10" max.

2. It is noted that paragraph H-10 of the proposed draft of 57-203-1B has omitted some of the material contained in paragraph H-8 of 57-203-1A. This material should be restored to the paragraph, otherwise the table of operating data is meaningless. It is also noted that in paragraph H-10, the values of penetration for Class B should read maximum instead of minimum as in 57-203-1A.

3. Inclosed are three copies of Figures 1, 2, and 3. These have been redrawn to parallel as closely as possible those submitted by this Arsenal for 57-203-2A.

For the Commanding Officer:

(s/t) G. L. COX
Lt. Colonel, Ord. Dept.
Assistant3 Incls. (in trip.)
Figs. 1, 2, & 3

APPENDIX B

Operating Characteristics

5/32" Electrode

150 Amperes D.C. Reverse Polarity

Travel Speed 5"/minute

Minimum Stable Arc Voltage

OPERATING CHARACTERISTICS

Welding Data

<u>Test</u>	<u>Weight Before</u>	<u>Weight After</u>	<u>Amp.</u>	<u>Volts</u>	<u>Time Seconds</u>	<u>Stub End</u>
(Shield Arc #85)						
128	3# 10.69 oz.	3# 11.55 oz.	150	24	63	2-5/16"
129	3# 9.72 oz.	3# 10.57 oz.	150	24	65	2-3/4"
130	3# 10.31 oz.	3# 11.15 oz.	150	24	64	2-3/8"
131	3# 11.46 oz.	----	150	24	64	2-7/16"
	----	----	150	24	63.5	2-9/16"
	----	----	150	24	64	2-3/8"
	----	3# 14.89 oz.	150	24	64	2-9/16"
132	3# 12.22 oz.	----	150	24	63	2-9/16"
	----	----	150	24	64	2-9/16"
	----	----	150	24	65	2-5/16"
	----	3# 15.69 oz.	150	24	65	2-1/4"
(Murex Molex)						
123	3# 10.12 oz.	3# 11.03 oz.	150	24/25	64	2-3/8"
124	3# 9.03 oz.	3# 9.94 oz.	150	24/25	66	2-1/4"
125	3# 10.35 oz.	3# 11.23 oz.	150	24/25	64	2-1/2"
126	3# 10.41 oz.	----	150	24/25	65	2-5/16"
	----	----	150	24/25	65	2-3/8"
	----	----	150	24/25	63	2-9/16"
	----	3# 13.99 oz.	150	24/25	67	2-1/8"
127	3# 11.66 oz.	----	150	24/25	66	2-5/16"
	----	----	150	24/25	63	2-5/8"
	----	----	150	24/25	64	2-5/8"
	----	3# 15.23 oz.	150	24/25	65	2-3/8"
(Sureweld MLY)						
173	3# 6.26 oz.	3# 7.12 oz.	150	26	75	2-1/4"
174	3# 11.50 oz.	3# 12.36 oz.	150	26	75	2-3/8"
175	3# 8.69 oz.	3# 9.56 oz.	150	26	76	2-1/8"
176	3# 8.81 oz.	----	150	26	75	2-1/4"
	----	----	150	26	75	2-1/4"
	----	----	150	26	75	2"
	----	3# 12.36 oz.	150	26	75	2-1/16"
177	3# 8.45 oz.	----	150	26	75	2-7/16"
	----	----	150	26	76	2"
	----	----	150	26	75	2-3/8"
	----	3# 11.87 oz.	150	26	75	2-5/16"

