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Irradiation Effects on Charpy Impact and Tensile Properties of Low Upper-Shelf Welds, HSSI Series 2 and 3

Prepared by
R. K. Nanstad, R. G. Berggren

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Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: June 1991
Date Published: August 1991

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Oak Ridge, TN 37831-6285

Prepared for
Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN L1098
Under Contract No. DE-AC05-84OR21400

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FOREWORD

The work reported here was performed at Oak Ridge National Laboratory (ORNL) under the Heavy-Section Steel Irradiation (HSSI) Program, W. R. Corwin, Program Manager. The program is sponsored by the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission (NRC). The technical monitor for the NRC is A. Taboada.

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IRRADIATION EFFECTS ON CHARPY IMPACT AND TENSILE PROPERTIES OF LOW UPPER-SHELF WELDS, HSSI SERIES 2 AND 3*

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ABSTRACT

When reactor pressure vessel steels exhibit Charpy V-notch impact upper-shelf energy levels of less than 68 J (50 ft-lb), the requirements of *Title 10, Code of Federal Regulations, Part 50*, Appendix G, are not met. The regulations require, as an option, that a fracture mechanics analysis be performed that conservatively demonstrates adequate safety margins for continued operation. Under conditions where large prefracture crack-tip plastic zones are present, linear-elastic fracture mechanics concepts are not applicable, and the use of elastic-plastic fracture mechanics concepts has been recommended by the U.S. Nuclear Regulatory Commission. A number of Babcock and Wilcox Company-fabricated reactor vessels in commercial pressurized water reactor plants include welds with both relatively low initial Charpy upper-shelf energies and high copper concentrations, which make them highly sensitive to neutron irradiation. As a result, the Charpy upper-shelf energies of many welds are expected to fall below 68 J (50 ft-lb) prior to reaching design life.

The Heavy-Section Steel Irradiation Program conducted the Second and Third Irradiation Series to investigate the effects of irradiation on the ductile fracture toughness of seven commercially fabricated, low upper-shelf welds. All seven submerged-arc welds were fabricated with copper-coated wire and Linde 80 flux and have average bulk copper contents ranging from 0.21 to 0.42% with nickel levels of about 0.6%. The preirradiation upper-shelf energies range from 74 to 111 J (55 to 82 ft-lb). Compact specimens up to 101.6-mm (4-in.) thick, 4TC(T), were irradiated at nominally 288°C in the Bulk Shielding Reactor at Oak Ridge National Laboratory to fluences ranging from about 4 to 12×10^{18} neutrons/cm^2 (>1 MeV). Charpy V-notch and tensile specimens were included in the capsules at available locations

*Research sponsored by the Office of Nuclear Regulatory Research, Division of Engineering, U.S. Nuclear Regulatory Commission under Interagency Agreement DOE 1886-8109-8L with the U.S. Department of Energy under Contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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which were subject to wide variations in irradiation temperature and fluence. This report presents analyses of the Charpy impact and tensile test data, including adjustments for irradiation temperature and fluence normalization, which make possible comparison of the irradiation sensitivity of the different welds. Analyses revealed a dependence of yield and ultimate strength on irradiation temperature of -1.1 and -0.8 MPa/°C, respectively. Similarly, the Charpy impact energy changes due to irradiation temperature were -0.5°C/°C for transition temperature shift and -0.06 J/°C for the upper-shelf energy decrease. After adjustment to an irradiation temperature of 288°C and normalization to a fluence of 8×10^{18} neutrons/cm^2, percentage increases in yield strength due to irradiation ranged from about 21 to 35%, while those for ultimate strength ranged from about 13 to 20%. The Charpy transition temperature shifts ranged from 59 to 123°C, while the postirradiation upper-shelf energies ranged from 58 to 79 J.

1. INTRODUCTION

Prevention of reactor pressure vessel (RPV) failure in light-water-moderated nuclear power reactors depends primarily on maintaining the RPV material fracture toughness at levels that will resist fracture, either brittle or ductile, during plant operation (including normal and emergency conditions). At startup and at operating conditions typical of currently operating nuclear plants, RPV fracture toughness properties provide adequate margins of safety against vessel failure. However, as plants accumulate service time, neutron radiation may reduce material fracture toughness and safety margins.

Results from RPV surveillance and test reactor irradiation programs indicate some operating pressurized-water reactors (PWRs) will have beltline materials (primarily weld metals) with Charpy V-notch (CVN) impact upper-shelf energy levels of less than 68 J (50 ft-lb) before the end of their design life. When RPV steels exhibit CVN upper-shelf energy levels of less than 68 J, the requirements of *Title 10, Code of Federal Regulations, Part 50* (10CFR50),[1] Appendix G, are not met. The regulations require, as an option, that a fracture mechanics analysis be performed that conservatively demonstrates adequate safety margins for continued operation. Linear-Elastic Fracture Mechanics (LEFM) is not applicable because of the large prefracture crack-tip plastic zones observed in RPV steels at upper-shelf temperatures. Therefore, RPV safety should be evaluated by comparing some measure of fracture resistance to a structural parameter, both being based on elastic-plastic fracture mechanics concepts. An acceptable method of analysis is described in the report[2] covering Generic Safety Issue A-11 on Reactor Vessel Materials Toughness. In resolving this issue, the U.S. Nuclear Regulatory Commission (NRC) has suggested that, under elastic-plastic conditions, the vessel be evaluated in terms of the tearing instability concept of

Paris et al.[3] These and other fracture mechanics concepts are being determined through intermediate-scale vessel tests under the Heavy-Section Steel Technology (HSST) Program. Merkle has recently provided an overview of the safety margin issue associated with the low upper-shelf toughness materials in RPVS.[4]

In recognizing the possibility of ductile fracture and the accompanying need for elastic-plastic fracture properties of irradiated RPV materials, R. R. Maccary of the NRC Office of Nuclear Reactor Regulation, requested in September 1975 that irradiation studies be conducted on the elastic-plastic fracture properties of early vintage nuclear pressure vessel welds. A portion of his request is excerpted below:

> "...we have recently reviewed the results of tests on samples from several reactor vessel radiation surveillance programs. These results indicate that weld metal representing the common practice prior to 1972 is more sensitive to radiation than the plate and forgings used. This is particularly evident in the Charpy V-notch upper-shelf values."
>
> "...because the recent results from surveillance programs indicate that the weld metal will be most limiting to reactor vessel operation, it is imperative that we develop fracture mechanics technology applicable to these early vintage welds as soon as possible..."

A portion of the HSST Program response to this request was the Second and Third HSSI Irradiation Series. This report presents results from these irradiation experiments with seven "low upper-shelf" weld metals and incorporated tensile and CVN impact tests.

The studies reported here are a part of an ongoing irradiation effects program[6] summarized below. In 1989, the HSST Program irradiation task was organized into a separate Heavy-Section Steel Irradiation (HSSI) Program, and all the irradiation series are now referred to as HSSI Program Series, e.g., HSSI Program Irradiation Series 2 and 3.

2. SUMMARY OF HSSI PROGRAM IRRADIATION SERIES

In 1972, the HSST Program began the first irradiation series in response to the need for information regarding the effects of neutron irradiation on the mechanical properties, particularly fracture toughness, of light-water nuclear RPV steels. Much research had already been performed in the area of LEFM for unirradiated materials, and, for these conditions, the effects of specimen size and temperature were known.

The Welding Research Council (WRC) published *WRC Bulletin 175* in August 1972 and established a reference stress intensity (K_{IR}) curve that was constructed as a lower-bound curve to K_{Ic}, K_{Id}, and K_{Ia} data available

for A533 grade B class 1 and A 508 steels.[7] This curve was incorporated into the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code* and is used as a guideline for operation of reactors to provide protection against nonductile failure. The effects of irradiation on initiation fracture toughness (K_{Ic} and K_{Id}) were not so well understood. A summary of the HSSI irradiation series that have either been accomplished or planned is shown in Table 1.

Series 1 examined static and dynamic fracture toughness with 101.6-mm [4TC(T)] compact specimens. That size was determined to be the practical upper limit beyond which neutron fluence variations through the thickness and gamma heating would be excessive. Both base-plate and submerged-arc weld metal were studied. The results of Series 1 showed that initiation fracture toughness vs test temperature curves shifted to higher temperatures by an amount approximated by the shift in CVN test results and that fracture initiation toughness reached high values at the higher test temperatures even after irradiation. However, few specimens of the larger sizes were irradiated and tested, and statistical analysis was not possible.

Series 2 and 3 were conducted to examine the effects of irradiation on the ductile-shelf toughness of submerged-arc welds fabricated with high copper levels and older commercial processes that resulted in a fairly low Charpy upper-shelf energy. A motivation for testing in the upper-shelf regime is the requirement for additional analyses in Appendices G and H of 10CFR50 (ref. 1), if the Charpy upper-shelf energy falls below 68 J (50 ft-lb) as determined from surveillance specimens. In addition to Charpy impact and tensile specimens, compact specimens ranging from 12.7 to 101.6 mm were irradiated and tested to determine ductile fracture toughness using elastic-plastic test and analysis techniques. The results of Series 2 and 3 are the subject of this report.

Series 4 was also a ductile-shelf study, except that the submerged-arc welds examined were fabricated with low-copper content and current-practice welding procedures, using the same plate material (HSST Plate 02) used in Series 1. Low upper-shelf materials from the Federal Republic of Germany (FRG) were also included in this study. Series 4 included only 25.4-mm-thick compact specimens [1TC(T)] in addition to the Charpy and tensile specimens. Sufficient specimens existed to perform statistical analyses of the results, a factor that was lacking in the previous series. Series 4 demonstrated that low-copper, submerged-arc welds fabricated with current practices show relatively small radiation-induced shifts of fracture toughness and little or no decrease of ductile fracture toughness, J_{Ic}, and tearing resistance.

Series 5 was conceived to validate the shift and shape of the K_{Ic} curve as a consequence of neutron irradiation. Currently, estimates of the K_{Ic} curve shift are based on results from Charpy impact testing with the assumption that the shift of the Charpy toughness curve to higher temperatures can be applied directly to the K_{Ic} curve. This is much the same as the objectives of Series 1, except that sufficient specimens of various sizes up to 101.6-mm thick were tested to allow for statistical

Table 1. Summary of Heavy-Section Steel Irradiation (HSSI) Program - December 1990

HSSI irradiation series number	Objective	Materials	Total specimen complement	Reactor irradiation dates	Neutron fluence [neutrons/cm^2 (E > 1 MeV)]	Irradiation temperature [°C (°F)]	Comments
1	Upper transition - fracture toughness of plate and weld metal	A 533, grade B, class 1 (plate 02), submerged-arc weld metal	4TCS - 6 CVCS - 140 CVN - 154 Ten - 34	Battelle Research Reactor, Columbus, Ohio; Westinghouse conducted 10/20/72 to 12/13/73	2.1-7.0 × 10^{19}	270-300 (515-570)	Static and dynamic fracture toughness tests conducted. Status: program completed. HEDL-TME 75-10. WCAP-8775. ORNL/TM-4729/VII.
2	Ductile shelf - fracture toughness of low CV shelf material	Low-shelf submerged-arc weld metal, 61W, 62W, and 63W; Cu: 0.29, 0.21, and 0.30%	4TCS - 6 1.6TCS - 6 0.8TCS - 12 0.5TCS - 117 CVN - 207 Ten - 27	Bulk Shielding Reactor, Oak Ridge, Tenn., 10/15/76 to 3/3/77	0.4-2.1 × 10^{19}	233-343 (450-650)	Temperature extremes and lower fluences were for smaller specimens. Status: program completed. NUREG/CR-5696 (ORNL/TM-11804). NUREG/CR-3506 (MEA-2028).
3	Ductile shelf - fracture toughness of low CV shelf weld material	Low-shelf submerged-arc weld metal, 64W, 65W, 66W, and 67W; Cu: 0.35, 0.22, 0.42, and 0.27%	4TCS - 6 1.6TCS - 6 0.8TCS - 12 0.5TCS - 117 CVN - 207 Ten - 27	Bulk Shielding Reactor, Oak Ridge, Tenn., 12/19/77 to 3/29/78	0.4-1.2 × 10^{19}	233-310 (450-590)	Temperature extremes and lower fluences were for smaller specimens. Status: program completed. NUREG/CR-5696 (ORNL/TM-11804). NUREG/CR-3506 (MEA-2028).
4	Ductile shelf - fracture toughness of state-of-the-art weld material	A 533, grade B class 1 (plate 02), current practice submerged-arc weld metal, 68W, 69W, 70W, and 71W; Cu: <0.10, two FRG materials	1TCS - 240 CVN - 348 Ten - 52	Bulk Shielding Reactor, Oak Ridge, Tenn., 12/18/79 to 7/25/82	0.5-2.7 × 10^{19}	288 (550)	Status: program completed. NUREG/CR-4880 (ORNL-6484).
5	K_{Ic} curve shift - compared with CVN curve shift; K_{Ic} values high as possible	Submerged-arc weld metals, 72W and 73W; Cu: 0.23 and 0.31%, no copper-coated electrodes, copper added to melt	4TCS - 16 2TCS - 36 1TCS - 60 CVN - 112 Ten - 32 DWT - 32	Oak Ridge Research Reactor, Oak Ridge, Tenn., 5/11/84 to 12/13/85	1.1-1.9 × 10^{19}	280-300 (536-572)	Status: testing completed, report in preparation.

Table 1. (continued)

HSSI irradiation series number	Objective	Materials	Total specimen complement	Reactor irradiation dates	Neutron fluence [neutrons/cm^2 (E > 1 MeV)]	Irradiation temperature [°C (°F)]	Comments
6	Crack arrest - toughness	Submerged-arc weld metals, 72W and 73W; Cu: 0.25 and 0.31%, no copper-coated electrodes, copper added to melt	1TCA - 14 1.3TCA - 30 (24 duplex) 1 × 3 × 3 - 16	Oak Ridge Research Reactor, Oak Ridge, Tenn., 12/23/85 to 5/2/86	Target: 1.75×10^{19}	Target: 288 (550)	Status: irradiation completed, testing of weld-embrittled specimens completed. NUREG/CR-5584 (ORNL/TM-11575).
7	Stainless steel cladding - fracture toughness of submerged-arc stainless steel cladding	309/308 single-wire oscillating and three-wire series arc	CVN - 110 Ten - 30 0.5TCS - 48	Nuclear Science and Technology Facility, Buffalo, New York; one-wire irradiated 1983, three-wire irradiated 1985	$2.0\text{-}2.5 \times 10^{19}$ and $5.3\text{-}5.8 \times 10^{19}$	274-302 (525-576)	Status: program completed except for precracked CVN. NUREG/CR-5511 (ORNL/TM-11439). NUREG/CR-3927 (ORNL/TM-9309).
8	K_{Ic} and K_{Ia} curve shifts	Planned: high-copper, low-CVN upper-shelf weld	Planned: 1-4TCS 1.0-1.3TCCA CVN, Ten	Planned to begin in 1993	Target: 2.0×10^{19}	Target: 288 (550)	Conceptually planned
9	Annealing effects in thick sections	Planned: same material as Series 8	Planned: 1-4TCS 1.0-1.3TCCA CVN, Ten	Planned to begin in 1994	Target: 2.0×10^{19} followed by 1.0×10^{19}	Target: 288 (550)	Conceptually planned
10	Commercial low upper-shelf weld - Midland Reactor vessel	Low-shelf submerged-arc weld metal: Linde 80 flux, one heat of copper-coated weld wire	Planned: 0.5-4TCS CVN, Ten, DWT	Planned to begin in 1991	Target: 5.0×10^{18}, 1×10^{19}, and 5.0×10^{19}	Target: 288 (550)	Detailed planning under way, unirradiated testing under way, and irradiation planning under way

analyses. Also, drop-weight specimens were included in the irradiation program. Submerged-arc welds were fabricated for inclusion in this series with two weld metals containing 0.23 and 0.31% Cu. The copper was added to the weld metal melt before the material was drawn into wire to provide a uniform copper content in the weld metal, compared to the less uniform distribution obtained with copper-coated wire. Series 5 showed radiation-induced fracture toughness shifts greater than the Charpy 41-J shifts for both welds. The effects on the K_{Ic} curve shape indicate some decrease in the slope of the mean curves after irradiation; construction of a lower-bound curve to the data for the irradiated higher copper weld metal also indicated a shallower K_{Ic} curve than for the unirradiated material.

Series 6 will determine the effect of irradiation on the ability of the pressure vessel material to arrest a rapidly propagating flaw. The submerged-arc weldments used for Series 5 are being used for Series 6. Crack-arrest toughness (K_{Ia}) is considered by many to represent the minimum toughness of a material, and it is essential that the effects of irradiation on that property be understood. Preliminary results from Phase I of Series 6 indicate good correspondence between the K_{Ia} and CVN 41-J shifts.

Series 7 was designed to determine the effects of irradiation on pressure vessel, stainless-steel-weld, overlay cladding. Analyses of certain thermal shock scenarios have been incomplete because of a lack of information regarding the fracture resistance of the cladding. The plan for Series 7 included submerged-arc cladding applied by both the single-wire oscillating and the three-wire, series-arc processes. Charpy impact, precracked Charpy, tensile, and 12.5-mm compact specimens [0.5TC(T)] were utilized. Series 7 demonstrated that the Charpy impact curve for stainless steel cladding exhibits a transition with test temperature in the unirradiated condition and undergoes a moderate transition temperature shift and an upper-shelf energy decrease as a consequence of irradiation. Moreover, the low tearing resistance exhibited prior to irradiation is further degraded by irradiation, such that the ductile fracture toughness, J_{Ic}, can be even lower than that from irradiated, low upper-shelf welds.

Series 8 will address the issues of K_{Ic} and K_{Ia} curve shifts and shape changes for high-copper, low upper-shelf welds. Series 9 will address the issue of thermal annealing effects in irradiated, heavy-section steels; Series 9 will likely utilize the same material as in Series 8. Both of those irradiation series are in the planning stages.

Series 10 is examining the effects of irradiation on a commercial high-copper, low upper-shelf, submerged-arc weld. Sections of the beltline and one nozzle course circumferential weld have been removed from the installed, but never operated, Midland Unit 1 RPV. The welds were fabricated with one heat of copper-coated weld wire and one lot of welding flux and were identified by Babcock and Wilcox Company (B&W) as WF-70. Welds carrying the WF-70 designation are the controlling materials in five operating nuclear power plants, a primary factor motivating this investigation. Charpy impact, tensile, and 0.5T

compact specimens will be irradiated to fluences of 5×10^{18}, 1×10^{19}, and 5×10^{19} neutrons/cm^2 (>1 MeV), while larger fracture toughness specimens will be irradiated at 1×10^{19} to investigate both transition range fracture toughness and ductile-shelf fracture resistance. Included in the characterization of the weld will be an extensive study, before irradiation, of the variation in reference temperature, RT_{NDT}, through the thickness and at a number of locations.

3. EXPERIMENT CONCEPT

There were several objectives that influenced the detailed experiment design for the Second and Third Series:

1. The materials should represent critical early (before 1972) RPV welds, i.e., they should have CVN upper-shelf energy levels of about 68 J (50 ft-lb) after irradiation.

2. Specimen sizes should be as large as practical in order to reach high elastic-plastic fracture toughness levels.

3. Several sizes of fracture toughness specimens should be irradiated to provide data on specimen size effects, since the larger specimens cannot be included in RPV surveillance programs.

4. CVN impact specimens should be irradiated to provide correlations of Charpy upper-shelf toughness with elastic-plastic fracture toughness.

5. The target fast neutron fluence was 1×10^{19} neutrons/cm^2 (>1 MeV) at an irradiation temperature of 288°C (550°F).

The largest practical fracture toughness specimen that could be irradiated, considering the constraints of irradiation temperature differentials due to gamma heating, irradiation temperature control as influenced by gamma heating, and neutron fluence differentials due to neutron flux attenuation in the specimens, was a 101.6-mm-thick compact specimen[8] [4TC(T)]. (The irradiation capsules were rotated 180° during the irradiation period to keep the neutron fluence distribution in the large specimens as symmetrical as possible.)

In addition to the 4TC(T) fracture toughness specimens, 0.5, 0.8, and 1.6TC(T) [12.7, 20.3, and 40.6-mm thick, respectively], CVN and tensile specimens were included in the irradiation capsules to provide data on size effects and facilitate correlation of tearing resistance with Charpy upper-shelf results.

Each of the six irradiation capsules of this study contained two 4TC(T) specimens. The 0.8 and 1.6TC(T) specimens were placed between the 4TC(T) specimens, and 0.5TC(T), Charpy, and tensile specimens were installed in the notches and loading holes of the 4TC(T) specimens to

conserve irradiation space. The irradiations were conducted in the Bulk Shielding Reactor (BSR) at Oak Ridge National Laboratory, a 2-MW, pool-type reactor.

Preliminary neutron dosimetry and gamma heating experiments were conducted to determine the neutron exposure and capsule design parameters.

4. MATERIALS

The seven submerged-arc welds in this study, identified as HSST 61W through 67W, were fabricated with materials and procedures used in early PWR pressure vessels. Weld HSST 61W, composed of 248-mm-thick (9.75-in.) A 533 grade B base metal welded with Linde 80 flux, was supplied by Westinghouse Electric Corporation, fabricated by B&W, and was part of a weldment fabricated for a PWR pressure vessel surveillance program. Welds HSST 62W through 67W, composed of 305-mm-thick (12-in.) A 508 class 2 base metal welded with Linde 80 flux, were supplied and fabricated by B&W and were from PWR pressure vessel nozzle dropouts. Information on whether any or all of these welds are from operating PWRs was not supplied. These welds had average copper levels ranging from 0.21 to 0.42% with nickel levels of around 0.6% and, thus, were considered "sensitive" to neutron irradiation embrittlement and typical of some early pressure vessel welds. The use of Linde 80 flux produced welds with large contents of very small inclusions which, although resulting in improved radiographs, have relatively low upper-shelf Charpy energies in the unirradiated condition.

All seven welds were made with 3.17-mm-diam (0.125-in.) MnMoNi copper-coated wire. With the exception of weld HSST 62W, each of the welds was made with a single heat of wire and lot of flux. The materials used to make weld HSST 62W were two heats of 1/8-in.-diam wire and two lots of flux (this was discovered after the study was in progress). One weld wire and flux combination (HSST 62WA) was used to fabricate approximately the first 184 to 190 mm (7.25 to 7.50 in.) thickness of weld starting at the inside surface of the vessel. The balance of the weld thickness, 114 to 121 mm (4.50 to 4.75 in.), was fabricated with a second weld wire and flux combination (HSST 62WB).[9] Complete welding parameter information was supplied only for weld HSST 62W. The following welding parameters were employed for this weld:

Preheat temperature: 121 to 204°C (250 to 400°F)
Interpass temperature: 149 to 260°C (300 to 500°F)
Amperage: 450 to 540 A
Voltage: 30 to 34 V
Travel speed: 254 to 305 mm/min (10 to 12 in./min)

Although complete welding parameter information for the other welds is not available, it may be assumed that they are close to the above parameters. The welding of all welds was an automatic, single-wire, submerged-arc process (multiple pass).

Postweld stress relief treatments were as follows:

Weld	Stress Relief
61W	25 h at 593 to 621°C (1100 to 1150°F)
62W	8 cycles of 6 h at 593 to 621°C (1100 to 1150°F)
63W	48 h at 593 to 621°C (1100 to 1150°F)
64W	48 h at 593 to 621°C (1100 to 1150°F)
65W	80 h at 593 to 621°C (1100 to 1150°F)
66W	48 h at 593 to 621°C (1100 to 1150°F)
67W	not available

Chemical compositions for the welds are presented in Table 2.

Further information on these weldments, as provided by the suppliers, is given in ref. 9. Chemical compositions at various depths in all the weldments, except HSST 62W, showed only normally expected variations. As mentioned above, HSST 62W was found to have been made with two weld wire-flux combinations. A detailed study of a different nozzle dropout from this same pressure vessel weld seam was conducted by B&W for the Electric Power Research Institute and is reported in ref. 9. Since weld HSST 62W and the dropout reported in ref. 9 were from the same weld seam chemical composition, information in ref. 9 should also pertain to weld HSST 62W. However, postweld heat treatments for HSST 62W were different than for the dropout reported in ref. 9, and mechanical properties data are probably not comparable.

Chemical composition determinations[9] made at numerous depths in weld HSST 62W showed no differences with depth in the carbon, silicon, molybdenum, tin, and aluminum levels and only minor differences with depth in manganese, sulphur, and nickel levels. However, phosphorus levels in HSST 62WA and 62WB were 0.013 and 0.019%, respectively. Chromium levels in HSST 62WA and 62WB were 0.080 and 0.165%, respectively. The copper levels through the weld thickness varied as shown in Fig. 1 (ref. 9). As stated earlier, the weld reported in ref. 9 did not receive the same postweld stress relief as weld 62W, and it is of interest to note that the toughness properties for wire-flux combination A differed in several respects from wire-flux combination B. The drop-weight nil-ductility transition temperature was -68°C (-90°F) for combination A and -51 to -57°C (-60 to -70°F) for combination B. The 68 J (50-ft-lb) CVN transition temperature was -6.7 to 1.7°C (20 to 35°F) for combination A and 21°C (70°F) for combination B, while the Charpy upper-shelf energy was 129 J (95 ft-lb) for combination A and 102 J (75 ft-lb) for combination B.[9] Since test specimens from weld 62W had been machined before the duplex nature of this weld was known, all the Charpy test specimens had been machined from combination B (HSST 62WB), and no Charpy data for weld wire A (HSST 62WA) are available.

Table 2. Chemical composition of HSSI welds 61W through 67W

Weld	Average[a] composition (wt %)									
	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	V
61W	0.09	1.48	0.020	0.014	0.57	0.16	0.63	0.37	0.28	0.005
	0.07	1.45	0.018	0.014	0.55	0.16	0.62	0.36	0.26	0.005
	0.10	1.52	0.021	0.015	0.58	0.17	0.64	0.38	0.31	0.005
62W[b]	0.083	1.51	0.016	0.007	0.59	0.120	0.537	0.377	0.210	0.010
	0.078	1.41	0.013	0.007	0.55	0.067	0.490	0.365	0.160	0.010
	0.088	1.61	0.020	0.008	0.63	0.173	0.585	0.390	0.260	0.011
62WA[b]	0.083	1.51	0.013	0.007	0.59	0.075	0.510	0.377	0.200	0.010
	0.078	1.41	0.012	0.007	0.55	0.070	0.480	0.365	0.140	0.010
	0.088	1.61	0.014	0.008	0.63	0.090	0.540	0.390	0.270	0.011
62WB[b]	0.083	1.51	0.018	0.007	0.59	0.170	0.550	0.377	0.177	0.010
	0.078	1.41	0.016	0.007	0.55	0.160	0.540	0.365	0.160	0.010
	0.088	1.61	0.020	0.008	0.63	0.180	0.600	0.390	0.230	0.011
63W	0.098	1.65	0.016	0.011	0.630	0.095	0.685	0.427	0.299	0.011
	0.088	1.62	0.015	0.010	0.580	0.073	0.663	0.415	0.272	0.010
	0.109	1.67	0.017	0.013	0.675	0.118	0.707	0.440	0.326	0.012
64W	0.085	1.59	0.014	0.015	0.520	0.092	0.660	0.420	0.350	0.007
	0.070	1.54	0.012	0.014	0.445	0.074	0.600	0.410	0.310	0.006
	0.100	1.64	0.017	0.016	0.600	0.110	0.720	0.430	0.390	0.008
65W	0.080	1.45	0.015	0.015	0.480	0.088	0.597	0.385	0.215	0.006
	0.070	1.42	0.014	0.013	0.450	0.076	0.585	0.370	0.180	0.005
	0.090	1.49	0.017	0.017	0.610	0.100	0.610	0.400	0.250	0.008
66W	0.092	1.63	0.018	0.009	0.540	0.105	0.595	0.400	0.420	0.009
	0.075	1.59	0.017	0.009	0.480	0.090	0.580	0.380	0.350	0.007
	0.110	1.67	0.020	0.010	0.600	0.120	0.610	0.420	0.490	0.012
67W	0.082	1.44	0.011	0.012	0.500	0.089	0.590	0.390	0.265	0.007
	0.070	1.40	0.010	0.012	0.410	0.067	0.580	0.370	0.220	0.005
	0.095	1.48	0.013	0.013	0.590	0.110	0.600	0.410	0.310	0.010

[a]Top entry is the average value, while numbers shown below each entry indicate the range of composition measurements.

[b]Weld 62W is a duplex weld with designations 62WA and 62WB (see text).

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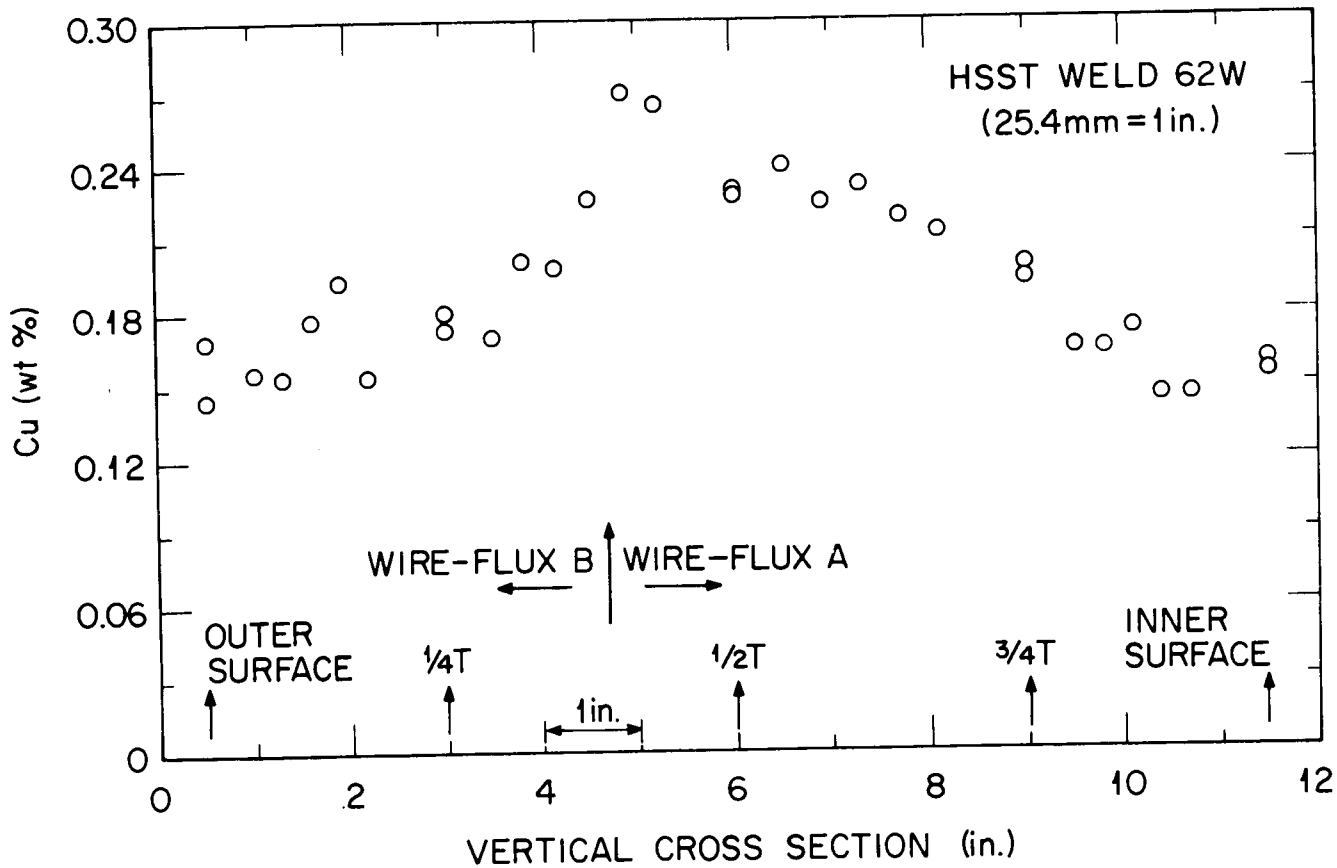


Fig. 1. Plot of copper distribution through the thickness of a submerged-arc weld, HSST weld 62W. *Source:* Babcock and Wilcox Company, Alliance, Ohio, and Lynchburg, Virginia, *An Investigation of Mechanical Properties and Chemistry Within a Thick MnMoNi Submerged Arc Weldment*, EPRI NP-373, Electric Power Research Institute, Palo Alto, Calif., February 1977.

5. SPECIMEN DESIGNS AND WELDMENT CUTTING

All test specimens were prepared by the suppliers (Westinghouse Electric Corporation and B&W). Standard CVN, miniature tensile, fatigue precracked Charpy, 0.5TC(T), 0.8TC(T), 1.6TC(T), and 4TC(T) specimens comprised the specimen complement.

The miniature tensile test specimens were designed to the overall size of a Charpy test specimen to fit into the irradiation capsules. The specimens are shown in Fig. 2. Two lengths of specimens were used to fit in the available spaces in the irradiation capsules.

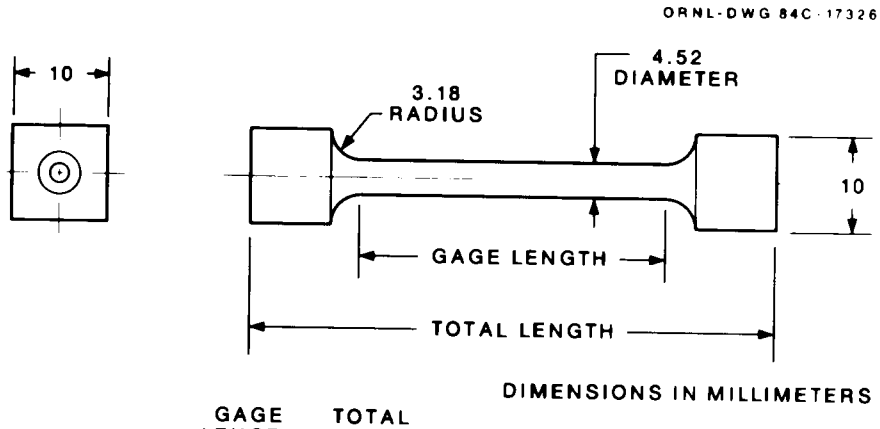
The Charpy specimens were ASTM standard CVN impact specimens (type A). The fatigue precracked Charpy specimens were standard CVN specimens fatigue precracked to a crack length-to-width ratio (a/W) of about 0.5.

Four sizes of compact specimens with thicknesses of 12.7, 20.3, 40.6, and 101.6 mm (0.5T, 0.8T, 1.6T, and 4T, respectively) were irradiated and tested. All dimensions of the specimens are proportional to the ASTM E 399 design,[11] except that most of the specimens incorporated a J-modified notch design to allow clip gage placement on the load line. These specimens had integrally machined seats on the load line for clip gage placement. The 4TC(T) specimen is shown in Fig. 3. The other sizes of compact specimens were scaled to the 4TC(T) specimen. The machined clip gage seats were later deemed inadequate because of the accuracy requirements of the single-specimen unloading compliance technique that evolved for making J-integral resistance (J-R) curve determinations after the irradiations had begun. Therefore, the specimens were remachined to provide for mounting razor blade edges on the load line of the 4TC(T) and 1.6TC(T) specimens or the front face of the 0.8TC(T) and 0.5TC(T) specimens. Details of those procedures are discussed elsewhere.[12]

Some of the compact specimens tested early in the program were smooth sided, while later tests utilized specimens that were either 10 or 20% side grooved after irradiation. Most of the tests were conducted on 20% side-grooved specimens (i.e., 10% of the specimen thickness on each side). All specimens were machined with the primary tension axis transverse to the welding direction and the fracture propagation direction in the welding direction, as shown in Fig. 4. Thus, the fracture plane was completely within the weld metal, as shown in Fig. 5.

6. IRRADIATION CAPSULE DESIGN

The design of the irradiation capsules was based on the design of the capsules used in the First HSSI Irradiation Series[8,13] conducted by Westinghouse Electric Corporation at the Battelle Research Reactor (BRR). Based on the experience gained in the BRR irradiation and on gamma heat measurements in a dummy capsule in the ORNL BSR, design details were



	GAGE LENGTH (mm)	TOTAL LENGTH (mm)
LONG SPECIMEN	31.75	55
SHORT SPECIMEN	29.24	50

Fig. 2. Tensile specimen configurations used in the Second and Third HSSI Irradiation Series.

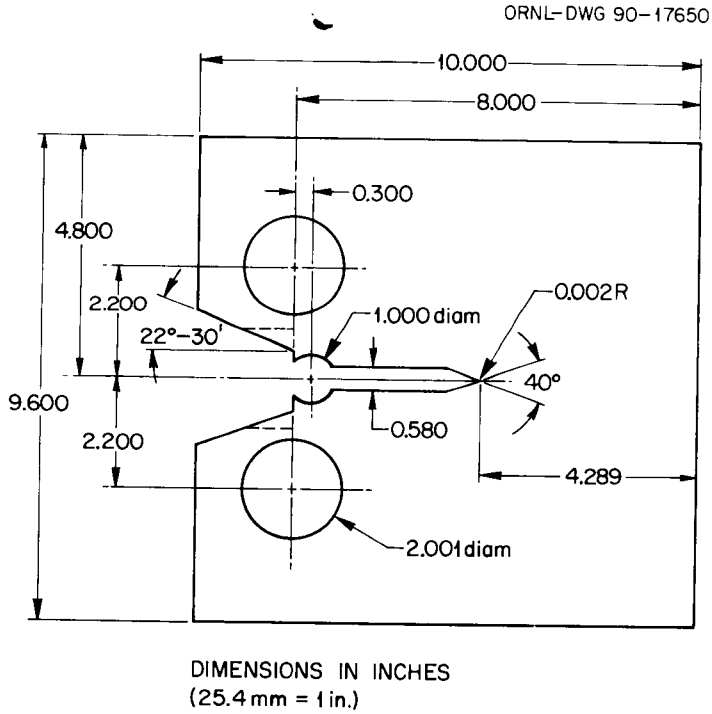


Fig. 3. Schematic drawing of the 4T compact specimen (101.6 mm thick). The dashed area was removed through remote machining of the irradiated specimens to permit attachment of razor blades at the load line. *Source:* A. L. Hiser, F. J. Loss, and B. H. Menke, *J-R Curve Characterization of Irradiated Low Upper Shelf Welds*, NUREG/CR-3506, MEA-2028, U.S. Nuclear Regulatory Commission, Washington, D.C., April 1984.

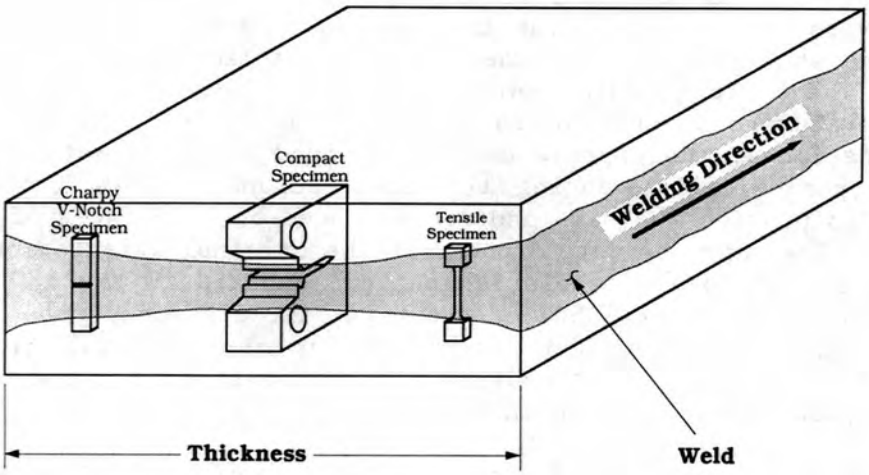


Fig. 4. Schematic drawing showing typical specimen orientation in weldments. The axis of loading is transverse to the weld, and fracture propagation is in the welding direction.

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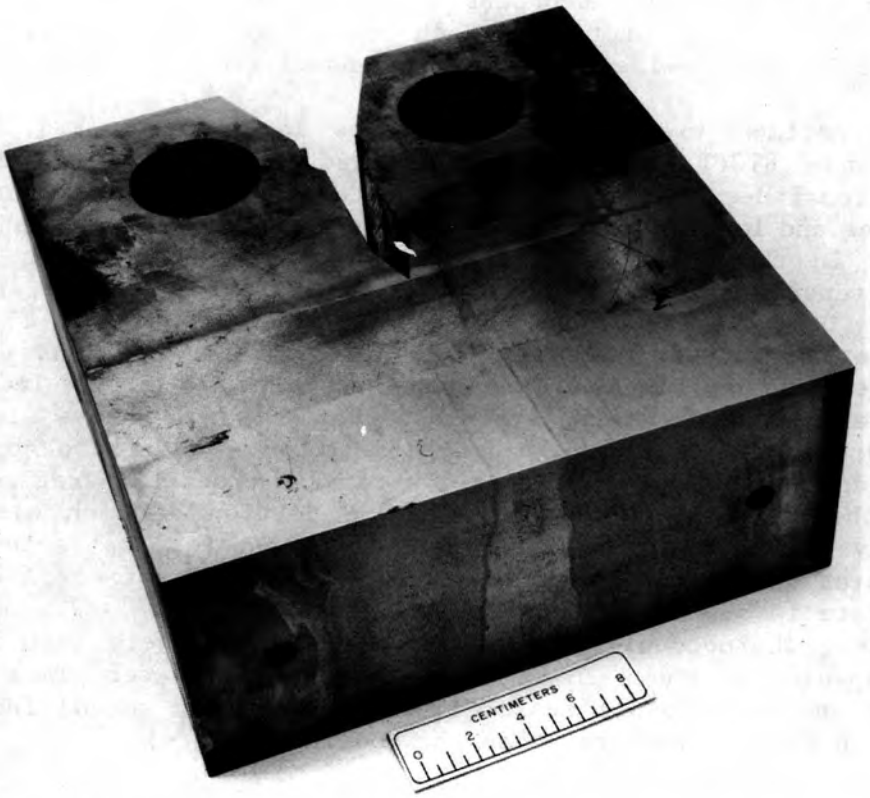

Fig. 5. Photograph of 4T compact specimen showing position of notch in weld.

modified for better control and more extensive knowledge of the irradiation conditions. In each of the Second and Third Irradiation Series, two capsules were irradiated at the east face and one at the north face of the BSR, as shown in Fig. 6. The specimen complements are presented in Table 3. The basic capsule design is shown in Figs. 7 and 8. Because of neutron flux gradients through the 101.6-mm (4-in.) thickness of the largest specimens, the capsule design provided for 180° rotation of the capsules, periodically, during the irradiations. This rotation was scheduled to provide the same neutron fluences on both faces of the 4TCS specimens. The capsules were exposed in the original orientation for the first 40% of the total irradiation period, exposed in the 180° rotated position for an additional 50% of the total irradiation period, and back to the original position for the final 10% of the total irradiation period. The resulting fast neutron fluence profile at the crack front of a 4TC(T) specimen is shown in Fig. 9.

The main heat source in the capsules was gamma heat generated within the specimens. Supplementary electrical heat was used to even out temperature differences in various parts of the capsules. Overall specimen temperatures were automatically controlled by adjusting the composition of a helium-nitrogen or helium-carbon dioxide gas mixture in the gaps between the heater plates and cooling water jackets (Fig. 8). Three electrical heater sections per capsule face were provided to compensate for vertical and front-to-back-face gamma heat variations. There were three 1-kW heater elements per heater section and these were manually adjusted, initially and periodically, during the irradiations. In each capsule, 46 thermocouples were provided for control, reactor safety, and recording functions. Each capsule also contained an array of neutron activation dosimeters to provide postirradiation fluence data.

The specimen layout in the capsules is shown in Fig. 10. The 1.6TC(T) and 0.8TC(T) specimens were located between the 4TC(T) specimens with the remainder of the specimens located in subcapsules installed in the notches and loading pinholes of the 4TC(T) specimens. The subcapsules installed in the notches of the 4TC(T) specimen contained 0.5TC(T), CVN, and tensile specimens. One 4TC(T) pinhole subcapsule per capsule contained 0.5TC(T) specimens, and the other three 4TC(T) pinhole subcapsules contained 0.5TC(T), CVN, and tensile specimens. Typical subcapsules and specimens ready for assembly are shown in Fig. 11. Heater elements were swaged, stainless-steel-clad, nichrome elements of 1-kW power capacity. The nichrome elements were welded to copper lead wire, using a short length of nickel wire as a transition region, before swaging the final heater. The nichrome portion of each element was completely contained in machined slots in the heater plates to minimize heat generation in the lead wire regions of the capsules. A completed heater plate is shown installed in the capsules in Fig. 12. Specimens, subcapsules, thermocouples, and neutron dosimeters were then installed in the capsules as shown in Fig. 13. The second heater plate was then installed and the capsule sealed by welding on the second face plate, as shown in Fig. 14 (before attaching cooling jackets).

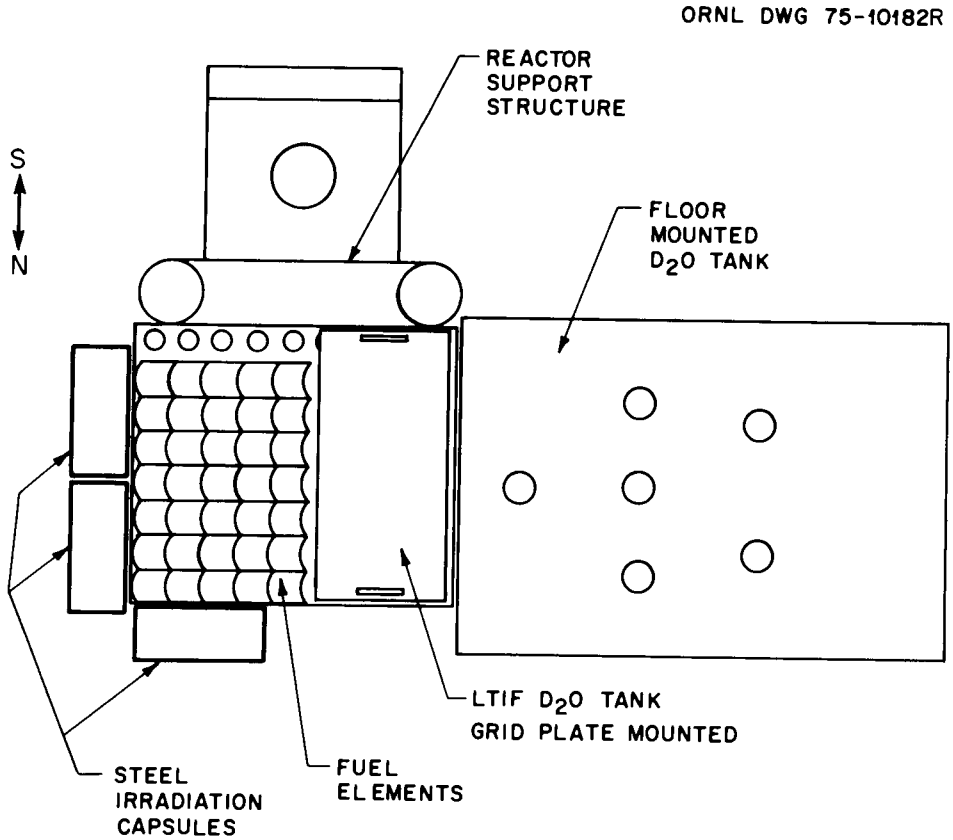

Fig. 6. Schematic drawing of the Bulk Shielding Reactor showing the location of the capsules for the Second and Third HSSI Irradiation Series.

Table 3. Irradiation capsule specimen complement for HSSI Second and Third Irradiation Series

Weld number[a]	Number of specimens per specimen type						
	4TCS	1.6TCS	0.8TCS	0.5TCS	Tensile	CVN	PCVN
61W (2A)	2	2	4	39	9	61	8
62W (2B)	2	2	4	39	9	61	8
63W (2C)	2	2	4	39	9	61	8
64W (3A)	2	2	4	39	9	61	8
65W (3B)	2	2	4	39	9	61	8
66W (3C)	0	2	2	20	6	25	8
67W (3C)	2	0	2	19	6	25	8

[a]Capsule number in parentheses.

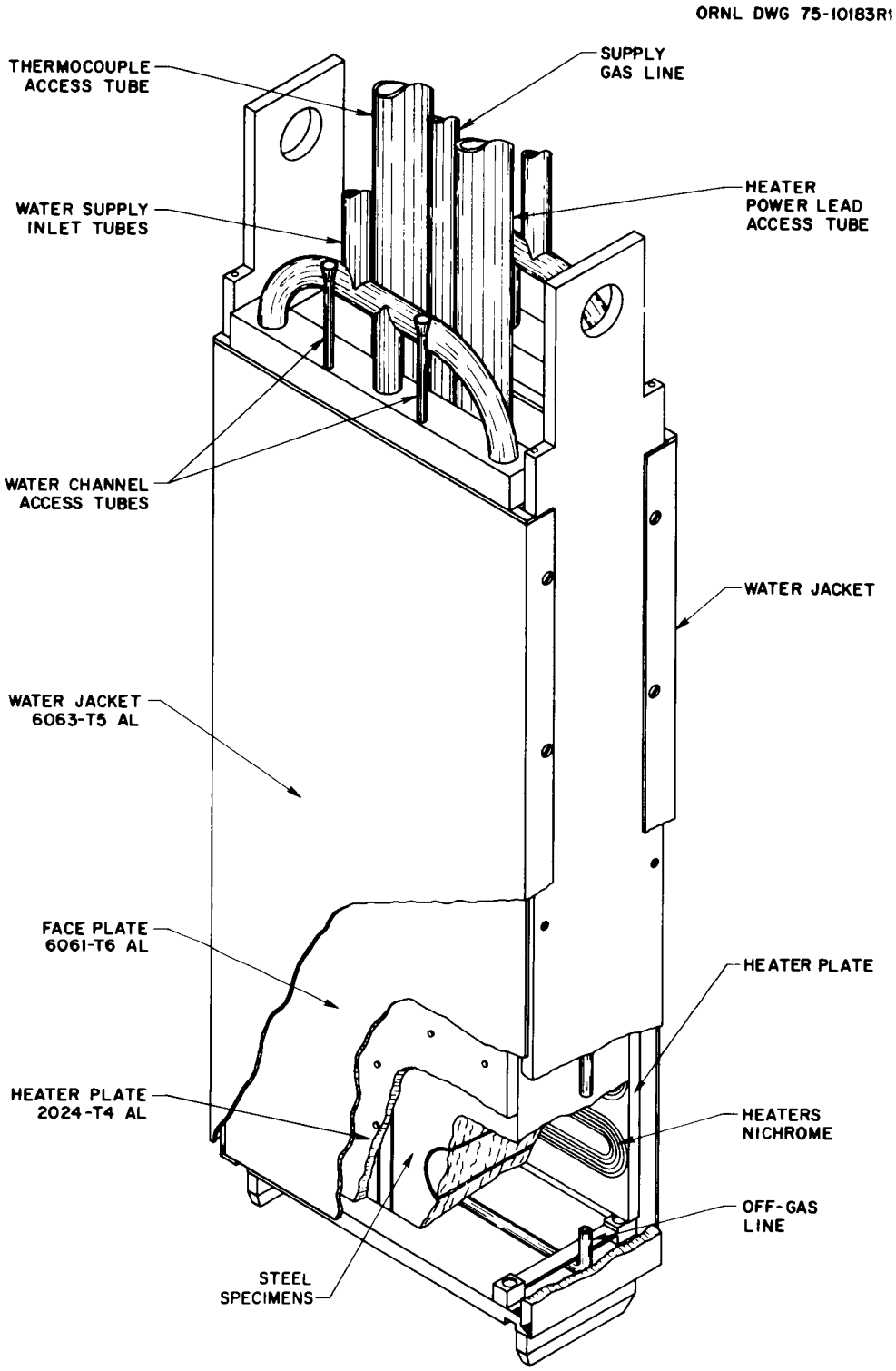

Fig. 7. Schematic drawing of the irradiation capsules with the various connections and the hardware components.

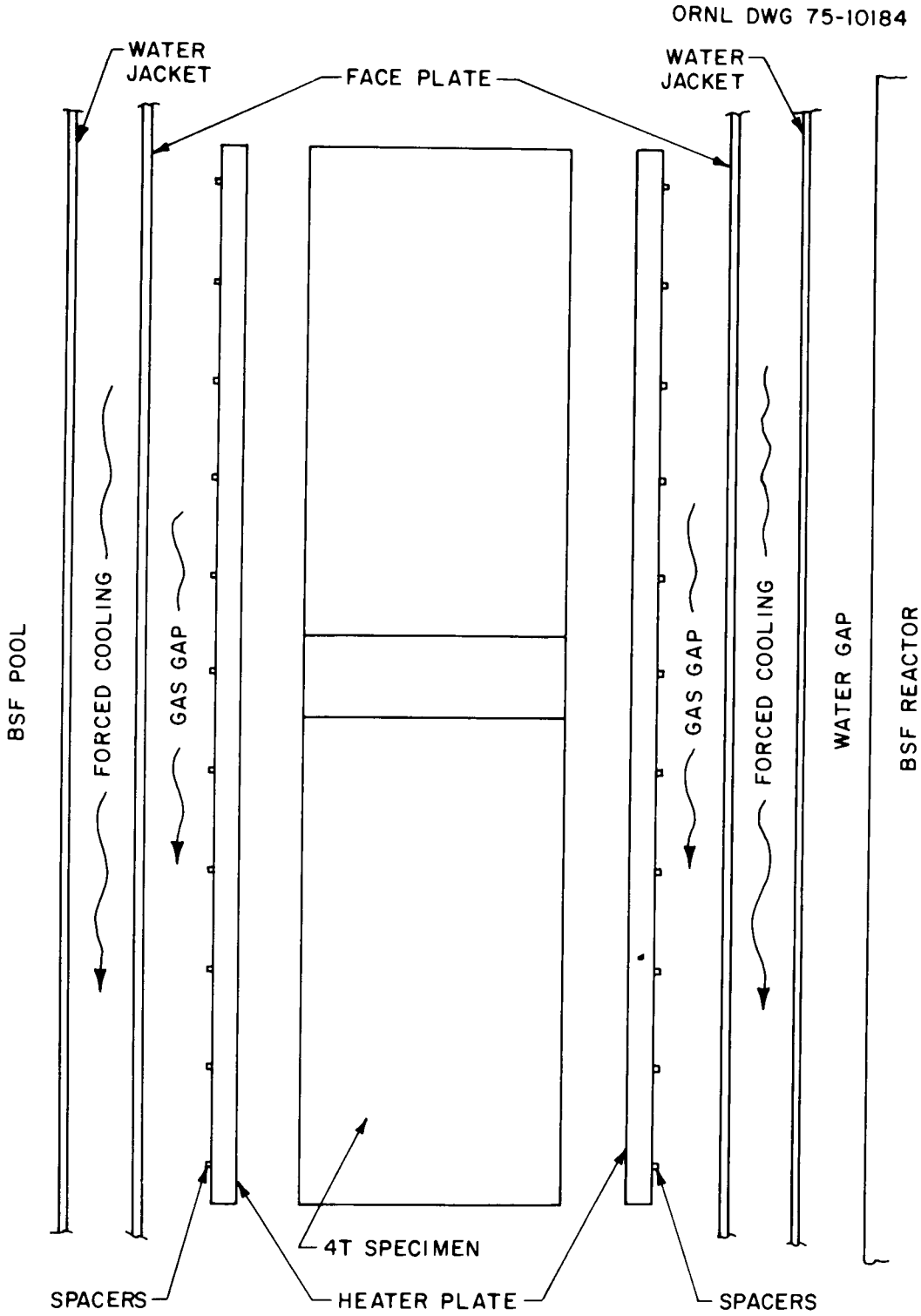

Fig. 8. Schematic drawing showing construction of irradiation capsules.

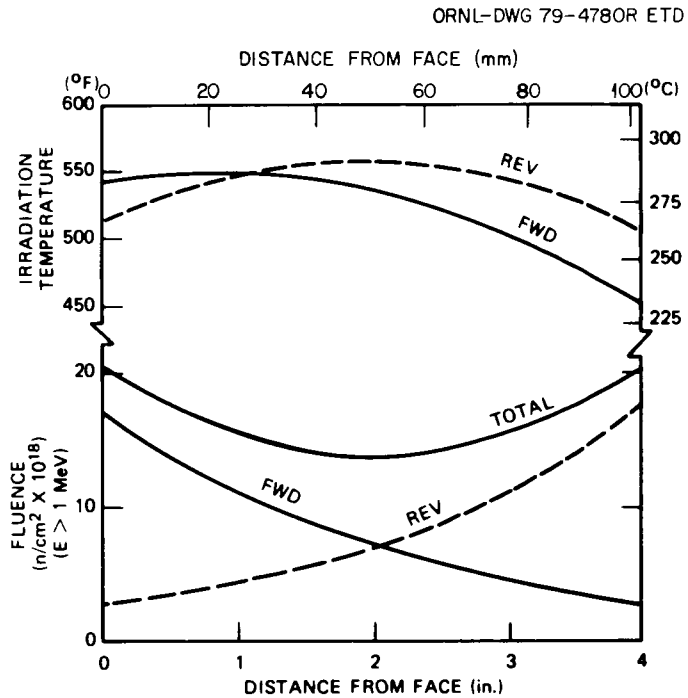

Fig. 9. Fast neutron fluence (>1 MeV) and irradiation temperature at crack front of a 4T compact specimen.

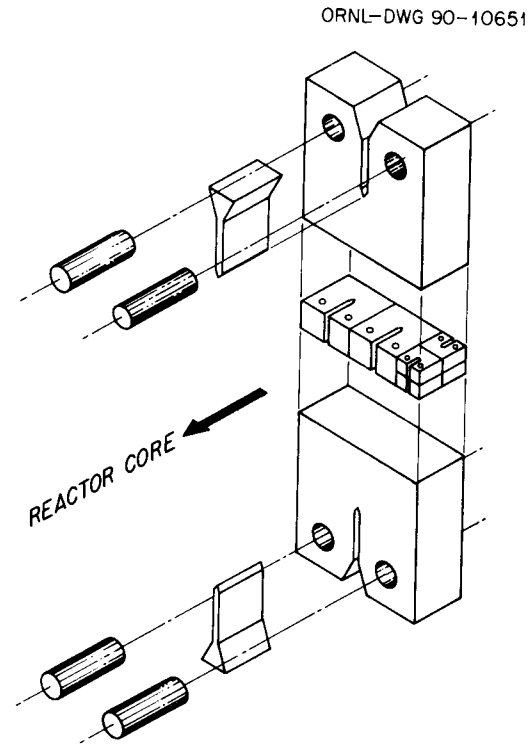

Fig. 10. Schematic drawing showing specimen placement in irradiation capsule. The 1.6TC(T) and 0.8TC(T) are located between the 4TC(T) while the 0.5TC(T), tensile, and Charpy specimens are located in the subcapsules which fill the notches and pinholes of the 4TC(T).

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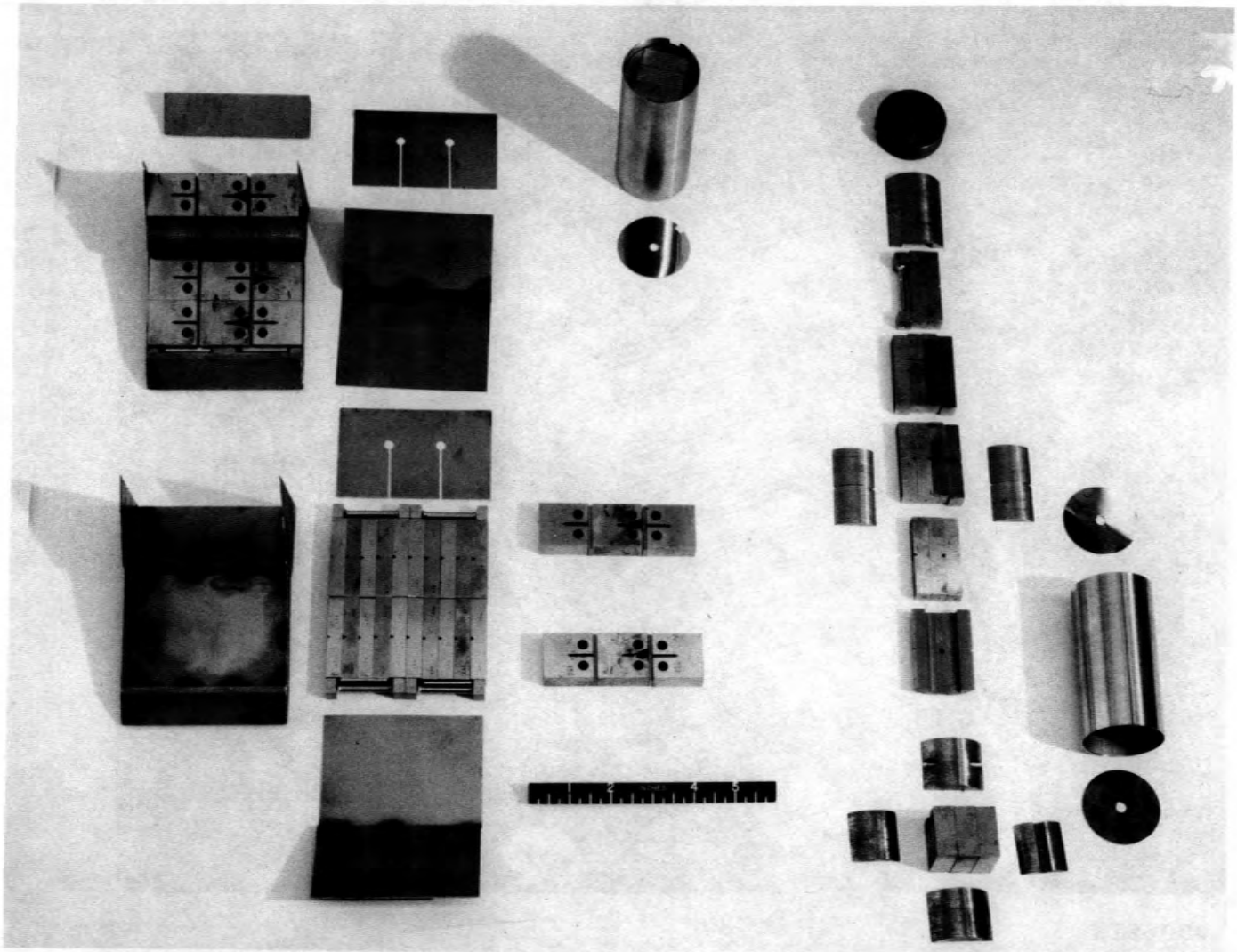

Fig. 11. Photograph of subcapsules and test specimens prior to assembly in one irradiation capsule.

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Fig. 12. Photograph of heater plate showing swaged, stainless-steel-clad, nichrome elements, prior to installation in the irradiation capsule.

