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THE MECHANICAL PROPERTIES OF WROUGHT
DEPLETED URANIUM AND OF WELDS
JOINING THIS MATERIAL

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ABSTRACT

This report describes the test program conducted to establish design allowables for tensile properties in wrought depleted uranium and in welds joining this material.

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THE MECHANICAL PROPERTIES OF WROUGHT
DEPLETED URANIUM AND OF WELDS
JOINING THIS MATERIAL

Introduction

A test program was conducted to establish design allowables for tensile properties in wrought depleted uranium and in welds joining this material. These allowables are the lower limit that will, at 95 percent confidence, have 95 percent of all values equal to or above the limit. Typical values of charpy impact were determined for the uranium and the butt welds. Free bend bars were cut across the weld joints and tested to learn of the behavior of welds in bending and to determine the modulus of rupture in bending. Typical values for longitudinal and transverse shear in fillet welds were determined.

This report describes the test program and recommends the design allowables for tensile properties in wrought depleted uranium and for welds used in joining this material.

Material

Two rolled plates of depleted uranium furnished by UCNC-Y12 were used in this program, and the purity levels of the two plates were:

<u>Element</u>	<u>Plate 1</u>	<u>Plate 2</u>
C	126 ppm	401 ppm
Fe	78 ppm	270 ppm
Total Fe, Ni, Cr	101 ppm	351 ppm
Total all others	383 ppm	802 ppm

Fabrication Procedure

The plate material had been subjected to the following treatment and rolling schedule by Y12:

1. 5 x 24 x 24-inch ingots were soaked for 14 hours in a salt bath at temperatures of 1150°F to 1170°F.
2. Plate 1 was rolled to a thickness of 3 inches, then turned 90 degrees and rolled to 0.75 x 52 x 74 inches. Plate 2 was rolled to a thickness of 3 inches, turned 90 degrees and rolled to a 1.5-inch thickness, then turned 90 degrees and rolled to 0.75 x 45 x 87 inches.
3. Rolling temperatures for Plate 1 were 1080°F at the start, 910°F at 3-inch thickness, and 790°F at the finish. Rolling temperatures for Plate 2 were 1080°F at the start, 1000° at 3-inch thickness, 820°F at 1.5-inch thickness, and 750°F at the finish.
4. Each plate was alpha annealed at 1130° to 1150°F for 15 minutes in a liquid salt bath.

The plates were cut, given a 37°30' chamfer, leaving a 1/16-inch land and welded so that all weld beads were normal to the direction of rolling. The following procedure was used:

1. Welding filler metal was sheared into strips 5/32 x 3/16 inch from two batches of sheet made from two heats having the following analysis:

<u>Element</u>	<u>Heat 3961</u>	<u>Heat 3963</u>
C	240 ppm	131 ppm
Fe	120 ppm	70 ppm
Total Fe, Ni, Cr	120 ppm	120 ppm
Total all others	146 ppm	217 ppm

All the strips were mixed together and no attempt was made to weld either plate with a particular heat of filler rod.

2. Welding was done by the inert gas shielded tungsten arc method, using 99.99 percent pure helium as the arc shield.
3. Butt welds were single vee, 75 degree included angle, 1/16-inch land. A copper backup strip having a groove 1/4-inch wide and 1/16-inch deep was used. All passes were made using DC straight polarity. The root pass was made at 190 amperes and 25 volts. Succeeding passes were made at 220 amperes and 25 volts, the butt welds being completed in from 9 to 13 passes.
4. The transverse fillet welds were made in three passes, the first at 190 amperes and 25 volts, and the remaining passes at 220 amperes and 25 volts. The longitudinal fillet welds were made in one pass at 165 amperes and 20 volts. No post weld heat treatments were employed.

All welds were subjected to radiographic examination and were found to be acceptable with the possible exceptions of the transverse fillet weld shear specimens made from Plate 2. Radiographs were judged in accordance with the UCNC Standard Y-ES 9.3-52. This standard is more rigid than the ASTM Code, Section VIII, concerning porosity and inclusions, but does allow some cracks. No cracks were detected by radiography or in the subsequent testing.

Tensile Properties

Tensile Testing

The test plates were cut up and machined by Y-12 to 2-inch gage length, 0.505-inch diameter, and 1.75-inch gage length, 0.357-inch diameter test bars. Tensile testing was done in Sandia Laboratory Section 1113-1 on a Universal testing machine at the temperatures of interest using a strain rate somewhat uncertain, the only known factor being the cross-head travel of 0.1 inch per minute throughout the test. The modulus was derived graphically from the stress-strain curve (see Figure 1) and the reported yield strength is the 0.2 percent offset intersection. The yield and ultimate strength are calculated on the basis of the original cross-sectional area.

