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Report No. 8926-095

Material - Welding Electrodes - Metal Arc - Smithway SW-151 (A. O. Smith Corporation)

Weld Strength and Ductility After Heat Treatment

T. J. Koppernal, H. C. Turner, W. M. Sutherland

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Abstract

SAE 4130 steel plates 1/4, 3/8 and 1/2 inch thick were double "V" chamfered with 1/16" lands on the edges to be welded. SAE 4130 steel plates 1/8 inch thick were squared preparatory to welding. The steel plates were welded with 1/8 inch diameter Smithway 151 (A. O. Smith Corporation, Milwaukee, Wisconsin), as follows: 1/8 and 1/4 inch thick, two passes, one from each side; 3/8 and 1/2 inch thick, four passes, two from each side. After welding, all test specimens were heat treated as follows: 1600°F one hour, oil quench, 830°F or 1000°F one hour, air cool. Tension, bend and shear testing subsequent to heat treatment showed the welds capable of developing satisfactory strengths in 150,000 psi (830°F temper) and 175,000 psi (1000°F temper) ranges. Those welds heat treated to the 150,000 psi range displayed satisfactory ductility, but those heat treated to the 175,000 psi range appeared to be somewhat brittle.

Reference: Koppernal, T. J., Turner, H. C., Sutherland, W. M., "Evaluation Tests of 1/8" Smithway SW-151 Electrodes," General Dynamics/Convair Report MP 56-660, San Diego, California, 10 June 1957. (Reference attached).

STRUCTURES-MATERIALS LABORATORY

CONVAIR
A DIVISION OF GENERAL DYNAMICS CORPORATION
SAN DIEGO

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MODEL F-106A

TITLE

REPORT NO. 56-660
EVALUATION TESTS OF 1/8" SMITHWAY
SW-151 ELECTRODES

MODEL F-106A

PREPARED BY T. J. Kopperud
T. J. Kopperud

GROUP MATERIALS & PROCESSES LAB.

CHECKED BY H. C. Turner
H. C. Turner

REFERENCE

CHECKED BY W. M. Sutherland
W. M. Sutherland,
Group Engineer

APPROVED BY E. F. Strong
E. F. Strong,
Chief of Test Laboratories

NO. OF PAGES 10

NO. OF DIAGRAMS 7

REVISIONS

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FORM 1812A-4

REPORT NO. 56-660
EVALUATION TESTS OF 1/8" SMITHWAY SW-151 ELECTRODES

OBJECT:

The object of this test was to qualify the use of Smithway SW-151 electrodes for production improvement and to establish an additional source of supply for electrodes that will respond satisfactorily to heat treatments for higher strength levels.

CONCLUSIONS:

1. The electrode can be heat treated to the 150 KSI and 175 KSI ranges.
2. Welded joints heat treated to 150 KSI showed good ductility values.
3. The 175 KSI heat treatment appeared to embrittle the weld-base metal interfaces.

MATERIALS:

Smithway SW-151 electrodes, 1/8" in diameter, were used throughout this test. The composition of this electrode is equivalent to AISI type 502 stainless steel. SAE 4130 steel plates of 1/8", 1/4", 3/8" and 1/2" thicknesses were employed as the base metals.

PROCEDURE:

Butt Welding

The 1/4", 3/8" and 1/2" thick plates were double "V" chamfered with 1/16" lands on the edges to be welded; the 1/8" material was not chamfered. The 1/8" and 1/4" panels were welded in two passes, one pass on each side. The 3/8" and 1/2" panels were welded in four passes, two passes on each side.

After heat treatment, tensile and bend test specimens were milled from the panels as seen in Figure 1. All weld beads were ground flat.

Fillet Welding

Dimensions of the "standard" fillet weld specimens are shown in Figure 2; Figure 4 shows the dimensions of the double shear specimens. Welds in the 1/8" and 1/4" plate were made with one pass along each side. The 3/8" and 1/2" material was welded with two passes along each side.

After heat treatment, mill cuts were machined in the specimens as seen in Figures 2 and 4.

All welding (butt and fillet) was accomplished in the Experimental Factory by a certified weldor.

PROCEDURE: (Cont'd.)

Heat Treating

All specimens were heat treated in the Engineering Test Laboratory using a controlled atmosphere (dissociated ammonia and natural gas).

Specimens were austenitized at 1600°F. for one hour and oil quenched. Appropriate specimens were tempered one hour at 530°F. and 1000°F. for the 175 KSI and 150 KSI ranges, respectively. The specimens were not normalized or stress relieved prior to heat treatment.