Y139002

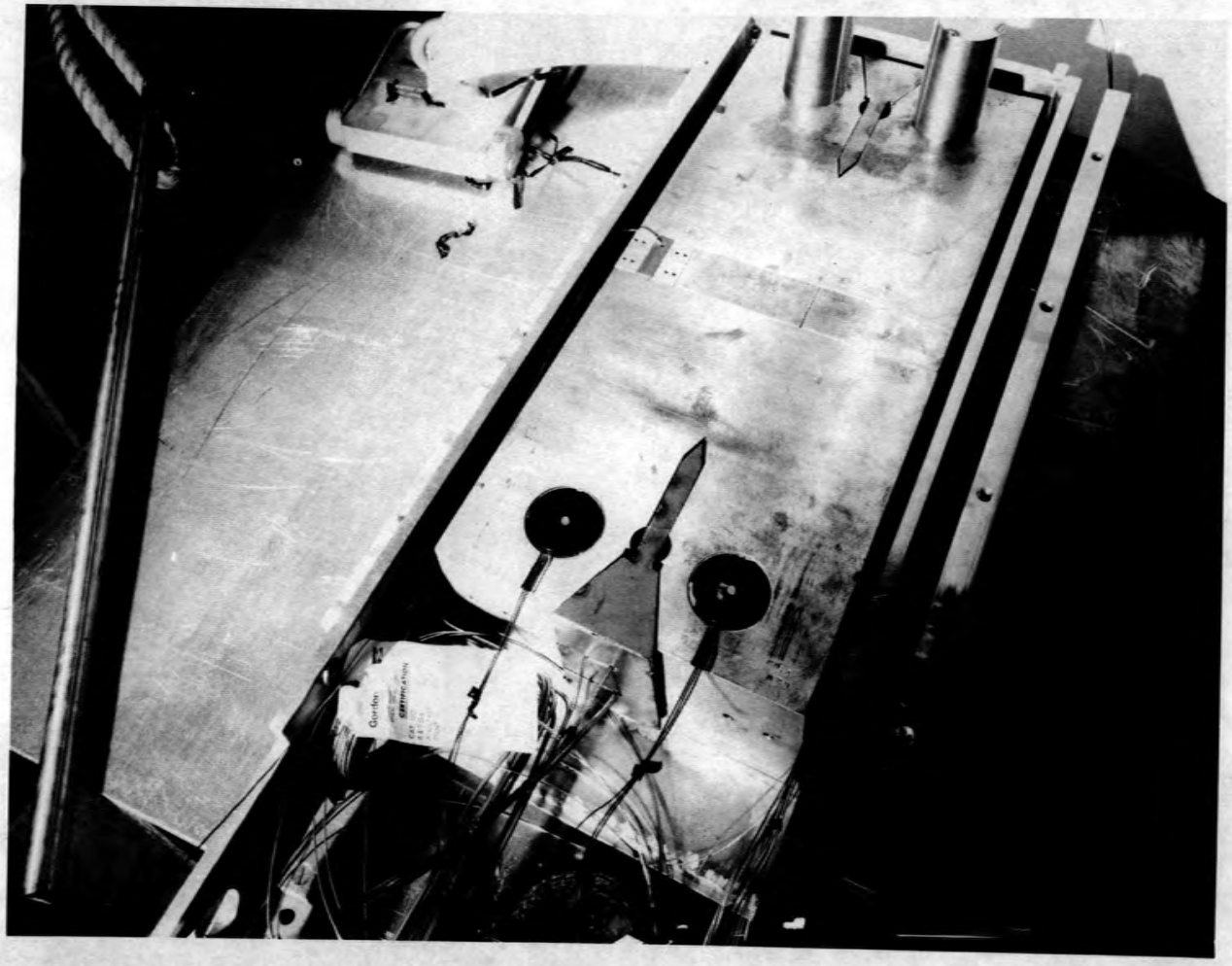

Fig. 13. Photograph of specimens after installation in the irradiation capsule.

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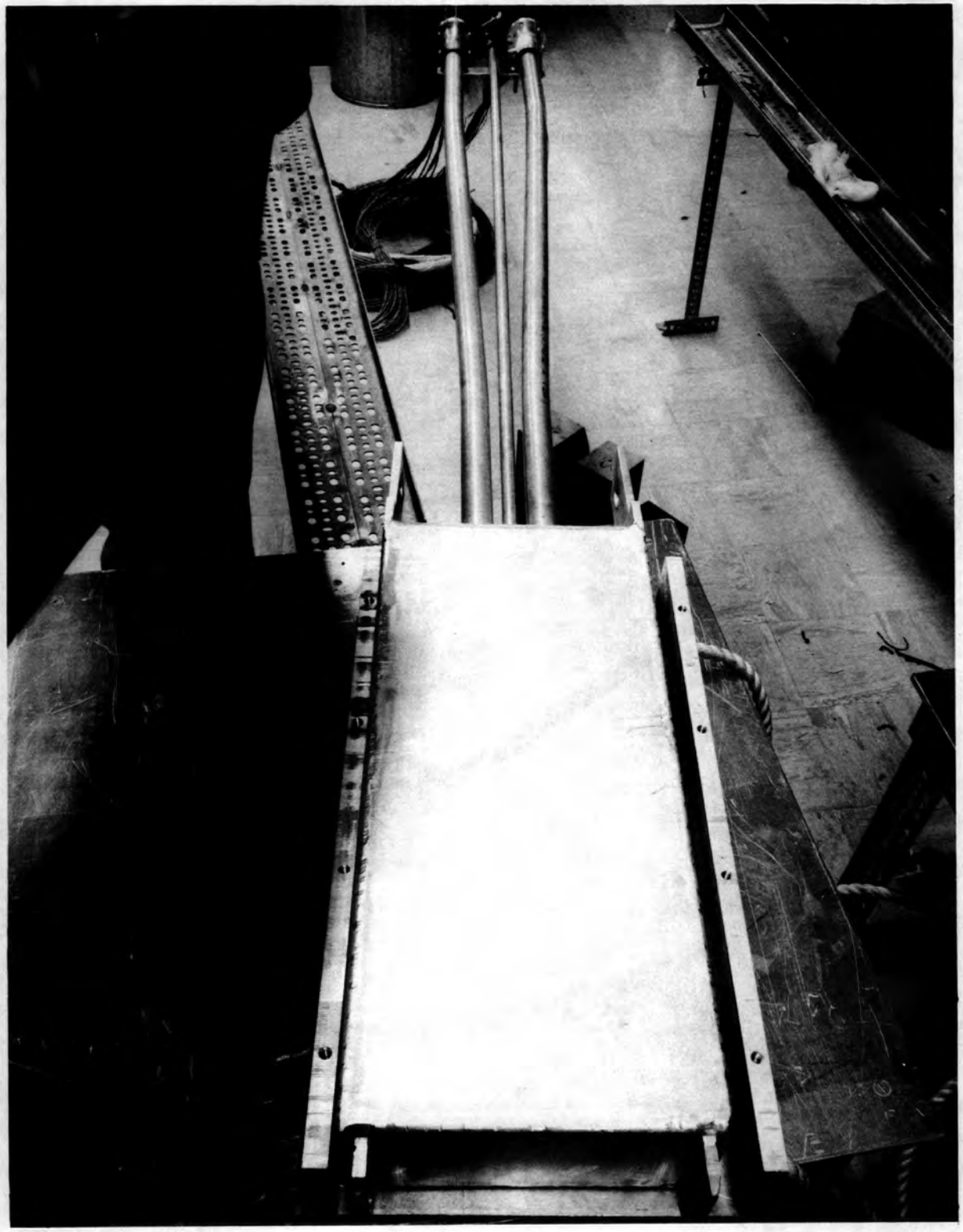

Fig. 14. Photograph of completed irradiation capsule before attaching cooling jackets.

The capsules were supported in the BSR pool on the structure shown in Figs. 15 through 17. Screw drives (Fig. 17) allowed for positioning the capsules at the BSR faces, retraction of the capsules for moving the bridge-mounted BSR to other irradiation facilities, and for installation, rotation, or removal of the capsules.

Operational parameters such as specimen temperatures, gas mixtures, reactor power, etc., were either continuously recorded on strip-chart recorders or periodically recorded on magnetic tape. The primary temperature control was at the fatigue crack front of the 4TC(T) specimens.

7. CAPSULE OPERATION

Results of preliminary gamma heat and neutron dosimetry experiments in BSR dummy capsules were used to set initial operational parameters for the capsules. However, the cumulative effects of a number of seemingly small factors caused some problems in the operation of the capsules. Some of these factors were changes in the BSR core loading, variations in the water gap between the specimens and the reactor face, variations in the gas gap between specimens and coolant channels, additional gamma heating from radiation backscattered from the water behind the capsules, and poor thermal contact between the small specimens in the subcapsules and the 4TC(T) specimens. In some capsules, maximum electrical heat was used to bring the 4TC(T) specimens to the desired 288°C (550°F) irradiation temperature, while in some other capsules almost pure helium gas and a small amount of electrical heat were used to keep temperatures down to the desired level. In addition, since there was no independent control of temperatures for the small specimens, they operated at temperatures above or below the desired temperatures, depending on their location in the capsules and the degree of thermal contact between them and the 4TC(T) specimens. The experiments were manned continuously during initial startup and capsule rotation. At other times only daily attention was required. Analyses of neutron dosimeters contained in each capsule were conducted after each irradiation,[14] and the results were used to set the irradiation period for later capsules.

Irradiation temperatures and fast neutron fluences for each specimen are summarized in Appendix A. An extreme example of temperature distribution in a capsule is shown in Fig. 18. Temperatures ranged from 238 to 346°C (460 to 655°F) at this time in this capsule. An example of temperature distribution in the same capsule in the rotated position is given in Fig. 19. At this time temperatures ranged from 254 to 340°C (490 to 645°F). It may be noted that temperatures in the central region of the 4TC(T) crack fronts are near the desired 288°C (550°F), and the extreme temperatures were recorded for the small specimens. An example of the relationship between irradiation temperature and neutron fluence at the 4TC(T) crack front in the initial and reversed positions is shown in Fig. 9. The portion of the 4TC(T) crack front receiving the higher fluxes was near the desired 288°C (550°F) in both the initial and reversed

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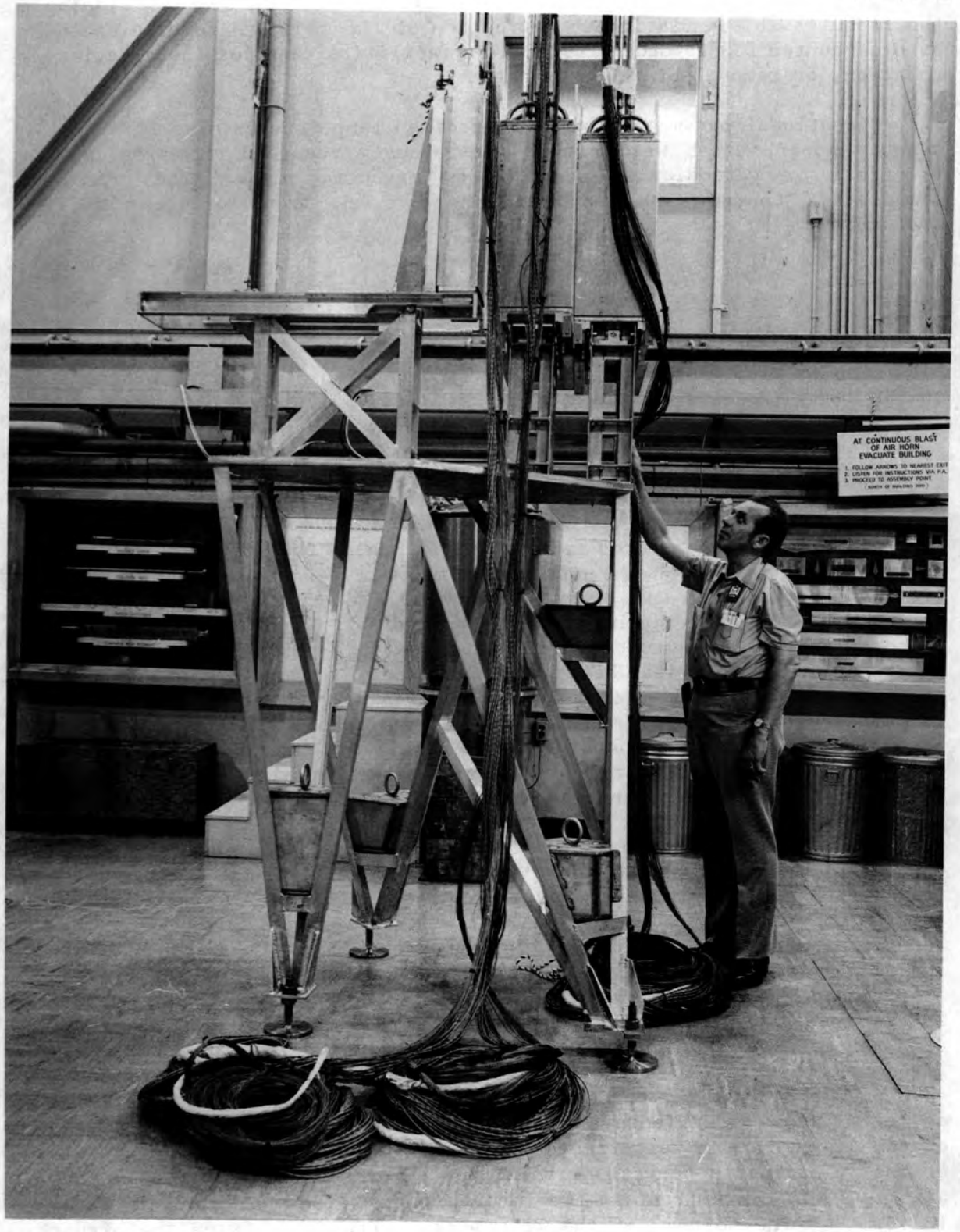

Fig. 15. Photograph showing capsules loaded in support structure.

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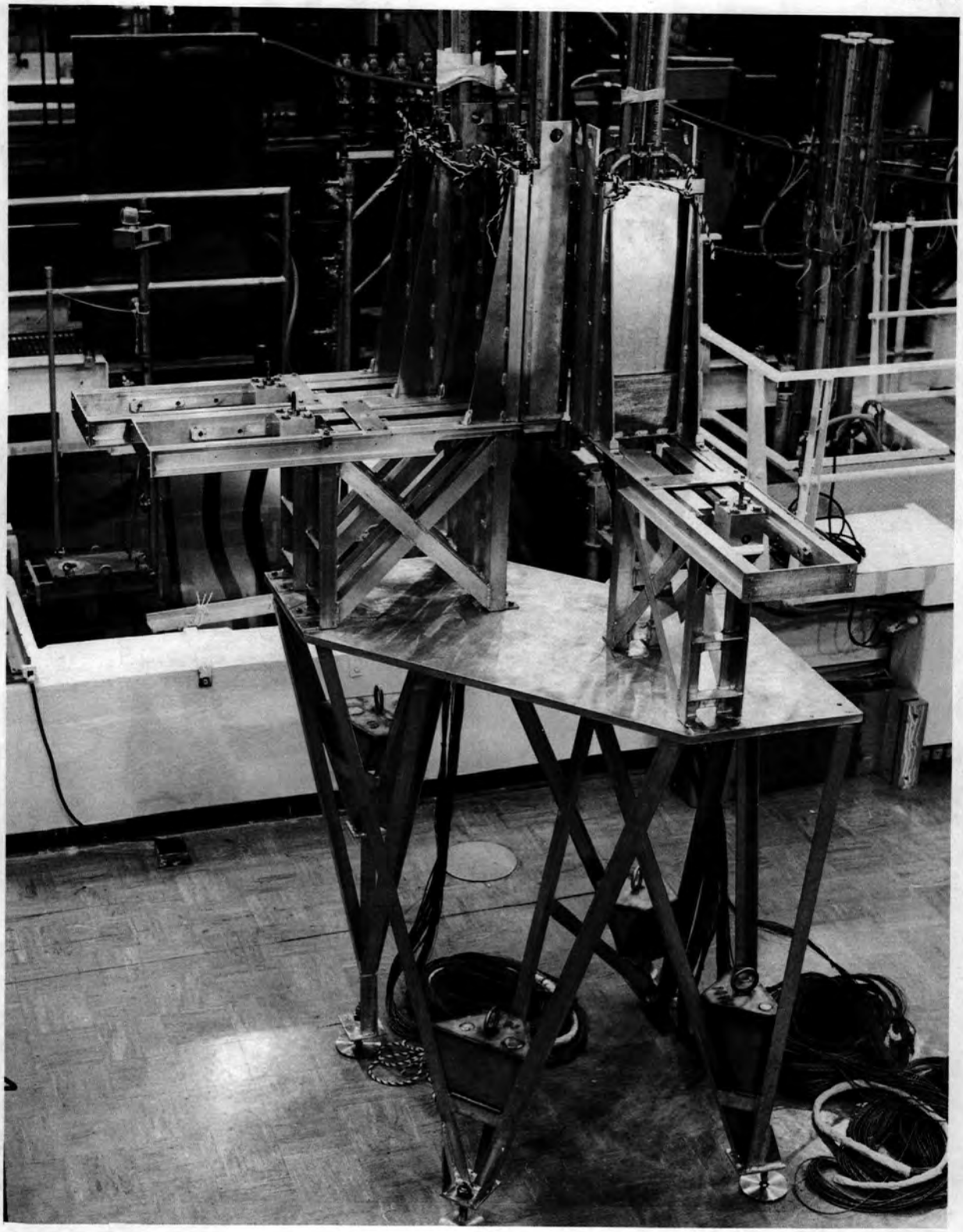

Fig. 16. Photograph of irradiation capsule support structure.

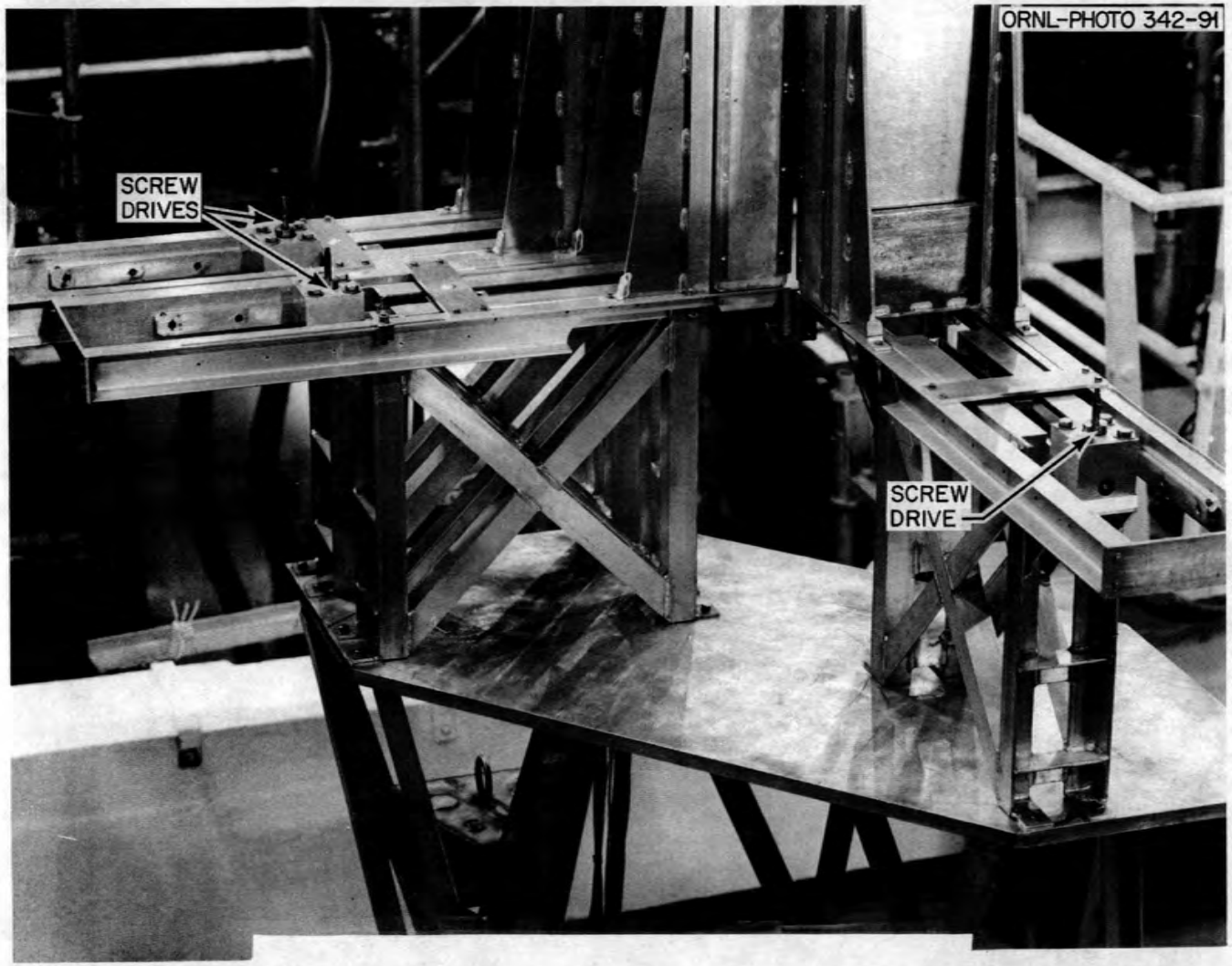

Fig. 17. Photograph of irradiation capsule support structure showing screw drives for positioning of capsules.

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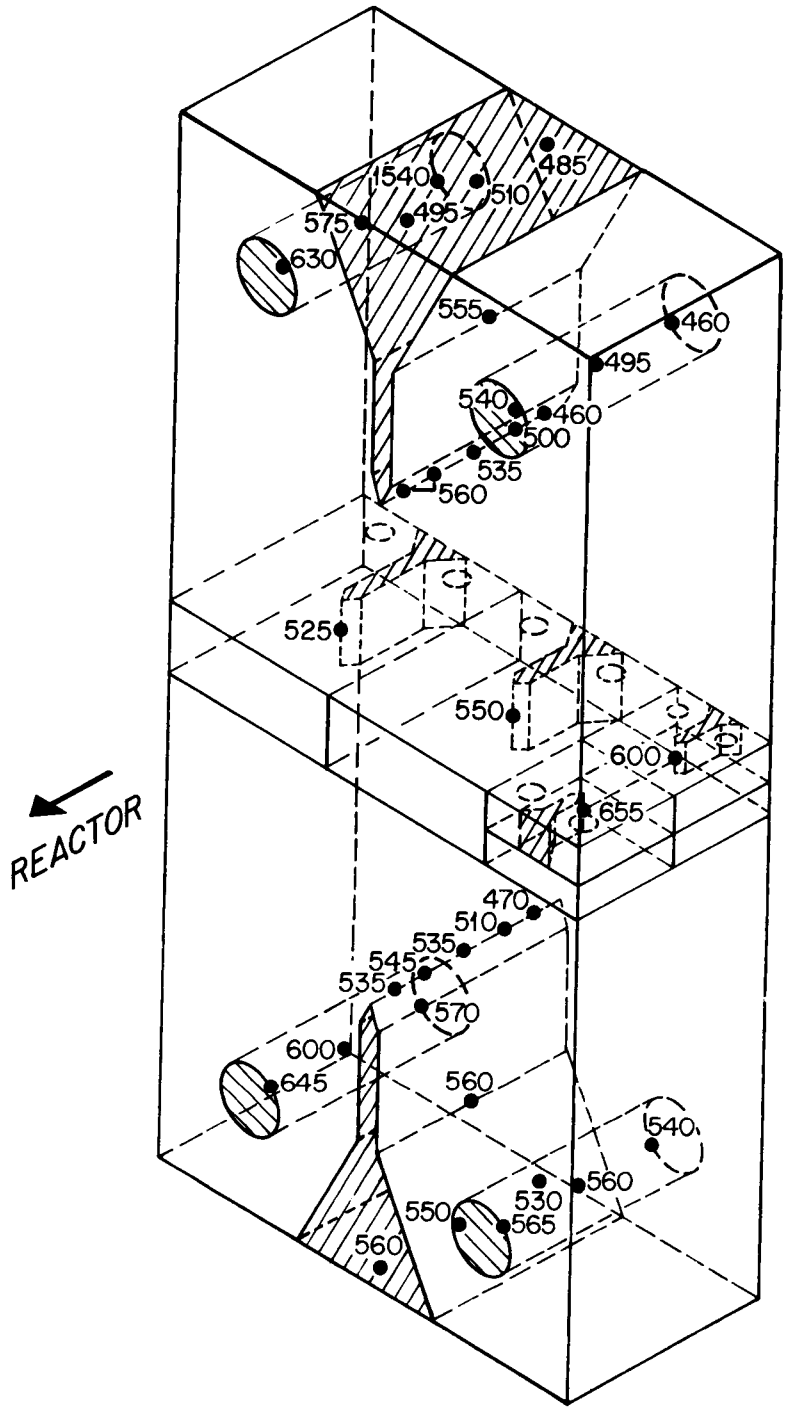

Fig. 18. Extreme example of wide temperature distribution in capsule of the Second HSSI irradiation series, forward position.

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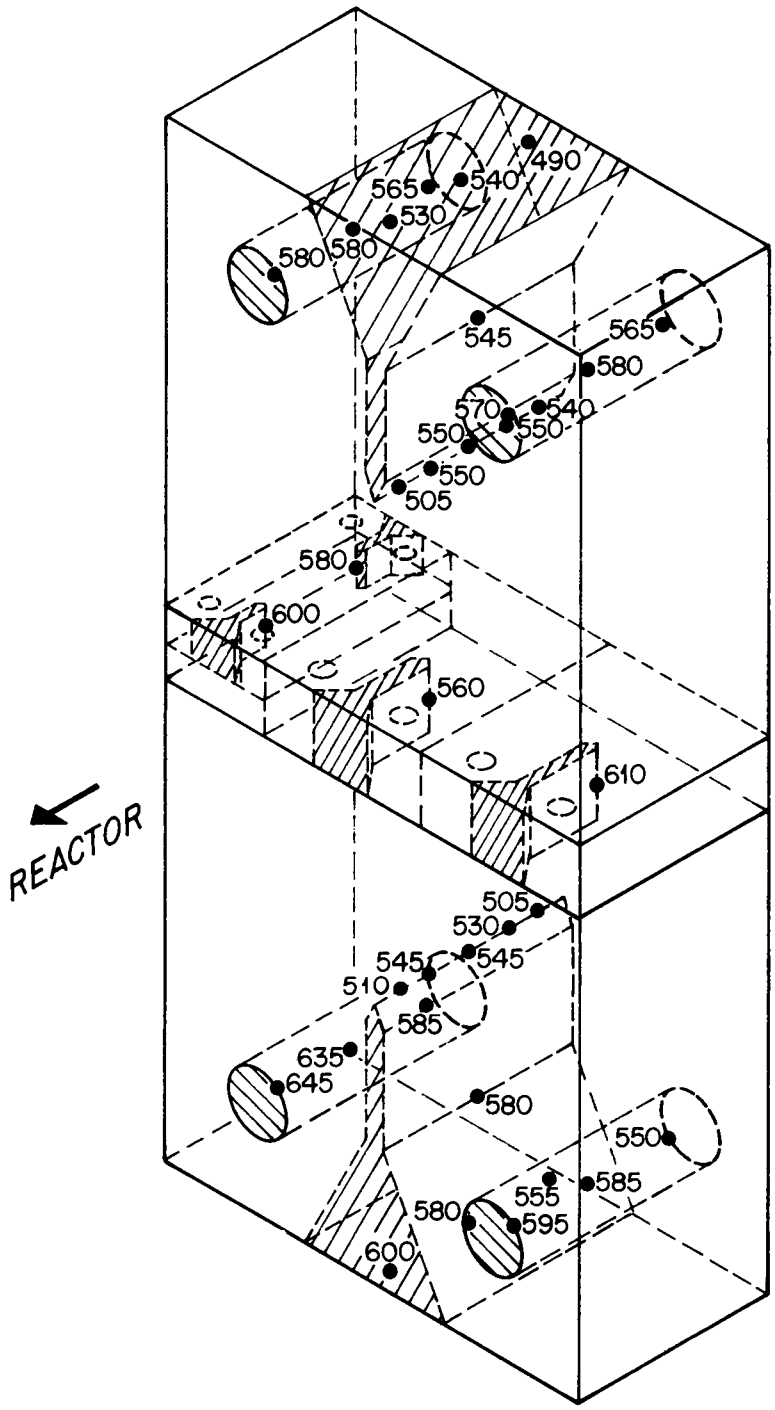


Fig. 19. Temperature distribution in capsule shown in Fig. 18, reverse position.

positions, while the portion of the crack front at lower temperatures was receiving low neutron fluxes. In addition, fast neutron fluxes varied on both horizontal and vertical planes as shown in Figs. 20 and 21.

Several problems, in addition to temperature control, were encountered in the operation of the capsules. In one of the first capsules operated, maximum electrical heat was required. This resulted in excessive heat generation in the transition connections between the sheathed and plastic-insulated, lead wire sections, melting of the plastic insulation, short circuits, and heater failure. This was repaired and operation continued. Later capsules were constructed to eliminate the problems. In another capsule, a leak developed in a lead tube, flooding the lead tube, and pool water drawn into the lead tube backed up into the exhaust plenum and down into the capsule. The leak was repaired, the capsule dried out, and operation continued. After irradiation, the lead tubes were cut off to permit transfer to the disassembly hot cell. Since it was necessary to cut the lead tubes under water, attempts were made to plug the tubes with epoxy cement before underwater cutting. This was not completely successful, and most of the capsules contained a small amount of pool water when they were opened in final disassembly. Some of the automatically recorded irradiation data could not be read by the computer due to parity errors on the magnetic tapes. These records were supplemented with manually recorded data to complete the records.

8. TEST PROCEDURES

Mechanical property tests were conducted by four laboratories: ORNL, Hanford Engineering Development Laboratory (HEDL), U.S. Naval Research Laboratory (NRL), and Materials Engineering Associates (MEA). Tensile tests of specimens from the Second HSSI Irradiation Series (welds HSST 61W, 62W, and 63W) were conducted by HEDL, and tests from the Third HSSI Irradiation Series (welds HSST 64W, 65W, 66W, and 67W) were conducted by ORNL. All CVN impact tests were conducted by ORNL. Notch-bend tests on precracked Charpy specimens from the Second HSSI Irradiation Series were completed by ORNL. The precracked Charpy specimens from the Third HSSI Irradiation Series were sent to B&W for testing (not funded as part of the HSSI Program). The results of all the precracked Charpy slow bend tests will be presented in a joint report. The initial fracture toughness tests on 0.5TC(T) specimens were conducted by HEDL and NRL, and later tests, including the larger specimen tests, were conducted by NRL and MEA.

8.1 TENSILE TESTS

The tensile test procedures used by HEDL for specimens of welds HSST 61W, 62W, and 63W are given elsewhere.[15] Tests on both unirradiated and irradiated specimens were conducted at room temperature, 149 and 288°C using an extensometer. Specimen strain rates calculated from extensometer data were in the range of 10^{-4} to 10^{-3}/s. Tensile test procedures used by

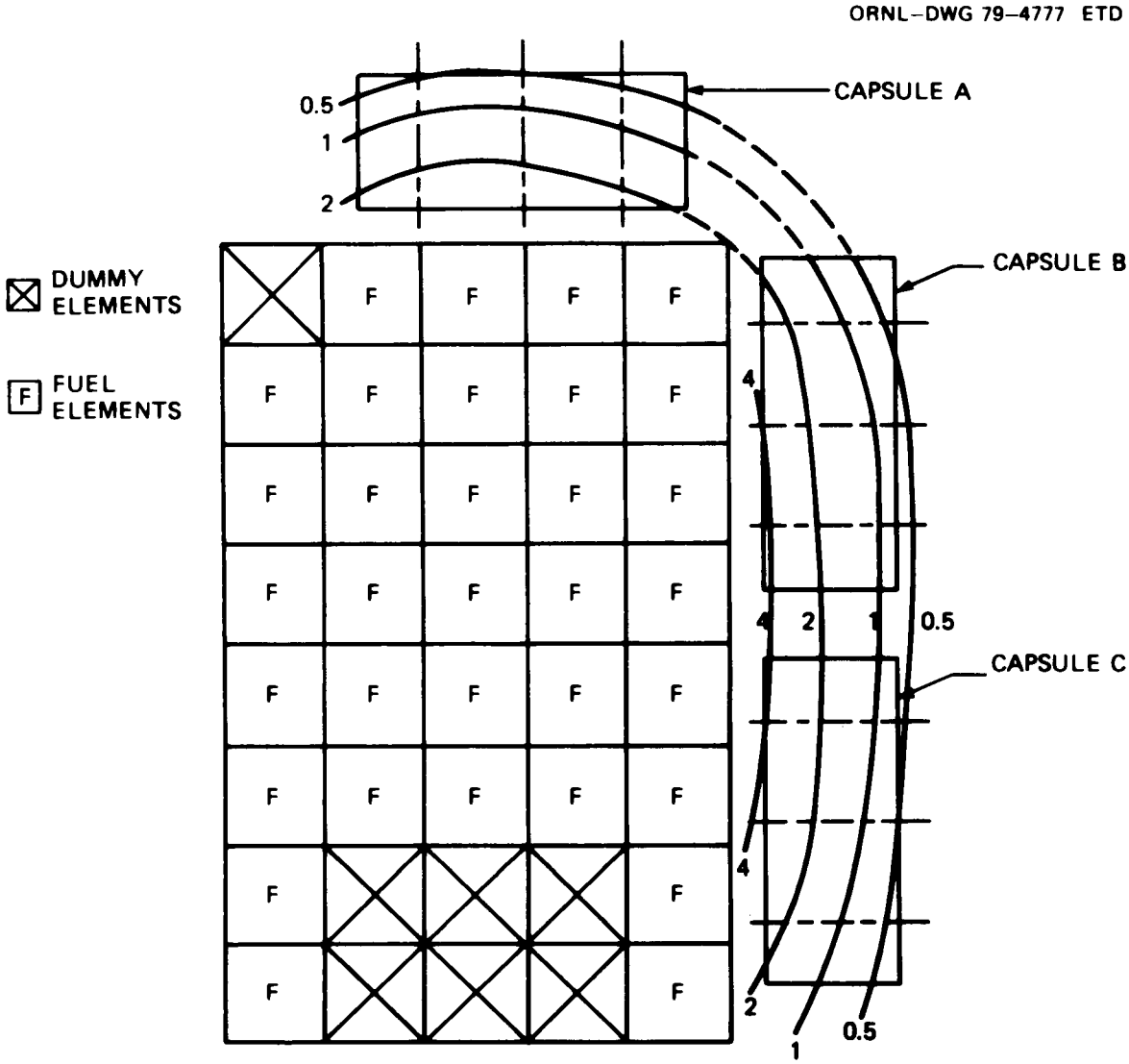
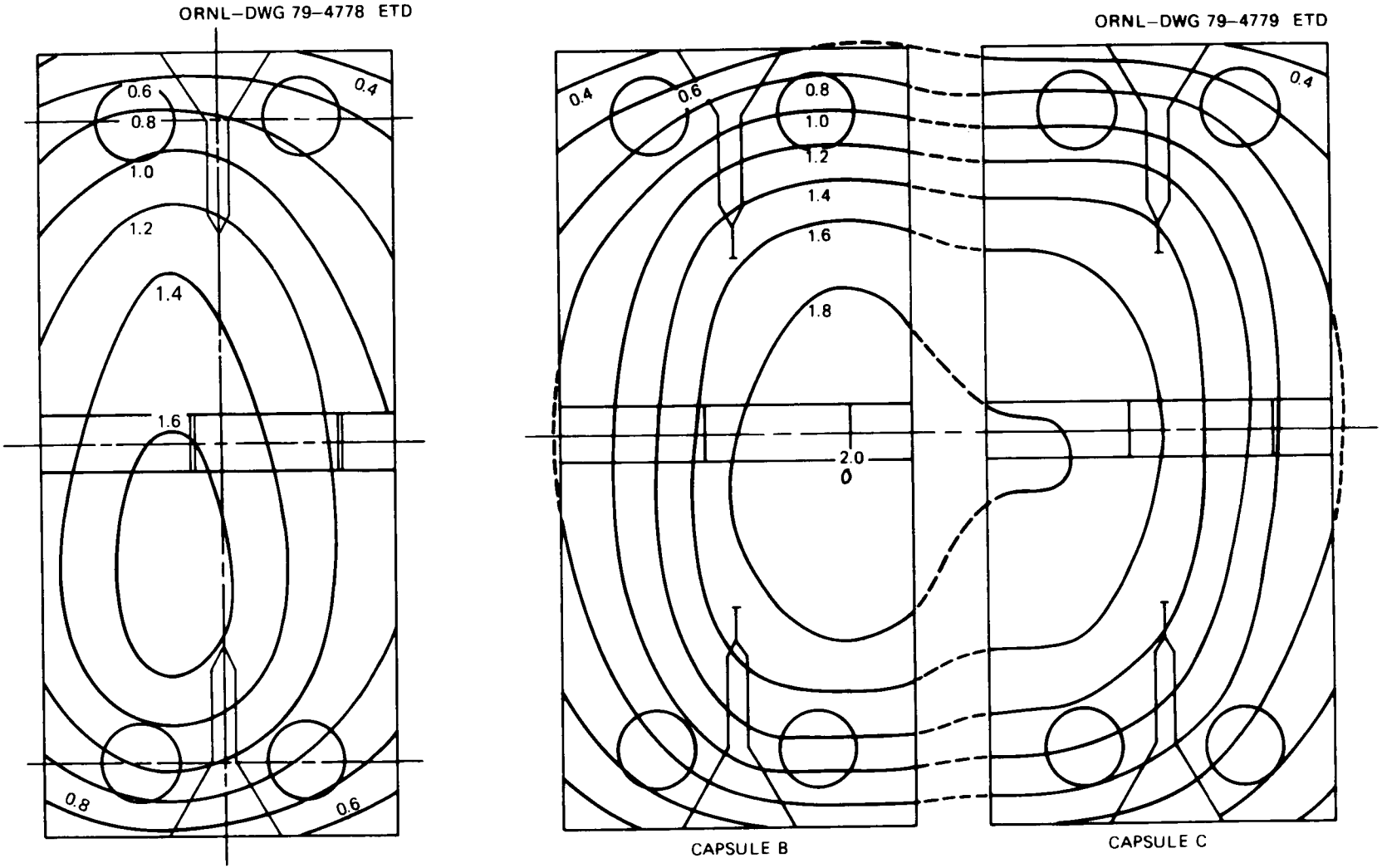


Fig. 20. Fast neutron (>1 MeV) flux ratios in the Second HSSI Irradiation Series (horizontal midplane of capsules).



(a) (b)

Fig. 21. Fast neutron (>1 MeV) flux ratios in the Second HSSI Irradiation Series, (a) vertical midplane of capsule A, and (b) vertical midplane of capsules B and C.

ORNL for specimens of welds HSST 64W, 65W, 66W, and 67W are also given elsewhere.[16] Tests at ORNL were conducted at the same temperatures used for the HEDL tests. An extensometer was not used, and yield strengths were based on crosshead displacement data. Errors in yield strength values determined from crosshead displacement were established to be less than 3% by use of an extensometer at room temperature. Specimen strain rates, based on crosshead displacements, were 2.7 to 2.9 $\times 10^{-4}$/s.

8.2 CHARPY V-NOTCH IMPACT TESTS

Charpy V-notch impact tests were conducted by ORNL in accordance with ASTM Standard Practice E 184. The testing machines were calibrated using standard specimens.[17] The testing machines were instrumented to provide load-time records for each test. The load-time records were used to estimate the percent ductile fracture in each specimen through a correlation with the fast load drop. Previous studies[18] have shown the existence of such a relationship. The procedure used herein is shown in Fig. 22, where the amount of fast load drop is divided by the maximum load in the test (assumed to represent the onset of crack extension).[19] In order to compare impact machines, the hot cell machine was also used for some of the unirradiated specimens.

8.3 COMPACT SPECIMEN TESTS

Testing of the compact specimens was initiated through a joint arrangement between HEDL and NRL. Due to the development of the J-R curve test procedure going on at the time, especially as applied to tests of irradiated specimens, the initial J-R curve data from these two laboratories, from welds 61W through 63W only, were of a relatively poor quality in comparison to the results obtained later in the program. Several of these initial tests were conducted at temperatures in the brittle-to-ductile transition region. These initial test results from NRL and HEDL have been previously published,[20,21] as were the initial irradiated 1.6T results.[22] Detailed discussion of the test and analysis procedures for the testing of compact specimens and the detailed report of fracture toughness test results by NRL and MEA have been published.[12]

9. RESULTS AND DISCUSSION

9.1 TENSILE TESTS

The results of all unirradiated tensile tests are given in Table B1 of Appendix B, while those for the irradiated specimens are given in Table B2 (tensile test results are also presented in refs. 15 and 16). Both tables provide the measured values of yield and ultimate strength,

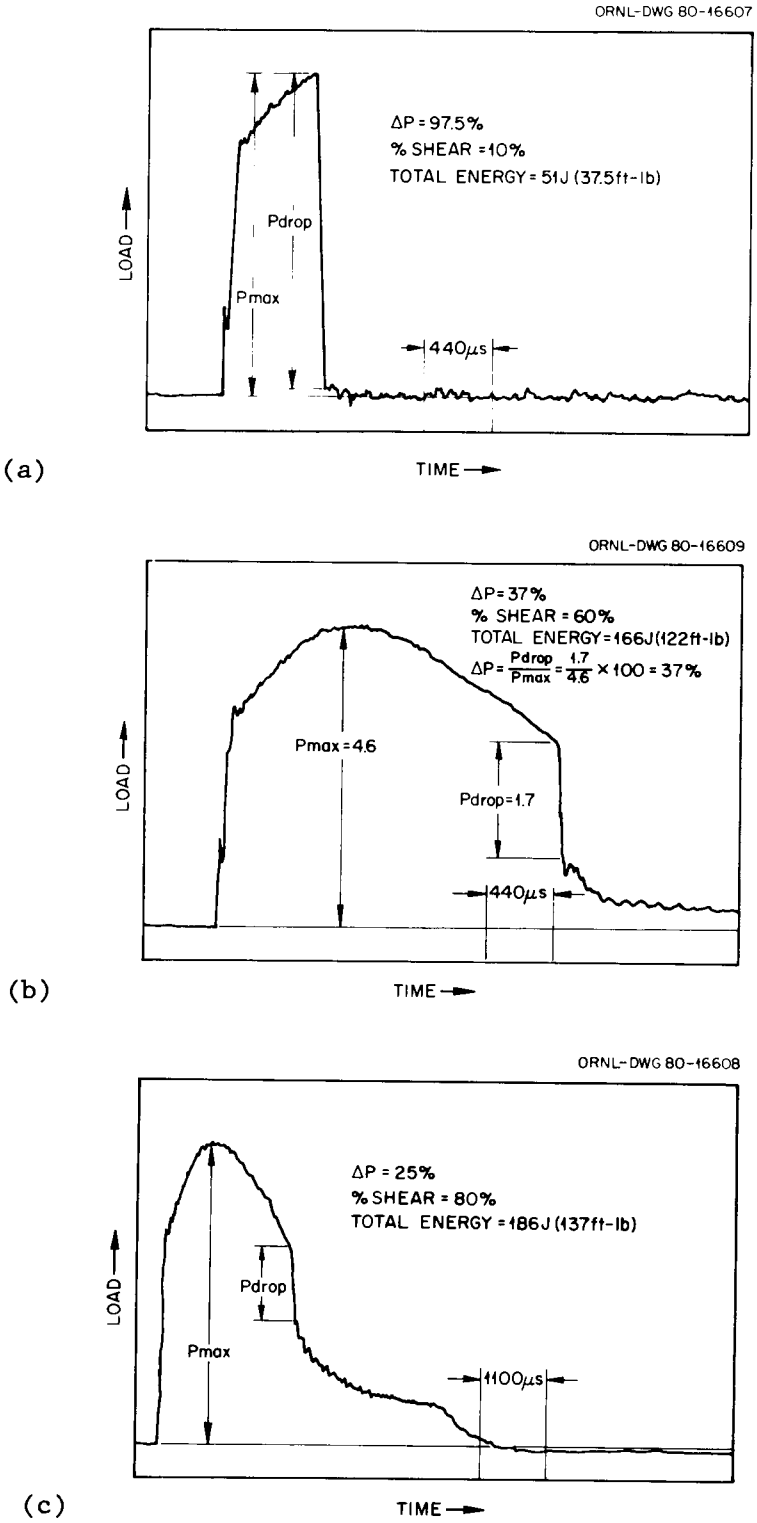


Fig. 22. Schematic showing procedure used to determine fast load drop ratio for correlation with percent shear fracture of Charpy impact specimens, (a) prior to maximum load, (b) after maximum, and (c) after maximum, showing drop is similar to that in (b) but an earlier onset of arrest as reflected by the percent shear.

reduction of area, uniform and total elongation. Table 4 provides a summary of the unirradiated results by test temperature for each weld. Additionally, Table B2 shows the irradiation-induced change in tensile properties from the average of the unirradiated specimens tested at the same nominal temperature. In addition to the actual change, the table shows the percentage change in each property. The irradiation fluence and irradiation temperature are also provided in Table B2 and, because of the relatively large variation in fluence, each irradiated tensile property was normalized to a fluence of 8×10^{18} neutrons/cm^2 to account for fluence differences. The normalization was performed by multiplying the measured property (e.g., yield strength) by the square root of the ratio of 8×10^{18} to the fluence of the specimen being normalized. An exponent of 0.5 was used for those normalizations because that is a typical value for hardening of pressure vessel steel welds irradiated in test reactors.[23] The same normalization procedure was applied to the property changes and the percent property changes. All the normalized results are given in Table B3 (as discussed later, a different normalization procedure was finally used).

Figures B1 through B22 of Appendix B provide plots of the raw unirradiated and irradiated tensile data vs test temperature as well as the irradiation-induced strength changes vs test temperature for each weld. They also show the effects of the above described normalization procedure on the yield and ultimate strengths. The best-fit curves shown are the results of polynomial regressions. The ductility values show a fairly large scatter and radiation-induced changes are not relatively great; therefore, the normalized ductility results for 61W are not presented graphically and none of the irradiated ductility results for welds 62W through 67W are graphically presented. They are, however, given in Table B3. That normalization procedure was not successful due to the insufficient number of data points with common exposure and test conditions and, as will be discussed later, a different procedure was used in which normalization for fluence was performed after adjusting for irradiation temperature.

As stated earlier, the irradiation temperatures for the various tensile specimens were quite varied. Attempts to analyze the normalized tensile results, as a function of irradiation temperature over the entire range of irradiation temperature for each weld, were not very successful because of the limited data for each combination of irradiation temperature and test temperature. Figures B23 through B26 show plots of the yield and ultimate strengths and the irradiation-induced strength changes, observed as well as normalized, as a function of irradiation temperature for welds 61W through 63W. For welds 64W through 67W, the irradiation temperature range was not adequate for this analysis. Although the scatter in results is large, the effects of irradiation temperature are generally the same. The general trend is that of decreasing strength change as irradiation temperature increases. There are data from some groups of tests conducted in sufficient numbers at the same test temperature that, after normalizing for fluence, could be analyzed for the effects of irradiation temperature. For 61W through 63W, irradiated tests conducted at room temperature were examined. For

Table 4. Summary of unirradiated tensile results for HSSI welds 61W through 67W

Weld	Test temperature (°C)	Strength (MPa)		Uniform strain (%)	Reduction in area (%)	Total elongation (%)
		Yield	Ultimate			
61W	26	480	599	10.4	65.8	18.4
	149	444	548	8.3	65.4	17.7
	288	418	536	7.0	63.8	16.0
62W	26	473	591	9.9	66.0	18.8
	149	428	534	9.4	68.6	15.8
	288	385	514	8.0	63.5	14.7
63W	26	482	600	10.2	66.4	20.4
	149	432	545	8.6	67.2	18.0
	288	410	530	7.6	63.4	16.6
64W	27	465	580	9.9	64.8	18.9
	150	417	530	9.7	66.5	17.8
	288	398	543	8.9	54.7	15.4
65W	27	457	571	9.7	65.1	18.1
	150	423	533	7.7	64.2	15.3
	288	412	549	8.2	58.0	14.8
66W	27	534	639	7.6	63.4	16.0
	150	506	597	6.7	64.2	14.1
	288	498	608	6.6	46.6	12.2
67W	27	462	583	9.4	66.5	17.9
	150	429	542	6.8	65.5	14.3
	288	430	562	9.9	57.9	13.5

64W through 67W, the greatest number of specimens tested at any one temperature was three and the irradiation temperatures were sufficiently close that regression analysis was not appropriate. In general, normalizing for fluence appears to have reduced the slope of the property change vs irradiation temperature curve for those three welds. Table B4 gives the results of linear regression analyses performed on each set of raw and normalized properties. The standard errors for most of the cases are relatively large, although some groups of test results are amenable to analysis.

Because the normal operating temperature of RPVs is considered to be 288°C, the tensile data were analyzed to allow for estimates of the irradiation-induced increases in the yield and ultimate strengths at the irradiation temperature of 288°C. Not all of the welds were represented by adequate numbers of test results for such analysis. For weld 61W, for example, this analysis required fitting the averaged and normalized results from 276 to 345°C and interpolating at 288°C. Table B5 gives the results of those estimates and, for welds 61W through 63W tested at room temperature, shows yield strength increases (using normalized results) from 103.7 to 135 MPa with ultimate strength increases from 83.3 to 112.9 MPa. In all three cases, the estimates of yield and ultimate strength increases at an irradiation temperature of 288°C were lower using the normalized properties compared to those using the observed properties. This is expected because the normalization fluence is lower than the observed fluences.

To provide a comprehensive analysis of all the tensile results for the seven welds, the results for 61W through 63W were used to obtain average changes vs irradiation temperature. Only the tests at room temperature were used because the number of test results were adequate for obtaining good regression results. The resulting average changes were -1.15 MPa/°C for yield strength, -0.79 MPa/°C for ultimate strength, and -0.014%/°C for total elongation. Table 5 provides a summary of the irradiated tensile results for each weld adjusted to an irradiation temperature of 288°C. The results not annotated were taken directly from the actual value column (obtained from the regression analysis) in Table B5. The annotated results were obtained by adjusting the observed test results in Table B2 for irradiation temperature using the multipliers given above. Figures 23 through 29 are plots of all the unirradiated results and the averaged irradiated results adjusted for an irradiation temperature of 288°C. The fluences are varied and the average values are given in Table 5. Then, because the available data were not generally adequate for fluence normalization using the individual data points as described earlier, all the data from Table 5 were adjusted to a fluence of 8×10^{18} neutrons/cm^2. Using the typical square root dependence on fluence for the irradiation-induced yield strength change resulted in strength increases which did not appear reasonable. Thus, the irradiation-induced yield strength changes obtained at an irradiation temperature of 288°C (±4°C) were plotted vs neutron fluence and fit to a power curve. The result showed a very low dependence on fluence for these welds over the fluence range examined. The exponent obtained by the analysis was 0.07 and the differences in strength (the ultimate strength

Table 5. Summary of irradiated tensile results for HSSI welds 61W through 67W adjusted to an irradiation temperature of 288°C

Weld	Test temperature (°C)	Fluence ($\times 10^{-18}$ n/cm^2)	Number of tests	Strength[a] (MPa)		Total elongation[a] (%)
				Yield	Ultimate	
61W	30	9.2	6	628	723	17.7
	150	11.9	1	562[b]	663[b]	17.3[b]
	288	9.5	2	527	647	16.4
62W	30	11.4	5	606	697	19.0
	150	10.2	2	537[c]	631[c]	15.4[c]
	288	9.3	2	479[c]	605[c]	15.4[c]
63W	30	9.0	6	619	709	16.9
	150	13.1	1	576[d]	675[d]	15.6[d]
	288	8.3	2	523	640	16.9
64W	30	4.6	2	596	691	17.1
	150	6.4	1	506[e]	614[e]	14.6[e]
	288	4.5	3	526	658	12.8
65W	30	4.8	2	560	660	18.4
	150	4.9	2	467	623	16.3
	288	5.2	3	508	638	15.6
66W	30	6.4	2	643[f]	724[f]	16.4[f]
	150	6.0	2	596[g]	684[g]	13.2[g]
	288	7.0	2	582	683	10.7
67W	30	1.8	1	608[h]	687[h]	15.3[h]
	150	4.8	2	552[i]	645[i]	13.6[i]
	288	6.9	3	531	656	13.3

[a]Insufficient data for regression at the irradiation temperatures indicated below. Results shown were adjusted by -1.146 MPa/°C for yield strength, -0.7907 MPa/°C for ultimate strength, and -0.0136%/°C for total elongation.

[b]277°C.

[c]272°C.

[d]279°C.

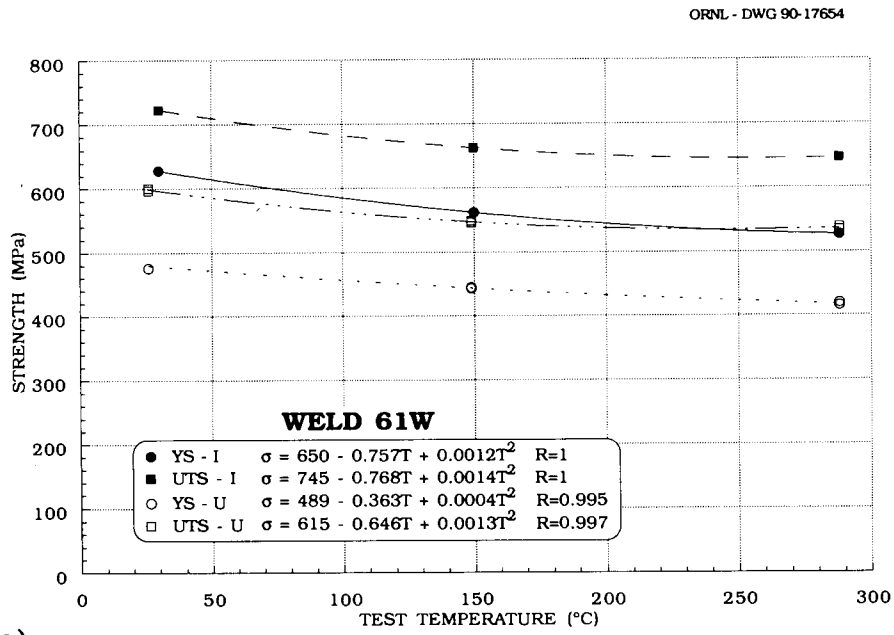
[e]273°C.

[f]280°C.

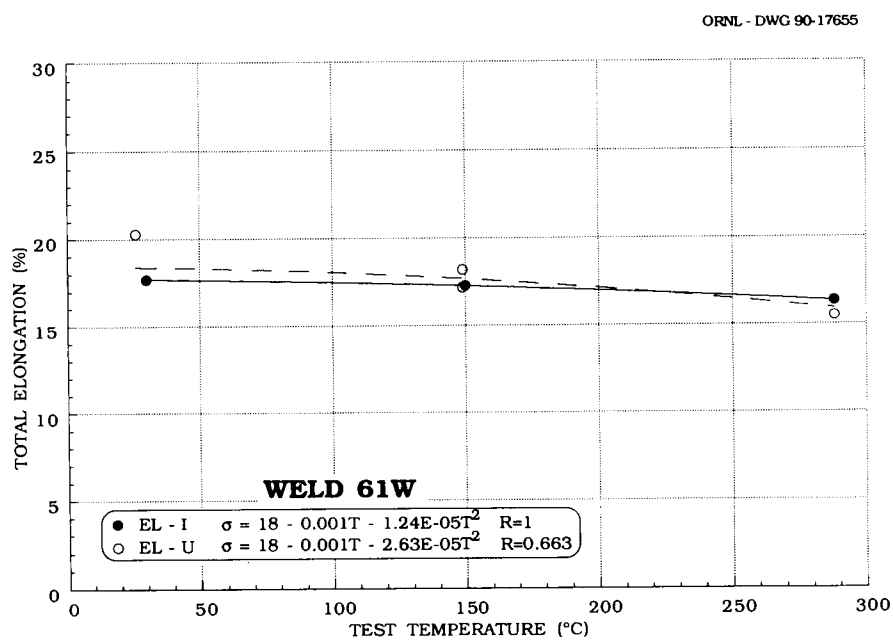
[g]284°C.

[h]284°C.

[i]282°C.

