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RADIATION STRENGTHENING AND EMBRITTLEMENT IN HEAVY-SECTION STEEL PLATES AND WELDS

W. J. Stelzman
R. G. Berggren

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Printed in the United States of America. Available from
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P.O. Box 62, Oak Ridge, Tennessee 37830
Price: Printed Copy $5.45 ; Microfiche $0.95

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Contract No. W-7405-eng-26

METALS AND CERAMICS DIVISION

RADIATION STRENGTHENING AND EMBRITTLEMENT IN HEAVY-SECTION STEEL PLATES AND WELDS

W. J. Stelzman R. G. Berggren

JUNE, 1973

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FOREWORD

This work has been sponsored by the Heavy-Section Steel Technology (HSST) Program. The HSST program is a USAEC-sponsored effort at Oak Ridge National Laboratory for investigating the effects of flaws, material inhomogeneities, and discontinuities on the strength and structural reliability of present and contemplated water-cooled reactor pressure vessels. The cognizant engineer for the USAEC is J. R. Hunter. At ORNL the program is under the Pressure Vessel Technology Program, of which G. D. Whitman is Director. This report is designated Heavy-Section Steel Technology Program Technical Report No. 26.

Prior reports in this series are:

1. S. Yukawa, *Evaluation of Periodic Proof Testing and Warm Prestressing Procedures for Nuclear Reactor Vessels,* Report No. HSSTP-TR-1, General Electric Company, Schenectady, New York, July 1, 1969.
2. L. W. Loechel, *The Effect of Section Size on the Transition Temperature in Steel*, Martin Marietta Company, Denver, Colorado, 1969.
3. P. N. Randall, *Gross Strain Measure of Fracture Toughness of Steels*, Report No. HSSTP-TR-3, TRW Systems Group, Redondo Beach, California, November 1, 1969.
4. C. Visser, S. E. Gabrielse, and W. VanBuren, *A Two-Dimensional Elastic-Plastic Analysis of Fracture Test Specimens*, WCAP-7368, Westinghouse Electric Corporation, PWR Systems Division, Pittsburgh, Pennsylvania, October 1969.
5. T. R. Mager, F. O. Thomas, and W. S. Hazelton, *Evaluation by Linear Elastic Fracture Mechanics of Radiation Damage to Pressure Vessel Steels*, WCAP-7328, Revised, Westinghouse Electric Corporation, PWR Systems Division, Pittsburgh, Pennsylvania, October 1969.
6. W. O. Shabbits, W. H. Pryle, and E. T. Wessel, *Heavy Section Fracture Toughness Properties of A533 Grade B Class 1 Steel Plate and Submerged Arc Weldment*, WCAP-7414, Westinghouse Electric Corporation, PWR Systems Division, Pittsburgh, Pennsylvania, December 1969.
7. F. J. Loss, *Dynamic Tear Test Investigations of the Fracture Toughness of Thick-Section Steel*, NRL Report 7056, U.S. Naval Research Laboratory, Washington, D.C., May 14, 1970.
8. P. B. Crosley and E. J. Ripling, *Crack Arrest Fracture Toughness of A533 Grade B Class 1 Pressure Vessel Steel,* HSSTP-TR-8, Materials Research Laboratory, Inc., Glenwood, Illinois, March 1970.
9. T. R. Mager, *Post-Irradiation Testing of 2T Compact Tension Specimens*, WCAP-7561, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, August 1970.
10. T. R. Mager, *Fracture Toughness Characterization Study of A533, Grade B, Class 1 Steel,* WCAP-7578, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, October 1970.
11. T. R. Mager, *Notch Preparation in Compact Tension Specimens*, WCAP-7579, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, November 1970.
12. N. Levy and P. V. Marcal, *Three-Dimensional Elastic-Plastic Stress and Strain Analysis for Fracture Mechanics, Phase I: Simple Flawed Specimens*, HSSTP-TR-12, Brown University, Providence, Rhode Island, December 1970.
13. W. O. Shabbits, *Dynamic Fracture Toughness Properties of Heavy Section A533 Grade B, Class 1 Steel Plate*, WCAP-7623, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, December 1970.

14. P. N. Randall, *Gross Strain Crack Tolerance of A533-B Steel*, HSSTP-TR-14, TRW Systems Group, Redondo Beach, California, May 1, 1971.

15. H. T. Corten and R. H. Sailors, *Relationship Between Material Fracture Toughness Using Fracture Mechanics and Transition Temperature Tests*, T&AM Report No. 346, University of Illinois, Urbana, Illinois, August 1, 1971.

16. T. R. Mager and V. J. McLoughlin, *The Effect of an Environment of High Temperature Primary Grade Nuclear Reactor Water and the Fatigue Crack Growth Characteristics of A533 Grade B Class 1 Plate and Weldment Material*, WCAP-7776, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, October 1971.

17. N. Levy and P. V. Marcal, *Three-Dimensional Elastic-Plastic Stress and Strain Analysis for Fracture Mechanics, Phase II: Improved Modeling*, HSSTP-TR-17, Brown University, Providence, Rhode Island, November 1971.

18. S. C. Grigory, *Six-Inch-Thick Flawed Tensile Tests, First Technical Summary Report, Longitudinal Specimens 1 through 7*, HSSTP-TR-18, SwRI 03-2520, Southwest Research Institute, San Antonio, Texas, June 1972.

19. P. N. Randall, *Effects of Strain Gradients on the Gross Strain Crack Tolerance of A533-B Steel*, HSSTP-TR-19, TRW Systems Group, Redondo Beach, California, May 1, 1972.

20. S. C. Grigory, *Tests of Six-Inch-Thick Flawed Tensile Specimens, Second Technical Summary Report, Transverse Specimens Numbers 8 through 10, Welded Specimens Numbers 11 through 13*, HSSTP-TR-20, Southwest Research Institute, San Antonio, Texas, June 1972.

21. Lee A. James and John A. Williams, *The Effect of Temperature and Neutron Irradiation Upon the Fatigue-Crack Propagation Behavior of ASTM A533-B Steel*, HEDL-TME 72-B2, Hanford Engineering Development Laboratory, Richland, Washington, August 1972.

22. S. C. Grigory, *Tests of Six-Inch-Thick Flawed Tensile Specimens, Third Technical Summary Report, Longitudinal Specimens Numbers 14 through 16, Unflawed Specimen Number 17*, HSSTP-TR-22, Southwest Research Institute, San Antonio, Texas, August 1972.

23. S. C. Grigory, *Tests of Six-Inch-Thick Flawed Tensile Specimens, Fourth Technical Summary Report, Tests of One-Inch-Thick Flawed Tensile Specimens for Size Effect Evaluation*, HSSTP-TR-23, Southwest Research Institute, San Antonio, Texas (in publication).

24. S. P. Ying and S. C. Grigory, *Tests of 6-Inch-Thick Tensile Properties, Fifth Technical Summary Report, Acoustic Emission Monitoring of One-Inch-Thick and Six-Inch-Thick Tensile Specimens*, HSSTP-TR-24, Southwest Research Institute, San Antonio, Texas (in publication).

25. R. W. Derby et al., *Test of 6-in.-Thick Pressure Vessels, Intermediate Test Vessels V-1 and V-2, Forged Cylinders* (in preparation).

Copies of these reports may be obtained by writing Laboratory Records Department, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee, 37830.

RADIATION STRENGTHENING AND EMBRITTLEMENT IN HEAVY-SECTION STEEL PLATES AND WELDS

W. J. Stelzman R. G. Berggren

ABSTRACT

Fast-neutron-induced changes in the mechanical properties of two 12-in.-thick A533-B, class 1 steel plates and a matching submerged-arc weldment and an electroslag weld in a 6⅜-in.-thick SA302-B (code case 1339) steel are presented. Postirradiation increases of strength and notch-impact transition temperature and decrease in ductility were determined for several irradiation temperatures. Some observations using data obtained from an instrumented Charpy testing machine are also given.

INTRODUCTION

Boiling water and pressurized water reactor central power stations are being built with capacities exceeding 1000 MW(e). These sizes involve the design and fabrication of large pressure vessels with thick sections, high-strength materials, high stresses, and nuclear radiation effects complicating the problems of preventing brittle fracture. The Heavy-Section Steel Technology (HSST)[1] Program was initiated to study the structural behavior of thick-section plates, welds, and vessels with emphasis on the effects of flaws, material inhomogeneities, and discontinuities under reactor operating and accident conditions. This study of radiation effects on brittle fracture of steels used HSST plates and welds as specimen materials.

At present, there are two primary approaches to design against brittle fracture. The older is the transition temperature approach, which is the basis for the study reported. The newer and much more quantitative approach is that based on fracture mechanics, which is the basis for concurrent studies at ORNL and other laboratories.[1] One objective of the HSST Program is to determine the degree of applicability of these two approaches for assessing safety of large nuclear pressure vessels.

The investigation reported is limited to the study of fast-neutron radiation effects on tensile and Charpy V-notch impact properties of quenched and tempered 12-in.-thick manganese-molybdenum-nickel steel plates (ASTM A533-B, class 1 steel),[2] a submerged-arc weld, and an electroslag weld.

MATERIAL DESCRIPTION

The materials investigated in this study were the HSST program steels and weldments listed below and whose fabrication history are thoroughly documented in other reports.[3,4]

1. HSST plate 01 – ASTM A533, grade B, class 1, 12-in.-thick plate;[3]
2. HSST plate 02 – ASTM A533, grade B, class 1, 12-in.-thick plate;[3]
3. submerged-arc process weld[4] in 12-in.-thick HSST plate 01;
4. electroslag process in 6⅜-in.-thick SA392, grade B (code case 1339) steel.[4]

---

1. F. J. Witt, "The USAEC Heavy Section Steel Technology Program: Objectives and Status," *Nucl. Eng. Des.* **20**(1), 169–80 (June 1972).

2. *1972 Annual Book of ASTM Standards*, Pt. 4, A533-70, pp. 617–22, American Society for Testing and Materials, Philadelphia, April 1972.

3. C. E. Childress, *Fabrication of the First Two 12-in.-thick ASTM A533, Grade B, Class 1 Steel Plates of the Heavy-Section Steel Technology Program, Documentary Report 1*, ORNL-4813 (February 1969).

4. C. E. Childress, *Fabrication Procedures and Acceptance Data for ASTM A533 Welds and a 10-in.-thick ASTM A543 Plate of the Heavy-Section Steel Technology Program, Documentary Report 3*, ORNL-4813-3 (January 1971).

Table 1. Composition and heat treatment of plates and welds

Type	Compositions (wt %)							Heat treatment			
	C	Mn	P	S	Si	Ni	Mo		Temp. (°F)	Time (hr)	Cooling
HSST plate 01; 12-in. thick ASTM A533, grade B, class 1	0.22	1.48	0.012	0.018	0.25	0.68	0.52	Normalize:	1700	4	Air cool
								Austenitize and quench:	1600	4	Water quench
								Temper:	1225	4	Furnace cool
								Stress relief:	1150	40	Furnace cool
HSST plate 02; 12-in. thick ASTM A533, grade B, class 1	0.24	1.42	0.010	0.017	0.22	0.70	0.50	Normalize:	1675	4	Air cool
								Austenitize and quench:	1600	4	Water quench
								Temper:	1225	4	Furnace cool
								Stress relief:	1150	40	Furnace cool
HSST no. 51; 11 3/4-in. thick submerged arc weldment	0.14	1.30	0.015	0.011	0.10	0.74	0.46	Stress relief:	1150	12	Furnace cool
HSST no. 53; 6 1/4-in. thick electroslag weldment	Plate:										
	0.18	1.11	0.006	0.014	0.25	0.44	0.45	Austenitize and quench:	1700	6	Water quench
	Filler metal specification:							Austenitize and quench:	1625	6	Water quench
(PVRC no. 315)	N.A.	1.90	0.025 (max)	0.014 (max)	0.25 (max)	N.A.	0.52	Temper:	1200	6	Water quench
								Stress relief:	1125	30	Furnace cool

Notes: Compositions of plates are check analyses (Mill report);
Compositions of submerged arc weld are averages for weld metal only;
Compositions of electroslag weld filler metal specification are averages; heat-treatment temperatures are ± 25°F.

The chemical compositions and heat treatment schedules for these materials are given in Table 1. More detailed metallography and chemical compositions will be presented for both plates and weldments in topical reports on the properties of unirradiated HSST plates and unirradiated HSST weldments to be issued as HSST Program Technical Reports 29 and 30, which are in preparation.

The plate and weldment sections from which the specimens were taken for this study are shown in Fig. 1. The 116-in.-long plate section 01L from plate 01 was cut in two lengths and joined at the sides by a submerged-arc weld[4] to form plate 51.

SPECIMEN IRRADIATION

All of the specimen irradiations were performed at the poolside facility of the Oak Ridge Research Reactor, attached to the rear (piggy-back position) of other experiments located at the reactor tank face. In that position, the neutron fluence is determined principally by the neutron absorbing capacity of the experimental capsule in front, the fuel loading, the length of the irradiation cycle between fuel changes, and the vertical flux profile of the reactor about the midplane. The effect of these variables was the spread of fluences presented in the test results.

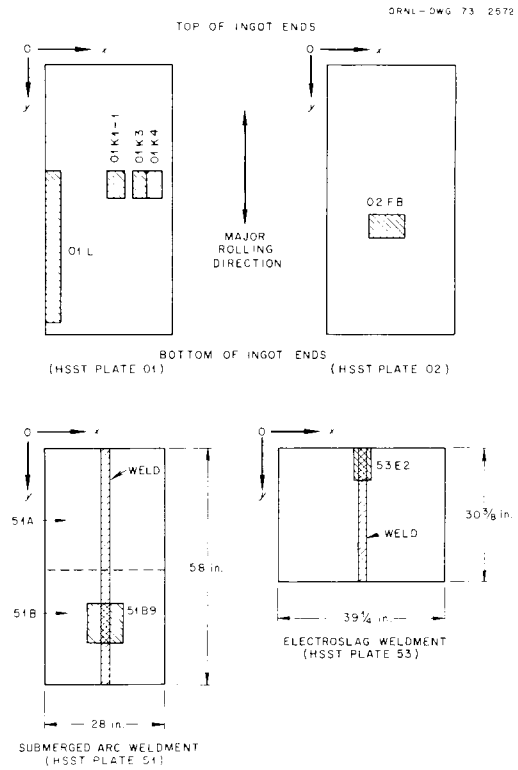

Fig. 1. Test locations in HSST plates and weldments.

The irradiation capsule was 26½ in. long × 2¾ in. wide × 2 in. deep and contained two vertical rows of specimens, a front row and a back row, aligned parallel to the reactor face. Each row contained 50 specimens, which were usually a mixture of groups of Charpy V and miniature tensile specimens. In the irradiating attitude, the capsule contained a layer of thermal insulation against the inside front face followed by a heater plate containing a series of flat wound sheathed heater elements used to supplement the gamma heating and maintain the desired temperature during irradiation. Next came the first row of specimens followed by a set of stiff leaf springs and a thick layer of insulating board. The rear row of specimens was sandwiched between the insulation and the rear surface of the can. The leaf springs were compressed during the final welding of the can and maintained sufficient pressure against both rows to provide adequate heat transfer to and from the specimens during irradiation. The front row was always used for elevated temperature, and the back row was used for the low-temperature irradiations.

The irradiation temperatures were determined by 36 sheathed thermocouples per experiment capsule, placed at the center of every second specimen in the front row and every tenth specimen in the back row. Front row heating was automatically controlled in six zones, so either one or two separate temperatures could be maintained in the front row during the irradiation.

The flux profile as a function of position in the irradiation capsule was measured with both cadmium-shielded and unshielded cobalt (aluminum wire containing 0.0964% Co), iron, and nickel neutron dosimeters. We corrected for the thermal neutron burnup of ^{58}Co in the cobalt and the separation of ^{59}Fe in the iron. Each row contained five sets of monitors. Fast-neutron fluences for the study ranged from 2.9 to 14.1 × 10^{18} neutrons/cm^2 (>1 MeV) at nominal temperatures of 150°F (66°C), 450°F (232°C), 550°F (288°C), and 650°F (343°C).

The atmosphere during irradiation was dry helium.

EXPERIMENTAL PROCEDURE

Tensile Testing

Tensile testing both in and out of the hot cell was performed on an Instron 10,000-lb tensile machine and met the requirements[5] of ASTM A370. The tensile specimen was held in slotted grips, which applied most of the load on the smooth fillets at the ends of the gage length. The specimen design, Fig. 2, took into account requirements dictated by the irradiation capsule design, hot cell handling, and ease of insertion into grips. This resulted in the use of the standard Charpy specimen blank for both notching and conversion to a miniature tensile specimen. The miniature tensile specimen (0.178 in. gage diam × 1.25 in. gage length) has a ratio of gage length to diameter (L/D) of 7; the standard specimen ratio is 4. The total elongation for L/D = 7 may be converted to a ratio of 4 by the following expression, which is derived in detail in HSST Technical Report No. 29 (in preparation):

$$e_{T,4} = 1.75e_{T,7} - 0.75e_{U,7} ,$$

where

$e_{T,4}$ = total elongation for $L/D = 4$,

$e_{T,7}$ = total elongation for $L/D = 7$,

$e_{U,7}$ = uniform elongation for $L/D = 7$.

Reduction of area was not measured for the irradiated specimens; however, the specimens have been stored. The strain rate was 0.016/min.

5. *1971 Annual Book of ASTM Standards*, Pt. 31, A370-71, pp. 4–54; E23-66, pp. 275–89, American Society for Testing and Materials, Philadelphia, July 1971.

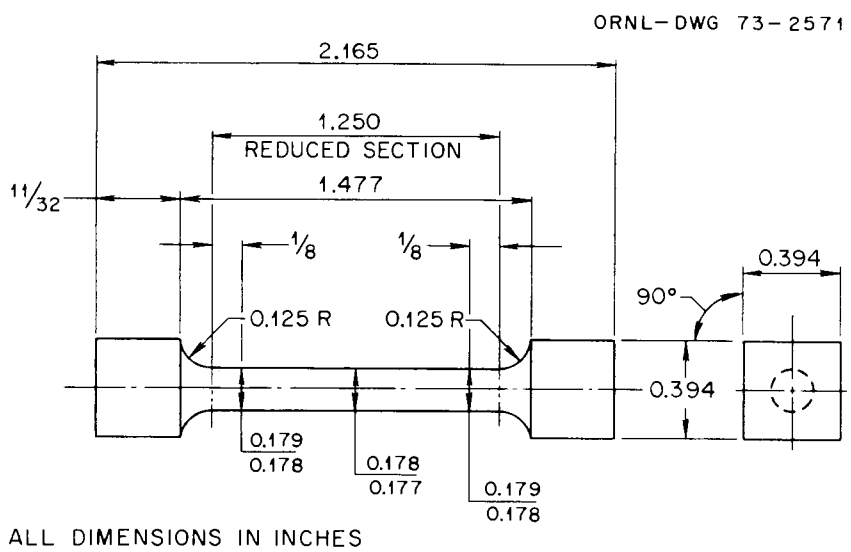

Fig. 2. Subsize tensile specimen machining detail.

Impact Testing

Charpy V-notch impact tests were conducted in accordance with the requirements of ASTM Standard Methods[5] A370 and E23 on a Testing Machines, Inc., 220-ft-lb impact tester meeting the supplementary requirements of paragraph 6 of ASTM E23. The test specimen was the Charpy V-notch (ASTM type A).[5] The impact machine was equipped with a specimen conditioning chamber containing carbon electrodes for resistance heating, a liquid-nitrogen manifold for cooling, and a spring-loaded contact thermocouple for temperature measurement. Specimens were transferred from the anvil to the temperature conditioning chamber and back by a pneumatic cylinder. The specimen was located in the exact test position by three pneumatic pistons, which were activated by the retracting piston. Interlocks prevented the hammer release until the transfer and locating pistons were all retracted. Return of the hammer to the raised position after test was automatic. The elapsed time from removal from the temperature conditioning chamber to impact was approximately 3 sec.

In addition to automating the Charpy machine, we equipped the striker with a strain gage bridge coupled to an oscilloscope and camera. The setup allowed the load-time phenomenon to be recorded during specimen fracture for subsequent analysis. The strain gage bridge was calibrated statically in a special setup on an Instron tensile machine.

SPECIMEN LOCATION AND ORIENTATION

The location of a point in any HSST Program plate, plate section, or specimen can be described in terms of an x-y-z (Cartesian) coordinate system having its origin at one of the corners of the parent plate. The origins for the plates and weldments studied are shown in Figs. 1 and 3. The coordinate system axes are assigned so the y axis is parallel to the principal rolling or welding direction and the x axis transverse. The thickness is measured along the z axis from the upper or top surface. A further detailed description may be found[6] in HSST Program Technical or Programatic Manuscript No. 1.

6. *A Guide for Material Control and Data Control for the Heavy-Section Steel Technology Program*, HSST Program Technical or Programmatic Manuscript No. 1; prepared by the Inspection Engineering Department, Oak Ridge National Laboratory, June 15, 1968 (undocumented).

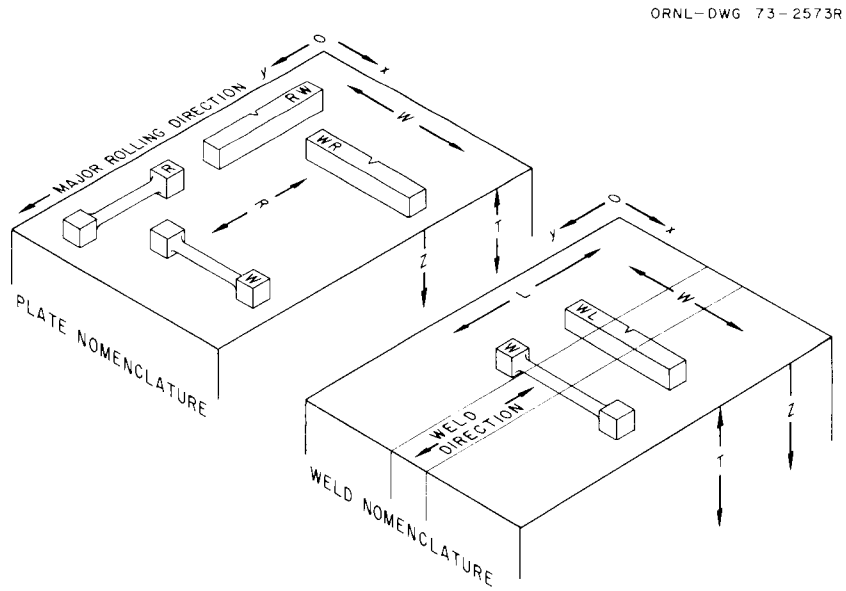

Fig. 3. Specimen orientation and nomenclature for HSST plate and weldment.

The coordinates are expressed in inches and eighths of an inch from the appropriate zero plane; and, by definition, the coordinates of all points carry a positive sign. The first three digits following each axis designation indicate whole inches, and the fourth digit denotes additional eighths of an inch. For example, X012-3 means $12\frac{3}{8}$ in. from the origin in the parent plate or weldment in the x direction.

Specimen orientation in the coordinate system is reported by placing an N in parentheses after the appropriate axis coordinate; for example, Y012-3 (N) indicates a longitudinal specimen and X012-3 (N) indicates a transverse specimen. All irradiated and control Charpy specimens were notched perpendicular to the plate surface or z plane, so the fracture propogated in either the positive x or positive y direction.