<u>Test</u>	<u>Weight Before</u>	<u>Weight After</u>	<u>Amp.</u>	<u>Volts</u>	<u>Time Seconds</u>	<u>Stub End</u>
(Blue Devil #85)						
236	3# 5.990 oz.	3# 6.875 oz.	150	26	72	1-7/8"
237	3# 7.170 oz.	3# 8.090 oz.	150	26	72	1-7/16"
238	3# 7.595 oz.	3# 8.450 oz.	150	26	72	1-13/16"
239	3# 6.765 oz.	----	150	26	72	1-7/8"
	----	----	150	26	72	1-7/8"
	----	----	150	26	72	1-7/8"
	----	3# 10.280 oz.	150	26	72	1-3/4"
240	3# 6.685 oz.	----	150	26	72	1-13/16"
	----	----	150	26	71	1-15/16"
	----	----	150	26	71	1-15/16"
	----	3# 10.185 oz.	150	26	72	1-13/16"
(Murex Type 90)						
168	3# 15.20 oz.	4# 0.05 oz.	150	26	62	2-1/2"
169	3# 7.89 oz.	3# 8.72 oz.	150	26	61.5	2-1/2"
170	3# 12.70 oz.	3# 13.49 oz.	150	26	62.5	2-9/16"
171	3# 11.33 oz.	----	150	26	62	2-7/16"
	----	----	150	26	61.5	2-7/16"
	----	----	150	26	61	2-7/16"
	----	3# 14.63 oz.	150	26	62	2-1/2"
172	3# 11.49 oz.	----	150	26	60	2-7/16"
	----	----	150	26	62	2-1/4"
	----	----	150	26	61	2-1/4"
	----	3# 14.72 oz.	150	26	62	2-1/4"
(SW-76)						
158	3# 15.44 oz.	4# 0.28 oz.	150	24	70	2-7/16"
159	3# 15.95 oz.	4# 0.79 oz.	150	24	70.5	2-1/2"
160	3# 15.55 oz.	4# 0.42 oz.	150	24	70.5	2-3/8"
161	3# 14.26 oz.	----	150	24	71	2-3/8"
	----	----	150	24	70.5	2-5/16"
	----	----	150	24	70.5	2-1/8"
	----	4# 1.76 oz.	150	24	68.5	2-5/16"
162	4# 3.094 oz.	----	150	24	68.5	2-1/4"
	----	----	150	24	68.5	2-5/16"
	----	----	150	24	70.5	2-5/16"
	----	4# 6.52 oz.	150	24	69.0	2-1/4"

<u>Test</u>	<u>Weight Before</u>	<u>Weight After</u>	<u>Amp.</u>	<u>Volts</u>	<u>Time Seconds</u>	<u>Stub End</u>
(Shield Arc #100)						
163	3# 7.02 oz.	3# 7.84 oz.	150	25	61.5	2-7/16"
164	3# 15.39 oz.	4# 0.26 oz.	150	25	62.0	2-3/8"
165	3# 15.65 oz.	4# 0.49 oz.	150	25	61.5	2-3/8"
166	3# 13.28 oz.	----	150	25	61.0	2-3/8"
	----	----	150	25	61.0	2-3/8"
	----	----	150	25	61.0	2-5/16"
	----	4# 0.75 oz.	150	25	60.0	2-3/8"
167	3# 14.25 oz.	----	150	25	62.0	2-3/8"
	----	----	150	25	62.0	2-1/2"
	----	----	150	25	61.0	2-1/2"
	----	4# 1.59 oz.	150	25	62.0	2-3/8"

Computed Values

<u>Test No.</u>	<u>Melting Rate (In. per Min.)</u>	<u>Deposition Rate (Oz. per Hour)</u>	<u>Deposition Efficiency %</u>
(Shield Arc #65)			
128	10.8	48.0	75.0
129	10.7	48.4	76.7
130	10.9	47.3	73.8
131	10.8	48.4	76.1
132	10.8	48.6	76.5
(Murex Molex)			
123	10.9	51.2	79.9
124	10.7	49.4	78.7
125	10.8	49.6	78.2
126	10.8	49.6	78.7
127	10.7	49.8	79.2
(Sureweld MLY)			
173	9.4	41.0	71.7
174	9.3	41.4	72.8
175	9.4	41.0	71.7
176	9.5	42.5	73.3
177	9.4	40.7	71.3

<u>Test No.</u>	<u>Melting Rate (In. per Min.)</u>	<u>Deposition Rate (Oz. per Hour)</u>	<u>Deposition Efficiency %</u>
(Blue Devil #85)			
236	10.1	46.4	77.9
237	10.4	46.1	74.2
238	10.1	42.8	70.7
239	10.1	43.9	72.9
240	10.1	43.9	72.7
(Murex Type 90)			
168	11.1	49.0	64.3
169	11.2	48.6	63.3
170	11.0	45.0	60.2
171	11.2	47.9	62.8
172	11.5	46.8	60.9
(SW-76)			
158	10.8	43.2	63.4
159	10.6	42.5	63.0
160	10.7	43.2	65.3
161	10.9	43.2	65.0
162	11.0	43.2	63.4
(Shield Arc #100)			
163	11.1	48.2	72.4
164	11.2	50.0	75.8
165	11.3	49.0	73.6
167	11.5	51.1	75.6
168	11.2	48.6	73.3

Weld Bead Contour
(Values = X5)

<u>Test No.</u>	<u>Section</u>	<u>Depth Inches*</u>	<u>Height Inches*</u>	<u>Width Inches*</u>
(Shield Arc #85)				
128	A	.547	.516	2.625
	B	.469	.469	2.750
	C	.468	.422	2.625