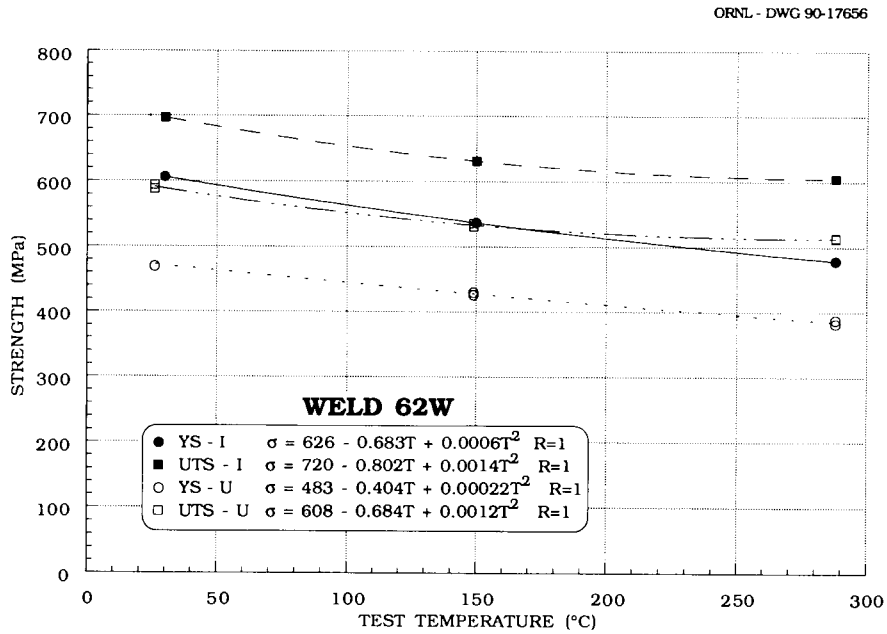


(a)

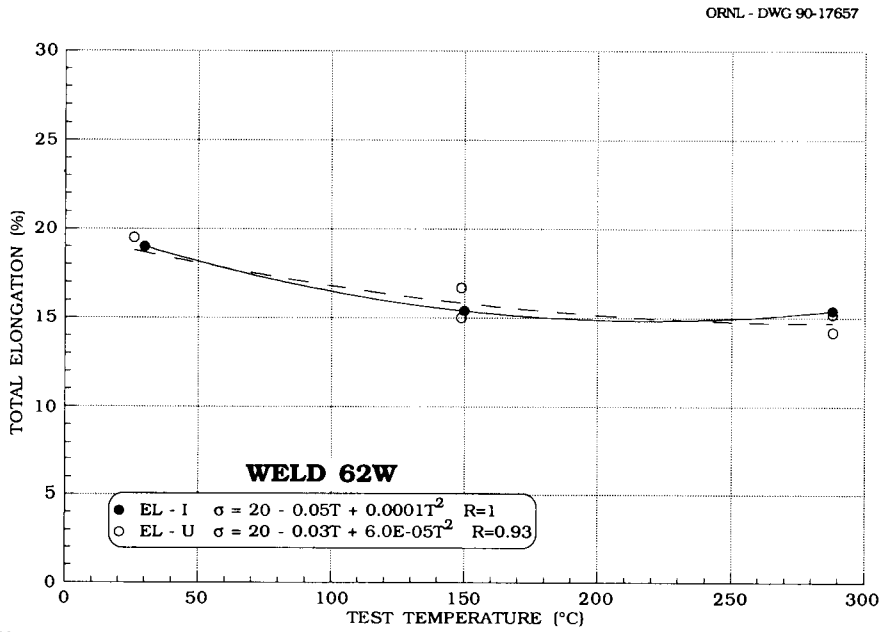


(b)

Fig. 23. Unirradiated and average of irradiated tensile results for HSSI weld 61W at an average fluence of 10.2×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

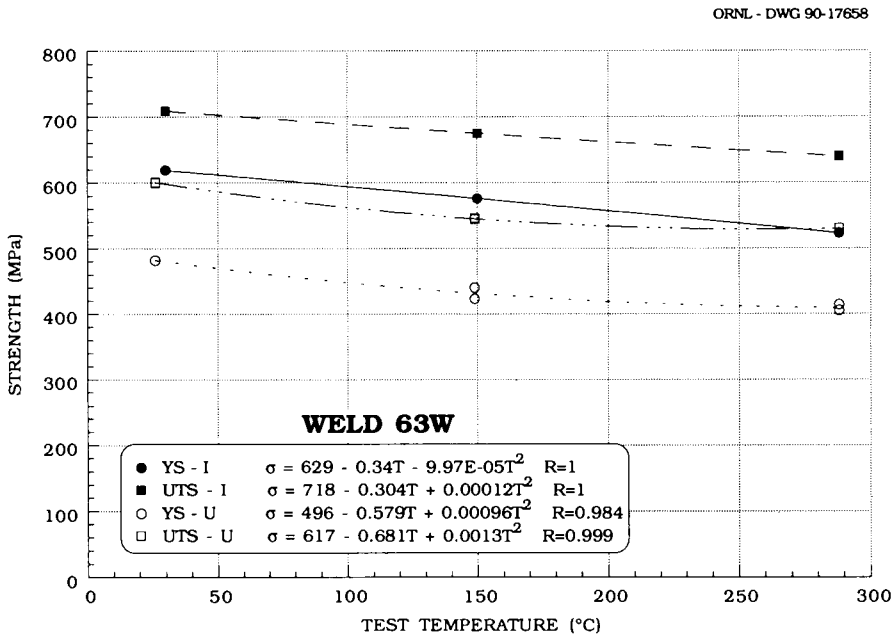


(a)

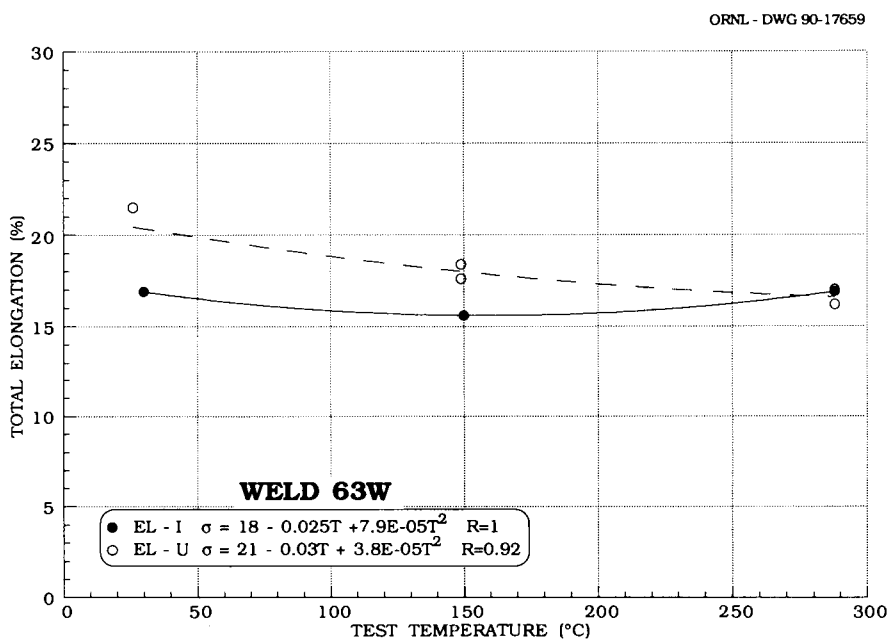


(b)

Fig. 24. Unirradiated and average of irradiated tensile results for HSSI weld 62W at an average fluence of 10.3×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

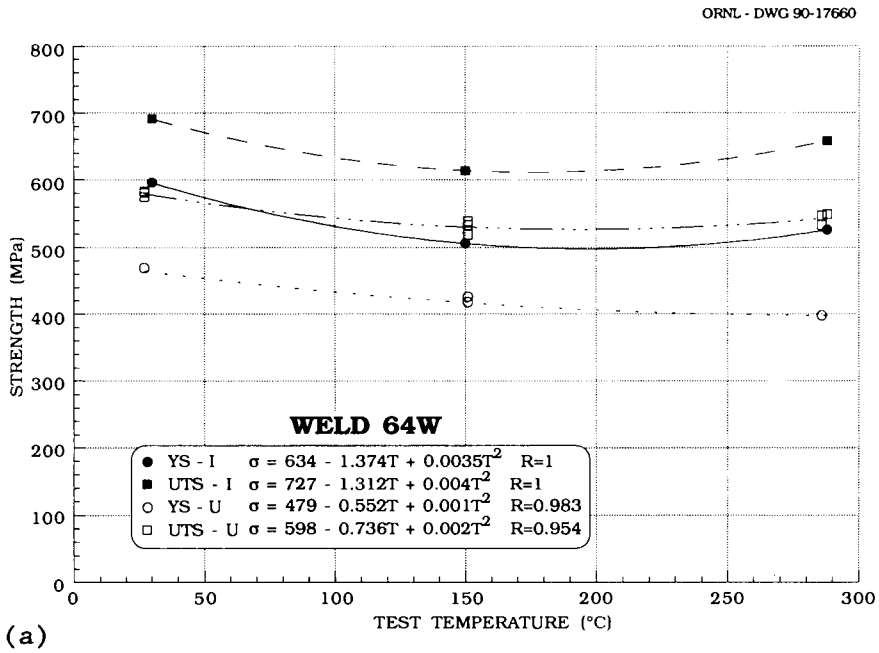


(a)

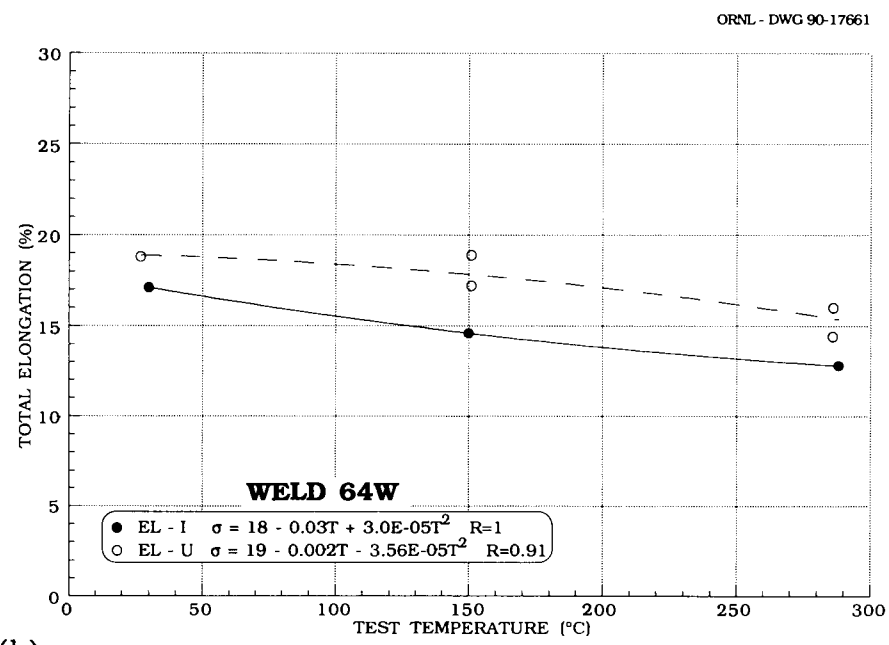


(b)

Fig. 25. Unirradiated and average of irradiated tensile results for HSSI weld 63W at an average fluence of 10.1×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

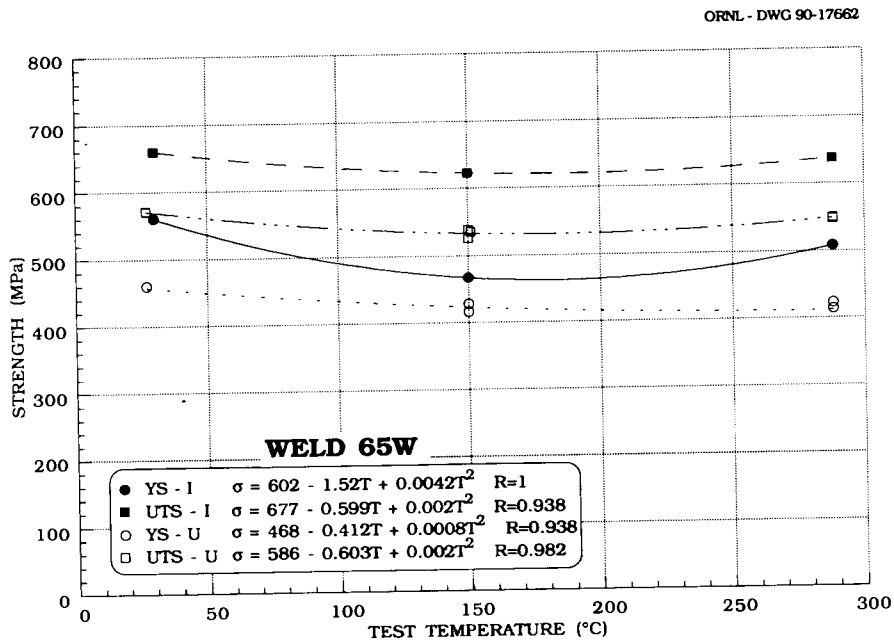


(a)

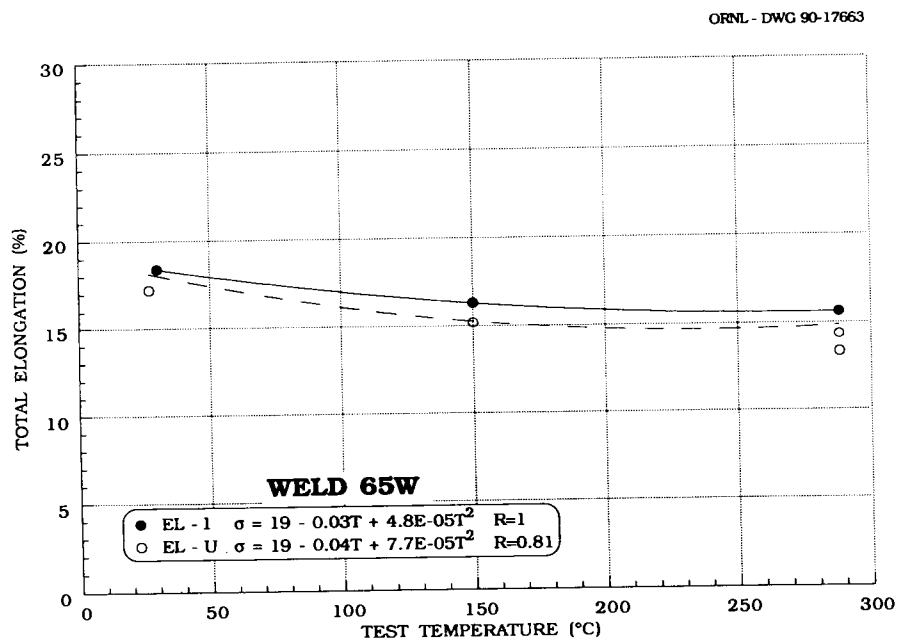


(b)

Fig. 26. Unirradiated and average of irradiated tensile results for HSSI weld 64W at an average fluence of 5.2×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

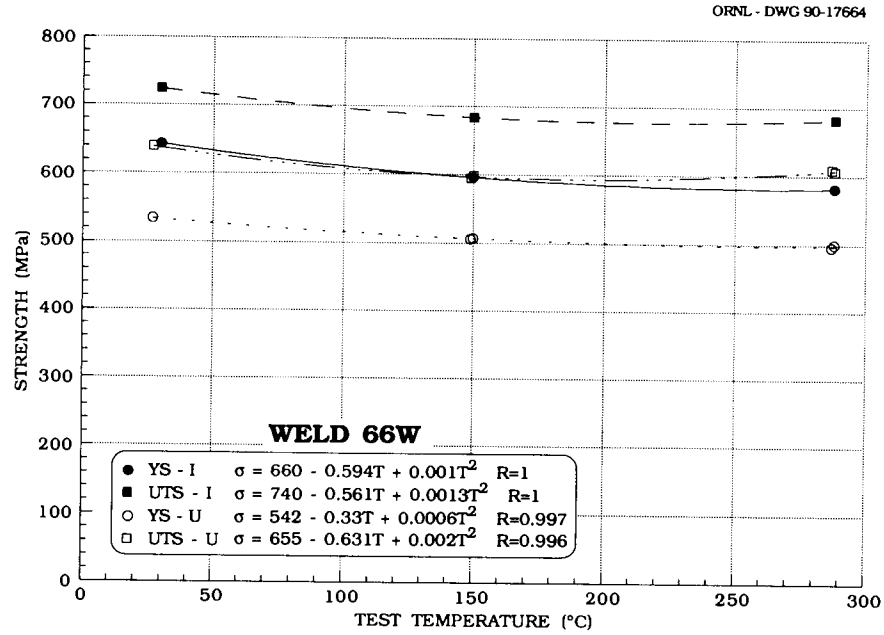


(a)

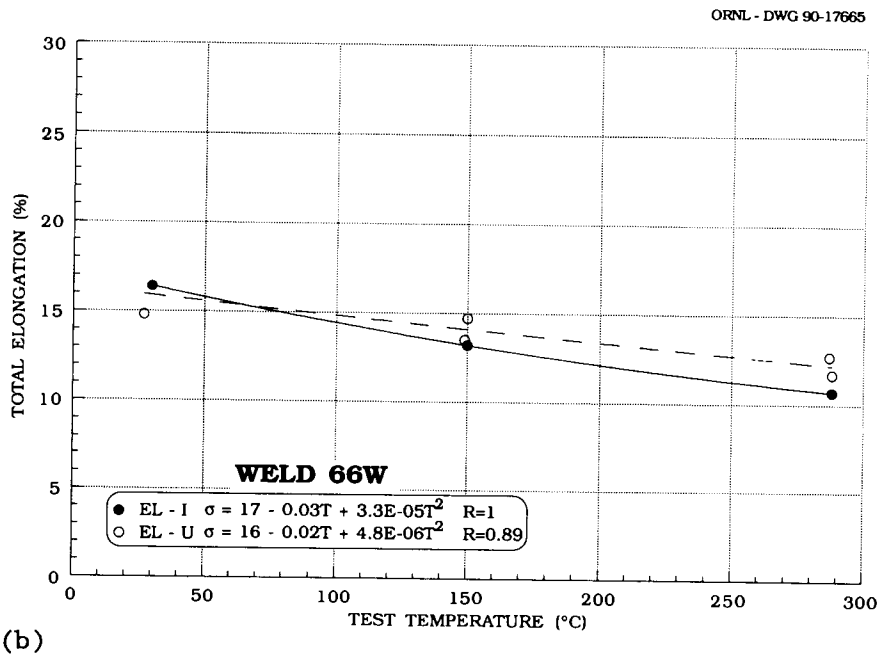


(b)

Fig. 27. Unirradiated and average of irradiated tensile results for HSSI weld 65W at an average fluence of 5.0×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

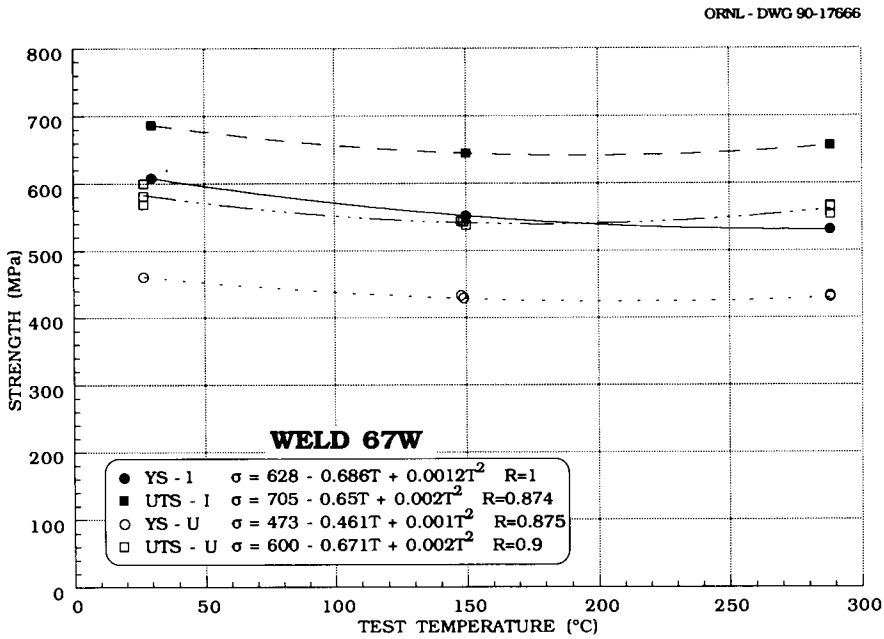


(a)

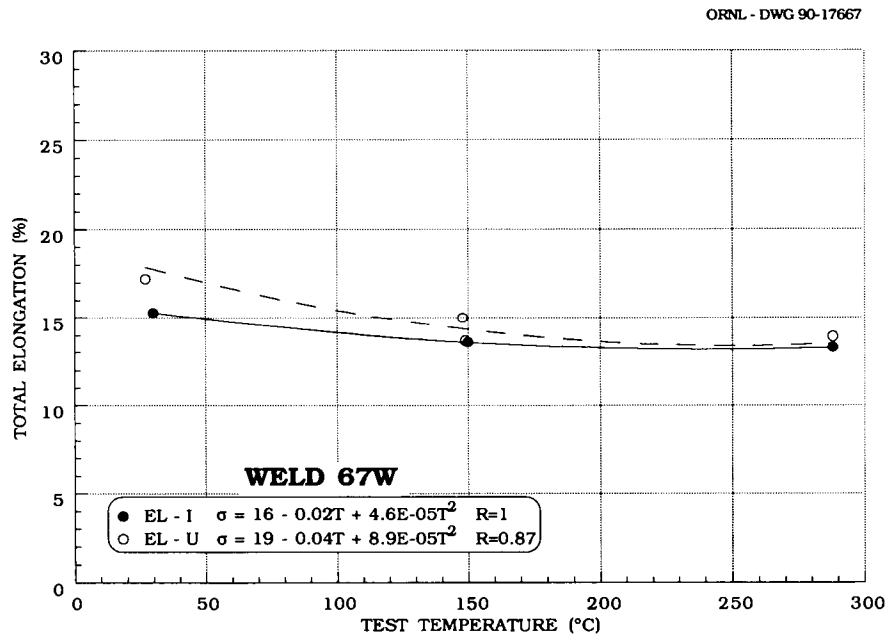


(b)

Fig. 28. Unirradiated and average of irradiated tensile results for HSSI weld 66W at an average fluence of 6.5×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.



(a)



(b)

Fig. 29. Unirradiated and average of irradiated tensile results for HSSI weld 67W at an average fluence of 4.5×10^{18} neutrons/cm^2 (>1 MeV) after adjustment for irradiation temperature to 288°C, (a) yield and ultimate tensile strengths, and (b) total elongation. The equations of fit shown in the legend are represented by the curves drawn on the graph.

changes were normalized using the same factor) between the unirradiated values in Table 4 and the irradiated values in Table 5 were multiplied by the factor $(8 \times 10^{18}/\text{average fluence})^{0.07}$. In this way, a consistently analyzed set of tensile results are presented in Table 6 for all seven welds and represent best estimates of the tensile properties for welds 61W through 67W irradiated at 288°C to a fluence of 8×10^{18} neutrons/cm^2. Figures 30 through 36 provide plots of the normalized results compared to the unirradiated curves. The total elongation results were not normalized for fluence. With two exceptions, most likely due to data scatter, the results are consistent.

The final adjusted results were all fit with second-order polynomials and the curve-fit coefficients are given in Table 7. Table 8 provides a summary of the radiation-induced changes in the yield and ultimate strengths of those welds, expressed both in terms of the measured strength changes and as percentage changes at the three nominal test temperatures. As the table shows, irradiation-induced strength increases at room temperature range from 107 to 162 MPa for yield strength and from 86 to 123 MPa for ultimate strength. Relative to the unirradiated strengths, those changes represent increases of 20.8 to 35.1% for yield strength and 13.5 to 20.5% for ultimate strength. Thus, the changes in yield strength were greater than those for ultimate strength, as is usually observed.

9.2 CHARPY V-NOTCH IMPACT TESTS

The results of all unirradiated (controls) CVN tests for HSST welds 61W through 67W are given in Tables B6 through B12 of Appendix B. As mentioned earlier, some unirradiated specimens from each weld were tested on the machine in the hot cell to allow for a determination of machine differences. The second column in each table indicates the applicable test machine. Figures 37(a-d) show plots of the CVN energy vs test temperature for unirradiated weld 61W. The curves shown are fits to the data using a hyperbolic tangent function which includes partial differentials to allow for a sloping upper shelf. Figure 37(c) shows the curve fit using all the data while Fig. 37(d) shows a comparison of the three curves. As expected, the curve using all the data falls between the other two curves. The upper-shelf energy determined on the hot cell machine is 85 J. Figures 38 through 43 show the results for welds 62W through 67W in a similar fashion. With the exception of 65W and 67W, the curves for the tests performed in the hot cell are consistently lower in the ductile-shelf region than those for the laboratory tests. Both machines were calibrated according to the requirements of ASTM E 184, and the reasons for the disparity are unknown. For 65W and 67W, the curves are essentially the same. Note that for 64W and 67W, the number of specimens tested on the ductile shelf in the hot cell was low and resulted in decreasing curves in the ductile-shelf region. Because the tests for both welds in the laboratory showed increasing curves in the upper-shelf region, the hot cell curve for each weld was modified to have the same slope as that for the corresponding laboratory curve. The 41-J transition temperatures are varied and, because testing in the lower

Table 6. Summary of irradiated tensile results for HSSI welds 61W through 67W adjusted to an irradiation temperature of 288°C and fluence of 8×10^{18} neutrons/cm^2

Weld[a]	Test temperature (°C)	Number of tests	Strength (MPa)		Total elongation (%)
			Yield	Ultimate	
61W	30	6	626	722	17.7
	150	1	559	660	17.3
	288	2	526	646	16.4
62W	30	5	603	694	19.0
	150	2	535	630	15.4
	288	2	478	604	15.4
63W	30	6	618	708	16.9
	150	1	571	671	15.6
	288	2	523	640	16.9
64W	30	2	601	695	17.1
	150	1	507	615	14.6
	288	3	531	663	12.8
65W	30	2	564	663	18.4
	150	2	468	626	16.3
	288	3	511	641	15.6
66W	30	2	645	725	16.4
	150	2	598	686	13.2
	288	2	583	684	10.7
67W	30	1	624	698	15.3
	150	2	557	649	13.6
	288	3	532	657	13.3

[a]For actual neutron fluences, see Table 5.

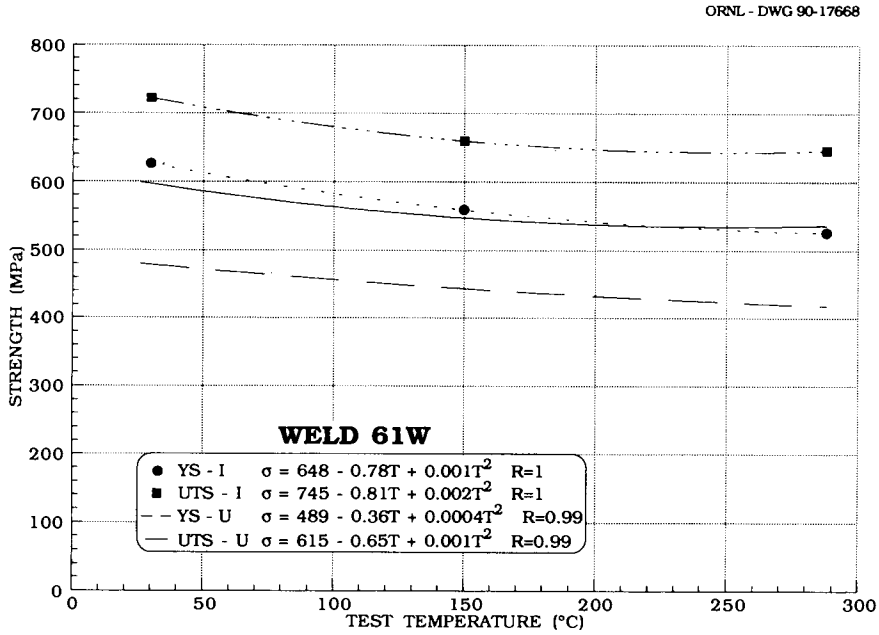


Fig. 30. Average of irradiated yield and ultimate strengths for HSSI weld 61W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

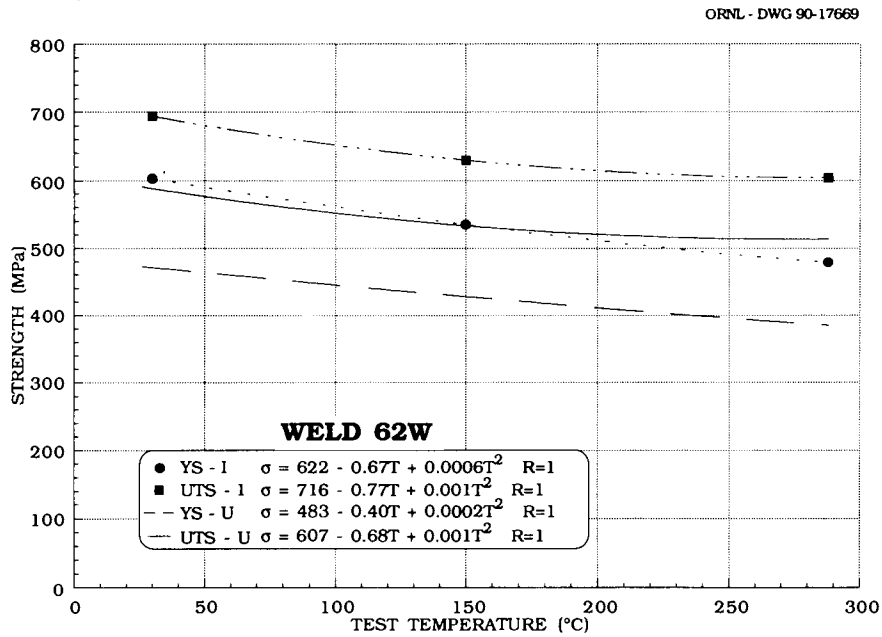


Fig. 31. Average of irradiated yield and ultimate strengths for HSSI weld 62W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

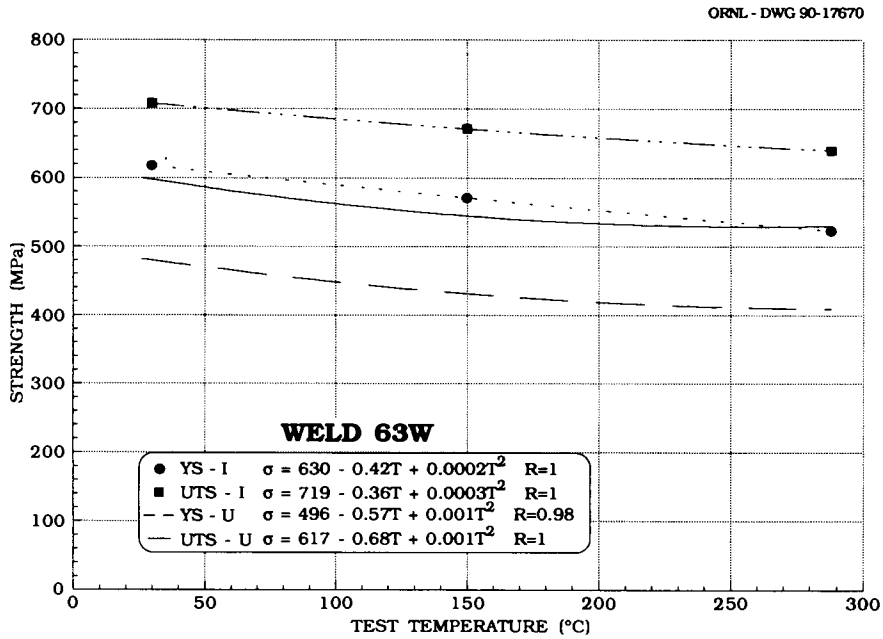


Fig. 32. Average of irradiated yield and ultimate strengths for HSSI weld 63W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

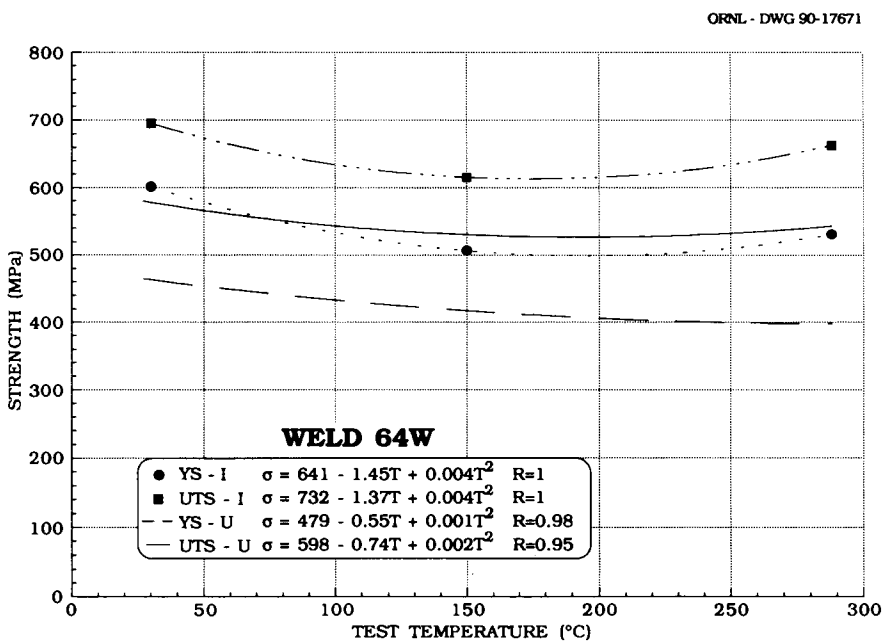


Fig. 33. Average of irradiated yield and ultimate strengths for HSSI weld 64W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

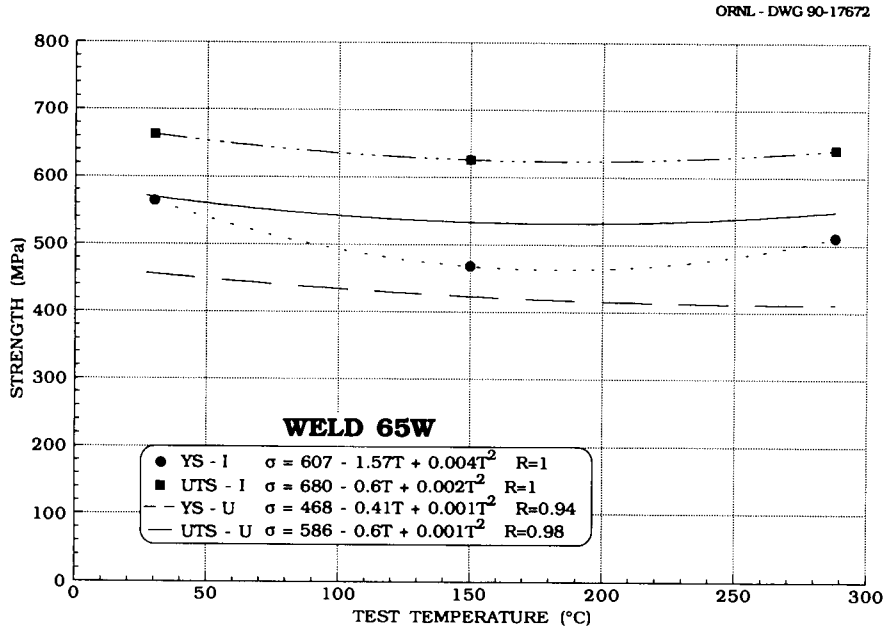


Fig. 34. Average of irradiated yield and ultimate strengths for HSSI weld 65W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

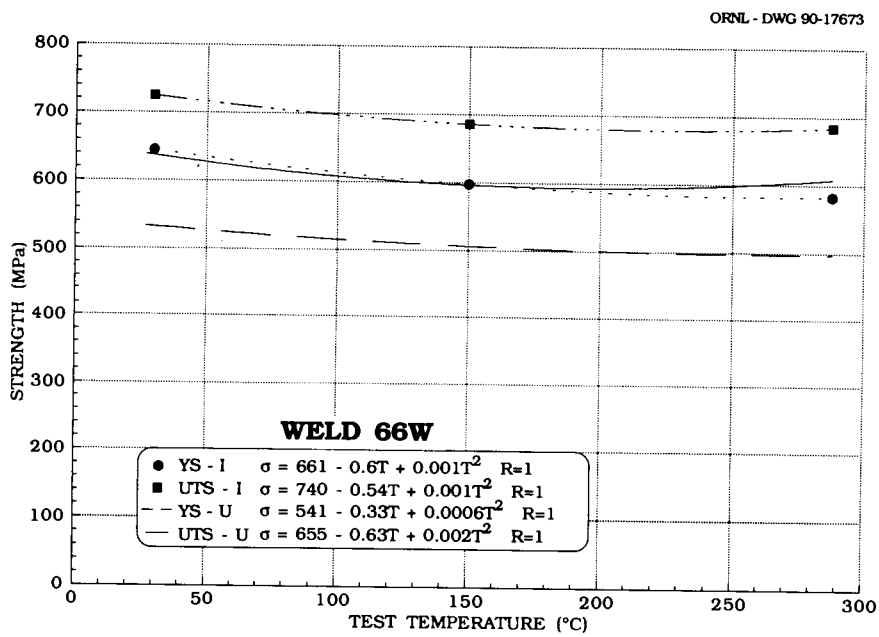


Fig. 35. Average of irradiated yield and ultimate strengths for HSSI weld 66W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

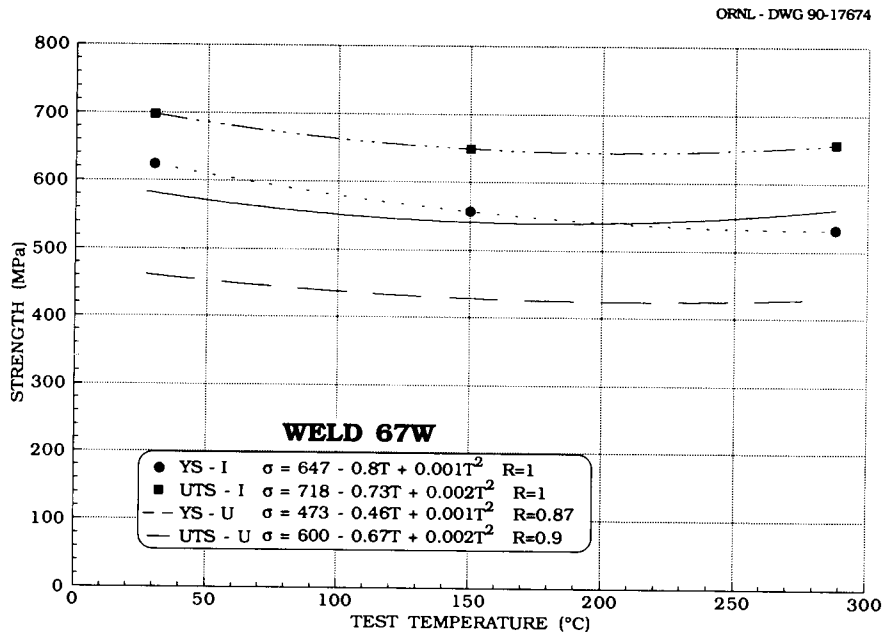


Fig. 36. Average of irradiated yield and ultimate strengths for HSSI weld 67W after adjustment for irradiation temperature to 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The unirradiated curves are shown for comparison and the equations of fit shown in the legend are represented by the curves drawn on the graph.

Table 7. Curve-fit coefficients for yield and ultimate strengths of HSSI welds 61W through 67W

Weld	Fluence ($n/cm^2 \times 10^{-18}$)	Strength[a]					
		Yield			Ultimate		
		A	B	C	A	B	C
61W	0	489	-0.363	0.0004	615	-0.646	0.0013
62W	0	483	-0.404	0.00022	608	-0.684	0.0012
63W	0	496	-0.579	0.00096	617	-0.681	0.0013
64W	0	479	-0.552	0.001	598	-0.736	0.002
65W	0	468	-0.412	0.0008	586	-0.603	0.002
66W	0	542	-0.33	0.0006	655	-0.631	0.002
67W	0	473	-0.461	0.001	600	-0.671	0.002
61W[b]	10.2	650	-0.757	0.0012	745	-0.768	0.0014
62W[b]	10.3	626	-0.683	0.0006	720	-0.802	0.0014
63W[b]	10.1	629	-0.34	-0.00001	718	-0.304	0.0012
64W[b]	5.2	634	-1.374	0.0035	727	-1.312	0.004
65W[b]	5.0	602	-1.52	0.0042	677	-0.599	0.002
66W[b]	6.5	660	-0.594	0.001	740	-0.561	0.0013
67W[b]	4.5	628	-0.686	0.0012	705	-0.65	0.002
61W[c]	8.0	648	-0.78	0.001	745	-0.81	0.002
62W[c]	8.0	622	-0.67	0.0006	716	-0.77	0.001
63W[c]	8.0	630	-0.42	0.0002	719	-0.36	0.0003
64W[c]	8.0	641	-1.45	0.004	732	-1.37	0.004
65W[c]	8.0	607	-1.57	0.004	680	-0.60	0.002
66W[c]	8.0	661	-0.60	0.001	740	-0.54	0.001
67W[c]	8.0	647	-0.80	0.001	718	-0.73	0.002

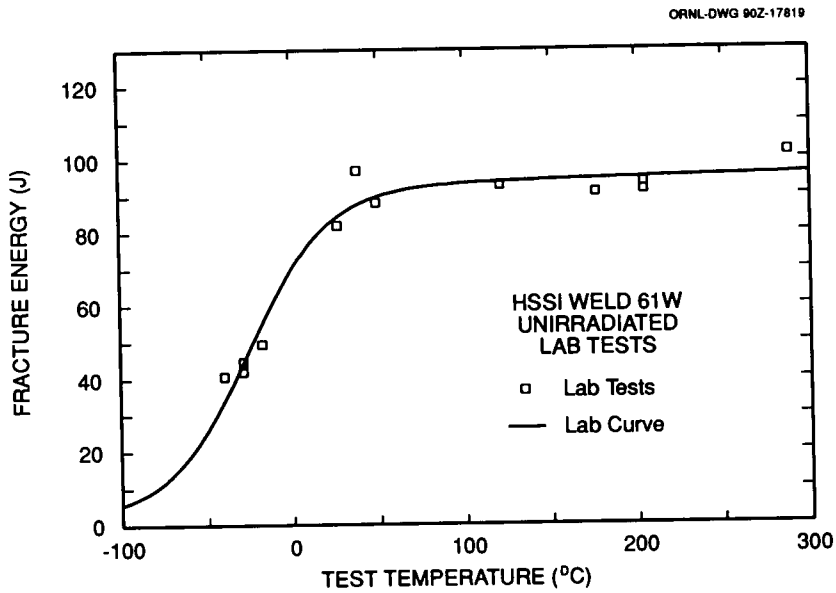
[a]Coefficients of $\sigma = A + BT + CT^2$, with σ in MPa and T in °C.

[b]Results adjusted to irradiation temperature of 288°C.

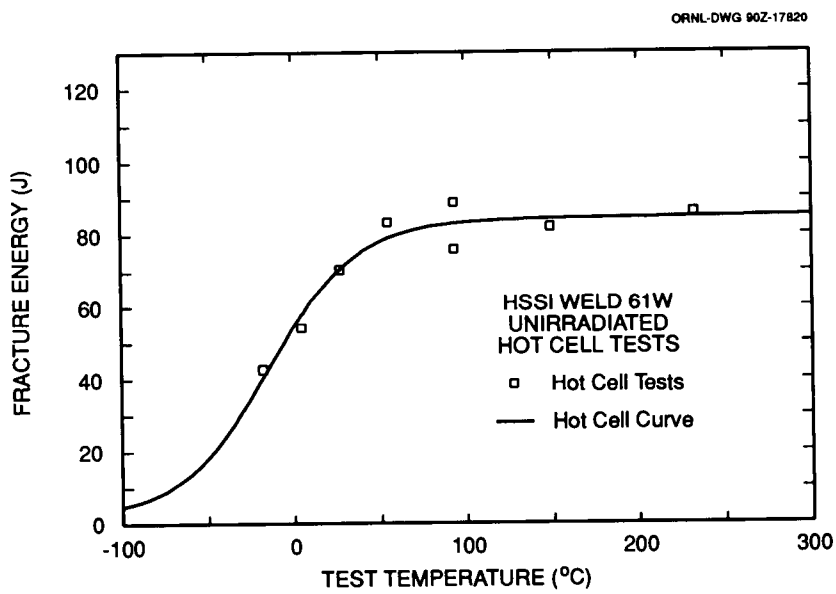
[c]Results at irradiation temperature of 288°C adjusted to fluence of 8×10^{18} neutrons/cm^2 (>1 MeV).

Table 8. Summary of irradiation effects on tensile properties of HSSI welds 61W through 67W irradiated at 288°C to a fluence of 8×10^{18} neutrons/cm^2

Weld	Strength change, MPa (%)					
	Yield			Ultimate		
	30°C	150°C	288°C	30°C	150°C	288°C
61W	146 (30.4)	115 (25.9)	108 (25.8)	123 (20.5)	112 (20.4)	110 (20.5)
62W	130 (27.5)	107 (25.0)	93 (24.1)	103 (17.4)	95 (17.8)	90 (17.5)
63W	136 (28.2)	139 (32.2)	113 (27.6)	108 (18.0)	126 (23.1)	110 (20.7)
64W	136 (29.2)	90 (21.6)	133 (33.4)	115 (19.8)	85 (16.0)	120 (22.1)
65W	107 (23.4)	45 (10.6)	99 (24.0)	92 (16.1)	93 (17.4)	92 (16.7)
66W	111 (20.8)	92 (18.2)	85 (17.1)	86 (13.5)	89 (14.9)	76 (12.5)
67W	162 (35.1)	138 (32.2)	102 (23.7)	115 (19.7)	107 (19.7)	95 (16.9)

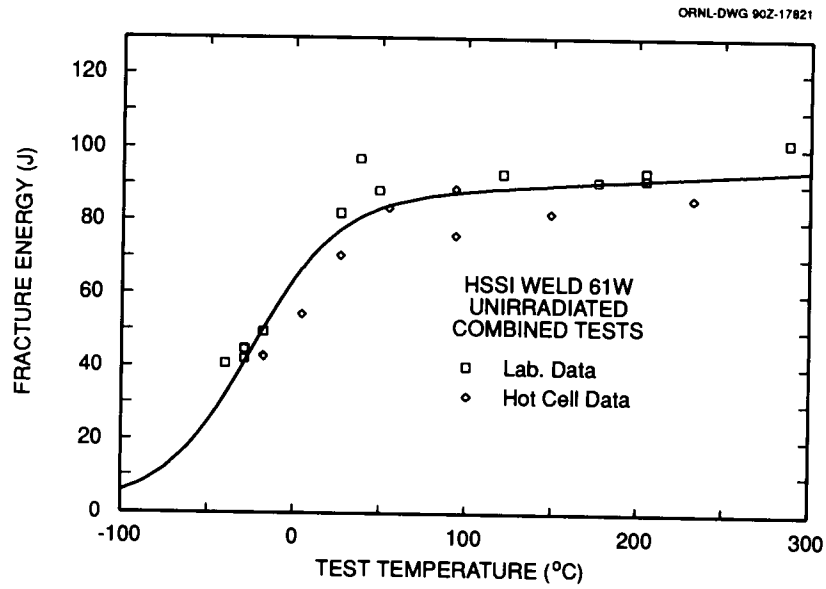


(a)

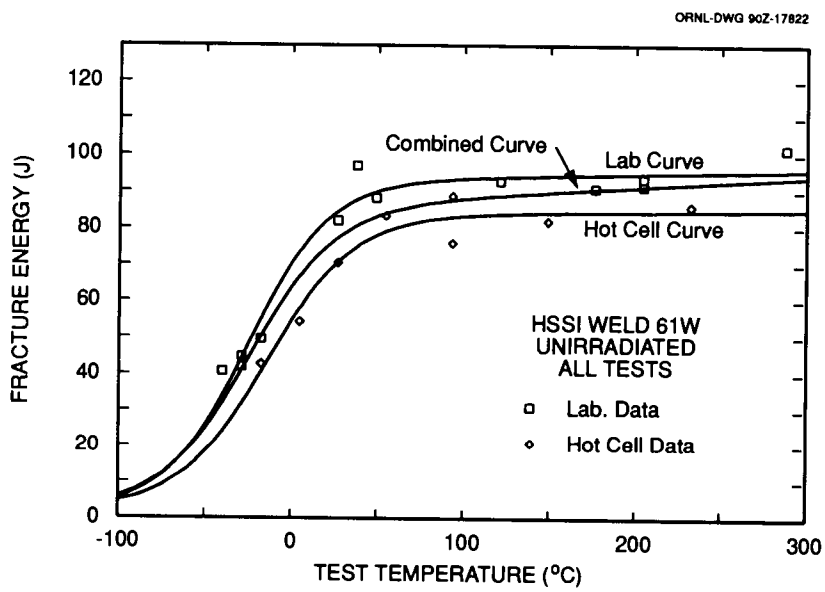


(b)

Fig. 37. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 61W, (a) laboratory test machine, (b) hot cell machine, (c) all tests, and (d) comparison of the three data sets. The curves shown in each case are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.

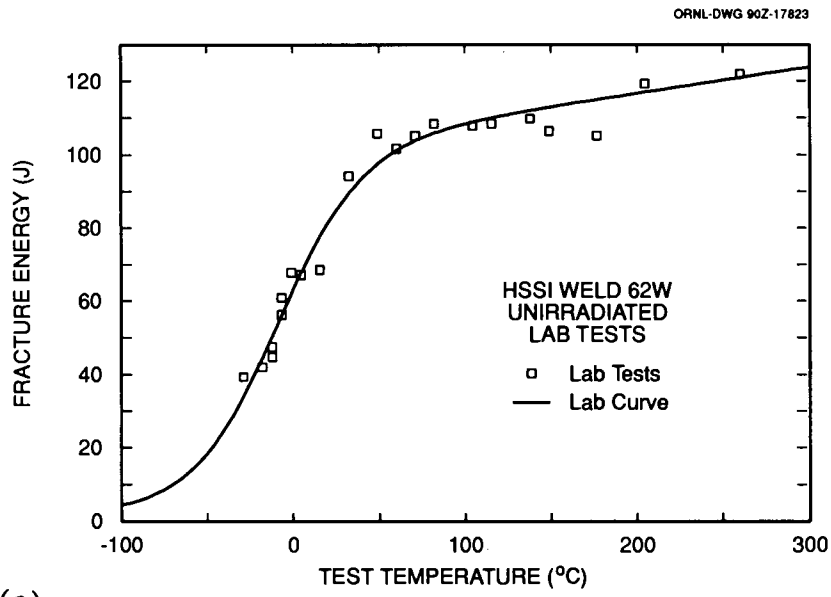


(c)

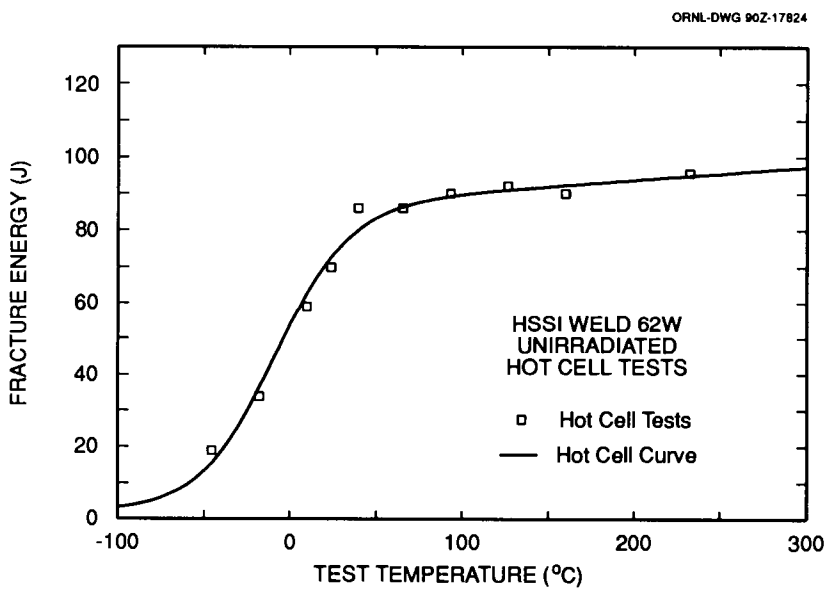


(d)

Fig. 37. (continued)

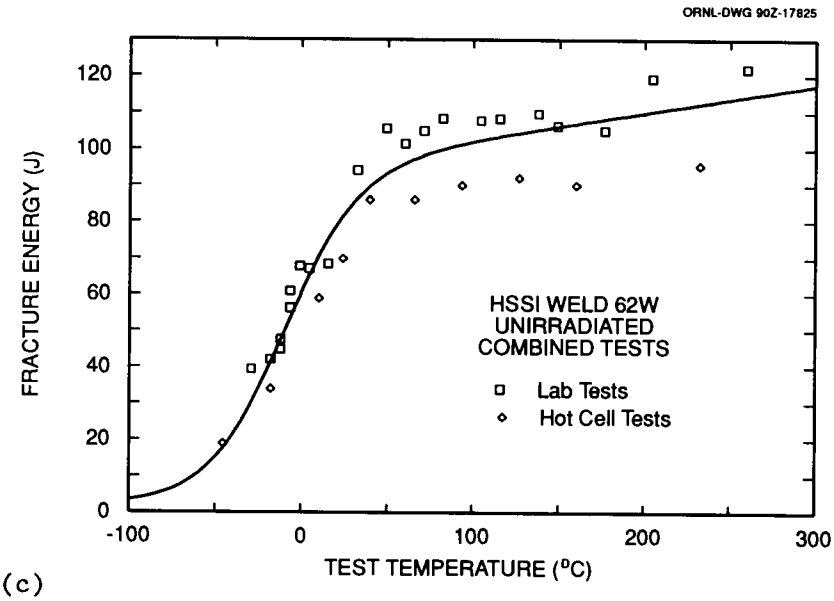


(a)

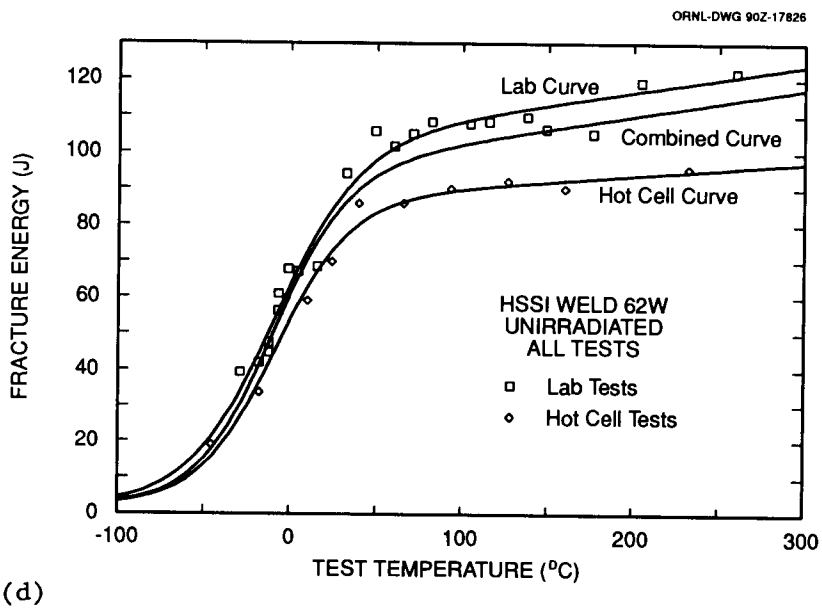


(b)

Fig. 38. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 62W, (a) laboratory test machine, (b) hot cell machine, (c) all tests, and (d) comparison of the three data sets. The curves shown in each case are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.

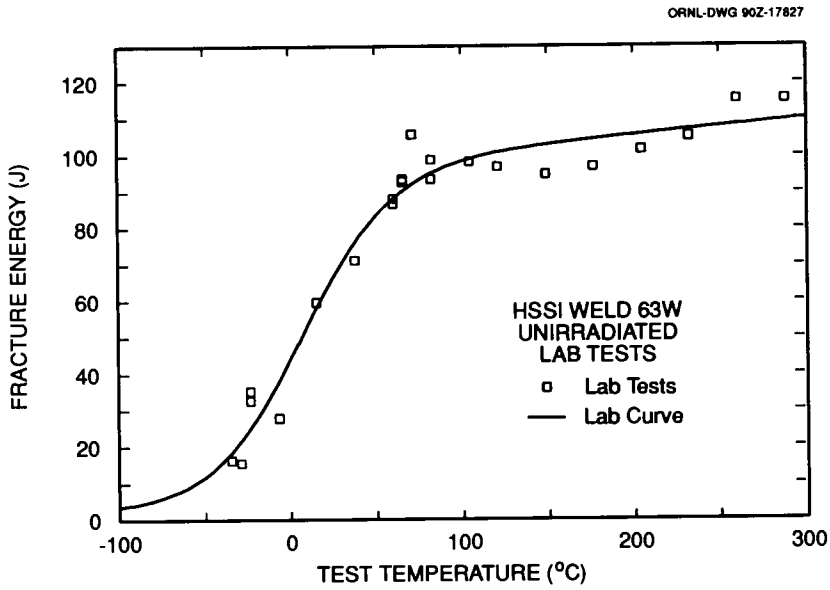


(c)

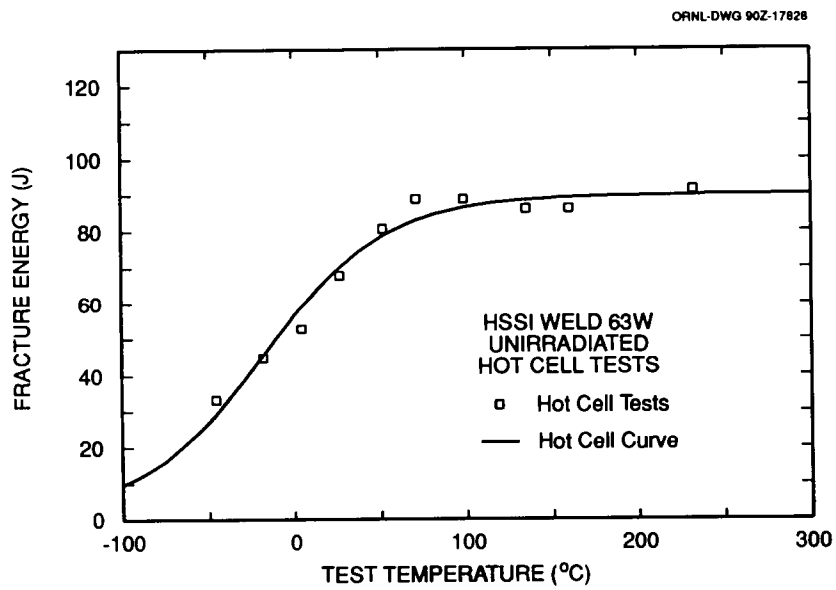


(d)

Fig. 38. (continued)

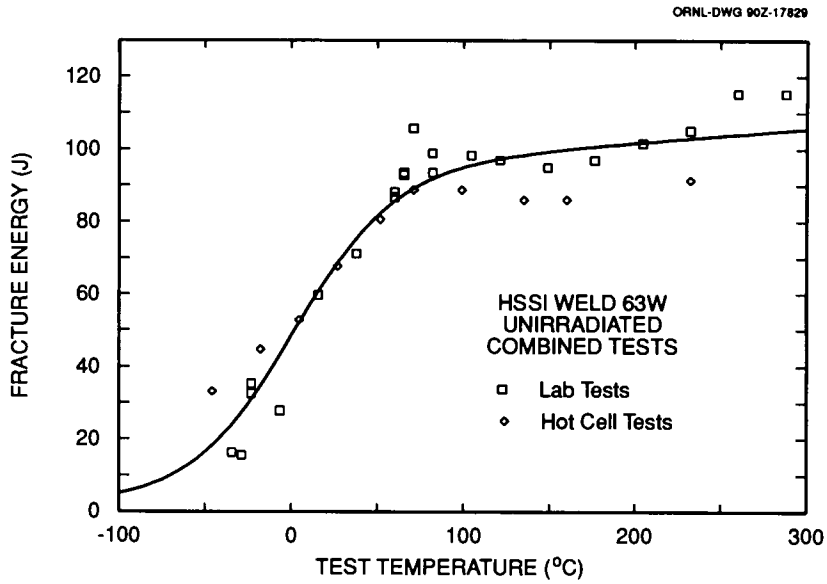


(a)

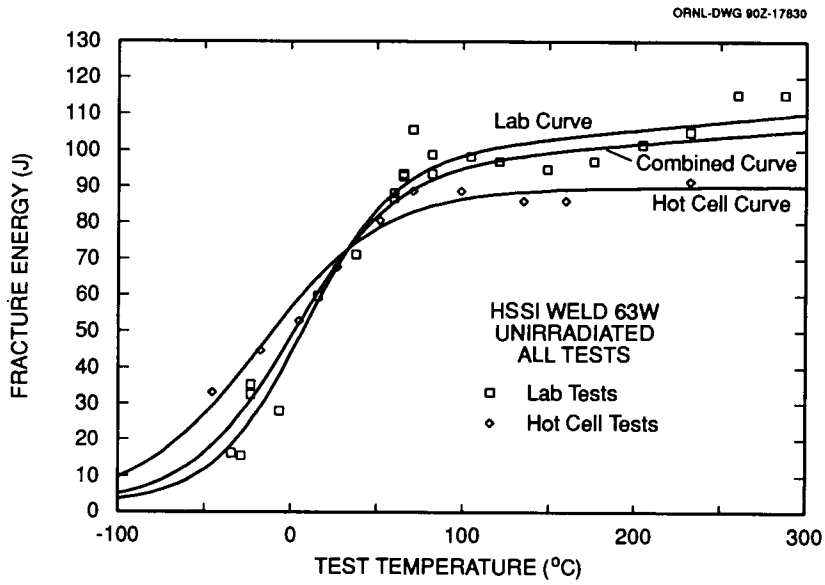


(b)

Fig. 39. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 63W, (a) laboratory test machine, (b) hot cell machine, (c) all tests, and (d) comparison of the three data sets. The curves shown in each case are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.

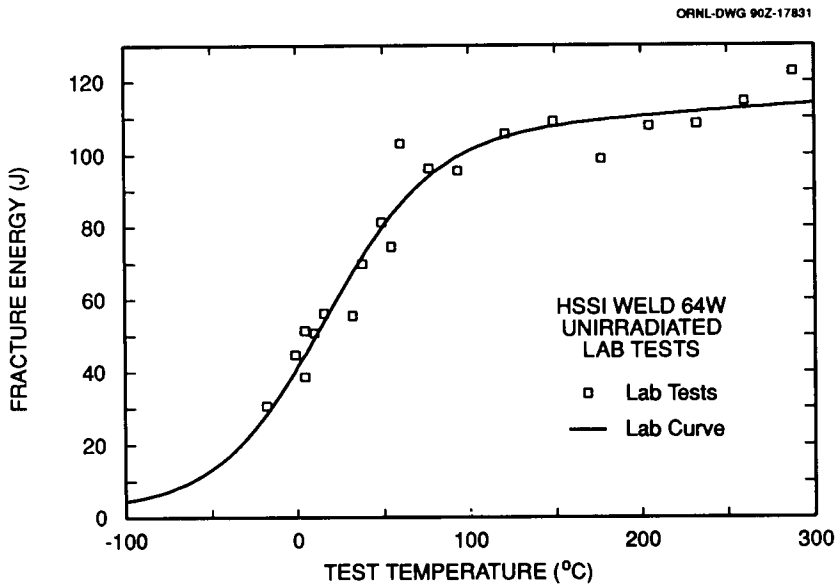


(c)

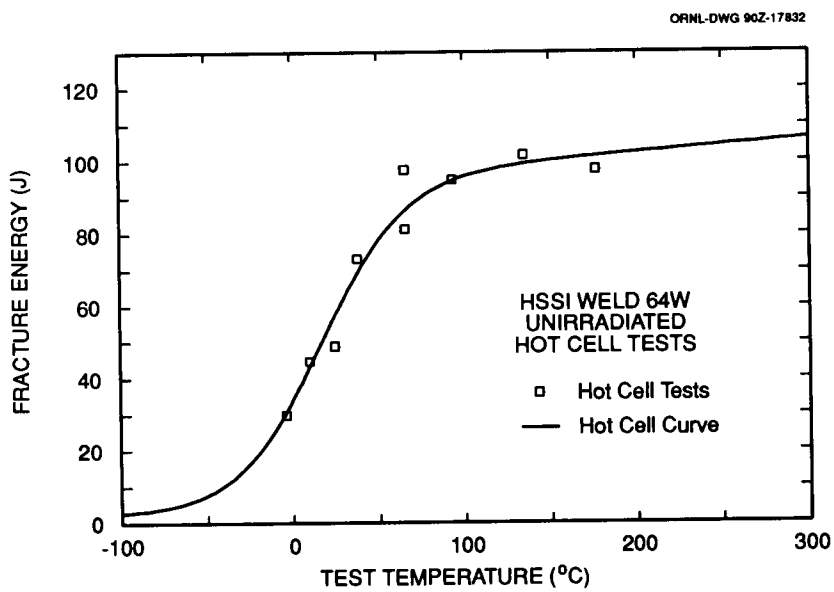


(d)

Fig. 39. (continued)

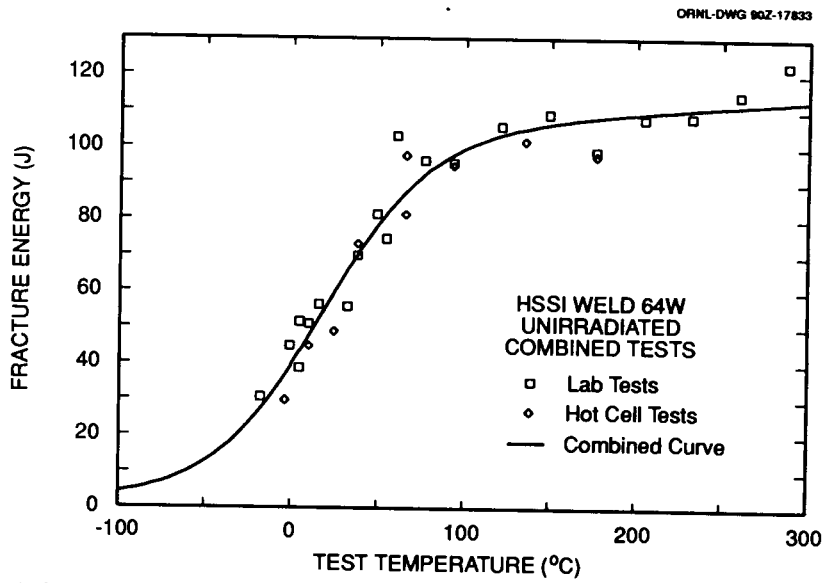


(a)



(b)

Fig. 40. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 64W, (a) laboratory test machine, (b) hot cell machine data with upper shelf modified to have same slope as in (a), (c) all tests, and (d) comparison of the three data sets. The curves shown in each case [except for (b)] are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.



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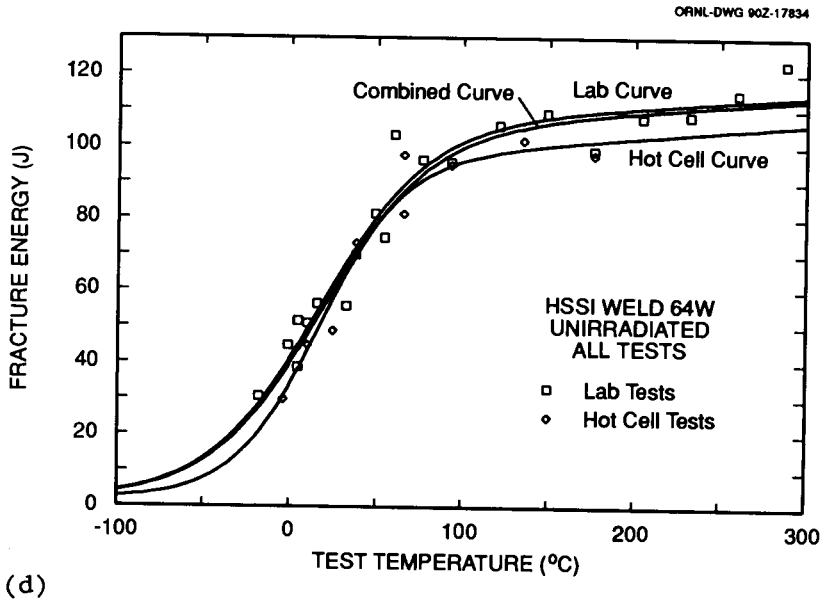
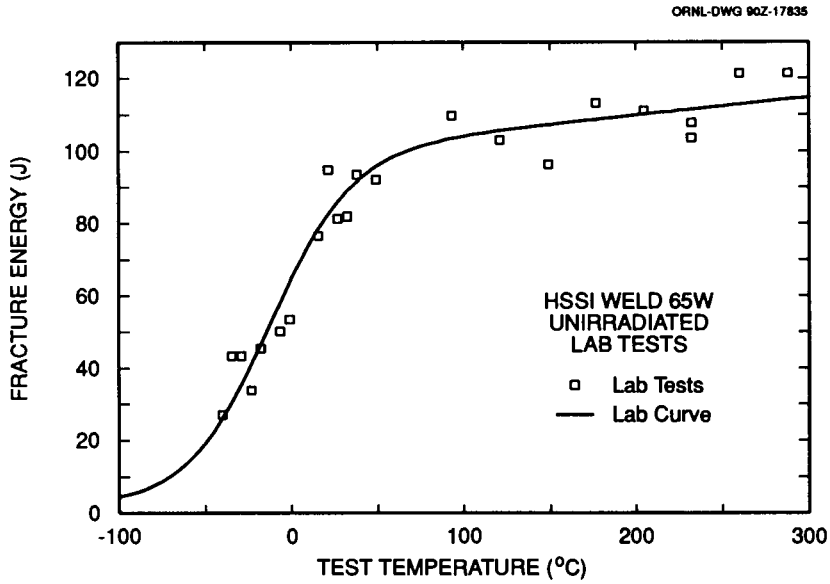
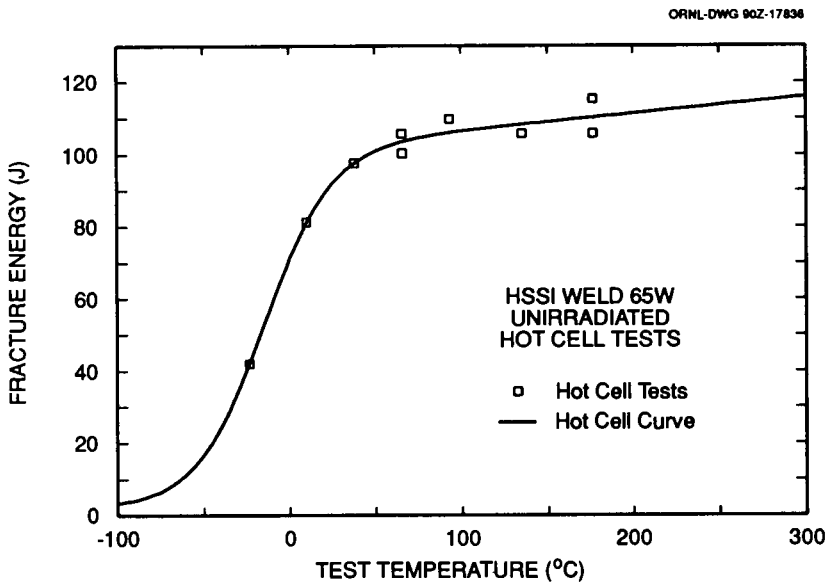


(d)

Fig. 40. (continued)

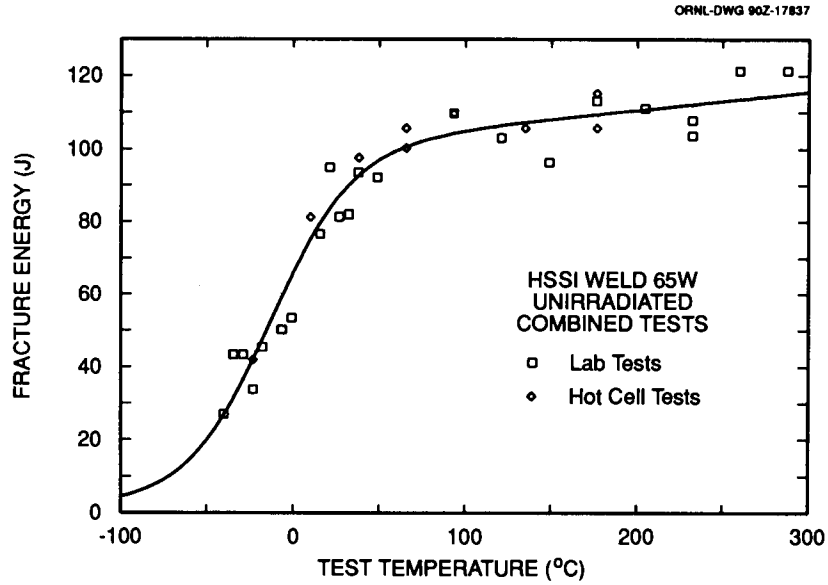


(a)

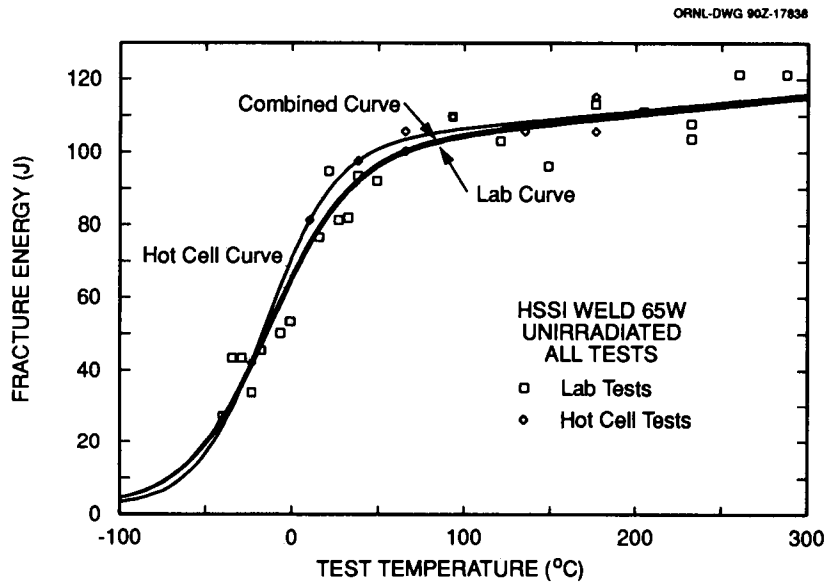


(b)

Fig. 41. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 65W, (a) laboratory test machine, (b) hot cell machine, (c) all tests, and (d) comparison of the three data sets. The curves shown in each case are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.