In reporting the test results, a widely used system of specifying specimen orientation in plate materials was adopted. It relates the principal directions in the original plate or weldment to the plate fracture plane and direction of fracture propagation. The three principal directions in the original plate are designated by (1) R, the principal rolling direction, (2) W, the width direction, perpendicular to the R direction, and parallel to the plate surface; and (3) T, the thickness direction, perpendicular to the surface of the plate. Weldments make it necessary to modify the notation since the weld orientation would not be easily apparent. Therefore, the three principal directions were modified for the weldment only and are orientated to the weld: L, the direction of the weld center line; W, the width direction perpendicular to the weld center line and parallel to the weld surface; and T, the thickness direction through the weld.

A combination of two of these symbols specifies specimen orientation for most tests. The first symbol indicates the normal to the fracture plane, which is usually the major axis of the specimen, and the second symbol indicates the direction of fracture. Figure 3 illustrates this method for the specimens tested. The symbol for the normal to the fracture plane is sufficient to define the specimen orientation in uniaxial tension tests.

TEST RESULTS AND DISCUSSION

Tensile

The results of tensile tests on irradiated material and unirradiated control material from the two plates and two weldments together with the irradiation data are presented in Table A-1 (Appendix A). Control specimens are identified as having zero fluence. Direct comparison of irradiation temperature and material variables is difficult because of the fluence variations mentioned in the irradiation conditions. To correct for the fluence differences, we can assume that the irradiation-induced increase in stresses is proportional to the square root of neutron fluence.[7–9] While this relationship is inadequate to correlate results for fluences varying over several orders of magnitude, it does appear to be sufficiently accurate for the fluence range reported. The increase in lower yield stress, a major property, was normalized to a fluence of 1×10^{19} neutrons/cm^2, >1 MeV, by the equation

$$(\Delta\sigma_{LY})_n = \Delta\sigma_{LY} \left(\frac{10^{19}}{\phi}\right)^{1/2} ,$$

7. A. D. Whapham and M. J. Makin, "The Hardening of Lithium Fluoride by Electron Irradiation," *Phil. Mag.* **5**, 237 (1960).

8. M. J. Makin and F. J. Minter, "Irradiation Hardening in Copper and Nickel," *Acta Met.* **8**, 691 (1960).

9. R. W. Nichols and D. R. Harries, "Brittle Fracture and Irradiation Effects in Ferritic Pressure Vessel Steels," p. 162 in *Radiation Effects on Metals and Neutron Dosimetry, Spec. Tech. Publ.* 341, American Society for Testing and Materials, Philadelphia, 1963.

where

ϕ = fast neutron fluence (neutrons/cm^2, >1 MeV),

$\Delta\sigma_{LY}$ = increase in lower yield stress due to irradiation (psi).

The normalized values have been included in Table A-1.

This fluence was chosen since it is near the average fluence for all the irradiations. All the irradiated specimens tested have been included. The control data are averages of at least three specimens and usually nine or more from locations dispersed throughout the region sampled. All specimens were tested at a strain rate of 0.016/min.

Coordinates for the specimens tested are listed in Table A-2. All data reported in previous publications and reports were referred to the nearest eighth-thickness levels ($0t$, $\frac{1}{8}t$, $\frac{1}{4}t$ ...). This represents plate thickness levels of every 1.5 in. in a 12-in.-thick plate and can become somewhat misleading, especially near the plate surfaces. Therefore, increments with a maximum thickness of 1 in. ($\frac{1}{12}t$), and in some instances smaller, are used in this report. This additional separation of data plus the addition of new data will cause some of the numerical values to differ from those published in progress reports. Therefore, the data and calculations presented in this report are based on all the testing completed to August 1, 1972.

Table A-3 lists the irradiation data and coordinates for all untested specimens, which have been stored and are available for future testing.

The normalized change in lower yield stress, $(\Delta\sigma_{LY})_n$, as a function of irradiation temperature has been plotted for each plate level and weldment and is shown in Figs. A-1 through A-6. These data are further reduced in Table 2 and Fig. 4, where $(\Delta\sigma_{LY})_n$ was averaged within irradiation temperature bands up to 25°F (usually less than 20°F) and replotted to show the effect of the radiation-induced damage upon the yield properties as a function of increasing irradiation temperature. These data indicate that $(\Delta\sigma_{LY})_n$ in the R direction in the 01K section increases with plate depth. This increase is substantial for irradiations at 140

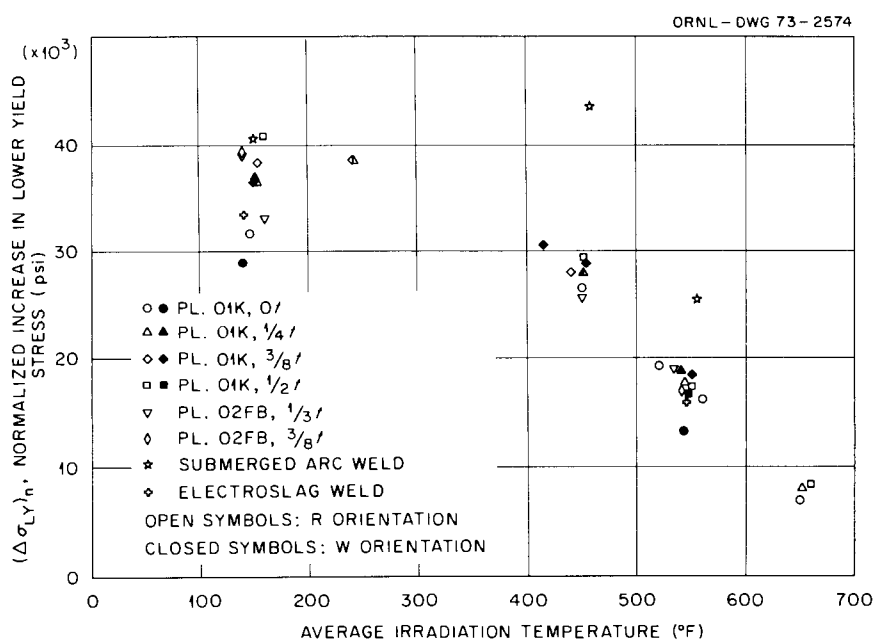

Fig. 4. Effect of temperature of neutron irradiation on yield properties of HSST plates and weldments.

Table 2. Summary of room-temperature tensile properties[a] of irradiated ASTM A533, grade B, class 1 steel plate and weldments normalized to a fluence of 1×10^{19} neutrons/cm^2 (>1 MeV)

R Orientation		W Orientation	
Average irradiation temperature (°F)	Change in lower yield stress $(\Delta\sigma_{LY})_n$ (psi)	Average irradiation temperature (°F)	Change in lower yield stress $(\Delta\sigma_{LY})_n$ (psi)
	$\times 10^3$		$\times 10^3$
Plate Section 01K, Surface Layer			
146	31.7	140	28.9
450	26.4		
520	19.3		
551	16.0	543	13.1
649	6.8		
Plate Section 01K, $\frac{1}{4}t$ Layer			
153	36.2	150	36.6
242	38.3		
452	27.6	450	27.4
546	17.7	542	18.6
651	7.4		
Plate Section 01K, $\frac{3}{8}t$ Layer			
153	38.2	150	36.5
240	38.2	415	30.3
440	28.0	453	28.7
		549	18.2
Plate Section 01K, $\frac{1}{2}t$ Layer			
158	40.8		
452	29.1		
550	17.1	547	16.4
659	8.1		
Plate Section 02FB, $\frac{1}{3}t$ Layer		**Submerged Arc Weldment, 51B**	
140	39.0	150	40.4
160	33.1	458	43.5
450	25.6	554	25.3
535	18.8		
Plate Section 02FB, $\frac{3}{8}t$ Layer		**Electroslag Weldment, 53E**	
140	39.2	140	33.6
542	16.6	546	15.8

[a]Strain rate 0.016/min.

to 150°F, much less at 450°F, and obscured by the scatter of the data at 550°F. For example, at 140 to 150°F the spread of the average $(\Delta\sigma_{LY})_n$ between the surface and the $\frac{1}{2}t$ material is about 9000 psi, while at 450°F it is only 3000 psi. Another way to state some of these results is that the yield strength is least sensitive to irradiation in the surface material, and increases with depth into the plate to midthickness.

Limited data from specimens irradiated at 240°F indicate that a maximum in the irradiation damage may occur near 240°F; however, additional data would be required to reach a definite conclusion. The trends in $(\Delta\sigma_{LY})_n$ at the higher irradiation temperatures indicate that the damage becomes markedly reduced as the irradiation temperature increases. At 550°F, $(\Delta\sigma_{LY})_n$ has been reduced by competing recovery processes to 55% for surface material and to 45% for the $\frac{1}{4}t$ to $\frac{1}{2}t$ materials when compared with the effect experienced at the 140 to 150°F irradiations. The 650°F irradiation produces only 20% of the $(\Delta\sigma_{LY})_n$ at the 140 to 150°F irradiations for all depths studied.

The effect of orientation, R and W, can also be inferred from the results. Transverse specimens, W, from the $\frac{1}{4}t$ to $\frac{1}{2}t$ levels of plate section 01K experienced similar radiation damage to the R-oriented specimens at all irradiation temperatures studied. The W-oriented surface specimens experienced significantly lower $(\Delta\sigma_{LY})_n$ than the R surface specimens, and the same difference persisted from 140 to 550°F. This would indicate that the W orientation of the surface material from plate section 01K sustains the least radiation damage in the areas and levels studied.

The $(\Delta\sigma_{LY})_n$ response of the 02FB plate section for both R and W orientations appears to be the same as for comparable levels in plate section 01K and comparable irradiation temperatures.

Limited electroslag weldment tensile results from W (transverse) oriented specimens from section 53E2 indicate the same degree of susceptibility of $(\Delta\sigma_{LY})_n$ to irradiation damage as the R-oriented surface material from plate section 01K.

The submerged-arc weldment tensile results from W-oriented specimens from section 51B9 indicate that the weld metal is the most susceptible to irradiation damage [as measured by $(\Delta\sigma_{LY})_n$] of all the materials studied. This effect is not pronounced for the 150°F irradiation, which produced a $(\Delta\sigma_{LY})_n$ the same as that of the $\frac{1}{2}t$, R-oriented material from plate section 01K. However, at 450°F, $(\Delta\sigma_{LY})_n$ is about 50% greater than that of the other plates and the electroslag weldment. At 550°F, the submerged-arc material $(\Delta\sigma_{LY})_n$ is still 40% higher. This greater damage to the weld may be due to its 0.15 to 0.33% Cu content.[10]

Charpy Impact

The individual Charpy V-notch impact data from plate sections 01K and 02FB and the submerged-arc and electroslag weldments after irradiation at 150, 450, 550, and 650°F (nominal) are presented in Table B-1, and the stored, untested specimens are listed in Table B-2 (Appendix B). Included are the specimen location coordinates and orientation data. The individual Charpy transition curves from these data at each irradiation temperature and depth together with the appropriate control curve are illustrated in Figs. B-1 through B-11. The ductile-to-brittle transition temperatures (DBTT), the ductile shelf energies, and the averaged irradiation conditions are shown in Table 3. The data were compared after normalization of the increase in ductile-to-brittle transition temperature (ΔDBTT) to a fluence of 1×10^{19} neutrons/cm^2, >1 MeV, by the equation

$$(\Delta\mathrm{DBTT})_n = \Delta\mathrm{DBTT}\left(\frac{10^{19}}{\phi}\right)^{1/2},$$

10. L. E. Steele, "Neutron Irradiation Embrittlement of Reactor Pressure Vessel Steels," *At. Energy Rev.* 7(2), 3–134 (1969).

Table 3. Charpy V-notch impact properties of unirradiated and irradiated ASTM A533, grade B, class 1 steel plates and weldments

Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	DBTT[a] (°F)	Change in DBTT (ΔDBTT) (°F)	Ductile shelf energy (ft-lb)	Normalized to 1×10^{19} neutrons/cm^2 (>1 MeV)[b]	
					$(\Delta DBTT)_n$ (°F)	$(DBTT)_n$ (°F)
$\times 10^{18}$						
Plate Section 01K, Surface, RW Orientation						
0		145		114		
4.1	142	−15	130	100	203	58
10.0	143	5	150	100	150	5
5.5	450	10	155	90	209	64
5.0	552	−75	70	102	99	−46
12.8	554	−50	95	102	84	61
11.1	642	−90	55	108	52	93
Plate Section 01K, ¼t, RW Orientation						
0		0		120		
4.6	146	150	150	106	221	221
6.0	155	175	175	106	226	226
9.7	143	190	190		193	193
6.6	454	165	165	100	203	203
8.8	556	100	100	102	107	107
12.4	550	115	115	102	103	103
13.4	655	45	45	116	39	39
Plate Section 01K, ¼t, WR Orientation						
0		25		97		
6.6	130	180	155	96	191	216
7.8	460	155	130	88	147	172
Plate Section 01K, ½t, RW Orientation						
0		15		118		
4.7	130	165	150	98	219	234
5.8	139	180	165	93	217	232
6.8	147	210	195	88	236	251
7.4	455	195	180	86	209	224
9.2	458	195	180		188	203
10.6	561	150	135	84	131	146
9.8	661	65	50	110	51	66
Plate Section 02FB, ⅓t, RW Orientation						
0		45		114		
10.6	150	235	190	100	185	230
12.6	451	235	190	86	169	214
5.3	548	95	50	108	69	114
Submerged Arc Weldment, 51B, WL Orientation						
0		−60		116		
6.5	130	135	195	110	242	182
7.9	457	200	260	75	293	233
11.6	563	130	190	76	176	116
Electroslag Weldment, 53E, WL Orientation						
0		−20		82		
9.5	130	140	160	66	164	144
11.2	557	55	75	84	71	51

[a]Ductile-to-brittle transition temperature at 32 ft-lb energy.

[b]From equation $(\Delta DBTT)_n = \Delta DBTT\ (10^{19}/\phi)^{1/2}$, where ΔDBTT is the change in transition temperature in °F, ϕ is the fluence in neutrons/cm^2, >1 MeV, and $(\Delta DBTT)_n$ is the ΔDBTT in °F normalized to 1×10^{19} neutrons/cm^2, >1 MeV.

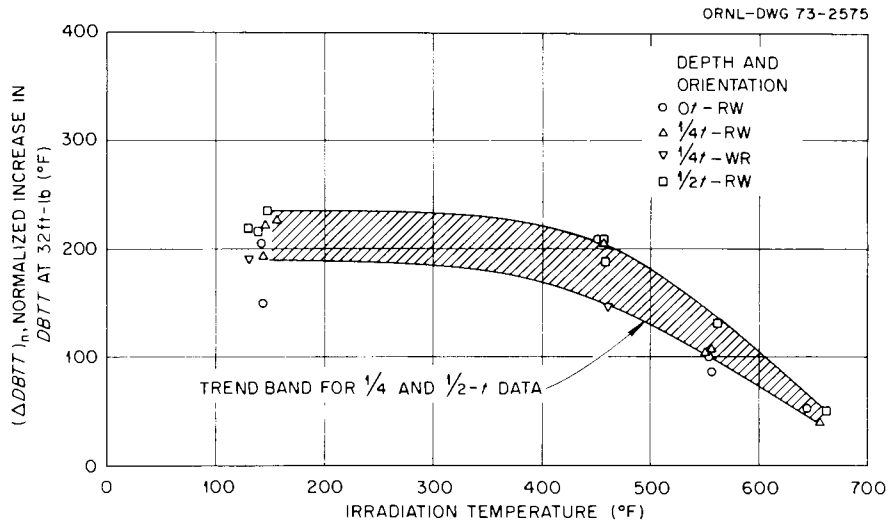

Fig. 5. Effect of temperature of neutron irradiation on ductile-to-brittle transition temperature at 32 ft-lb of HSST plate 01.

where

ϕ = fast neutron fluence (neutrons/cm^2, >1 MeV),

ΔDBTT = change in ductile-to-brittle transition temperature (°F) due to irradiation.

The normalized ΔDBTT data are included in Table 3 and are plotted in Fig. 5, which depicts the variation of the averaged $(\Delta\text{DBTT})_n$ with irradiation temperature. These data indicate that the fracture properties of all the HSST material tested and represented by the $(\Delta\text{DBTT})_n$ are most seriously affected in the irradiation temperature range 130 to 450°F, where little improvement is indicated with increasing temperature. The irradiation damage, indicated by an increase in the $(\Delta\text{DBTT})_n$, becomes considerably less above 450°F, where the $(\Delta\text{DBTT})_n$ drops at 550°F to 50% and at 650°F to 25% of the 130 to 140°F level of damage. The $(\Delta\text{DBTT})_n$) of the RW specimens from plate section 01K appear to be somewhat depth sensitive except for the 450°F irradiation.

The surface materials appear to exhibit the least damage, but additional data would be needed to confirm this. The WR-oriented specimens from the ¼t level of 01K seem to be less prone to damage than RW-oriented specimens from the same depth.

The RW-oriented specimens from plate section 02FB and the WL-oriented specimens from the electroslag weld section, 53E2, appear to sustain less irradiation damage than the RW and WR specimens from 01K. These results are shown in Fig. 6. The electroslag results and the 01K surface results show similar irradiation responses, which were the least of all the materials and levels studied.

Data from WL-oriented submerged-arc weld specimens from section 51B9 show more severe irradiation damage to the fracture properties than that observed for any of the other HSST materials studied. At temperatures as high as 560°F, the $(\Delta\text{DBTT})_n$ is only slightly less than the average for the inner material of the plate at 140°F. This deterioration in fracture properties may also be attributed to the 0.15 to 0.33% Cu content of the submerged-arc weld.

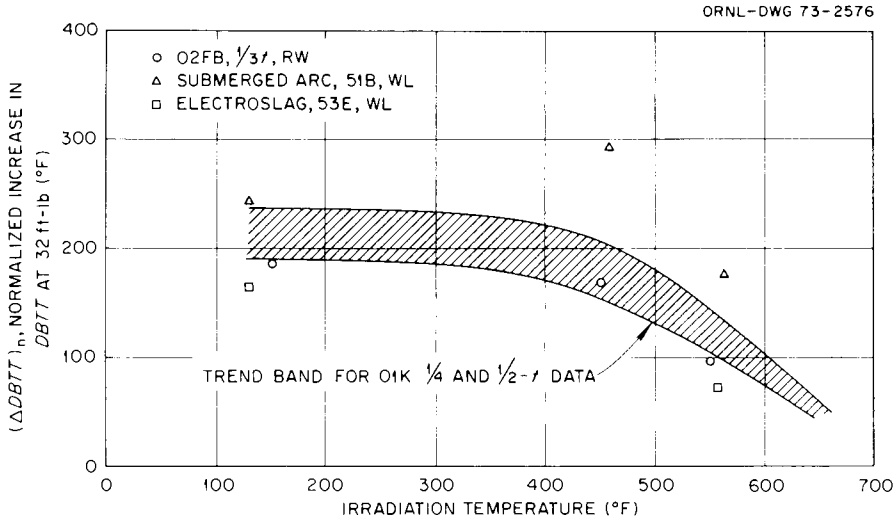

Fig. 6. Effect of temperature of neutron irradiation on ductile-to-brittle transition temperature at 32 ft-lb of HSST plate 02 and weldments.

Instrumented Charpy Results

During the notch-impact testing, load-time records were obtained from strain gages attached to the striker of the testing machine. Typical oscilloscope records from a series of unirradiated and irradiated (560°F) Charpy V-notch impact test specimens from the $\frac{1}{4}t$ depth and RW orientation of plate section 01K are shown in Fig. 7. Brittle cleavage fracture, indicated by a sudden drop in load, occurred with little or no plastic deformation at the lowest test temperature (−80°F). As the test temperature was increased, brittle fracture occurred at greater deflections until at 140°F the fracture in unirradiated material was fully ductile. We also tried to correlate the various stages of fracture, from initial generation to final rupture, with the oscilloscope trace. The study will be presented in the topical report on the characterization of the unirradiated HSST plate material, HSST Program Technical Report No. 29 (in preparation).

These additional data from each Charpy test permit the determination of the loading characteristics and energy distribution contributing to the fracture of the specimen and permit comparison with similar data from other specimens or test series of specimens. As an example, Fig. 8 illustrates an overlay of three such records from three specimens tested at about the same temperature, 200°F. The unirradiated specimen fractured in a fully ductile mode, the specimen irradiated at 150°F fractured in a largely cleavage mode after plastic hinges had developed, and the specimen irradiated at 552°F fractured in a mixed mode, cleaving after considerable deformation (0.18 in. deflection) and tearing at the notch root. Note that the gross yield is considerably increased by irradiation. Figure 9 compares the results for three specimens that gave about the same fracture energy. The irradiation-induced increase in gross yield (related to tensile yield stress) is apparent but not as marked as in Fig. 8 because of the differences in test temperature. Figure 10 is a similar comparison for a higher fracture energy. All were mixed-mode fractures, but the specimen irradiated at 150°F showed very little cleavage fracture. Once again, the radiation-induced yield stress increase is apparent in the higher gross yield loads for the irradiated specimens. The shape of the record for the specimen irradiated at 150°F suggests that the ductile fracture initiated at the notch root at considerably less deflection than for the other two specimens because of reduced strain to fracture as a consequence of the irradiation.

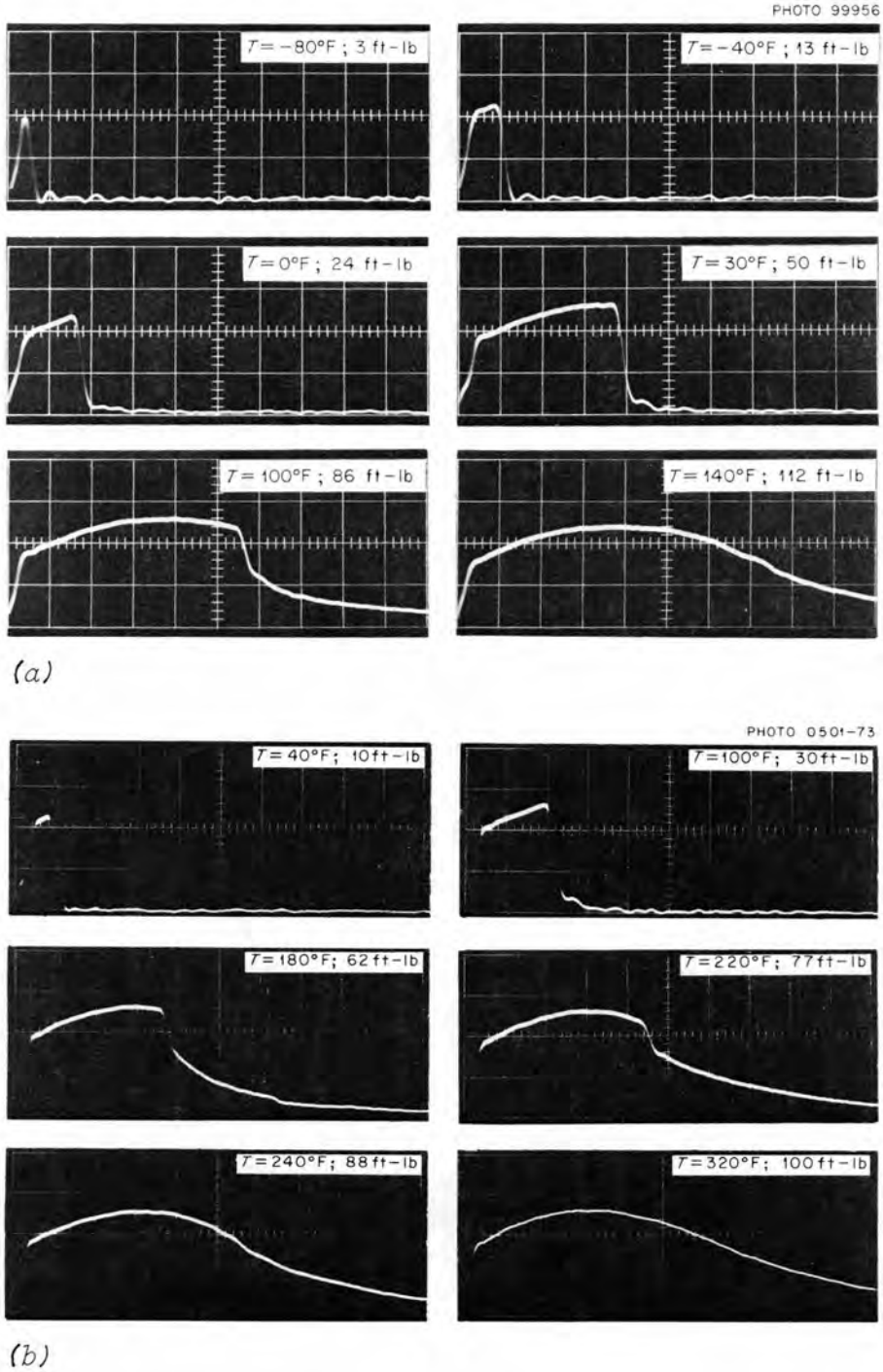

Fig. 7. Typical load-time records from instrumented Charpy V-notch impact tests on ASTM A 533 B1 steel; HSST plate 01, quarter thickness level, RW orientation. In these records, each major division on the abscissa is 200 μsec (equivalent to 0.041 in. deflection) and on the ordinate is 1640 lb load. (*a*) Unirradiated; (*b*) irradiated at 560°F.