<u>Test No.</u>	<u>Section</u>	<u>Depth Inches*</u>	<u>Height Inches*</u>	<u>Width Inches*</u>
		(Shield Arc #85)		
130	A	.484	.500	2.625
	B	.484	.516	2.688
	C	.438	.500	2.625
		(Murex Molex)		
124	A	.423	.469	2.563
	B	.406	.438	2.688
	C	.375	.469	2.625
		(Murex Molex)		
125	A	.406	.422	2.625
	B	.406	.484	2.625
	C	.440	.465	2.625
		(Sureweld MLY)		
174	A	.547	.531	2.563
	B	.609	.469	2.500
	C	.641	.406	2.438
		(Sureweld MLY)		
175	A	.531	.500	2.563
	B	.531	.500	2.500
	C	.500	.422	2.563
		(Blue Devil #85)		
236	A	.578	.563	2.438
	B	.547	.541	2.375
	C	.531	.609	2.313
		(Blue Devil #85)		
237	A	.641	.547	2.375
	B	.578	.563	2.344
	C	.500	.594	2.375
		(Murex Type 90)		
168	A	.359	.484	2.750
	B	.438	.500	2.750
	C	.406	.438	2.750
		(Murex Type 90)		
170	A	.359	.469	2.750
	B	.406	.406	2.688
	C	.406	.422	2.750

<u>Test No.</u>	<u>Section</u>	<u>Depth Inches*</u>	<u>Height Inches*</u>	<u>Width Inches*</u>
(SW-76)				
158	A	.500	.469	2.625
	B	.484	.406	2.563
	C	.500	.391	2.625
(SW-76)				
159	A	.469	.438	2.594
	B	.500	.422	2.563
	C	.469	.391	2.656
(Shield Arc #100)				
163	A	.516	.563	2.850
	B	.484	.469	2.750
	C	.453	.484	2.875
(Shield Arc #100)				
165	A	.453	.500	2.625
	B	.484	.469	2.688
	C	.453	.422	2.719

*With respect to plate surface.

(Averages)

<u>Electrode</u>	<u>Melting Rate</u>	<u>Deposition Rate</u>	<u>Deposition Efficiency</u>	<u>Penetration</u>
SA-85	10.8"	48.1 oz.	75.6%	.096"
Molex	10.8"	49.9 oz.	78.9%	.082"
MLY	9.4"	41.3 oz.	72.2%	.112"
BD-85	10.2"	44.6 oz.	73.7%	.112"
Type 90	11.2"	47.5 oz.	62.3%	.080"
SW-76	10.8"	43.1 oz.	64.0%	.096"
SA-100	11.3"	49.4 oz.	74.1%	.094"

APPENDIX C

Butt Welds - 3/4" Mild Steel Plate

60° Single Vee, 1/2" Root Opening
1/4" Mild Steel Backing

(Figure 1 - Specification 57-203-1B)

Welding Data
Radiographic Soundness
Weld Metal Analyses

Butt Welds - 3/4" Plate

<u>Weld</u>	<u>Electrode</u>	<u>Amperes*</u>	<u>Volts*</u>	<u>Layers</u>	<u>Radiographic</u>
SA85-1	5/32" Shield Arc #85	135-140	24-26	8	Standard I
SA85-2	5/32" Shield Arc #85	135-140	24-26	7	Standard I
SA85-3	5/32" Shield Arc #85	135-140	24-26	7	Standard I
Mo-1	5/32" Murex Molex	135-140	23-24	7	Standard III
Mo-2	5/32" Murex Molex	150	24	7	Standard III
Mo-3	5/32" Murex Molex	155-160	24-26	7	Standard II
Mo-4	5/32" Murex Molex	160	24-25	7	Standard III
Mo-5	5/32" Murex Molex	160	24-25	7	Standard II
MLY-1	5/32" Hollup MLY	135-140	24-26	7	Standard I
MLY-2	5/32" Hollup MLY	135-140	24-26	8	Standard I
MLY-3	5/32" Hollup MLY	135-140	24-26	8	Standard I
BD85-1	3/16" Blue Devil #85	190-195	25-26	8	Standard I
BD85-2	3/16" Blue Devil #85	190-195	25-26	8	Standard I
BD85-3	3/16" Blue Devil #85	190-195	25-26	8	Standard I
90-1	5/32" Murex Type 90	135-140	26-28	8	Standard I
90-2	5/32" Murex Type 90	135-140	26-28	8	Standard I
90-3	5/32" Murex Type 90	135-140	26-28	8	Standard I
76-1	5/32" SW-76	135-140	26-28	8	Standard I
76-2	5/32" SW-76	135-140	26-28	8	Standard I
76-3	5/32" SW-76	135-140	26-28	8	Standard I
100-1	5/32" Shield Arc #100	135-140	24-26	7	Standard I
100-2	5/32" Shield Arc #100	135-140	24-26	7	Standard I
100-3	5/32" Shield Arc #100	135-140	24-26	7	Standard I