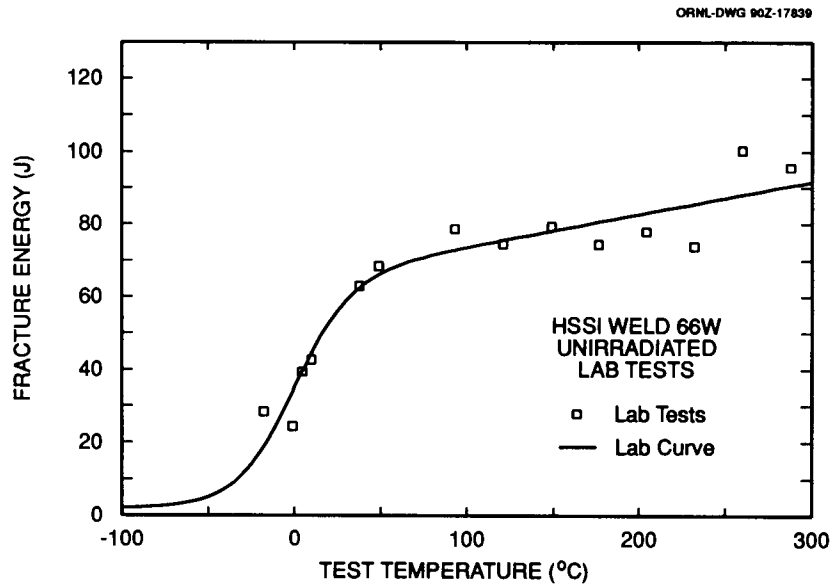


(c)

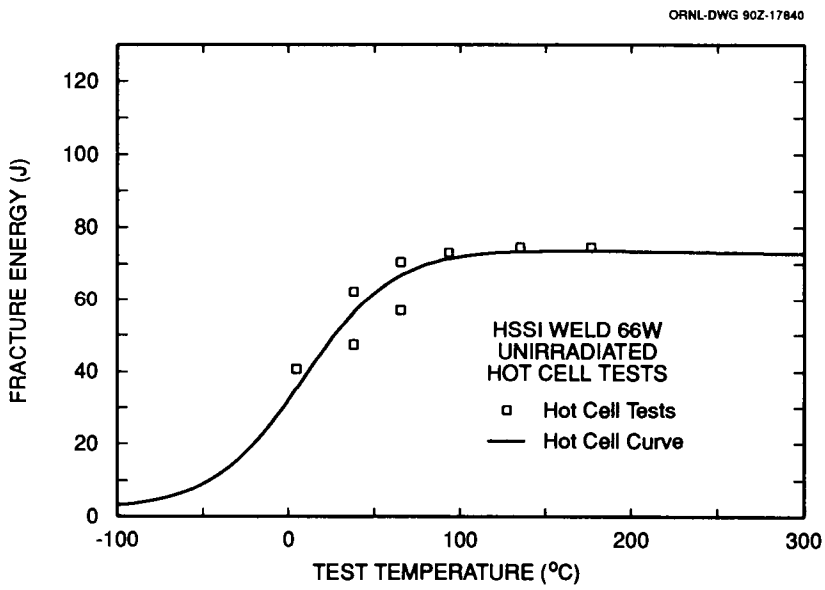


(d)

Fig. 41. (continued)

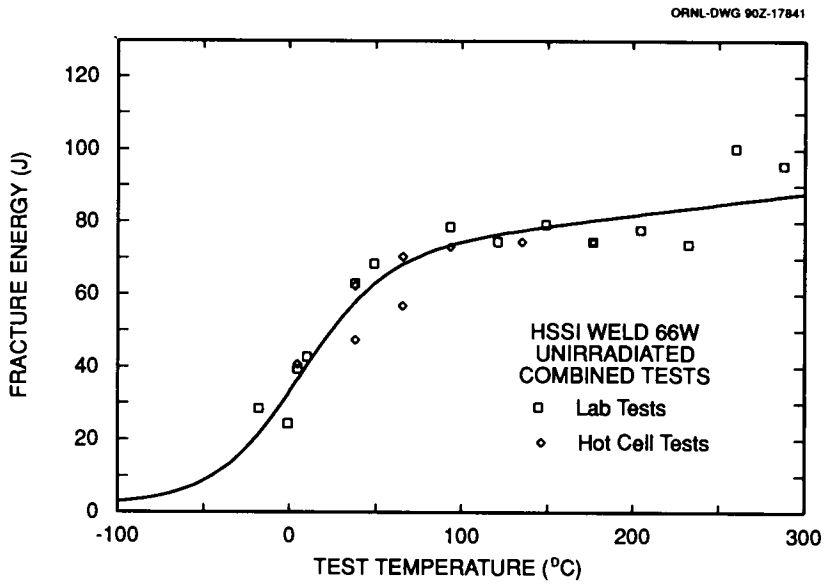


(a)

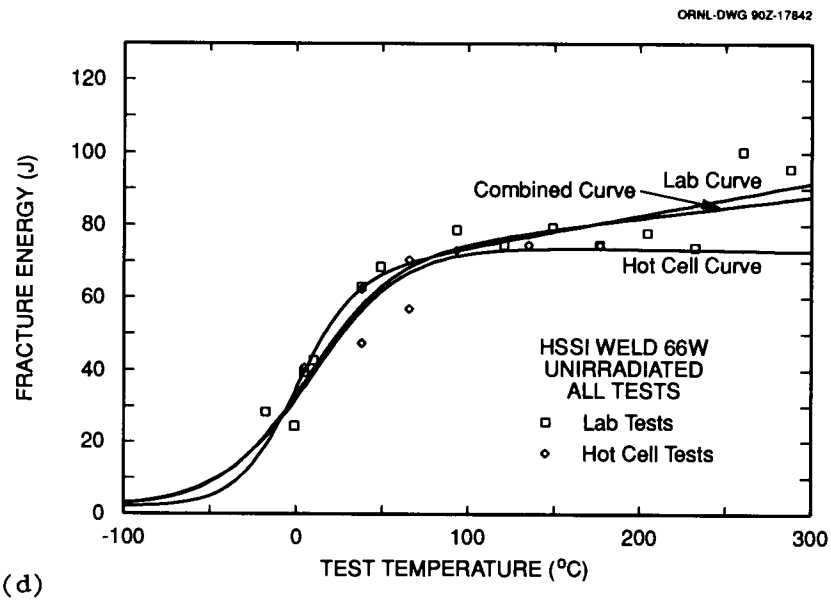


(b)

Fig. 42. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 66W, (a) laboratory test machine, (b) hot cell machine, (c) all tests, and (d) comparison of the three data sets. The curves shown in each case are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.

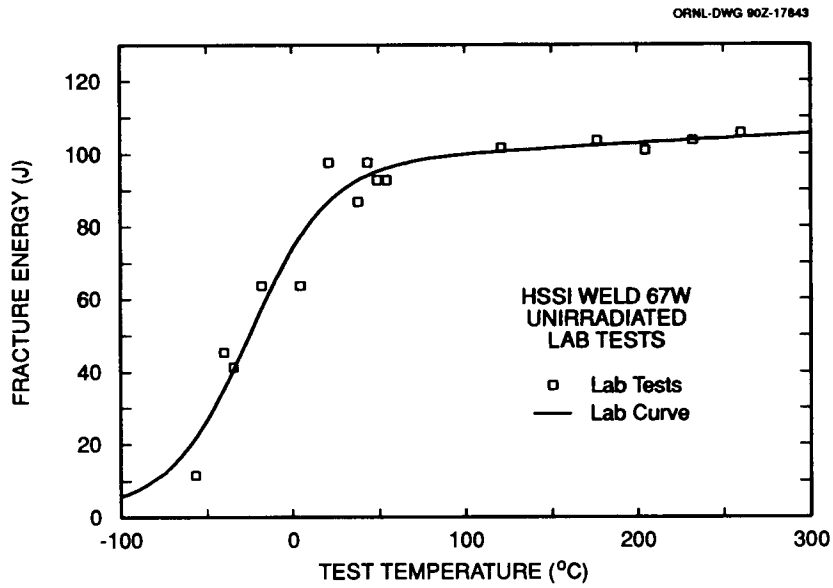


(c)

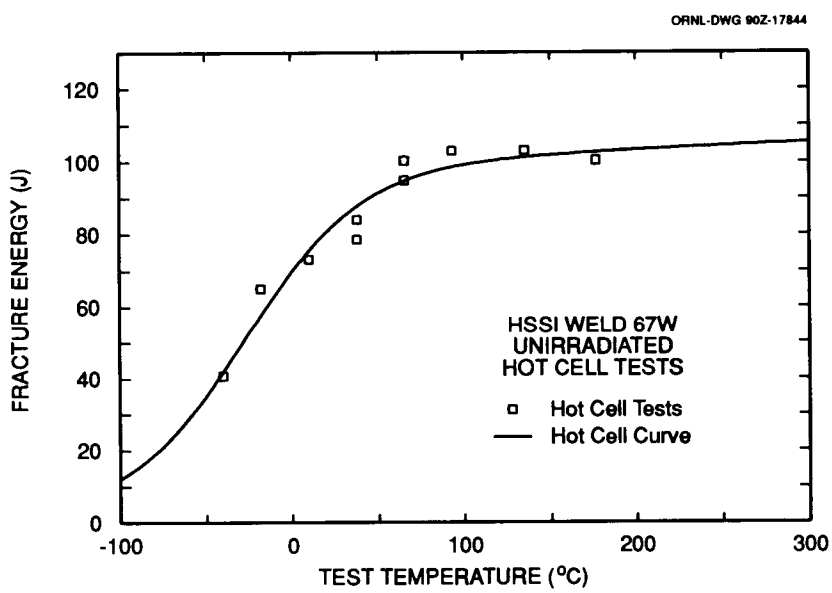


(d)

Fig. 42. (continued)

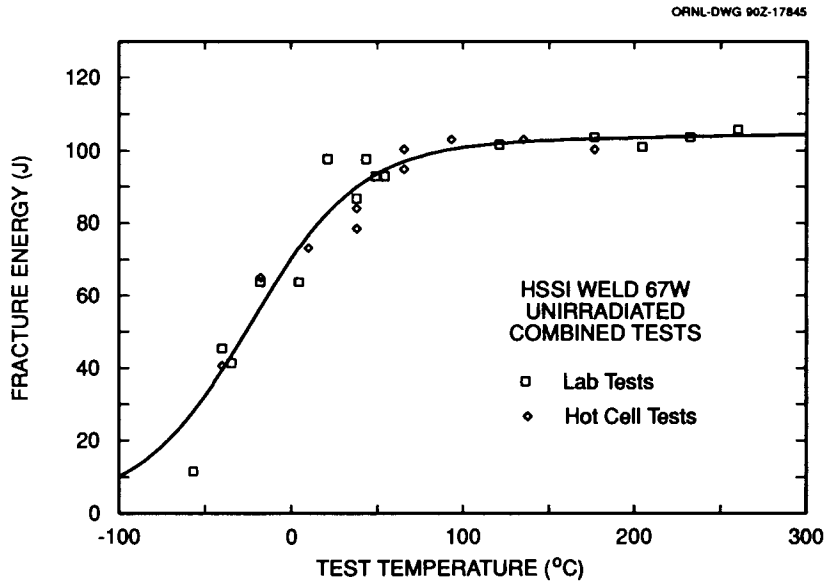


(a)



(b)

Fig. 43. Unirradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 67W, (a) laboratory test machine, (b) hot cell machine data with upper shelf modified to have same slope as in (a), (c) all tests, and (d) comparison of the three data sets. The curves shown in each case [except for (c)] are best fits using a hyperbolic tangent with the lower shelf fixed at 3 J and a sloping upper shelf.



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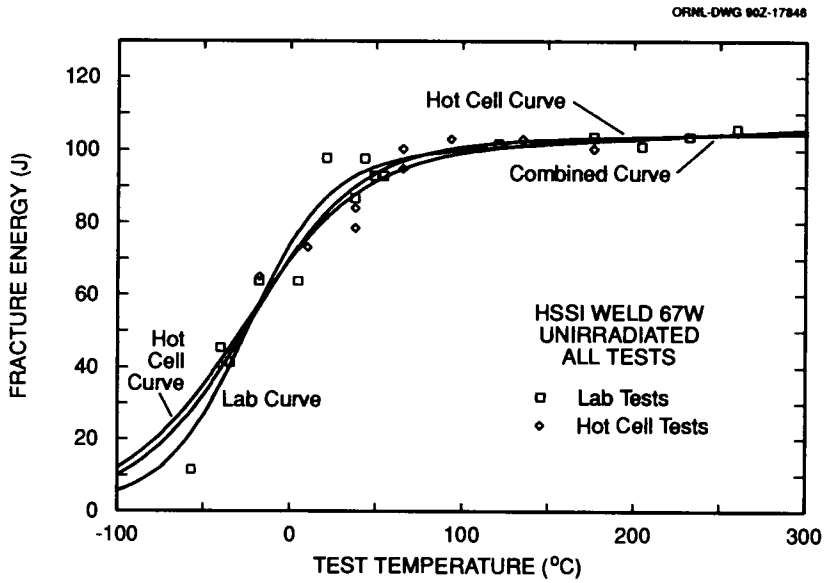


(d)

Fig. 43. (continued)

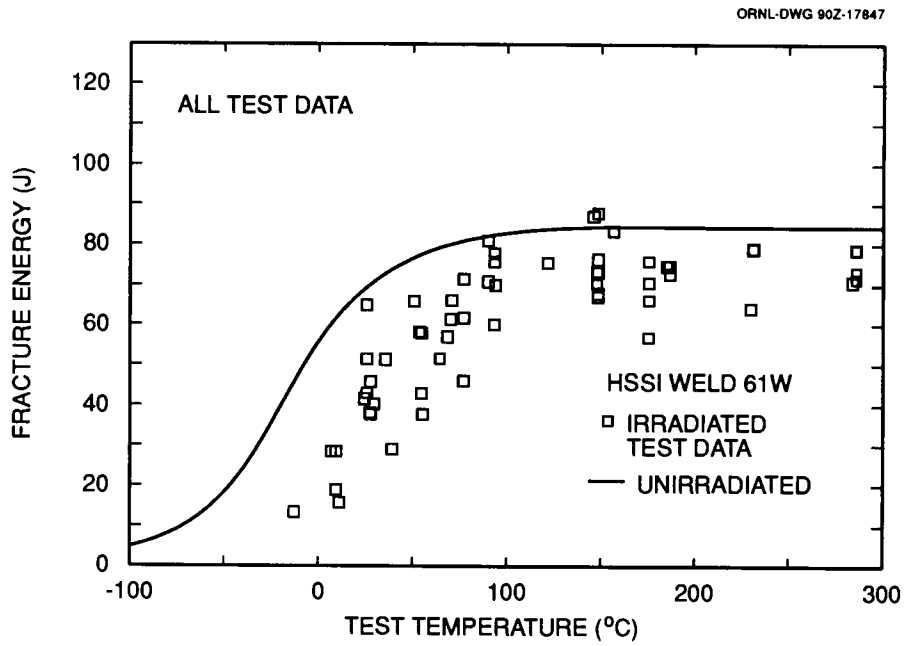
transition region was limited, a comparison is not considered very reliable. Even so, the differences that do result are less than about 20°C.

Because large differences between laboratory and hot cell machine data on the ductile shelf exist for many of the welds, the hot cell machine data will be used as the reference data for unirradiated results. Table 9 provides the upper-shelf energies at 200°C and the 41-J transition temperatures for each weld. The 41-J transition temperatures vary from -41 to 13°C (-42 to 55°F) while the ductile shelf energies vary from 74 to 111 J (55 to 82 ft-lb). The lowest, unirradiated, ductile-shelf energy of 74 J (55 ft-lb) was exhibited by weld 66W and is only slightly above the 68-J (50 ft-lb) minimum required by 10CFR50 for irradiated material. The current minimum, unirradiated, upper-shelf energy required in 10CFR50 is 102 J (75 ft-lb). Welds 64W, 65W, and 67W are the only welds which meet that minimum and are at, or only slightly above, the 102-J level.

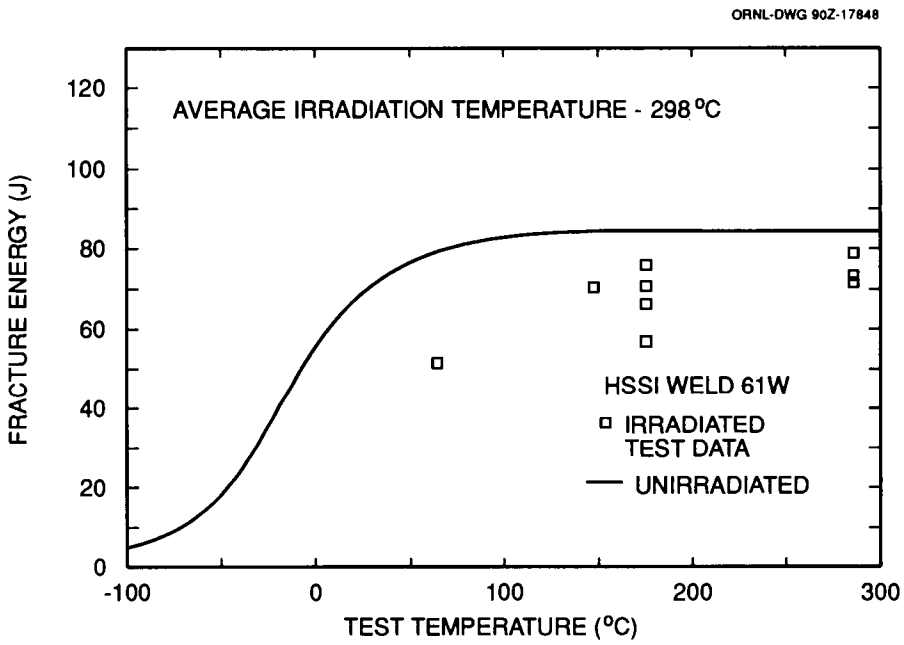
The irradiated CVN tests were all conducted in the hot cell on the same machine used for the previously presented unirradiated hot cell tests. As discussed earlier, the irradiation temperatures and neutron fluences varied significantly throughout each irradiation capsule. Because the CVN specimens were located throughout the capsules and experienced such variations, comparisons of unirradiated and irradiated results must include those differences. Inspection of Tables B13 through B19 in Appendix B shows that the tests are grouped according to irradiation temperature. Additionally, the data for each weld are separated according to either transition region tests or ductile-shelf tests (zero fast load drop). Some groups have only one specimen. Within each group, there are also fluence variations. Figures 44(a) through 44(f) show plots of the irradiated CVN results for weld 61W. The plot with all the data [Fig. 44(a)] shows the large variability through the test temperature range. Figures 44(b) through 44(f) show the data for each group by irradiation temperature. The curve shown in each plot is the hyperbolic

Table 9. Summary of Charpy 41-J temperature and upper-shelf energy for unirradiated HSSI welds 61W through 67W

Weld	Charpy impact parameters			
	41-J temperature		Upper-shelf energy	
	(°C)	(°F)	(J)	(ft-lb)
61W	-17	1	85	63
62W	-13	9	94	69
63W	-26	-15	90	66
64W	7	45	102	75
65W	-24	-11	111	82
66W	13	55	74	55
67W	-41	-42	103	76

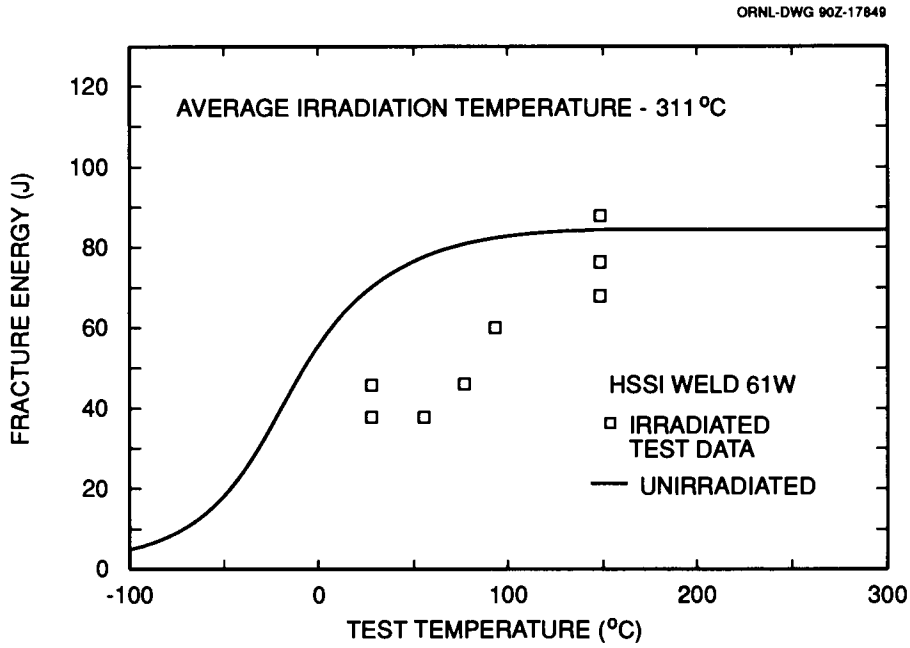


(a)

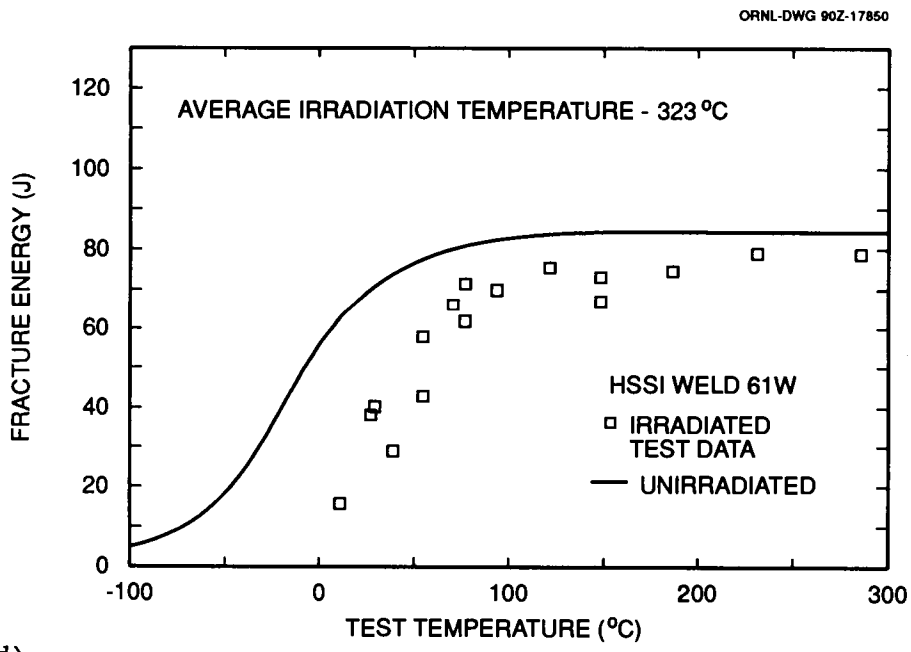


(b)

Fig. 44. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 61W irradiated at various temperatures, (a) all tests, (b) 298°C, (c) 311°C, (d) 323°C, (e) 329°C, and (f) 345°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

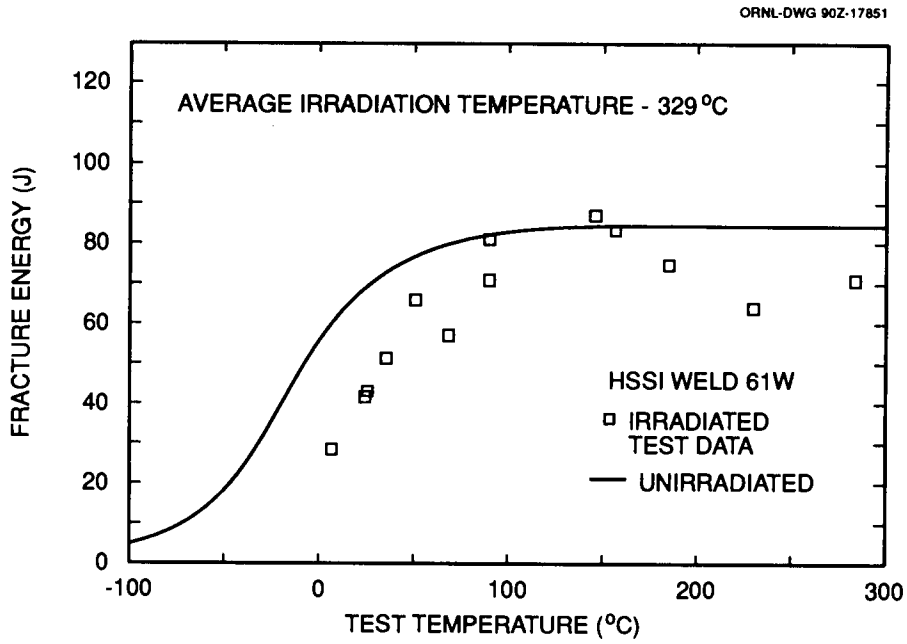


(c)

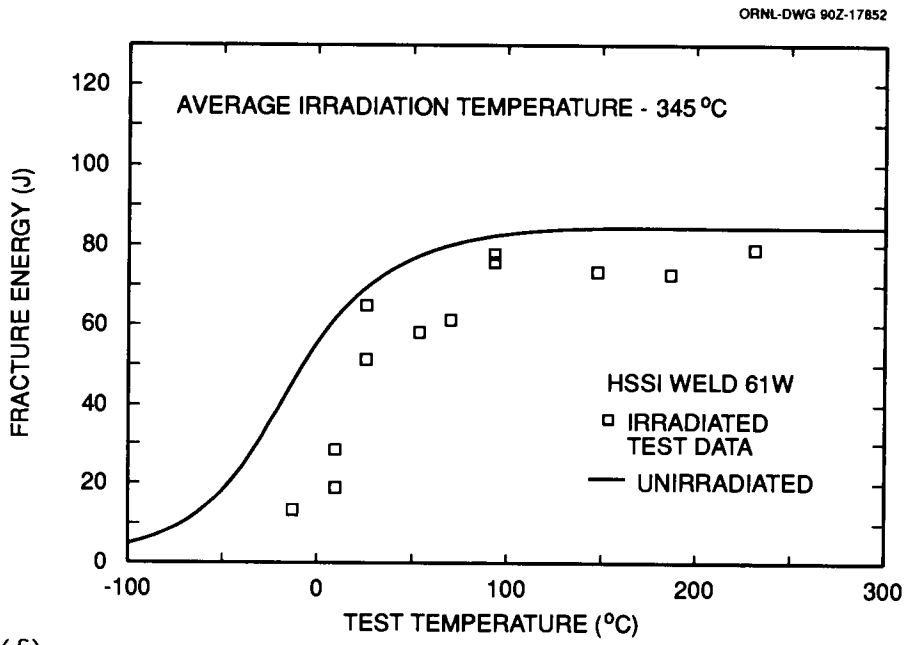


(d)

Fig. 44. (continued)



(e)



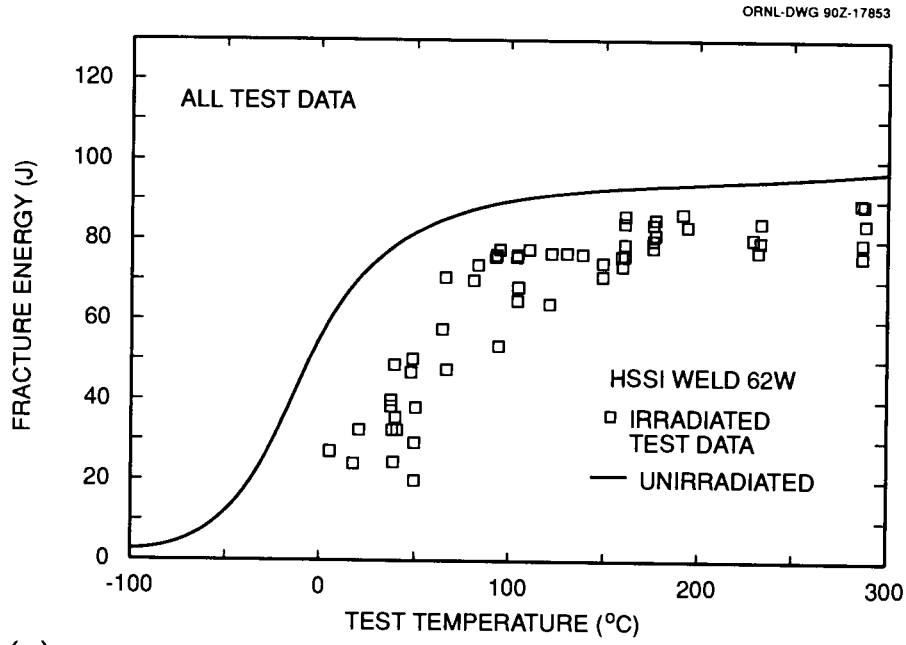
(f)

Fig. 44. (continued)

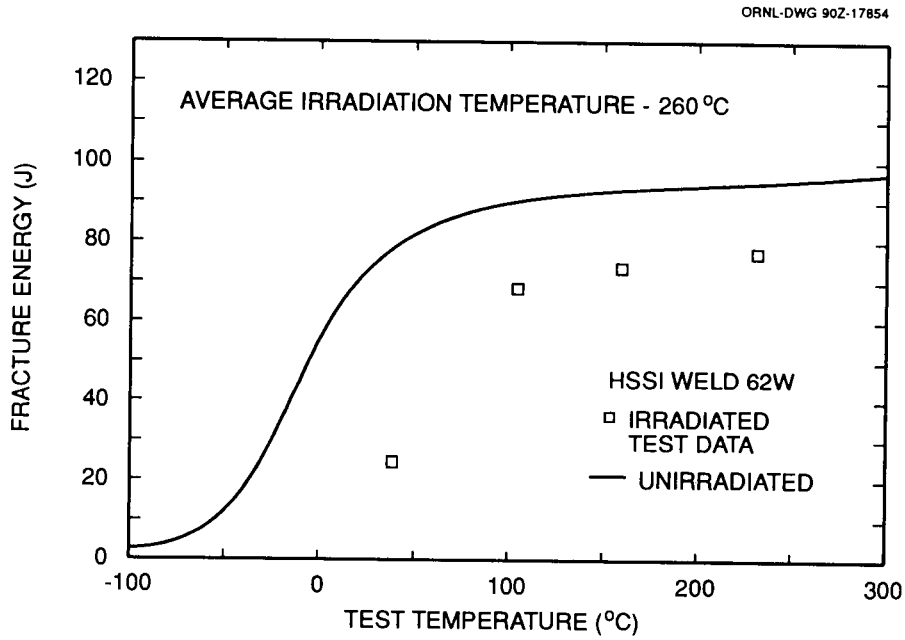
tangent fit to the unirradiated data obtained in the hot cell. The unirradiated data were also fit with linear curves. The lower shelf was assumed to be 3 J, while the upper shelf was fit with a linear regression to data representing only fully ductile behavior. The transition region is represented by a linear regression to all the data representing less than fully ductile fracture. The linear and hyperbolic tangent functions provide essentially the same information and both are included in the tables of Appendix B, but the linear fits are not presented graphically. For welds 62W through 67W, plots of the irradiated results, grouped by nominal irradiation temperature, are shown in Figs. 45 through 50, respectively.

The irradiated data from each weld were not fit with curves because of the variations in irradiation temperature and neutron fluence. To account for fluence differences, each test result was normalized to a fluence of 8×10^{18} neutrons/cm^2. For the transition region data, the normalization was performed by multiplying the observed transition temperature increase for each test result (e.g., the temperature difference between the irradiated result and the unirradiated reference curve at the energy level measured) by the square root of the ratio of 8×10^{18} neutrons/cm^2 to the fluence of the test specimen. An exponent of 0.5 was used because that is a typical value for the Charpy shift dependence on fluence for pressure vessel steel welds irradiated in test reactors.[23] For the upper-shelf data, the normalization was performed in the same manner except that the observed energy change (percent) was normalized by the fluence ratio. Tables B13 through B19 in Appendix B provide the tabulated results of these normalization calculations. For example, in Table B13 for specimen 61224 the fracture energy was 51.5 J. At that energy level, the temperature increase relative to that of the hyperbolic tangent curve for 61W was 70.1°C. After normalization, the temperature increase is 68.9°C. Normalization decreased the transition temperature change because the fluence for that specimen was greater than 8×10^{18}. For specimens with fluences lower than 8×10^{18}, the normalized transition temperature will be greater than the observed value. A similar result occurs on the upper shelf where, for example, the observed upper-shelf change (in percent) will be normalized to a greater change for specimens with fluences less than 8×10^{18}. Each table includes summaries for both the transition temperature and ductile-shelf regions which provide the average fluence, as well as the average results, both observed and normalized, grouped by irradiation temperature.

Figure 51(a) shows all the transition temperature region data for 61W plotted as the observed transition temperature increase vs irradiation temperature. The unirradiated hyperbolic tangent curves for each weld (based on the unirradiated specimens tested in the hot cell) are used as the reference curves in all the analyses. Thus, the transition temperature increase for each irradiated test result is relative to the unirradiated curve at the measured energy level. Figure 51(b) is a similar plot using the results normalized for fluence. Although the results are somewhat scattered, the trend is certainly one of lower transition temperature increases with higher irradiation temperatures. Figures 51(c) and (d) are similar plots for the decrease in ductile-shelf

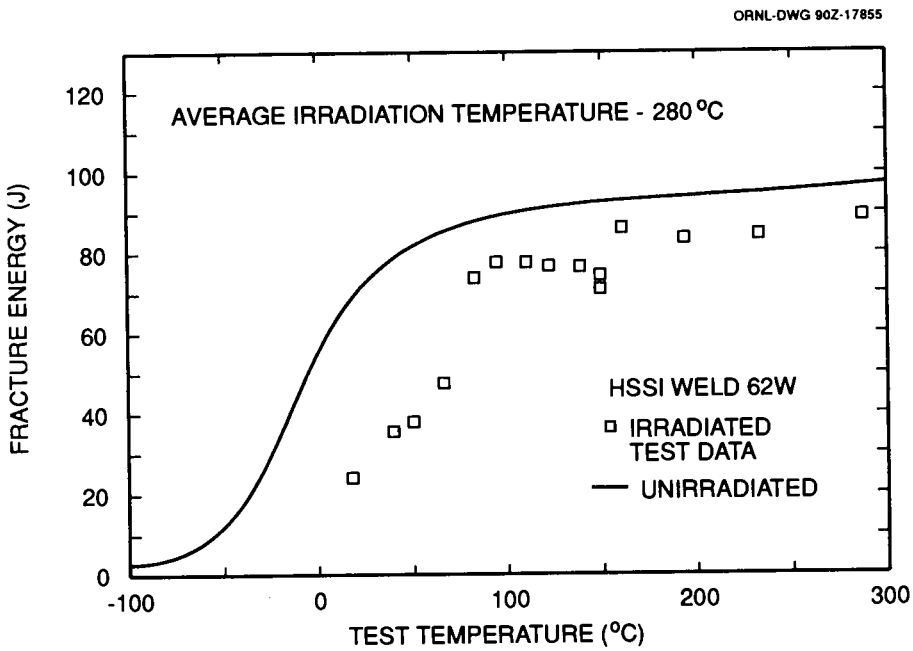


(a)

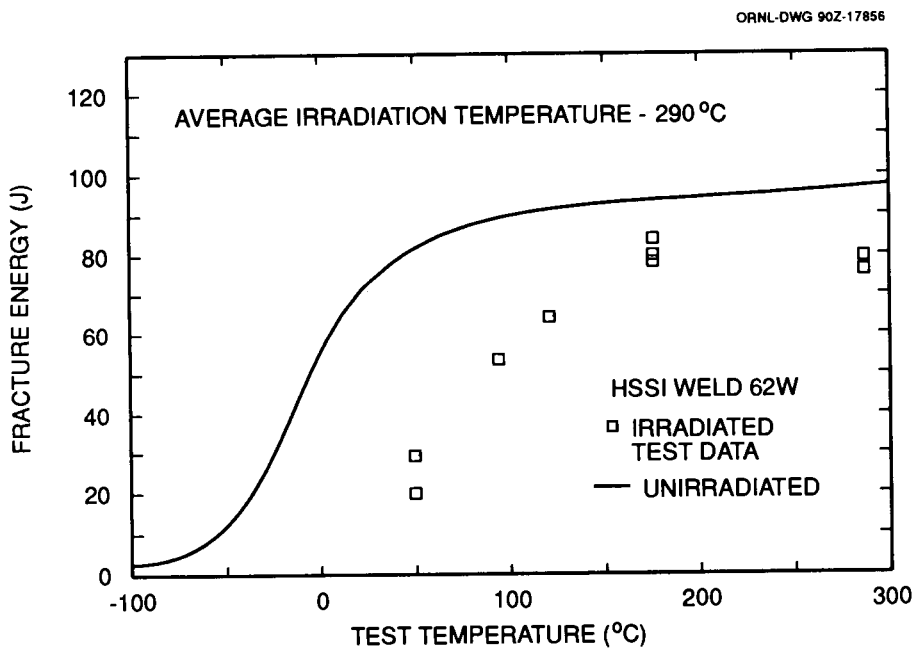


(b)

Fig. 45. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 62W irradiated at various temperatures, (a) all tests, (b) 260°C, (c) 280°C, (d) 290°C, (e) 301°C, and (f) 312°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

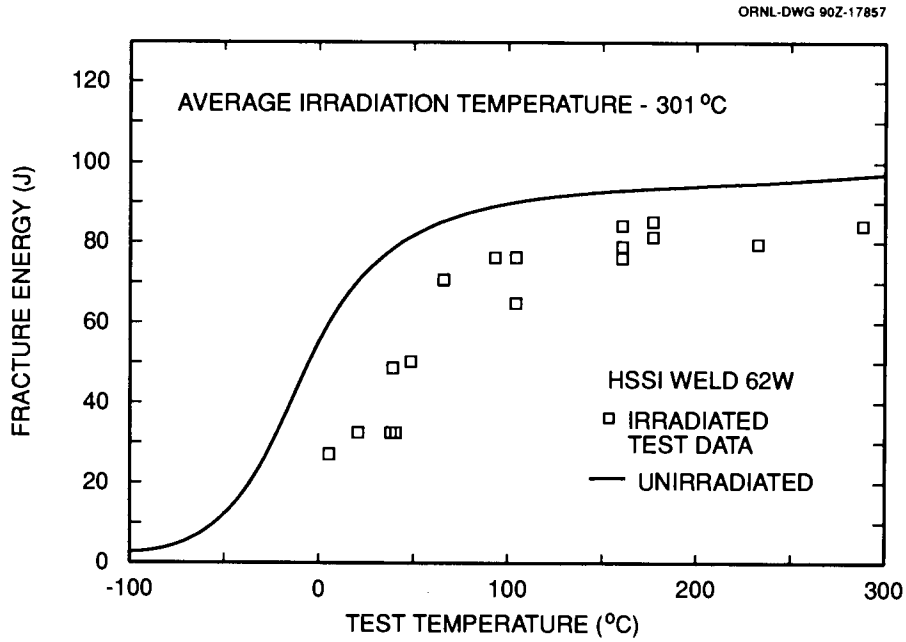


(c)

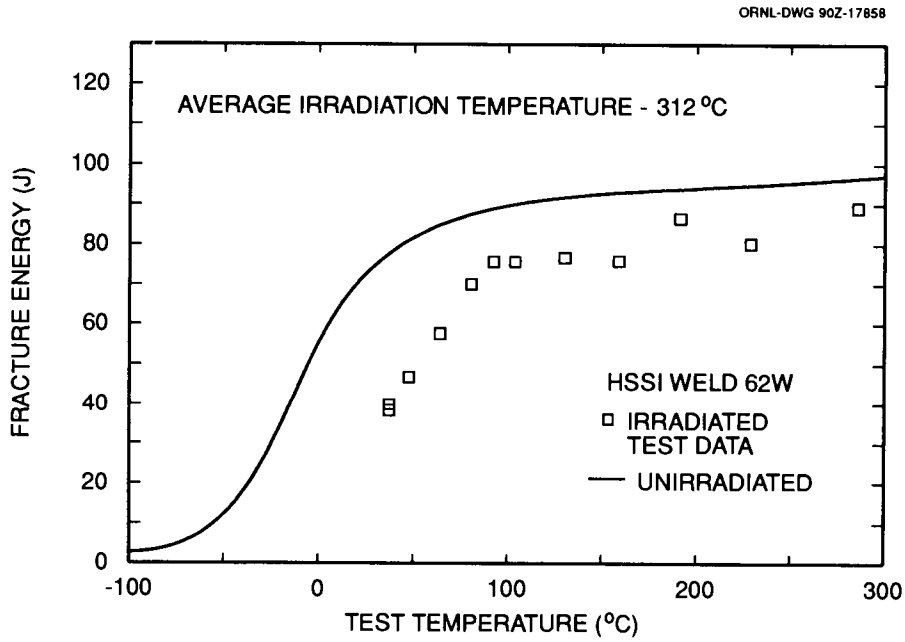


(d)

Fig. 45. (continued)

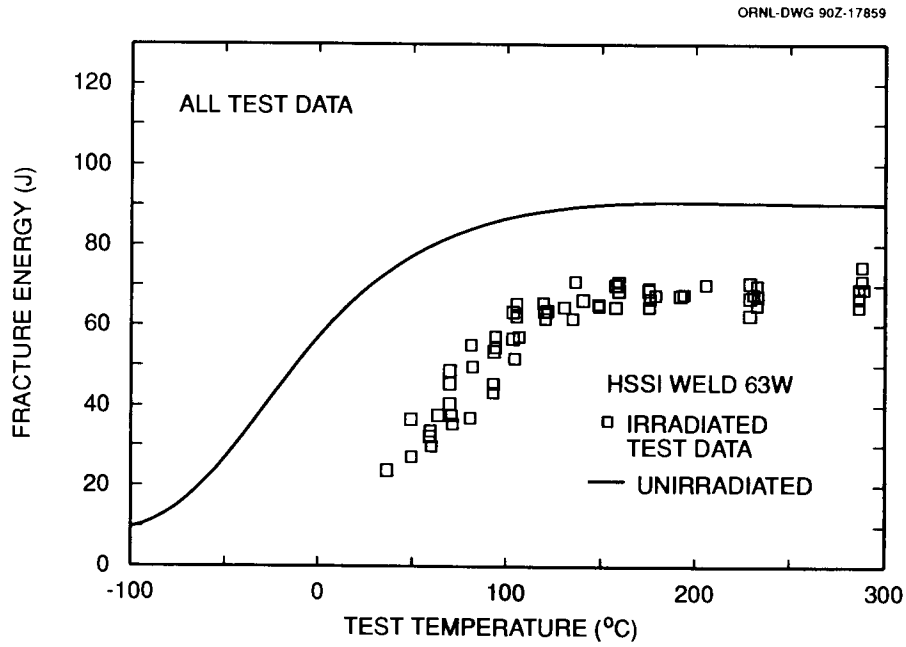


(e)

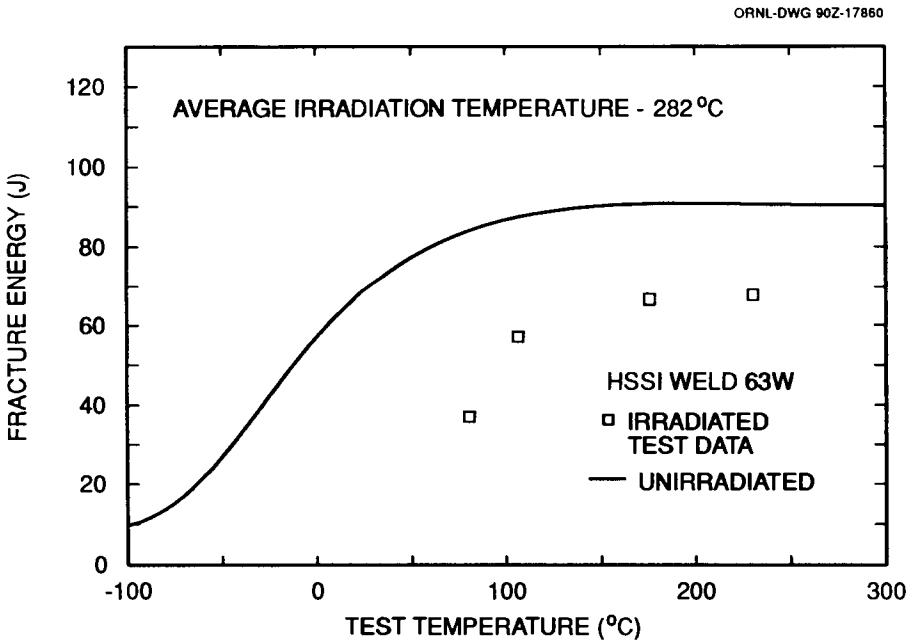


(f)

Fig. 45. (continued)

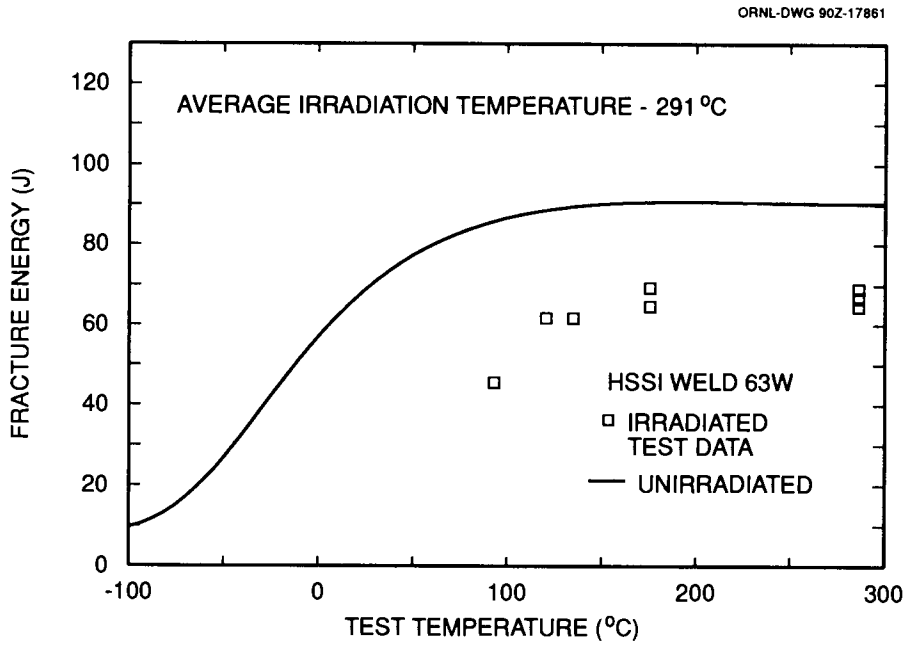


(a)

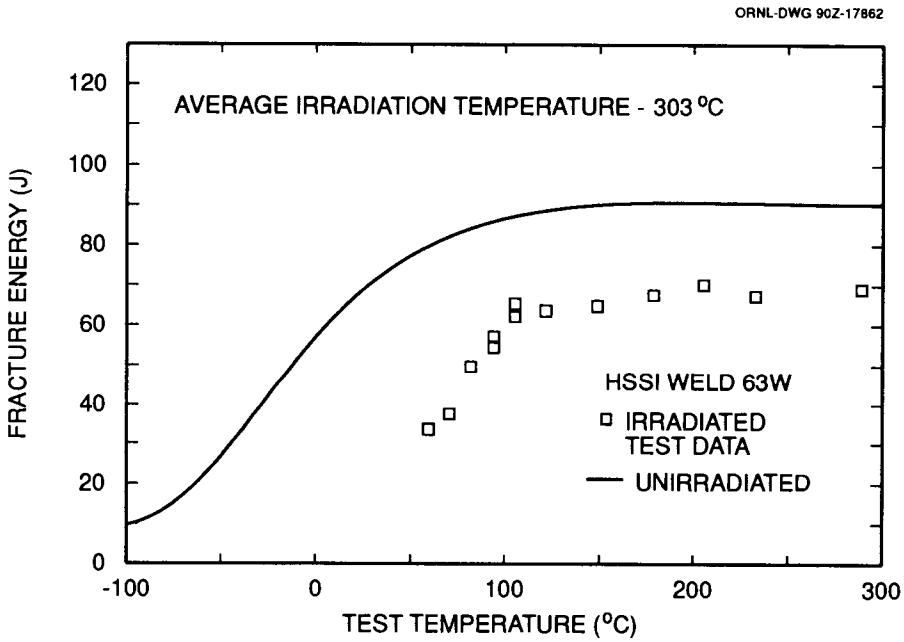


(b)

Fig. 46. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 63W irradiated at various temperatures, (a) all tests, (b) 282°C, (c) 291°C, (d) 303°C, (e) 310°C, and (f) 316°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

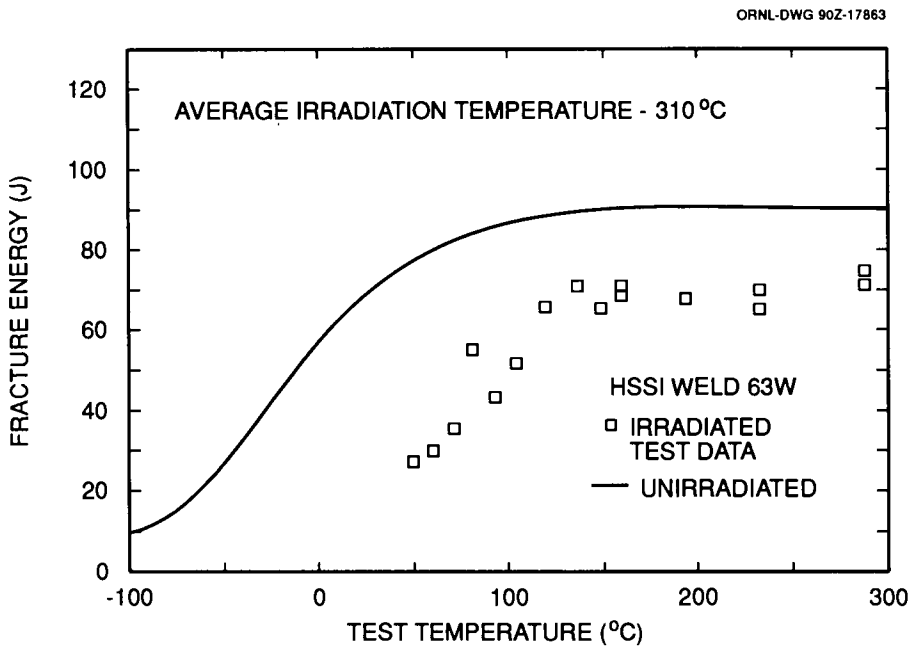


(c)

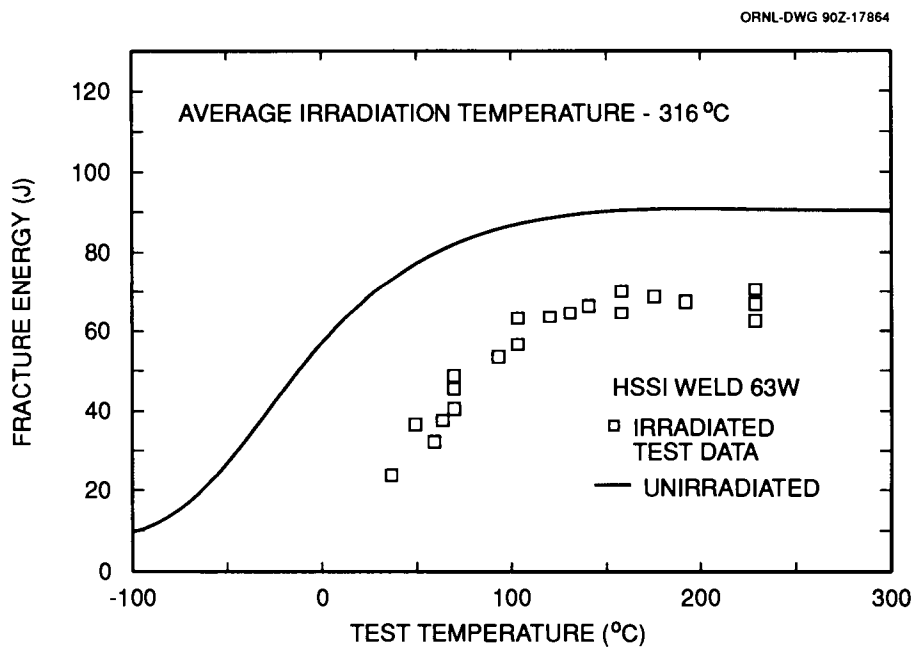


(d)

Fig. 46. (continued)

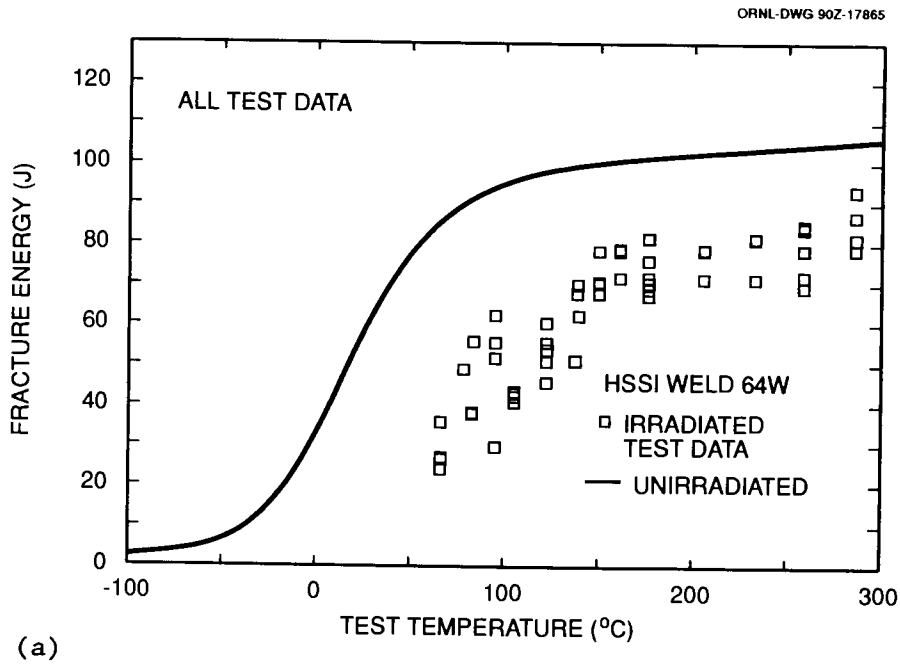


(e)

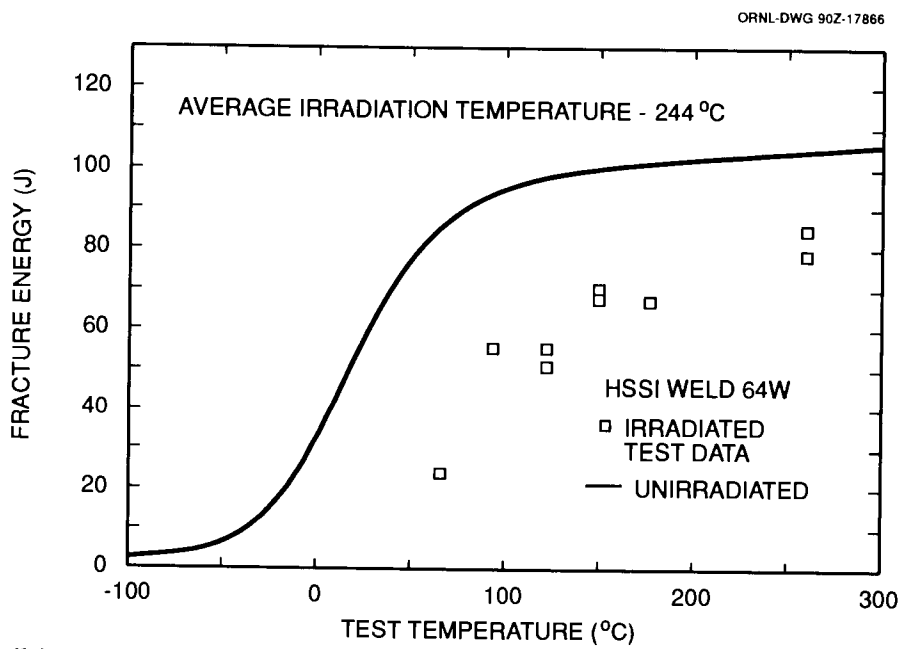


(f)

Fig. 46. (continued)

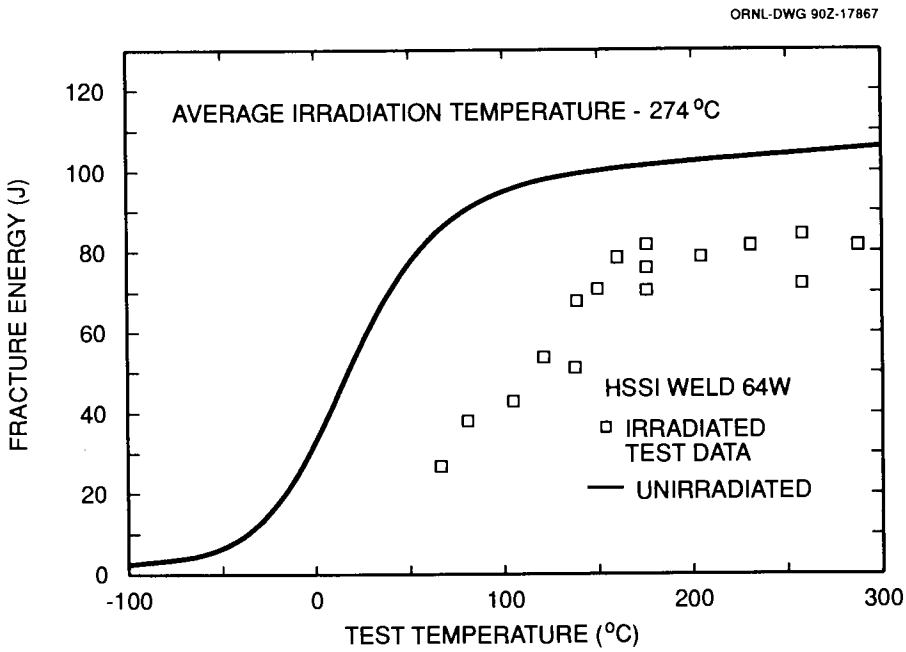


(a)

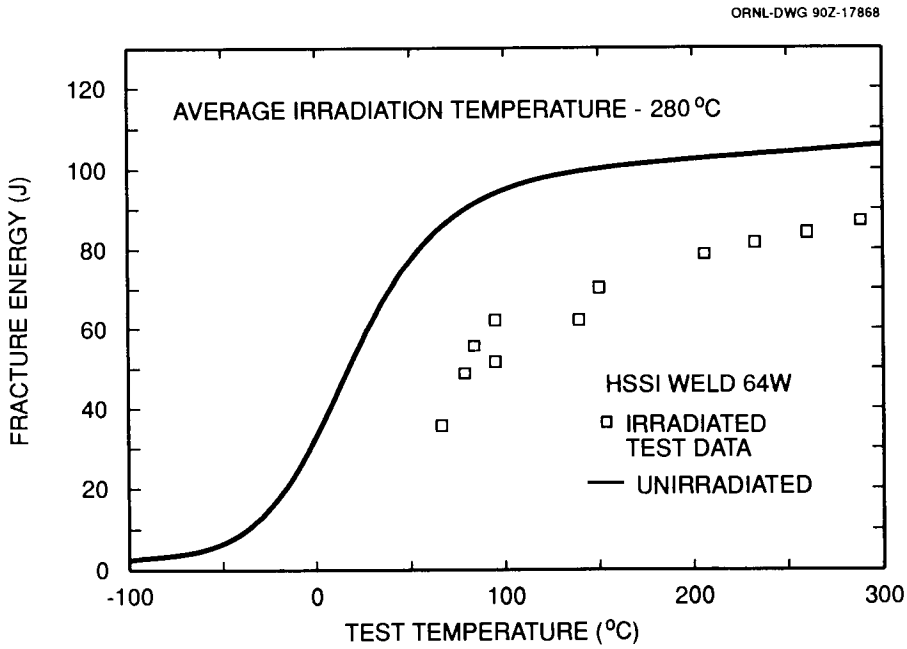


(b)

Fig. 47. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 64W irradiated at various temperatures, (a) all tests, (b) 244°C, (c) 274°C, (d) 280°C, and (e) 287°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

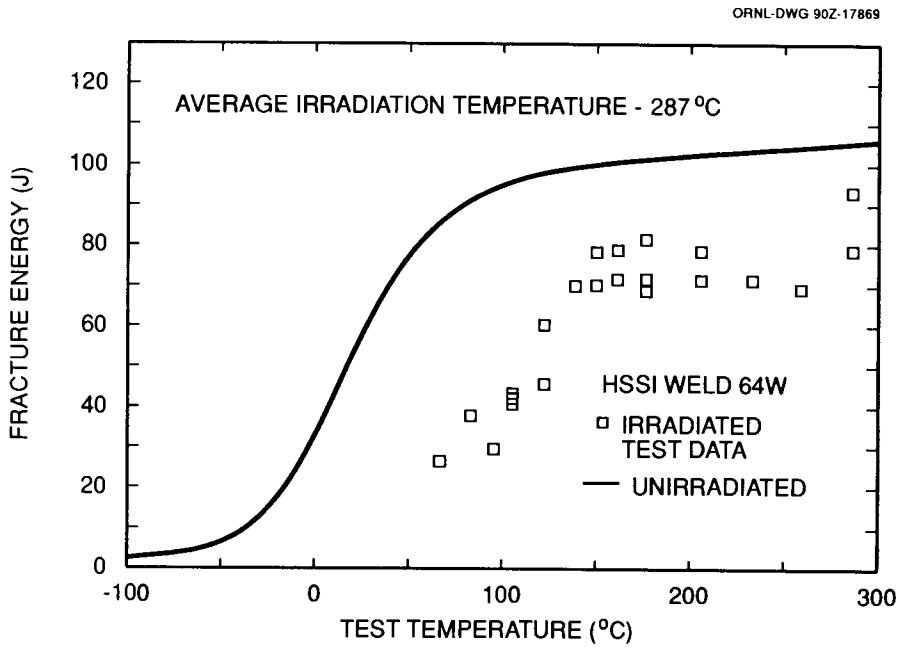


(c)