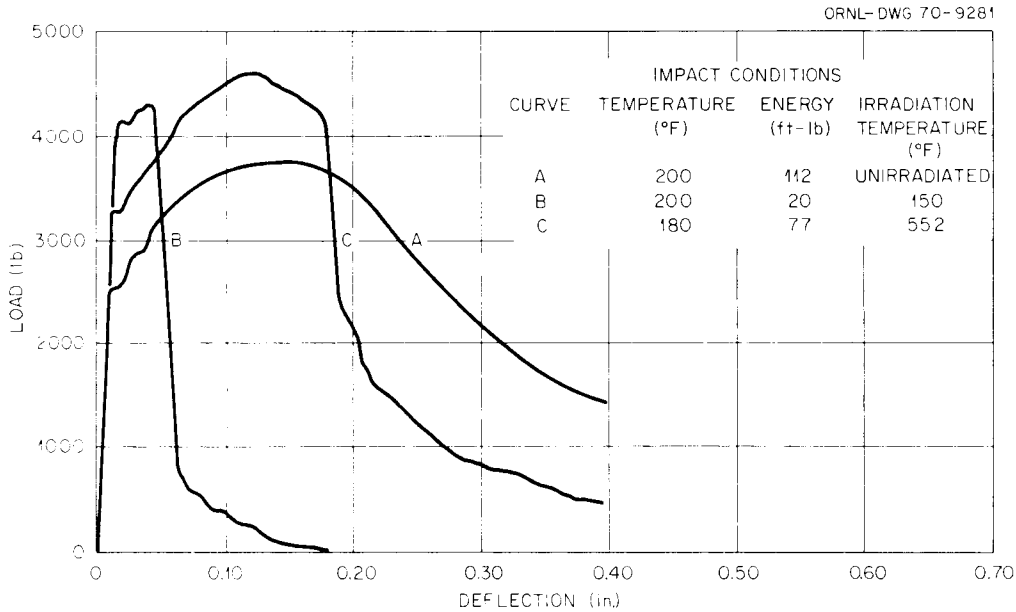

Fig. 8. Effect of irradiation on load-deflection behavior at one test temperature.

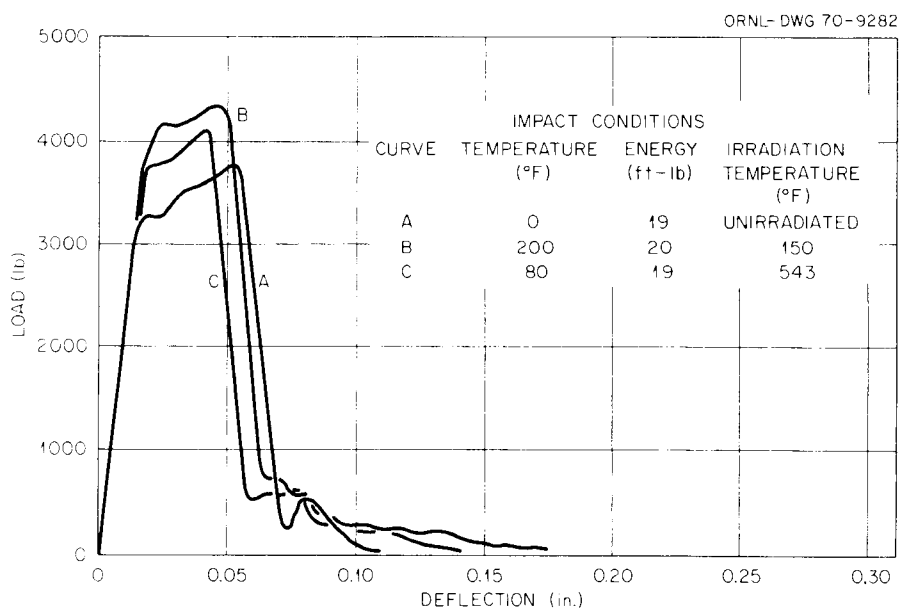

Fig. 9. Effect of irradiation on load-deflection behavior below the nil-ductility temperature.

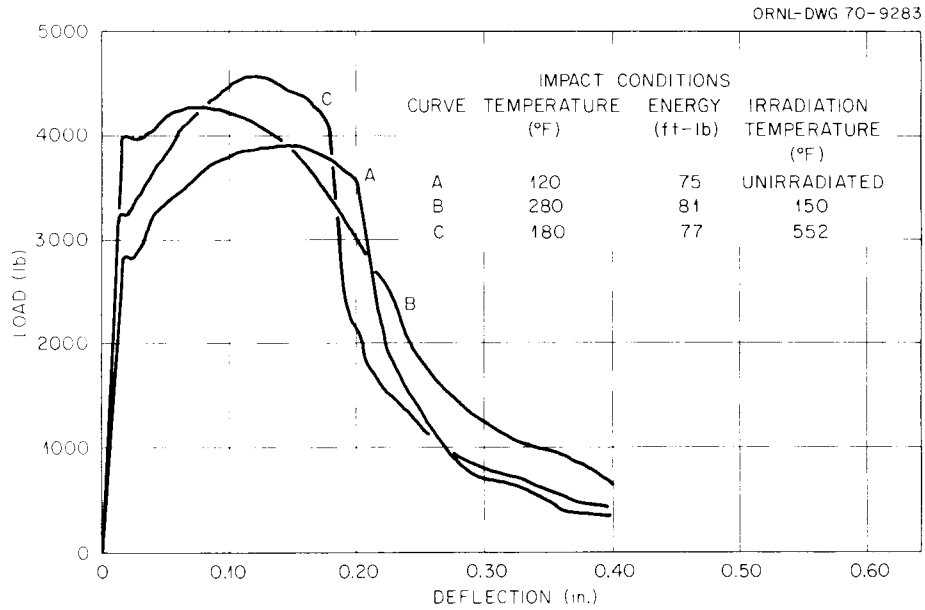

Fig. 10. Effect of irradiation on load-deflection behavior above the nil-ductility temperature.

Table C-1 (Appendix C) lists load and energy values for several series of irradiated Charpy specimens tested. The loads and energies have not been determined for all irradiated specimens tested, but the records from which similar data may be obtained are available for the major portion of the tests. Figures 11 and 12 display the fracture load values for unirradiated and 530°F irradiated specimens of plate section 02FB, $\frac{3}{8}t$ level, and RW orientation and unirradiated and irradiated (565°F) specimens of submerged-arc weldment 51B, $\frac{1}{2}t$ level and WL orientation. Comparison of the effects of irradiation at nominally 550°F on the submerged-arc weldment and plate section 02FB, a comparable base plate material, indicates that irradiation causes the load values in both cases to shift to higher loads and higher test temperatures. However, the magnitude of the loads for each separate condition (irradiated or unirradiated) does not appear to differ greatly, although the shift to higher temperature due to irradiation appears to be much greater for the submerged-arc weldment.

Comparison of the energy values of the same materials in Figs. 13 and 14 indicates a fair-sized decrease due to irradiation in all values except the energy to maximum load, where the decrease is small. The shift of energies to higher test temperatures after irradiation is also apparent. The magnitudes of the energy values of both materials in the unirradiated condition, although not equal, are comparable. After irradiation, the submerged-arc material shows a much greater shift of energies to higher test temperatures than does the 02FB.

SUMMARY

Miniature tensile and Charpy V specimens taken from two 12-in.-thick A533-B, class 1 steel plates, HSST 01 and 02, and a submerged-arc weldment, 51B, and $6\frac{3}{8}$-in.-thick electroslag weldment, 53E, were irradiated at several temperatures (150, 240, 450, 550, and 650°F, nominal) to fluences ranging from 2.9 to 14.1×10^{18} neutrons/cm^2, >1 MeV. The principal observations and conclusions from the investigation may be discussed in two groups.

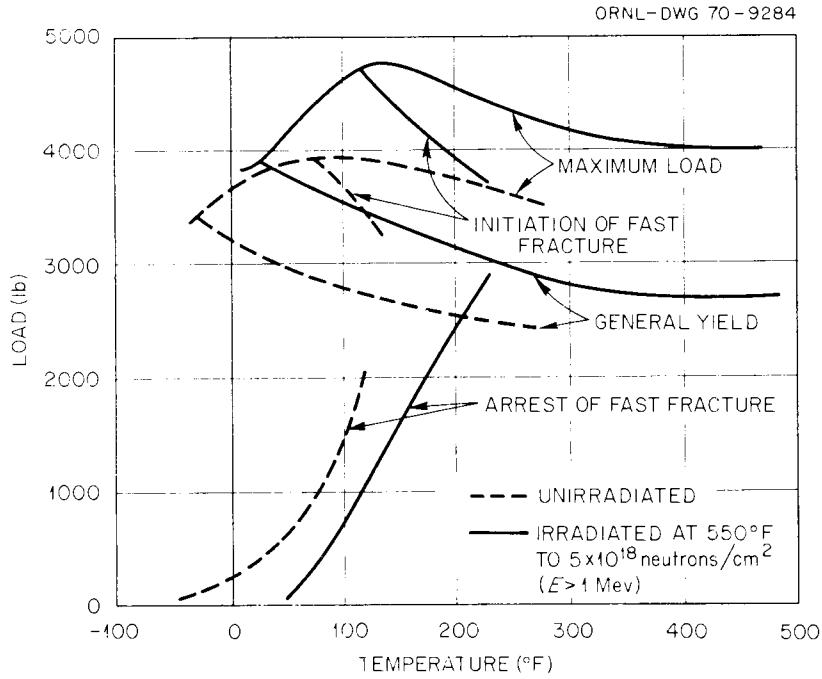

Fig. 11. Effect of irradiation at 550°F on load values in notch-impact tests of HSST plate section 02FB, $^1/_3t$ level, RW orientation.

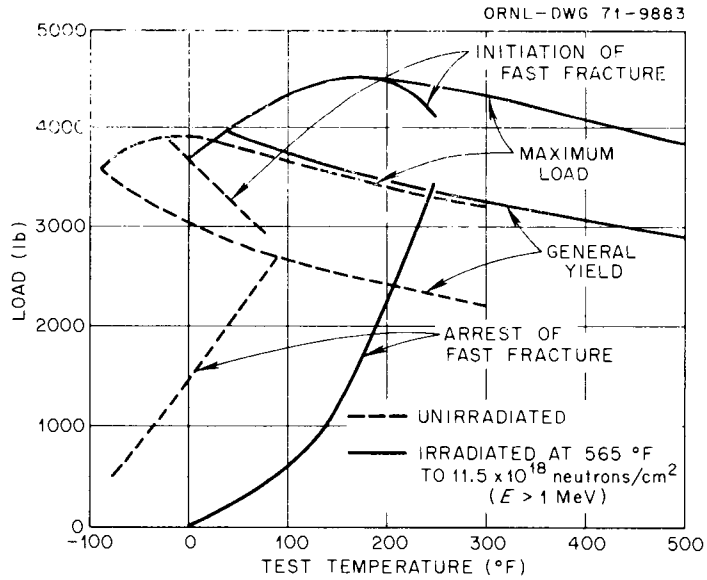

Fig. 12. Effect of irradiation on load values determined in instrumented Charpy tests on irradiated and unirradiated HSST submerged-arc weldment 51B; WL-oriented specimens.

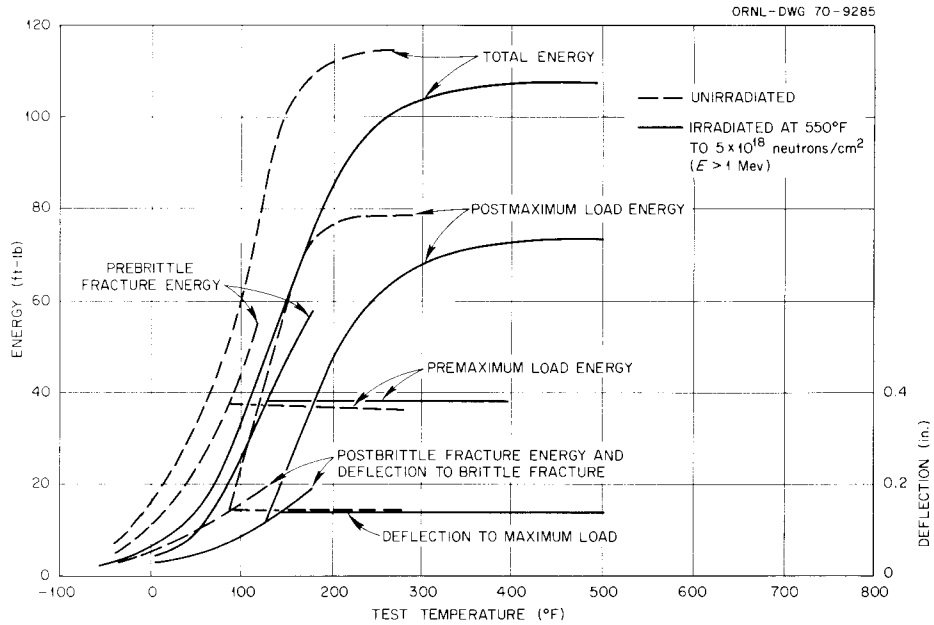

Fig. 13. Effect of irradiation at 550°F on energy and deflection values in notch-impact tests of HSST plate section 02FB, $\frac{1}{3}t$ level, RW orientation.

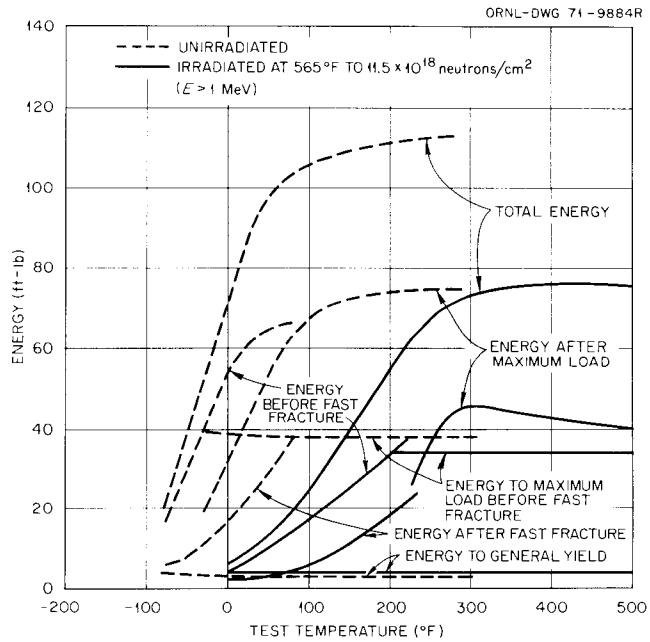

Fig. 14. Effect of irradiation on energy values determined in instrumented Charpy test on irradiated and unirradiated HSST submerged-arc weldment 51B; WL-oriented specimens.

Postirradiation strength properties represented by the change in lower yield stress ($\Delta\sigma_{LY}$) indicated that for the materials and levels studied:

1. Irradiation response for all materials was greatest in the range 140 to 450°F and became significantly less at the higher irradiation temperatures.
2. R-oriented inner material from plates 01 and 02 and W-oriented electroslag weld material showed similar irradiation response.
3. Irradiation damage in R-oriented material from plate 01 was depth sensitive, especially between 140 and 450°F. By 650°F little if any differences remain. The effect of irradiation on yield strength increased with depth into the plate.
4. The submerged-arc weld exhibited the greatest irradiation damage of all the materials tested.
5. W-oriented, surface specimens from plate 01 showed less response to irradiation than R-oriented specimens and were the least affected of all the materials tested. No such orientation difference was noted for the inner plate material.

Postirradiation fracture properties represented by the change in ductile-to-brittle transition temperature (ΔDBTT) of RW- and WL-oriented specimens at the 32-ft-lb correlation energy indicate that for the materials and levels studied:

1. Response to irradiation is greatest and fairly constant for all materials tested from 130 to 450°F and drops rapidly at the higher irradiation temperatures.
2. The only depth sensitivity observed in material from plate 01 was that the surface material was less sensitive to irradiation embrittlement than inner material.
3. Inner material from plate 02 appeared to be less responsive to irradiation than comparable material from plate 01.
4. Electroslag weld and surface material from plate 01 exhibited similar radiation response and were the least affected of all the materials tested.
5. Submerged-arc weld metal shows the greatest response to irradiation of all the materials tested.
6. Instrumented Charpy data have shown the increases in the radiation-induced transition temperature to be the result of a general increase in loads or strengths and a shift to higher test temperature, a general increase in the temperature at which any given deformation or fracture characteristic is observed, and a general decrease in the energy values along with a shift to higher temperature.

The submerged-arc weld metal appears to exhibit the severest degradation of strength and impact properties due to irradiation of all the materials studied at all irradiation temperatures. This degradation may be due in part to the higher copper content of the weld.

Appendix A

TENSILE DATA

Table A-1. Tensile properties of irradiated ASTM A533, grade B, class 1 steel plate and two weldments at a strain rate of 0.016/min

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperature (°F)		Strength properties (psi)[a]			Elongation (%)[b]			Normalized $\Delta\sigma_{LY}$ (psi)
		Irradiation	Test	Upper yield	Lower yield	Ultimate	Luders	Uniform	Total	
	$\times 10^{18}$			$\times 10^3$	$\times 10^3$	$\times 10^3$				$\times 10^3$
Plate Section 01K, Surface Layer, R Orientation										
	0		77	82.7	80.5	97.0		11.2	21.2	
01K-6236	9.8	512	88	106.0	99.6	112.9	2.2	9.2	16.5	19.3
01K-6237	10.1	528	88	102.8	100.0	113.4	1.5	7.9	15.1	19.4
01K-6255	5.3	552	72	99.5	95.3	109.3	2.1	10.8	19.5	20.3
01K-6261	5.7	557	71	100.5	94.0	107.7	2.0	11.0	20.4	17.9
01K-6262	5.9	450	68	107.3	100.9	111.7	2.1	9.9	18.6	26.6
01K-6268	5.8	450	69	103.7	100.5	111.7	2.2	10.4	18.4	26.3
01K-6269	4.9	147	73	113.9	105.8	107.0	4.8	7.8	16.8	36.1
01K-6274	5.3	151	71	111.7	105.2	106.0		7.5	17.3	33.9
01K-6281	5.6	155	72	114.1	104.4	105.2		7.2	16.7	31.9
01K-6291	13.0	650	73	94.0	87.6	102.5	1.7	11.2	19.8	6.2
01K-6295	12.1	648	73	93.1	88.7	102.8	1.8	11.1	20.1	7.5
01K-6300	5.5	155	72	116.5	107.7	108.1	5.3	7.0	17.3	36.7
01K-6313	3.8	149	72	109.4	101.7	104.1	4.1	8.5	19.2	34.4
01K-6318	3.6	146	73	107.3	100.1	102.9	4.2	8.0	18.2	32.7
01K-6682	7.4	140	92	105.4	102.0	105.0	2.8	6.8	22.9	25.0
01K-6683	7.5	140	90	109.9	105.5	107.7	1.8	6.0	15.0	28.9
01K-6684	7.7	140	92	111.9	107.7	108.5	1.7	6.4	15.3	31.0
01K-6685	7.9	140	92	111.3	107.5	107.9	2.1	4.2	12.5	21.3
01K-6686	7.8	140	92	109.9	107.1	108.1	1.4	3.4	11.8	30.1
01K-6687	7.6	140	92	111.1	106.6	108.0	1.6	4.5	12.8	29.9
01K-6688	7.5	140	92	107.9	104.3	105.9		6.2	15.5	27.5
01K-6691	10.3	548	88	95.8	94.6	112.0	1.0	9.7	17.0	13.9
01K-6692	10.5	555	88	96.3	95.1	111.7	1.3	9.2	16.7	14.2
01K-6693	10.8	560	88	97.0	95.0	111.5	1.2	10.6	18.6	14.0
01K-6696	7.6	160	86	110.7	105.0	107.0	3.7	6.2	14.8	28.1
01K-6704	7.3	140	92	115.5	110.2				16.1	34.8
01K-6707	7.1	140	94	116.1	109.3				16.0	34.2
01K-6708	6.9	140	92	115.9	107.9				16.3	33.0
01K-6709	6.7	140	92	113.7	108.2				16.3	33.8
01K-6710	6.5	140	89	115.3	109.7				13.0	36.2
01K-6879	11.5	552	88	103.5	96.6	110.7	1.7	10.6	18.8	15.0
01K-6881	13.8	548	88	102.6	98.6	111.6	2.1	9.3	17.7	15.4
01K-6884	13.9	537	88	106.8	101.2	114.1	1.6	10.2	17.8	17.6
01K-6885	8.9	160	85	119.2	110.7				13.0	32.0
01K-6887	10.8	160	88	123.8	115.7				9.5	33.9
01K-6890	10.9	160	86	118.7	113.9				12.7	32.0
Plate Section 01K, Surface Layer, W Orientation										
	0		72	82.0	79.4	97.4		8.8	18.1	
01K-6909	9.5	538	90	92.6	92.2	109.6	1.1	9.9	17.3	13.1
01K-6910	8.7	548	90	94.3	91.7	110.1	1.0	10.5	18.3	13.2
01K-6912	8.2	140	92	111.2	107.1	107.9		6.1	15.4	30.6
01K-6913	8.2	140	92	107.8	104.0	106.0	3.2	6.1	14.8	27.2
Plate Section 01K, $\frac{1}{4}t$ Layer, R Orientation										
	0		76	70.0	68.6	90.1		9.7	18.9	
01K-6002	7.8	237	88	102.9	102.5	103.7		5.0	13.5	38.4
01K-6007	9.0	243	86		104.5	107.7	1.4	5.0	9.9	37.8
01K-6015	10.3	253	85		106.6	108.8		4.1	11.3	37.4
01K-6023	8.7	242	85	109.3	105.3				12.4	39.3
01K-6031	7.1	234	86	104.3	101.1	102.3	2.0	5.7	13.7	38.6
01K-6032	8.8	452	86	96.1	94.7	108.8	1.0	8.7	15.5	27.8