Testing

Rockwell "C" hardness readings were made on the weld and two inches from each side of the weld on all butt welded samples, and one inch from the weld on all fillet welded samples.

All other testing was accomplished on a 120,000 lb. Baldwin-Southwark testing machine.

Retesting

Because of the high strength levels attained in the 1/4" and 3/8" butt welded tensile samples, additional samples of the original heat treated 1/4" and 3/8" panels were retempered using the same temperature and holding time. These samples were tested as discussed above.

RESULTS AND DISCUSSION:

The results of the tensile, bend and shear tests are shown in Tables I, III, and IV, respectively. Table II contains the results of the retests on the 1/4" and 3/8" butt welded tensile coupons.

The ultimate tensile strengths indicate that the electrode can be heat treated to the 150 KSI and 175 KSI ranges. The samples heat treated to the 150 KSI range showed good elongation values but the samples at 175 KSI, except for the 1/8" samples, displayed poor elongation values. The retest of the 1/4" and 3/8" samples (processed with a second temper equivalent to the original temper) did not show any great change in values. Inasmuch as all of the 1/4", 3/8" and 1/2" tensile samples heat treated to 175 KSI had poor elongation values with failures taking place in the weld or at the weld-base metal interface, it can be concluded that the 175 KSI heat treatment introduces a very brittle weld and/or weld-base metal interface.

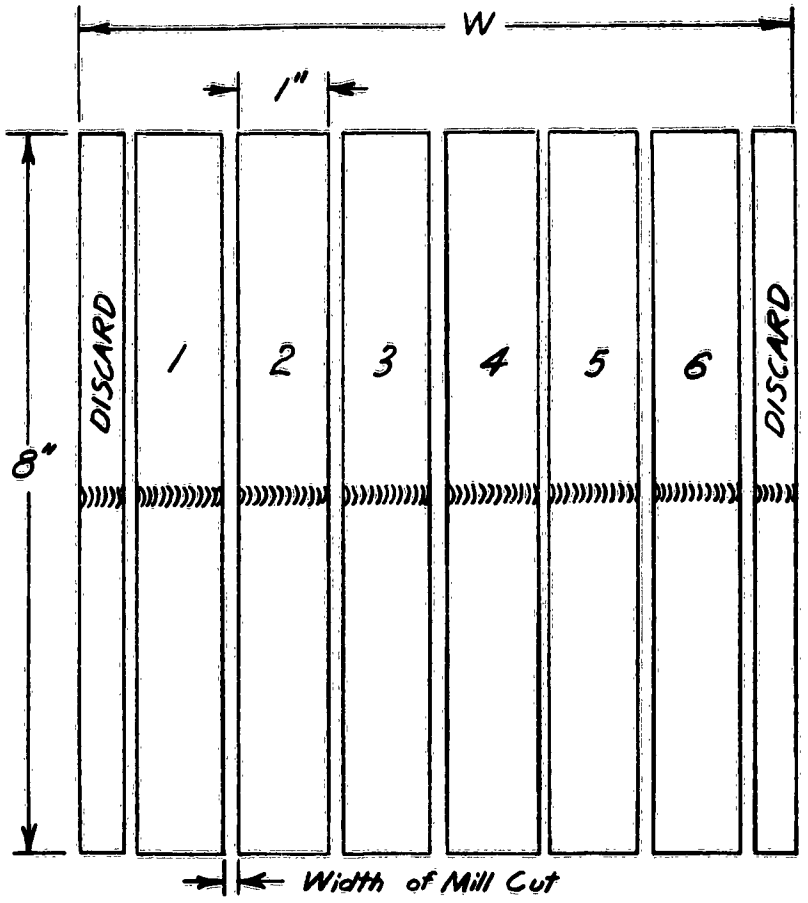
The bend test showed that the bend ductility of the 1/8" samples was significantly greater than the 1/4" samples. All of the 1/4" samples failed at the weld-base metal interface even though the 1/4" samples elongated more than the 1/8" samples. It should also be noted that the elongation on the

RESULTS AND DISCUSSION: (Cont'd.)

weld of the 1/4" samples was greater than on the 1/8" samples. These data would indicate that the weld-base metal interface was responsible for the poor ductility of the welded joints.

The shear samples showed satisfactory results. The low strength of the 1/2" shear samples and the double shear samples can be attributed to the low hardness. This was probably caused by over-tempering.