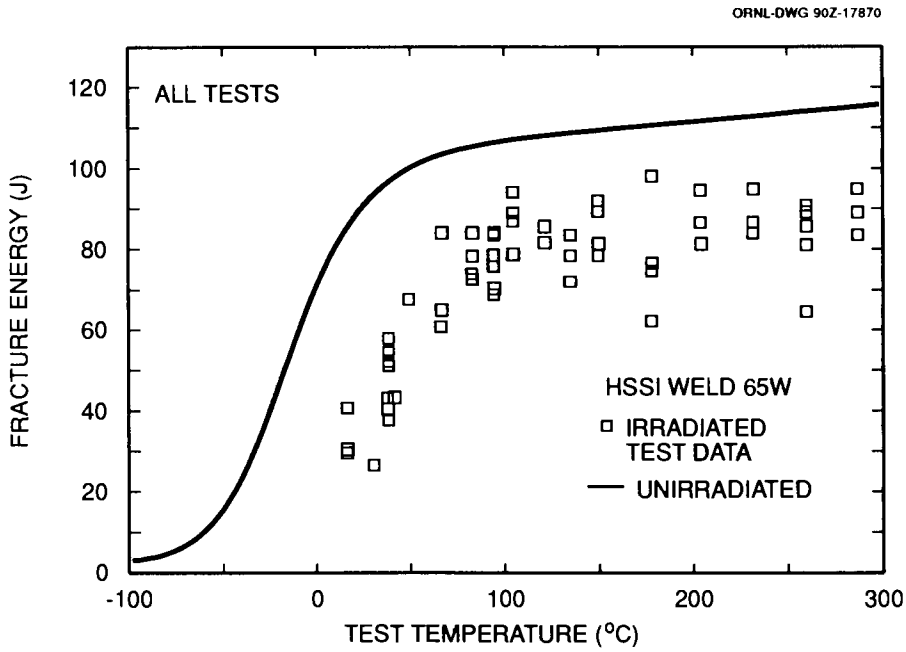
(d)

Fig. 47. (continued)

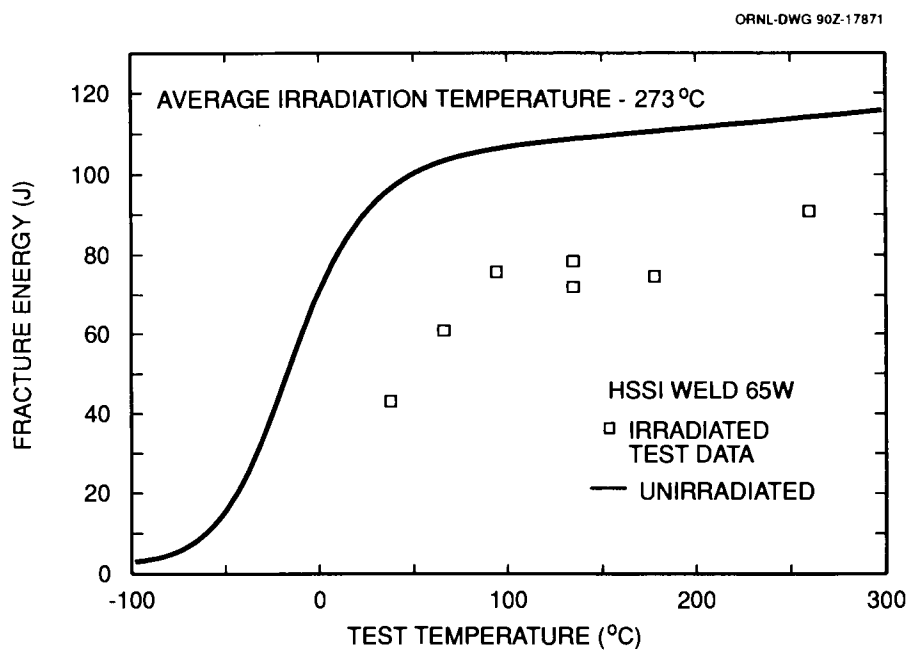


(e)

Fig. 47. (continued)

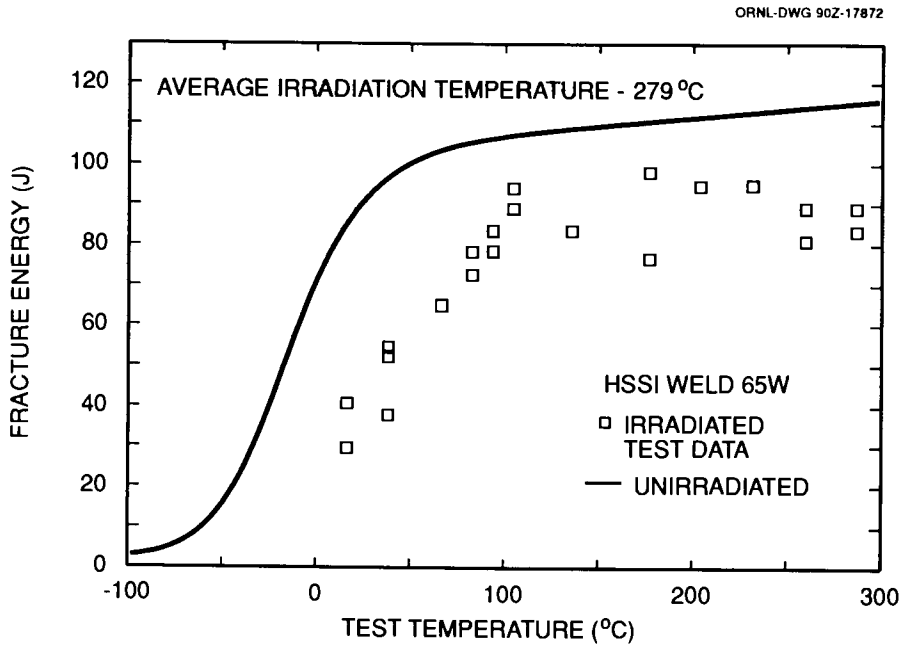


(a)

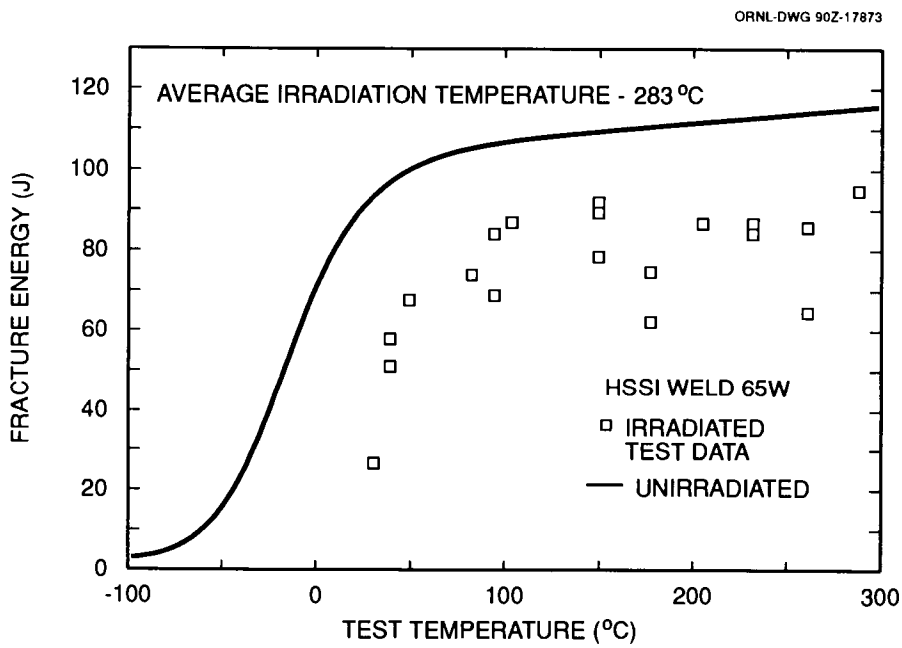


(b)

Fig. 48. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 65W irradiated at various temperatures, (a) all tests, (b) 273°C, (c) 279°C, (d) 283°C, and (e) 285°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

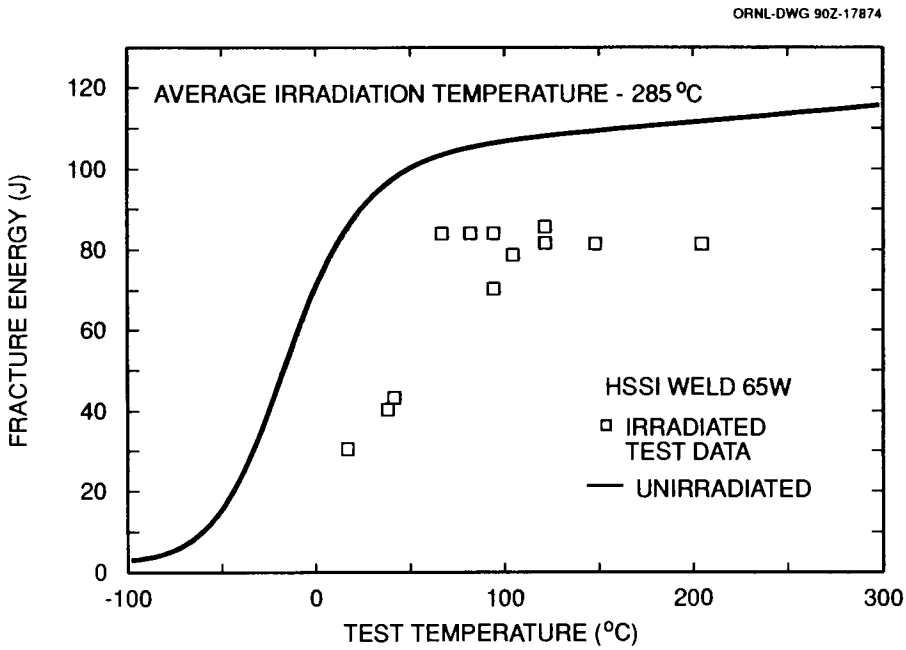


(c)



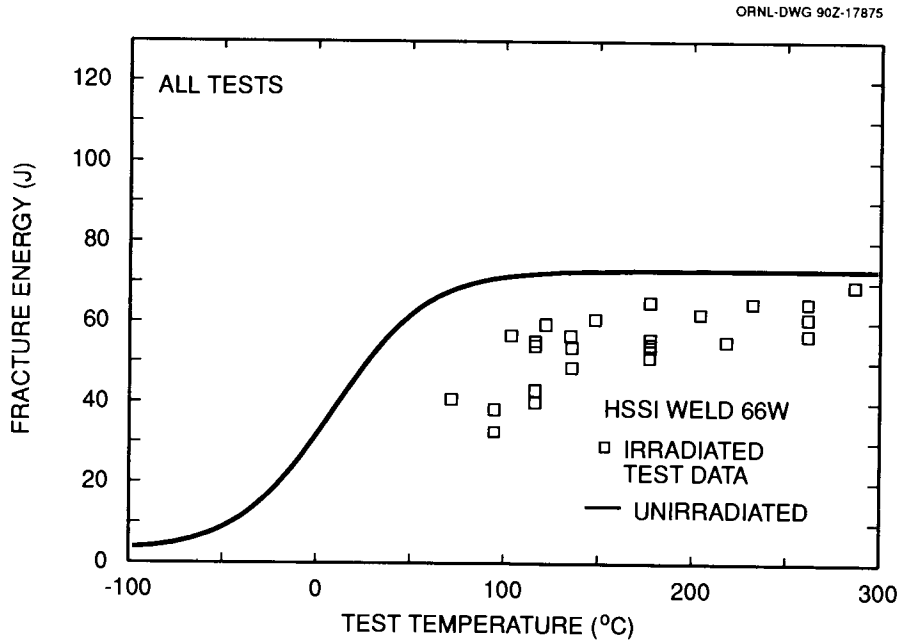
(d)

Fig. 48. (continued)

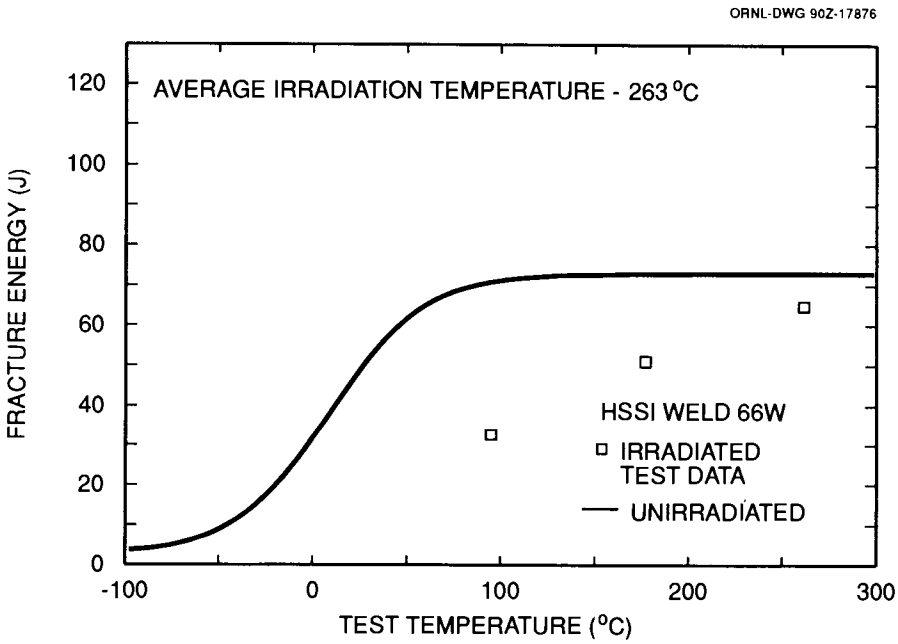


(e)

Fig. 48. (continued)

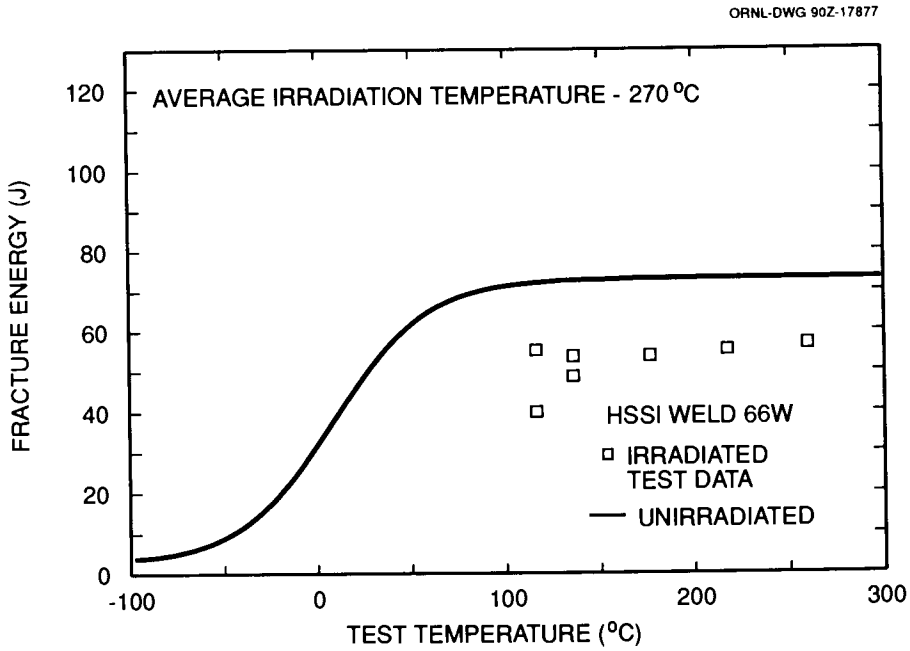


(a)

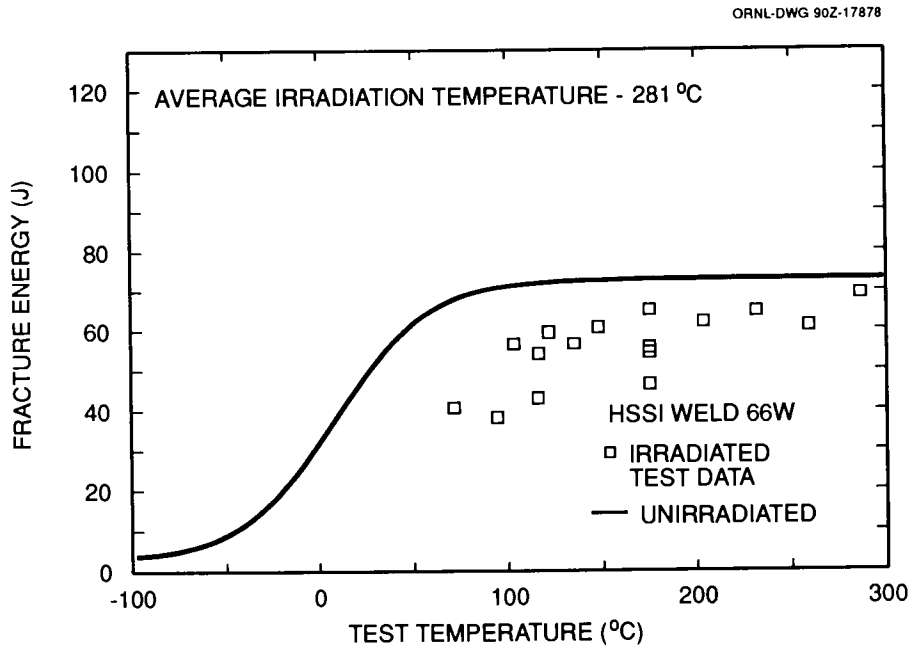


(b)

Fig. 49. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 66W irradiated at various temperatures, (a) all tests, (b) 263°C, (c) 270°C, and (d) 281°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

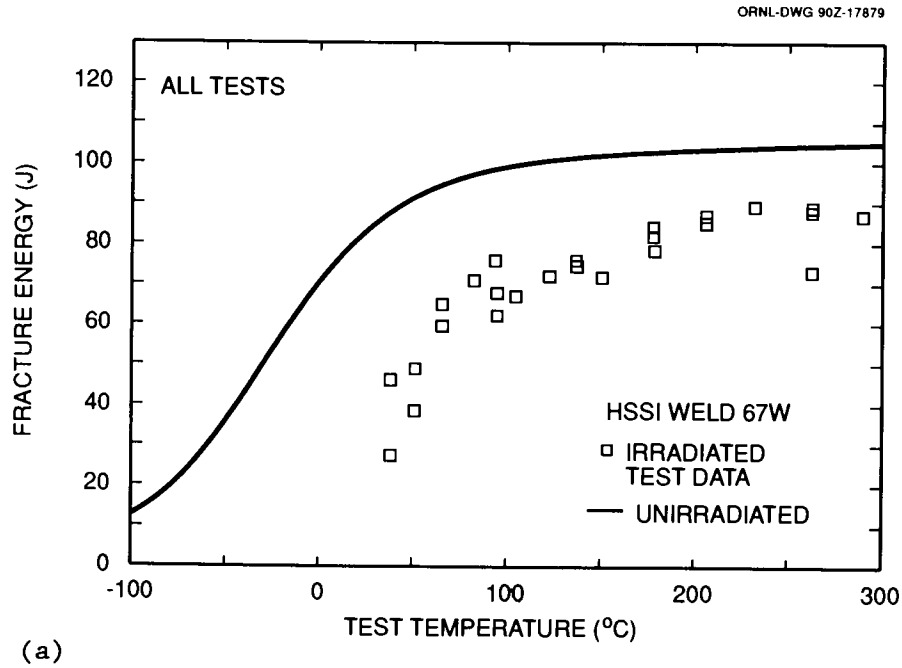


(c)

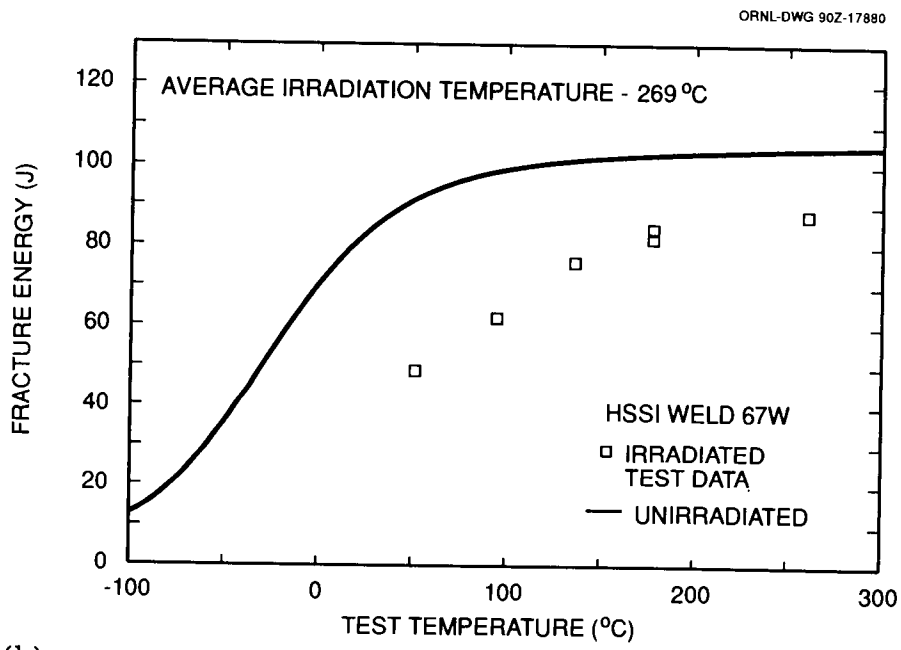


(d)

Fig. 49. (continued)

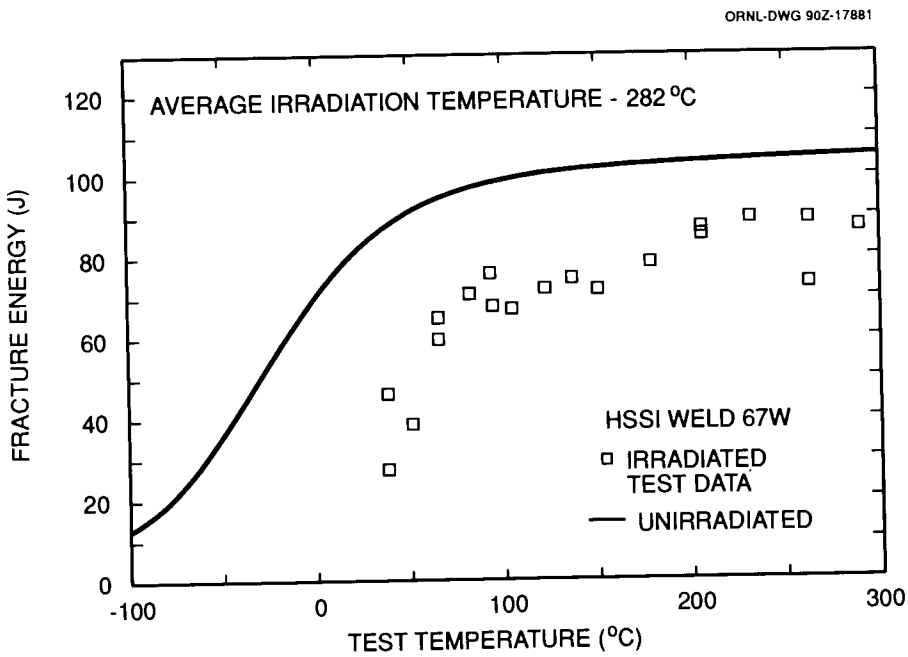


(a)



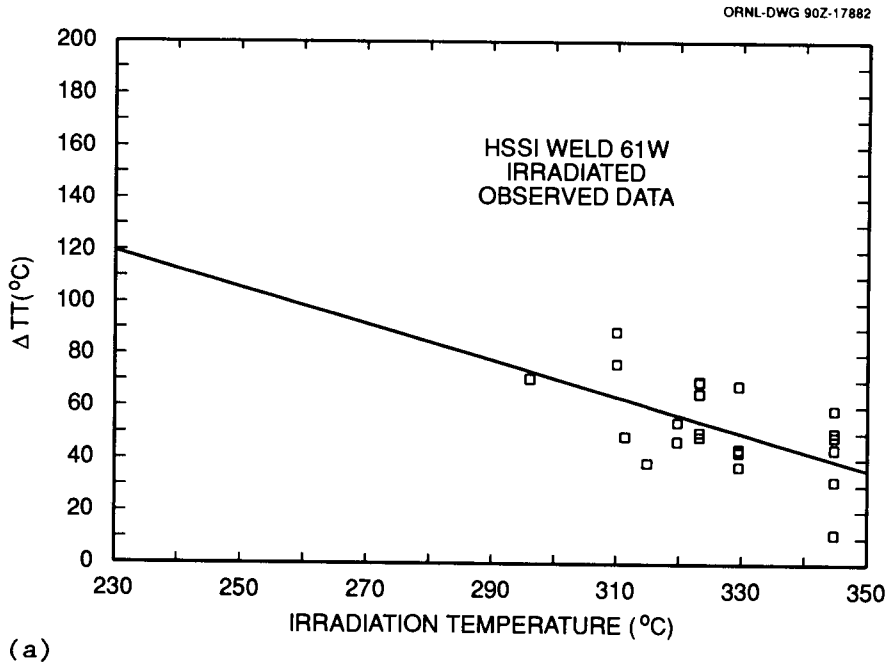
(b)

Fig. 50. Irradiated Charpy V-Notch impact energy vs test temperature for HSSI weld 67W irradiated at various temperatures, (a) all tests, (b) 269°C, and (c) 282°C. The curves shown represent the unirradiated data from the hot cell machine with the hyperbolic tangent fit.

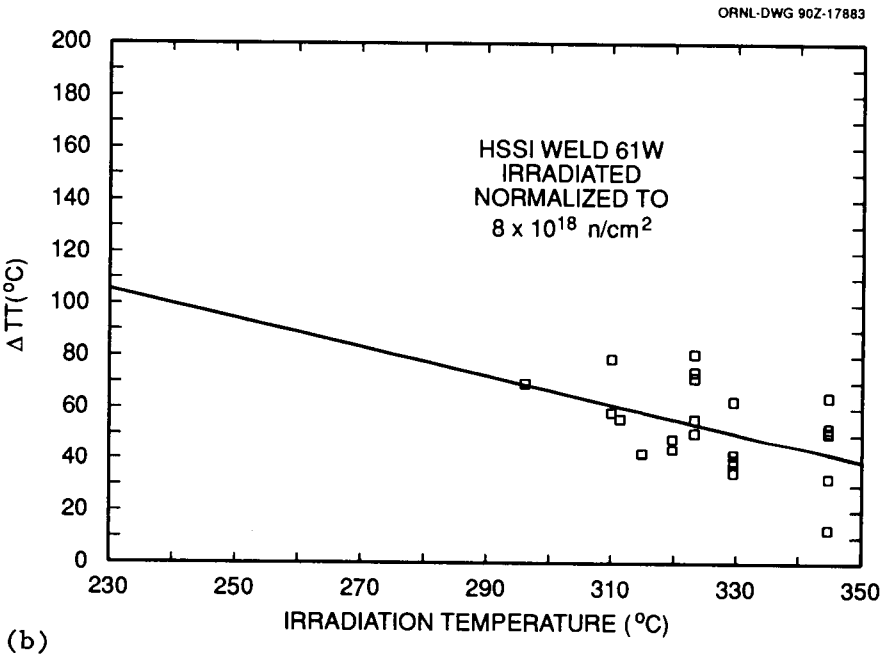


(c)

Fig. 50. (continued)

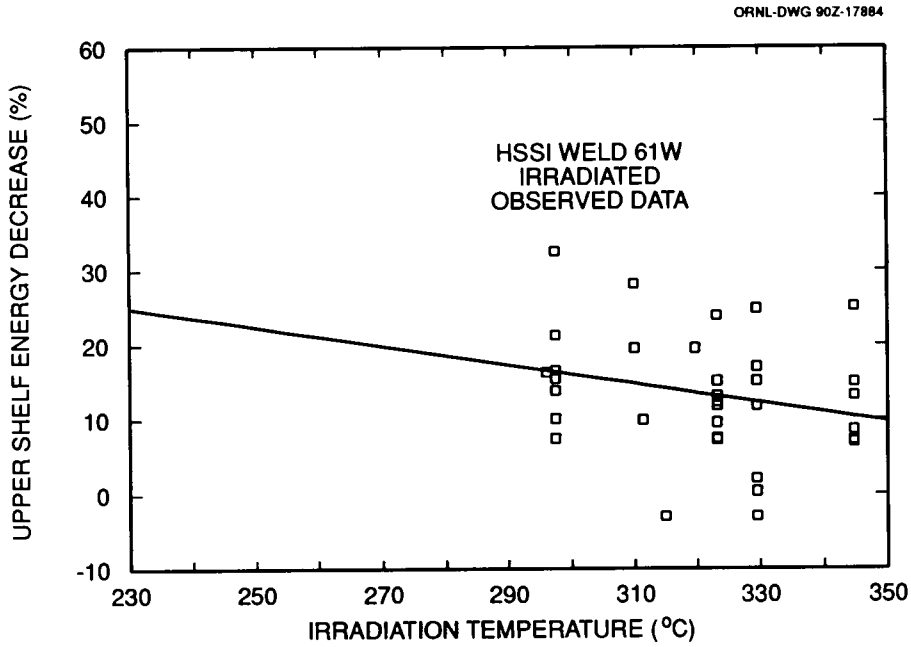


(a)

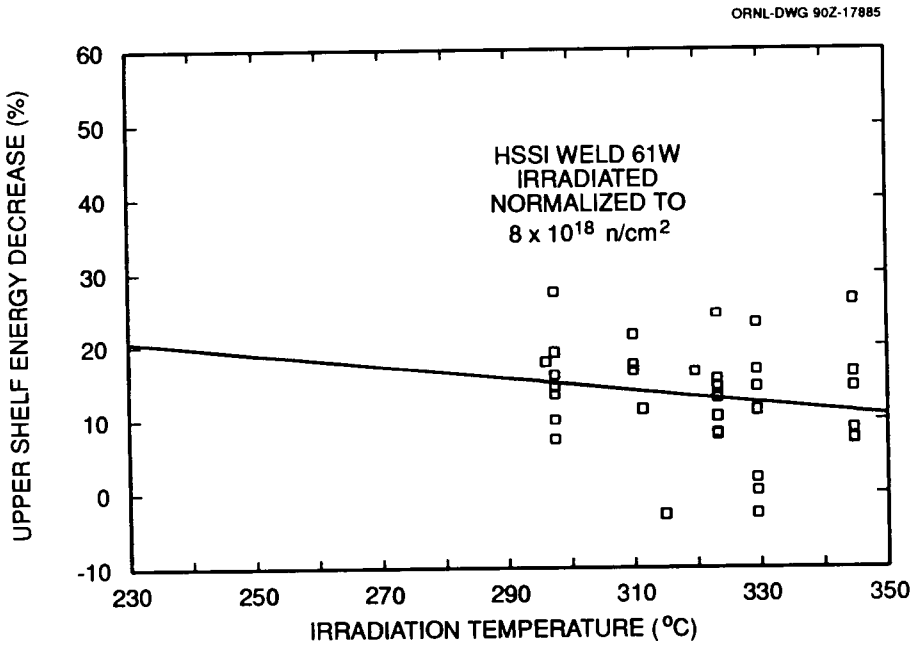


(b)

Fig. 51. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 61W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.



(c)



(d)

Fig. 51. (continued)

energy (percent change). As expected, the effects of irradiation on the ductile-shelf energy become less at higher irradiation temperatures. Figures 52 through 57 provide similar plots for welds 62W through 67W, respectively. Except for the normalized upper-shelf data for 63W and the normalized transition region data for 64W, the results for all the welds show the same trends of decreasing effects of irradiation with increasing irradiation temperature.

Because the nominal operating temperature of RPVs is considered to be 288°C, the CVN data were analyzed to allow for estimates of the transition temperature and ductile-shelf energy changes at an irradiation temperature of 288°C. For 61W, for example, this analysis required fitting the observed and normalized results and extrapolating to 288°C. For other welds interpolation was used. Both linear and quadratic fits were performed but the range of irradiation temperatures for most of the welds was too small for the quadratic analysis to be meaningful. Thus, linear fits have been used to relate the observed transition temperature increase, ΔTT, and the upper-shelf energy decrease, ΔUSE, to irradiation temperature according to:

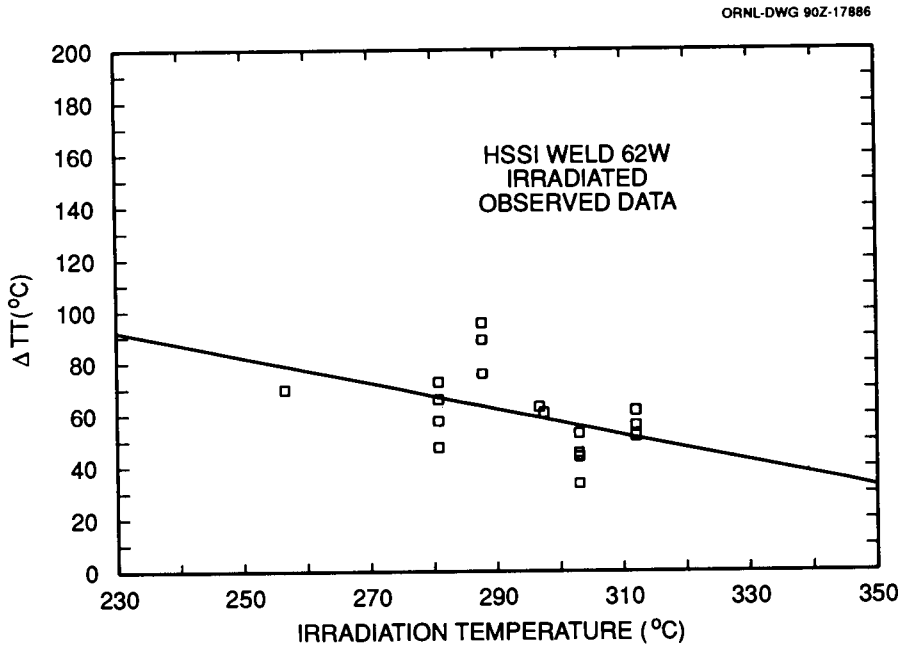
$$\Delta TT = A_1 + B_1 T, \ ^\circ C \ , \tag{1}$$

and

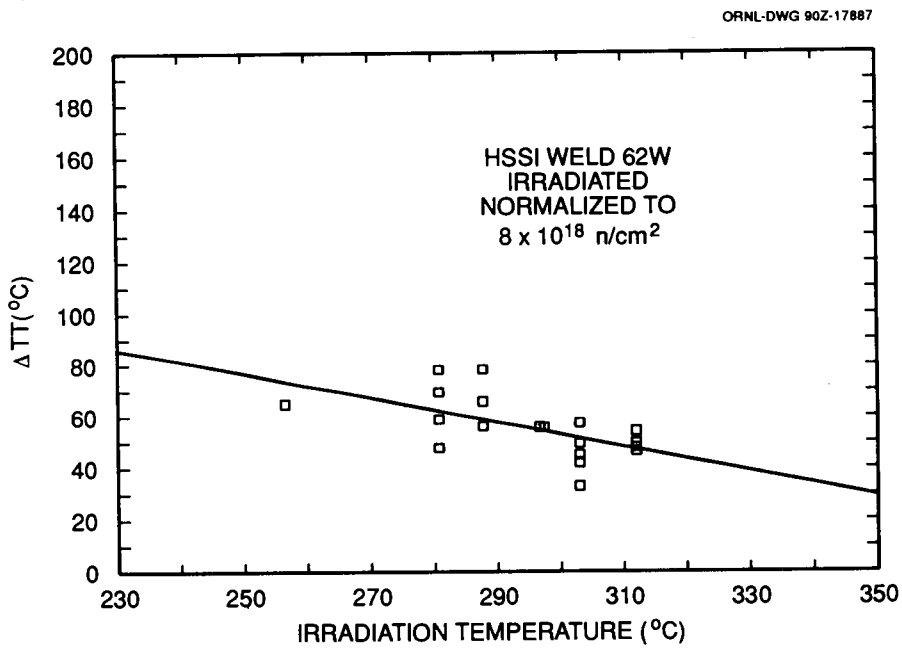
$$\Delta USE = A_2 + B_2 T, \ J, \ . \tag{2}$$

The linear regression analysis results are given in Table B20 for all welds. The normalized transition temperature increase results for 65W, 66W, and 67W show an average standard error value on B_1 of close to one, whereas those for 61W through 64W are much less, indicating a more favorable data set for performing estimations. Using those regression results for 61W through 64W gives average dependencies on irradiation temperature of -0.413°C/°C for transition temperature and -0.058 J/°C for upper-shelf energy change. Interestingly, using the observed changes results in average dependencies of -0.415°C/°C and -0.066 J/°C. Tables 10 and 11 summarize the results of transition temperature increase and upper-shelf energy decrease estimates, respectively. These tables provide the mean fluence, fluence standard deviation, and number of observations in the population for each weld, as well as the estimated changes at an irradiation temperature of 288°C for both the observed and normalized data. Finally, the 41-J temperatures and upper-shelf energies (at 200°C) estimated for an irradiation temperature of 288°C are provided and compared to the estimates from *Regulatory Guide 1.99* (Rev. 2).[24]

Using the linear fits, the transition temperature increases range from 57 to 108°C (103 to 194°F) for the observed results and from 59 to 123°C (106 to 221°F) for the normalized results. Normalization resulted in substantial changes to the estimates for welds 64W through 67W. The mean fluences for those four welds are much further removed from the normalization fluence than are those for 61W through 63W. Regarding the upper-shelf changes, the decreases range from 16.2 to 26.2% for the observed results and from 15.7 to 37.0% for the normalized results. As

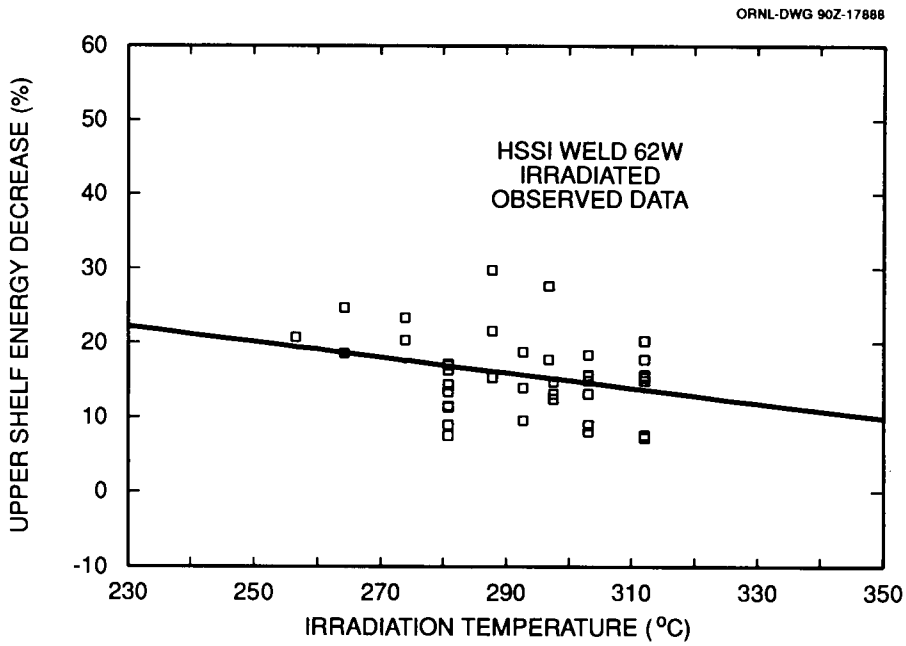


(a)

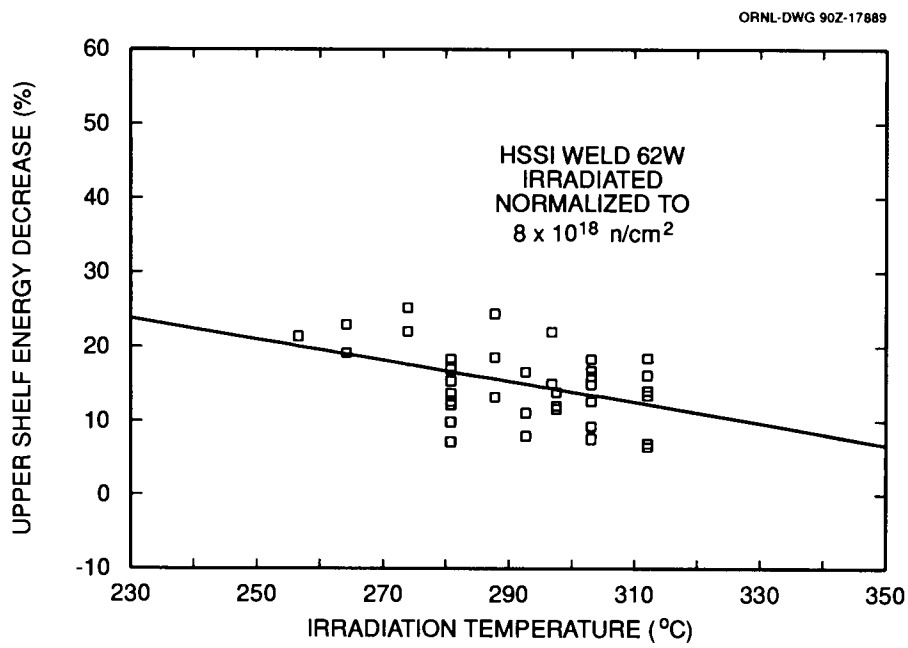


(b)

Fig. 52. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 62W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.

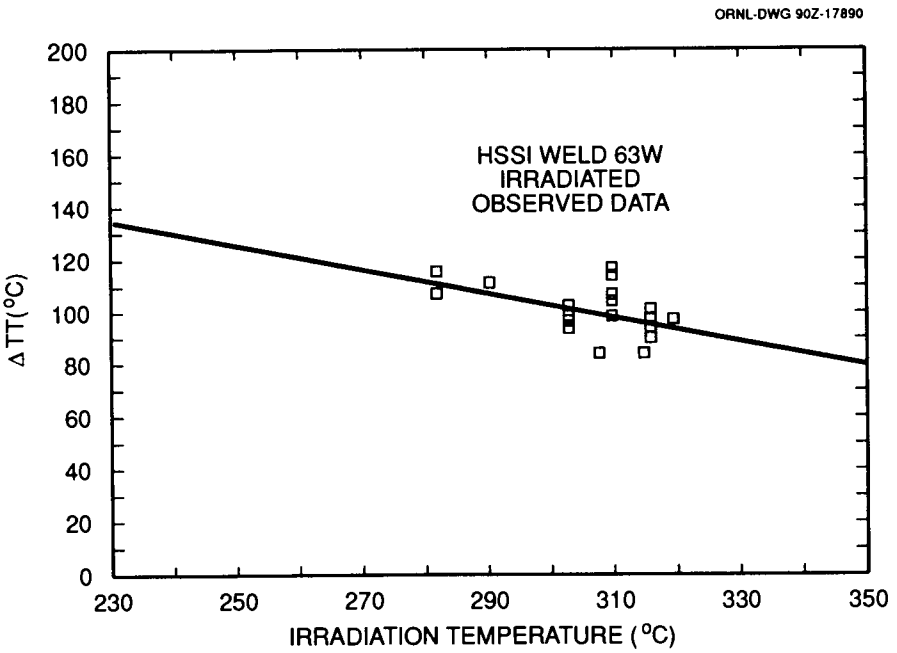


(c)

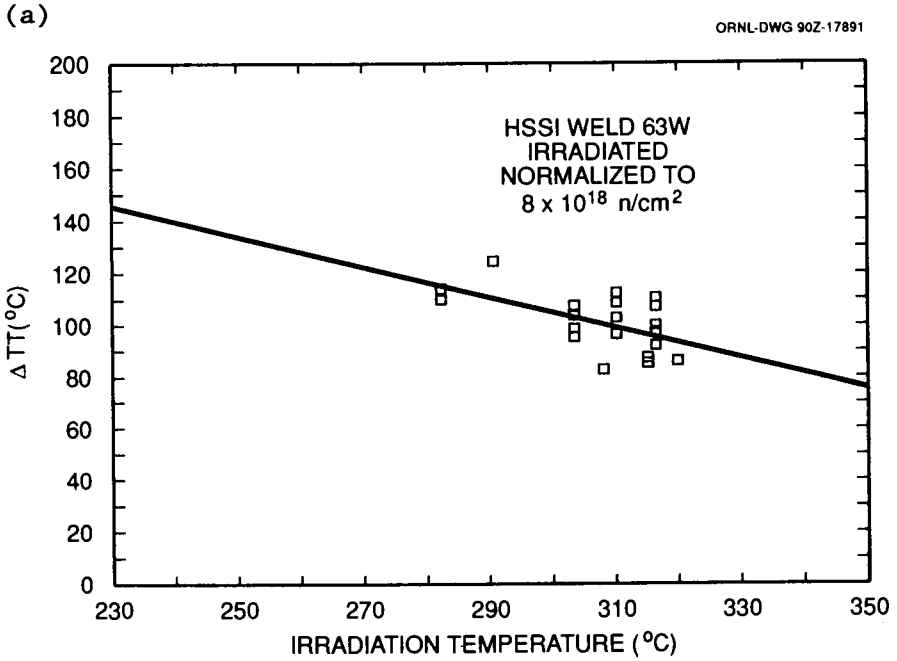


(d)

Fig. 52. (continued)

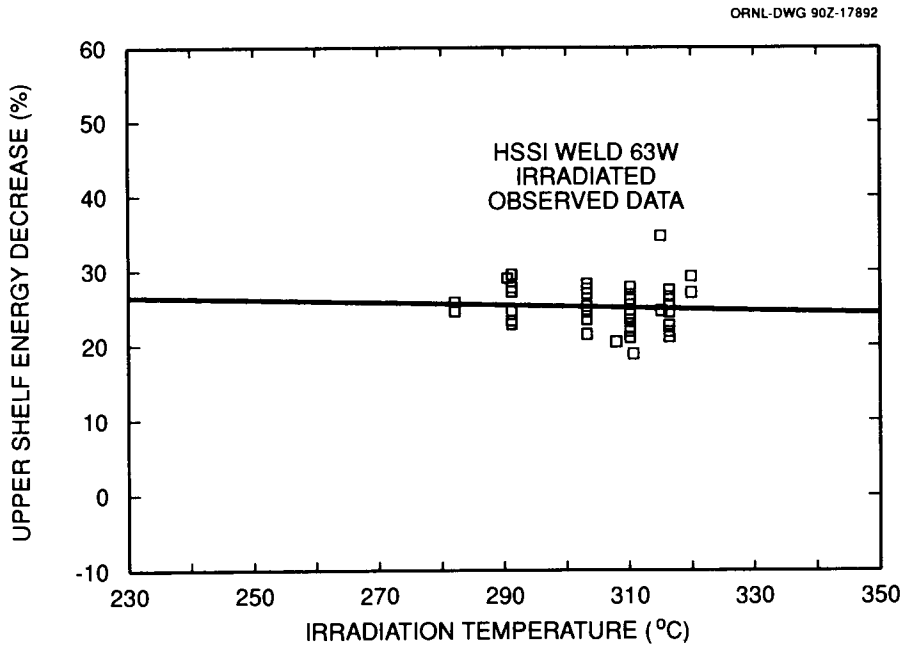


(a)



(b)

Fig. 53. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 63W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.



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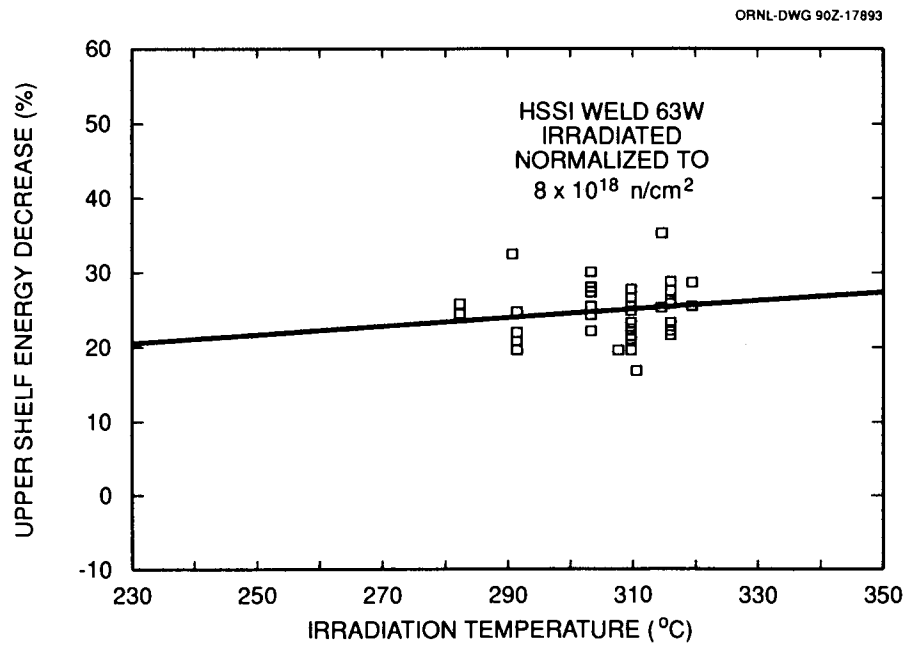
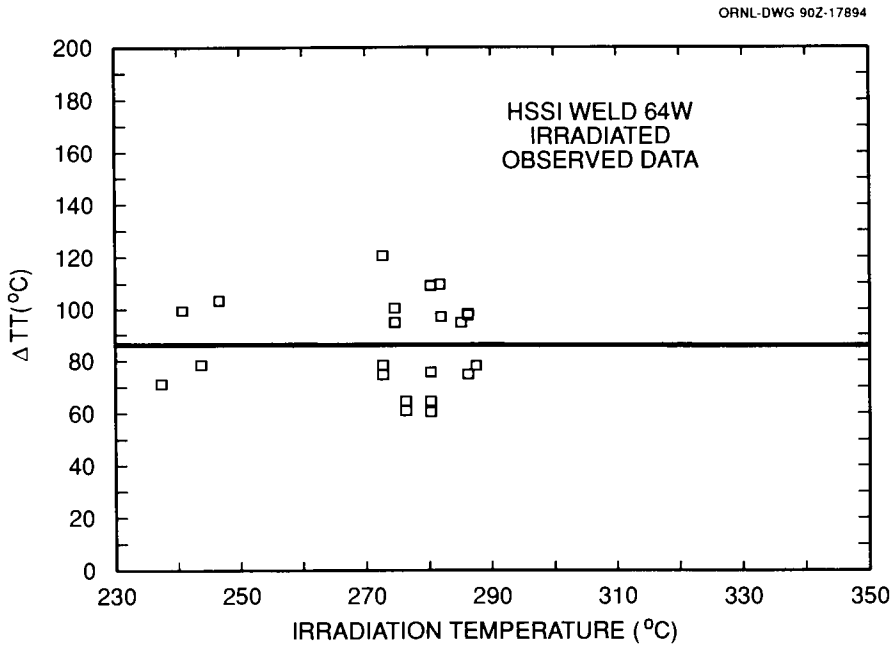
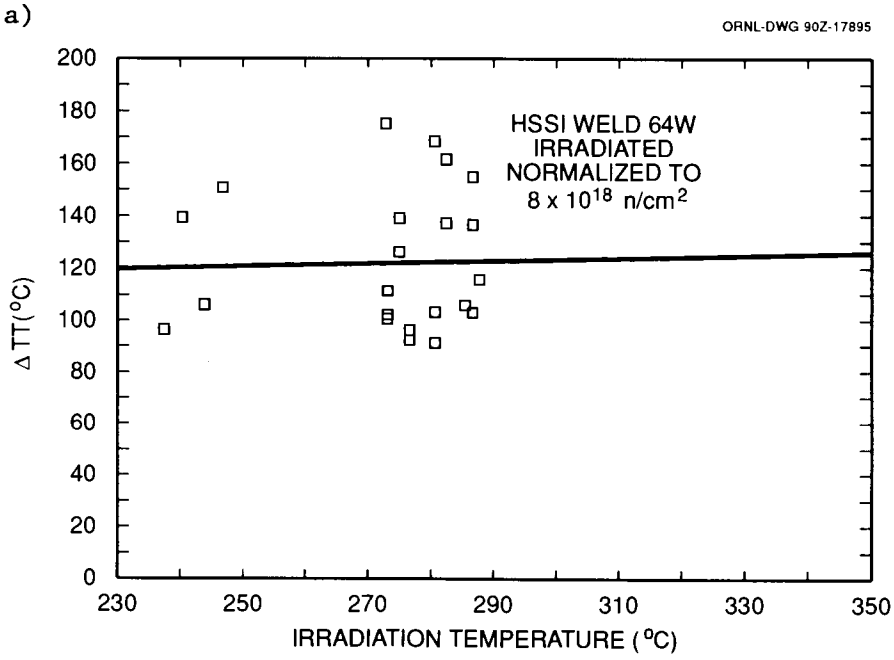


(d)

Fig. 53. (continued)

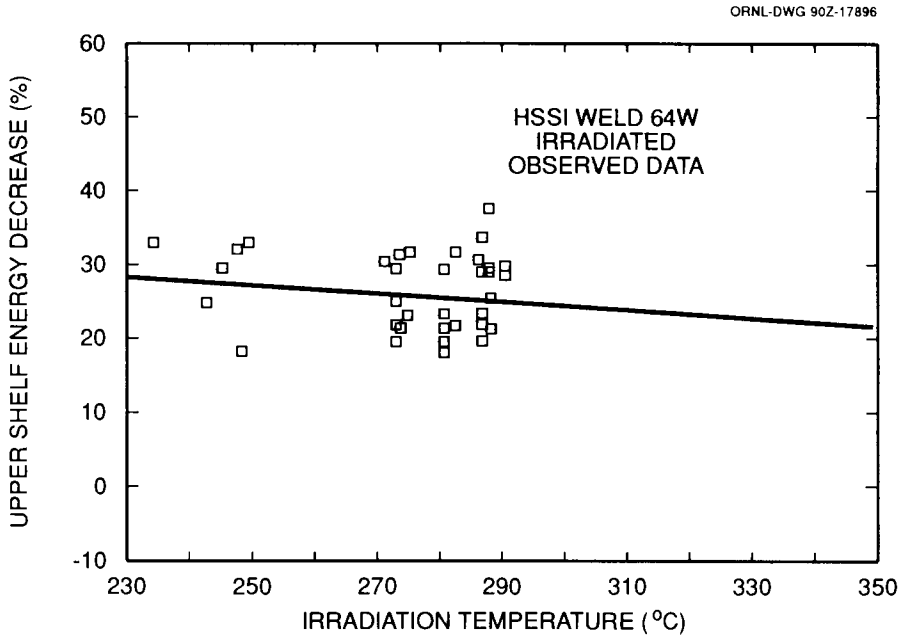


(a)

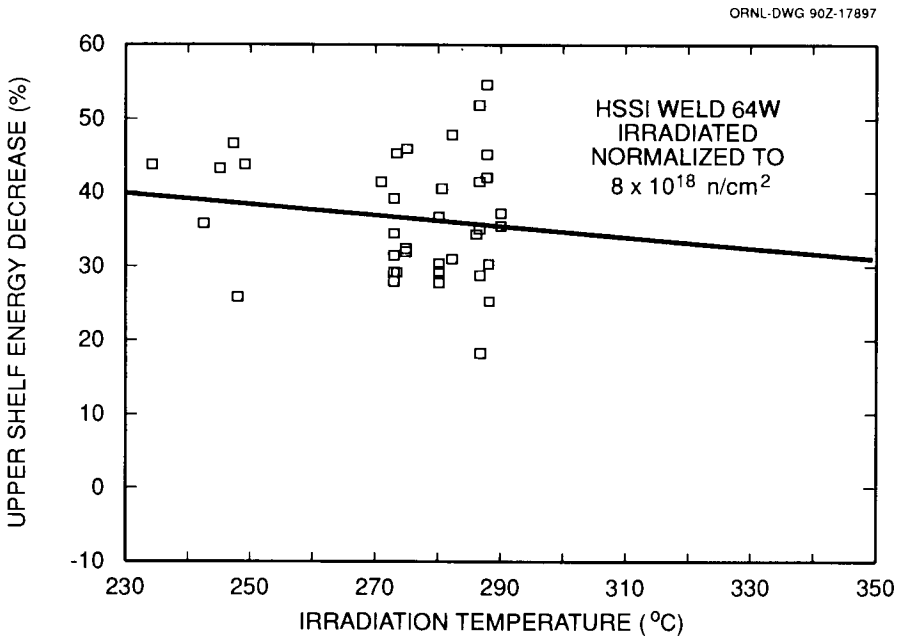


(b)

Fig. 54. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 64W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.

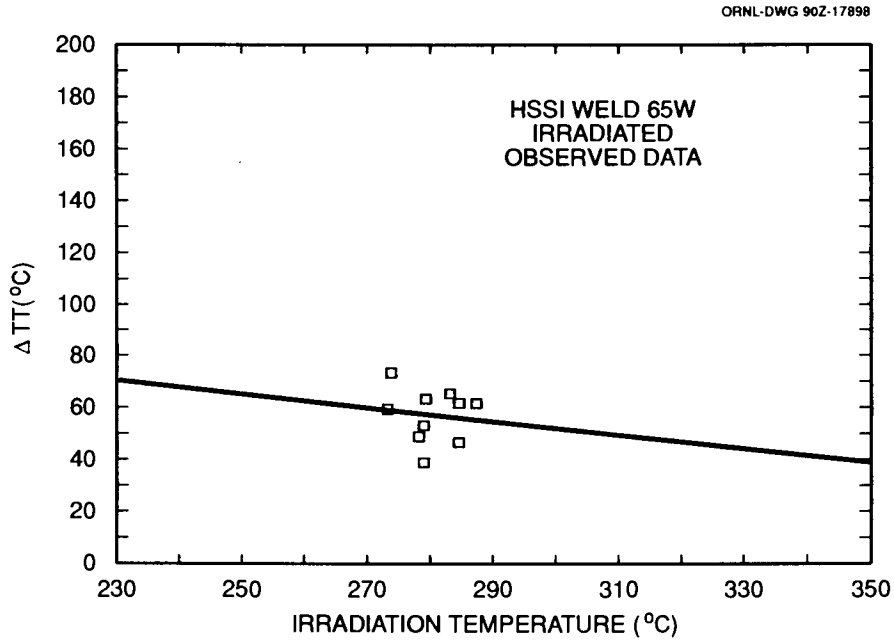


(c)

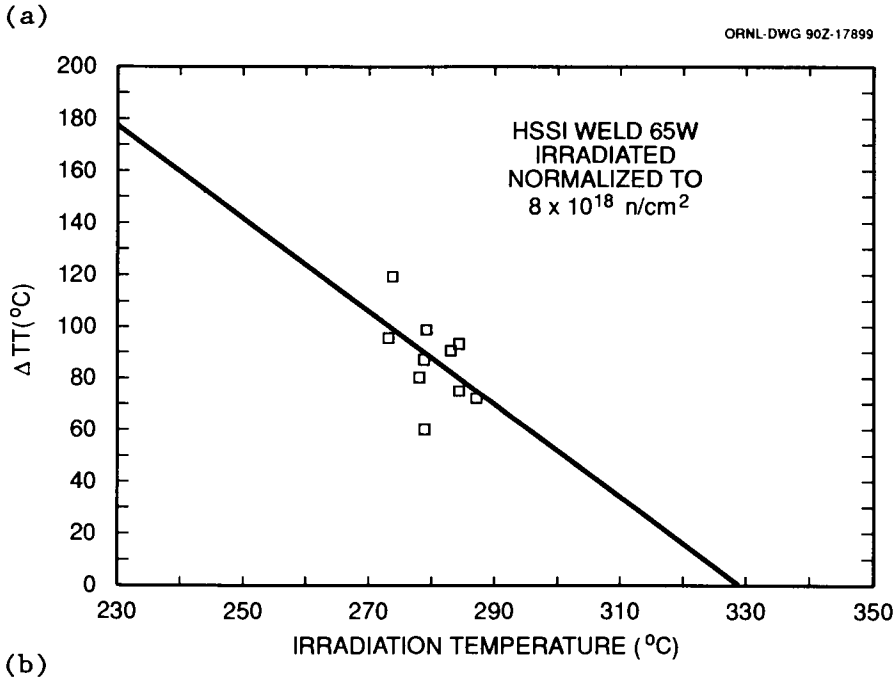


(d)

Fig. 54. (continued)

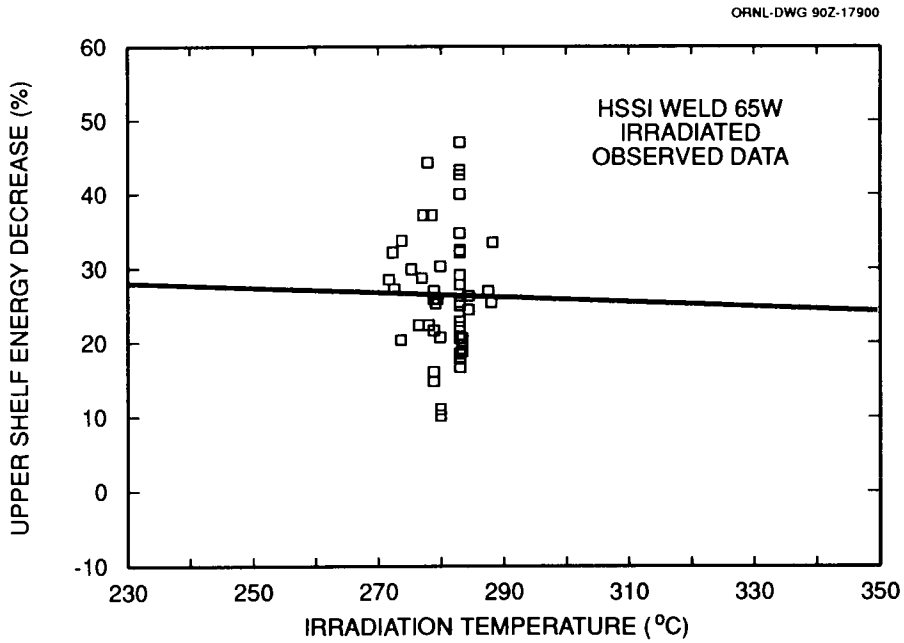


(a)



(b)

Fig. 55. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 65W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.



