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February 23rd, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1603.

Qualification Tests for Stelco Welding
Electrodes for Use in Ship Construction.

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Bureau of Mines
Division of Metallic
Minerals

Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Introduction:

On January 20th, 1944, Sub-Lieut. L. E. Sibley, on behalf of the Director of Technical Research, Department of National Defence, Naval Services, Ottawa, Ontario, requested our assistance in determining the suitability of Steel Company of Canada welding electrodes in ship construction.

It was decided to subject the electrodes to the electrode qualification procedure laid down by the American Welding Society. Since this Department is not in a position to do the actual welding, it was necessary to make arrangements for this to be done outside of these Laboratories. Mr. H. Thomasson, Welding Engineer of the Canadian Westinghouse Company Limited, Hamilton, Ontario, willingly agreed to provide the necessary facilities.

Origin of Material:

The Steel Company of Canada Limited submitted three types of electrodes to be used to weld the test plates necessary for qualification tests. Below are listed the type numbers of the electrodes, together with the American Welding Society specifications to which these electrodes are said to conform:

<u>Steel Company Type No.</u>		<u>American Welding Society Specification No.</u>
604	-	E 6012
704	-	E 6010
804	-	E 6030

In Types 604 and 704, 5 pounds of electrodes of each of 5/32 in. and 3/16 in. diameters were supplied. In Type 804, 5 pounds of 5/32-inch-diameter electrodes only was supplied.

Procedure:

The following table lists the electrode sizes used, polarity and current settings recommended by the Steel Company of Canada, together with the current settings actually used to weld the test plates. The actual current setting used was determined by inserting an ammeter into the welding circuit, and the arc voltage was measured by means of a voltmeter across the arc.

<u>Electrode Type No.</u>	<u>Electrode diameter, inches</u>	<u>RECOMMENDED</u>			<u>ACTUALLY USED</u>	
		<u>Polarity</u>	<u>Current</u>	<u>Voltage</u>	<u>Current</u>	<u>Voltage</u>
604	5/32	Straight.	135-170	22-25	150	24
604	3/16	Straight.	180-220	25-28	205	25
704	5/32	Reverse.	130-160	22-27	140	25
704	3/16	Reverse.	150-200	25-28	180	25
804	5/32	Straight.	150-180	25-26	165	25

All welding procedure was in accordance with the American Welding Society regulations governing edge preparation, root gap, pass sequence, etc., using A.S.T.M. A7 type open

(Procedure, cont'd) -

hearth steel. A tensile test plate for each individual electrode size was prepared, together with a bend test plate for each type of electrode. All welding was supervised and witnessed by the writer.

On completion of welding, the test plates were shipped to these Laboratories. Here, test pieces were machined according to the specification. Tensile test specimens were stress-relieved at 1150° F. before testing. Bend test specimens were tested in the "as welded" condition.

RESULTS OF TESTS:

The following table lists the specification requirements as compared with the properties revealed in the above tests:

Tensile Tests.

Electrode Type No.	Electrode diameter, inches	Tensile strength, p.s.i.	Yield point, p.s.i.	Elongation in 2 inches, per cent
AWS - E 6010		:60,000 min.	:47,000 min.	27 min.
(1) Stelco 704	: 5/32	:68,800	:52,500	21.0
(2) " 704	: 5/32	:70,500	:55,000	19.0
(3) " 704	: 3/16	:61,500	:44,900	35.0
(4) " 704	: 3/16	:65,600	:51,700	39.5
AWS - E 6012		:60,000 min.	:47,000 min.	22 min.
(1) Stelco 604	: 5/32	:75,200	:61,600	26.5
(2) " 604	: 5/32	:76,100	:62,500	28.0
(3) " 604	: 3/16	:76,500	:63,500	27.5
(4) " 604	: 3/16	:77,400	:65,600	29.0
AWS - E 6030		:60,000 min.	:47,000 min.	30 min.
(1) Stelco 804	: 5/32	:64,000	:54,400	38.0
(2) " 804	: 5/32	:65,200	:55,100	36.0

(Continued on next page)

(Results of Tests, cont'd) -

Bend Tests.

The AWS specification requires that the convex surface of the test specimen show no crack or open defect exceeding 1/8 inch measured in any direction after bending. Bend tests were made in a bending jig conforming to the specification dimensions. The table below lists the test results:

<u>Position</u>	<u>Steel Co. No.</u>	<u>AWS Specification</u>	<u>Remarks</u>
Face	704	E 6010	Crack $\frac{1}{8}$ inch long at fusion zone.
Face	704	E 6010	Crack, full length of fusion zone.
Root	704	E 6010	Sound.
Root	704	E 6010	Sound.
Face	604	E 6012	Broke in fusion zone before complete bend.
Face	604	E 6012	Sound.
Root	604	E 6012	Broke in fusion zone before complete bend.
Root	604	E 6012	Sound.
Face	804	E 6030	Sound.
Face	804	E 6030	Sound.
Root	804	E 6030	Sound.
Root	804	E 6030	Sound.

Discussion:

Type No. 604 (E 6012) has good operating characteristics and easy slag removal. On the other hand, Type No. 704 has poor operating characteristics over the entire range of recommended welding currents. Main difficulties are: wild arc, which is impossible to control fully by shortening the arc length; pronounced splatter, resulting in poor transferring efficiency; and too fluid slag, which tends to flow ahead of the arc and increases slag inclusion probability. It was found, also, that the slag was difficult to remove from the weld when cold, tending to powder rather than to flake off.

Type No. 804 has fair operating characteristics. Some splatter was noticeable but not to an objectionable extent. The slag freezes at a considerably lower temperature

(Discussion, cont'd) -

than the molten metal, producing a gummy slag difficult to remove from a hot crater. The slag, however, is quite easily removed when cold.

Type No. 704 fails to meet AWS Specification E 6010 physical properties requirements. Two bend tests failed by cracking, two tensile tests in elongation, and one tensile test in minimum yield point.

Type No. 604 meets AWS Specification E 6012 with regard to physical properties. However, it fails to meet the bend test requirements.

Type No. 804 meets AWS Specification E 6030 with regard to both physical properties and bend test requirements.

CONCLUSIONS:

1. Operating characteristics and general workability of Type No. 604 (E 6012) electrodes are satisfactory. Physical properties are above the specification minimums but bend tests are unsatisfactory.

2. Operating characteristics and general workability of Type No. 704 (E 6010) electrodes are unsatisfactory. Moreover, bend and tensile tests fail to meet specification requirements.

3. Operating characteristics and general workability of Type No. 804 (E 6030) electrodes are satisfactory. Physical properties are above the specification and bend tests are satisfactory.

Recommendations:

1. Type No. 804 is satisfactory for use in welding ship-quality mild steel plate.

2. Types Nos. 704 and 604 should be used only on mild steel not of structural importance.

HJN:GHB.

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