Figure 1
Stress-Strain Curve

The extensometer used was the microformer type with a magnification of 250 to 1. The elongation was determined by measuring the distance between gage marks after rupture, using a divider.

Tensile Data

The tensile property data were given a statistical treatment by Section 2561-3, Sandia Laboratory, to obtain the lower limit at a confidence level such that 95 percent of the time 95 percent of all values will be the lower limit or above. The assumption is made that the data has normal distribution. This can neither be proved nor disproved with the quantity of data available. The degree of confidence actually present in the results is wholly dependent on the accuracy of this assumption. The K factors used for sigma for the number of samples involved were:

<u>N</u>	<u>K</u>
4	5.18
5	4.23
6	3.73
7	3.42
8	3.21

These factors were taken from Lieberman and Resnikoff.

Specimens that broke in the radius or in the threads were considered no test. Those that broke in the 0.505 straight section but outside the gage marks were used for all properties except the elongation. Occasionally there was malfunction of the extensometer because of interference of its extension rods with the furnace or cold box, resulting in no curve.

The tensile data are tabulated in Table I, Appendix B; graphic summaries are also presented in Appendix B, Figures B-1 through B-4.

Discussion of the Tensile Data

Generally, the tensile ultimate and tensile yield strengths were lower and elongation higher in Plate 1 than in Plate 2 which may be attributed to the higher purity in Plate 1. This trend occurred in welded joints in the two plates. In bars cut across weld joints it is felt that yield strength is of value to the designer, whereas elongation probably is of little value because of the composite structure. In weld joints tested at elevated temperature, practically all the elongation had taken place in the parent metal (see E; Figure 2). The all weld metal bars showed a higher yield strength, lower ultimate strength, and lower elongation than plate material tested at room temperature.

Figure 2. Test Bars

The modulus values showed considerable scatter, a partial explanation being the difficulty in fitting a modulus line to the stress-strain curve. The error tends to be toward a lower modulus value. Hueschen and Pitt of the Hanford Atomic Products Operations reported an average modulus, graphically determined, of 23×10^6 . Their moduli at elevated temperatures correlate fairly well with those of this report. From a curve of modulus versus temperature determined by Mayfield, Chiswick and Mackerey of Argonne National Laboratories, the room temperature modulus is 22.75×10^6 , again graphically determined.

Investigators using the sonic method (longitudinal wave velocities) report values up to 30×10^6 . Reynolds of Knolls Atomic Power Laboratory reports a sonically measured modulus of 25.5×10^6 , an average of 12 samples each having measurements in three mutually perpendicular directions. Bernard and Coureau show that sonically determined moduli are fairly constant for cast, extruded, or rolled uranium. Grain orientation appears to have some effect on the sonic modulus. This effect can be reduced by working and heat treatment. As indicated in the work of Hueschen and Pitt, the graphically determined moduli do not vary greatly for uranium with impurity limits of 126 to 730 ppm carbon and 50 to 270 ppm of iron. It does seem unrealistic to use lower limits of the moduli since it appears that the modulus is not entirely dependent on anisotropy or previous metallurgical history. A study should be made of the distribution curve for a large number of samples, using better methods to establish the modulus line. The recommended value to use for the modulus in tension is 23×10^6 .

Effect of Impurities on Tensile Properties

The impurity level of the depleted uranium has a significant effect on the tensile properties, the carbon content having the greatest effect. From data Union Carbide Nuclear Company, Y-12 Plant, collected over a period of twelve months, a distribution curve for carbon content for all heats of "Tuballoy" that produced rolled and formed products shows the mode of the distribution curve to be about 250 ppm carbon. Within the two sigma distribution limits, the carbon content varies between 100 ppm and 450 ppm covering about 90 percent of all heats. Plates 1 and 2 of this report are approximately at these two sigma distribution points so that the data here presented cover about 90 percent of UCNC heats.

Impact Properties

Impact testing was done using charpy bars per ASTM E23-47T and on a standard pendulum-type tester using the 260-foot-pound range. All impact data were generated at room temperature and the data tabulated in Table II (see Appendix B).