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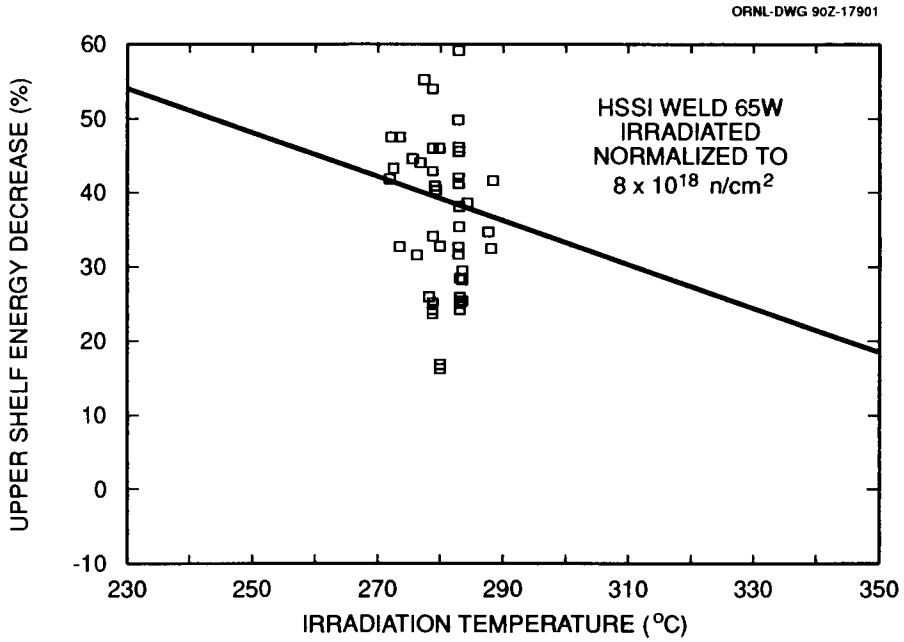

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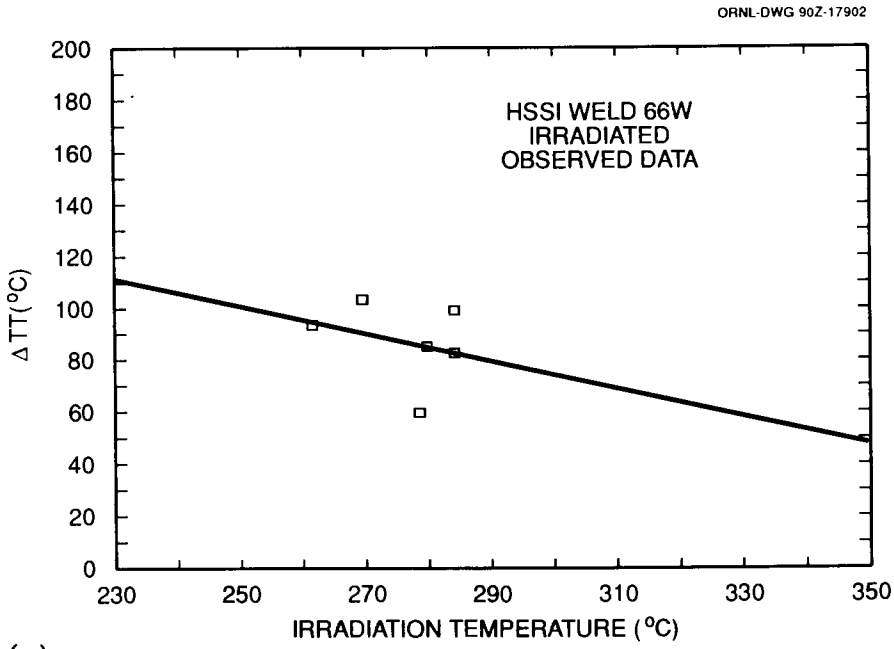
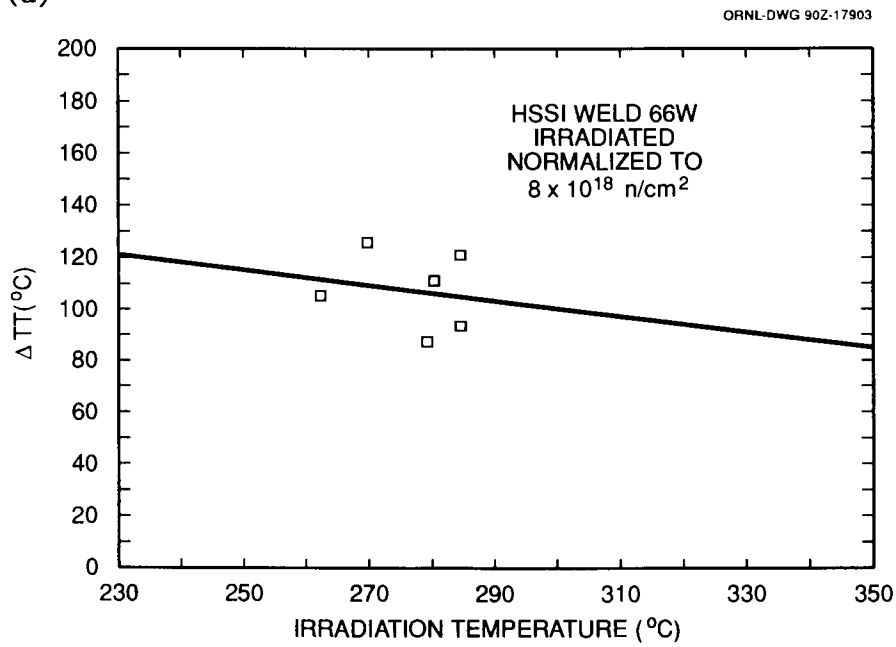
Fig. 55. (continued)

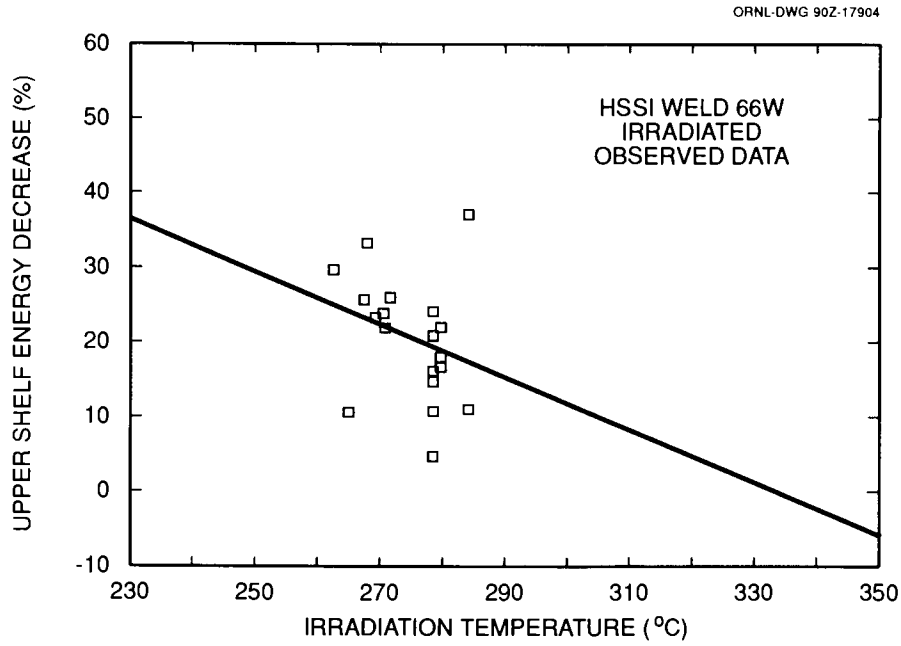


(a)



(b)

Fig. 56. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 66W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.



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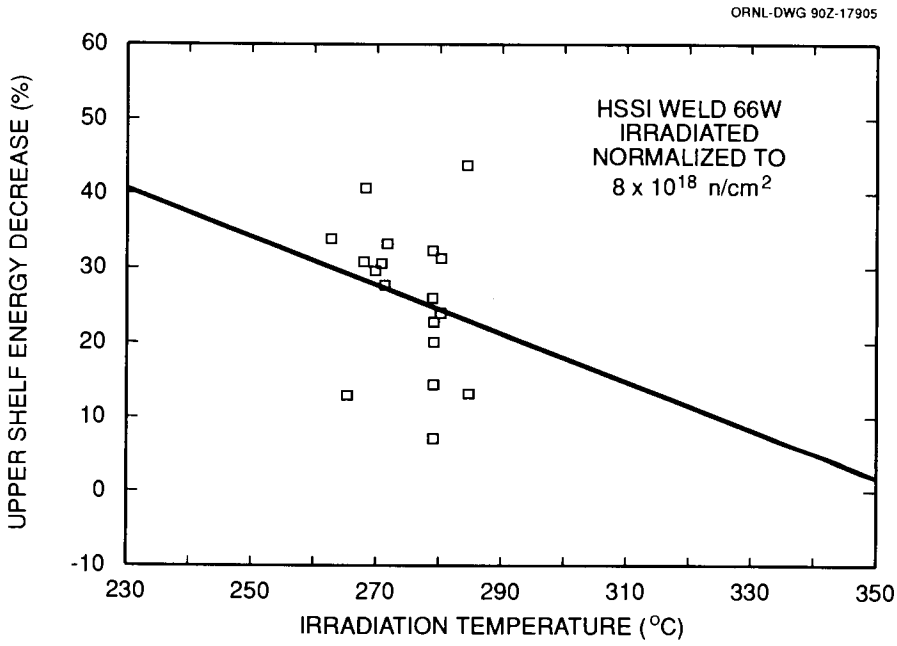

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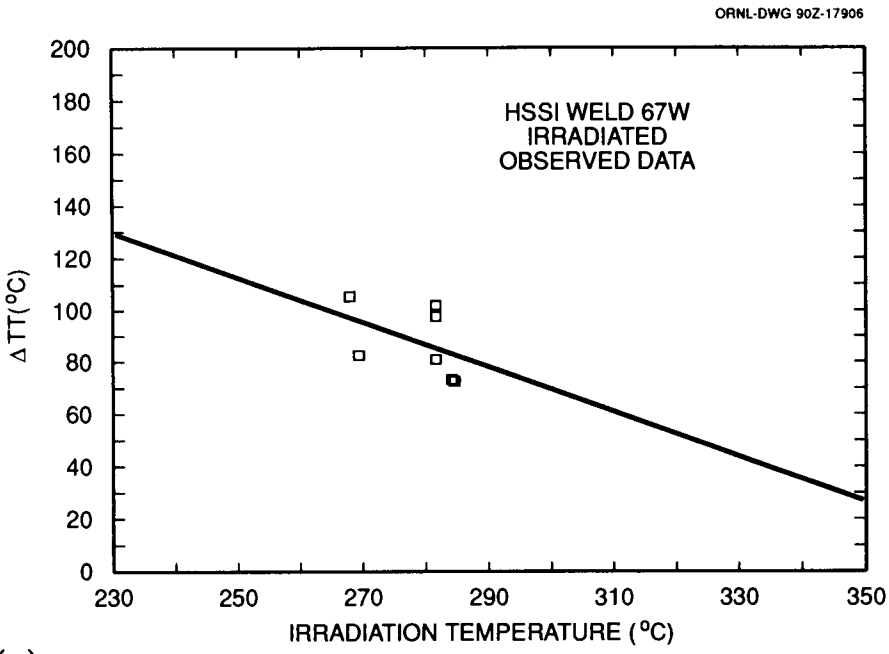
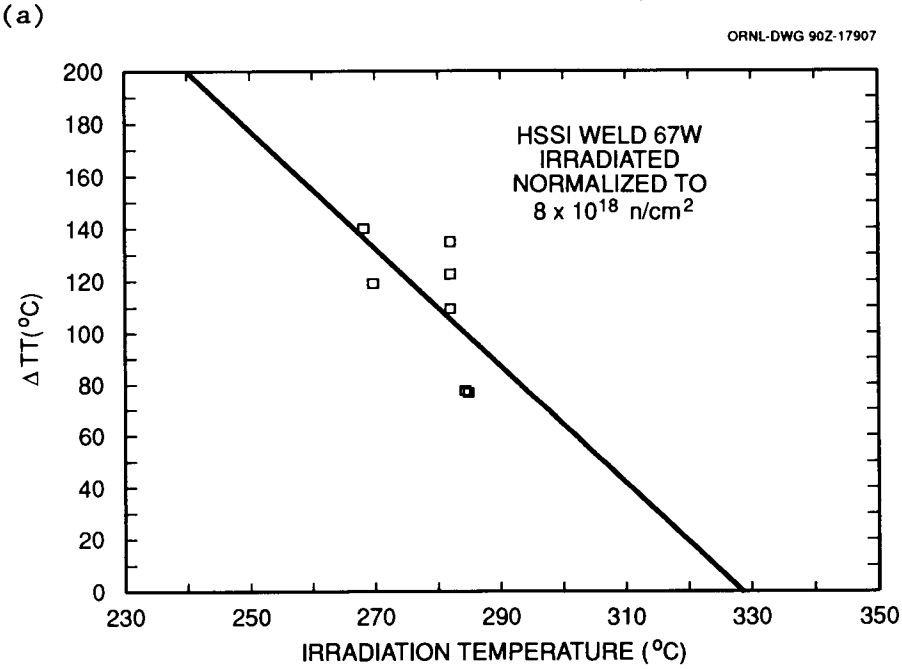
Fig. 56. (continued)

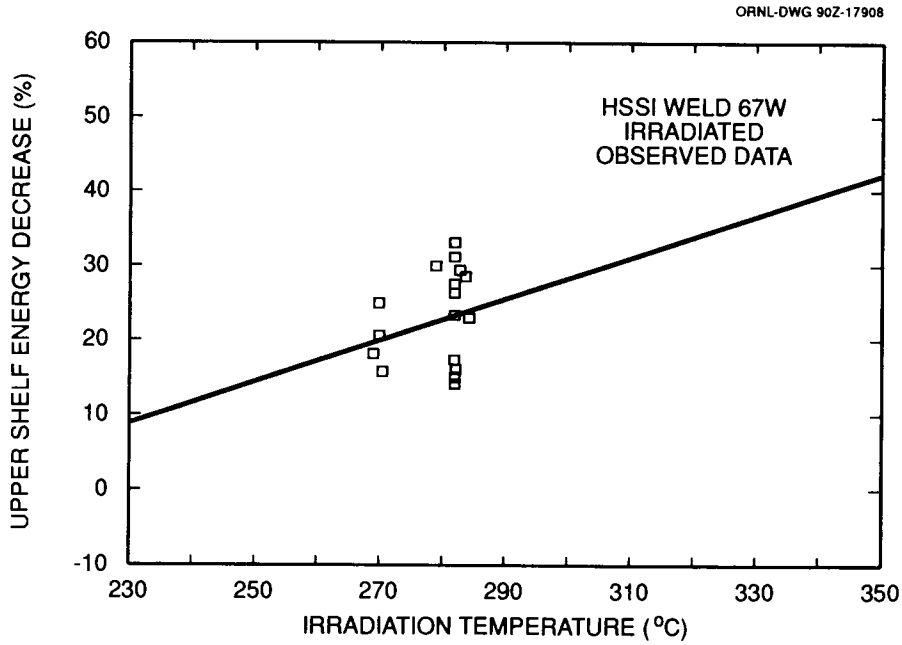


(a)



(b)

Fig. 57. Radiation-induced change in Charpy V-Notch impact toughness for HSSI weld 67W, (a) transition temperature increase vs irradiation temperature for all data, (b) transition temperature increase vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV), and (c) upper-shelf energy decrease vs irradiation temperature, and (d) upper-shelf energy decrease vs irradiation temperature for data normalized to 8×10^{18} neutrons/cm^2 (>1 MeV). All measures of change are relative to the hyperbolic tangent curve fit to the unirradiated data obtained on the hot cell machine. The curves shown are linear fits to the data.



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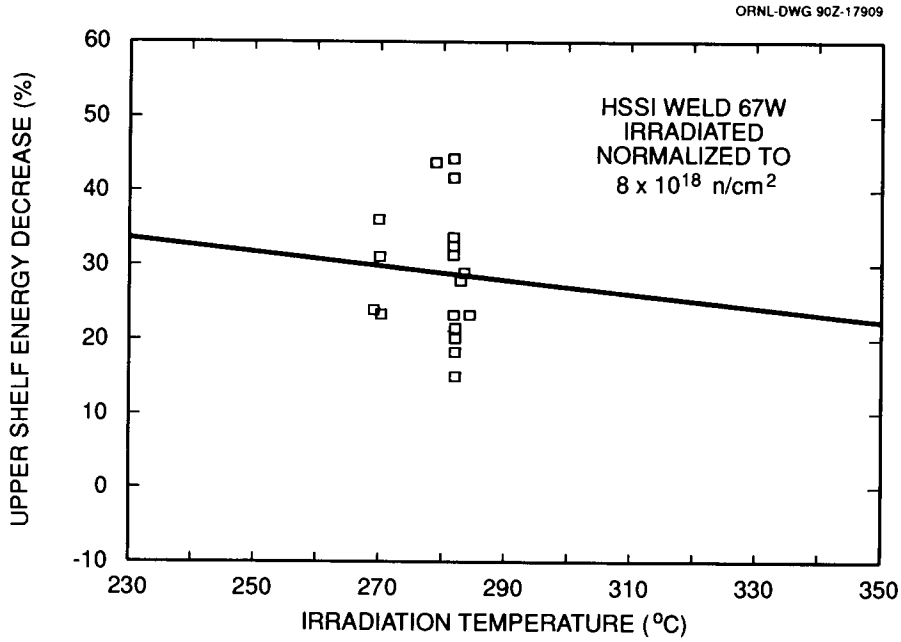

(d)

Fig. 57. (continued)

with the transition region data, the fluences for 64W through 67W were relatively low and normalization resulted in substantial increases in the estimates. It is interesting to compare the estimates derived from these analyses with predictions based on *Regulatory Guide 1.99* (Rev. 2)[24] without the "margin" specified in the Regulatory Guide. Tables 10 and 11 give those predictions and show that, for the observed transition temperature increases, the *Regulatory Guide 1.99* predictions exceed the observed results in every case except for 63W where the difference is only 2°C. For the normalized case (i.e., for a fluence of 8×10^{18} neutrons/cm^2), the *Regulatory Guide 1.99* predictions exceed the test results in every case except for 63W and 64W. For the upper-shelf energy decreases (percent decrease), the *Regulatory Guide 1.99* predictions exceed the weld results in every case except for 65W. Most of the measured upper-shelf energy decreases for the welds were much less than the *Regulatory Guide 1.99* predictions. The 41-J temperature given for each irradiated weld was calculated by adding the estimated transition temperature increase of the normalized data to the 41-J temperature for the unirradiated results. The results indicate that, for an irradiation temperature of 288°C and a neutron fluence of 8×10^{18} neutrons/cm^2 (>1 MeV), the welds in this program would have 41-J temperatures from 46 to 130°C (115 to 266°F) and upper-shelf energies (at 200°C) from 58 to 79 J (43 to 58 ft-lb).

9.3 CHARPY AND TENSILE CORRELATIONS AND COMPARISONS

Various comparisons of CVN test results were examined for potential use as correlations. Figure 58 shows lateral expansion vs fracture energy for all the unirradiated CVN tests. The scatter is rather large but data from seven welds are represented. Figure 59 is a plot of the same comparison for one of the welds, 61W, and shows that the scatter is much less. Figure 60 is a similar plot for all the irradiated data. A linear regression for all the data in Fig. 58 gives the equation:

$$LE = -0.089 + 0.017*E \ , \qquad (3)$$

where LE is lateral expansion in millimeters and E is absorbed energy in Joules. For a material with the same average yield strength [482 MPa (70 ksi)], *WRC Bulletin 175* (ref. 7) provides plots of Charpy energy vs yield strength for various lateral expansions. Scaling of the curves from those plots followed by a linear regression of the measured data gave the equation:

$$LE = 0.101 + 0.014*E \ . \qquad (4)$$

Using those equations, for a Charpy energy of 70 J, Eq. (3) would predict a lateral expansion of 1.101 mm while Eq. (4) would predict 1.081 mm, an excellent agreement. A similar fit to the irradiated data gives:

Table 10. Radiation-induced Charpy impact transition temperature results for HSSI welds 61W through 67W adjusted to irradiation temperature of 288°C

Weld	Observed fluence[a] ($n/cm^2 \times 10^{-18}$)	Number of tests	Charpy transition temperature increase, °C				41-J temperature, °C (°F)	
			Observed fluence		Normalized fluence[b]			
			Observed result	RG 1.99 prediction	Normalized result	RG 1.99 prediction	Observed	Normalized[b]
61W	8.14 ± 1.86	24	79	100	74	100	62 (144)	57 (135)
62W	9.37 ± 2.35	19	63	85	59	81	50 (122)	46 (115)
63W	7.75 ± 1.01	22	108	106	112	107	82 (180)	86 (187)
64W	4.00 ± 0.61	23	86	92	123	115	93 (199)	130 (266)
65W	3.65 ± 0.82	10	57	66	74	86	33 (91)	50 (122)
66W	5.25 ± 0.90	6	81	105	104	120	94 (201)	117 (243)
67W	5.20 ± 1.24	7	80	82	92	94	39 (102)	51 (124)

[a]±1 standard deviation.

[b]Normalized to fluence of 8×10^{18} neutrons/cm^2.

Table 11. Radiation-induced Charpy impact upper-shelf energy results for HSSI welds 61W through 67W adjusted to irradiation temperature of 288°C

Weld	Observed fluence[a] ($n/cm^2 \times 10^{-18}$)	Number of tests	Charpy upper-shelf decrease						Upper-shelf energy, J (ft-lb)	
			Observed result (J)	Normalized[b] result (J)	Observed fluence (%)		Normalized fluence[b] (%)			
					Observed result	RG 1.99 pred.	Normalized result	RG 1.99 pred.	Observed	Normalized[b]
61W	8.32 ± 1.70	35	14.9	13.4	17.7	41	15.8	40	70 (52)	72 (53)
62W	8.93 ± 1.73	40	15.0	14.5	16.2	35	15.7	34	79 (58)	79 (58)
63W	8.34 ± 1.82	39	22.8	21.4	25.6	41	24.0	41	67 (49)	68 (50)
64W	4.05 ± 0.70	38	25.8	36.5	25.3	37	35.8	41	76 (56)	65 (48)
65W	3.72 ± 0.67	51	28.0	39.6	26.2	24	37.0	34	83 (61)	70 (52)
66W	5.04 ± 0.72	19	12.0	16.2	16.4	37	22.1	41	62 (46)	58 (43)
67W	5.20 ± 1.75	18	25.0	28.6	25.2	30	28.4	37	78 (57)	74 (55)

[a]±1 standard deviation.

[b]Normalized to fluence of 8×10^{18} neutrons/cm^2.

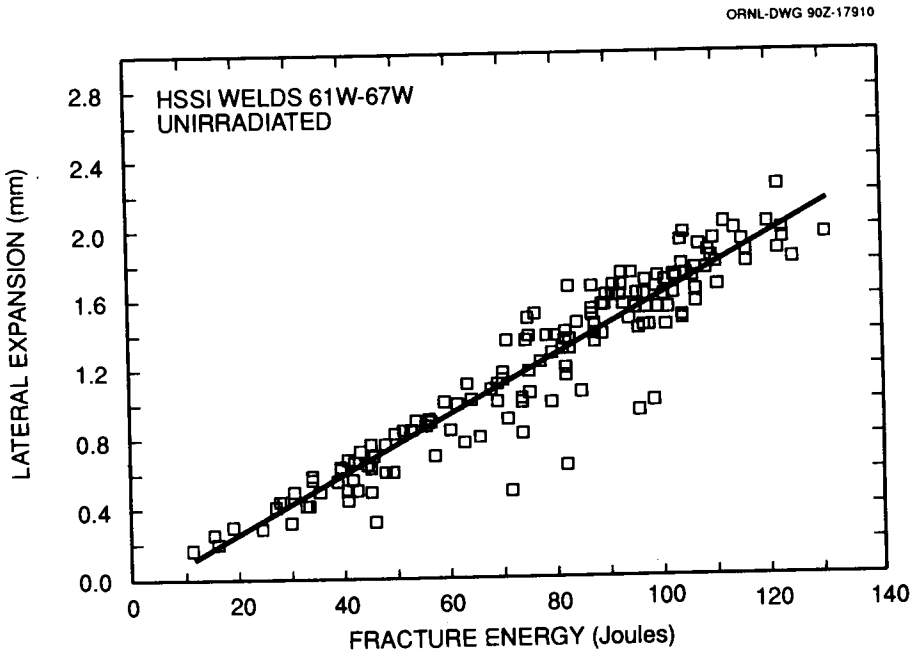

Fig. 58. Unirradiated Charpy V-Notch impact test lateral expansion vs absorbed energy for HSSI welds 61W through 67W.

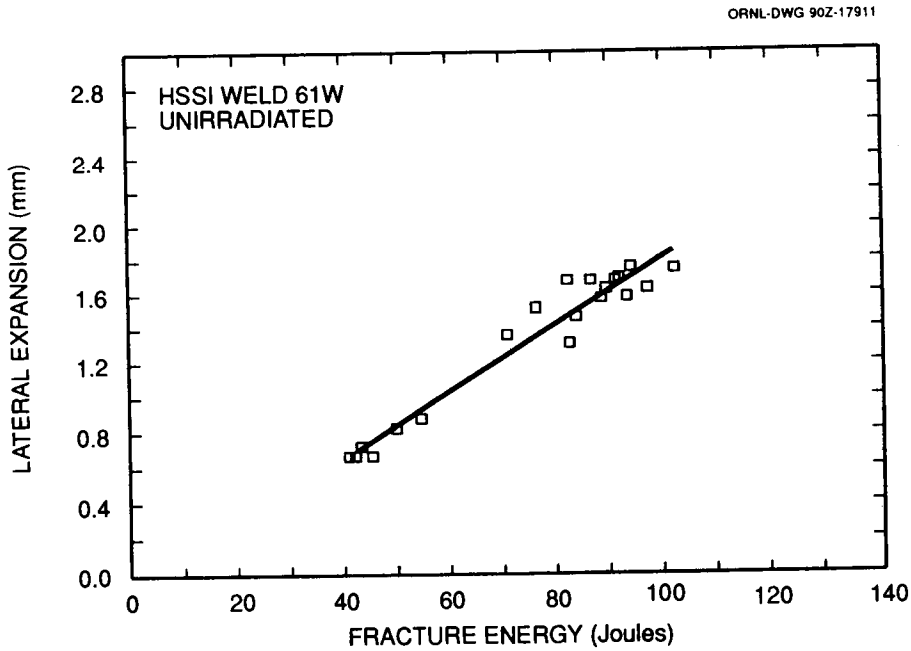

Fig. 59. Unirradiated Charpy V-Notch impact test lateral expansion vs absorbed energy for HSSI weld 61W.

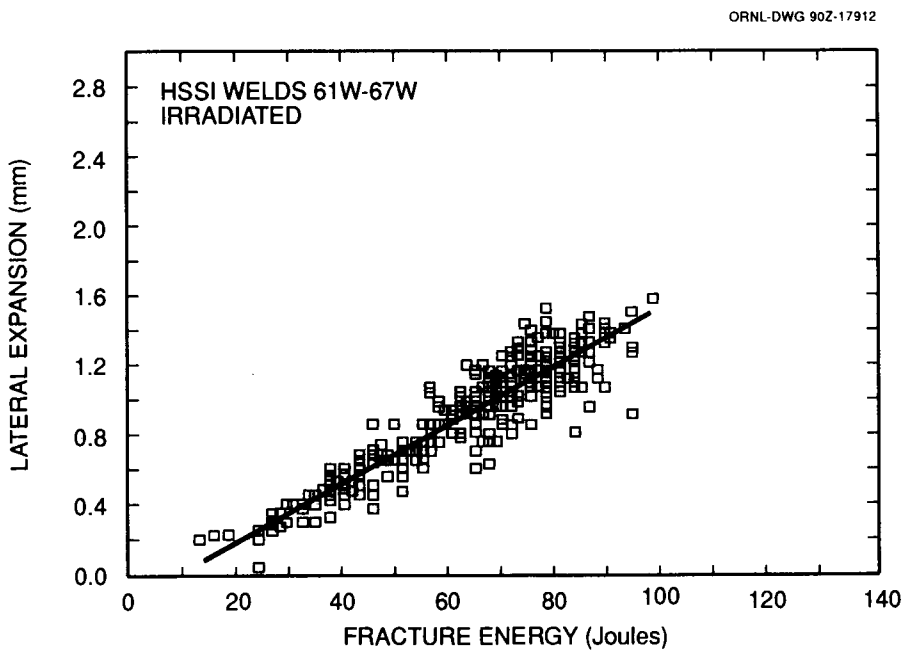

Fig. 60. Irradiated Charpy V-Notch impact test lateral expansion vs absorbed energy for HSSI welds 61W through 67W.

$$LE = -0.142 + 0.017*E \ . \tag{5}$$

The slope (millimeters/Joules) of the fit is only about 3% less than that for the unirradiated data, and the predicted lateral expansion value at an energy value of 70 J is 1.048 mm. Thus, the relationship does not appear to have changed for the irradiated welds 61W through 67W even though their yield strengths increased significantly. The relationships shown in *WRC Bulletin 175*, however, imply that, at a given energy level, lateral expansion decreases substantially with increasing yield strength.

Regarding the effects of irradiation temperature on yield strength, Odette and Lucas[25] reported an average change of -1.8 MPa/°C for high-copper alloys irradiated at high fluxes. As presented earlier, the tensile results for the low upper-shelf welds in this study exhibited an average dependence of yield strength on irradiation temperature of -1.15 MPa/°C, a reasonably good agreement with the average results of ref. 25, considering the wide variations discussed in their paper.

In ref. 25, Odette and Lucas provide an extensive discussion of the hardening (i.e., increase in yield strength) dependence on neutron fluence. The power law dependencies are quite variable depending on flux, composition, fluence, material form, and irradiation temperature. Although they conclude that an exponent of about 0.5 is a good overall average, they presented data which indicated exponents varying from less than 0.1 to greater than 1. As mentioned earlier, the data in this study were relatively sparse but a power law fit to the yield strength results gave an exponent of about 0.07 (quite low compared to the average results in ref. 25, even considering the reported scatter). It is noted, however, that the fluence range for the welds in this study was relatively small, less than one order of magnitude.

Regarding correlations between Charpy impact and tensile data, Odette, Lombrozo, and Wullaert[26] reported an average relationship between Charpy 41-J shift and yield strength increase as:

$$\Delta TT_{41} = C*(\Delta\sigma_y) \ , \tag{6}$$

where the parameter C is about 0.65°C/MPa for welds. For welds 61W through 67W irradiated at 288°C to a fluence of 8×10^{18} neutrons/cm^2, the average value of C is 0.70 MPa/°C (the individual values ranging from 0.454 to 0.937), in excellent agreement with those of ref. 26.

As discussed earlier, the Charpy impact data obtained at the measured fluences were normalized to a fluence of 8×10^{18} neutrons/cm^2 using an exponential dependence on fluence of 0.5. That value is reported by Odette and Lucas[23] to be an average result for high-flux irradiations in test reactors. It is interesting to note that they report an exponent of 0.18 for welds irradiated in surveillance capsules to intermediate fluences. In the same reference, they report an approximate sensitivity to bulk copper concentration such that:

$$\Delta TT_{41} \approx C(Cu - 0.1)^{0.5} \ , \tag{7}$$

where C = 200 ± 25°C. A similar analysis of welds 61W through 67W gives:

$$\Delta TT_{41} = 234*(Cu - 0.01)^{0.57} , \quad (8)$$

in reasonably good agreement with those of ref. 23. Figure 61 shows a log-log plot of the transition temperature shifts for welds 61W through 67W (adjusted to an irradiation temperature of 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2) vs the parameter (Cu - 0.1). Within the reported scatter, the dependence on copper (neglecting influences of other variables) for the Charpy shifts of the low upper-shelf welds of this study is similar to those reported results.

Regarding the dependence of Charpy impact transition temperature shift on irradiation temperature, Fig. 62 shows a schematic of nuclear steam system temperatures for some nuclear plants.[27] This figure provides one practical motivation for concern about the influence of irradiation temperature on transition temperature shift for test reactor irradiations. Odette and Lucas[23] report changes from -0.4 to 2°C/°C with the majority around -1 ± 0.2°C/°C. Those results are averaged for all materials over the irradiation temperature range from 250 to 310°C. For the low upper-shelf welds of this study, a similar range of values was found. However, only welds 61W through 64W experienced sufficiently wide ranges of irradiation temperatures for adequate analysis. The average dependence on irradiation temperature for those four welds was determined to be -0.413 ± 0.21°C/°C (±1 standard deviation). Lowe[28] performed an analysis for welds 61W through 63W and determined a dependence of -0.668 ± 0.141°C/°C (he reported their result as °F/°F). Using only 61W through 63W in this study yields a dependence of -0.535 ± 0.043°C/°C, closer to the value reported by Lowe. In this study, the dependence of upper-shelf energy on irradiation temperature was determined to be -0.058 J/°C. Lowe[28] reported a change of about -0.23 J/°C (he reported -0.094 ft-lb/°F). That value is quite different from that determined in this analysis, and inspection of the unirradiated upper-shelf energies used by Lowe shows them to be substantially higher than those used in the present study. That undoubtedly reflects the fact that he used all the reported unirradiated Charpy test results as opposed to this study which used only the lower tending results from the hot cell Charpy impact machine.

Berggren and Stallman[29] performed nonlinear regression analyses of the Charpy data for 61W through 67W and developed model equations dependent on fluence, irradiation temperature, and copper content. Transition temperature and upper-shelf energy regions were fitted separately, and linear expressions describing the energy vs test temperature relationship in both the transition and upper-shelf regions for unirradiated results were fitted to the data. For both the transition and upper-shelf regions, the temperature differences between the irradiated data and the linear fit of unirradiated data were entered into the fitting program. The models used for the fitting program are:

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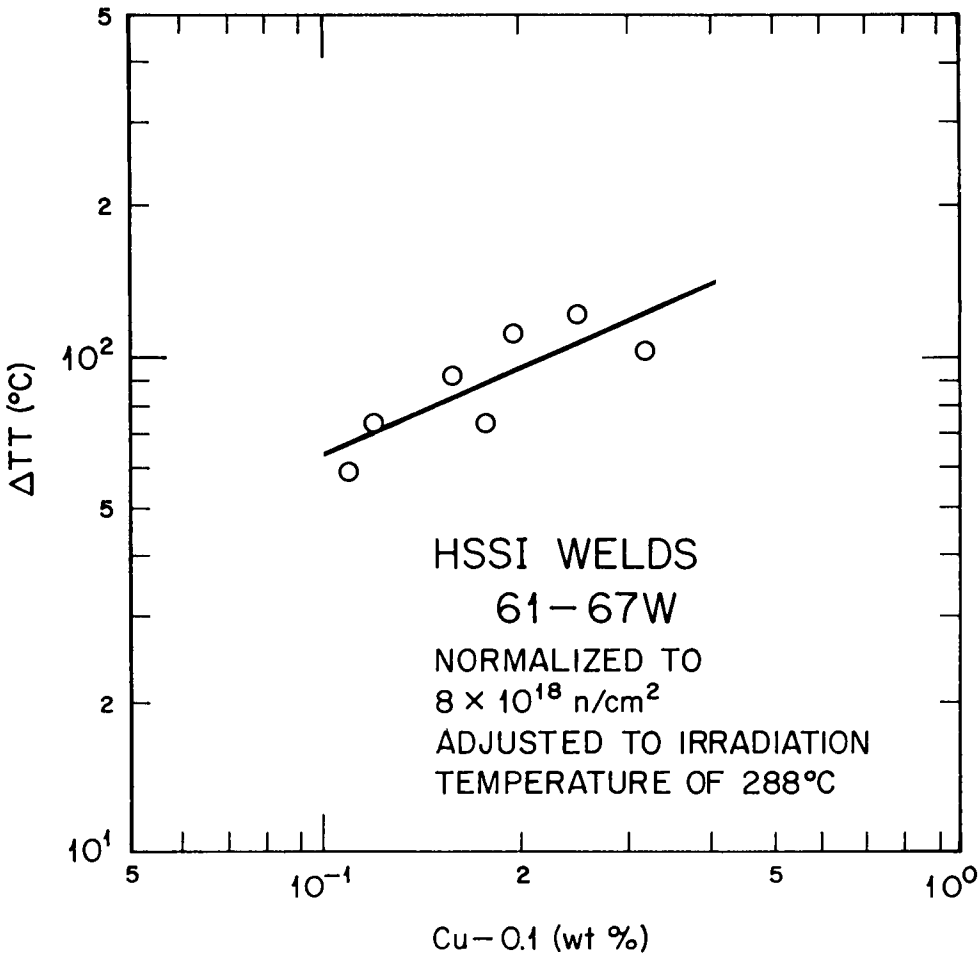

Fig. 61. Log-log plot of Charpy transition temperature shift vs the compositional parameter (Cu - 0.1) for HSSI welds 61W through 67W. The Charpy shift results are adjusted for an irradiation temperature of 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). The curve represents a linear regression to the results.

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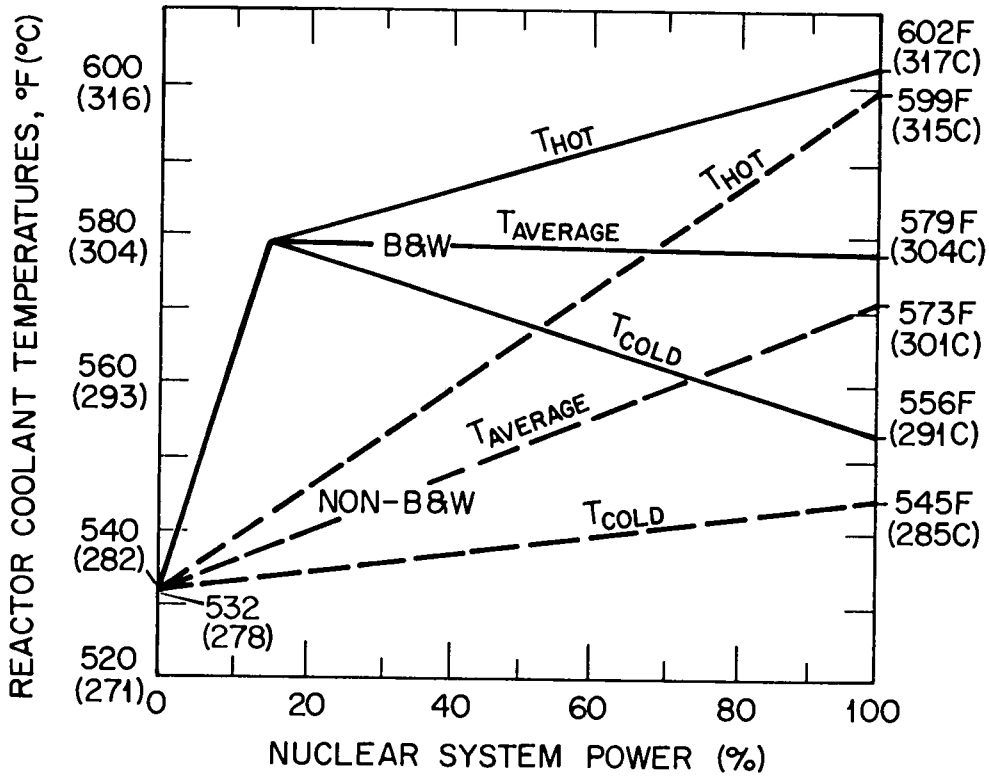

Fig. 62. Comparison of B&W-designed and non-B&W-designed nuclear steam system temperatures as related to power level. *Source:* A. L. Lowe, Jr., "Review of B&W Reactor Vessel Irradiated Materials Data," pp. 15-1 to 15-20 in Proceedings of the 15th MPA Seminar, University of Stuttgart, Federal Republic of Germany, Oct. 5-6, 1989.

$$\Delta TT_{41} = f^{0.5}[C_1 + C_2(T_i - 299) + C_3(Cu - 0.30)] \ , \qquad (9)$$

$$\Delta E_{204} = f^{0.5}[C_4 + C_5(T_i - 299) + C_6(Cu - 0.30)] \ , \qquad (10)$$

where

ΔTT_{41} = 41-J (30 ft-lb) transition temperature shift (°C),
ΔE_{204} = upper-shelf energy drop at 204°C (400°F) (Joules),
$f^{0.5}$ = neutron fluence in units of 10^{18} neutrons/cm^2 (>1 MeV) raised to the 0.5 power,
T_i = median irradiation temperature (°C),
Cu = copper content (wt %), and
C_1 to C6 = coefficients determined in the fitting process.

The authors of ref. 29 discuss the vagaries of including other parameters in the model relative to the added complexities, and the reader is referred to ref. 29 for those details. They also stated that a number of combinations of other components, e.g., nickel, phosphorous, and sulphur, were tried but were rejected on statistical grounds due to insufficient information. However, they did state that a combination of nickel and copper gave a slightly better agreement than the results for copper alone. The fitting yielded the results shown below:

Value	Standard Deviation
C_1 = 30.7	0.61
C_2 = -0.218	0.024
C_3 = 89	9.43
C_4 = 10.63	0.21
C_5 = -0.122	0.013
C_6 = 11.7	3.98

The authors note that the models must be applied with caution outside the ranges of the variables within which they were developed.

Heller and Lowe[30] developed models for Linde 80, submerged-arc welds as part of a large study on low upper-shelf welds by B&W. The equations they developed for Charpy shift and upper-shelf energy change are as follows:

$$\text{Shift (°F)} = -4.66 + (Fl/5 \times 10^{16})^{0.326}(-18.17 + 61.88Ni + 49.12Cu), \qquad (11)$$

$$\text{Drop } (\Delta/\text{Initial}) = [-1.684 - 1.24Si + 0.727Cu + 0.0014Ni/Cu - 0.429Mo/Cu - 1.15C{\times}Cr/Cu + 0.388Si/Cu + 0.7717Ln(\log_{10} Fl)] \ , \qquad (12)$$

where Fl is neutron fluence, n/cm^2 (>1 MeV).

For the Charpy shift, they reported a coefficient of correlation of 0.86 and a standard deviation of 28°F, while the 95/95 upper tolerance bound was given as shift + k(28), where k = 2.37. Thus, the upper bound is the calculated shift plus 66.4°F (36.9°C). For the fractional upper-shelf energy drop, the coefficient of correlation was 0.67 with a standard deviation of 0.08; thus, the upper bound is the calculated drop plus 0.20.

Tables 12 and 13 provide a comparison between the predictions using the models from Berggren and Stallman[29] and those of Heller and Lowe[30] with the results obtained in this study. All the values shown are based on an irradiation temperature and a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV). Table 12 shows that, for the transition temperature shift, the model predictions compare fairly well for the seven welds. The mean shifts predicted by the models are less than the results from this study for 63W, 64W, and 67W. For the Heller and Lowe model, the upper tolerance bound would exceed the current results by a large margin. Regarding the upper-shelf energy, Table 13 shows that the Berggren and Stallman model overpredicts the drop for all welds except 65W. The model predictions from Heller and Lowe are mixed, with underpredictions in four cases and overpredictions in three cases. The upper tolerance bound from the latter model would encompass all the results. The two models do not compare very well for the upper-shelf case, probably as a result of the different values used for some of the unirradiated upper-shelf energies.

10. COMPARISON OF TEST REACTOR AND SURVEILLANCE PROGRAMS RESULTS

Comparison of these test reactor irradiation results with those from commercial power reactor surveillance programs is not generally possible because the correspondence between the HSST welds and the B&W weld designations is not presently available. Lowe[28] presented analyses of the data from the Second and Third Irradiation Series and compared the results with several power reactor surveillance program results with the same welds, 63W, 65W, 66W, and 67W. That report listed the surveillance program specimen irradiation temperature as 304°C. A later paper[27] gives the irradiation temperature as 293°C for those same results. In that paper, the surveillance results are compared with Charpy test results from the Second and Third Series tested at an average temperature and fluence close to those from the surveillance program. For example, in the case of weld 63W, the subset of Charpy test results used had an average irradiation temperature of 285°C compared to the 293°C for surveillance. For weld 66W, the corresponding temperatures were 279 and 293°C, respectively. The average fluences used were fairly close, except for weld 67W where they were 7.83 and 10.3×10^{18} neutrons/cm^2 for the test reactor and surveillance data sets, respectively. Comparison of the results on those bases showed that the Charpy transition temperature shifts for the power reactor data exceeded those from the test reactor irradiations, with the differences ranging from 5 to 27°C.

To compare surveillance results with the results from this study, the surveillance results provided by Lowe[28] were adjusted to an

Table 12. Model predictions of Charpy transition temperature shift compared with results for irradiations at 288°C to 8 × 10^{18} neutrons/cm^2

Weld	Content (wt %)			Transition temperature shift (°C)			
	Cu	Ni	P	Result[a]	S-B[b]	H-L[c]	RG 1.99[d]
61W	0.28	0.63	0.020	74	91	98	100
62W	0.21	0.54	0.016	59	71	72	81
63W	0.30	0.69	0.016	112	94	109	107
64W	0.35	0.66	0.014	123	106	113	115
65W	0.22	0.60	0.015	74	73	84	86
66W	0.42	0.60	0.018	104	123	112	120
67W	0.27	0.59	0.011	92	86	88	94

[a]Results from this study.

[b]From F. W. Stallman and R. G. Berggren.

[c]From A. S. Heller and A. L. Lowe, Jr.

[d]From *Regulatory Guide 1.99, Rev. 2*, without margin.

Table 13. Model predictions of Charpy upper-shelf energy decrease compared with results for irradiations at 288°C to 8 × 10^{18} neutrons/cm^2

Weld	Content (wt %)			Upper-shelf energy decrease (%)			
	Cu	Ni	P	Result[a]	S-B[b]	H-L[c]	RG 1.99[d]
61W	0.28	0.63	0.020	16	39	25	40
62W	0.21	0.54	0.016	16	32	27	34
63W	0.30	0.69	0.016	24	39	19	41
64W	0.35	0.66	0.014	36	35	23	41
65W	0.22	0.60	0.015	37	29	21	34
66W	0.42	0.60	0.018	22	51	29	41
67W	0.27	0.59	0.011	28	44	23	37

[a]Results from this study.

[b]From F. W. Stallman and R. G. Berggren.

[c]From A. S. Heller and A. L. Lowe, Jr.

[d]From *Regulatory Guide 1.99, Rev. 2*, without margin.

effective irradiation temperature of 288°C and an effective fluence of 8×10^{18} neutrons/cm^2. Table 14 shows the surveillance results before and after adjustment. Since the irradiation temperature was given as 293°C, and using the previously determined temperature dependence of about -0.5°C/°C, the transition temperature shifts were decreased by 3°C (rounded from 2.5°C). The temperature-adjusted values were then normalized for fluence by using the fluence dependence term from *Regulatory Guide 1.99* (Rev. 2).[24] This procedure was used because the *Regulatory Guide 1.99* model is based on power reactor surveillance data; the power exponent is about 0.3 rather than the 0.5 value used in this study to adjust the test reactor data. The same procedure was followed for the Charpy upper-shelf energy results except that the irradiation temperature adjustment was based on the previously determined dependence of -0.058 J/°C. As the table shows, the results are mixed for both the transition temperature shifts and upper-shelf energy decreases. Figure 63 provides a graphical comparison of these results.

Considering the variations of irradiation temperature and fluence in the Second and Third Irradiation Series experiments, as well as the uncertainties associated with the temperature histories of the surveillance specimens, it is difficult to evaluate the relationship between the test reactor and power reactor surveillance results. Because of the differences observed between the test reactor and surveillance results, Lowe[28] recommended that only power reactor surveillance data be used in B&W Owners Group reactor vessel licensing applications. That observation applied to the tensile, Charpy, and fracture toughness tests. On the one hand, it may be advantageous to compare results from subsets of data without the uncertainties of adjustment procedures; on the other hand, using the whole data base (for test reactor and power reactor) for a given material, even with the adjustments, may provide a better comparison from a statistical basis. As the overall data base for surveillance results increases, the developing view seems to be that a given material irradiated in a power reactor will experience somewhat greater effects of irradiation than the same material irradiated in a test reactor at the same temperature and to the same fluence. In other words, there appears to be a flux effect such that irradiating at lower fluxes produces greater radiation damage.[25,26,31,32] However, that is a complicated phenomenon which may depend on fluence, neutron spectrum, material parameters, etc. The availability of data with which to make direct comparisons is very sparse and, thus, comparisons between power reactor and test reactor effects will likely continue to be done from a statistical viewpoint.

11. SUMMARY AND CONCLUSIONS

The HSSI Second and Third Irradiation Series had the primary objective to investigate the effects of irradiation on the ductile fracture toughness of seven commercially fabricated, low upper-shelf, submerged-arc welds. All the welds were fabricated with copper-coated

Table 14. Comparison of test reactor and power reactor irradiations on Charpy impact toughness for HSSI welds

Weld	Power reactor, observed results				Adjusted results			
					ΔTT (°C)		ΔUSE (J)	
	Temperature (°C)	Fluence ($\times 10^{-18}$ n/cm^2)	ΔTT (°C)	ΔUSE (J)	Power reactor[a]	Test reactor	Power reactor[a]	Test reactor
63W	293	7.8	119	32.5	123	112	32.4	21.4
65W	293	5.1	82	29.8	98	74	34.0	39.6
66W	293	6.6	75	17.6	83	104	18.4	16.2
67W	293	10.3	79	28.5	76	92	26.2	28.6

[a]Adjusted from observed irradiation temperature to 288°C by -0.5°C/°C. Adjusted from observed fluence to 8×10^{18} neutrons/cm^2 (>1 MeV) using the fluence dependence factor from *Regulatory Guide 1.99 (Rev. 2)*.

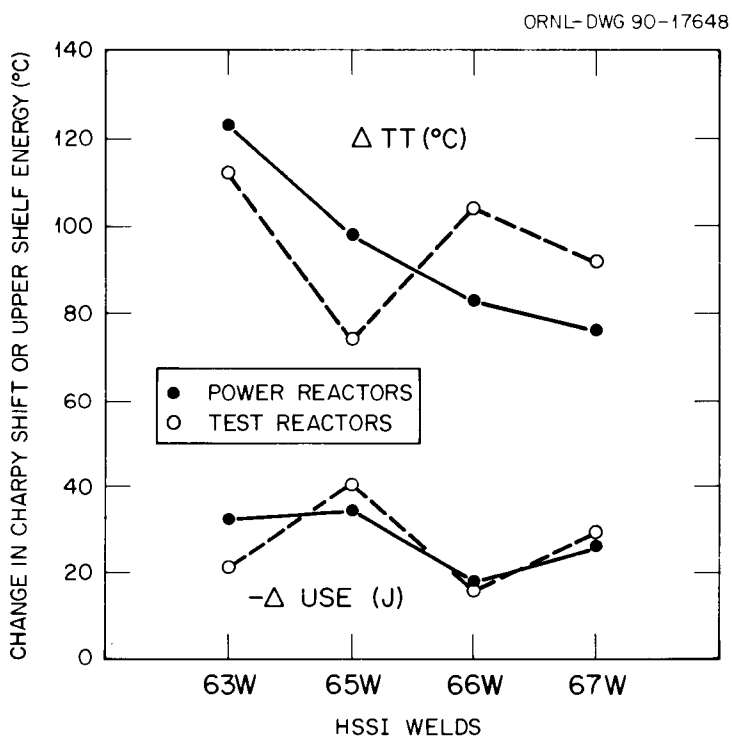

Fig. 63. Comparison of Charpy transition temperature shifts and upper-shelf energy decreases for some of the HSSI upper-shelf welds irradiated in both a test reactor and commercial power reactor surveillance programs. All results were adjusted to an irradiation temperature of 288°C and normalized to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV).

weld wire and Linde 80 flux which produced welds having relatively low Charpy upper-shelf energies in the unirradiated condition and relatively high sensitivity to neutron radiation. The development of experimental elastic-plastic fracture mechanics methods was pursued concurrently with the conduct of these irradiation series. The irradiation of compact specimens up to 101.6-mm thickness [4TC(T)] and testing of those specimens to obtain J-integral resistance curves represented a major undertaking which was shared by a number of organizations.

Irradiation of the compact specimens at a nominal temperature of 288°C to an average fluence of about 8×10^{18} neutrons/cm^2 (>1 MeV) was relatively successful. However, the Charpy impact and tensile specimens were located at positions in the capsule where temperature control was less effective and the irradiation temperatures spanned the range of 235 to 345°C for those specimens. Additionally, the neutron fluences varied from about 4 to 13×10^{18} neutrons/cm^2 (>1 MeV). Although not desirable within the intended context of the experiments, those variations did provide the opportunity to investigate the effects of irradiation temperature and fluence (over the ranges observed) on the tensile and Charpy impact properties of these low upper-shelf welds. The data available for such analyses were limited from a statistical viewpoint, yet did allow for some reasonable observations which could be compared with results from other studies. For most of those comparisons, the Charpy and tensile results were normalized for fluence variations to an average fluence of 8×10^{18}.

It is clear from the results obtained that all the welds experienced significant radiation-induced Charpy impact transition temperature shifts, from 59 to 123°C, and upper-shelf energy decreases, from 16 to 37%. Likewise, the increases in yield and ultimate tensile strengths as a consequence of irradiation were significant at room temperature, 21 to 35% and 13 to 20%, respectively. Regarding the ductile fracture toughness, not presented in this report, all the welds exhibited significant decreases in J_{Ic} and tearing modulus, 24 and 53%, respectively, at 200°C. Similarly, at 288°C, the average decreases were 33 and 68%, respectively. Thus, the effects of irradiation on all measured properties were consistent and followed expected trends.

Analyses of the effects of irradiation temperature on tensile properties and Charpy impact data showed that, within the irradiation temperature range experienced by these welds and for a constant fluence, the radiation-induced increase in yield strength changes -1.15 MPa/°C, while the ultimate strength and total elongation change -0.79 MPa/°C and -0.014%/°C, respectively. For the Charpy impact data, the effect of irradiation temperature on transition temperature shift is about -0.5°C/°C, meaning that a 1°C increase in irradiation temperature will cause a 0.5°C decrease in the transition temperature shift. Likewise, the effect on upper-shelf energy decrease is about -0.06 J/°C, meaning that a 1°C increase in irradiation temperature will cause a 0.06-J decrease in the upper-shelf energy drop. A correlation for the seven welds shows that the radiation-induced increase in Charpy transition temperature in degrees Celsius is about 70% that of the yield strength increase in megapascals,

i.e., 0.70°C/MPa. Only the yield strength data were analyzed for the dependence on fluence (over a range of less than a factor of 10) and showed a power law exponent of 0.07, which is much lower than that reported for other materials.

A comparison of the Charpy results from this study with those from commercial reactor surveillance programs with the same materials showed mixed results. The analysis by B&W used small subsets of data from this study having similar irradiation temperatures and fluences compared with the surveillance data. Of the four common materials for which results are available, the transition temperature shifts and upper-shelf energy decreases from the surveillance programs, with no adjustments for fluence or irradiation temperature, exceeded those from the test reactor irradiations. From the analyses conducted in this study using all the data for each weld adjusted to a common irradiation temperature and fluence, the surveillance results exceeded those from the test reactor in two cases, and vice versa. Because of the need for adjustment procedures to account for differences in irradiation temperature and neutron fluences, and uncertainties in the irradiation temperatures for the surveillance specimens, a definitive trend for these four welds is not evident. It is recognized, however, that there is a developing view that the lower neutron fluxes in power reactors cause greater radiation-induced changes than in test reactors, at least up to some medium to high fluence level.

The important observations and conclusions which can be stated based on the Charpy impact and tensile results from the HSSI Second and Third Irradiation Series are enumerated below.

1. Analyses of irradiated tensile data showed a dependence on irradiation temperature of -1.15 MPa/°C for yield strength, -0.79 MPa/°C for ultimate strength, and -0.014%/°C for total elongation.

2. Analyses of irradiated Charpy data showed a dependence on irradiation temperature of about -0.5°C/°C for transition temperature shift and -0.06 J/°C for upper-shelf energy drop.

3. The results indicated that the radiation-induced changes in yield strengths in megapascals and Charpy transition temperature shifts in degrees Celsius for the seven welds can be expressed as $\Delta TT_{41} \approx 0.70 * \Delta\sigma_y$.

4. The Charpy results indicated a dependence on copper concentration which can be expressed as $\Delta TT_{41} = 234 * (Cu - 0.1)^{0.57}$, where ΔTT_{41} is degrees Celsius and copper (Cu) is weight percent.

5. Comparison of the Charpy results with data for the same materials irradiated in power reactor surveillance programs showed mixed results with the power reactor changes being greater in some cases and the test reactor changes greater in others.

12. ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of Domenic A. Canonico (now with ABB-Combustion Engineering) and G. D. Whitman (now retired) for guidance and leadership in formulating and initiating the program, Walter J. Stelzman (deceased) for assistance with irradiation capsule construction and operation, and T. N. Jones (now retired) for tensile and Charpy testing and hot cell coordination. We also thank William R. Corwin, HSSI Program Manager, and Alfred Taboada, NRC Technical Monitor, for financial support. Finally, in preparation of the report, we express our thanks to Julia L. Bishop for manuscript preparation, John G. Merkle and Fahmy M. Haggag for technical review, and G. R. Carter for preparation of the final document.