Table A-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperature (°F)		Strength properties (psi)[a]			Elongation (%)[b]			Normalized $\Delta\sigma_{LY}$ (psi)
		Irradiation	Test	Upper yield	Lower yield	Ultimate	Luders	Uniform	Total	
01K-6033	7.6	158	86	107.0	102.3	103.6	1.4	4.2	13.0	38.7
01K-6034	11.7	547	86	90.2	87.6	106.5	1.0	9.5	16.8	17.6
01K-6035	12.1	648	73		78.0	98.0	0.9	9.7	16.0	8.5
01K-6053	12.9	655	73		75.9	96.1	1.2	10.5	18.3	6.4
01K-6060	7.8	453	79	94.8	92.8	107.7	0.8	9.0	16.2	27.4
01K-6061	6.8	158	81	104.0	101.1	102.2	2.5	5.2	13.6	39.4
01K-6062	10.4	548	85	85.2	83.2	102.5	1.2	10.0	19.1	14.3
01K-6714	13.9	538	86	90.7	89.8	107.2	1.0	9.1	15.8	18.0
01K-6717	13.5	543	87	89.8	88.2	106.4	1.1	10.3	18.3	16.9
01K-6719	10.8	547	88	90.1	87.6	106.2	1.0	10.3	18.4	18.3
01K-6720	10.9	160	88	108.9	106.4				13.7	36.2
01K-6729	10.7	160	86	110.9	106.7				13.1	36.8
01K-6730	8.5	160	88	105.8	103.2				10.5	37.5
01K-6731	8.4	140	92	103.8	100.6	102.0	2.8	6.3	14.3	34.0
01K-6732	10.3	140	92	105.9	102.3				15.8	33.2
01K-6739	10.4	140	92	105.5	103.1				14.8	33.8
01K-6756	9.4	556	88	87.7	86.1	104.7	1.2	10.6	18.0	18.0
01K-6757	9.1	555	88	87.0	85.8	104.7	1.1	10.6	17.7	18.0
01K-6762	8.9	546	88	88.5	86.4	105.0	0.9	9.6	17.0	18.9
01K-6763	8.6	538	86	87.9	86.7	104.8	1.1	11.0	18.6	19.5
01K-6774	6.8	160	88	99.6	95.9	97.9		7.0	15.9	33.1
Plate Section 01K, $\frac{1}{4}t$ Layer, W Orientation										
	0		75	71.0	69.0	90.7		9.3	17.4	
01K-6746	8.5	440	76	96.1	94.9	109.1	0.5	7.2	14.2	28.1
01K-6747	6.9	460	76	92.9	91.3	107.0	0.8	8.4	15.7	26.8
01K-6759	9.3	542	89	87.9	86.9	105.9	0.9	10.1	17.2	18.6
01K-6760	7.1	150	75	102.7	99.8	101.9	1.4	5.6	15.4	36.6
01K-6761	5.8	150	75	101.8	96.9	100.2	2.4	5.7	13.5	36.6
Plate Section 01K, $\frac{3}{8}t$ Layer, R Orientation										
	0		75	71.3	69.7	91.6		8.9	17.8	
01K-6326	6.0	230	83	102.0	99.3	105.0	1.6	6.5	13.7	38.2
01K-6333	7.6	236	83	110.3	106.6	108.5	2.8	4.8	11.4	42.3
01K-6334	9.2	244	85	105.2	104.5	108.6	0.8	5.0	10.7	36.3
01K-6335	10.1	254	83	107.2	107.0	110.7	0.4	4.2	8.6	37.1
01K-6336	8.5	240	83	110.4	106.3	107.0	0.4	2.3	10.5	39.7
01K-6337	6.9	234	85	105.8	101.4	104.0	2.2	5.9	14.1	38.2
01K-6345	5.5	240	85	97.5	96.0	103.0	0.4	6.0	13.3	35.5
01K-6346	5.3	150	68	102.6	99.4	101.4	2.8	6.2	12.4	40.8
01K-6349	6.2	150	72	103.2	102.0	102.8	3.0	5.5	13.1	41.0
01K-6353	7.3	150	73	106.9	102.5	102.5			12.7	38.4
01K-6366	9.1	150	68	112.4	107.5	107.9			11.9	39.6
01K-6375	10.9	150	68	112.2	107.3	107.7			11.3	36.0
01K-6385	10.5	150	68	112.5	106.8	106.8			9.4	36.2
01K-6395	8.5	150	73	109.0	105.0	105.0			10.3	38.3
01K-6406	7.2	150	73	109.6	105.6	106.0		5.5	12.9	42.3
01K-6409	6.4	150	73	106.1	102.1	104.1	2.1	6.0	14.0	45.5
01K-6410	9.5	415	85		99.5	111.7	1.0	7.1	13.4	30.6
01K-6415	10.9	450	88	99.0	98.2	112.4	1.0	8.7	15.0	27.3
01K-6416	10.7	450	85	99.0	98.4	112.6	1.1	7.7	14.8	27.7
01K-6426	8.1	447	85	95.1	93.5	108.5	0.8	8.1	15.4	26.4
01K-6427	7.4	160	88	104.5	99.6	100.4		5.5	13.7	34.8
01K-6428	8.8	160	88	106.1	101.1				10.8	33.5
01K-6430	8.4	160	88	107.2	101.6				13.2	34.2
01K-6431	5.9	160	84	101.9	97.4	99.0	2.3	6.0	15.3	36.1

Table A-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperature (°F) Irradiation	Temperature (°F) Test	Strength properties (psi)[a] Upper yield	Lower yield	Ultimate	Elongation (%)[b] Lüders	Uniform	Total	Normalized $\Delta\sigma_{LY}$ (psi)
Plate Section 01K, $\frac{3}{8}t$ Layer, W Orientation										
	0		75	70.8	69.4	91.4		9.1	17.5	
01K-6796	9.1	546	92	87.6	86.0	104.7	1.2	9.7	16.6	17.4
01K-6797	8.5	554	90	87.2	85.6	105.0	0.8	9.4	15.1	17.6
01K-6798	6.2	405	75	93.9	93.5	108.1	0.6	8.1	15.7	30.6
01K-6799	6.3	425	75	94.1	93.3	108.3	0.7	7.9	14.4	30.1
01K-6805	6.6	450	75	94.2	93.4	109.1	0.8	8.2	14.8	29.5
01K-6809	6.0	457	75	95.8	91.1	107.8	0.9	7.8	14.9	28.0
01K-6925	5.4	453	75	92.6	90.5	107.1	0.3	7.5	15.2	28.7
01K-6926	5.0	150	75	98.2	95.0	99.4	2.0	6.2	15.9	36.2
01K-6932	5.7	150	75	101.8	96.9	100.6	2.1	6.2	13.6	36.4
01K-6936	5.2	150	75	100.0	96.8	100.8	0.9	6.0	14.1	38.0
01K-6941	4.6	150	75	97.8	93.4	99.0	1.9	7.0	16.8	35.4
01K-6943	8.3	558	92		84.0	103.0	1.1	10.6	17.8	16.0
01K-6944	8.1	548	89		86.9	106.6	0.9	10.9	17.9	19.4
01K-6945	7.9	538	90	89.3	88.1	105.0	0.9	6.3	9.4	21.0
Plate Section 01K, $\frac{1}{2}t$ Layer, R Orientation										
	0		75	69.0	68.0	90.0		9.3	18.0	
01K-6079	8.5	453	81	95.2	94.6	108.9	0.8	7.8	14.5	28.9
01K-6085	9.0	452	81	96.6	95.9	110.7	0.6	7.5	14.1	29.4
01K-6086	7.2	150	82	106.6	102.4	103.2	1.8	4.5	12.3	40.5
01K-6092	7.8	15.7	83	108.3	104.2	105.3	1.5	4.9	11.8	41.0
01K-6093	11.3	552	85	87.8	86.7	106.5	0.6	9.1	15.8	17.6
01K-6099	11.9	548	85	88.5	86.1	105.6	1.0	7.8	14.7	16.6
01K-6100	11.1	664	73	77.7	75.3	96.6	0.7	10.1	17.4	6.9
01K-6103	11.8	654	73		78.1	99.7	1.1	11.1	18.7	9.3
01K-6104	7.7	160	85	106.7	103.5	104.3		5.2	12.9	40.5
01K-6107	8.5	160	85	108.3	103.9	104.7		4.3	12.6	38.9
01K-6108	8.1	160	85	107.9	105.9				13.5	42.1
01K-6117	6.2	160	85	104.1	100.9	101.7	1.9	4.6	11.3	41.8
Plate Section 01K, $\frac{1}{2}t$ Layer, W Orientation										
	0		77	68.5	67.5	89.2		9.5	15.2	
01K-6948	8.9	547	92		83.0	101.5	0.9	8.1	11.9	16.4
Plate Section 02FB, $\frac{1}{3}t$ Layer, R Orientation										
	0		77	73.1	72.2	94.9		8.8	17.0	
02FB-6580	11.8	160	85	112.1	107.7	107.7			12.6	32.7
02FB-6587	11.5	160	82	107.5	107.1				13.3	32.5
02FB-6588	13.9	450	85	101.4	100.2	113.9	1.0	8.4	15.5	23.7
02FB-6595	13.9	450	82	101.5	99.9	114.4	1.2	8.6	15.2	23.5
02FB-6596	9.1	160	85	108.6	103.4	105.0		5.3	14.4	32.7
02FB-6597	8.7	160	85	109.1	104.7	105.4		5.7	13.0	34.8
02FB-6598	11.1	450	82	102.4	101.6	116.9	1.1	8.9	15.5	27.9
02FB-6599	11.0	450	84	102.2	101.0	116.3	1.1	8.0	14.9	27.5
02FB-8001	4.1	523	79	90.1	87.7	109.1	0.8	8.7	17.5	24.2
02FB-8002	4.2	537	79	86.4	83.9	104.4	0.8	8.5	17.1	18.1
02FB-8003	4.3	548	79	84.6	83.0	103.9	0.8	9.2	16.3	16.5
02FB-8007	4.7	555	79	84.9	83.2	103.7	1.0	8.6	16.4	16.0
02FB-8008	5.7	548	79	85.0	84.2	105.1	0.5	8.5	16.0	15.9
02FB-8013	5.8	542	79	84.9	84.1	104.2	1.3	9.3	16.5	16.0
02FB-8016	5.7	547	79	86.4	85.6	105.1	1.1	8.7	15.0	17.7
02FB-8017	4.7	543	78	85.6	84.4	104.7	1.1	10.4	17.0	17.8
02FB-8024	4.1	565	78	83.3	80.5	100.6	1.1	9.0	15.6	13.0

Table A-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperature (°F)		Strength properties (psi)[a]			Elongation (%)[b]			Normalized $\Delta\sigma_{LY}$ (psi)
		Irradiation	Test	Upper yield	Lower yield	Ultimate	Lüders	Uniform	Total	
02FB-8026	3.9	560	78	80.7	80.3	100.2	0.7	9.1	16.5	13.0
02FB-8027	3.8	547	78	81.7	80.5	100.7	1.1	10.0	18.3	13.5
02FB-8028	3.7	532	78	85.5	83.0	102.5	1.1	9.1	16.4	17.8
02FB-8029	3.3	140	79	99.4	94.6	101.8	1.7	7.4	16.8	39.0
Plate Section 02FB, $^3/_8t$ Layer, R Orientation										
	0			69.4	68.5	90.3		9.6	18.4	
02FB-8038	3.8	140	78	95.3	91.3	96.9	1.8	6.8	15.7	37.0
02FB-8046	4.4	140	75	96.9	93.3	99.0	0.9	5.2	12.9	37.4
02FB-8057	4.6	140	75	101.4	96.9	101.0	1.5	5.6	13.8	41.9
02FB-8067	4.0	140	79	101.5	95.4	101.9	0.7	6.8	15.5	42.5
02FB-8075	3.5	140	79	101.1	95.4	101.5	1.7	6.4	14.8	45.5
02FB-8082	2.9	140	75	95.0	90.1	97.4	1.9	6.6	15.0	40.1
02FB-8141	9.7	542	94	85.2	84.8	103.1	0.8	10.0	17.0	16.6
02FB-8142	8.1	140	92	102.7	100.2	101.1		5.5	13.2	35.2
02FB-8143	8.0	140	92	102.3	99.0	101.1	2.9	6.0	13.6	34.1
Submerged-Arc Weldment, 51B, W Orientation										
	0		76	64.2	62.4	79.6		11.4	21.9	
51B-2020	7.1	458	75	101.5	99.9	108.7	1.3	8.9	17.6	44.5
51B-2021	8.5	458	75	103.3	101.7	110.5	2.5	9.2	17.1	42.6
51B-2026	5.8	150	75	97.9	93.1	93.1			11.2	40.3
51B-2027	7.1	150	75	101.0	96.6	96.6			9.2	40.6
51B-2037	12.3	560	92	89.9	88.7	102.0	1.3	11.5	18.7	23.7
51B-2041	12.5	548	89	93.8	92.5	105.7	1.7	10.5	17.7	26.9
Electroslag Weldment, 53E, W Orientation										
	0		77	63.5	61.9	81.0		11.0	21.4	
53E-2000	12.5	547	72	80.2	79.4	95.6	0.9	9.6	17.3	15.7
53E-2001	12.5	546	90	81.4	80.6	96.8	1.1	10.7	17.9	16.7
53E-2003	12.3	543	92	79.6	78.6	94.8	1.1	10.7	18.6	15.1
53E-2004	10.0	547	90		77.7	95.4	0.7	10.5	18.2	15.8
53E-2006	10.4	140	92	100.6	96.9	96.9			11.8	34.3
53E-2009	10.3	140	92	98.0	95.4	95.4			10.8	33.0
53E-2010	8.4	140	92	95.4	92.6	92.6			12.6	33.5

[a]Engineering stresses: load divided by original area.

[b]Length-to-diameter ratio: 7.

[c]Normalized to 1×10^{19} neutrons/cm^2, >1 MeV, by equation: $(\Delta\sigma_{LY})_n = \Delta\sigma_{LY}\,(10^{19}/\phi)^{1/2}$, where ϕ is the fluence in neutrons/cm^2, >1 MeV; $\Delta\sigma_{LY}$ is the increase in lower yield stress due to irradiation.

Table A-2. Coordinates for irradiated and tested miniature tensile specimens

Specimen	Coordinates (in.)		
	x	*y*	*z*
Plate Section 01K, Surface Layer, R Orientation			
01K-6236	094-6	117-6(N)	000-3
01K-6237	094-1	117-6(N)	000-3
01K-6255	098-7	115-1(N)	000-2
01K-6261	102-5	115-1(N)	000-2
01K-6262	103-2	115-1(N)	000-2
01K-6268	107-0	115-1(N)	000-2
01K-6269	107-5	115-1(N)	000-2
01K-6274	110-6	115-1(N)	000-2
01K-6281	115-1	115-1(N)	000-2
01K-6291	098-7	112-6(N)	000-2
01K-6295	101-3	112-6(N)	000-2
01K-6300	104-4	112-6(N)	000-2
01K-6313	112-5	112-6(N)	000-2
01K-6318	115-6	112-6(N)	000-2
01K-6682	082-4	115-2(N)	000-3
01K-6683	083-1	115-2(N)	000-3
01K-6684	083-6	115-2(N)	000-3
01K-6685	084-3	115-2(N)	000-3
01K-6686	085-0	115-2(N)	000-3
01K-6687	085-5	115-2(N)	000-3
01K-6688	086-2	115-2(N)	000-3
01K-6691	092-2	114-0(N)	000-3
01K-6692	092-7	114-0(N)	000-3
01K-6693	093-4	114-0(N)	000-3
01K-6696	095-3	114-0(N)	000-3
01K-6704	086-2	126-4(N)	000-3
01K-6707	092-2	125-2(N)	000-3
01K-6708	092-7	125-2(N)	000-3
01K-6709	093-4	125-2(N)	000-3
01K-6710	094-1	107-5(N)	000-3
01K-6879	061-3	107-5(N)	000-3
01K-6881	062-5	107-5(N)	000-3
01K-6884	064-4	107-5(N)	000-3
01K-6885	065-1	107-5(N)	000-3
01K-6887	070-4	106-3(N)	000-3
01K-6890	072-3	106-3(N)	000-3
Plate Section 01K, Surface Layer, W Orientation			
01K-6909	061-6(N)	127-4	000-3
01K-6910	064-3(N)	127-4	000-3
01K-6912	070-5(N)	124-4	000-3
01K-6913	073-2(N)	124-4	000-3
Plate Section 01K, $\frac{1}{4}t$ Layer, R Orientation			
01K-6002	097-5	117-7(N)	003-0
01K-6007	098-7	115-1(N)	003-0
01K-6015	101-3	115-1(N)	003-0
01K-6023	103-7	115-1(N)	003-0
01K-6031	106-3	115-1(N)	003-0
01K-6032	107-0	117-1(N)	003-0
01K-6033	107-0	115-1(N)	003-0
01K-6034	107-5	117-1(N)	003-0
01K-6035	107-5	115-1(N)	003-0
01K-6053	113-2	115-1(N)	003-0

Table A-2 (continued)

Specimen	Coordinates (in.)		
	x	*y*	*z*
01K-6060	115-6	117-1(N)	003-0
01K-6061	115-6	115-1(N)	003-0
01K-6062	116-3	117-7(N)	003-0
01K-6714	082-4	115-2(N)	003-0
01K-6717	084-3	115-2(N)	003-0
01K-6719	085-5	115-2(N)	003-0
01K-6720	086-2	115-2(N)	003-0
01K-6729	093-4	114-0(N)	003-0
01K-6730	094-1	114-0(N)	003-0
01K-6731	094-0	114-0(N)	003-0
01K-6732	095-3	114-0(N)	003-0
01K-6739	083-1	119-0(N)	003-0
01K-6756	095-3	117-6(N)	003-0
01K-6757	096-0	117-6(N)	003-0
01K-6762	082-4	122-6(N)	003-0
01K-6763	083-1	122-6(N)	003-0
01K-6774	094-1	121-4(N)	003-0
Plate Section 01K, $\frac{1}{4}t$ Layer, W Orientation			
01K-6746	083-4(N)	116-7	000-3
01K-6747	083-4(N)	117-4	000-3
01K-6759	092-3(N)	119-7	000-3
01K-6760	095-0(N)	119-2	000-3
01K-6761	095-0(N)	119-2	000-3
Plate Section 01K, $\frac{3}{8}t$ Layer, R Orientation			
01K-6326	097-0	110-3(N)	004-4
01K-6333	101-3	110-3(N)	004-4
01K-6334	102-0	110-3(N)	004-4
01K-6335	102-5	110-3(N)	004-4
01K-6336	103-2	110-3(N)	004-4
01K-6337	103-7	110-3(N)	004-4
01K-6345	108-7	110-3(N)	004-4
01K-6346	109-4	110-3(N)	004-4
01K-6349	111-3	110-3(N)	004-4
01K-6353	113-7	110-3(N)	004-4
01K-6366	098-2	112-6(N)	004-4
01K-6375	103-7	112-6(N)	004-4
01K-6385	110-1	112-6(N)	004-4
01K-6395	116-3	112-6(N)	004-4
01K-6406	099-4	115-1(N)	004-4
01K-6409	101-3	115-1(N)	004-4
01K-6410	102-0	115-1(N)	004-4
01K-6415	105-1	115-1(N)	004-4
01K-6416	105-6	115-1(N)	004-4
01K-6426	112-0	115-1(N)	004-4
01K-6427	112-5	115-1(N)	004-4
01K-6428	113-2	115-1(N)	004-4
01K-6430	114-4	115-1(N)	004-4
01K-6431	115-1	115-1(N)	004-4
Plate Section 01K, $\frac{3}{8}t$ Layer, W Orientation			
01K-6796	086-1(N)	120-5	004-4
01K-6797	086-1(N)	121-3	004-4
01K-6798	092-3(N)	122-7	004-4
01K-6799	092-3(N)	123-5	004-4

Table A-2 (continued)

Specimen	Coordinates (in.)		
	x	y	z
01K-6805	086-1(N)	125-1	004-4
01K-6809	095-0(N)	127-3	004-4
01K-6925	064-3(N)	106-2	004-4
01K-6926	070-5(N)	107-6	004-4
01K-6932	064-3(N)	109-2	004-4
01K-6936	073-2(N)	111-4	004-4
01K-6941	064-3(N)	113-6	004-4
01K-6943	070-5(N)	116-0	004-4
01K-6944	073-2(N)	115-2	004-4
01K-6945	073-2(N)	116-0	004-4
Plate Section 01K, $\frac{1}{2}t$ Layer, R Orientation			
01K-6079	097-5	115-1(N)	006-0
01K-6085	099-4	115-1(N)	006-0
01K-6086	100-1	117-7(N)	006-0
01K-6092	102-0	117-7(N)	006-0
01K-6093	102-0	115-1(N)	006-0
01K-6099	103-7	115-1(N)	006-0
01K-6100	104-4	117-7(N)	006-0
01K-6103	105-1	115-1(N)	006-0
01K-6104	105-6	117-7(N)	006-0
01K-6107	106-3	115-1(N)	006-0
01K-6108	107-0	117-7(N)	006-0
01K-6117	109-4	115-1(N)	006-0
Plate Section 01K, $\frac{1}{2}t$ Layer, W Orientation			
01K-6948	064-3(N)	108-4	006-0
Plate Section 02FB, $\frac{1}{3}t$ Layer, R Orientation			
02FB-6580	047-4	146-2(N)	004-1
02FB-6587	051-0	146-2(N)	004-1
02FB-6588	051-4	146-2(N)	004-1
02FB-6595	055-0	146-2(N)	004-1
02FB-6596	055-4	146-2(N)	004-1
02FB-6597	056-0	146-2(N)	004-1
02FB-6598	056-4	146-2(N)	004-1
02FB-6599	057-0	146-2(N)	004-1
02FB-8001	053-4	154-1(N)	004-0
02FB-8002	054-0	154-1(N)	004-0
02FB-8003	054-4	154-1(N)	004-0
02FB-8007	056-4	154-1(N)	004-0
02FB-8008	057-0	154-1(N)	004-0
02FB-8013	059-4	154-1(N)	004-0
02FB-8016	061-0	154-1(N)	004-0
02FB-8017	061-4	154-1(N)	004-0
02FB-8024	065-0	154-1(N)	004-0
02FB-8026	066-0	154-1(N)	004-0
02FB-8027	066-4	154-1(N)	004-0
02FB-8028	067-0	154-1(N)	004-0
02FB-8029	067-4	154-1(N)	004-0
Plate Section 02FB, $\frac{3}{8}t$ Layer, R Orientation			
02FB-8038	046-0	149-1(N)	004-6
02FB-8046	050-0	149-1(N)	004-6
02FB-8057	055-4	149-1(N)	004-6
02FB-8067	060-4	149-1(N)	004-6

Table A-2 (continued)

Specimen	Coordinates (in.)		
	x	*y*	*z*
01K-8075	064-4	149-1(N)	004-6
01K-8082	068-0	149-1(N)	004-6
01K-8141	045-4	154-1(N)	004-6
01K-8142	046-0	154-1(N)	004-6
01K-8143	046-4	154-1(N)	004-6
Submerged Arc Weldment, 51B, W Orientation			
51B-2020	012-7(N)	041-5	004-4
51B-2021	012-7(N)	042-1	004-4
51B-2026	012-7(N)	044-5	004-4
51B-2027	012-7(N)	045-1	004-4
51B-2037	012-7(N)	044-1	007-0
51B-2041	012-7(N)	046-1	007-0
Electroslag Weldment, 53E, W Orientation			
53E-2000	020-0(N)	011-3	001-1
53E-2001	020-0(N)	011-7	001-1
53E-2003	020-0(N)	011-3	001-7
53E-2004	020-0(N)	011-7	001-7
53E-2006	020-0(N)	011-3	004-2
53E-2009	020-0(N)	011-3	005-0
53E-2010	020-0(N)	011-7	005-0