The impact properties in the weld heat affected zone are the lowest. No significant differences occur between weld metal and parent metal. A large increase in toughness occurred in the Plate 2 material when the notch was transverse to rolling.

Modulus of Rupture of Butt-Welded Uranium Bars

Two types of tests were performed to determine the modulus of rupture in bending of butt-welded uranium bars. In the first series of tests, pure bending moment was applied to the center portion of the specimen, using a two-point loading system. The second series of tests employed a concentrated load at the center of the specimen, producing both shear and moment in the weld. Both test systems are illustrated in Figure 3.

The specimens tested were taken from two different plates and were tested in two orientations: with the face of the weld in tension and with the face of the weld in compression.

In the first series of tests, two bars from the same plate were tested in pure bending using both orientations. SR4 strain gage measurements indicated that the strains were largest in the parent metal, decreased in the heat affected zone, and were smallest in the weld. The bar oriented with the face of the weld on the compression side experienced the larger deflections of the two specimens. Load was applied to both specimens until the deflections became so large that a further increase in load was impossible. No failure occurred in either case with the total angle change between the tangents at the ends of the bars being about 65 degrees.

Four bars were tested in the second series of tests, using a single point loading arrangement. Three of the specimens were from Plate 2 while the fourth specimen was taken from Plate 1. The deflections in this series of tests were considerably less than in the two-point loading setup. This difference in deflection is due in part to the method of loading. By assuming elastic conditions, the deflection in the two-point loading setup is about 1.34 times the deflection in the single point loading arrangement for the same moment. The specimen from Plate 1 experienced a total angle change of 35 degrees at rupture, while the specimens from Plate 2 had a maximum total angle change of 20 degrees at rupture.

Figure 3
Loading Systems for Bend Bar Tests

Failure in three of the bars tested in the second series occurred in the center of the weld; the fourth bar failed in the heat affected zone. The modulus of rupture ranged from 159,000 to 180,000 psi. Since the modulus of rupture is dependent both on the size and shape of the cross section, the above values should be used with caution.

Fillet Weld Shear Values

Specimens for the shear values of fillet welds were made according to the American Welding Society requirements. Pieces were cut from the plate so that the direction of rolling in the pieces making up the specimen was along the long axis of the specimen. Testing was done at 76°F, using a crosshead speed of 0.1 inch per minute. The data are tabulated in Table III, Appendix B. The shear strength was calculated from the mean load on the theoretical throat distance for the specified fillet weld size.

Plate 1 had higher shear values than Plate 2, and the longitudinal values in both plates were higher than transverse shear. Fractures in the specimens occurred mainly in the welds but did, in various instances, occur in both welds and the butt strip and in the heavier plate (see Figure 4).

Metallography

Metallographic samples from both plates were cut from the threaded ends of broken tensile bars and the vise clamped ends of charpy bars. The grain size of both plates varied from about 40 to 80 microns. Grain size of the weld metal was about 150 microns. Both plates had a great number of fine inclusions and a sparse scattering of large inclusions. Anisotropy was more pronounced in Plate 2 than in Plate 1. The dark lines traversing the grains were present in samples from the plates as well as from the broken specimens. The light spots are the fine inclusions. The metallographic samples were electropolished (using chrome-acetic acid); viewed, and photographed with polarized light (see Figures 5, 6, and 7).

Figure 4
Fillet Weld Test Specimen

Longitudinal to
Rolling, 390x

Transverse to
Rolling, 390x

Figure 5
Microstructure of Depleted Uranium, Plate 1

Longitudinal to
Rolling, 390x

Transverse to
Rolling, 390x

Figure 6
Microstructure of Depleted Uranium, Plate 2

Figure 7. Weld Structures

Weld Metal, 390x

Macroetch of Weld,
4x

Conclusions

The lower value of the appropriate lower limit of the two plates should be used as the design allowable for that property, in the temperature range of interest. The recommended value for modulus in tension is 23×10^6 . Charpy impact values averaged 14.0 ft-lbs for the plates in both transverse and longitudinal to rolling directions. In the weld joint the heat-affected zone had charpy values of 9.7 ft-lbs. The modulus of rupture in welds is 170,000 psi for the cross-section tested. Longitudinal shear in fillet welds is 61,000 psi and transverse shear is 51,500 psi.

APPENDIX A

LIST OF REFERENCES

"Mechanical Properties of Rolled Uranium Rods", by R. M. Mayfield, H. H. Chiswick, and R. E. Macherey, Argonne National Laboratory, ANL-5296.