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APPENDIX A

UNIRRADIATED AND IRRADIATED TENSILE AND CHARPY V-NOTCH IMPACT TEST RESULTS FOR HSSI SECOND AND THIRD IRRADIATION SERIES

Table A1. Fast neutron fluences and median irradiation temperatures for the Second HSSI Irradiation Series, HSSI welds 61W-63W

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
Tens. MT-S	61W-1	0	-6	1.0(3.0)	10.62	289	553	4.2	286	548	14.82	288	550
	-2	0	-6	3.0(1.0)	4.2	263	505	10.62	288	550	14.82	275	528
	-3	0	6	1.0(3.0)	8.49	291	555	3.36	286	548	11.86	288	551
	-4	0	6	3.0(1.0)	3.36	267	513	8.49	286	548	11.86	277	530
	-5	0	10.7	1.0(3.0)	2.95	300	573	1.17	307	585	4.11	304	579
	-6	0	10.7	3.0(1.0)	1.17	300	573	2.95	310	590	4.11	305	581
Tens. MT	-7	-1.6(1.6)	-8.4	2.3(1.7)	4.13	325	618	5.35	331	628	9.48	328	623
	-8	1.6(-1.6)	8.4	2.3(1.7)	3.08	328	623	4.7	361	683	7.78	345	653
	-9	-2.8(2.8)	8.4	2.3(1.7)	3.38	320	608	3.66	327	620	7.04	323	614
4T-CT-J	-20	0	-4.8	0	17.42	285	545	2.73	270	518	20.15	277	531
		0	-4.8	0.5	13.82	286	548	3.44	275	528	17.26	281	538
		0	-4.8	1	10.96	288	550	4.34	288	550	15.3	288	550
		0	-4.8	1.5	8.69	284	543	5.47	291	555	14.16	287	549
		0	-4.8	2	6.9	279	535	6.9	292	558	13.73	286	546
		0	-4.8	2.5	5.47	271	520	8.69	289	553	14.16	280	536
		0	-4.8	3	4.34	260	500	10.96	288	550	15.3	274	525
		0	-4.8	3.5	3.44	246	475	13.82	278	533	17.26	262	504
		0	-4.8	4	2.73	236	458	17.42	261	503	20.15	249	480
	-21	0	-4.8	0	14.37	292	558	2.25	282	540	16.62	287	549
		0	4.8	0.5	11.4	292	558	2.84	282	540	14.24	287	549
		0	4.8	1	9.04	291	555	3.58	282	540	12.62	286	548
		0	4.8	1.5	7.17	286	548	4.51	286	548	11.69	286	548
		0	4.8	2	5.69	281	538	5.69	289	553	11.38	285	545
		0	4.8	2.5	4.51	275	528	7.17	288	550	11.69	282	539
		0	4.8	3	3.58	267	513	9.04	286	548	12.62	277	530
		0	4.8	3.5	2.84	256	493	11.4	278	533	14.24	267	513
		0	4.8	4	2.25	245	473	14.37	267	513	16.62	256	493
1.6T-CT-J	-30	-2.9(2.9)	0	1.6(2.4)	7.78	300	573	4.3	303	578	12.08	302	575
	-31	1.0(-1.0)	0	1.6(2.4)	7.47	263	505	5.77	284	543	13.24	273	524

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
0.8T-CT-J	-40	3.8(-3.8)	0.4	1.2(2.8)	6.68	288	550	4.14	306	583	10.82	297	566
	-41	3.8(-3.8)	-0.4	1.2(2.8)	6.74	288	550	4.2	306	583	10.94	297	566
	-42	3.8(-3.8)	0.4	2.8(1.2)	3.18	278	533	8.68	328	623	11.86	303	578
	-43	3.8(-3.8)	-0.4	2.8(1.2)	3.21	278	533	8.8	328	623	12.01	303	578
0.5TCT-STD	-100	0	-6.8	0.5(3.5)	12.69	299	570	3.16	288	550	15.86	293	560
	-101	0	-6.8	3.5(0.5)	3.16	274	525	12.69	288	550	15.86	281	538
	102	0	-8	0.5(3.5)	11.4	296	565	2.84	288	550	14.24	292	558
	103	0	-8	1.8(2.2)	2.84	306	583	11.4	320	608	14.24	313	595
	104	-0.7(0.7)	-10	0.5(3.5)	7.77	292	558	2.6	302	575	10.37	297	566
	105	-0.7(0.7)	-10	3.5(0.5)	1.94	304	580	10.45	335	635	12.39	320	608
	106	0.7(-0.7)	-10	0.5(3.5)	10.45	292	558	1.94	302	575	12.39	297	566
	107	0.7(-0.7)	-10	3.5(0.5)	2.6	303	578	7.77	335	635	10.37	319	606
	108	-0.7(0.7)	10.3	3.5(0.5)	1.25	304	580	4.58	325	618	5.83	315	599
	109	-0.7(0.7)	10.3	0.5(3.5)	5.01	304	580	1.14	318	605	6.15	311	593
	110	0.7(-0.7)	10.3	0.5(3.5)	4.58	304	580	1.25	318	605	5.83	311	593
0.5TCT-STD	-111	0.7(-0.7)	10.3	3.5(0.5)	1.12	304	580	4.75	325	618	5.87	315	599
0.5TCT-STD	112	2.2(-2.2)	-8.3	0.5(3.5)	8.98	304	580	2.75	298	568	11.73	301	574
0.5TCT-STD	113	2.2(-2.2)	-8.8	0.5(3.5)	8.2	304	580	2.58	298	568	10.78	301	574
0.5TCT-STD	114	2.2(-2.2)	-8.3	2.0(2.0)	4.48	298	568	5.51	331	628	9.99	314	598
0.5TCT-STD	115	2.2(-2.2)	-8.8	2.0(2.0)	4.09	298	568	5.17	331	628	9.26	314	598
0.5TCT-STD	116	2.2(-2.2)	-9.3	2.0(2.0)	3.79	298	568	4.74	331	628	8.53	314	598
0.5TCT-STD	117	2.2(-2.2)	8.3	0.5(3.5)	6.82	341	645	2.02	345	653	8.84	343	649
0.5TCT-STD	118	2.2(-2.2)	8.8	0.5(3.5)	6.39	341	645	1.87	345	653	8.26	343	649
0.5TCT-STD	119	2.2(-2.2)	9.3	0.5(3.5)	5.79	341	645	1.72	345	653	7.51	343	649
0.5TCT-J	123	0	-6.8	1.8(2.2)	12.69	293	560	3.16	293	560	15.86	293	560
0.5TCT-J	124	0	-8	3.5(0.5)	2.82	282	540	11.31	282	540	14.13	282	540
0.5TCT-J	125	-0.7(0.7)	-10	1.8(2.2)	4.26	299	570	3.26	298	568	7.52	298	569
0.5TCT-J	126	0.7(-0.7)	-10	1.8(2.2)	3.78	299	570	3.5	298	568	7.28	298	569
0.5TCT-J	127	-0.7(0.7)	10.3	1.8(2.2)	3.69	295	563	3.14	298	568	6.83	296	565
0.5TCT-J	128	0.7(-0.7)	10.3	1.8(2.2)	3.78	295	563	3.46	298	568	7.24	296	565

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
0.5TCT-J	129	2.2(-2.2)	-9.3	0.5(3.5)	7.6	304	580	2.39	298	568	9.99	301	574
0.5TCT-J	130	2.2(-2.2)	-8.3	3.5(0.5)	2.22	285	545	11.05	334	633	13.27	309	589
0.5TCT-J	131	2.2(-2.2)	-8.8	3.5(0.5)	2.07	285	545	10.45	334	633	12.52	309	589
0.5TCT-J	132	2.2(-2.2)	-9.3	3.5(0.5)	1.89	285	545	9.58	334	633	11.47	309	589
0.5TCT-J	133	-2.2(2.2)	-8.3	0.5(3.5)	11.05	342	648	2.22	310	590	13.27	326	619
0.5TCT-J	134	-2.2(2.2)	-8.8	0.5(3.5)	10.45	342	648	2.07	310	590	12.52	326	619
0.5TCT-J	135	-2.2(2.2)	-9.3	0.5(3.5)	9.58	342	648	1.89	310	590	11.47	326	619
0.5TCT-J	136	-2.2(2.2)	-8.7	3.7(0.3)	2.41	314	598	9.28	341	645	11.69	327	621
0.5TCT-J	137	2.2(-2.2)	8.7	3.7(0.3)	1.47	313	595	8.43	364	688	9.9	338	641
0.5TCT-J	138	-2.2(2.2)	8.3	0.5(3.5)	8.12	334	633	1.7	307	585	9.82	320	609
0.5TCT-J	139	-2.2(2.2)	8.8	0.5(3.5)	7.6	334	633	1.59	307	585	9.19	320	609
0.5TCT-J	140	-2.2(2.2)	9.3	0.5(3.5)	6.82	334	633	1.44	307	585	8.26	320	609
0.5TCT-J	141	-2.2(2.2)	8.7	3.7(0.3)	1.73	307	585	7.11	332	630	8.84	320	608
Charpy V-Std	-208	0	-9.7	0.2(3.8)	9.62	298	568	1.82	298	568	11.44	298	568
Charpy V-Std	209	0	-9.7	0.6(3.4)	8	298	568	2.19	298	568	10.18	298	568
Charpy V-Std	210	0	-9.7	1.0(3.0)	6.64	298	568	2.63	298	568	9.27	298	568
Charpy V-Std	211	0	-9.7	1.4(2.6)	5.52	298	568	3.17	298	568	8.69	298	568
Charpy V-Std	212	0	-9.7	1.8(2.2)	4.59	298	568	3.81	298	568	8.4	298	568
Charpy V-Std	213	0	-9.7	2.2(1.8)	3.81	298	568	4.59	298	568	8.4	298	568
Charpy V-Std	214	0	-9.7	2.6(1.4)	3.17	298	568	5.52	298	568	8.69	298	568
Charpy V-Std	215	0	-9.7	3.0(1.0)	2.63	304	580	6.64	335	635	9.27	320	608
Charpy V-Std	216	0	-9.7	3.4(0.6)	2.19	304	580	8	335	635	10.18	320	608
Charpy V-Std	217	0	-9.7	3.8(0.2)	1.82	304	580	9.62	335	635	11.44	320	608
Charpy V-Std	218	0	7.3	0.2(3.8)	10.62	310	590	2	310	590	12.62	310	590
Charpy V-Std	219	0	7.3	1.0(3.0)	7.33	310	590	2.9	310	590	10.23	310	590
Charpy V-Std	220	0	7.3	1.8(2.2)	5.06	310	590	4.2	310	590	9.26	310	590
Charpy V-Std	221	0	7.3	2.2(1.8)	4.2	310	590	5.06	310	590	9.26	310	590
Charpy V-Std	222	0	7.3	3.0(1.0)	2.9	310	590	7.33	310	590	10.23	310	590
Charpy V-Std	223	0	7.3	3.8(0.2)	2	310	590	10.62	310	590	12.62	310	590
Charpy V-Std	-224	0	9.5	0.2(3.8)	6.95	296	565	1.31	296	565	8.26	296	565

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
Charpy V-Std	225	0	9.5	1.0(3.0)	4.79	296	565	1.9	296	565	6.69	296	565
Charpy V-Std	226	0	9.5	1.8(2.2)	3.31	304	580	2.75	318	605	6.06	311	593
Charpy V-Std	227	0	9.5	2.2(1.8)	2.75	304	580	3.31	318	605	6.06	311	593
Charpy V-Std	228	0	9.5	3.0(1.0)	1.9	304	580	4.79	325	618	6.69	315	599
Charpy V-Std	229	0	9.5	3.8(0.2)	1.31	304	580	6.95	325	618	8.26	315	599
Charpy V-Std	230	-1.6(1.6)	-8.8	2.3(1.7)	4.61	325	618	5.05	334	633	9.66	329	625
Charpy V-Std	231	-1.6(1.6)	-9.2	2.3(1.7)	4.28	325	618	4.7	334	633	8.98	329	625
Charpy V-Std	232	-2.0(2.0)	-8.2	2.3(1.7)	4.91	325	618	5.25	334	633	10.16	329	625
Charpy V-Std	233	-2.0(2.0)	-8.6	2.3(1.7)	4.65	325	618	5	334	633	9.65	329	625
Charpy V-Std	234	-2.0(2.0)	-9	2.3(1.7)	4.46	325	618	4.66	334	633	9.12	329	625
Charpy V-Std	235	-2.0(2.0)	-9.4	2.3(1.7)	4.13	325	618	4.31	334	633	8.44	329	625
Charpy V-Std	236	-2.4(2.4)	-8.2	2.3(1.7)	4.8	325	618	5.1	334	633	9.9	329	625
Charpy V-Std	237	-2.4(2.4)	-8.6	2.3(1.7)	4.58	325	618	4.8	334	633	9.38	329	625
Charpy V-Std	238	-2.4(2.4)	-9	2.3(1.7)	4.35	325	618	4.46	334	633	8.81	329	625
Charpy V-Std	239	-2.4(2.4)	-9.4	2.3(1.7)	4.05	325	618	4.11	334	633	8.16	329	625
Charpy V-Std	240	-2.8(2.8)	-8.4	2.3(1.7)	4.73	325	618	4.66	334	633	9.39	329	625
Charpy V-Std	241	-2.8(2.8)	-8.8	2.3(1.7)	4.39	325	618	4.41	334	633	8.8	329	625
Charpy V-Std	242	-2.8(2.8)	-9.2	2.3(1.7)	4.13	325	618	4.16	334	633	8.29	329	625
Charpy V-Std	243	1.6(-1.6)	8.8	2.3(1.7)	2.89	328	623	4.46	361	683	7.35	345	653
Charpy V-Std	244	1.6(-1.6)	9.2	2.3(1.7)	2.7	328	623	3.96	361	683	6.66	345	653
Charpy V-Std	245	2.0(-2.0)	8.2	2.3(1.7)	3.04	328	623	4.75	361	683	7.79	345	653
Charpy V-Std	246	2.0(-2.0)	8.6	2.3(1.7)	2.93	328	623	4.51	361	683	7.44	345	653
Charpy V-Std	247	2.0(-2.0)	9	2.3(1.7)	2.74	328	623	4.16	361	683	6.9	345	653
Charpy V-Std	248	2.0(-2.0)	9.4	2.3(1.7)	2.51	328	623	3.76	361	683	6.27	345	653
Charpy V-Std	249	2.4(-2.4)	8.2	2.3(1.7)	2.93	328	623	4.66	361	683	7.59	345	653
Charpy V-Std	250	2.4(-2.4)	8.6	2.3(1.7)	2.78	328	623	4.46	361	683	7.24	345	653
Charpy V-Std	251	2.4(-2.4)	9	2.3(1.7)	2.63	328	623	4.06	361	683	6.69	345	653
Charpy V-Std	252	2.4(-2.4)	9.4	2.3(1.7)	2.4	328	623	3.76	361	683	6.16	345	653
Charpy V-Std	253	2.8(-2.8)	8.4	2.3(1.7)	2.78	328	623	4.46	361	683	7.24	345	653
Charpy V-Std	254	2.8(-2.8)	8.8	2.3(1.7)	2.59	328	623	4.11	361	683	6.7	345	653

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
Charpy V-Std	255	2.8(-2.8)	9.2	2.3(1.7)	2.44	328	623	3.86	361	683	6.3	345	653
Charpy V-Std	256	-2.8(2.8)	8.8	2.3(1.7)	3.11	320	608	3.47	327	620	6.58	323	614
Charpy V-Std	257	-2.8(2.8)	9.2	2.3(1.7)	2.93	320	608	3.22	327	620	6.15	323	614
Charpy V-Std	258	-2.4(2.4)	8.2	2.3(1.7)	3.56	320	608	3.86	327	620	7.42	323	614
Charpy V-Std	259	-1.6(1.6)	8.4	2.3(1.7)	3.6	320	608	4.06	327	620	7.66	323	614
Charpy V-Std	260	-1.6(1.6)	9.2	2.3(1.7)	3.04	320	608	3.57	327	620	6.61	323	614
Charpy V-PC	261	0	7.3	0.6(3.4)	8.82	310	590	2.41	310	590	11.23	310	590
Charpy V-PC	262	0	7.3	1.4(2.6)	6.09	310	590	3.49	310	590	9.58	310	590
Charpy V-PC	263	0	7.3	2.6(1.4)	3.49	310	590	6.09	310	590	9.58	310	590
Charpy VPC	264	0	7.3	3.4(0.6)	2.41	310	590	8.82	310	590	11.23	310	590
Charpy V-PC	265	0	9.5	0.6(3.4)	5.77	296	565	1.58	296	565	7.35	296	565
Charpy V-PC	266	0	9.5	1.4(2.6)	3.98	300	573	2.28	307	585	6.27	304	579
Charpy V-PC	267	0	9.5	2.6(1.4)	2.28	304	580	3.98	321	610	6.27	313	595
Charpy V-PC	-268	0	9.5	3.4(0.6)	1.58	304	580	5.77	325	618	7.35	315	599
Charpy V-Std	-289	-2.4(2.4)	8.6	2.3(1.7)	3.38	320	608	3.66	327	620	7.04	323	614
Charpy V-Std	-290	-2.4(2.4)	9	2.3(1.7)	3.11	320	608	3.47	327	620	6.58	323	614
Charpy V-Std	-291	-2.4(2.4)	9.4	2.3(1.7)	2.78	320	608	3.17	327	620	5.95	323	614
Charpy V-Std	-292	-2.0(2.0)	8.2	2.3(1.7)	3.6	320	608	4.06	327	620	7.66	323	614
Charpy V-Std	-293	-2.0(2.0)	8.6	2.3(1.7)	3.41	320	608	3.86	327	620	7.27	323	614
Charpy V-Std	-294	-2.0(2.0)	9	2.3(1.7)	3.15	320	608	3.62	327	620	6.77	323	614
Charpy V-Std	-295	-2.0(2.0)	9.4	2.3(1.7)	2.81	320	608	3.32	327	620	6.13	323	614
Charpy V-Std	-296	-1.6(1.6)	8.8	2.3(1.7)	3.26	320	608	3.76	327	620	7.02	323	614
Tens: MT	62W-1	-1.6(1.6)	-8.4	2.3(1.7)	4.13	317	603	6.83	307	585	10.96	312	594
Tens: MT	-2	1.6(-1.6)	8.4	2.3(1.7)	4.05	256	493	4.21	306	583	8.26	281	538
Tens: MT	-3	-2.8(2.8)	8.4	2.3(1.7)	2.63	303	578	5.55	303	578	8.18	303	578
Tens: MT-S	-8	0	-6	1.0(3.0)	11.1	285	545	4.39	277	530	15.49	281	538
Tens: MT-S	9	0	-6	3.0(1.0)	4.39	264	508	11.1	284	543	15.49	274	525
Tens: MT-S	10	0	6	1.0(3.0)	9.86	292	558	3.91	288	550	13.77	290	554
Tens: MT-S	11	0	6	3.0(1.0)	3.91	260	500	9.86	288	550	13.77	274	525
Tens: MT-S	13	0	10.7	1.0(3.0)	3.42	260	500	1.36	271	520	4.78	266	510

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
		X	Y	Z	Fluence (n/cm2)	Temperature		Fluence (n/cm2)	Temperature				
Type	Number	Fwd (Rev)		Fwd (Rev)		(°C)	(°F)		(°C)	(°F)		(°C)	(°F)
Tens: MT-S	19	0	10.7	3.0(1.0)	1.36	260	500	3.42	281	538	4.78	270	519
4TCT-J	20	0	-4.8	0	18.61	282	540	2.92	259	498	21.53	270	519
		0	-4.8	0.5	14.77	284	543	3.68	267	513	18.44	275	528
		0	-4.8	1	11.71	286	548	4.64	277	530	16.35	282	539
		0	-4.8	1.5	9.29	285	545	5.85	282	540	15.14	284	543
		0	-4.8	2	7.37	281	538	7.37	285	545	14.74	283	541
		0	-4.8	2.5	5.85	274	525	9.29	284	543	15.14	279	534
		0	-4.8	3	4.64	266	510	11.71	282	540	16.35	274	525
		0	-4.8	3.5	3.68	252	485	14.77	271	520	18.44	261	503
		0	-4.8	4	2.92	238	460	18.61	260	500	21.53	249	480
	25	0	4.8	0	17.31	288	550	2.71	277	530	20.02	282	540
		0	4.8	0.5	13.73	291	555	3.42	282	540	17.15	286	548
		0	4.8	1	10.89	292	558	4.31	285	545	15.2	288	551
		0	4.8	1.5	8.64	289	553	5.44	286	548	14.08	288	550
		0	4.8	2	6.85	279	535	6.85	288	550	13.71	284	543
		0	4.8	2.5	5.44	271	520	8.64	286	548	14.08	279	534
		0	4.8	3	4.31	260	500	10.89	286	548	15.2	273	524
		0	4.8	3.5	3.42	245	473	13.73	273	523	17.15	259	498
		0	4	4	2.71	232	450	17.31	259	498	20.02	245	474
1.6TCT-J	34	1.0(-1.0)	0	1.6(2.4)	9.8	289	553	5.77	293	560	15.57	291	556
	35	-2.9(2.9)	0	1.6(2.4)	6.59	273	523	7.02	320	608	13.61	296	565
0.8TCT-J	41	3.8(-3.8)	0.4	2.8(1.2)	5.77	316	600	6.87	314	598	12.64	315	599
	42	3.8(-3.8)	-0.4	2.8(1.2)	5.8	316	600	6.87	314	598	12.67	315	599
	43	3.8(-3.8)	0.4	1.2(2.8)	12.11	346	655	3.27	306	583	15.38	326	619
	44	3.8(-3.8)	-0.4	1.2(2.8)	12.17	346	655	3.27	306	583	15.44	326	619
0.5TCT-J	100	0	-6.8	1.8(2.2)	7.21	285	545	5.99	293	560	13.2	289	553
0.5TCT-J	101	0	-8	3.5(0.5)	2.99	268	515	12	302	575	14.99	285	545
0.5TCT-J	102	-0.7(0.7)	-10	1.8(2.2)	4.26	289	553	3.77	300	573	8.03	295	563
0.5TCT-J	103	0.7(-0.7)	-10	1.8(2.2)	4.54	289	553	3.54	306	583	8.08	298	568
0.5TCT-J	104	0.7(-0.7)	10.3	1.8(2.2)	4.44	264	508	3.5	284	543	7.94	274	525

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
0.5TCT-J	105	-0.7(0.7)	10.3	1.8(2.2)	4.2	264	508	3.69	284	543	7.89	274	525
0.5TCT-J	106	2.2(-2.2)	-9.3	0.5(3.5)	10.36	296	565	1.91	307	585	12.27	302	575
0.5TCT-J	107	2.2(-2.2)	-8.3	3.5(0.5)	3.01	282	540	8.89	341	645	11.9	311	593
0.5TCT-J	109	2.2(-2.2)	-8.8	3.5(0.5)	2.8	282	540	8.38	341	645	11.18	311	593
0.5TCT-J	110	2.2(-2.2)	-9.3	3.5(0.5)	2.58	282	540	7.69	341	645	10.27	311	593
0.5TCT-J	111	-2.2(2.2)	-8.3	0.5(3.5)	8.89	341	645	3.01	286	548	11.9	313	596
0.5TCT-STD	114	0	-6.8	0.5(3.5)	13.21	288	550	3.29	279	535	16.5	284	543
0.5TCT-STD	115	0	-6.8	3.5(0.5)	3.29	263	505	13.21	293	560	16.5	278	533
0.5TCT-STD	116	0	-8	0.5(3.5)	12	293	560	2.99	296	565	14.99	295	563
0.5TCT-STD	117	0	-8	1.8(2.2)	6.57	292	558	5.46	303	578	12.03	297	568
0.5TCT-STD	118	-0.7(0.7)	-10	3.5(0.5)	1.94	278	533	8.2	316	600	10.14	297	566
0.5TCT-STD	119	-0.7(0.7)	-10	0.5(3.5)	7.77	295	563	2.04	291	555	9.81	293	559
0.5TCT-STD	120	0.7(-0.7)	-10	0.5(3.5)	8.2	295	563	1.94	291	555	10.14	293	559
0.5TCT-STD	121	0.7(-0.7)	-10	3.5(0.5)	20.4	278	533	7.77	316	600	9.81	297	566
0.5TCT-J	128	-2.2(2.2)	-8.8	0.5(3.5)	8.38	341	645	2.8	286	548	11.18	313	596
	129	-2.2(2.2)	-9.3	0.5(3.5)	7.69	341	645	2.58	286	548	10.27	313	596
	130	-2.2(2.2)	-8.7	3.7(0.3)	1.73	299	570	12.41	313	595	14.14	306	583
	132	2.2(-2.2)	8.7	3.7(0.3)	2.1	236	458	6.92	300	573	9.02	268	515
	133	-2.2(2.2)	8.3	0.5(3.5)	6.91	334	633	2.43	296	565	9.34	315	599
	134	-2.2(2.2)	8.8	0.5(3.5)	6.04	334	633	2.22	296	565	6.26	315	599
0.5TCT-STD	142	0.7(-0.7)	10.3	0.5(3.5)	5.18	257	495	1.14	256	493	6.32	257	494
	143	0.7(-0.7)	10.3	3.5(0.5)	1.29	250	483	4.58	278	533	5.87	264	508
	144	-0.7(0.7)	10.3	0.5(3.5)	1.32	257	495	1.29	256	493	5.61	257	494
	146	-0.7(0.7)	10.3	3.5(0.5)	1.08	250	483	5.18	278	533	6.26	264	508
	147	2.2(-2.2)	-8.3	0.5(3.5)	12.09	296	565	2.22	307	585	14.31	302	575
	148	2.2(-2.2)	-8.8	0.5(3.5)	11.23	296	565	2.09	307	585	13.32	302	575
	149	2.2(-2.2)	-8.3	2.0(2.0)	6.03	293	560	4.44	335	635	10.47	314	598
	150	2.2(-2.2)	-8.8	2.0(2.0)	5.6	293	560	4.18	335	635	9.78	314	598
	151	2.2(-2.2)	-9.3	2.0(2.0)	5.17	293	560	3.84	335	635	9.01	314	598
	152	2.2(-2.2)	8.3	0.5(3.5)	9.76	282	540	1.7	296	565	11.46	289	553

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
	153	2.2(-2.2)	8.8	0.5(3.5)	8.98	282	540	1.53	296	565	10.51	289	553
	155	2.2(-2.2)	9.3	0.5(3.5)	8.12	282	540	1.36	296	565	9.48	289	553
0.5TCT-J	158	-2.2(2.2)	9.3	0.5(3.5)	5.44	334	633	2.02	296	565	7.46	315	599
	159	-2.2(2.2)	8.7	3.7(0.3)	1.43	282	540	10.14	304	580	11.57	293	560
Charpy V-PC	208	0	7.3	0.6(3.4)	10.22	291	555	2.79	285	545	13.02	288	550
Charpy V-PC	209	0	7.3	1.4(2.6)	7.06	291	555	4.05	285	545	11.1	288	550
Charpy V-PC	210	0	7.3	2.6(1.4)	4.05	291	555	7.06	285	545	11.1	288	550
Charpy V-PC	211	0	7.3	3.4(0.6)	2.79	291	555	10.22	285	545	13.02	288	550
Charpy V-PC	213	0	9.5	0.6(3.4)	6.43	257	495	1.76	256	493	8.19	257	494
Charpy V-PC	216	0	9.5	1.4(2.6)	4.44	261	503	2.55	271	520	6.99	266	511
Charpy V-PC	217	0	9.5	2.6(1.4)	2.55	259	498	4.44	281	538	6.99	270	518
Charpy V-PC	218	0	9.5	3.4(0.6)	1.76	250	483	6.43	278	533	8.19	264	508
Charpy V-Std.	305	0	-9.7	0.2(3.8)	10.62	295	563	2	291	555	12.62	293	559
	306	0	-9.7	0.6(3.4)	8.82	295	563	2.41	291	555	11.23	293	559
	307	0	-9.7	1.0(3.0)	7.33	295	563	2.9	291	555	10.23	293	559
	308	0	-9.7	1.4(2.6)	6.03	289	553	3.46	306	583	9.49	298	568
	309	0	-9.7	1.8(2.2)	5.01	289	553	4.16	306	583	9.18	298	568
	310	0	-9.7	2.2(1.8)	4.16	289	553	5.01	306	583	9.18	298	568
	311	0	-9.7	2.6(1.4)	3.46	289	553	6.03	306	583	9.49	298	568
	312	0	-9.7	3.0(1.0)	2.9	278	533	7.33	316	600	10.23	297	566
	313	0	-9.7	3.4(0.6)	2.41	278	533	8.82	316	600	11.23	297	566
Charpy V-Std.	314	0	-9.7	3.8(0.2)	2	278	533	10.62	316	600	12.62	297	566
	315	0	7.3	0.2(3.8)	12.3	291	555	2.32	285	545	14.63	288	550
	316	0	7.3	1.0(3.0)	8.49	291	555	3.36	285	545	11.86	288	550
	317	0	7.3	1.8(2.2)	5.86	291	555	4.87	285	545	10.73	288	550
	318	0	7.3	2.2(1.8)	4.87	291	555	5.86	285	545	10.73	288	550
	319	0	7.3	3.0(1.0)	3.36	291	555	8.49	285	545	11.86	288	550
	320	0	7.3	3.8(0.2)	2.32	291	555	12.3	285	545	14.63	288	550
	321	0	9.5	0.2(3.8)	7.74	257	495	1.46	256	493	9.2	257	494
	322	0	9.5	1.0(3.0)	5.34	257	495	2.16	256	493	7.46	257	494

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
	323	0	9.5	1.8(2.2)	3.69	264	508	3.06	284	543	6.75	274	525
	324	0	9.5	2.2(1.8)	3.06	264	508	3.69	284	543	6.75	274	525
	325	0	9.5	3.0(1.0)	2.16	250	483	5.34	278	533	7.46	264	508
	326	0	9.5	3.8(0.2)	1.46	250	483	7.74	278	533	9.2	264	508
	327	-1.6(1.6)	-8.8	2.3(1.7)	3.9	317	603	6.44	307	585	10.34	312	594
	328	-1.6(1.6)	-9.2	2.3(1.7)	3.71	317	603	6.04	307	585	9.75	312	594
	329	-2.0(2.0)	-8.2	2.3(1.7)	4.01	317	603	6.93	307	585	10.94	312	594
	330	-2.0(2.0)	-8.6	2.3(1.7)	3.83	317	603	6.54	307	585	10.37	312	594
	331	-2.0(2.0)	- 9	2.3(1.7)	3.6	317	603	6.24	307	585	9.84	312	594
	332	-2.0(2.0)	-9.4	2.3(1.7)	3.38	317	603	5.89	307	585	9.27	312	594
	335	-2.4(2.4)	-8.2	2.3(1.7)	3.75	317	603	6.98	307	585	10.73	312	594
	336	-2.4(2.4)	-8.6	2.3(1.7)	3.64	317	603	6.54	307	585	10.18	312	594
	337	-2.4(2.4)	- 9	2.3(1.7)	3.38	317	603	6.24	307	585	9.62	312	594
	338	-2.4(2.4)	-9.4	2.3(1.7)	3.19	317	603	5.89	307	585	9.08	312	594
	339	-2.8(2.8)	-8.4	2.3(1.7)	3.45	317	603	6.93	307	585	10.38	312	594
	340	-2.8(2.8)	-8.8	2.3(1.7)	3.3	317	603	6.44	307	585	9.77	312	594
	341	-2.8(2.8)	-9.2	2.3(1.7)	3.11	317	603	6.04	307	585	9.15	312	594
	342	1.6(-1.6)	8.8	2.3(1.7)	3.83	256	493	3.86	306	583	7.69	281	538
	343	1.6(-1.6)	9.2	2.3(1.7)	3.45	256	493	3.47	306	583	6.92	281	538
	344	2.0(-2.0)	8.2	2.3(1.7)	4.39	256	493	4.11	306	583	8.5	281	538
	345	2.0(-2.0)	8.6	2.3(1.7)	4.09	256	493	3.81	306	583	7.9	281	538
	346	2.0(-2.0)	9	2.3(1.7)	3.75	256	493	3.47	306	583	7.22	281	538
	347	2.0(-2.0)	9.4	2.3(1.7)	3.41	256	493	3.07	306	583	6.48	281	538
	348	2.4(-2.4)	8.2	2.3(1.7)	4.35	256	493	3.86	306	583	8.21	281	538
	349	2.4(-2.4)	8.6	2.3(1.7)	4.09	256	493	3.57	306	583	7.66	281	538
	350	2.4(-2.4)	9	2.3(1.7)	3.75	256	493	3.29	306	583	7.04	281	538
	351	2.4(-2.4)	9.4	2.3(1.7)	3.45	256	493	2.97	306	583	6.42	281	538
	352	2.8(-2.8)	8.4	2.3(1.7)	4.2	256	493	3.52	306	583	7.72	281	538
	353	2.8(-2.8)	8.8	2.3(1.7)	3.86	256	493	3.27	306	583	7.13	281	538
	354	2.8(-2.8)	9.2	2.3(1.7)	3.64	256	493	2.97	306	583	6.61	281	538

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
	355	-2.8(2.8)	8.8	2.3(1.7)	2.48	303	578	5.1	303	578	7.58	303	578
	356	-2.8(2.8)	9.2	2.3(1.7)	2.25	303	578	4.75	303	578	7	303	578
	357	-2.4(2.4)	8.2	2.3(1.7)	2.96	303	578	5.75	303	578	8.71	303	578
	358	-2.4(2.4)	8.6	2.3(1.7)	2.7	303	578	5.35	303	578	8.05	303	578
	359	-2.4(2.4)	9	2.3(1.7)	2.51	303	578	4.95	303	578	7.46	303	578
Charpy V-Std	360	-2.4(2.4)	9.4	2.3(1.7)	2.25	303	578	4.56	303	578	6.81	303	578
Charpy V-Std	361	-2.0(2.0)	8.2	2.3(1.7)	3.11	303	578	5.75	303	578	8.86	303	578
Charpy V-Std	362	-2.0(2.0)	8.6	2.3(1.7)	2.93	303	578	5.4	303	578	8.33	303	578
Charpy V-Std	363	-2.0(2.0)	9	2.3(1.7)	2.7	303	578	4.95	303	578	7.65	303	578
Charpy V-Std	364	-2.0(2.0)	9.4	2.3(1.7)	2.33	303	578	4.51	303	578	6.84	303	578
Charpy V-Std	365	-1.6(1.6)	8.4	2.3(1.7)	3.23	303	578	5.45	303	578	8.68	303	578
Charpy V-Std	366	-1.6(1.6)	8.8	2.3(1.7)	2.89	303	578	5.15	303	578	8.04	303	578
Charpy V-Std	367	-1.6(1.6)	9.2	2.3(1.7)	2.63	303	578	4.75	303	578	7.38	303	578
Tens: MT-S	63W 1	0	-6	3.0(1.0)	3.63	279	535	9.18	288	550	12.81	284	543
Tens: MT-S	2	0	-6	1.0(3.0)	9.18	289	553	3.63	268	515	12.81	279	534
Tens: MT-S	3	0	6	1.0(3.0)	9.38	291	555	3.72	282	540	13.1	286	548
Tens: MT-S	4	0	6	3.0(1.0)	3.72	273	523	9.38	282	540	13.1	277	531
Tens: MT-S	5	0	10.7	3.0(1.0)	1.05	285	545	2.74	291	555	3.82	288	550
Tens: MT-S	9	0	10.7	1.0(3.0)	2.74	288	550	1.05	285	545	3.82	286	548
Tens: MT	13	2.8(-2.8)	-8.4	2.3(1.7)	2.63	286	548	6.34	334	633	8.97	310	590
	14	-2.8(2.8)	8.4	2.3(1.7)	3.75	316	600	3.42	291	555	7.17	303	578
	15	1.6(-1.6)	8.4	2.3(1.7)	3.11	291	555	4.95	342	648	8.06	316	601
4TCT-J	22	0	-4.8	0(4.0)	15.68	271	520	2.46	250	483	18.13	261	501
		0	-4.8	.5(3.5)	12.43	278	533	3.1	259	498	15.53	268	515
		0	-4.8	1.0(3.0)	9.86	286	548	3.91	267	513	13.77	277	530
		0	-4.8	1.5(2.5)	7.82	288	550	4.92	278	533	12.75	283	541
		0	-4.8	2.0(2.0)	6.21	288	550	6.21	284	543	12.41	286	546
		0	-4.8	2.5(1.5)	4.92	285	545	7.82	286	548	12.75	286	546
		0	-4.8	3.0(1.0	3.91	274	525	9.86	286	548	13.77	280	536
		0	-4.8	3.5(0.5)	3.1	267	513	12.43	282	540	15.53	275	526

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
		0	-4.8	4.0(0)	2.46	263	505	15.68	278	533	18.13	270	519
	23	0	4.8	0(4.0)	15.95	296	565	2.5	281	538	18.45	288	551
				0.5(3.5)	12.65	293	560	3.15	282	540	15.8	288	550
				1.0(3.0)	10.03	291	555	3.97	282	540	14.01	286	548
				1.5(2.5)	7.96	286	548	5.01	282	540	12.97	284	544
				2.0(2.0)	6.31	282	540	6.31	282	540	12.63	282	540
				2.5(1.5)	5.01	275	528	7.96	282	540	12.97	279	534
				3.0(1.0)	3.97	270	518	10.03	282	540	14.01	276	529
				3.5(0.5)	3.15	259	498	12.65	273	523	15.8	266	510
				4.0(0)	2.5	250	483	15.95	263	505	18.45	257	494
1.6 TCT-J	30	-2.9(2.9)	0	1.6(2.4)	9.39	320	608	3.97	278	533	13.36	299	570
	31	1.0(-1.0)	0	1.6(2.4)	7.42	256	493	6.09	271	520	13.51	263	506
0.8 TCT-J	40	3.8(-3.8)	0.4	1.2(2.8)	5.68	271	520	5.36	299	570	11.04	285	545
	41	3.8(-3.8)	-0.4	1.2(2.8)	5.68	271	520	5.44	299	570	11.12	285	545
	42	3.8(-3.8)	0.4	2.8(1.2)	2.71	267	513	11.24	328	623	13.95	297	568
	43	3.8(-3.8)	-0.4	2.8(1.2)	2.71	267	513	11.43	328	623	14.14	297	568
0.5 TCT-Std.	100	0	-6.8	3.5(0.5)	2.72	293	560	10.92	299	570	13.64	296	565
0.5 TCT-Std.	101	0	-6.8	0.5(3.5)	10.92	293	560	2.72	274	525	13.64	284	543
0.5 TCT-Std.	102	0	-8	3.5(0.5)	2.41	304	580	9.67	307	585	12.08	306	583
0.5 TCT-Std.	104	0	-8	1.8(2.2)	5.3	316	600	4.4	306	583	9.7	311	591
0.5 TCT-Std.	105	-0.7(0.7)	-10	3.5(0.5)	1.76	321	610	6.3	318	605	8.06	320	608
0.5 TCT-Std.	106	-0.7(0.7)	-10	0.5(3.5)	7.08	318	605	1.57	298	568	8.65	308	586
0.5 TCT-J	108	0	-6.8	1.8(2.2)	5.98	299	570	4.97	293	560	10.95	296	565
0.5 TCT-J	109	0	-8	0.5(3.5)	9.67	304	580	2.41	296	565	12.08	300	573
0.5 TCT-J	110	-0.7(0.7)	-10	1.8(2.2)	3.88	321	610	2.87	309	588	6.75	315	599
0.5 TCT-J	112	0.7(-0.7)	-10	1.8(2.2)	3.45	321	610	3.22	309	588	6.67	315	599
0.5 TCT-J	113	-0.7(0.7)	10.3	1.8(2.2)	2.79	291	555	2.04	291	555	4.83	291	555
0.5 TCT-Std.	114	0.7(-0.7)	-10	3.5(0.5)	1.57	321	610	7.08	318	605	8.65	320	608
0.5 TCT-Std.	115	0.7(-0.7)	-10	0.5(3.5)	6.3	318	605	1.76	298	568	8.06	308	586
0.5 TCT-Std.	116	-0.7(0.7)	10.3	3.5(0.5)	1.27	279	535	4.49	289	553	5.76	284	544

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
0.5 TCT-Std.	117	-0.7(0.7)	10.3	0.5(3.5)	5.09	285	545	1.12	278	533	6.21	282	539
0.5 TCT-Std.	118	0.7(-0.7)	10.3	3.5(0.5)	1.12	279	535	5.09	289	553	6.21	284	544
0.5 TCT-Std.	119	0.7(-0.7)	10.3	0.5(3.5)	4.49	285	545	1.27	278	533	5.76	282	539
0.5 TCT-Std.	120	-2.2(2.2)	-8.3	0.5(3.5)	10.88	328	623	1.72	259	498	12.6	293	560
0.5 TCT-J	121	0.7(-0.7)	10.3	1.8(2.2)	2.46	291	555	2.32	291	555	4.78	291	555
0.5 TCT-J	122	-2.2(2.2)	-9.3	0.5(3.5)	9.5	328	623	1.48	259	498	10.98	293	560
0.5 TCT-J	123	-2.2(2.2)	-8.3	3.5(0.5)	2.71	303	578	6.91	279	535	9.62	291	556
0.5 TCT-J	124	-2.2(2.2)	-8.8	3.5(0.5)	2.58	303	578	6.39	279	535	8.97	291	556
0.5 TCT-J	125	-2.2(2.2)	-9.3	3.5(0.5)	2.34	303	578	5.96	279	535	8.3	291	556
0.5 TCT-J	127	2.2(-2.2)	-8.3	0.5(3.5)	6.91	298	568	2.71	299	570	9.62	298	569
0.5 TCT-Std.	128	-2.2(2.2)	-8.8	0.5(3.5)	10.36	328	623	1.59	259	498	11.95	293	560
0.5 TCT-Std.	129	-2.2(2.2)	-8.3	2.0(2.0)	5.43	320	608	3.45	278	533	8.88	299	570
0.5 TCT-Std.	130	-2.2(2.2)	-8.8	2.0(2.0)	5.17	320	608	3.19	278	533	8.36	299	570
0.5 TCT-Std.	131	-2.2(2.2)	-9.3	2.0(2.0)	4.74	320	608	2.97	278	533	7.71	299	570
0.5 TCT-Std.	132	-2.2(2.2)	8.3	0.5(3.5)	8.64	338	640	1.7	284	543	10.34	311	591
0.5 TCT-Std.	133	-2.2(2.2)	8.8	0.5(3.5)	7.86	338	640	1.53	284	543	9.39	311	591
0.5 TCT-Std.	134	-2.2(2.2)	9.3	0.5(3.5)	6.99	338	640	1.4	284	543	8.39	311	591
0.5 TCT-J	135	2.2(-2.2)	-8.8	0.5(3.5)	6.39	298	568	2.58	299	570	8.97	298	569
0.5 TCT-J	138	2.2(-2.2)	-9.3	0.5(3.5)	6.04	298	568	2.41	299	570	8.45	298	569
0.5 TCT-J	140	2.2(-2.2)	-8.7	3.7(0.3)	1.51	260	500	11.37	313	595	12.88	286	548
0.5 TCT-J	157	-2.2(2.2)	8.7	3.7(0.3)	1.82	293	560	7.01	286	548	8.83	290	554
0.5 TCT-J	158	2.2(-2.2)	8.3	0.5(3.5)	6.82	302	575	2.15	323	613	8.97	312	594
0.5 TCT-J	159	2.2(-2.2)	8.8	0.5(3.5)	6.13	302	575	1.96	323	613	8.09	312	594
0.5 TCT-J	160	2.2(-2.2)	9.3	0.5(3.5)	5.61	302	575	1.74	323	613	7.35	312	594
0.5 TCT-J	162	2.2(-2.2)	8.7	3.7(0.3)	1.45	277	530	8.81	338	640	10.26	307	585
Charpy V-PC	201	0	7.3	3.4(0.6)	2.66	295	563	9.73	288	550	12.39	291	556
Charpy V-PC	202	0	7.3	2.6(1.4)	3.85	295	563	6.72	288	550	10.57	291	556
Charpy V-PC	203	0	7.3	1.4(2.6)	6.72	295	563	3.85	288	550	10.57	291	556
Charpy V-PC	204	0	7.3	0.6(3.4)	9.73	295	563	2.66	288	550	12.39	291	556
Charpy V-PC	205	0	9.5	3.4(0.6)	1.67	282	540	6.1	282	540	7.77	282	540

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
		X	Y	Z	Fluence (n/cm2)	Temperature		Fluence (n/cm2)	Temperature				
Type	Number	Fwd (Rev)		Fwd (Rev)		(°C)	(°F)		(°C)	(°F)		(°C)	(°F)
Charpy V-PC	206	0	9.5	2.6(1.4)	2.42	286	548	4.21	286	548	6.63	286	548
Charpy V-PC	207	0	9.5	1.4(2.6)	4.21	286	548	2.42	286	548	6.63	286	548
Charpy V-PC	208	0	9.5	0.6(3.4)	6.1	282	540	1.67	282	540	7.77	282	540
Charpy V-Std.	242	0	-9.7	3.8(0.2)	1.61	321	610	8.53	318	605	10.14	320	608
Charpy V-Std.	243	0	-9.7	3.4(0.6)	1.94	321	610	7.09	318	605	9.03	320	608
Charpy V-Std.	244	0	-9.7	3.0(1.0)	2.33	321	610	5.89	318	605	8.22	320	608
Charpy V-Std.	245	0	-9.7	2.6(1.4)	2.81	321	610	4.89	309	588	7.7	315	599
Charpy V-Std.	246	0	-9.7	2.2(1.8)	3.38	321	610	4.07	309	588	7.45	315	599
Charpy V-Std.	247	0	-9.7	1.8(2.2)	4.07	321	610	3.38	309	588	7.45	315	599
Charpy V-Std.	248	0	-9.7	1.4(2.6)	4.89	321	610	2.81	309	588	7.7	315	599
Charpy V-Std.	249	0	-9.7	1.0(3.0)	5.89	318	605	2.33	298	568	8.22	308	586
Charpy V-Std.	250	0	-9.7	0.6(3.4)	7.09	318	605	1.94	298	568	9.03	308	586
Charpy V-Std.	251	0	-9.7	0.2(3.8)	8.53	318	605	1.61	298	568	10.14	308	586
Charpy V-Std.	252	0	7.3	3.8(0.2)	2.21	295	563	11.71	288	550	13.92	291	556
Charpy V-Std.	253	0	7.3	3.0(1.0)	3.2	295	563	8.08	288	550	11.28	291	556
Charpy V-Std.	254	0	7.3	2.2(1.8)	4.64	295	563	5.58	288	550	10.22	291	556
Charpy V-Std.	255	0	7.3	1.8(2.2)	5.58	295	563	4.64	288	550	10.22	291	556
Charpy V-Std.	256	0	7.3	1.0(3.0)	8.08	295	563	3.2	288	550	11.28	291	556
Charpy V-Std.	257	0	7.3	0.2(3.8)	11.71	295	563	2.21	288	550	13.92	291	556
Charpy V-Std.	258	0	9.5	3.8(0.2)	1.39	282	540	7.34	282	540	8.73	282	540
Charpy V-Std.	259	0	9.5	3.0(1.0)	2.01	282	540	5.07	282	540	7.08	282	540
Charpy V-Std.	260	0	9.5	2.2(1.8)	2.91	291	555	3.5	291	555	6.41	291	555
Charpy V-Std.	261	0	9.5	1.8(2.2)	3.5	291	555	2.91	291	555	6.41	291	555
Charpy V-Std.	262	0	9.5	1.0(3.0)	5.07	282	540	2.01	282	540	7.08	282	540
Charpy V-Std.	263	0	9.5	0.2(3.8)	7.34	282	540	1.39	282	540	8.73	282	540
Charpy V-Std.	264	2.8(-2.8)	-8.8	2.3(1.7)	2.55	286	548	5.99	334	633	8.54	310	590
Charpy V-Std.	265	2.8(-2.8)	-9.2	2.3(1.7)	2.4	286	548	5.75	334	633	8.15	310	590
Charpy V-Std.	266	2.4(-2.4)	-8.2	2.3(1.7)	2.93	286	548	6.44	334	633	9.37	310	590
Charpy V-Std.	267	2.4(-2.4)	-8.6	2.3(1.7)	2.76	286	548	6.04	334	633	8.8	310	590
Charpy V-Std.	268	2.4(-2.4)	- 9	2.3(1.7)	2.63	286	548	5.82	334	633	8.45	310	590

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
Charpy V-Std.	269	2.4(-2.4)	-9.4	2.3(1.7)	2.51	286	548	5.45	334	633	7.96	310	590
Charpy V-Std.	270	2.0(-2.0)	-8.2	2.3(1.7)	3.15	286	548	6.34	334	633	9.49	310	590
Charpy V-Std.	271	2.0(-2.0)	-8.6	2.3(1.7)	3	286	548	5.99	334	633	8.99	310	590
Charpy V-Std.	272	2.0(-2.0)	-9	2.3(1.7)	2.89	286	548	5.75	334	633	8.64	310	590
Charpy V-Std.	273	2.0(-2.0)	-9.4	2.3(1.7)	2.74	286	548	5.45	334	633	8.19	310	590
Charpy V-Std.	274	1.6(-1.6)	-8.4	2.3(1.7)	3.3	286	548	5.99	334	633	9.29	310	590
Charpy V-Std.	275	1.6(-1.6)	-8.8	2.3(1.7)	3.08	286	548	5.7	334	633	8.78	310	590
Charpy V-Std.	276	1.6(-1.6)	-9.2	2.3(1.7)	2.93	286	548	5.4	334	633	8.33	310	590
Charpy V-Std.	277	-2.8(2.8)	8.8	2.3(1.7)	3.45	316	600	3.27	291	555	6.72	303	578
Charpy V-Std.	278	-2.8(2.8)	9.2	2.3(1.7)	3.15	316	600	2.97	291	555	6.12	303	578
Charpy V-Std.	279	-2.4(2.4)	8.2	2.3(1.7)	3.86	316	600	3.86	291	555	7.72	303	578
Charpy V-Std.	280	-2.4(2.4)	8.6	2.3(1.7)	3.56	316	600	3.52	291	555	7.08	303	578
Charpy V-Std.	281	-2.4(2.4)	9	2.3(1.7)	3.34	316	600	3.32	291	555	6.66	303	578
Charpy V-Std.	282	-2.4(2.4)	9.4	2.3(1.7)	3	316	600	3.02	291	555	6.02	303	578
Charpy V-Std.	283	-2.0(2.0)	8.2	2.3(1.7)	3.83	316	600	4.01	291	555	7.84	303	578
Charpy V-Std.	284	-2.0(2.0)	8.6	2.3(1.7)	3.56	316	600	3.86	291	555	7.42	303	578
Charpy V-Std.	285	-2.0(2.0)	9	2.3(1.7)	3.34	316	600	3.52	291	555	6.86	303	578
Charpy V-Std.	286	-2.0(2.0)	9.4	2.3(1.7)	3	316	600	3.27	291	555	6.27	303	578
Charpy V-Std.	287	-1.6(1.6)	8.4	2.3(1.7)	3.75	316	600	4.16	291	555	7.91	303	578
Charpy V-Std.	288	-1.6(1.6)	8.8	2.3(1.7)	3.45	316	600	3.91	291	555	7.36	303	578
Charpy V-Std.	289	-1.6(1.6)	9.4	2.3(1.7)	3.08	316	600	3.42	291	555	6.5	303	578
Charpy V-Std.	290	1.6(-1.6)	8.8	2.3(1.7)	2.96	291	555	4.56	342	648	7.52	316	601
Charpy V-Std.	291	1.6(-1.6)	9.2	2.3(1.7)	2.7	291	555	4.06	342	648	6.76	316	601
Charpy V-Std.	292	2.0(-2.0)	8.2	2.3(1.7)	3.04	291	555	5.05	342	648	8.09	316	601
Charpy V-Std.	293	2.0(-2.0)	8.6	2.3(1.7)	2.92	291	555	4.7	342	648	7.62	316	601
Charpy V-Std.	294	2.0(-2.0)	9	2.3(1.7)	2.66	291	555	4.41	342	648	7.07	316	601
Charpy V-Std.	295	2.0(-2.0)	9.4	2.3(1.7)	2.48	291	555	3.96	342	648	6.44	316	601
Charpy V-Std.	296	2.4(-2.4)	8.2	2.3(1.7)	2.93	291	555	5.05	342	648	7.98	316	601
Charpy V-Std.	297	2.4(-2.4)	8.6	2.3(1.7)	2.66	291	555	4.75	342	648	7.41	316	601
Charpy V-Std.	298	2.4(-2.4)	9	2.3(1.7)	2.51	291	555	4.41	342	648	6.92	316	601

Table A1 (Continued)

Specimen		Capsule coordinates			Forward position			Reverse position			Total fluence (n/cm2)	Median temperature	
Type	Number	X Fwd (Rev)	Y	Z Fwd (Rev)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)	Fluence (n/cm2)	Temperature (°C)	Temperature (°F)		(°C)	(°F)
Charpy V-Std.	299	2.4(-2.4)	9.4	2.3(1.7)	2.29	291	555	3.96	342	648	6.25	316	601
Charpy V-Std.	300	2.8(-2.8)	8.4	2.3(1.7)	2.63	291	555	4.95	342	648	7.58	316	601
Charpy V-Std.	301	2.8(-2.8)	8.8	2.3(1.7)	2.44	291	555	4.56	342	648	7	316	601
Charpy V-Std.	302	2.8(-2.8)	9.2	2.3(1.7)	2.25	291	555	4.21	342	648	6.46	316	601

Table A2. Fast neutron fluences and median irradiation temperatures for the Third HSSI Irradiation Series, HSSI welds 64W-67W

CAPSULE A

Specimen Type	Specimen Number	Capsule Coordinates Forward Position (in.)			Forward Position			Reverse Position			Total Fluence (n/m^2)[a]	Median Temperature	
		X	Y	Z	Fluence (n/m^2)[a]	Temperature (°C)	(°F)	Fluence (n/m^2)[a]	Temperature (°C)	(°F)		(°C)	(°F)
4T-CS[b]	64W-22	0	-4.8	0	7.29×10^{22}	289	553	1.21×10^{22}	262	503	8.50×10^{22}	276	528
				1/4	6.76	289[c]	553[c]	1.37	264[c]	508[c]	8.13	277	530
				0.5	6.23	289	553	1.56	268	514	7.79	279	534
				1.0	5.15	289[c]	553[c]	2.02	272[c]	522[c]	7.17	281	538
				1.5	4.16	288	551	2.59	278	532	6.75	283	542
				2.0	3.30	286	547	3.30	283	542	6.60	285	545
				2.5	2.59	280	536	4.16	287	549	6.75	283	542
				3.0	2.02	272[c]	521[c]	5.15	289[c]	553[c]	7.17	281	537
				3.5	1.56	264	507	6.23	287	549	7.79	176	528
				3 3/4	1.37	259[c]	498[c]	2.76	284[c]	544[c]	8.13	272	521
				4	1.21	254	490	7.29	283	541	8.50	269	516
	64W-23	0	4.8	0	7.09	284	543	1.18	280	536	8.27	282	540
				1/4	6.70	286[c]	546[c]	1.34	281[c]	538[c]	8.04	283	542
				0.5	6.06	289	552	1.52	283	542	7.58	286	547
				1.0	5.00	292[c]	557[c]	1.98	286[c]	547[c]	6.98	289	552
				1.5	4.04	292	557	2.52	288	551	6.56	290	554
				2.0	3.21	292[c]	557[c]	3.21	290[c]	554[c]	6.42	291	556
				2.5	2.52	291	555	4.04	291	555	6.56	291	555
				3.0	1.98	289[c]	553[c]	5.00	291[c]	556[c]	6.98	290	554
				3.5	1.52	288	551	6.06	289	552	7.58	289	552
				3 3/4	1.34	288[c]	550[c]	6.70	287[c]	549[c]	8.04	288	550
				4	1.18	287	549	7.09	286	547	8.27	287	548

[a] 10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.
[b] Compact specimen.
[c] Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

Table A2 (Continued)

CAPSULE B

Specimen Type	Specimen Number	Capsule Coordinates Forward Position (in.)			Forward Position			Reverse Position			Total Fluence (n/m^2)[a]	Median Temperature	
		X	Y	Z	Fluence (n/m^2)[a]	Temperature (°C)	(°F)	Fluence (n/m^2)[a]	Temperature (°C)	(°F)		(°C)	(°F)
4T-CS[b]	65W-24	0	-4.8	0	8.26×10^{22}	287	548	1.42×10^{22}	253	488	9.68×10^{22}	270	518
				1/4	7.62	288[c]	551[c]	1.62	257[c]	494[c]	9.24	272	522
				0.5	6.88	290	554	1.82	262	504	8.70	276	529
				1.0	5.69	291[c]	556[c]	2.30	271[c]	519[c]	7.99	281	538
				1.5	4.65	289	552	2.94	277	531	7.58	283	542
				2.0	3.72	284[c]	543[c]	3.72	283[c]	541[c]	7.44	283	542
				2.5	2.94	278	533	4.65	288	550	7.58	283	542
				3.0	2.30	273[c]	523[c]	5.69	291[c]	556[c]	7.99	282	540
				3.5	1.82	265	509	6.88	292	557	8.70	278	533
				3 3/4	1.62	261[c]	502[c]	7.62	291[c]	556[c]	9.24	276	529
				4	1.42	258	496	8.26	291	555	9.68	274	526
	65W-25	0	4.8	0	6.72	288	550	1.17	287	548	7.88	287	549
				1.4	6.26	288[c]	551[c]	1.32	288[c]	550[c]	7.58	288	550
				0.5	5.63	289	552	1.50	289	552	7.13	289	552
				1.0	4.67	289[c]	553[c]	1.88	291[c]	555[c]	6.55	290	554
				1.5	3.82	288	551	2.41	292	558	6.23	290	554
				2.0	3.05	287[c]	548[c]	3.05	294[c]	561[c]	6.11	290	554
				2.5	2.41	283	542	3.82	295	563	6.23	289	552
				3.0	1.88	279[c]	535[c]	4.67	296[c]	565[c]	6.55	288	550
				3.5	1.50	276	528	5.63	294	561	7.13	284	544
				3 3/4	1.32	273[c]	524[c]	6.26	292[c]	558[c]	7.58	283	541
				4	1.17	271	520	6.72	291	555	7.88	281	538

[a] 10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.
[b] Compact specimen.
[c] Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

Table A2 (Continued)

CAPSULE C

Specimen Type	Specimen Number	Capsule Coordinates Forward Position (in.)			Forward Position			Reverse Position			Total Fluence $(n/m^2)^a$	Median Temperature	
		X	Y	Z	Fluence $(n/m^2)^a$	Temperature (°C)	(°F)	Fluence $(n/m^2)^a$	Temperature (°C)	(°F)		(°C)	(°F)
4T-CS[b]	67W-23	0	-4.8	0	9.45×10^{22}	288	551	1.63×10^{22}	288	509	11.08×10^{22}	277	530
				1/4	8.70	289[c]	553[c]	1.86	267[c]	513[c]	10.56	278	533
				0.5	7.99	291	555	2.11	271	520	10.10	281	538
				1.0	6.57	291[c]	556[c]	2.67	277[c]	530[c]	9.24	284	543
				1.5	5.33	288	550	3.40	281	538	8.73	284	544
				2.0	4.30	283[c]	542[c]	4.30	285[c]	545[c]	8.60	284	544
				2.5	3.40	278	533	5.33	288	551	8.73	283	542
				3.0	2.67	272[c]	521[c]	6.57	289[c]	552[c]	9.24	280	536
				3.5	2.11	263	506	7.99	287	548	10.10	275	527
				3 3/4	1.86	257[c]	494[c]	8.70	283[c]	541[c]	10.56	270	518
				4	1.63	253	487	9.45	281	538	11.08	270	518
	67W-24	0	4.8	0	10.58	282	540	1.83	276	529	12.41	279	534
				1.4	9.71	284[c]	544[c]	2.14	278[c]	532[c]	11.85	281	538
				0.5	8.94	288	550	2.36	280	536	11.30	284	543
				1.0	7.36	292[c]	557[c]	3.01	283[c]	542[c]	10.37	287	548
				1.5	5.96	292	558	3.80	285	545	9.76	289	552
				2.0	4.81	292[c]	557[c]	4.81	287[c]	548[c]	9.62	289	552
				2.5	3.80	291	555	5.96	288	551	9.76	289	553
				3.0	3.01	289[c]	552[c]	7.36	289[c]	552[c]	10.37	289	552
				3.5	2.36	286	547	8.94	288	550	11.30	287	548
				3 3/4	2.14	284[c]	543[c]	9.71	286[c]	546[c]	11.85	284	544
				4	1.83	282	540	10.58	284	543	12.41	283	542

[a] 10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.
[b] Compact specimen.
[c] Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

Table A2 (Continued)

CAPSULE A

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 64W

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence (n/m^2)[b]	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)		(°C)	(°F)
1.6T-CS	64W-30	3.33×10^{22}	279[c]	534[c]	2.90×10^{22}	292[c]	557[c]	6.23×10^{22}	286	546
	31	4.44	298[c]	569[c]	2.27	278[c]	533[c]	6.71	288	551
0.8T-CS	64W-40	5.25	298[c]	568[c]	2.48	271[c]	519[c]	7.73	284	544
	43	5.25	298[c]	568[c]	2.48	271[c]	591[c]	7.73	284	544
	45	2.48	274[c]	526[c]	5.25	291[c]	556[c]	7.73	283	541
	44	2.48	274[c]	526[c]	5.25	291[c]	556[c]	7.73	283	541
0.5T-CS	64W-101	5.38	294[c]	562[c]	1.34	268[c]	514[c]	6.72	281	538
	107	3.12	298	569	2.58	279	535	5.70	286	547
	104	1.35	294	561	5.38	293	560	6.72	293	560
	108	4.65	277	531	1.17	266	510	5.82	271	520
	110	2.71	281[c]	538[c]	2.24	278[c]	533[c]	4.95	279	535
	111	1.17	277	530	4.65	296	565	5.82	287	548
	114	3.05	238[c]	461[c]	0.70	234[c]	453[c]	3.75	236	457
	112	1.77	242[c]	468[c]	1.36	246[c]	475[c]	3.13	244	472
	113	0.75	238[c]	460[c]	2.86	258[c]	497[c]	3.61	248	479
	115	2.86	238	461	0.75	234	453	3.61	244	472
	116	1.65	242	468	1.45	246	475	3.00	244	472
	117	0.70	238	460	3.05	258	497	3.75	248	479
	118	2.54	272[c]	521[c]	0.59	269[c]	517[c]	3.09	271	519
	119	1.46	278[c]	532[c]	1.13	273[c]	524[c]	2.56	276	528
	121	0.62	276[c]	528[c]	2.37	270[c]	518[c]	2.98	273	523
	122	2.37	272	521	0.62	269	517	2.98	271	519
	123	1.38	278	532	1.21	273	524	2.54	276	528
	124	0.59	276	528	2.54	270	518	3.09	273	523
	125	4.15	291	556	0.79	259	498	4.94	275	527
	127	4.48	292[c]	558[c]	0.85	259[c]	499[c]	5.33	276	528
	129	4.82	291	556	0.93	259	498	5.75	275	527
	130	2.02	275	527	1.68	270	518	3.70	272	522
	131	2.17	276[c]	529[c]	1.81	271[c]	519[c]	3.98	273	524
	132	2.35	275	527	1.95	270	518	4.30	272	522
	133	0.91	258	497	3.22	268	515	4.13	263	506
	134	0.99	259[c]	498[c]	3.48	269[c]	516[c]	4.47	264	507
	135	1.06	258	497	3.75	268	515	4.81	263	506
	138	3.75	279	535	1.06	288	550	4.81	283	542
	136	3.48	279	535	0.99	288	550	4.47	283	542
	139	3.22	279	535	0.91	288	550	4.13	283	542
	140	0.84	245[c]	473[c]	5.16	281[c]	538[c]	6.00	263	506
	141	4.52	292[c]	558[c]	0.88	277[c]	531[c]	5.40	284	544
	142	4.15	292	558	0.81	277	531	4.96	284	544
	143	3.66	292	558	0.72	277	531	4.38	284	544
	144	0.89	290[c]	554[c]	3.78	275[c]	527[c]	4.61	282	540
	145	3.51	272	521	1.00	282	540	4.51	277	530
	146	3.22	272[c]	521[c]	0.91	282[c]	540[c]	4.13	277	530
	147	2.85	272	521	0.81	282	540	3.66	277	530
	148	0.79	277[c]	531[c]	4.84	285[c]	545[c]	5.63	281	538

Table A2 (Continued)

CAPSULE A

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 64W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)	(n/m^2)[b]	(°C)	(°F)
Cv-	64W-200	3.76×10^{22}	238	460	0.75×10^{22}	231	448	4.61×10^{22}	234	454
	201	3.35	239	463	0.92	236	456	4.27	238	460
	202	2.87	241	466	1.13	240	464	4.00	241	465
	203	2.43	242	468	1.38	243	470	3.81	243	469
	204	2.02	243	470	1.67	247	477	3.69	246	474
	205	1.67	242	468	2.02	251	484	3.69	247	476
	206	1.38	241	466	2.43	254	489	3.81	248	478
	207	1.13	240	464	2.87	257	494	4.00	248	479
	208	0.92	239	462	3.35	259	499	4.27	249	480
	209	0.75	237	458	3.76	262	504	4.61	249	481
	276	5.29	286	546	1.03	286	547	6.32	286	546
	277	3.95	289	552	1.56	288	550	5.51	288	551
	278	2.79	291[c]	556[c]	2.31	289[c]	553[c]	5.10	290	554
	279	2.31	291[c]	556[c]	2.79	289[c]	553[c]	5.10	290	554
	280	1.56	290	554	3.95	287	548	5.51	288	551
	281	1.03	289[c]	552[c]	5.29	284[c]	543[c]	6.32	287	548
	282	3.58	272	522	0.70	270	518	4.28	271	520
	283	2.67	275	527	1.06	272	522	3.73	273	524
	284	1.90	279	534	1.56	274	526	3.49	277	530
	285	1.56	279	534	1.90	274	526	3.49	277	530
	286	1.06	278	532	2.67	273	523	3.73	276	528
	287	0.70	277	530	3.58	271	520	4.28	274	525
	288	1.66	262	503	2.57	284	544	4.23	273	524
	289	1.54	262	503	2.39	284	544	3.93	273	524
	293	1.75	262	503	2.80	284	544	4.55	273	524
	292	1.66	264	507	2.65	286	547	4.31	273	524
	291	1.55	264	507	2.48	286	547	4.03	273	524
	290	1.43	262	503	2.28	284	544	3.71	273	524
	294	1.68	262	503	2.77	284	544	4.45	273	524
	295	1.59	264[c]	507[c]	2.62	286[c]	547[c]	4.21	275	527
	296	1.49	264	507	2.45	286	547	3.94	275	527
	297	1.42	262[c]	503[c]	2.35	284[c]	544[c]	3.77	273	524
	298	1.54	262	503	2.65	284	544	4.19	273	524
	299	1.43	262	503	2.46	284	544	3.89	273	524
	300	1.33	262	503	2.30	284	544	3.63	273	524
	301	1.77	293	560	2.05	281	537	3.82	287	548
	302	1.59	293	560	1.84	281	537	3.43	287	548
	303	1.92	293	560	2.16	281	537	4.08	287	548
	304	1.81	294	562	2.04	282	539	3.85	288	550
	305	1.65	294	562	1.86	282	539	3.51	288	550
	306	1.51	293	560	1.68	281	537	3.19	287	548
	307	1.90	293	560	2.07	281	537	3.97	287	548
	308	1.79	294[c]	562[c]	1.95	282[c]	539[c]	3.74	288	550
	309	1.64	294	562	1.78	282	539	3.42	288	550
	310	1.48	293	560	1.61	281	537	3.09	287	548

Table A2 (Continued)

CAPSULE B

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 65W

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)	(n/m^2)[b]	(°C)	(°F)
1.6T-CS	65W-37	4.63×10^{22}	304[c]	579[c]	2.07×10^{22}	274[c]	526[c]	6.70×10^{22}	289	552
	39	3.00	274[c]	525[c]	3.20	308[c]	586[c]	6.20	291	556
0.8T-CS	65W-41	5.01	291[c]	556[c]	2.43	276[c]	528[c]	7.44	283	542
	42	5.09	291[c]	556[c]	2.47	276[c]	528[c]	7.56	283	542
	44	2.43	270[c]	518[c]	5.01	298[c]	568[c]	7.44	284	543
	45	2.47	270[c]	518[c]	5.09	298[c]	568[c]	7.56	284	543
0.5T-CS	65W-100	6.07	297[c]	566[c]	1.60	269[c]	517[c]	7.67	283	542
	101	3.55	289	552	2.97	283	541	6.52	286	546
	103	1.60	278	532	6.07	293	559	7.67	286	546
	104	4.98	294	561	1.31	279	534	6.29	287	548
	105	2.92	286[c]	547[c]	2.44	287[c]	548[c]	5.36	287	548
	106	1.31	275	527	4.98	297	566	6.29	283	542
	107	2.15	286[c]	546[c]	0.62	266[c]	510[c]	3.77	273	523
	108	1.24	278[c]	532[c]	1.16	279[c]	534[c]	2.40	278	533
	109	0.56	267[c]	512[c]	2.39	289[c]	552[c]	2.95	278	532
	111	2.39	286	546	0.56	266	510	2.95	273	523
	112	1.38	278	532	1.04	279	534	2.42	278	533
	113	0.62	267	512	2.15	289	552	3.77	278	532
	115	1.90	262[c]	503[c]	0.56	273[c]	524[c]	2.46	270	518
	118	1.11	258[c]	497[c]	1.03	276[c]	528[c]	2.14	267	512
	120	0.50	264[c]	508[c]	2.10	273[c]	523[c]	2.60	269	516
	122	2.10	262	503	0.50	273	524	2.60	268	514
	123	1.24	258	497	0.93	276	528	2.17	267	512
	124	0.56	264	508	1.90	273	523	2.46	269	516
	126	2.80	282	541	1.01	273	524	3.81	268	514
	127	3.36	283[c]	542[c]	1.21	274[c]	526[c]	4.57	279	534
	129	3.74	283	541	1.35	273	524	5.09	268	514
	130	1.48	269	516	2.10	296	565	3.58	282	540
	131	1.77	269[c]	517[c]	2.51	298[c]	569[c]	4.28	284	543
	133	1.98	269[c]	516[c]	2.81	296[c]	565[c]	4.79	282	540
	136	0.72	252	486	4.00	302	576	4.72	277	531
	137	0.85	253[c]	487[c]	4.76	304[c]	580[c]	5.61	279	534
	138	0.96	252	486	5.33	302	576	6.29	277	531
	139	5.33	319	607	0.96	258	497	6.29	289	552
	140	4.76	320[c]	608[c]	0.85	259[c]	498[c]	5.61	289	553
	142	4.00	319	607	0.72	258	497	4.72	289	552
	143	1.24	267[c]	513[c]	4.10	272[c]	522[c]	5.34	269	516
	144	3.04	276	528	1.06	295	563	4.10	286	546
	145	2.71	276[c]	528[c]	0.95	295[c]	563[c]	3.66	286	546
	146	2.36	276	528	0.82	295	563	3.18	286	546
	157	0.70	265[c]	507[c]	4.44	292[c]	557[c]	5.14	278	532
	159	4.26	293	559	0.77	276	528	5.03	284	544
	160	3.81	293[c]	559[c]	0.69	276[c]	528[c]	4.50	284	544
	161	3.31	293	559	0.60	276	528	3.91	284	544
	162	0.96	276[c]	528[c]	3.22	269[c]	516[c]	4.18	272	522

Table A2 (Continued)

CAPSULE A

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 64W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence (n/m^2)[b]	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)		(°C)	(°F)
C_V-	64W-311	1.84×10^{22}	293	560	1.91×10^{22}	281	537	3.75×10^{22}	287	548
	312	1.71	293	560	1.78	281	537	3.49	287	548
	313	1.54	293	560	1.60	281	537	3.14	287	548
	314	1.54	275	527	2.36	287	548	3.90	281	538
	315	1.39	275	527	2.13	287	548	3.52	281	538
	316	1.63	275	527	2.58	287	548	4.21	281	538
	317	1.53	277	531	2.43	288	551	3.96	283	541
	318	1.40	277	531	2.22	288	551	3.62	283	541
	319	1.27	275	527	2.01	287	548	3.28	281	538
	320	1.56	275	527	2.56	287	548	4.12	281	538
	321	1.47	277[c]	531[c]	2.41	288[c]	551[c]	3.88	283	541
	322	1.34	277	531	2.20	288	551	3.54	283	541
	323	1.21	275[c]	527[c]	1.99	287[c]	548[c]	3.20	281	538
	324	1.43	275	527	2.47	287	548	3.90	281	538
	325	1.34	275	527	2.30	287	548	3.64	281	538
	326	1.20	275	527	2.07	287	548	3.27	281	538
PCC_V	64W-210C	4.61	287	549	1.27	287	549	5.88	287	549
	211C	3.34	290	554	1.90	289	552	5.24	289	553
	212C	1.90	291	555	3.34	288	551	5.24	289	553
	213C	1.27	289[c]	553[c]	4.61	284[c]	543[c]	5.88	287	548
	214C	3.12	273	523	0.86	271	519	3.98	272	521
	215C	2.26	277	531	1.28	273	524	3.54	276	528
	216C	1.28	278	533	2.26	274	525	3.54	276	529
	217C	0.86	277	531	3.12	272	522	3.98	274	526
Tensile	64W-4	4.80	293	560	1.89	269	516	6.69	281	538
	5	1.89	277	530	4.80	287	548	6.69	282	539
	6	1.76	292	558	0.69	287	548	2.45	289	553
	7	0.69	289	553	1.76	291	555	2.45	290	554
	8	4.60	275	527	1.82	272	522	6.42	273	524
	9	1.82	277	530	4.60	271	520	6.42	274	525
	1	1.77	262	503	2.75	284	544	4.52	273	524
	2	1.89	293	560	2.21	281	537	4.10	287	548
	3	1.65	275	527	2.54	287	548	4.19	281	538

[a]CS - compact specimen, C_V - standard Charpy V-notch impact specimen, PCC_V - precracked Charpy V-notch specimen, tensile - 0.178-in. gage diameter.