*Direct Current, Reverse Polarity (Electrode Positive)

Chemical Analyses - Weld Metal

<u>Electrode</u>	<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>	<u>Cu</u>
Shield Arc #85	.08	.46	.34	.022	.017	—	.03	.46	—	.01
Molex	.06	.53	.27	.026	.012	—	.08	.46	—	.01
Hollup MLY	.13	.44	.41	.027	.013	—	.01	.64	—	.10
Blue Devil #85	.08	.40	.19	.042	.016	Trace	.04	.26	Tr.	.18
Type 90	.08	.48	.08	.021	.026	1.10	.12	.65	—	.01
SW-76	.06	.36	.08	.028	.021	Trace	.01	.37	.03	.01
Shield Arc #100	.10	.64	.35	.026	.019	Trace	.08	.88	.14	.01

APPENDIX D

Tensile Properties of Weld Metal

0.505" Diameter Test Specimens

As Welded

Stress Relieved - 1000°F for 4 Hours
- 1150°F for 4 Hours

WELD METAL TENSION TESTS

<u>Electrode</u>	<u>Yield Strength(psi)</u>		<u>Tensile Strength(psi)</u>	<u>Elong. %</u>	<u>Reduction of Area</u>
	<u>0.05% Offset</u>	<u>0.10% Offset</u>			
<u>AS WELDED</u>					
SA-85	68,000	69,000	83,500	24.0	59.8
	66,500	68,000	84,600	18.5	46.9
Molex	64,500	64,500	81,600	20.5	46.2
	65,500	64,500	81,200	20.0	46.2
	61,500	61,500	78,300	21.0	40.6
	64,000	63,500	79,500	19.5	37.2
	62,500	64,000	80,000	15.5	41.8
	65,500	67,000	82,300	18.0	42.1
Hollup MLY	75,000	73,500	89,800	18.5	36.9
	75,000	75,500	90,800	22.5	54.3
BD-85	70,000	70,000	81,200	19.3	39.8
	----	73,250	81,750	19.5	40.9
Type 90	77,000	77,500	94,100	21.5	51.3
	75,000	76,500	93,200	17.5	38.4
SW-76	69,500	70,500	91,750	20.0	39.0
	71,000	72,000	93,000	20.0	45.1
SA-100	100,500	100,500	114,300	14.5	37.2
	97,000	96,500	112,100	20.5	56.2
<u>STRESS RELIEVED - 1000°F (4 Hours)</u>					
SA-85	73,000	73,500	89,000	25.5	62.3
	73,500	74,000	89,600	22.5	63.2
Molex	68,000	68,500	84,800	22.5	49.9
	69,500	70,000	85,200	26.0	60.8
Hollup MLY	81,000	77,000	91,800	23.0	58.3
	79,000	77,500	92,500	17.0	31.0
BD-85	----	70,000	79,750	24.5	54.6
	70,620	66,250	80,000	21.0	49.1
Type 90	87,000	86,000	99,500	22.5	52.4
	87,000	86,000	100,200	22.5	55.1
SW-76	92,000	90,500	106,750	17.0	38.4
	90,500	89,000	103,700	15.5	29.4
SA-100	102,000	101,500	114,900	15.5	49.6
	98,500	97,500	111,500	18.0	53.0

<u>Electrode</u>	<u>Yield Strength(psi)</u>		<u>Tensile Strength(psi)</u>	<u>Elong. %</u>	<u>Reduction of Area</u>
	<u>0.05% Offset</u>	<u>0.10% Offset</u>			
<u>STRESS RELIEVED - 1150°F (4 Hours)</u>					
SA-85	69,000 66,000	69,000 67,000	83,900 81,900	26.0 23.5	62.7 62.0
Molox	67,500 65,500	68,500 66,500	81,400 79,700	18.5 22.5	50.2 59.8
Hollup MLY	76,000 76,000	75,500 76,500	88,900 90,600	21.0 23.5	54.6 60.8
BD-85	----- 70,620	72,750 70,620	82,000 82,750	20.5 17.0	46.9 32.7
Type 90	81,500 80,500	81,000 81,500	93,500 93,100	21.0 16.5	56.7 50.2
SW-76	87,000 84,000	86,000 84,500	99,400 98,600	18.5 19.0	45.1 48.0
SA-100	105,000 107,000	105,000 106,000	118,200 120,500	19.5 14.0	53.0 43.3

FRACTURES

As Welded	Somewhat irregular, generally fibrous with scattered pinholes and fisheyes.
Stress Relieved	Generally cupped and fibrous with very few pinholes. Molox retains some fisheyes.