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"Mechanical Behavior of Uranium", by J. Bernard, G. Coureau. CEA 693 (1957). (Translated from French) General Electric Company, Hanford Atomic Products Operation, Document No. HW-TR-9.

"New Elastic Constants of Some Metals", by Myron B. Reynolds. Knolls Atomic Power Laboratory, Schenectady, New York, May 1, 1951, KAPL-576.

APPENDIX B
TABULATION OF DATA

TABLE I

		PLATE 1				PLATE 2			
		Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$	Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$
Plate material	Position in plate	E	E	E	E	C	C	C	C (5)
Transverse to rolling	Temperature of test	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F
Low temperature	Number of samples	2 (1)	3	2	2	3 (1)	4	3	3
	Minimum value	45500 -	97000 -	3.0	21.00	49200 -	104100 -	2.0	20.00
	Maximum value	49000	98500	4.0	22.50	51500	114000	2.5	24.25
	Mean	47250	98000	3.50	21.75	50650	109400	2.30	22.90
	Standard deviation	---	---	---	---	---	5000	---	---
	Lower limit	--- (4)	---	---	---	---	83500	---	---
Plate material	Position in plate	F	F	F	F	F	F	F	F
Parallel to rolling	Temperature of test	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F
Low temperature	Number of samples	8	8	8	8	8	8	8	8
	Minimum value	35500 -	97000 -	5.0	20.50	37000 -	114000 -	3.0	19.20
	Maximum value	49200	99600	6.0	23.00	41000	118000	4.0	23.50
	Mean	41150	98350	5.75	21.80	39400	116400	3.25	21.60
	Standard deviation	5900	995	0.45	---	1250	1060	0.45	---
	Lower limit	22200	95150	4.30	---	35400	113000	1.80	---
Weld joint	Position in plate	J	J	J	J	B	B	B	B
Bars cut	Temperature of test	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F	-65°F
Transverse to joint	Number of samples	5 (2)	8	8	5	7	7	7	7
	Minimum value	42000 -	76400 -	2.0	17.00	47500 -	95000 -	2.0	20.50
	Maximum value	45200	81600	3.5	21.65	50700	103000	2.5	23.50
	Mean	43400	79200	2.60	19.30	49050	101000	2.15	22.30
	Standard deviation	1260	1660	0.60	---	1330	2800	1.58	---
	Lower limit	38050	73850	0.65	---	44500	91400	0	---

- Notes: (1) Specimens that broke in threads or in radius were considered no test.
 (2) Malfunction in recorder system. No curve.
 (3) Broke out of gage section.
 (4) Dashes indicate not enough data for statistical treatment.
 (5) Position of specimens in plates is shown in B-4.

TABLE I (cont)

		PLATE 1				PLATE 2			
		Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$	Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$
Plate material	Position in plate	C	C	C	C	E	E	E	E
Transverse to rolling	Temperature of test	76°F	76°F	76°F	76°F	74°F	74°F	74°F	74°F
Room temperature	Number of samples	7 (2)	8	8	7	8	8	5 (3)	8
	Minimum value	42500 -	100000 -	9.5	18.20	48500 -	104000 -	7.0	20.00
	Maximum value	47500	108000	17.0	22.80	54500	116000	10.5	27.00
	Mean	44900	105000	13.90	20.40	51250	110000	8.00	23.90
	Standard deviation	1830	5350	2.60		2350	8700	1.40	
	Lower limit	38650	87800	5.60		43700	82000	2.10	
Plate material	Position in plate	D	D	D	D	D	D	D	D
Parallel to rolling	Temperature of test	76°F	76°F	76°F	76°F	72°F	72°F	72°F	72°F
Room temperature	Number of samples	8	8	8	8	6 (2)	8	8	6
	Minimum value	35200 -	109000 -	18.0	20.20	37700 -	118000 -	13.0	19.20
	Maximum value	37500	112000	24.5	24.80	42200	129000	19.5	22.80
	Mean	36500	110750	21.80	22.10	39300	123950	16.00	21.40
	Standard deviation	1510	1045	2.35		1650	8400	2.05	
	Lower limit	31650	107400	14.20		33200	97050	9.40	
Weld joint	Position in plate	B	B	B	B	J	J	J	J
Bars cut	Temperature of test	72°F	72°F	72°F	72°F	73°F	73°F	73°F	73°F
Transverse to joint	Number of samples	7 (2)	8	8	7	6 (3)	7	7	6
	Minimum value	37800 -	88500 -	4.5	16.00	40500 -	98600 -	4.5	18.20
	Maximum value	40500	95000	8.0	22.90	51000	100000	6.5	25.20
	Mean	39150	91350	6.10	18.75	43200	99400	5.20	22.70
	Standard deviation	1050	1960	1.10		4350	645	0.90	
	Lower limit	35550	85050	2.55		26950	97200	2.05	
All weld metal	Position in plate	A	A	A	A	A	A	A	A
	Temperature of test	69°F	69°F	69°F	69°F	69°F	69°F	69°F	69°F
	Number of samples	5	5	5	5	4 (2)	4	5	5
	Minimum value	52800 -	94200 -	7.0	18.50	53800 -	95600 -	5.0	20.50
	Maximum value	53700	99200	9.0	21.00	56000	98200	7.0	23.20
	Mean	53100	96400	8.20	19.50	55000	97450	6.00	21.45
	Standard deviation	280	1890	0.85		1020	1280	1.00	
	Lower limit	51900	88400	4.60		49700	90800	1.80	