NOTE: The data from which this report was prepared can be found in Engineering Test Laboratories Notebook 991.

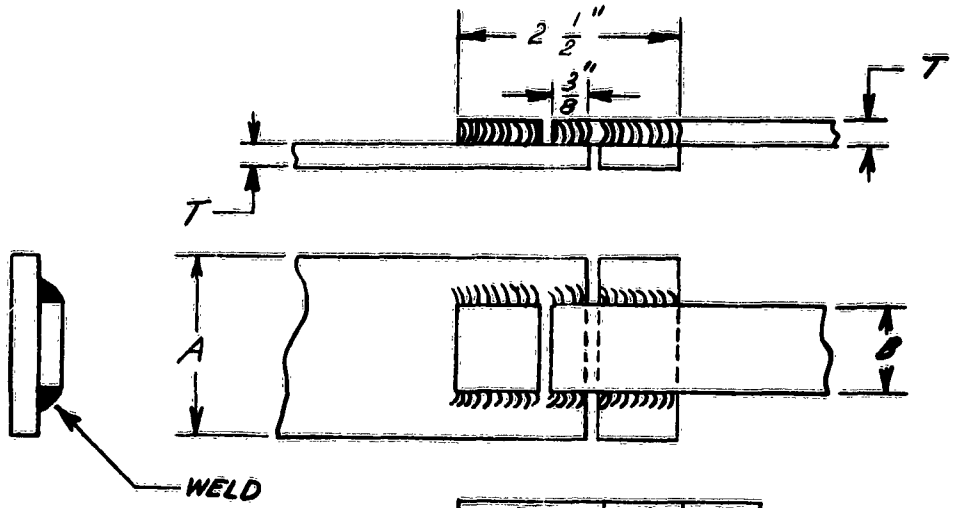


W = 8" for $\frac{1}{8}$" & $\frac{1}{4}$" Thick 4130 (as shown)
W = 6" for $\frac{3}{8}$" & $\frac{1}{2}$" Thick 4130 (5 and 6 omitted)

FIGURE 1 BUTT WELD TEST PANELS AND SPECIMEN POSITION

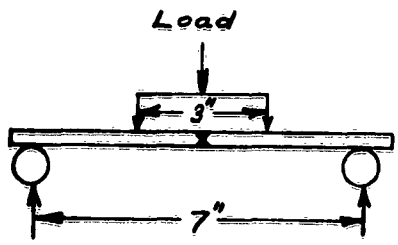
FIGURE 1

FIGURE 2 SINGLE SHEAR SPECIMEN DESIGN



T	A	B
1/8" & 1/4"	2"	1"
3/8" & 1/2"	3"	1 1/2"