Table A-3. Untested irradiated miniature tensile specimens

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	y	z
	$\times 10^{18}$				
		Plate Section 01K, Surface Layer, R Orientation			
01K-6256	5.3	553	099-4	115-1(N)	000-2
01K-6257	5.4	557	100-1	115-1(N)	000-2
01K-6258	5.5	558	100-6	115-1(N)	000-2
01K-6259	5.6	558	101-3	115-1(N)	000-2
01K-6260	5.6	558	102-0	115-1(N)	000-2
01K-6263	5.9	450	103-7	115-1(N)	000-2
01K-6264	5.9	450	104-4	115-1(N)	000-2
01K-6265	5.9	450	105-1	115-1(N)	000-2
01K-6266	5.8	450	105-6	115-1(N)	000-2
01K-6267	5.8	450	106-3	115-1(N)	000-2
01K-6270	5.0	148	108-2	115-1(N)	000-2
01K-6271	5.1	149	108-7	115-1(N)	000-2
01K-6272	5.2	150	109-4	115-1(N)	000-2
01K-6273	5.3	150	110-1	115-1(N)	000-2
01K-6275	5.4	152	111-3	115-1(N)	000-2
01K-6276	5.4	153	112-0	115-1(N)	000-2
01K-6277	5.5	153	112-5	115-1(N)	000-2
01K-6278	5.5	154	113-2	115-1(N)	000-2
01K-6280	5.6	154	114-4	115-1(N)	000-2
01K-6282	5.6	155	115-6	115-1(N)	000-2
01K-6283	5.6	156	116-3	115-1(N)	000-2
01K-6284	5.6	156	117-0	115-1(N)	000-2
01K-6292	12.7	650	099-4	112-6(N)	000-2
01K-6293	12.5	650	100-2	112-6(N)	000-2
01K-6294	12.3	650	100-6	112-6(N)	000-2
01K-6296	5.6	156	102-0	112-6(N)	000-2
01K-6297	5.6	156	102-5	112-6(N)	000-2
01K-6298	5.6	156	103-2	112-6(N)	000-2
01K-6299	5.5	156	103-7	112-6(N)	000-2
01K-6301	5.4	155	105-1	112-6(N)	000-2
01K-6302	5.3	155	105-6	112-6(N)	000-2
01K-6303	5.2	154	106-3	112-6(N)	000-2
01K-6304	5.1	154	107-0	112-6(N)	000-2
01K-6305	5.0	153	107-5	112-6(N)	000-2
01K-6306	4.9	153	108-2	112-6(N)	000-2
01K-6308	4.7	152	109-4	112-6(N)	000-2
01K-6309	4.6	151	110-1	112-6(N)	000-2
01K-6310	4.4	151	110-6	112-6(N)	000-2
01K-6311	4.2	150	111-3	112-6(N)	000-2
01K-6312	4.1	149	112-0	112-6(N)	000-2
01K-6316	3.7	148	114-4	112-6(N)	000-2
01K-6317	3.7	147	115-1	112-6(N)	000-2
01K-6694	11.0	558	094-1	114-0(N)	000-3
01K-6695	11.3	555	094-6	114-0(N)	000-3
01K-6697	7.8	160	096-0	114-0(N)	000-3
01K-6698	8.0	160	082-4	126-4(N)	000-3
01K-6699	8.2	160	083-1	126-4(N)	000-3
01K-6700	8.4	160	083-6	126-4(N)	000-3
01K-6701	8.6	160	084-3	126-4(N)	000-3
01K-6702	8.8	160	085-0	126-4(N)	000-3
01K-6882	13.9	540	063-2	107-5(N)	000-3
01K-6888	10.9	160	071-1	106-3(N)	000-3
01K-6889	10.9	160	071-6	106-3(N)	000-3
01K-6891	13.9	538	073-0	106-3(N)	000-3

Table A-3 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	y	z
Plate Section 01K, $^1/_4t$ Layer, R Orientation					
01K-6003	8.0	238	097-5	115-1(N)	003-0
01K-6004	8.2	240	098-2	117-7(N)	003-0
01K-6005	8.5	241	098-2	115-1(N)	003-0
01K-6006	8.8	242	098-7	117-7(N)	003-0
01K-6008	9.4	245	099-4	117-7(N)	003-0
01K-6009	9.7	247	099-4	115-1(N)	003-0
01K-6010	9.9	248	100-1	117-7(N)	003-0
01K-6011	10.1	249	100-1	115-1(N)	003-0
01K-6012	10.3	250	100-6	117-7(N)	003-0
01K-6013	10.5	252	100-6	115-1(N)	003-0
01K-6014	10.4	253	101-3	117-7(N)	003-0
01K-6016	9.9	254	102-0	117-7(N)	003-0
01K-6017	9.7	254	102-0	115-1(N)	003-0
01K-6018	9.6	252	102-5	117-7(N)	003-0
01K-6019	9.4	250	102-5	115-1(N)	003-0
01K-6020	9.2	248	103-2	117-7(N)	003-0
01K-6021	9.0	246	103-2	115-1(N)	003-0
01K-6022	8.8	244	103-7	117-7(N)	003-0
01K-6024	8.3	238	104-4	117-7(N)	003-0
01K-6025	8.1	237	104-4	115-1(N)	003-0
01K-6026	8.0	236	105-1	117-7(N)	003-0
01K-6027	7.8	235	105-1	115-1(N)	003-0
01K-6028	7.6	234	105-6	117-7(N)	003-0
01K-6029	7.4	234	105-6	115-1(N)	003-0
01K-6030	7.2	234	106-3	117-7(N)	003-0
01K-6038	8.7	452	108-7	117-7(N)	003-0
01K-6039	7.5	158	108-7	115-1(N)	003-0
01K-6040	11.5	547	109-4	117-7(N)	003-0
01K-6041	12.3	648	109-4	115-1(N)	003-0
01K-6042	8.5	452	110-1	117-7(N)	003-0
01K-6043	7.3	158	110-1	115-1(N)	003-0
01K-6044	11.3	547	110-6	117-7(N)	003-0
01K-6045	12.5	648	110-6	115-1(N)	003-0
01K-6046	8.3	453	111-3	117-7(N)	003-0
01K-6047	7.2	158	111-3	115-1(N)	003-0
01K-6048	11.1	547	112-0	117-7(N)	003-0
01K-6049	12.7	652	112-0	115-1(N)	003-0
01K-6050	8.2	453	112-5	117-7(N)	003-0
01K-6051	7.1	158	112-5	115-1(N)	003-0
01K-6052	10.9	547	113-2	117-7(N)	003-0
01K-6056	8.0	453	114-4	117-7(N)	003-0
01K-6057	6.9	158	114-4	115-1(N)	003-0
01K-6058	10.6	547	115-1	117-7(N)	003-0
01K-6715	13.8	539	083-1	115-2(N)	003-0
01K-6716	13.7	542	083-6	115-2(N)	003-0
01K-6727	10.8	160	092-2	114-0(N)	003-0
01K-6728	10.8	160	092-7	114-0(N)	003-0
01K-6733	10.3	140	096-0	114-0(N)	003-0
01K-6738	10.4	140	082-4	119-0(N)	003-0
01K-6751	10.6	547	092-2	117-6(N)	003-0
01K-6752	10.3	550	092-7	117-6(N)	003-0
01K-6753	10.1	553	093-4	117-6(N)	003-0
01K-6754	9.9	555	094-1	117-6(N)	003-0

Table A-3 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	y	z
01K-6755	9.6	557	094-6	117-6(N)	003-0
01K-6764	8.3	160	083-6	122-6(N)	003-0
01K-6765	8.1	160	084-3	122-6(N)	003-0
01K-6766	7.9	160	085-0	122-6(N)	003-0
01K-6767	7.8	160	085-5	122-6(N)	003-0
01K-6768	7.5	160	086-2	122-6(N)	003-0
01K-6771	7.4	160	092-2	121-4(N)	003-0
01K-6772	7.2	160	092-7	121-4(N)	003-0
01K-6773	7.0	160	093-4	121-4(N)	003-0
Plate Section 01K, $\frac{1}{4}t$ Layer, W Orientation					
01K-6735	8.6	445	092-3(N)	116-1	003-0
01K-6736	8.6	443	095-0(N)	115-4	003-0
01K-6737	8.6	442	095-0(N)	116-1	003-0
01K-6748	7.2	150	086-1(N)	116-7	003-0
01K-6749	7.2	150	086-1(N)	117-4	003-0
01K-6758	7.2	150	092-3(N)	119-2	003-0
Plate Section 01K, $\frac{3}{8}t$ Layer, R Orientation					
01K-6327	6.2	231	097-5	110-3(N)	004-4
01K-6329	6.6	233	098-7	110-3(N)	004-4
01K-6330	6.8	234	099-4	110-3(N)	004-4
01K-6331	7.1	235	100-1	110-3(N)	004-4
01K-6332	7.4	236	100-6	110-3(N)	004-4
01K-6338	6.7	235	104-4	110-3(N)	004-4
01K-6339	6.6	235	105-1	110-3(N)	004-4
01K-6340	6.4	236	105-6	110-3(N)	004-4
01K-6341	6.2	237	106-3	110-3(N)	004-4
01K-6342	6.0	238	107-0	110-3(N)	004-4
01K-6343	5.9	239	107-5	110-3(N)	004-4
01K-6344	5.7	239	108-2	110-3(N)	004-4
01K-6347	5.6	150	110-1	110-3(N)	004-4
01K-6348	5.9	150	110-6	110-3(N)	004-4
01K-6350	6.5	150	112-0	110-3(N)	004-4
01K-6351	6.8	150	112-5	110-3(N)	004-4
01K-6352	7.0	150	113-2	110-3(N)	004-4
01K-6354	7.6	150	114-4	110-3(N)	004-4
01K-6355	7.9	150	115-1	110-3(N)	004-4
01K-6356	8.1	150	115-6	110-3(N)	004-4
01K-6357	8.4	150	116-3	110-3(N)	004-4
01K-6358	8.6	150	117-0	110-3(N)	004-4
01K-6365	8.9	150	097-5	112-6(N)	004-4
01K-6367	9.4	150	098-7	112-6(N)	004-4
01K-6368	9.6	150	099-4	112-6(N)	004-4
01K-6369	9.9	150	100-1	112-6(N)	004-4
01K-6370	10.1	150	100-6	112-6(N)	004-4
01K-6371	10.3	150	101-3	112-6(N)	004-4
01K-6372	10.5	150	102-0	112-6(N)	004-4
01K-6373	10.6	150	102-5	112-6(N)	004-4
01K-6374	10.8	150	103-2	112-6(N)	004-4
01K-6376	11.1	150	104-4	112-6(N)	004-4
01K-6377	11.2	150	105-1	112-6(N)	004-4
01K-6378	11.2	150	105-6	112-6(N)	004-4
01K-6379	11.2	150	106-3	112-6(N)	004-4
01K-6380	11.1	150	107-0	112-6(N)	004-4
01K-6381	11.0	150	107-5	112-6(N)	004-4

Table A-3 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	y	z
01K-6383	10.8	150	108-7	112-6(N)	004-4
01K-6384	10.7	150	109-4	112-6(N)	004-4
01K-6386	10.3	150	110-6	112-6(N)	004-4
01K-6387	10.1	150	111-3	112-6(N)	004-4
01K-6388	10.0	150	112-0	112-6(N)	004-4
01K-6389	9.7	150	112-5	112-6(N)	004-4
01K-6390	9.5	150	113-2	112-6(N)	004-4
01K-6392	9.3	150	114-4	112-6(N)	004-4
01K-6393	9.0	150	115-1	112-6(N)	004-4
01K-6394	8.8	150	115-6	112-6(N)	004-4
01K-6396	8.2	150	117-0	112-6(N)	004-4
01K-6403	8.0	150	097-5	115-1(N)	004-4
01K-6404	7.7	150	098-2	115-1(N)	004-4
01K-6405	7.5	150	098-7	115-1(N)	004-4
01K-6407	7.0	150	100-1	115-1(N)	004-4
01K-6408	6.7	150	100-6	115-1(N)	004-4
01K-6411	9.8	430	102-5	115-1(N)	004-4
01K-6412	10.1	437	103-2	115-1(N)	004-4
01K-6413	10.4	442	103-7	115-1(N)	004-4
01K-6414	10.6	445	104-4	115-1(N)	004-4
01K-6417	10.4	450	106-3	115-1(N)	004-4
01K-6418	10.1	450	107-0	115-1(N)	004-4
01K-6419	9.8	450	107-5	115-1(N)	004-4
01K-6421	9.5	450	108-7	115-1(N)	004-4
01K-6422	9.3	450	109-4	115-1(N)	004-4
01K-6423	9.0	450	110-1	115-1(N)	004-4
01K-6424	8.7	450	110-6	115-1(N)	004-4
01K-6425	8.4	448	111-3	115-1(N)	004-4
Plate Section 01K, $^3/_8t$ Layer, W Orientation					
01K-6800	6.5	450	095-0(N)	122-7	004-4
01K-6801	6.6	454	095-0(N)	123-5	004-4
01K-6802	6.8	458	083-4(N)	124-3	004-4
01K-6803	6.9	458	083-4(N)	125-1	004-4
01K-6804	6.8	455	086-1(N)	124-3	004-4
01K-6806	6.5	450	092-3(N)	126-5	004-4
01K-6807	6.3	449	092-3(N)	127-3	004-4
01K-6808	6.2	452	095-0(N)	126-5	004-4
01K-6923	5.7	459	061-6(N)	106-2	004-4
01K-6924	5.6	456	064-3(N)	105-4	004-4
01K-6927	5.1	150	070-5(N)	108-4	004-4
01K-6928	5.3	150	073-2(N)	107-6	004-4
01K-6929	5.4	150	073-2(N)	108-4	004-4
01K-6930	5.5	150	061-6(N)	109-2	004-4
01K-6931	5.7	150	061-6(N)	110-0	004-4
01K-6933	5.6	150	064-3(N)	110-0	004-4
01K-6934	5.5	150	070-5(N)	111-4	004-4
01K-6935	5.3	150	070-5(N)	112-2	004-4
01K-6937	5.1	150	073-2(N)	112-2	004-4
01K-6938	5.0	150	061-6(N)	113-0	004-4
01K-6939	4.8	150	061-6(N)	113-6	004-4
01K-6940	4.7	150	064-3(N)	113-0	004-4
01K-6942	5.9	458	070-5(N)	115-2	004-4

Table A-3 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	*y*	*z*
Plate Section 01K, ½*t* Layer, R Orientation					
01K-6080	8.7	453	098-2	117-7(N)	006-0
01K-6081	8.8	453	098-2	115-1(N)	006-0
01K-6082	9.0	453	098-7	117-7(N)	006-0
01K-6083	9.1	452	098-7	115-1(N)	006-0
01K-6084	9.2	452	099-4	117-7(N)	006-0
01K-6087	7.3	151	100-1	115-1(N)	006-0
01K-6088	7.4	152	100-6	117-7(N)	006-0
01K-6089	7.6	153	100-6	115-1(N)	006-0
01K-6090	7.8	155	101-3	117-7(N)	006-0
01K-6091	7.9	156	101-3	115-1(N)	006-0
01K-6094	11.5	550	102-5	117-7(N)	006-0
01K-6095	11.6	550	102-5	115-1(N)	006-0
01K-6096	11.8	548	103-2	117-7(N)	006-0
01K-6097	11.9	548	103-2	115-1(N)	006-0
01K-6098	12.0	548	103-7	117-7(N)	006-0
01K-6101	11.3	662	104-4	115-1(N)	006-0
01K-6102	11.6	658	105-1	117-7(N)	006-0
01K-6105	8.0	160	105-6	115-1(N)	006-0
01K-6106	8.3	160	106-3	117-7(N)	006-0
01K-6109	7.8	160	107-0	115-1(N)	006-0
01K-6110	7.6	160	107-5	117-7(N)	006-0
01K-6111	7.3	160	107-5	115-1(N)	006-0
01K-6114	7.0	160	108-7	117-7(N)	006-0
01K-6115	6.7	160	108-7	115-1(N)	006-0
01K-6116	6.4	160	109-4	117-7(N)	006-0
Plate Section 02FB, ⅜*t* Layer, R Orientation					
02FB-6581	11.9	160	048-0	146-2(N)	004-1
02FB-6582	11.9	160	048-4	146-2(N)	004-1
02FB-6583	11.9	160	049-0	146-2(N)	004-1
02FB-6584	11.9	160	049-4	146-2(N)	004-1
02FB-6585	11.8	160	050-0	146-2(N)	004-1
02FB-6586	11.7	160	050-4	146-2(N)	004-1
02FB-6589	14.0	447	052-0	146-2(N)	004-1
02FB-6590	14.1	447	052-4	146-2(N)	004-1
02FB-6591	14.1	447	053-0	146-2(N)	004-1
02FB-6592	14.1	448	053-4	146-2(N)	004-1
02FB-6593	14.1	450	054-0	146-2(N)	004-1
02FB-6594	14.0	450	054-4	146-2(N)	004-1
02FB-8004	4.4	552	055-0	154-1(N)	004-0
02FB-8005	4.5	555	055-4	154-1(N)	004-0
02FB-8006	4.6	555	056-0	154-1(N)	004-0
02FB-8009	5.8	545	057-4	154-1(N)	004-0
02FB-8010	5.8	543	058-0	154-1(N)	004-0
02FB-8012	5.8	542	059-0	154-1(N)	004-0
02FB-8014	5.8	542	060-0	154-1(N)	004-0
02FB-8015	5.8	544	060-4	154-1(N)	004-0
02FB-8018	4.6	543	062-0	154-1(N)	004-0
02FB-8019	4.5	546	062-4	154-1(N)	004-0
02FB-8020	4.4	550	063-0	154-1(N)	004-0
02FB-8021	4.3	555	063-4	154-1(N)	004-0
02FB-8023	4.2	561	064-4	154-1(N)	004-0
02FB-8025	4.0	563	065-5	154-1(N)	004-0
02FB-8030	3.3	140	068-0	154-1(N)	004-0
02FB-8031	3.4	140	068-4	154-1(N)	004-0

Table A-3 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	*y*	*z*
02FB-8032	3.5	140	069-0	154-1(N)	004-0
02FB-8034	3.6	140	070-0	154-1(N)	004-0
02FB-8035	3.7	140	070-4	154-1(N)	004-0
02FB-8037	3.7	140	045-4	149-1(N)	004-6
02FB-8039	3.9	140	046-4	149-1(N)	004-6
02FB-8040	4.0	140	047-0	149-1(N)	004-6
02FB-8041	4.0	140	047-4	149-1(N)	004-6
02FB-8042	4.1	140	048-0	149-1(N)	004-6
02FB-8043	4.2	140	048-4	149-1(N)	004-6
02FB-8044	4.3	140	049-0	149-1(N)	004-6
02FB-8045	4.3	140	049-4	149-1(N)	004-6
02FB-8047	4.4	140	050-4	149-1(N)	004-6
02FB-8048	4.5	140	051-0	149-1(N)	004-6
02FB-8049	4.5	140	051-4	149-1(N)	004-6
02FB-8051	4.6	140	052-4	149-1(N)	004-6
02FB-8052	4.6	140	053-0	149-1(N)	004-6
02FB-8053	4.6	140	053-4	149-1(N)	004-6
02FB-8054	4.6	140	054-0	149-1(N)	004-6
02FB-8055	4.6	140	054-4	149-1(N)	004-6
02FB-8056	4.6	140	055-0	149-1(N)	004-6
02FB-8058	4.5	140	056-0	149-1(N)	004-6
02FB-8059	4.5	140	056-4	149-1(N)	004-6
02FB-8060	4.5	140	057-0	149-1(N)	004-6
02FB-8061	4.4	140	057-4	149-1(N)	004-6
02FB-8062	4.4	140	058-0	149-1(N)	004-6
02FB-8063	4.3	140	058-4	149-1(N)	004-6
02FB-8064	4.3	140	059-0	149-1(N)	004-6
02FB-8065	4.2	140	059-4	149-1(N)	004-6
02FB-8066	4.1	140	060-0	149-1(N)	004-6
02FB-8068	4.0	140	061-0	149-1(N)	004-6
02FB-8069	3.9	140	061-4	149-1(N)	004-6
02FB-8071	3.8	140	062-4	149-1(N)	004-6
02FB-8072	3.7	140	063-0	149-1(N)	004-6
02FB-8073	3.6	140	063-4	149-1(N)	004-6
02FB-8074	3.5	140	064-0	149-1(N)	004-6
02FB-8076	3.4	140	065-0	149-1(N)	004-6
02FB-8077	3.3	140	065-4	149-1(N)	004-6
02FB-8078	3.2	140	066-0	149-1(N)	004-6
02FB-8079	3.2	140	066-4	149-1(N)	004-6
02FB-8080	3.1	140	067-0	149-1(N)	004-6
02FB-8081	3.0	140	067-4	149-1(N)	004-6
Submerged-Arc Weldment, 51B, W Orientation					
51B-2022	8.6	455	012-7(N)	042-5	004-4
51B-2023	8.6	452	012-7(N)	043-1	004-4
51B-2025	8.6	450	012-7(N)	044-1	004-4
51B-2031	7.2	150	012-7(N)	047-1	004-4
51B-2032	7.2	150	012-7(N)	041-5	007-0
51B-2034	7.2	150	012-7(N)	042-5	007-0
51B-2039	12.4	548	012-7(N)	045-1	007-0
51B-2040	12.5	548	012-7(N)	045-5	007-0
Electroslag Weldment, 53E, W Orientation					
53E-2002	12.4	544	020-0(N)	004-6	001-1
53E-2007	10.4	140	020-0(N)	004-2	004-2
53E-2008	10.4	140	020-0(N)	004-6	004-6

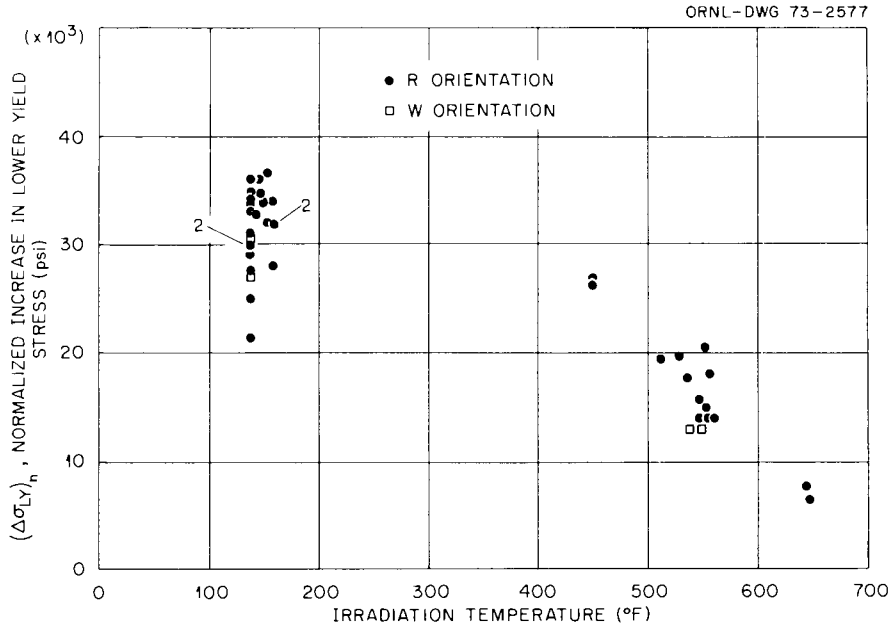

Fig. A-1. Effect of temperature of neutron irradiation on yield properties of HSST plate 01K, surface layer.