TABLE I (cont)

		PLATE 1				PLATE 2			
		Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$	Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus $\times 10^6$
Plate material	Position in plate	E	E	E	E	E	E	E	E
Transverse to rolling	Temperature of test	350°F	350°F	350°F	350°F	350°F	350°F	350°F	350°F
Elevated temperature	Number of samples	7 (2)	7	8	7	8	8	8	8
	Minimum value	36000 -	55700 -	45.5	16.00	45200 -	68300 -	25.5	16.85
	Maximum value	39000	67000	54.0	19.80	48700	72200	34.0	21.00
	Mean	37500	62400	49.80	17.90	47000	70800	32.60	19.00
	Standard deviation	2720	1560	3.35		1240	1210	3.25	
	Lower limit	28200	47050	39.00		43000	66900	22.20	
Plate material	Position in plate	F	F	F	F	F	F	F	F
Parallel to rolling	Temperature of test	350°F	350°F	350°F	350°F	350°F	350°F	350°F	350°F
Elevated temperature	Number of samples	8	8	8	8	8	8	8	8
	Minimum value	21500 -	59800	46.0	14.50	42000	73800	36.0	16.50
	Maximum value	35700	66700	51.0	18.50	44200	77300	41.5	19.85
	Mean	33000	64500	50.30	16.10	43100	74850	38.30	17.95
	Standard deviation	4700	2700	2.10		720	1420	2.30	
	Lower limit	17900	55850	43.50		40800	70300	31.00	
Weld joint	Position in plate	J	J	J	J	J	J	J	J
Bars cut	Temperature of test	350°F	350°F	350°F	350°F	350°F	350°F	350°F	350°F
Transverse to joint	Number of samples	8	8	4 (3)	8	8	8	7 (3)	8
Elevated temperature	Minimum value	34000 -	62100 -	27.5	13.50	39700 -	73300 -	22.0	14.50
	Maximum value	36500	71200	32.0	19.20	42500	77900	28.0	18.25
	Mean	34500	66700	29.50	16.65	41400	75900	25.10	16.10
	Standard deviation	2000	2660	1.95		965	1250	2.05	
	Lower limit	28050	58150	19.40		38300	71900	18.10	

TABLE I (cont)

PLATE 1						PLATE 2			
		Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus x 10 ⁶	Tensile yield	Tensile ultimate	Elongation, % in two inches	Modulus x 10 ⁶
Plate material	Position in plate	E	E	E	E	E	E	E	E
Transverse to rolling	Temperature of test	500°F	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Elevated temperature	Number of samples	8	8	8	8	8	8	8	8
	Minimum value	31100 -	41000 -	42.5	16.00	41000 -	52400 -	16.5	17.00
	Maximum value	32500	43200	53.0	18.50	45700	54700	27.0	18.15
	Mean	31700	42100	47.80	17.20	44000	54100	24.10	17.40
	Standard deviation	1090	2040	3.35		1620	1050	4.10	
	Lower limit	28200	35550	37.00		38800	50800	11.00	
Plate material	Position in plate	F	F	F	F	F	F	F	F
Parallel to rolling	Temperature of test	500°F	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Elevated temperature	Number of samples	7 (2)	8	8	7	8	8	8	8
	Minimum value	28200 -	38600 -	50.0	16.25	38700 -	53600 -	36.0	16.10
	Maximum value	29500	40900	59.0	20.00	40500	58000	42.0	19.25
	Mean	28750	40050	54.75	18.20	39700	55300	38.80	18.35
	Standard deviation	425	885	3.00		595	1280	2.10	
	Lower limit	27300	37200	45.15		37800	51200	32.00	
Weld joint	Position in plate	J	J	J	J	J	J	J	J
Bars cut	Temperature of test	500°F	500°F	500°F	500°F	500°F	500°F	500°F	500°F
Transverse to joint	Number of samples	7 (2)	8	2 (3)	7	8	8	7 (3)	7
	Minimum value	30000 -	44300 -	23.0	13.50	24700	54300	18.0	12.85
	Maximum value	33000	46600	23.50	18.20	40500	57200	25.0	14.75
	Mean	31200	45400	23.20	16.50	37900	55600	22.20	14.50
	Standard deviation	1025	795	---		5350	1250	2.45	
	Lower limit	27700	42850	---		20700	51600	13.80	