FIGURE 3 METHOD OF LOADING FREE BEND BUTT WELD SPECIMENS



Initially Bent to Approx. 30° as Above

Final Bending

FIGURES 2 & 3

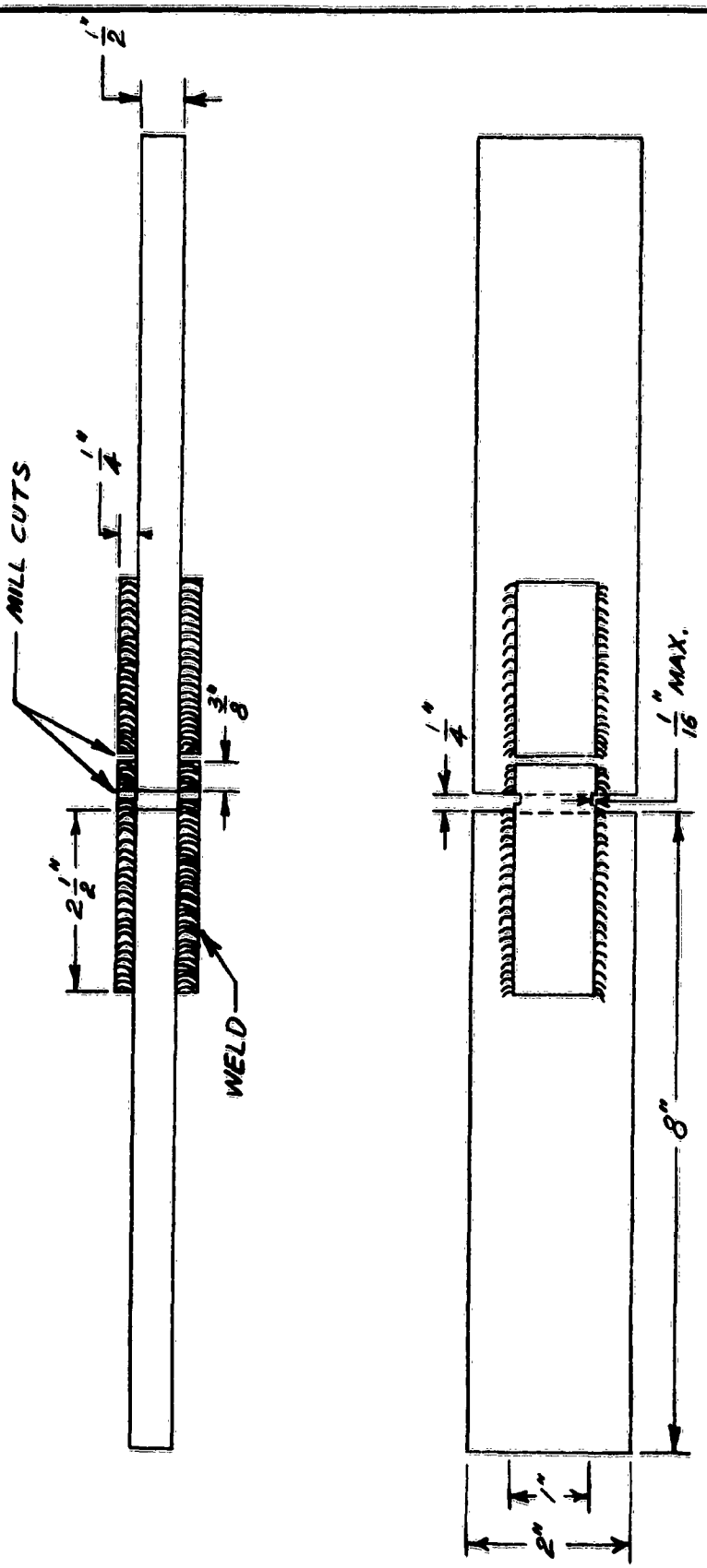


FIGURE 4 DOUBLE SHEAR SPECIMEN DESIGN

FIGURE 4

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TABLE I STRENGTH OF BUTT WELDS IN 4130 STEEL USING SW-151 ELECTRODES

Nominal Thickness of 4130	Heat Treat, KSI	Specimen Position (1)	R_c Hardness (2) Left	R_c Hardness (2) Weld	R_c Hardness (2) Right	Ultimate Tensile Strength PSI	Elong., % in 2"	Location of Failure, Inches From Weld
1/8"	150	2	33.5	35.0	33.2	158,700	8	0.4"
	150	4	32.2	37.2	33.9	157,900	8	0.5"
	175	2	37.0	40.0	36.5	182,700	9.6	0.8"
	175	4	33.0	41.0	35.0	180,000	7.5	1.7"
1/4"	150	2	32.5	39.0	35.5	170,400	14.5	1.0"
	150	4	35.5	39.0	37.0	170,700	12.0	0.9"
	175	2	43.0	42.0	42.5	187,600	2.0	(3)
	175	4	43.0	42.5	43.0	194,200	3.0	(3)
3/8"	150	2	36.5	39.5	38.5	173,100	13.0	1.1"
	150	3	36.6	37.5	37.5	171,800	12.0	0.8"
	175	2	42.0	41.0	43.0	190,200	2.5	(3)
	175	3	43.0	44.5	41.0	196,900	4.5	(3)
1/2"	150	2	34.5	32.0	33.5	148,100	20.0	1.3"
	150	3	33.5	37.0	32.0	148,400	17.5	1.4"
	175	2	42.0	41.5	40.5	178,500	4.5	(3)
	175	3	40.5	41.5	41.0	175,200	3.5	(3)

(1) See Figure one.