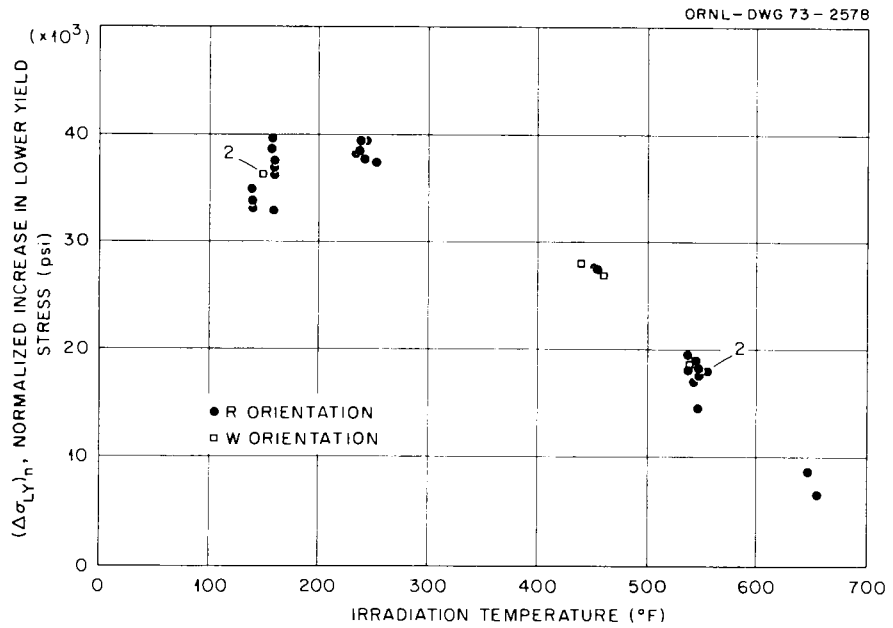

Fig. A-2. Effect of temperature of neutron irradiation on yield properties of HSST plate 01K, $\frac{1}{4}t$ layer.

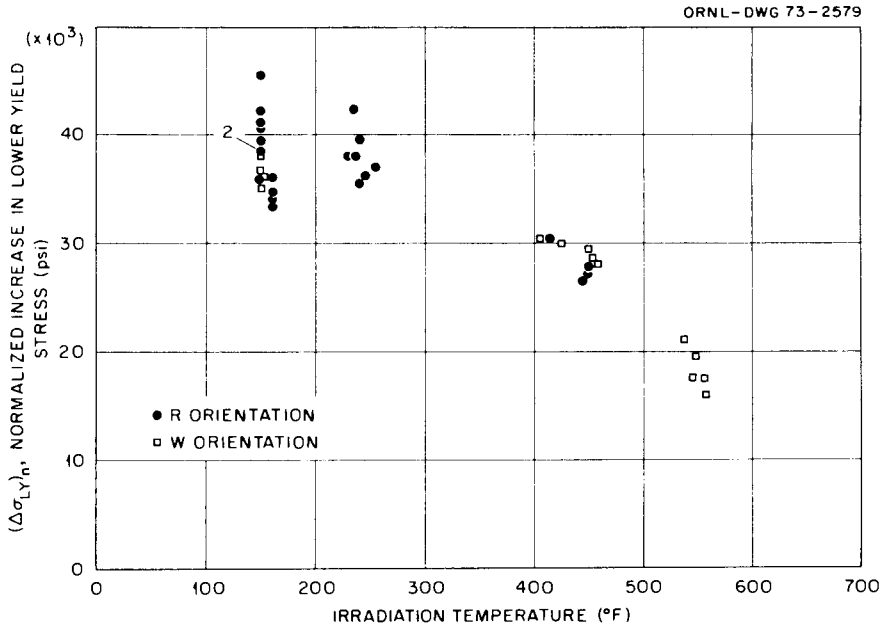

Fig. A-3. Effect of temperature of neutron irradiation on yield properties of HSST plate 01K, $^{3}/_{8}t$ layer.

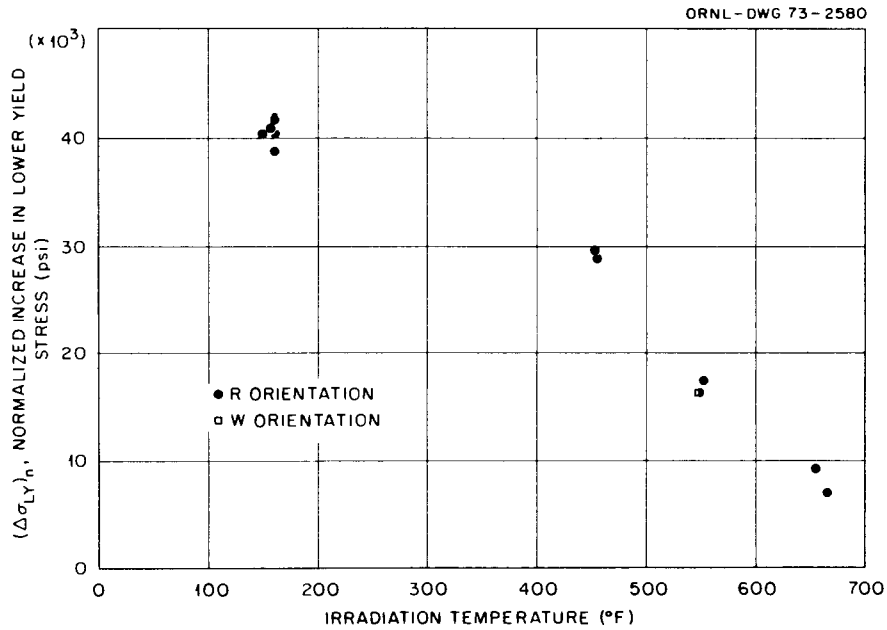

Fig. A-4. Effect of temperature of neutron irradiation on yield properties of HSST plate 01K, midthickness layer.

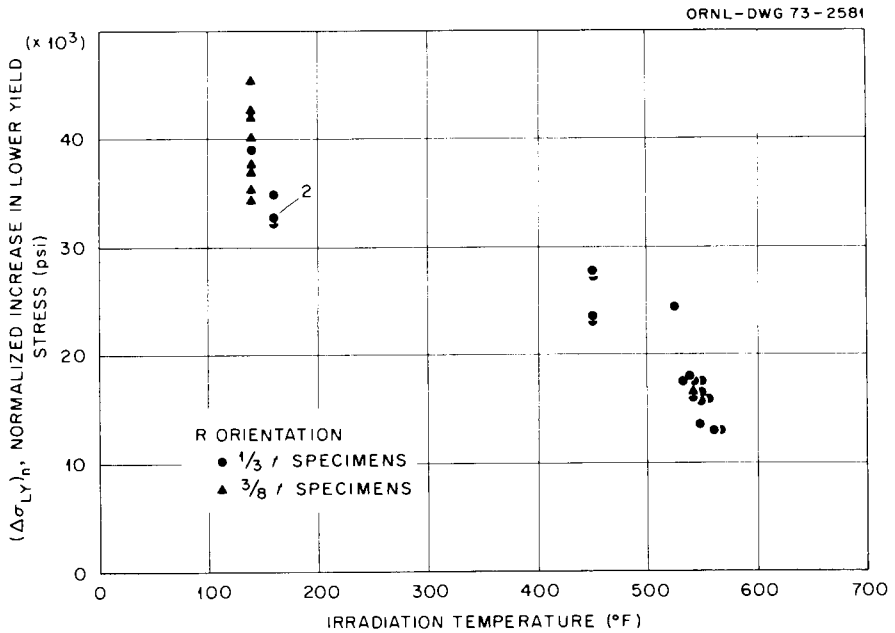

Fig. A-5. Effect of temperature of neutron irradiation on yield properties of HSST plate 02FB.

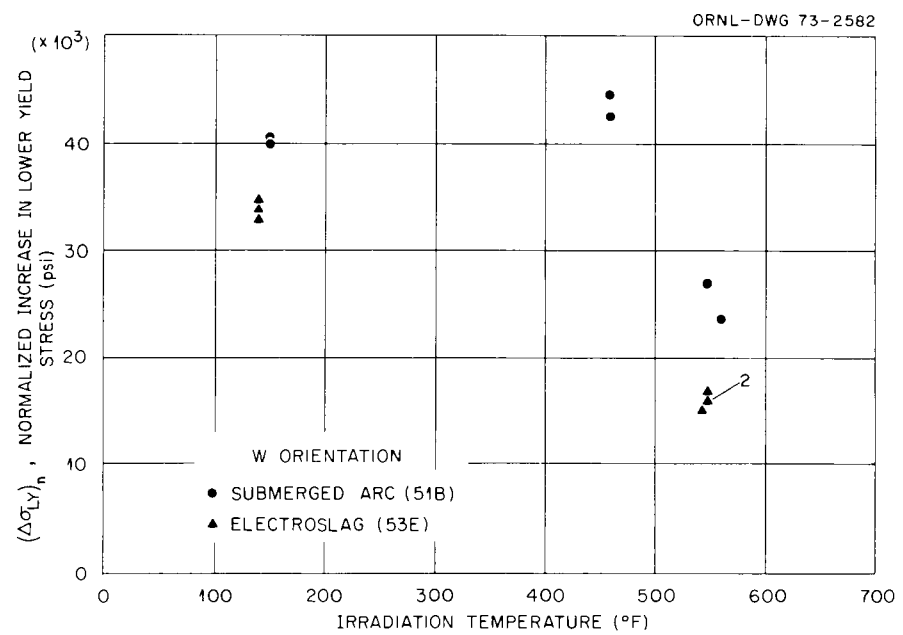

Fig. A-6. Effect of temperature of neutron irradiation on yield properties of HSST submerged-arc and electroslag weldments.

Appendix B

CHARPY V-NOTCH DATA

Table B-1. Charpy V-notch impact properties of irradiated ASTM A533, grade B, class 1 steel plate and two weldments

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				x	y	z
	$\times 10^{18}$					$\times 10^{-3}$			
			Plate Section 01K, Surface Layer, RW Orientation						
01K-7757	3.9	515	−100	14	10	9	098-6	110-3(N)	000-2
01K-7758	4.0	525	100	24	22	14	099-3	110-3(N)	000-2
01K-7759	4.1	535	−100	22	24	15	100-0	110-3(N)	000-2
01K-7760	4.2	540	−100	28	24	16	100-5	110-3(N)	000-2
01K-7761	4.3	545	32	85	100	61	101-2	110-3(N)	000-2
01K-7762	4.4	560	−100	24	18	13	101-7	110-3(N)	000-2
01K-7763	4.5	562	10	58	65	36	102-4	110-3(N)	000-2
01K-7764	4.6	560	60	35	36	21	103-1	110-3(N)	000-2
01K-7765	4.7	557	150	20	16	13	103-6	110-3(N)	000-2
01K-7766	4.8	552	150	95	100	75	104-3	110-3(N)	000-2
01K-7767	4.9	550	−200	8	3	5	105-0	110-3(N)	000-2
01K-7768	5.0	550	240	100	100	73	105-5	110-3(N)	000-2
01K-7769	5.1	550	75	91	100	67	106-2	110-3(N)	000-2
01K-7770	5.2	550	80	28	30	18	106-7	110-3(N)	000-2
01K-7772	5.8	550	450	102	100	80	108-1	110-3(N)	000-2
01K-7773	5.8	548	−175	15	8	7	108-6	110-3(N)	000-2
01K-7774	5.9	547	25	70	86	51	109-3	110-3(N)	000-2
01K-7775	5.9	450	−150	8	0	1	110-0	110-3(N)	000-2
01K-7778	5.9	450	400	90	100	75	111-7	110-3(N)	000-2
01K-7779	5.9	450	25	26	22	13	112-4	110-3(N)	000-2
01K-7780	5.7	450	−200	3	0	3	113-1	110-3(N)	000-2
01K-7793	5.7	450	−120	15	8	4	098-6	108-0(N)	000-2
01K-7794	5.6	450	200	85	100	64	099-3	108-0(N)	000-2
01K-7795	5.5	450	10	24	21	6	100-0	108-0(N)	000-2
01K-7796	5.4	450	80	53	56	23	100-5	108-0(N)	000-2
01K-7797	5.4	450	120	86	100	30	101-2	108-0(N)	000-2
01K-7798	5.3	450	−50	22	13	8	101-7	108-0(N)	000-2
01K-7799	5.2	448	32	48	48	15	102-4	108-0(N)	000-2
01K-7800	5.1	445	10	32	33	22	103-1	108-0(N)	000-2
01K-7801	5.0	438	80	22	20	14	103-6	108-0(N)	000-2
01K-7802	4.9	430	20	38	45	27	104-3	108-0(N)	000-2
01K-7803	4.8	422	0	33	33	21	105-0	108-0(N)	000-2
01K-7804	4.6	415	0	35	35	22	105-5	108-0(N)	000-2
01K-7805	4.5	407	0	35	37	23	106-2	108-0(N)	000-2
01K-7806	3.5	137	150	95	100	70	106-7	108-0(N)	000-2
01K-7807	3.6	137	70	88	100	62	107-4	108-0(N)	000-2
01K-7808	3.7	138	20	72	86	54	108-1	108-0(N)	000-2
01K-7809	3.8	139	10	78	84	53	108-6	108-0(N)	000-2
01K-7810	3.9	140	0	60	70	43	109-3	108-0(N)	000-2
01K-7811	4.0	140	−250	2	0	2	110-0	108-0(N)	000-2
01K-7812	4.1	141	160	8	5	3	110-5	108-0(N)	000-2
01K-7813	4.2	142	200	94	100	72	111-2	108-0(N)	000-2
01K-7814	4.3	143	32	79	87	56	111-7	108-0(N)	000-2
01K-7815	4.4	144	32	71	79	55	112-4	108-0(N)	000-2
01K-7816	4.5	144	−120	10	7	4	113-1	108-0(N)	000-2
01K-7829	4.6	145	−60	10	7	4	098-6	105-5(N)	000-2
01K-7830	4.7	146	0	18	16	10	099-3	105-5(N)	000-2
01K-7831	4.8	147	100	88	100	61	100-0	105-5(N)	000-2
01K-7832	11.9	648	−60	50	53	33	100-5	105-5(N)	000-2
01K-7833	11.7	647	−150	20	14	10	101-2	105-5(N)	000-2
01K-7834	11.4	645	40	111	100	70	101-7	105-5(N)	000-2
01K-7835	11.1	643	0	99	100	67	102-4	105-5(N)	000-2
01K-7836	10.9	640	−100	28	24	15	103-1	105-5(N)	000-2

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				*x*	*y*	*z*
01K-7837	10.6	637	−30	66	65	44	103-6	105-5(N)	000-2
01K-7838	10.4	632	200	100	100	72	104-3	105-5(N)	000-2
01K-7839	10.1	625	−200	3	0	1	105-0	105-5(N)	000-2
01K-7840	9.9	612	30	108	100	69	105-5	105-5(N)	000-2
01K-7841	9.6	600	−100	26	20	12	106-2	105-5(N)	000-2
01K-7842	9.4	587	−100	22	15	10	106-7	105-5(N)	000-2
01K-7843	9.1	575	100	21	12	8	107-4	105-5(N)	000-2
01K-9756	9.1	143	50	68	77	49	096-7	122-7(N)	000-2
01K-9757	9.3	143	0	37	36	21	097-3	122-7(N)	000-2
01K-9758	9.5	143	300	100	100	68	097-7	122-7(N)	000-2
01K-9759	9.7	143	200	92	100	67	098-3	122-7(N)	000-2
01K-9760	9.8	143	75	82	93	59	098-7	122-7(N)	000-2
01K-9761	10.0	143	50	12	5	4	099-3	122-7(N)	000-2
01K-9762	10.2	143	150	4	3	2	099-7	122-7(N)	000-2
01K-0763	10.3	143	98	85	95	58	100-3	122-7(N)	000-2
01K-9764	10.5	143	25	11	8	6	100-7	122-7(N)	000-2
01K-9765	10.6	143	−100	5	0	1	101-3	122-7(N)	000-2
01K-9766	10.7	143	25	54	58	36	101-7	122-7(N)	000-2
01K-9767	10.8	143	150	91	100	69	102-3	122-7(N)	000-2
01K-9768	11.7	550	−100	23	15	11	102-7	122-7(N)	000-2
01K-9769	12.0	547	275	99	100	75	103-3	122-7(N)	000-2
01K-9770	12.2	546	100	86	100	62	103-7	122-7(N)	000-2
01K-9771	12.4	545	−200	4	3	5	104-3	122-7(N)	000-2
01K-9772	12.6	550	0	41	45	28	104-7	122-7(N)	000-2
01K-9773	12.8	555	200	100	100	77	105-3	122-7(N)	000-2
01K-9774	13.0	559	−150	20	15	10	105-7	122-7(N)	000-2
01K-9775	13.2	563	350	104	100	80	106-3	122-7(N)	000-2
01K-9776	13.3	563	50	80	92	58	106-7	122-7(N)	000-2
01K-9777	13.5	562	25	66	70	44	107-3	122-7(N)	000-2
01K-9778	13.6	558	50	31	30	18	107-7	122-7(N)	000-2
01K-9779	13.7	555	−150	11	10	7	108-3	122-7(N)	000-2
				¼*t* Layer					
01K-7008	7.7	453	180	34	42	25	097-4	127-0(N)	003-0
01K-7009	7.5	454	140	17	16	9	097-4	124-5(N)	003-0
01K-7010	7.3	454	260	72	88	55	097-4	122-3(N)	003-0
01K-7011	7.2	454	260	62	86	56	097-4	120-1(N)	003-0
01K-7012	7.0	454	220	54	73	48	097-4	112-7(N)	003-0
01K-7013	6.8	454	300	86	100	70	097-4	110-5(N)	003-0
01K-7014	6.7	454	360	99	100	75	097-4	108-3(N)	003-0
01K-7015	6.5	454	420	96	100	78	097-4	106-0(N)	003-0
01K-7016	6.3	454	120	8	5	2	098-1	127-0(N)	003-0
01K-7017	6.2	455	180	45	47	28	098-1	124-5(N)	003-0
01K-7018	6.0	455	320	91	100	65	098-1	122-3(N)	003-0
01K-7019	5.8	455	50	6	5	5	098-1	120-1(N)	003-0
01K-7020	5.7	455	180	44	56	36	098-1	112-7(N)	003-0
01K-7021	5.5	453	100	18	8	9	098-1	110-5(N)	003-0
01K-7022	5.3	449	160	46	55		098-1	108-3(N)	003-0
01K-7023	5.2	442	160	30	34	19	098-1	106-0(N)	003-0
01K-7024	5.0	432	160	40	31	22	098-1	127-0(N)	003-0
01K-7025	4.8	425	160	34	28	18	098-1	124-5(N)	003-0
01K-7026	6.7	158	160	19	23	14	098-6	122-3(N)	003-0
01K-7027	6.5	158	240	83	100	62	098-6	120-1(N)	003-0
01K-7028	6.4	158	200	50	68	41	098-6	112-7(N)	003-0
01K-7029	6.2	157	180	36	50	29	098-6	110-5(N)	003-0
01K-7030	6.1	156	400	100	100	83	098-6	108-3(N)	003-0

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				*x*	*y*	*z*
01K-7031	6.0	156	120	8	0	5	098-6	106-0(N)	003-0
01K-7032	5.8	155	280	101	100	75	099-3	127-0(N)	003-0
01K-7033	5.7	154	80	6	3	2	099-3	124-5(N)	003-0
01K-7034	5.5	153	40	3	0	0	099-3	122-3(N)	003-0
01K-7035	5.4	152	0	2	0	0	099-3	120-1(N)	003-0
01K-7036	5.3	151	350	102	100	80	099-3	112-7(N)	003-0
01K-7037	5.1	150	220	82	88	67	099-3	110-5(N)	003-0
01K-7038	5.0	149	140	22	24	17	099-3	108-3(N)	003-0
01K-7039	4.8	148	300	96	100	76	099-3	106-0(N)	003-0
01K-7040	4.7	147	170	60	70	42	100-0	127-0(N)	003-0
01K-7041	4.6	146	100	5	5	2	100-0	124-5(N)	003-0
01K-7042	4.4	145	120	15	20	10	100-0	122-3(N)	003-0
01K-7043	4.3	144	180	70	82	48	100-0	120-1(N)	003-0
01K-7044	10.2	550	140	40	39	31	100-0	112-7(N)	003-0
01K-7045	10.0	553	240	88	100	74	100-0	110-5(N)	003-0
01K-7046	9.8	555	80	28	25	17	100-0	108-3(N)	003-0
01K-7047	9.6	557	180	62	59	75	100-0	106-0(N)	003-0
01K-7048	9.4	558	220	77	88	62	100-5	127-0(N)	003-0
01K-7049	9.2	560	100	30	28	13	100-5	124-5(N)	003-0
01K-7050	9.0	560	40	11	8	9	100-5	122-3(N)	003-0
01K-7051	8.7	560	320	100	100	77	100-5	120-1(N)	003-0
01K-7052	8.5	560	400	102	100	80	100-5	112-7(N)	003-0
01K-7053	8.3	558	140	47	55	37	100-5	110-5(N)	003-0
01K-7054	8.1	557	60	27	30	19	100-5	108-3(N)	003-0
01K-7055	7.9	555	20	10	10	10	100-5	106-0(N)	003-0
01K-7056	7.7	552	0	8	5	4	101-2	127-0(N)	003-0
01K-7057	7.5	550	-40	4	0	1	101-2	124-5(N)	003-0
01K-7058	7.3	550	100	37	40	25	101-2	122-3(N)	003-0
01K-7059	7.0	553	100	30	35	23	101-2	120-1(N)	003-0
01K-7060	6.8	560	100	42	47	27	101-2	112-7(N)	003-0
01K-7061	6.6	570	100	45	50	30	101-2	110-5(N)	003-0
01K-7062	13.1	660	83	72	80	48	101-2	108-3(N)	003-0
01K-7063	13.3	662	0	10	5	2	101-2	106-0(N)	003-0
01K-7064	13.4	662	130	89	90	56	101-7	127-0(N)	003-0
01K-7065	13.5	662	40	44	45	26	101-7	124-5(N)	003-0
01K-7066	13.6	660	200	133	100	80	101-7	122-3(N)	003-0
01K-7067	13.7	658	20	13	16	8	101-7	120-1(N)	003-0
01K-7068	13.7	655	400	116	100	86	101-7	112-7(N)	003-0
01K-7069	13.6	650	30	17	19	11	101-7	110-5(N)	003-0
01K-7070	13.5	648	-40	6	5	4	101-7	108-3(N)	003-0
01K-7071	13.4	648	160	94	100	65	101-7	106-0(N)	003-0
01K-7072	13.3	648	50	40		25	102-4	127-0(N)	003-0
01K-7073	13.1	650	75	58	65	39	102-4	124-5(N)	003-0
01K-7080	13.5	540	250	94	100	62	103-1	127-0(N)	003-0
01K-7081	13.4	545	50	10	10	6	103-1	124-5(N)	003-0
01K-7082	13.2	550	150	40	40	25	103-1	122-3(N)	003-0
01K-7083	13.0	552	400	101	100	73	103-1	120-1(N)	003-0
01K-7084	12.8	554	-50	3	5	4	103-1	112-7(N)	003-0
01K-7085	12.6	555	300	96	100	67	103-1	110-5(N)	003-0
01K-7086	12.4	555	350	100	100	63	103-1	108-3(N)	003-0
01K-7087	12.2	556	100	29	30	20	103-1	106-0(N)	003-0
01K-7088	11.8	553	125	40	42	23	103-6	127-0(N)	003-0
01K-7089	11.7	550	200	68	85	52	103-6	124-5(N)	003-0
01K-7090	11.4	548	175	55	50	31	103-6	122-3(N)	003-0
01K-7091	11.2	547	0	5	5	5	103-6	120-1(N)	003-0
01K-7092	10.6	143	400	108	100	71	103-6	112-7(N)	003-0