TABLE II

Charpy Impact Data

Position in plate or weld	Plate 1		Plate 2	
	Sample No. (ft-lbs)		Sample No. (ft-lbs)	
Bar cut transverse to weld, notch in heat-affected zone of parent metal	1H11	10.0	2H11	10.0
	1H12	10.0	2H12	9.0
	1H13	9.0	2H13	10.0
	Mean	9.7	Mean	9.7
Bar cut transverse to weld, notch in weld metal and parallel to main axis of weld	1H21	----	2H21	12.5
	1H22	12.0	2H22	9.5
	1H23	13.5	2H23	11.0
	Mean	12.7	Mean	11.0
Bar cut from weld, notch in weld metal transverse to main axis of weld	1H34	12.0	2H32	10.5
	1H35	10.5	2H33	10.0
	1H36	12.0	2H34	10.0
	Mean	11.5	Mean	10.2
Bar cut from plate, notch parallel with direction of rolling	1H42	10.0	2H41	13.0
	1H47	10.0	2H42	12.5
	1H49	10.0	2H43	12.2
	Mean	10.0	Mean	12.6
Bar cut from plate, notch transverse to direction of rolling	1H54	12.5	2H50	22.0
	1H55	12.0	2H54	22.2
	1H56	12.0	2H58	18.2
	Mean	12.2	Mean	20.8

TABLE III

Fillet Weld Shear			
	Specimen No.	Total load	Location of fractures
Longitudinal Shear fillet welds Plate 1	1M1-1	68500	Weld first then butt strip
	1M1-2	65500	Weld first then butt strip
	1M1-3	67000	Weld first then butt strip
	1M1-4	66000	In welds then butt strip
	1M -5	78000	In both butt strips
	1M -6	77000	In both butt strips
	1M -7	74500	Weld first then butt strip
	1M -8	72000	In both butt strips
	1M -9	75000	In both butt strips
	Mean	71500	
		67300 psi shear	
Plate 2	2M2-1	65500	Weld first then butt strip
	2M2-2	67000	Weld first then butt strip
	2M2-3	67250	Weld first then butt strip
	2M -4	67000	In welds (all 4)
	2M -5	69500	Weld first then plate
	2M -6	57500	In welds
	2M -7	70000	Weld first then plate
	2M -8	72500	In plate
	2M -9	48500	In welds
	Mean	65000	
		61100 psi shear	
Transverse shear in fillet welds Plate 1	1L1-1	86500	In one weld and plate
	1L1-2	87750	In one weld and plate
	1L1-3	87500	In welds
	1L1-4	86000	In welds and plate
	1L1-5	85500	In welds
	1L1-6	87000	In welds
	1L1-7	77500	In welds
	1L1-8	75500	In welds and butt strip
	Mean	84200	
		63300 psi shear	
Plate 2	2L1-1	61500	In welds
	2L1-2	57500	In welds
	2L1-3	67500	In welds
	2L1-4	66500	In welds
	2L1-5	67500	In welds
	2L1-6	59750	In welds
	2L1-7	57500	In welds
	2L1-8	63500	In welds
	2L1-9	68000	In welds
	Mean	63250	
		51500 psi shear

MEAN TENSILE VALUES VS. TEMP.
BUTT WELD JOINTS

Figure B-1

Figure B-2

MEAN TENSILE VALUES VS. TEMP.
PARALLEL TO ROLLING

Figure B-3

Figure B-4