(2) Location of Rockwell readings:

(3) Specimens Failed In Weld and at the Weld-Base Metal Interface

TABLE I

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TABLE II RE-TEST OF 1/4" & 3/8" BUTT WELDS

Nominal Thickness of 4130	Heat Treat, KSI (1)	Specimen Position (2)	Rc Hardness (3) Left	Weld	Right	Ultimate Tensile Strength, PSI	Elong., % in 2"	Location of Failure, Inches from Weld
1/4"	150	1	31.5	37.0	33.0	167,400	3.5	In Weld
	150	6	32.5	37.5	34.5	173,000	10.5	0.3"
	175	1	38.0	40.5	38.0	182,400	2.0	In Weld
	175	6	38.0	39.5	38.5	183,200	2.5	In Weld
3/8"	150	1	34.0	36.5	34.0	173,800	13.5	0.6"
	150	4	33.5	37.0	34.0	173,400	9.5	(4)
	175	1	38.0	40.0	37.5	193,800	6.5	(4)
	175	4	38.5	39.5	37.0	193,200	6.0	(4)

(1) - 150 KSI, Two separate tempers of 1000°F for 1 hour.
175 KSI, Two separate tempers of 830°F for 1 hour.

(2) See figure 1.

(3) Same as in footnote (2) of Table I

(4) Failure took place at the weld-base metal interface.

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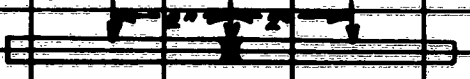
TABLE III FREE BEND DUCTILITY IN 4130 STEEL USING SW-151 ELECTRODES

	Nominal Thickness of 4130	Heat Treat, KSI	Specimen Position (1)	R_c Hardness Left	R_c Hardness Weld	R_c Hardness Right (2)	Elong., % in 2"	Elong., % in Weld	Angle of Bend	Location of Failure
	1/8"	150	3	34.0	34.3	34.1	9	4	127°	.5" From Weld
		↓	5	30.8	32.9	32.7	9	3	112°	.4" From Weld
*		175	3	37.7	41.3	38.7	12	5	170°	.4" From Weld
		↓	5	39.3	40.9	39.3	11	5	168°	.4" From Weld
	1/4"	150	3	38.8	38.8	38.0	7	6	84°	(3)
		↓	5	37.1	38.8	38.0	8	7	76°	(3)
		175	3	42.0	41.9	42.2	7	7	69°	(3)
		↓	5	42.2	42.9	41.9	5	8	70°	(3)

(1) See Figure One

(2) Location Of Hardness Readings



(3) Failure Took Place At The Weld-Base Metal Interface

TABLE III

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TABLE III SHEAR STRENGTHS IN 4130 STEEL USING SW-151 ELECTRODES

Type Of Specimen	Nominal Thickness Of 4130 Inches (1)	Heat Treat KSI (2)	Actual Thickness Of Tongue Inches T	Length Of Weld Inches L (3)	Ultimate Load Lbs.	Load Per Linear Inch Of Weld S	Shear Strength PSI S/T	Rc Of Base Material
Single Shear	1/8"	150	.118	.785	7540	9600	81,400	34.9
		↓	.118	.810	7480	9230	78,200	29.2
		175	.118	.775	7700 (4)	9940 MIN.	84,200 MIN.	34.4
		↓	.119	.775	7200	9340	78,500	34.0
	1/4"	150	.246	.800	12,240	15,300	62,200	35.8
		↓	.245	.780	11,460	14,700	60,000	95.4
		175	.246	.755	12,880	17,100	69,500	39.4
		↓	.246	.825	13,360	16,200	65,900	39.4
	3/8"	150	.370	.835	19,220	23,000	62,200	33.5
		↓	.367	.790	19,480	24,700	67,300	32.2
		175	.369	.795	18,540	23,300	63,100	38.7
		↓	.373	.785	19,740	25,200	67,600	37.2
	1/2"	150	.503	.880	17,500	19,900	39,600	24.4
		↓	.498	.735	15,800	21,500	43,200	26.1
Single Shear		175	.498	.770	16,100	20,900	42,000	27.9
		↓	.498	.715	14,900	20,800	41,800	28.8
Double Shear	1/4" TO 1/2"	150	.246	1.500	17,150	11,400	46,300	25.3
		↓	.246	1.490	18,650	12,500	50,810	23.2
↓		175	.246	1.525	16,850	11,000	44,700	25.7
		↓	.246	1.515	21,700	14,300	58,100	27.3

(1) SEE FIGURES 2 AND 4 FOR SPECIMEN CONFIGURATION.
(2) 1000°F, 1 HOUR TEMPER USED FOR 150 KSI RANGE.
890°F, 1 HOUR TEMPER USED FOR 175 KSI RANGE.
(3) TOTAL LENGTH OF ALL EFFECTIVE WELDS.
(4) WELD DID NOT FAIL. FAILURE TOOK PLACE IN TONGUE.

TABLE III