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				x	y	z
01K-7093	10.4	143	175	10	10	7	103-6	110-5(N)	003-0
01K-7094	10.3	143	50	3	0	0	103-6	108-3(N)	003-0
01K-7095	10.2	143	250	92	100	68	103-6	106-0(N)	003-0
01K-7096	10.0	143	190	45	54	32	104-3	127-0(N)	003-0
01K-7097	9.8	143	150	6	5	4	104-3	124-5(N)	003-0
01K-7098	9.6	143	350	104	100	73	104-3	122-3(N)	003-0
01K-7099	9.4	143	300	106	100	67	104-3	120-1(N)	003-0
01K-7100	9.3	143	125	5	5	1	104-3	112-7(N)	003-0
01K-7101	9.1	143	200	70	84	55	104-3	110-5(N)	003-0
01K-7102	8.9	143	75	4	3	1	104-3	108-3(N)	003-0
01K-7103	8.7	143	100	4	5	4	104-3	106-0(N)	003-0
				$\frac{1}{2}t$ Layer					
01K-7312	6.0	435	120	20	30	20	097-4	127-0(N)	006-0
01K-7313	6.1	440	120	15	20	13	097-4	124-5(N)	006-0
01K-7314	6.3	447	120	20	27	18	097-4	122-3(N)	006-0
01K-7315	6.4	452	0	4	10	8	097-4	120-1(N)	006-0
01K-7316	6.6	454	50	5	12	9	097-4	112-7(N)	006-0
01K-7317	6.7	456	340	86	100	66	097-4	110-5(N)	006-0
01K-7318	6.8	456	400	79	100	65	097-4	108-3(N)	006-0
01K-7319	7.0	456	120	13	15	10	097-4	106-0(N)	006-0
01K-7320	7.1	455	280	83	100	65	098-1	127-0(N)	006-0
01K-7321	7.3	455	160	24	32	19	098-1	124-5(N)	006-0
01K-7322	7.4	455	240	54	66	38	098-1	122-3(N)	006-0
01K-7323	7.5	455	200	34	44	35	098-1	120-1(N)	006-0
01K-7324	7.7	455	60	7	10	13	098-1	112-7(N)	006-0
01K-7325	7.8	454	260	60	75	47	098-1	110-5(N)	006-0
01K-7326	8.0	454	180	22	34	21	098-1	108-3(N)	006-0
01K-7327	8.1	454	100	10	17	12	098-1	106-0(N)	006-0
01K-7328	8.2	454	220	45	59	39	098-6	127-0(N)	006-0
01K-7329	8.4	454	150	15	18	11	098-6	124-5(N)	006-0
01K-7330	4.4	127	160	28	24	14	098-6	122-3(N)	006-0
01K-7331	4.5	129	200	77	100	64	098-6	120-1(N)	006-0
01K-7332	4.7	130	350	96	100	67	098-6	112-7(N)	006-0
01K-7333	4.8	131	280	92	100	73	098-6	110-5(N)	006-0
01K-7334	5.0	132	100	8	5	5	098-6	108-3(N)	006-0
01K-7335	5.1	133	400	91	100	67	098-6	106-0(N)	006-0
01K-7336	5.3	134	75	3	0	1	099-3	127-0(N)	006-0
01K-7337	5.4	136	120	5	5	3	099-3	124-5(N)	006-0
01K-7338	5.6	137	300	87	100	69	099-3	122-3(N)	006-0
01K-7339	5.7	138	50	3	3	4	099-3	120-1(N)	006-0
01K-7340	5.9	140	140	8	10	6	099-3	112-7(N)	006-0
01K-7341	6.1	141	160	24	29	16	099-3	110-5(N)	006-0
01K-7342	6.2	142	200	46	60	34	099-3	108-3(N)	006-0
01K-7343	6.4	143	220	66	82	54	099-3	106-0(N)	006-0
01K-7344	6.5	144	240	78	100	64	100-0	127-0(N)	006-0
01K-7345	6.7	146	280	75	100	63	100-0	124-5(N)	006-0
01K-7346	6.8	147	350	84	100	72	100-0	122-3(N)	006-0
01K-7347	7.0	148	200	23	30	9	100-0	120-1(N)	006-0
01K-7348	8.6	400	220	30	37	22	100-0	112-7(N)	006-0
01K-7349	8.7	413	160	14	12	3	100-0	110-5(N)	006-0
01K-7350	8.9	425	160	21	18	11	100-0	108-3(N)	006-0
01K-7351	9.0	437	160	11	7	1	100-0	106-0(N)	006-0
01K-7352	9.2	450	160	23	23	12	100-5	127-0(N)	006-0
01K-7353	9.4	468	160	28	25	16	100-5	124-5(N)	006-0
01K-7354	9.5	487	240	55	68	48	100-5	122-3(N)	006-0

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				x	y	z
01K-7355	9.6	510	180	26	37	22	100-5	120-1(N)	006-0
01K-7356	9.8	530	100	16	19	8	100-5	112-7(N)	006-0
01K-7357	10.0	560	260	74	97	66	100-5	110-5(N)	006-0
01K-7358	10.1	568	400	73	100	62	100-5	108-3(N)	006-0
01K-7359	10.2	568	300	84	100	71	100-5	106-0(N)	006-0
01K-7376	10.4	565	350	86	100	65	102-4	127-0(N)	006-0
01K-7377	10.6	563	250	77	100	63	102-4	124-5(N)	006-0
01K-7378	10.7	560	170	36	52	34	102-4	122-3(N)	006-0
01K-7379	10.9	557	50	10	10	12	102-4	120-1(N)	006-0
01K-7380	11.0	555	220	66	79	51	102-4	112-7(N)	006-0
01K-7381	11.2	553	140	36	40	24	102-4	110-5(N)	006-0
01K-7382	7.8	620	30	16	18	11	102-4	108-3(N)	006-0
01K-7383	8.0	630	70	34	36	22	102-4	106-0(N)	006-0
01K-7384	8.3	637	200	106	100	77	103-1	127-0(N)	006-0
01K-7385	8.6	645	300	104	100	72	103-1	124-5(N)	006-0
01K-7386	8.9	652	−40	4	5	4	103-1	122-3(N)	006-0
01K-7387	9.2	657	240	108	100	83	103-1	120-1(N)	006-0
01K-7388	9.4	660	86	37	42	27	103-1	112-7(N)	006-0
01K-7389	9.7	663	170	88	100	62	103-1	110-5(N)	006-0
01K-7390	10.0	663	50	32	35	22	103-1	108-3(N)	006-0
01K-7391	10.2	664	130	66	80	46	103-1	106-0(N)	006-0
01K-7392	10.5	665	400	112	100	75	103-6	127-0(N)	006-0
01K-7393	10.8	664	10	15	18	13	103-6	124-5(N)	006-0
Plate Section 01K, ¼t Layer, WR Orientation									
01K-5101	8.5	440	220	46	55	34	061-6(N)	108-3	003-0
01K-5102	8.4	443	50	8	5	2	064-3(N)	108-3	003-0
01K-5104	8.3	446	150	37	30	18	073-2(N)	105-3	003-0
01K-5105	8.2	450	0	2	3	2	061-6(N)	112-1	003-0
01K-5106	8.1	452	300	75	90	53	064-3(N)	112-1	003-0
01K-5107	8.0	457	180	37	40	26	070-5(N)	109-1	003-0
01K-5108	7.8	464	100	12	10	5	073-2(N)	109-1	003-0
01K-5110	7.7	471	260	73	87	53	064-3(N)	115-7	003-0
01K-5111	7.5	474	450	87	100	68	070-5(N)	112-7	003-0
01K-5112	7.4	477	130	22	25	16	073-2(N)	112-7	003-0
01K-5113	7.2	473	150	30	34	22	061-6(N)	119-7	003-0
01K-5114	7.1	472	360	85	90	54	064-3(N)	119-7	003-0
01K-5115	7.1	130	350	85	100	67	070-5(N)	116-7	003-0
01K-5118	7.0	130	180	35	40	26	061-6(N)	121-3	003-0
01K-5119	6.9	130	250	78	90	56	064-3(N)	120-5	003-0
01K-5120	6.8	130	180	28	32	20	064-3(N)	121-3	003-0
01K-5121	6.8	130	400	94	100	73	070-5(N)	122-7	003-0
01K-5122	6.7	130	150	22		15	070-5(N)	123-5	003-0
01K-5123	6.5	130	150	17	20	11	073-2(N)	122-7	003-0
01K-5124	6.4	130	100	8	8	4	073-2(N)	123-5	003-0
01K-5125	6.3	130	0	3	0	1	061-6(N)	124-3	003-0
01K-5126	6.2	130	300	35	100	66	061-6(N)	125-1	003-0
01K-5127	6.1	130	450	92	100	68	064-3(N)	124-3	003-0
01K-5128	6.0	130	200	63	73	45	064-3(N)	125-1	003-0
Plate Section 02FB, ⅓t Layer, RW Orientation									
02FB-9575	9.8	150	400	83	100	62	048-3	137-6(N)	004-1
02FB-9578	10.3	150	250	34	62	32	049-7	137-6(N)	004-1
02FB-9580	10.7	150	200	22	31	18	050-7	137-6(N)	004-1
02FB-9582	11.2	150	300	92	100	70	051-7	137-6(N)	004-1
02FB-9583	11.3	150	150	4	2	1	052-3	137-6(N)	004-1

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation		
		Irradiation	Test				*x*	*y*	*z*
02FB-9584	11.5	150	500	100	100	72	052-7	137-6(N)	004-1
02FB-9585	11.6	150	280	81	100	66	053-3	137-6(N)	004-1
02FB-9586	11.4	150	450	100	100	81	053-7	137-6(N)	004-1
02FB-9588	11.0	150	175	7	5	4	054-7	137-6(N)	004-1
02FB-9590	10.6	150	275	88	100	69	055-7	137-6(N)	004-1
02FB-9592	10.1	150	350	97	100	72	056-7	137-6(N)	004-1
02FB-9594	9.7	150	225	48	62	34	047-7	140-1(N)	004-1
02FB-9596	9.2	150	260	86	100	63	048-7	140-1(N)	004-1
02FB-9598	11.4	448	175	18	17	11	049-7	140-1(N)	004-1
02FB-9600	11.9	440	400	80	100	61	050-7	140-1(N)	004-1
02FB-9602	12.4	440	500	84	100	66	051-7	140-1(N)	004-1
02FB-9604	12.8	445	200	18	26	11	052-7	140-1(N)	004-1
02FB-9606	13.2	455	100	6	2	3	053-7	140-1(N)	004-1
02FB-9607	13.4	457	150	7	7	3	054-3	140-1(N)	004-1
02FB-9608	13.6	455	300	60	80	47	054-7	140-1(N)	004-1
02FB-9609	13.7	452	250	34	43	28	055-3	140-1(N)	004-1
02FB-9610	13.7	450	125	6	5	4	055-7	140-1(N)	004-1
02FB-9612	13.4	450	225	20	25	11	056-7	140-1(N)	004-1
02FB-9614	13.0	457	275	53	52	35	047-7	142-4(N)	004-1
02FB-9616	12.5	457	350	77	100	65	048-7	142-4(N)	004-1
02FB-9618	12.0	455	450	88	100	76	049-7	142-4(N)	004-1
02FB-9619	11.8	453	250	44	63	36	050-3	142-4(N)	004-1
02FB-9620	11.5	452	325	76	100	58	050-7	142-4(N)	004-1
02FB-9621	11.3	452	100	6	3	3	051-3	142-4(N)	004-1
02FB-9630	5.1	543	80	19	20	17	055-7	142-4(N)	004-1
02FB-9631	5.3	547	100	30	32	22	056-3	142-4(N)	004-1
02FB-9633	4.8	550	0	8	7	8	044-7	149-1(N)	004-0
02FB-9634	4.9	547	450	119	100	77	045-3	149-1(N)	004-0
02FB-9635	5.0	544	40	12	8	6	045-7	149-1(N)	004-0
02FB-9637	5.2	543	500	107	100	70	046-7	149-1(N)	004-0
02FB-9638	5.3	543	240	100	100	66	047-3	149-1(N)	004-0
02FB-9640	5.4	552	120	45	35	25	048-3	149-1(N)	004-0
02FB-9641	5.5	552	−60	2	0	0	048-7	149-1(N)	004-0
02FB-9642	5.6	552	360	106	100	68	049-3	149-1(N)	004-0
02FB-9643	5.6	552	500	98	100	68	049-7	149-1(N)	004-0
02FB-9644	5.7	552	180	77	75	55	050-3	149-1(N)	004-0
02FB-9649	5.4	549	120	45	36	30	052-7	149-1(N)	004-0
02FB-9653	5.1	550	80	31	23	20	054-7	149-1(N)	004-0
Submerged-Arc Weldment, 51B, $^5/_{12}t$ Layer, WL Orientation									
51B-1278	7.2	453	175	26	32	17	012-7(N)	041-4	005-1
51B-1279	7.4	453	200	29	46	22	012-7(N)	042-0	005-1
51B-1280	7.5	453	450	72	100	59	012-7(N)	042-4	005-1
51B-1281	7.6	453	150	12	25	10	012-7(N)	043-0	005-1
51B-1282	7.8	454	350	70	100	53	012-7(N)	043-4	005-1
51B-1283	7.9	455	400	70	100	55	012-7(N)	044-0	005-1
51B-1284	8.0	457	30	4	2	2	012-7(N)	044-4	005-1
51B-1285	8.1	459	250	51	72	44	012-7(N)	045-0	005-1
51B-1286	8.2	461	500	78	100	57	012-7(N)	045-4	005-1
51B-1287	8.3	463	300	62	99	48	012-7(N)	046-0	005-1
51B-1288	8.4	462	100	6	2	2	012-7(N)	046-4	005-1
51B-1289	8.5	460	200	30	39	20	012-7(N)	047-0	005-1

Table B-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F) Irradiation	Temperatures (°F) Test	Energy (ft-lb)	Fracture appearance (% fibrous)	Lateral expansion (in.)	Specimen location (in.) and orientation x	y	z
				$\frac{1}{2}t$ Layer					
51B-1291	5.9	130	200	91	100	72	012-7(N)	042-0	005-6
51B-1292	6.0	130	300	109	100	76	012-7(N)	042-4	005-6
51B-1294	6.2	130	100	27	37	17	012-7(N)	043-4	005-6
51B-1295	6.3	130	400	100	100	80	012-7(N)	044-0	005-6
51B-1296	6.4	130	150	32	55	26	012-7(N)	044-4	005-6
51B-1298	10.8	547	225	58	90	46	012-7(N)	045-4	005-6
51B-1299	11.1	549	200	50	72	39	012-7(N)	046-0	005-6
51B-1300	6.5	130	500	112	100	76	012-7(N)	046-4	005-6
51B-1301	6.6	130	80	12	10	7	012-7(N)	047-0	005-6
51B-1302	6.7	130	130	27	43	21	012-7(N)	041-4	006-3
51B-1303	6.8	130	180	56	87	51	012-7(N)	042-0	006-3
51B-1304	11.3	555	125	28	40	21	012-7(N)	042-4	006-3
51B-1305	6.9	130	30	4	5	2	012-7(N)	043-0	006-3
51B-1306	7.0	130	125	27	42	19	012-7(N)	043-4	006-3
51B-1307	7.1	130	250	90	100	72	012-7(N)	044-0	006-3
51B-1308	11.4	561	300	80	100	65	012-7(N)	044-4	006-3
51B-1309	11.6	567	250	71	100	57	012-7(N)	045-0	006-3
51B-1310	11.8	570	400	76	100	63	012-7(N)	045-4	006-3
51B-1311	11.9	573	150	48	70	40	012-7(N)	046-0	006-3
51B-1312	12.1	573	500	72	100	70	012-7(N)	046-4	006-3
51B-1313	12.2	573	50	16	27	15	012-7(N)	047-0	006-3
				Electroslag Weldment, 53E, $\frac{1}{8}t$ Layer, WL Orientation					
53E-1000	12.2	547	−25	7	5	4	020-0(N)	007-6	001-1
53E-1001	12.0	548	300	82	100	68	020-0(N)	008-2	001-1
53E-1002	11.8	552	25	22	25	15	020-0(N)	008-6	001-1
53E-1003	11.7	554	103	53	60	39	020-0(N)	009-2	001-1
53E-1004	11.5	558	50	28	28	17	020-0(N)	009-6	001-1
53E-1005	11.4	560	150	69	87	56	020-0(N)	010-2	001-1
53E-1006	11.2	562	200	78	100	61	020-0(N)	010-6	001-1
				$\frac{1}{4}t$ Layer					
53E-1007	11.0	563	75	34	49	26	020-0(N)	007-6	001-7
53E-1008	10.8	563	400	84	100	63	020-0(N)	008-2	001-7
53E-1009	10.6	563	−50	5	12	7	020-0(N)	008-6	001-7
53E-1010	10.4	558	125	70	78	49	020-0(N)	009-2	001-7
53E-1011	10.2	553	0	24	30	21	020-0(N)	009-6	001-7
53E-1012	10.3	130	175	70	100	56	020-0(N)	010-2	001-7
53E-1013	10.2	130	250	69	100	59	020-0(N)	010-6	001-7
				$\frac{5}{8}t$ Layer					
53E-1014	10.0	130	75	6	5	3	020-0(N)	007-6	004-2
53E-1015	9.9	130	50	4	2	3	020-0(N)	008-2	004-2
53E-1020	9.7	130	350	67	100	65	020-0(N)	010-6	004-2
				$\frac{3}{4}t$ Layer					
53E-1021	9.6	130	150	23	34	18	020-0(N)	007-6	005-0
53E-1022	9.5	130	125	40	21	14	020-0(N)	008-2	005-0
53E-1023	9.3	130	300	64	100	63	020-0(N)	008-6	005-0
53E-1024	9.1	130	125	22	24	13	020-0(N)	009-2	005-0
53E-1025	9.0	130	100	18	15	9	020-0(N)	009-6	005-0
53E-1026	8.8	130	175	55	88	50	020-0(N)	010-2	005-0
53E-1027	8.6	130	200	49	85	46	020-0(N)	010-6	005-0

Table B-2. Untested irradiated Charpy V-notch specimens

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Irradiation temperature (°F)	Specimen location (in.) and orientation		
			x	*y*	*z*
	$\times 10^{18}$				
Plate Section 01K, $\frac{1}{4}t$ Layer, RW Orientation					
01K-7104	8.6	130	105-0	127-0(N)	003-0
01K-7105	8.8	130	105-0	124-5(N)	003-0
01K-7106	8.9	130	105-0	122-3(N)	003-0
01K-7107	9.1	130	105-0	120-1(N)	003-0
01K-7108	9.3	130	105-0	112-7(N)	003-0
01K-7109	9.4	130	105-0	110-5(N)	003-0
01K-7110	9.6	130	105-0	108-3(N)	003-0
01K-7111	9.7	130	105-0	106-0(N)	003-0
01K-7112	9.9	130	105-5	127-0(N)	003-0
01K-7113	10.0	130	105-5	124-5(N)	003-0
01K-7114	10.1	130	105-5	122-3(N)	003-0
01K-7115	10.2	130	105-5	120-1(N)	003-0
Plate Section 02FB, $\frac{3}{8}t$ Layer, RW Orientation					
02FB-9573	9.3	150	047-3	137-6(N)	004-1
02FB-9574	9.5	150	047-7	137-6(N)	004-1
02FB-9577	10.1	150	049-3	137-6(N)	004-1
02FB-9579	10.5	150	050-3	137-6(N)	004-1
02FB-9581	11.0	150	051-3	137-6(N)	004-1
02FB-9587	11.2	150	054-3	137-6(N)	004-1
02FB-9589	10.8	150	055-3	137-6(N)	004-1
02FB-9591	10.3	150	056-3	137-6(N)	004-1
02FB-9593	9.9	150	047-3	140-1(N)	004-1
02FB-9595	9.4	150	048-3	140-1(N)	004-1
02FB-9597	8.9	150	049-3	140-1(N)	004-1
02FB-9599	11.6	443	050-3	140-1(N)	004-1
02FB-9601	12.2	438	051-3	140-1(N)	004-1
02FB-9603	12.6	442	052-3	140-1(N)	004-1
02FB-9605	13.0	448	053-3	140-1(N)	004-1
02FB-9611	13.6	450	056-3	140-1(N)	004-1
02FB-9613	13.3	453	047-3	142-4(N)	004-1
02FB-9615	12.7	458	048-3	142-4(N)	004-1
02FB-9617	12.3	457	049-3	142-4(N)	004-1
02FB-9632	5.6	547	056-7	142-4(N)	004-1
02FB-9645	5.7	547	050-7	149-1(N)	004-0
02FB-9646	5.6	547	051-3	149-1(N)	004-0
02FB-9648	5.5	548	052-3	149-1(N)	004-0
02FB-9650	5.3	552	053-3	149-1(N)	004-0
02FB-9651	5.2	555	053-7	149-1(N)	004-0
02FB-9652	5.2	553	054-3	149-1(N)	004-0
02FB-9654	5.0	547	055-3	149-1(N)	004-0
02FB-9655	4.9	542	055-7	149-1(N)	004-0
02FB-9656	4.8	542	056-3	149-1(N)	004-0

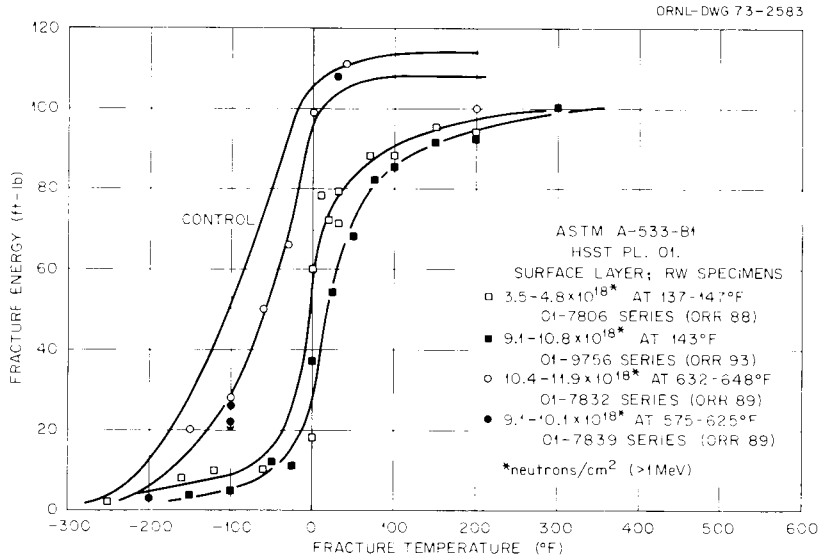

Fig. B-1. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, surface layer.

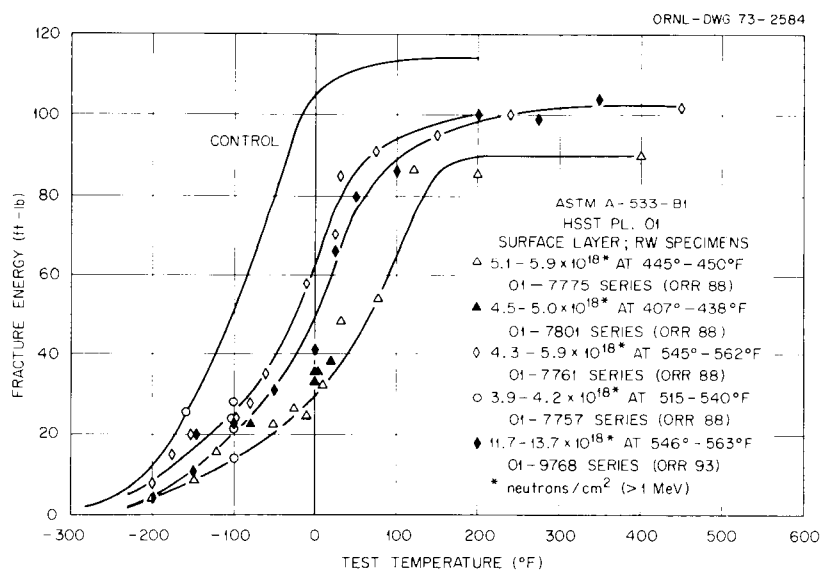

Fig. B-2. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, surface layer.

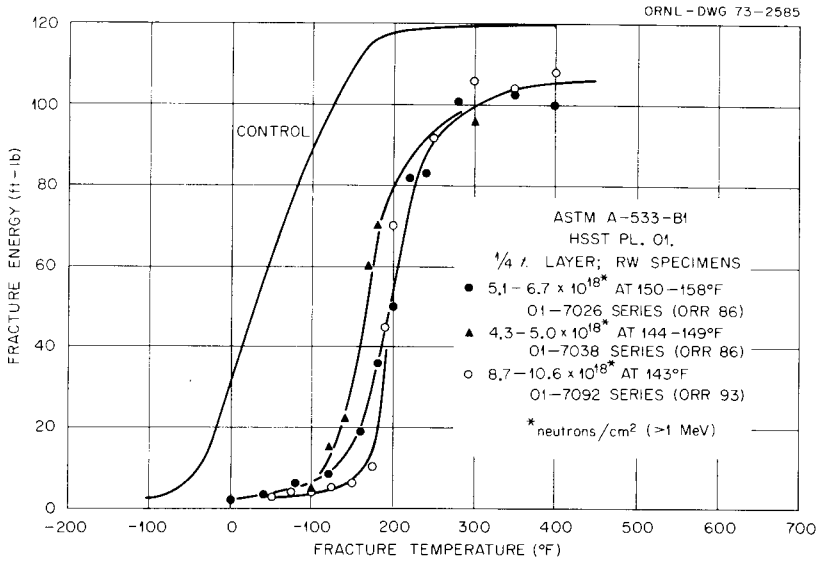

Fig. B-3. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, ¼ *t* layer.

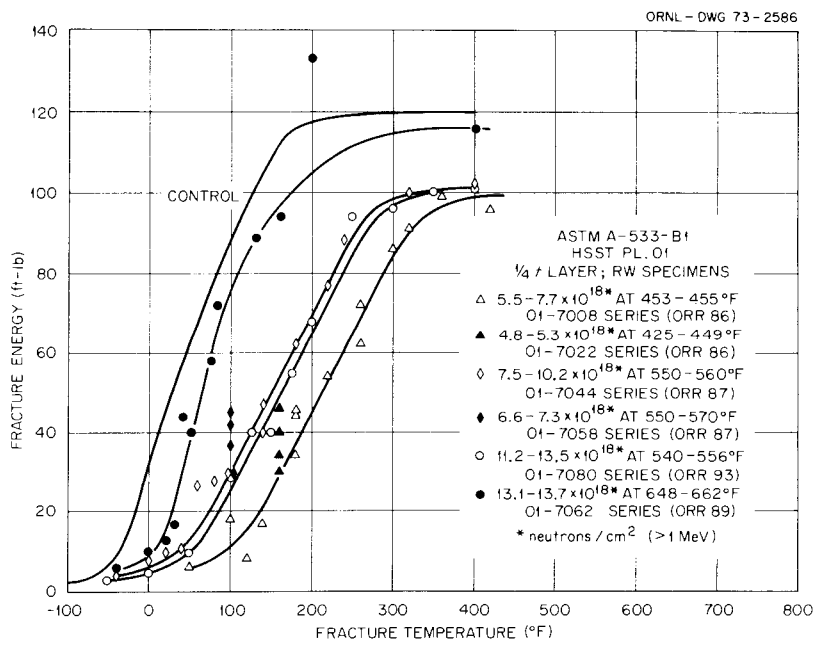

Fig. B-4. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, ¼ *t* layer.

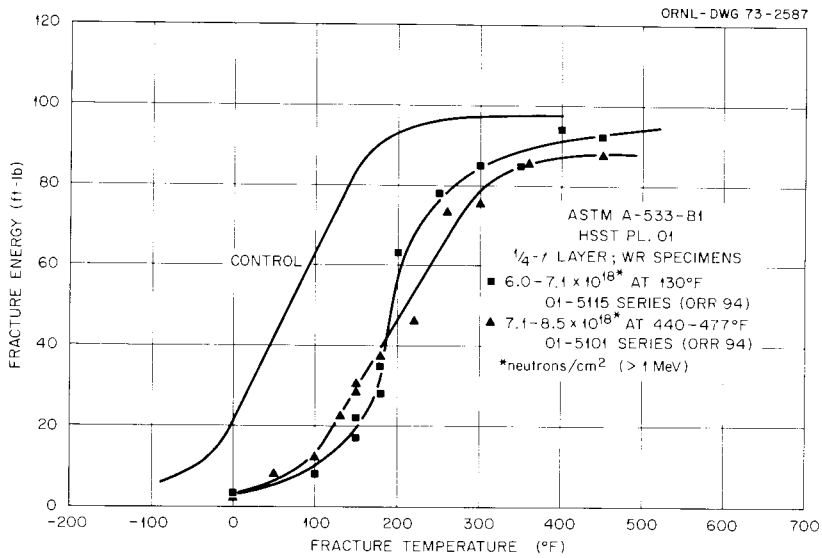

Fig. B-5. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, $\frac{1}{4}t$ layer.

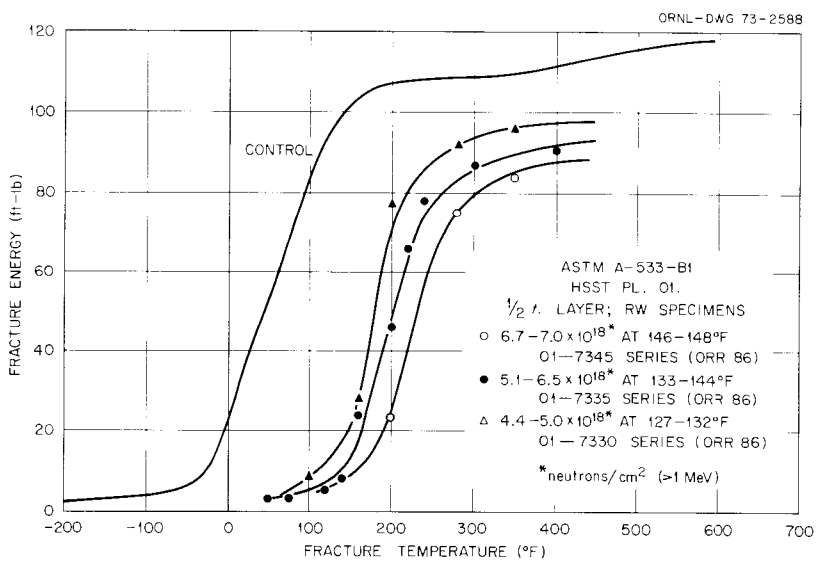

Fig. B-6. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, midthickness layer.

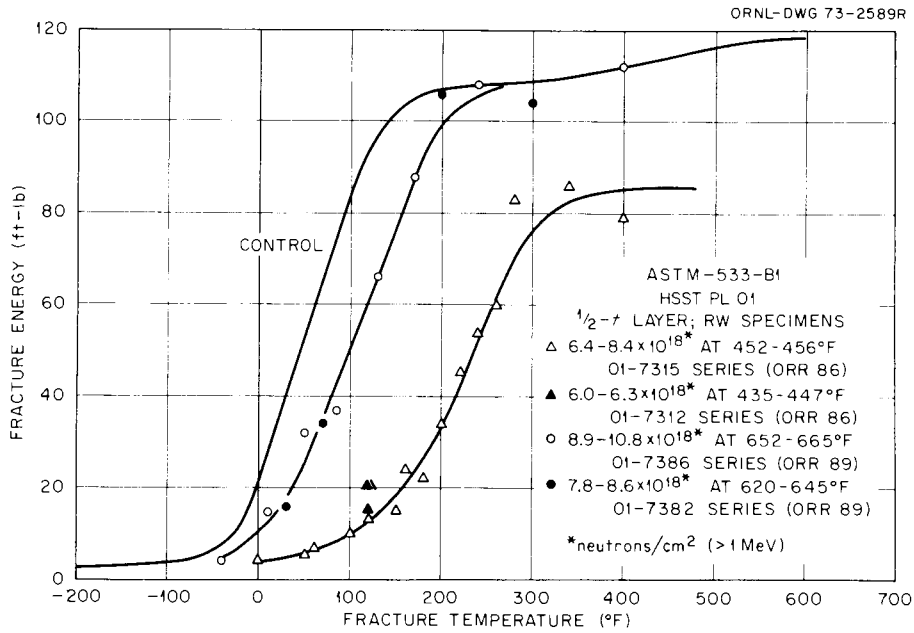

Fig. B-7. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, midthickness layer.

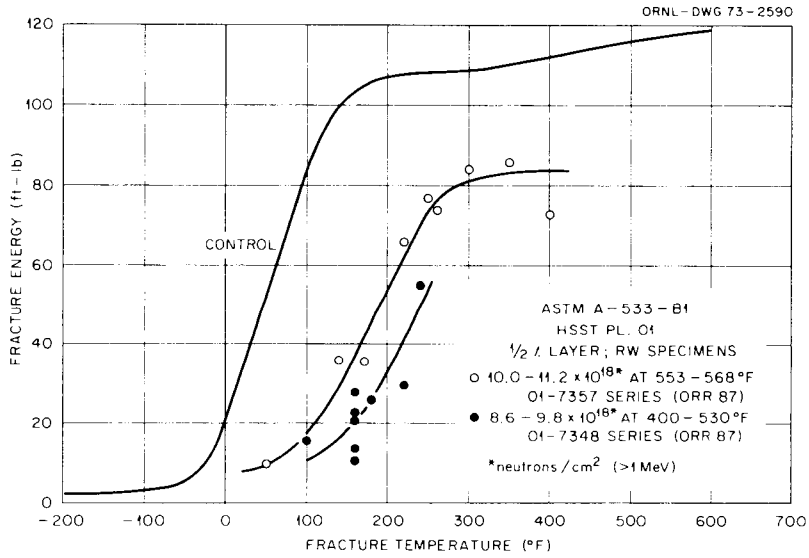

Fig. B-8. Effect of neutron irradiation on notch-impact behavior of HSST plate section 01K, midthickness layer.

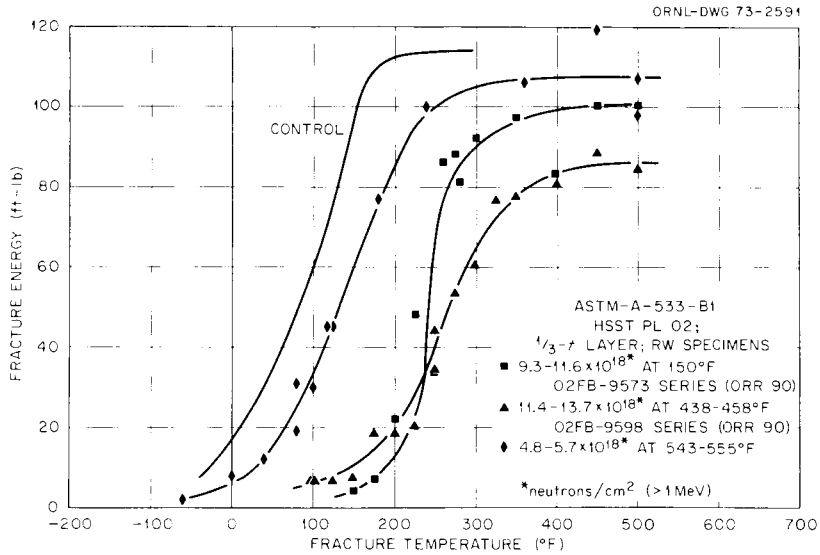

Fig. B-9. Effect of neutron irradiation on notch-impact behavior of HSST plate section 02FB, $^1/_3 t$ layer.

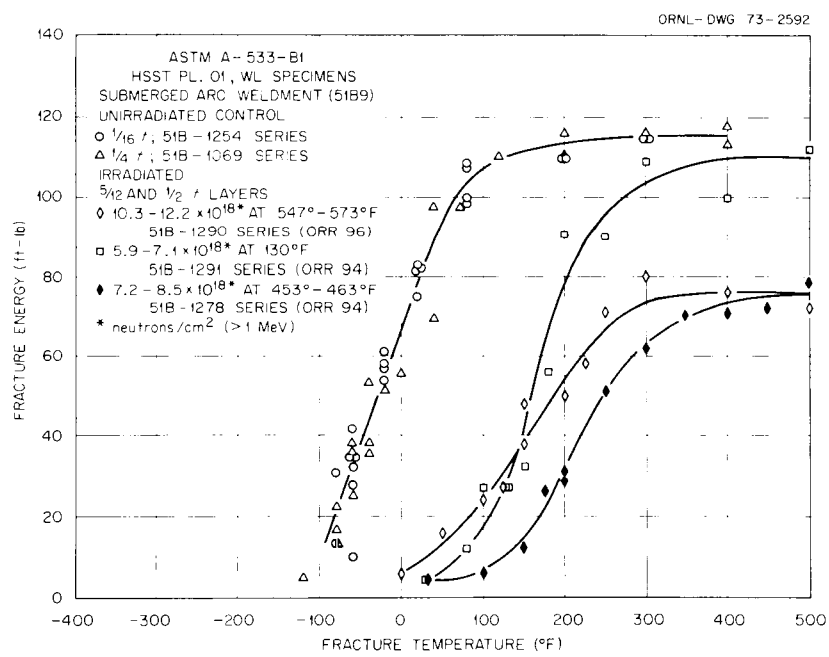

Fig. B-10. Effect of neutron irradiation on notch-impact behavior of HSST submerged-arc weldment section 51B.

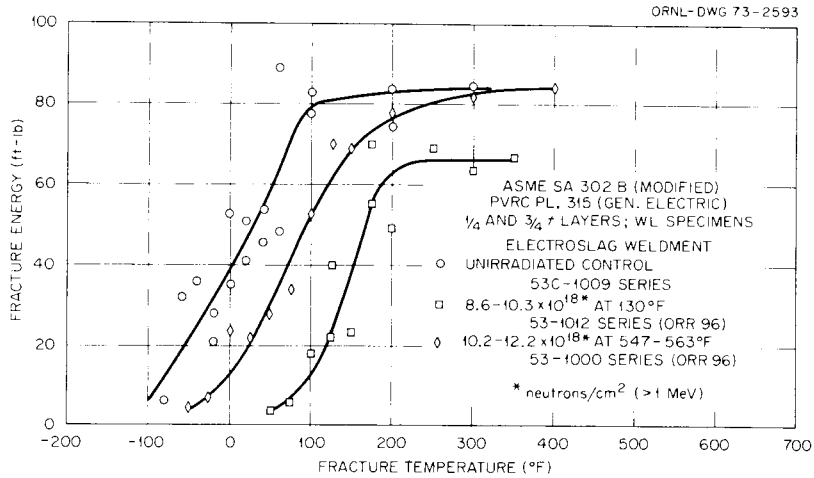

Fig. B-11. Effect of neutron irradiation on notch-impact behavior of HSST electroslag weldment section 53E.

Appendix C

INSTRUMENTED CHARPY DATA

Table C-1. Instrumented Charpy striker impact properties of irradiated ASTM A533, grade B, class 1 steel plate and two weldments

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Loads (lb)				Energies (ft-lb)		
		Irradiation	Test	General yield	Fracture initiation	Fracture arrest	Maximum	Pre-fracture initiation	Pre-maximum load	Total
	$\times 10^{18}$									
Plate Section 01K, ¼t Layer, RW Orientation										
01K-7026	6.7	158	160	3825	4075	250				19
01K-7027	6.5	158	240	3750	3000	2250	4300			83
01K-7028	6.4	158	200	3750	4400	2025				50
01K-7029	6.2	157	180	3825	4250	1500				36
01K-7030	6.1	156	400	3175			3825			100
01K-7031	6.0	156	120		3750	0				8
01K-7032	5.8	155	280	3575			4250			101
01K-7011	7.2	454	260	3425	4400	2850				62
01K-7012	7.0	454	220	3500	4400	2375				54
01K-7013	6.8	454	300	3250			4300			86
01K-7014	6.7	454	360	3250			4475			99
01K-7015	6.5	454	420	3075			4300			96
01K-7045	10.0	553	240	3075			4250			88
01K-7046	9.8	555	80	3575	4300	0				28
01K-7047	9.6	557	180	3175	4250	2500	4300			62
01K-7048	9.4	558	220	3075	3825	2500	4300			77
01K-7049	9.2	560	100	3500	4300	650				30
01K-7050	9.0	560	40	3575	3750	0				11
01K-7051	8.7	560	320	3075			4300			100
01K-7052	8.5	560	400	2950			4250			102
01K-7062	13.1	660	83	3075	4575	2025	4625			72
01K-7063	13.3	662	0		3550	375				10
01K-7064	13.4	662	130	3075	4400	2600	4575			89
01K-7065	13.5	662	40	3325	4800	375				44
01K-7066	13.6	660	200	2950			4475			133
01K-7067	13.7	658	20	3425	3425	300				13
01K-7068	13.7	655	400	2600			3900			116
01K-7069	13.6	650	30	3250	3575	475				17
½t Layer										
01K-7340	5.9	140	140		3825	0				8
01K-7341	6.1	141	160	3750	4250	475				24
01K-7342	6.2	142	200	3750	4300	1850				46
01K-7343	6.4	143	220	3650	3650	2100	4150			66
01K-7344	6.5	144	240	3575	2500	1775	4150			78
01K-7345	6.7	146	280	3500			3825			75
01K-7346	6.8	147	350	3250			3825			84
01K-7347	7.0	148	200	3500	3650	875				23
01K-7317	6.7	456	340	3175			4300			86
01K-7318	6.8	456	400	3175			4150			79
01K-7319	7.0	456	120	3575	3650	475				13
01K-7320	7.1	455	280	3250			4250			83
01K-7322	7.4	455	240	3425	4075	1950	4300			54
01K-7323	7.5	455	200	3500	4250	1400				34
01K-7348	8.6	400	220	3675	4225	1200				30
01K-7354	9.5	487	240	3250	4150	2050				55
01K-7355	9.6	510	180	3325	3825	1125				26
01K-7356	9.8	530	100	3575	3900	200				16
01K-7357	10.0	560	260	3100			4075			74
01K-7380	11.0	555	220	3150	4075	2925	4300			66
01K-7381	11.2	553	140	3325	4150	1050				36

Table C-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Loads (lb)				Energies (ft-lb)		
		Irradiation	Test	General yield	Fracture initiation	Fracture arrest	Maximum	Pre-fracture initiation	Pre-maximum load	Total
01K-7386	8.9	652	-40		2525	0				4
01K-7387	9.2	657	240	2750			4150			108
01K-7388	9.4	660	86	3250	4200	1350				37
01K-7389	9.7	663	170	3000			4400			88
01K-7390	10.0	663	50	3425	4300	650				32
01K-7391	10.2	664	130	3250	4475	2925				66
01K-7392	10.5	665	400	2775			4075			112
01K-7393	10.8	664	10	3500	3650	300				15
Plate Section 02FB, $^1/_3t$ Layer, RW Orientation										
02FB-9575	9.8	150	400	3370			3900			83
02FB-9578	10.3	150	250		3900	2150				34
02FB-9580	10.7	150	200	4140	4280	720				22
02FB-9582	11.2	150	300	3820			4230			92
02FB-9583	11.3	150	150		1660	0				4
02FB-9584	11.5	150	500	3070			3770			100
02FB-9585	11.6	150	280	3970	2430	1860	4310			81
02FB-9586	11.4	150	450	3170			4140			100
02FB-9588	11.0	150	175		3250	0				7
02FB-9590	10.6	150	275	3900			4300			88
02FB-9592	10.1	150	350	3670			4140			97
02FB-9594	9.7	150	225	4140	4480	1980				48
02FB-9596	9.2	150	260	3750	3250	2430	4230			86
02FB-9598	11.4	448	175	3840	4170	480		12.3		18
02FB-9602	12.4	440	500	3300			4370		33.8	84
02FB-9606	13.2	455	100		3270	0		2.9		6
02FB-9609	13.7	452	250	3600	4420	1380		23.4		34
02FB-9610	13.7	450	125		3460	0		2.9		6
02FB-9612	13.4	450	225	3600	4090	810		11.6		20
02FB-9614	13.0	457	275	3510	4530	2480	4690	37.0	31.6	53
02FB-9616	12.5	457	350	3430			4420		26.0	77
02FB-9618	12.0	455	450	3270			4450		31.2	88
02FB-9619	11.8	453	250	3460	4530	2280		28.5		44
02FB-9620	11.5	452	325	3430			4530		30.9	76
02FB-9621	11.3	452	100		3510	0		2.9		6
02FB-9630	5.1	543	80	3680	4090	480		10.9		19
02FB-9631	5.3	547	100	3680	4500	930		21.6		30
02FB-9633	4.8	550	0		3840	0		4.6		8
02FB-9634	4.9	547	450	2860			4170		37.8	119
02FB-9635	5.0	544	40	3840	3970	0		8.2		12
02FB-9638	5.3	543	240	3100			4500		37.0	100
02FB-9640	5.4	552	120	3510	4740	1460		32.0		45
02FB-9642	5.6	552	360	2530			4010		39.0	106
02FB-9643	5.6	552	500	2780			4090		32.2	98
02FB-9644	5.7	552	180	3200	4170	2370	4500	56.9	36.6	77
02FB-9649	5.4	549	120	3510	4830	890		37.1		45
02FB-9653	5.1	550	80	3600	4580	400		25.3		31

Table C-1 (continued)

Specimen	Fluence (>1 MeV) (neutrons/cm^2)	Temperatures (°F)		Loads (lb)				Energies (ft-lb)		
		Irradiation	Test	General yield	Fracture initiation	Fracture arrest	Maximum	Pre-fracture initiation	Pre-maximum load	Total
Submerged-Arc Weldment, 51B, ½*t* Layer, WL Orientation										
51B-1298	10.8	547	225	3460	4300	3100	4370	38.3	33.3	58
51B-1299	11.1	549	200	3510	4530	2370		33.3		50
51B-1304	11.3	555	125	3710	4420	920		20.1		28
51B-1308	11.4	561	300	3300			4420		34.6	80
51B-1309	11.6	567	250	3350	4170	3350	4420		34.6	71
51B-1310	11.8	570	400	3050			4090		33.6	76
51B-1311	11.9	573	150	3550	4530	2530		34.2		48
51B-1312	12.1	573	500	2890			3840		32.2	72
51B-1313	12.2	573	50	3840	4090	400		10.9		16

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