[b]10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.

[c]Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

Table A2 (Continued)

CAPSULE B

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 65W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)	(n/m^2)[b]	(°C)	(°F)
Cv-	65W-233	3.28×10^{22}	287	548	0.67×10^{22}	261	502	3.95×10^{22}	274	525
	234	2.84	286	546	0.82	266	510	3.66	276	528
	235	2.43	283	542	0.99	271	520	3.42	277	531
	236	2.06	281	538	1.20	275	527	3.26	278	532
	237	1.73	278	532	1.44	279	534	3.17	278	533
	238	1.44	277	530	1.73	282	540	3.17	279	535
	239	1.20	274	525	2.06	286	546	3.26	280	536
	241	0.99	271	520	2.43	288	550	3.42	279	535
	240	0.82	267	512	2.84	289	552	3.66	278	532
	242	0.67	264	508	3.28	289	552	3.95	279	530
	243	4.87	281	538	1.01	293	560	5.88	287	549
	244	3.65	282	540	1.49	295	563	5.14	289	552
	245	2.60	281[c]	537[c]	2.17	296[c]	565[c]	4.77	288	551
	246	2.17	279	535	2.60	296	565	4.77	288	550
	247	1.49	274	525	3.65	292	558	5.14	283	542
	248	1.01	268	514	4.87	289	552	5.88	278	533
	249	3.07	267	513	0.64	278	532	3.71	272	522
	250	2.32	267	512	0.94	280	536	3.26	273	524
	251	1.65	266	510	1.38	282	540	3.03	274	525
	252	1.38	266	510	1.65	282	540	3.03	274	525
	253	0.94	266	510	2.32	280	536	3.26	273	523
	254	0.64	266	511	3.07	277	530	3.71	271	520
	255	2.10	294	561	2.19	273	524	4.29	283	542
	256	1.83	294	561	1.91	273	524	3.74	283	542
	257	2.42	294	561	2.37	273	524	4.79	283	542
	258	2.22	294	562	2.17	273	524	4.39	284	543
	259	2.00	294	562	1.96	273	524	3.96	284	543
	260	1.71	294	561	1.68	273	524	3.39	283	542
	262	2.44	294	561	2.24	273	524	4.68	283	542
	261	2.24	294[c]	562[c]	2.06	273[c]	524[c]	4.30	284	543
	263	2.02	294	562	1.85	273	524	3.87	284	543
	264	1.73	294[c]	561[c]	1.58	273[c]	524[c]	3.31	283	542
	265	2.35	294	561	2.03	273	524	4.38	283	542
	266	2.14	294	561	1.85	273	524	3.99	283	542
	267	1.87	294	561	1.61	273	524	3.48	283	542
	268	1.33	269	516	2.21	298	568	3.54	283	542
	269	1.20	269	516	1.99	298	568	3.19	283	542
	270	1.43	269	516	2.54	298	568	3.97	283	542
	271	1.32	270	518	2.34	299	571	3.66	284	544
	272	1.19	270	518	2.12	299	571	3.31	284	544
	273	1.06	269	516	1.90	298	568	2.96	283	542
	274	1.35	269	516	2.57	298	568	3.92	283	542
	275	1.25	270[c]	518[c]	2.37	299[c]	571[c]	3.62	284	544
	276	1.13	270	518	2.14	299	571	3.27	284	544
	277	1.01	269[c]	516[c]	1.92	298[c]	568[c]	2.93	283	542

Table A2 (Continued)

CAPSULE B

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldment 65W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence (n/m^2)[b]	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)		(°C)	(°F)
C_V-	65W-278	1.24×10^{22}	269	516	2.50×10^{22}	290	568	3.74×10^{22}	283	542
	279	1.12	269	516	2.27	290	568	3.39	283	542
	280	1.01	269	516	2.05	290	568	3.06	283	542
	281	1.68	284	543	1.75	274	526	3.43	279	534
	284	1.51	284	543	1.58	274	526	3.09	279	534
	287	1.94	284	543	1.89	274	526	3.83	279	534
	290	1.79	285	545	1.74	276	528	3.53	288	536
	293	1.62	285	545	1.58	276	528	3.20	288	536
	296	1.45	284	543	1.41	274	526	2.86	279	534
	299	1.95	284	543	1.79	274	526	3.74	279	534
	302	1.79	285	545	1.65	276	528	3.44	288	536
	305	1.62	285	545	1.49	276	528	3.11	288	536
	308	1.45	284[c]	543[c]	1.33	274[c]	526[c]	2.78	279	534
	311	1.89	284	543	1.63	274	526	3.52	279	534
	314	1.72	284	543	1.48	274	526	3.20	279	534
	317	1.54	284	543	1.33	274	526	2.87	279	534
PCC_V	65W-200C	4.27	282	540	1.23	294	562	5.50	288	551
	201C	3.10	282	540	1.80	296	564	4.90	289	552
	202C	1.80	277	530	3.10	294	562	4.90	286	546
	203C	1.23	269[c]	517[c]	4.27	289[c]	553[c]	5.50	282	540
	204C	2.71	267	513	0.78	279	534	3.49	273	524
	205C	1.97	266	511	1.14	281	538	3.11	273	524
	206C	1.14	266	510	1.97	281	538	3.11	273	524
	207C	0.78	266	511	2.71	278	533	3.49	272	522
Tensile	65W-4	5.44	293	560	2.20	266	510	7.64	279	535
	5	2.20	277	530	5.44	292	558	7.64	284	544
	6	1.39	285	545	0.57	291	555	1.96	288	550
	7	0.57	277	530	1.39	296	565	1.96	287	548
	8	4.27	262	504	1.74	274	526	6.01	268	515
	9	1.74	266	510	4.27	274	525	6.01	270	518
	1	2.30	294	561	2.43	273	524	4.73	283	542
	2	1.46	269	516	2.93	290	568	4.39	283	542
	3	1.85	284	343	1.94	274	526	3.79	281	538

[a]CS - compact specimen, C_V - standard Charpy V-notch impact specimen, PCC_V - precracked Charpy V-notch specimen, tensile - 0.178-in. gage diameter.

[b]10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.

[c]Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

Table A2 (Continued)

CAPSULE C

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldments 66W, 67W

Specimen Type[a]	Specimen Number	Forward Position Fluence (n/m^2)[b]	Forward Position Temperature (°C)	Forward Position Temperature (°F)	Reverse Position Fluence (n/m^2)[b]	Reverse Position Temperature (°C)	Reverse Position Temperature (°F)	Total Fluence (n/m^2)[b]	Median Temperature (°C)	Median Temperature (°F)
1.6T-CS	66W-31	3.88×10^{22}	292[c]	558[c]	4.66×10^{22}	269[c]	517[c]	8.54×10^{22}	281	538
	32	6.73	314[c]	597[c]	2.71	267[c]	512[c]	9.44	290	554
0.8T-CS	66W-41	6.97	316	600	3.33	268	514	10.30	292	557
	40	6.81	316	600	3.41	268	514	10.22	292	557
	67W-42	3.41	279[c]	535[c]	6.81	289[c]	553[c]	10.22	284	544
	43	3.33	279[c]	535[c]	6.97	289[c]	553[c]	10.30	284	544
0.5T-CS	66W-116	7.09	297[c]	566[c]	1.87	272[c]	521[c]	8.96	284	544
	117	4.16	294	561	3.47	283	541	7.63	288	551
	119	1.87	277	530	7.09	286	546	8.96	281	538
	120	6.30	287	549	1.66	271	519	7.96	279	534
	125	3.69	284[c]	544[c]	3.08	282[c]	539[c]	6.77	283	542
	126	1.66	268	515	6.30	284	544	7.96	277	530
	127	4.30	273[c]	523[c]	0.97	260[c]	500[c]	5.27	267	512
	132	2.51	270[c]	518[c]	1.80	271[c]	520[c]	4.31	271	519
	133	1.11	253[c]	487[c]	3.68	274[c]	525[c]	4.79	263	506
	134	3.68	273	523	1.11	260	500	4.79	267	512
	139	2.15	270	518	2.09	271	520	4.24	271	519
	140	0.97	253	487	4.30	274	525	5.27	263	506
	67W-121	2.09	263[c]	505[c]	0.47	257[c]	495[c]	2.56	260	500
	122	1.21	258[c]	496[c]	0.87	256[c]	493[c]	2.08	257	494
	123	0.54	252	485	1.78	249	480	2.32	250	482
	126	1.78	263	505	0.54	257	495	2.32	260	500
	124	1.04	258	496	1.01	256	493	2.05	257	494
	127	0.47	252	485	2.09	249	480	2.56	250	482
	128	5.98	288	551	0.96	247	477	6.94	268	514
	129	6.74	289[c]	552[c]	1.09	248[c]	478[c]	7.83	268	515
	130	7.18	288	551	1.16	247	477	8.34	268	514
	131	3.11	284	544	2.01	260	500	5.12	272	522
	132	3.50	286[c]	546[c]	2.26	261[c]	501[c]	5.76	273	523
	133	3.73	284[c]	544[c]	2.41	260[c]	500[c]	6.17	272	522
	134	1.44	264	507	3.73	261	501	5.17	262	504
	135	1.63	264[c]	508[c]	4.20	261[c]	501[c]	5.83	263	505
	136	1.73	264	507	4.48	261	501	6.21	262	504
	66W-141	4.48	276	528	1.78	286	546	6.26	281	537
	146	4.20	276[c]	528[c]	1.67	286[c]	546[c]	5.87	281	537
	147	3.73	276	528	1.48	286	546	5.21	281	537
	148	1.05	249[c]	481[c]	7.83	312[c]	593[c]	8.88	281	537
	153	6.21	296	564	0.97	264	507	7.18	280	536
	154	5.43	296[c]	564[c]	0.85	264[c]	507[c]	6.28	280	536
	155	4.53	296	564	0.71	264	507	5.24	280	536
	157	1.32	284[c]	544[c]	4.05	260[c]	500[c]	5.37	272	522
	67W-138	3.77	269	517	1.50	286	546	5.27	278	532
	139	3.30	269[c]	517[c]	1.31	286[c]	546[c]	4.61	278	532
	140	2.75	269	517	1.09	286	546	3.84	278	532
	141	0.88	266[c]	511[c]	6.70	289[c]	553[c]	7.58	278	532

Table A2 (Continued)

CAPSULE C

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldments 66W, 67W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence (n/m^2)[b]	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)		(°C)	(°F)
Cv-	66W-215	5.18 x 10^{22}	274	526	1.05 x 10^{22}	258	496	6.23 x 10^{22}	266	511
	216	4.46	274	525	1.28	261	502	5.74	268	514
	217	3.81	273	524	1.56	266	510	5.37	269	517
	218	3.24	272	522	1.89	269	517	5.13	271	520
	219	2.71	271	520	2.27	272	522	4.98	272	521
	220	2.27	268	515	2.71	273	523	4.98	271	519
	221	1.89	264	508	3.24	274	526	5.13	269	517
	222	1.56	261	502	3.81	275	527	5.37	268	514
	223	1.28	254	490	4.46	276	528	5.74	265	509
	224	1.05	250	482	5.18	276	528	6.23	263	505
	67W-203A	7.34	286	546	1.49	280	536	8.83	283	541
	206A	5.40	286	547	2.20	282	540	7.60	284	544
	207A	3.85	286[c]	546[c]	3.21	284[c]	543[c]	7.06	284	544
	226	3.21	285	545	3.85	284	543	7.06	284	544
	227	2.20	283	541	5.40	284	544	7.60	283	542
	232	1.49	281	538	7.34	283	542	8.83	282	540
	233	3.70	271	520	0.75	267	512	4.45	269	516
	234	2.72	271	520	1.11	268	515	3.83	270	518
	235	1.94	271	520	1.62	269	517	3.56	270	518
	240	1.62	271	519	1.94	269	517	3.56	270	518
	241	1.11	269	516	2.72	270	518	3.83	269	517
	242	0.75	267	512	3.70	269	517	4.45	268	514
	66W-211	2.16	261	501	3.92	308	587	6.08	284	544
	212	1.88	261	501	4.18	308	587	6.06	284	544
	213	1.78	261	501	3.96	308	587	5.74	284	544
	214	1.65	261	501	3.66	308	587	5.21	284	544
	225	2.36	292	557	2.23	266	511	4.89	279	534
	226	2.85	292	557	2.50	266	511	5.35	279	534
	227	2.54	293	559	2.23	267	513	4.77	280	536
	228	2.22	293	559	1.94	267	513	4.16	280	536
	229	1.89	292	557	1.66	266	511	3.55	279	534
	230	2.87	292	557	2.36	266	511	5.23	279	534
	231	2.56	293[c]	559[c]	2.10	267[c]	513[c]	4.66	280	536
	232	2.23	293	559	1.83	267	513	4.06	280	536
	233	1.91	292[c]	557[c]	1.56	266[c]	511[c]	3.47	279	534
	234	2.69	292	557	2.08	266	511	4.77	279	534
	290A	2.38	292	557	1.84	266	511	4.22	279	534
	67W-243	2.06	292	557	1.59	266	511	3.65	279	534
	248	1.70	270	518	3.10	294	561	4.80	282	540
	249	1.91	270	518	3.73	294	561	5.64	282	540
	250	1.70	270	518	3.33	294	561	5.03	282	540
	251	1.48	270	518	2.90	294	561	4.38	282	540
	256	1.27	270	518	2.48	294	561	3.75	282	540
	257	1.80	270	518	3.77	294	561	5.57	282	540

Table A2 (Continued)

CAPSULE C

Fast Neutron Fluences and Median Irradiation Temperatures for the Specimens from Weldments 66W, 67W (Continued)

Specimen Type[a]	Specimen Number	Forward Position			Reverse Position			Total Fluence (n/m^2)[b]	Median Temperature	
		Fluence (n/m^2)[b]	Temperature (°C)	(°F)	Fluence (n/m^2)[b]	Temperature (°C)	(°F)		(°C)	(°F)
C_V-	67W-258	1.60×10^{22}	270[c]	518[c]	3.36×10^{22}	294[c]	561[c]	4.96×10^{22}	282	540
	259	1.40	270	518	2.93	294	561	4.33	282	540
	264	1.19	270[c]	518[c]	2.50	294[c]	561[c]	3.69	282	540
	265	1.59	270	518	3.53	294	561	5.12	282	540
	266	1.41	270	518	3.12	294	561	4.53	282	540
	267	1.22	270	518	2.70	294	561	3.92	282	540
PCC_V	67W-200C	6.31	286	546	1.82	281	538	8.13	283	541
	201C	4.55	286	547	2.66	283	542	7.21	284	544
	203C	2.66	284	543	4.55	284	544	7.21	284	544
	208C	1.82	282[c]	539[c]	6.31	284[c]	543[c]	8.13	283	541
	210C	3.18	271	520	0.92	268	514	4.10	269	517
	211C	2.29	271	520	1.34	269	516	3.63	270	518
	217C	1.34	270	518	2.29	270	518	3.63	270	518
	218C	0.92	268	514	3.18	270	518	4.10	269	516
	66W-201C	2.19	261	501	4.29	308	587	6.48	284	544
	202C	2.08	261	502	4.07	310	590	6.15	286	546
	203C	1.95	261	502	3.81	310	590	5.76	286	546
	204C	1.78	261	501	3.48	308	587	5.26	284	544
	205C	2.07	261	501	4.33	308	587	6.40	284	544
	207C	1.96	261[c]	502[c]	4.10	310[c]	590[c]	6.06	286	546
	209C	1.84	261	502	3.84	310	590	5.68	286	546
	206C	1.68	261[c]	501[c]	3.51	308[c]	587[c]	5.19	284	544
Tensile	66W-11	6.22	297	566	2.52	274	525	8.74	286	546
	12	2.52	274	525	6.22	288	550	8.74	281	538
	67W-17	1.27	288	550	0.51	281	538	1.78	284	544
	18	0.51	285	545	1.27	287	548	1.78	286	546
	15	6.74	264	507	2.73	258	497	9.47	261	502
	16	2.73	253	488	6.74	250	482	9.47	252	485
	66W-3	2.28	261	501	4.14	308	587	6.42	284	544
	5	2.67	292	557	2.52	266	511	5.19	279	534
	67W-4	1.92	270	518	3.50	294	561	5.42	282	540
	66W-4	1.99	261	501	3.63	308	587	5.62	284	544
	9	2.04	292	557	1.93	266	511	3.97	279	534
	67W-9	1.47	270	518	2.68	294	561	4.15	282	540

[a]CS - compact specimen, C_V - standard Charpy V-notch impact specimen, PCC_V - precracked Charpy V-notch specimen, tensile - 0.178-in. gage diameter.

[b]10^{22} n/m^2 = 10^{18} n/cm^2, E > 1 MeV.

[c]Thermocouples were located at these coordinate sites; other temperature readings were interpolated.

APPENDIX B

UNIRRADIATED AND IRRADIATED CHARPY V-NOTCH IMPACT AND TENSILE TEST RESULTS FOR HSSI SECOND AND THIRD IRRADIATION SERIES

Table B1. Unirradiated tensile results for HSSI welds 61W through 67W

SPECIMEN ID	TEST TEMP. (°C)	STRENGTH (MPa) YIELD	ULTIMATE	UNIFORM STRAIN (%)	REDUCTION IN AREA (%)	TOTAL ELONGATION (%)
61W10	26	484	601	10.4	65.7	16.5
61W12	26	476	597	10.4	66	20.3
61W11	149	445	546	8.3	66.2	17.2
61W13	149	443	549	8.3	64.7	18.2
61W14	288	420	534	7.1	64.5	15.5
61W15	288	416	539	7	63.8	16.4
62W4	26	477	594	10.1	67	18.1
62W12	26	469	588	9.7	65	19.5
62W5	149	430	536	9.2	68	15
62W14	149	426	531	9.5	69.3	16.7
62W6	288	382	514	8	65.5	14.2
62W15	288	388	513	8	61.5	15.2
63W16	26	482	600	10.5	67.9	19.4
63W6	26	482	601	10	66.8	21.5
63W17	149	440	544	8.6	65.7	18.4
63W7	149	423	546	8.6	68.7	17.6
63W18	288	414	530	8.1	63.3	17
63W8	288	405	530	7.2	63.6	16.2
64W10	27	467	583	9.9	65.8	19.5
64W11	27	469	581	9.6	64.5	18.8
64W16	27	458	575	10.1	64.1	18.4
64W12	151	426	539	9	65.5	17.2
64W13	151	418	533	9.9	67.4	18.9
64W17	151	407	519	9	66.7	17.4
64W14	286	398	547	8.4	60	16
64W18	286	398	533	8.6	51.5	14.4
64W15	288	398	549	9.6	52.7	15.8
65W10	27	461	572	10.1	63.9	19.6
65W11	27	460	571	9.5	64.4	17.2
65W16	27	451	571	9.5	67.2	17.6
65W13	150	428	538	8	63.6	15.2
65W17	150	416	526	7.4	66	15.2
65W12	151	425	535	7.7	62.9	15.4
65W14	288	423	550	7.5	55.5	13.3
65W15	288	414	548	7.8	57.3	14.3
65W18	288	398	550	9.3	61.1	16.9
66W1	27	533	639	8.4	63.3	17.1
66W7	27	534	639	6.8	63.4	14.8
66W8	149	506	595	6.2	63.5	13.5
66W2	150	507	599	7.2	64.9	14.7
66W6	287	496	610	6.8	46.3	12.7
66W10	288	500	607	6.4	47	11.7
67W1	27	445	569	8.2	65.8	16.2
67W2	27	461	581	8.5	67.7	17.2
67W8	27	479	600	11.4	66.1	20.2
67W10	148	433	544	7.3	64.6	15
67W5	149	429	543	6.5	63.9	13.7
67W3	150	424	538	6.5	67.9	14.3
67W6	288	431	565	7.3	61	13.9
67W7	288	433	567	7.7	55.1	13.9
67W11	288	427	554	7.3	57.7	12.8

Table B2. Irradiated tensile results for HSSI welds 61W through 67W

SPECIMEN NUMBER	IRRAD. FLUENCE(a) n/cm^2	IRRAD. TEMP. (Deg.C)	TEST TEMP. (deg.C)	-----MEASURED VALUE OF PROPERTY----------E1- YLD.STR (Mpa)	U.T.S. (Mpa)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)	------CHANGE IN PROPERTY--UNITS---------- YLD.STR (Mpa)	U.T.S. (Mpa)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)	-----PERCENT CHANGE IN PROPERTY---------- YLD.STR (%)	U.T.S. (%)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)
61W8	7.8	345	28	580	678	9.3	59.0	15.7	100.7	80.2	-1.1	-6.8	-2.7	21.0	13.4	-10.2	-10.4	-14.7
61W7	9.6	329	28	594	699	9.3	56.9	17.0	114.7	101.2	-1.1	-8.9	-1.4	23.9	16.9	-10.2	-13.6	-7.6
61W9	7.0	325	28	583	700	9.6	57.4	16.9	103.7	102.2	-0.8	-8.4	-1.5	21.6	17.1	-7.3	-12.8	-8.1
61W6	4.1	308	288	499	625	6.5	61.4	14.1	81.0	88.5	-0.6	-2.8	-1.9	19.4	16.5	-7.8	-4.3	-11.6
61W5	4.1	304	28	605	703	8.6	56.8	17.4	125.7	105.2	-1.8	-9.0	-1.0	26.2	17.6	-17.0	-13.7	-5.4
61W1	14.8	288	28	631	724	8.9	59.7	17.5	151.7	126.2	-1.5	-6.1	-0.9	31.6	21.1	-14.1	-9.3	-4.9
61W3	11.9	288	28	632	724	8.9	58.9	17.6	152.7	126.2	-1.5	-6.9	-0.8	31.9	21.1	-14.1	-10.6	-4.3
61W4	11.9	277	149	575	672	9.3	59.7	17.5	131.0	124.5	1.0	-5.8	-0.2	29.5	22.7	12.0	-8.8	-1.1
61W2	14.8	276	288	544	660	8.4	50.1	17.8	126.0	123.5	1.3	-14.1	1.8	30.1	23.0	19.1	-21.9	11.6
62W10	13.8	290	26	602	697	10.0	60.8	18.9	129.0	106.0	0.1	-5.2	0.1	27.3	17.9	1.0	-7.9	0.5
62W8	15.5	278	26	621	705	9.4	58.6	b	148.0	114.0	-0.5	-7.4	b	31.3	19.3	-5.1	-11.2	b
62W3	8.2	303	26	576	678	9.5	67.8	18.4	103.0	87.0	-0.4	1.8	-0.4	21.8	14.7	-4.0	2.7	-2.1
62W2	8.3	306	26	593	693	10.4	63.5	18.1	120.0	102.0	0.5	-2.5	-0.7	25.4	17.3	5.1	-3.8	-3.7
62W1	11.0	310	26	575	678	10.3	61.8	18.2	102.0	87.0	0.4	-4.2	-0.6	21.6	14.7	4.0	-6.4	-3.2
62W13	4.8	267	149	539	627	8.3	57.8	16.3	111.0	93.5	-1.0	-10.9	0.5	25.9	17.5	-11.2	-15.8	2.8
62W9	15.5	277	149	572	661	8.1	61.4	15.0	144.0	127.5	-1.2	-7.3	-0.8	33.6	23.9	-13.4	-10.6	-5.4
62W11	13.8	274	288	520	632	8.3	53.2	15.7	135.0	118.5	0.3	-10.3	1.0	35.1	23.1	3.7	-16.2	6.8
62W19	4.8	270	288	476	605	7.7	58.2	15.5	91.0	91.5	-0.3	-5.3	0.8	23.6	17.8	-3.8	-8.3	5.4
63W15	8.1	316	28	581	681	10.3	58.5	17.5	100.1	81.7	0.1	-8.9	-2.9	20.8	13.6	0.8	-13.2	-14.2
63W5	3.8	288	28	609	701	9.4	61.9	17.1	128.1	101.7	-0.8	-5.5	-3.3	26.6	17.0	-8.0	-8.1	-16.2
63W1	12.8	285	27	628	718	9.6	55.9	15.9	146.5	118.1	-0.6	-11.5	-4.5	30.4	19.7	-6.2	-17.0	-22.2
63W13	9.0	310	28	603	695	9.4	53.1	17.7	122.1	95.7	-0.8	-14.3	-2.7	25.4	16.0	-8.0	-21.2	-13.2
63W3	13.1	285	28	625	712	9.0	59.5	17.6	144.1	112.7	-1.2	-7.9	-2.8	30.0	18.8	-11.9	-11.7	-13.7
63W14	7.2	303	28	598	694	10.0	63.0	17.1	117.1	94.7	-0.2	-4.4	-3.3	24.3	15.8	-2.1	-6.5	-16.2
63W4	13.1	279	149	587	683	8.0	56.7	15.7	155.5	138.0	-0.6	-10.5	-2.3	36.0	25.3	-7.0	-15.6	-12.8
63W2	12.8	280	288	536	636	6.8	57.5	15.6	126.5	106.0	-0.9	-6.0	-1.0	30.9	20.0	-11.1	-9.4	-6.0
63W9	3.8	286	288	526	639	5.8	56.4	16.6	116.5	109.0	-1.9	-7.1	0.0	28.4	20.6	-24.2	-11.1	0.0
64W1	4.5	273	288	519	640	7.5	39.0	11.9	121.0	96.5	-1.4	-15.5	-3.5	30.4	17.8	-15.4	-28.5	-22.6
64W4	6.7	281	33	610	709	10.0	58.4	17.1	148.3	133.1	0.2	-6.8	-1.8	32.1	23.1	1.7	-10.4	-9.4
64W5	6.7	282	288	527	656	8.3	40.4	14.0	129.0	112.5	-0.6	-14.1	-1.4	32.4	20.7	-6.4	-25.9	-8.9
64W6	2.4	289	33	594	688	10.9	56.5	17.1	132.3	112.1	1.1	-8.7	-1.8	28.7	19.5	10.8	-13.3	-9.4
64W7	2.4	290	289	525	658	7.2	52.1	12.2	127.0	114.1	-1.7	-2.3	-3.2	31.9	21.0	-18.8	-4.2	-20.5
64W8	6.4	273	149	524	626	7.5	56.5	14.8	106.5	95.4	-1.8	-10.1	-3.1	25.5	18.0	-19.4	-15.2	-17.1
65W4	7.6	279	28	582	676	11.2	63.0	20.2	125.0	105.2	1.5	-2.2	2.1	27.4	18.4	15.8	-3.3	11.6
65W7	2.0	287	28	562	662	10.6	57.7	18.6	105.0	91.2	0.9	-7.5	0.5	23.0	16.0	9.6	-11.5	2.8
65W8	6.0	268	150	493	592	9.1	62.4	17.1	69.9	59.0	1.4	-1.8	1.8	16.5	11.1	18.1	-2.8	12.0
65W3	3.8	281	151	476	612	9.3	61.3	16.6	53.1	79.1	1.6	-2.8	1.3	12.6	14.8	20.9	-4.4	8.8
65W5	7.6	284	287	507	644	9.3	53.6	16.7	95.4	95.0	1.1	-4.4	1.9	23.2	17.3	13.6	-7.6	12.6
65W9	6.0	270	288	475	601	8.0	49.5	15.0	63.3	51.7	-0.2	-8.5	0.2	15.4	9.4	-2.4	-14.6	1.1
65W6	2.0	288	288	504	627	8.2	62.1	14.7	92.3	77.7	0.0	4.1	-0.1	22.4	14.1	0.0	7.1	-0.9
66W3	6.4	284	149	599	684	6.7	67.4	13.4	92.4	86.9	0.0	3.2	-0.7	18.2	14.6	-0.1	4.9	-5.0
66W4	5.6	284	149	603	692	6.8	52.4	13.3	96.4	94.9	0.1	-11.8	-0.8	19.0	15.9	1.4	-18.4	-5.7
66W5	5.2	279	287	573	683	7.1	50.8	12.8	75.0	74.7	0.5	4.0	0.6	15.1	12.3	7.6	8.7	4.9
66W9	4.0	279	34	635	715	6.8	59.3	14.8	103.5	79.7	-0.7	-4.5	-1.0	19.5	12.6	-9.7	-7.1	-6.6
66W11	8.7	286	290	580	683	6.0	42.2	11.2	81.9	73.7	-0.6	-4.0	-1.0	16.4	12.1	-9.2	-8.6	-7.9
66W12	8.7	281	34	671	746	8.0	60.8	18.2	139.5	110.7	0.5	-3.0	2.4	26.3	17.4	6.3	-4.7	14.9
67W17	1.8	284	34	613	691	8.6	61.4	15.4	154.1	111.6	-0.5	-5.2	-2.2	33.6	19.3	-5.9	-7.8	-12.5
67W4	5.4	282	149	566	645	6.7	66.3	13.5	137.3	103.3	-0.1	0.8	-0.8	32.0	19.1	-1.0	1.3	-5.8
67W9	4.2	282	149	553	655	7.5	60.8	13.9	124.3	113.3	0.7	-4.7	-0.4	29.0	20.9	10.8	-7.1	-3.0
67W16	9.5	252	288	511	627	7.1	52.7	12.8	80.7	65.0	-0.3	-5.2	-0.7	18.7	11.6	-4.5	-9.0	-5.4
67W15	9.5	261	288	519	632	7.1	60.7	13.0	88.7	70.0	-0.3	2.8	-0.5	20.6	12.5	-4.5	4.8	-3.9
67W18	1.8	286	288	529	655	8.0	59.7	13.3	98.7	93.0	0.6	1.8	-0.2	22.9	16.5	7.6	3.0	-1.7

Notes: a. Units are in 10E18 neutrons/cm^2 (>1 MeV). b. Value is far out of scatter bands. Probable error in measurement.

Table B3. Irradiated tensile results for HSSI welds 61W through 67W normalized for neutron fluence

SPECIMEN NUMBER	IRRAD. FLUENCE(a) n/cm^2	IRRAD. TEMP. (Deg.C)	TEST TEMP. (deg.C)	-----NORMALIZED VALUE OF PROPERTY---------- YLD.STR (Mpa)	U.T.S. (Mpa)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)	--NORMALIZED CHANGE IN PROPERTY--UNITS------- YLD.STR (Mpa)	U.T.S. (Mpa)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)	--NORMALIZED PERCENT CHANGE IN PROPERTY------ YLD.STR (%)	U.T.S. (%)	UNIF.EL. (%)	R.A. (%)	TOT.EL. (%)
61W8	7.8	345	28	581.3	679.0	9.3	58.9	15.7	102.0	81.2	-1.1	-6.9	-2.7	21.3	13.6	-10.3	-10.5	-14.8
61W7	9.6	329	28	584.0	690.2	9.4	57.7	17.1	104.7	92.3	-1.0	-8.2	-1.3	21.8	15.4	-9.3	-12.4	-6.9
61W9	7.0	325	28	590.2	707.1	9.5	56.8	16.8	110.8	109.2	-0.8	-9.0	-1.6	23.1	18.3	-7.8	-13.7	-8.7
61W6	4.1	308	288	531.1	660.1	6.3	60.3	13.4	113.1	123.6	-0.8	-3.8	-2.6	27.1	23.0	-10.9	-6.0	-16.2
61W5	4.1	304	28	654.9	744.7	7.9	53.2	17.0	175.6	146.9	-2.5	-12.6	-1.4	36.6	24.6	-23.7	-19.2	-7.6
61W1	14.8	288	28	590.8	690.6	9.3	61.3	17.7	111.5	92.7	-1.1	-4.5	-0.7	23.3	15.5	-10.4	-6.9	-3.6
61W3	11.9	288	28	604.5	701.3	9.2	60.2	17.7	125.2	103.4	-1.2	-5.7	-0.7	26.1	17.3	-11.5	-8.7	-3.5
61W4	11.9	277	149	551.4	649.6	9.1	60.7	17.5	107.4	102.1	0.8	-4.7	-0.2	24.2	18.6	9.9	-7.2	-0.9
61W2	14.8	276	288	510.6	627.3	8.0	53.8	17.3	92.6	90.8	1.0	-10.3	1.4	22.2	16.9	14.1	-16.1	8.5
62W10	13.8	290	26	571.2	671.7	10.0	62.0	18.9	98.2	80.7	0.1	-4.0	0.1	20.8	13.7	0.8	-6.0	0.4
62W8	15.5	278	26	579.3	672.9	9.5	60.7	b	106.3	81.9	-0.4	-5.3	b	22.5	13.9	-3.6	-8.1	b
62W3	8.2	303	26	574.7	676.9	9.5	67.8	18.4	101.7	85.9	-0.4	1.8	-0.4	21.5	14.5	-4.0	2.7	-2.1
62W2	8.3	306	26	590.8	691.1	10.4	63.5	18.1	117.8	100.1	0.5	-2.5	-0.7	24.9	16.9	5.0	-3.7	-3.7
62W1	11.0	310	26	560.0	665.2	10.2	62.4	18.3	87.0	74.2	0.3	-3.6	-0.5	18.4	12.6	3.4	-5.4	-2.7
62W13	4.8	267	149	571.3	654.2	8.0	54.6	16.4	143.3	120.7	-1.4	-14.0	0.6	33.5	22.6	-14.5	-20.4	3.7
62W9	15.5	277	149	531.5	625.1	8.5	63.4	15.2	103.5	91.6	-0.9	-5.2	-0.6	24.2	17.2	-9.6	-7.6	-3.9
62W11	13.8	274	288	487.8	603.7	8.2	55.7	15.5	102.8	90.2	0.2	-7.8	0.8	26.7	17.6	2.9	-12.4	5.2
62W19	4.8	270	288	502.5	631.6	7.6	56.7	15.7	117.5	118.1	-0.4	-6.8	1.0	30.5	23.0	-4.8	-10.8	7.0
63W15	8.1	316	28	580.4	680.5	10.3	58.6	17.5	99.4	81.2	0.1	-8.8	-2.9	20.7	13.6	0.8	-13.1	-14.1
63W5	3.8	288	28	666.7	746.9	9.0	59.4	15.6	185.8	147.6	-1.2	-7.9	-4.8	38.6	24.6	-11.6	-11.8	-23.5
63W1	12.8	285	27	597.3	693.3	9.7	58.3	16.8	115.8	93.4	-0.5	-9.1	-3.6	24.1	15.6	-4.9	-13.5	-17.5
63W13	9.0	310	28	596.0	689.5	9.4	53.9	17.9	115.1	90.2	-0.8	-13.5	-2.5	23.9	15.1	-7.5	-20.0	-12.5
63W3	13.1	285	28	593.5	687.4	9.3	61.2	18.2	112.6	88.1	-1.0	-6.2	-2.2	23.4	14.7	-9.3	-9.1	-10.7
63W14	7.2	303	28	604.3	699.1	10.0	62.8	16.9	123.4	99.8	-0.2	-4.6	-3.5	25.7	16.7	-2.2	-6.8	-17.1
63W4	13.1	279	149	553.0	652.8	8.1	59.0	16.2	121.5	107.8	-0.5	-8.2	-1.8	28.2	19.8	-5.5	-12.2	-10.0
63W2	12.8	280	288	509.5	613.8	7.0	58.7	15.8	100.0	83.8	-0.7	-4.7	-0.8	24.4	15.8	-8.8	-7.4	-4.8
63W9	3.8	286	288	578.5	688.2	5.0	53.2	16.6	169.0	158.2	-2.7	-10.2	0.0	41.3	29.8	-35.1	-16.1	0.0
64W1	4.5	273	288	559.3	672.2	7.0	33.8	10.7	161.4	128.7	-1.8	-20.7	-4.6	40.5	23.7	-20.6	-38.0	-30.1
64W4	6.7	281	33	623.8	721.3	10.0	57.8	16.9	162.1	145.4	0.2	-7.4	-1.9	35.1	25.2	1.8	-11.3	-10.3
64W5	6.7	282	288	539.0	666.4	8.2	39.1	13.9	141.0	122.9	-0.6	-15.4	-1.5	35.4	22.6	-7.0	-28.3	-9.8
64W6	2.4	289	33	703.3	780.5	11.8	49.4	15.6	241.6	204.6	1.9	-15.8	-3.2	52.3	35.5	19.7	-24.3	-17.2
64W7	2.4	290	289	629.9	752.2	5.8	50.2	9.6	231.9	208.4	-3.0	-4.2	-5.8	58.3	38.3	-34.3	-7.7	-37.5
64W8	6.4	273	149	536.6	637.3	7.3	55.3	14.4	119.0	106.6	-2.0	-11.3	-3.4	28.5	20.1	-21.6	-17.0	-19.1
65W4	7.6	279	28	585.2	678.7	11.2	62.9	20.3	128.3	107.9	1.6	-2.2	2.2	28.1	18.9	16.2	-3.4	11.9
65W7	2.0	287	28	667.0	753.2	11.5	50.2	19.1	210.1	182.4	1.9	-15.0	1.0	46.0	31.9	19.1	-22.9	5.5
65W8	6.0	268	150	503.8	601.1	9.3	62.1	17.4	80.8	68.1	1.6	-2.0	2.1	19.1	12.8	21.0	-3.2	13.8
65W3	3.8	281	151	500.0	647.7	10.0	60.0	17.2	77.1	114.7	2.3	-4.1	1.9	18.2	21.5	30.3	-6.4	12.8
65W5	7.6	284	287	509.5	646.5	9.3	53.5	16.7	97.8	97.5	1.1	-4.5	1.9	23.8	17.8	14.0	-7.8	13.0
65W9	6.0	270	288	484.8	609.0	8.0	48.2	15.0	73.1	59.7	-0.2	-9.8	0.2	17.8	10.9	-2.8	-16.9	1.3
65W6	2.0	288	288	596.3	704.7	8.2	66.2	14.6	184.7	155.3	0.0	8.3	-0.3	44.9	28.3	0.0	14.3	-1.8
66W3	6.4	284	149	609.9	694.3	6.7	67.8	13.3	103.4	97.2	0.0	3.5	-0.8	20.4	16.3	-0.1	5.5	-5.6
66W4	5.6	284	149	621.8	710.5	6.8	50.1	13.1	115.3	113.4	0.1	-14.1	-1.0	22.8	19.0	1.7	-22.0	-6.9
66W5	5.2	279	287	591.0	700.9	7.2	51.8	12.9	93.0	92.6	0.6	5.0	0.7	18.7	15.2	9.4	10.7	6.0
66W9	4.0	279	34	677.9	748.0	6.5	57.4	14.4	146.4	112.8	-1.0	-6.4	-1.5	27.6	17.7	-13.7	-10.0	-9.3
66W11	8.7	286	290	576.6	680.0	6.0	42.4	11.2	78.6	70.7	-0.6	-3.8	-0.9	15.8	11.6	-8.8	-8.2	-7.6
66W12	8.7	281	34	665.3	741.5	8.0	60.9	18.1	133.8	106.2	0.5	-2.9	2.3	25.2	16.7	6.0	-4.5	14.3
67W17	1.8	284	34	783.8	814.6	8.0	55.6	13.0	324.8	235.2	-1.1	-11.0	-4.6	70.8	40.6	-12.4	-16.5	-26.3
67W4	5.4	282	149	595.8	667.4	6.7	66.5	13.3	167.2	125.8	-0.1	1.0	-1.0	39.0	23.2	-1.2	1.5	-7.1
67W9	4.2	282	149	600.3	698.1	7.8	59.0	13.7	171.6	156.4	1.0	-6.4	-0.6	40.0	28.9	15.0	-9.8	-4.2
67W16	9.5	252	288	504.4	621.6	7.1	53.1	12.9	74.0	59.7	-0.3	-4.8	-0.7	17.2	10.6	-4.1	-8.3	-5.0
67W15	9.5	261	288	511.7	626.2	7.1	60.5	13.0	81.4	64.2	-0.3	2.5	-0.5	18.9	11.4	-4.1	4.4	-3.6
67W18	1.8	286	288	638.4	758.1	8.6	61.7	13.0	208.0	196.1	1.2	3.7	-0.5	48.3	34.9	16.1	6.4	-3.6

Notes: a. Units are in 10E18 neutrons/cm^2 (>1 MeV). b. Value is far out of scatter bands. Probable error in measurement.

Table B4. Results of linear regression analyses for tensile results of HSSI welds 61W through 67W

MAT'L CODE	REGRESSION OUTPUT	TEST TEMP. CODE	NUMB OF TSTS	VAL. Y.S. (MPa)	VAL. UTS (MPa)	VAL. U.E. (%)	VAL. R.A. (%)	VAL. T.E. (%)	NRM.V Y.S. (MPa)	NRM.V UTS (MPa)	NRM.V U.E. (%)	NRM.V R.A. (%)	NRM.V T.E. (%)
61W	CONSTANT	30	6	8.96E+02	9.27E+02	5.68E+00	6.35E+01	2.54E+01	7.55E+02	8.10E+02	6.76E+00	6.76E+01	2.61E+01
61W	STD.ERR.CNST	30		7.81E+00	5.76E+00	2.88E-01	1.31E+00	3.48E-01	2.81E+01	2.41E+01	6.40E-01	3.10E+00	3.85E-01
61W	R SQUARED	30		9.07E-01	9.12E-01	4.98E-01	1.06E-01	8.03E-01	1.74E-01	1.22E-01	8.57E-02	6.25E-02	7.98E-01
61W	X COEFF.	30		-9.31E-01	-7.08E-01	1.09E-02	-1.71E-02	-2.68E-02	-4.91E-01	-3.43E-01	7.47E-03	-3.05E-02	-2.91E-02
61W	STD.ERR.COEF	30		1.49E-01	1.10E-01	5.48E-03	2.49E-02	6.63E-03	5.35E-01	4.59E-01	1.22E-02	5.91E-02	7.34E-03
61W	CONSTANT	150	1										
61W	STD.ERR.CNST	150											
61W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
61W	X COEFF.	150											
61W	STD.ERR.COEF	150											
61W	CONSTANT	288	2	9.32E+02	9.62E+02	2.48E+01	-4.74E+01	4.97E+01	3.34E+02	3.44E+02	2.32E+01	-2.14E+00	5.13E+01
61W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61W	X COEFF.	288		-1.41E+00	-1.09E+00	-5.94E-02	3.53E-01	-1.16E-01	6.41E-01	1.03E+00	-5.50E-02	2.03E-01	-1.23E-01
61W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	CONSTANT	30	5	9.92E+02	9.19E+02	3.05E+00	1.21E+01	3.02E+01	6.23E+02	6.37E+02	4.49E+00	3.07E+01	2.89E+01
62W	STD.ERR.CNST	30		8.72E+00	7.27E+00	3.90E-01	3.04E+00	1.33E-01	1.28E+01	1.10E+01	3.70E-01	2.64E+00	1.60E-01
62W	R SQUARED	30		8.45E-01	7.22E-01	4.48E-01	4.18E-01	9.07E-01	3.46E-02	3.20E-02	3.61E-01	2.85E-01	8.40E-01
62W	X COEFF.	30		-1.34E+00	-7.70E-01	2.31E-02	1.69E-01	-3.92E-02	-1.59E-01	1.31E-01	1.83E-02	1.10E-01	-3.46E-02
62W	STD.ERR.COEF	30		3.31E-01	2.76E-01	1.48E-02	1.15E-01	8.88E-03	4.85E-01	4.17E-01	1.40E-02	1.00E-01	1.07E-02
62W	CONSTANT	150	2	-3.42E+02	-2.81E+02	1.36E+01	-3.83E+01	5.10E+01	1.64E+03	1.43E+03	-4.22E+00	-1.80E+02	4.82E+01
62W	STD.ERR.CNST	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	R SQUARED	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	X COEFF.	150		3.30E+00	3.40E+00	-2.00E-02	3.60E-01	-1.30E-01	-3.98E+00	-2.91E+00	4.58E-02	8.80E-01	-1.19E-01
62W	STD.ERR.COEF	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	CONSTANT	288	2	-2.49E+03	-1.22E+03	-3.28E+01	3.96E+02	2.00E+00	1.49E+03	2.51E+03	-3.39E+01	1.24E+02	3.41E+01
62W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	X COEFF.	288		1.10E+01	6.75E+00	1.50E-01	-1.25E+00	5.00E-02	-3.67E+00	-6.98E+00	1.54E-01	-2.50E-01	-6.79E-02
62W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	CONSTANT	30	6	9.55E+02	9.66E+02	2.57E+00	7.64E+01	9.61E+00	9.01E+02	9.23E+02	2.90E+00	8.28E+01	1.09E+01
63W	STD.ERR.CNST	30		8.22E+00	6.07E+00	3.77E-01	4.04E+00	6.32E-01	3.07E+01	2.43E+01	3.99E-01	3.16E+00	9.83E-01
63W	R SQUARED	30		8.25E-01	8.34E-01	4.78E-01	4.80E-02	2.71E-01	1.95E-01	1.81E-01	4.27E-01	1.29E-01	9.52E-02
63W	X COEFF.	30		-1.17E+00	-8.94E-01	2.37E-02	-5.95E-02	2.53E-02	-9.90E-01	-7.51E-01	2.26E-02	-7.98E-02	2.09E-02
63W	STD.ERR.COEF	30		2.69E-01	1.99E-01	1.23E-02	1.32E-01	2.07E-02	1.01E+00	7.97E-01	1.31E-02	1.03E-01	3.22E-02
63W	CONSTANT	150	1										
63W	STD.ERR.CNST	150											
63W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
63W	X COEFF.	150											
63W	STD.ERR.COEF	150											
63W	CONSTANT	288	2	1.00E+03	4.96E+02	5.35E+01	1.09E+02	-3.11E+01	-2.71E+03	-2.86E+03	1.01E+02	3.17E+02	-2.11E+01
63W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	X COEFF.	288		-1.67E+00	5.00E-01	-1.67E-01	-1.83E-01	1.67E-01	1.15E+01	1.24E+01	-3.35E-01	-9.21E-01	1.32E-01
63W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	CONSTANT	30	2	1.17E+03	1.45E+03	-2.16E+01	1.25E+02	1.71E+01	-2.17E+03	-1.36E+03	-5.19E+01	3.54E+02	6.26E+01
64W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	X COEFF.	30		-2.00E+00	-2.63E+00	1.13E-01	-2.38E-01	-1.25E-07	9.94E+00	7.40E+00	2.20E-01	-1.05E+00	-1.63E-01
64W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	CONSTANT	150	1										
64W	STD.ERR.CNST	150											
64W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
64W	X COEFF.	150											
64W	STD.ERR.COEF	150											
64W	CONSTANT	288	3	4.21E+02	3.49E+02	1.20E+01	-1.70E+02	6.47E+00	-5.55E+02	-5.99E+02	2.61E+01	-2.28E+02	2.79E+01
64W	STD.ERR.CNST	288		3.94E+00	5.28E+00	7.82E-01	4.52E+00	1.58E+00	4.71E+01	3.93E+01	1.51E+00	2.78E+00	3.05E+00
64W	R SQUARED	288		5.53E-01	8.57E-01	5.33E-02	8.03E-01	2.74E-02	5.13E-01	6.65E-01	2.24E-01	9.45E-01	5.08E-02
64W	X COEFF.	288		3.64E-01	1.07E+00	-1.54E-02	7.58E-01	2.21E-02	4.02E+00	4.60E+00	-6.75E-02	9.56E-01	-5.87E-02
64W	STD.ERR.COEF	288		3.27E-01	4.39E-01	6.51E-02	3.76E-01	1.32E-01	3.92E+00	3.27E+00	1.25E-01	2.31E-01	2.53E-01

Table B4. (Continued)

MAT'L CODE	REGRESSION OUTPUT	TEST TEMP. CODE	NUMB OF TSTS	V.CH. Y.S. (MPa)	V.CH. UTS (MPa)	V.CH. U.E. (%)	V.CH. R.A. (%)	V.CH. T.E. (%)	NRM.CH Y.S. (MPa)	NRM.CH UTS (MPa)	NRM.CH U.E. (%)	NRM.CH R.A. (%)	NRM.CH T.E. (%)
61W	CONSTANT	30	6	4.16E+02	3.29E+02	-4.68E+00	-2.38E+00	7.02E+00	2.75E+02	2.12E+02	-3.60E+00	1.72E+00	7.74E+00
61W	STD.ERR.CNST	30		7.81E+00	5.76E+00	2.88E-01	1.31E+00	3.48E-01	2.81E+01	2.41E+01	6.40E-01	3.10E+00	3.85E-01
61W	R SQUARED	30		9.07E-01	9.12E-01	4.98E-01	1.06E-01	8.03E-01	1.74E-01	1.22E-01	8.57E-02	6.25E-02	7.98E-01
61W	X COEFF.	30		-9.31E-01	-7.08E-01	1.09E-02	-1.71E-02	-2.68E-02	-4.91E-01	-3.43E-01	7.47E-03	-3.05E-02	-2.91E-02
61W	STD.ERR.COEF	30		1.49E-01	1.10E-01	5.48E-03	2.49E-02	6.63E-03	5.35E-01	4.59E-01	1.22E-02	5.91E-02	7.34E-03
61W	CONSTANT	150	1										
61W	STD.ERR.CNST	150											
61W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
61W	X COEFF.	150											
61W	STD.ERR.COEF	150											
61W	CONSTANT	288	2	5.14E+02	4.25E+02	1.77E+01	-1.12E+02	3.38E+01	-8.43E+01	-1.92E+02	1.62E+01	-6.63E+01	3.54E+01
61W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61W	X COEFF.	288		-1.41E+00	-1.09E+00	-5.94E-02	3.53E-01	-1.16E-01	6.41E-01	1.03E+00	-5.50E-02	2.03E-01	-1.23E-01
61W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	CONSTANT	30	5	5.19E+02	3.28E+02	-6.85E+00	-5.39E+01	1.14E+01	1.50E+02	4.56E+01	-5.41E+00	-3.53E+01	1.01E+01
62W	STD.ERR.CNST	30		8.72E+00	7.27E+00	3.90E-01	3.04E+00	1.33E-01	1.28E+01	1.10E+01	3.70E-01	2.64E+00	1.60E-01
62W	R SQUARED	30		8.45E-01	7.22E-01	4.48E-01	4.18E-01	9.07E-01	3.46E-02	3.20E-02	3.61E-01	2.85E-01	8.40E-01
62W	X COEFF.	30		-1.34E+00	-7.70E-01	2.31E-02	1.69E-01	-3.92E-02	-1.59E-01	1.31E-01	1.83E-02	1.10E-01	-3.46E-02
62W	STD.ERR.COEF	30		3.31E-01	2.76E-01	1.48E-02	1.15E-01	8.88E-03	4.85E-01	4.17E-01	1.40E-02	1.00E-01	1.07E-02
62W	CONSTANT	150	2	-7.70E+02	-8.14E+02	4.29E+00	-1.07E+02	3.52E+01	1.21E+03	8.98E+02	-1.36E+01	-2.49E+02	3.24E+01
62W	STD.ERR.CNST	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	R SQUARED	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	X COEFF.	150		3.30E+00	3.40E+00	-2.00E-02	3.60E-01	-1.30E-01	-3.98E+00	-2.91E+00	4.58E-02	8.80E-01	-1.19E-01
62W	STD.ERR.COEF	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	CONSTANT	288	2	-2.88E+03	-1.73E+03	-4.08E+01	3.32E+02	-1.27E+01	1.11E+03	2.00E+03	-4.19E+01	6.07E+01	1.94E+01
62W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62W	X COEFF.	288		1.10E+01	6.75E+00	1.50E-01	-1.25E+00	5.00E-02	-3.67E+00	-6.98E+00	1.54E-01	-2.50E-01	-6.79E-02
62W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	CONSTANT	30	6	4.72E+02	3.64E+02	-7.72E+00	9.03E+00	-1.09E+01	4.18E+02	3.21E+02	-7.39E+00	1.55E+01	-9.57E+00
63W	STD.ERR.CNST	30		8.13E+00	5.92E+00	3.74E-01	4.04E+00	6.41E-01	3.08E+01	2.44E+01	3.95E-01	3.16E+00	9.83E-01
63W	R SQUARED	30		8.26E-01	8.39E-01	4.87E-01	4.83E-02	2.71E-01	1.92E-01	1.77E-01	4.37E-01	1.30E-01	9.79E-02
63W	X COEFF.	30		-1.16E+00	-8.85E-01	2.39E-02	-5.96E-02	2.56E-02	-9.82E-01	-7.42E-01	2.28E-02	-7.99E-02	2.12E-02
63W	STD.ERR.COEF	30		2.67E-01	1.94E-01	1.22E-02	1.32E-01	2.10E-02	1.01E+00	8.01E-01	1.29E-02	1.03E-01	3.22E-02
63W	CONSTANT	150	1										
63W	STD.ERR.CNST	150											
63W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
63W	X COEFF.	150											
63W	STD.ERR.COEF	150											
63W	CONSTANT	288	2	5.93E+02	-3.40E+01	4.58E+01	4.54E+01	-4.77E+01	-3.12E+03	-3.39E+03	9.32E+01	2.53E+02	-3.77E+01
63W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
63W	X COEFF.	288		-1.67E+00	5.00E-01	-1.67E-01	-1.83E-01	1.67E-01	1.15E+01	1.24E+01	-3.35E-01	-9.21E-01	1.32E-01
63W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	CONSTANT	30	2	7.10E+02	8.71E+02	-3.14E+01	6.00E+01	-1.23E+00	-2.63E+03	-1.93E+03	-6.17E+01	2.88E+02	4.37E+01
64W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	X COEFF.	30		-2.00E+00	-2.63E+00	1.13E-01	-2.38E-01	-1.94E-03	9.94E+00	7.40E+00	2.20E-01	-1.05E+00	-1.63E-01
64W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
64W	CONSTANT	150	1										
64W	STD.ERR.CNST	150											
64W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
64W	X COEFF.	150											
64W	STD.ERR.COEF	150											
64W	CONSTANT	288	3	2.30E+01	-1.89E+02	3.11E+00	-2.26E+02	-9.27E+00	-9.54E+02	-1.14E+03	1.71E+01	-2.85E+02	1.22E+01
64W	STD.ERR.CNST	288		3.93E+00	5.43E+00	7.81E-01	4.58E+00	1.57E+00	4.71E+01	3.91E+01	1.51E+00	2.84E+00	3.04E+00
64W	R SQUARED	288		5.54E-01	8.45E-01	5.26E-02	8.02E-01	3.11E-02	5.13E-01	6.65E-01	2.24E-01	9.43E-01	4.90E-02
64W	X COEFF.	288		3.65E-01	1.05E+00	-1.53E-02	7.66E-01	2.34E-02	4.02E+00	4.58E+00	-6.74E-02	9.64E-01	-5.73E-02
64W	STD.ERR.COEF	288		3.27E-01	4.52E-01	6.50E-02	3.81E-01	1.31E-01	3.92E+00	3.25E+00	1.25E-01	2.36E-01	2.53E-01

Table B4. (Continued)

MAT'L CODE	REGRESSION OUTPUT	TEST TEMP. CODE	NUMB OF TSTS	V.CH. Y.S. (MPa)	V.CH. UTS (MPa)	V.CH. U.E. (%)	V.CH. R.A. (%)	V.CH. T.E. (%)	NRM.CH Y.S. (MPa)	NRM.CH UTS (MPa)	NRM.CH U.E. (%)	NRM.CH R.A. (%)	NRM.CH T.E. (%)
65W	CONSTANT	30	2	8.23E+02	5.93E+02	2.25E+01	1.83E+02	5.79E+01	-2.72E+03	-2.49E+03	-8.41E+00	4.41E+02	4.24E+01
65W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	X COEFF.	30		-2.50E+00	-1.75E+00	-7.50E-02	-6.63E-01	-2.00E-01	1.02E+01	9.31E+00	3.57E-02	-1.59E+00	-1.44E-01
65W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	CONSTANT	150	2	4.17E+02	-3.56E+02	-2.87E+00	2.04E+01	1.19E+01	1.57E+02	-8.93E+02	-1.31E+01	4.09E+01	5.49E+00
65W	STD.ERR.CNST	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	R SQUARED	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	X COEFF.	150		-1.29E+00	1.55E+00	1.59E-02	-8.26E-02	-3.74E-02	-2.83E-01	3.59E+00	5.49E-02	-1.60E-01	-1.26E-02
65W	STD.ERR.COEF	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	CONSTANT	288	3	-4.18E+02	-4.52E+02	-8.88E+00	-1.69E+02	-4.85E+00	-1.30E+03	-1.20E+03	-9.55E+00	-2.37E+02	-3.15E+00
65W	STD.ERR.CNST	288		7.36E+00	1.80E+01	9.01E-01	4.48E+00	1.51E+00	4.82E+01	2.84E+01	9.29E-01	6.85E+00	1.62E+00
65W	R SQUARED	288		9.13E-01	6.60E-01	1.91E-01	7.57E-01	2.91E-02	6.61E-01	8.26E-01	2.03E-01	7.28E-01	1.21E-02
65W	X COEFF.	288		1.79E+00	1.88E+00	3.27E-02	5.92E-01	1.95E-02	5.04E+00	4.63E+00	3.51E-02	8.38E-01	1.34E-02
65W	STD.ERR.COEF	288		5.51E-01	1.34E+00	6.74E-02	3.35E-01	1.13E-01	3.61E+00	2.13E+00	6.95E-02	5.12E-01	1.21E-01
66W	CONSTANT	30	2	-4.92E+03	-4.24E+03	-1.68E+02	-2.14E+02	-4.75E+02	1.91E+03	1.03E+03	-2.08E+02	-4.94E+02	-5.22E+02
66W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	X COEFF.	30		1.80E+01	1.55E+01	6.00E-01	7.50E-01	1.70E+00	-6.31E+00	-3.29E+00	7.41E-01	1.75E+00	1.87E+00
66W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	CONSTANT	150	2										
66W	STD.ERR.CNST	150											
66W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
66W	X COEFF.	150											
66W	STD.ERR.COEF	150											
66W	CONSTANT	288	2	-2.01E+02	1.12E+02	4.47E+01	3.23E+02	6.28E+01	6.69E+02	9.66E+02	4.86E+01	3.56E+02	6.71E+01
66W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	X COEFF.	288		9.90E-01	-1.34E-01	-1.58E-01	-1.14E+00	-2.23E-01	-2.07E+00	-3.13E+00	-1.72E-01	-1.26E+00	-2.38E-01
66W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
67W	CONSTANT	30	1										
67W	STD.ERR.CNST	30											
67W	R SQUARED	30		INSUFFICIENT	DATA	FOR	REGRESSION						
67W	X COEFF.	30											
67W	STD.ERR.COEF	30											
67W	CONSTANT	150	2										
67W	STD.ERR.CNST	150											
67W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
67W	X COEFF.	150											
67W	STD.ERR.COEF	150											
67W	CONSTANT	288	3	-4.43E+01	-1.49E+02	-7.63E+00	-4.10E+01	-4.26E+00	-9.93E+02	-1.03E+03	-1.25E+01	-5.46E+01	-1.67E+00
67W	STD.ERR.CNST	288		2.55E+00	1.90E+00	1.88E-01	4.84E+00	5.33E-02	2.22E+01	2.48E+01	3.13E-01	4.01E+00	1.07E-01
67W	R SQUARED	288		9.60E-01	9.92E-01	9.35E-01	3.83E-01	9.78E-01	9.57E-01	9.49E-01	9.35E-01	6.23E-01	4.89E-01
67W	X COEFF.	288		5.02E-01	8.44E-01	2.85E-02	1.53E-01	1.41E-02	4.18E+00	4.28E+00	4.76E-02	2.07E-01	4.19E-03
67W	STD.ERR.COEF	288		1.02E-01	7.63E-02	7.53E-03	1.94E-01	2.14E-03	8.90E-01	9.97E-01	1.26E-02	1.61E-01	4.28E-03
65W	CONSTANT	30	2	8.23E+02	5.93E+02	2.25E+01	1.83E+02	5.79E+01	-2.72E+03	-2.49E+03	-8.41E+00	4.41E+02	4.24E+01
65W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	X COEFF.	30		-2.50E+00	-1.75E+00	-7.50E-02	-6.63E-01	-2.00E-01	1.02E+01	9.31E+00	3.57E-02	-1.59E+00	-1.44E-01
65W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	CONSTANT	150	2	4.17E+02	-3.56E+02	-2.87E+00	2.04E+01	1.19E+01	1.57E+02	-8.93E+02	-1.31E+01	4.09E+01	5.49E+00

Table B4. (Continued)

MAT'L CODE	REGRESSION OUTPUT	TEST TEMP. CODE	NUMB OF TSTS	V.CH. Y.S. (MPa)	V.CH. UTS (MPa)	V.CH. U.E. (%)	V.CH. R.A. (%)	V.CH. T.E. (%)	NRM.CH Y.S. (MPa)	NRM.CH UTS (MPa)	NRM.CH U.E. (%)	NRM.CH R.A. (%)	NRM.CH T.E. (%)
65W	STD.ERR.CNST	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	R SQUARED	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	X COEFF.	150		-1.29E+00	1.55E+00	1.59E-02	-8.26E-02	-3.74E-02	-2.83E-01	3.59E+00	5.49E-02	-1.60E-01	-1.26E-02
65W	STD.ERR.COEF	150		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
65W	CONSTANT	288	3	-4.18E+02	-4.52E+02	-8.88E+00	-1.69E+02	-4.85E+00	-1.30E+03	-1.20E+03	-9.55E+00	-2.37E+02	-3.15E+00
65W	STD.ERR.CNST	288		7.36E+00	1.80E+01	9.01E-01	4.48E+00	1.51E+00	4.82E+01	2.84E+01	9.29E-01	6.85E+00	1.62E+00
65W	R SQUARED	288		9.13E-01	6.60E-01	1.91E-01	7.57E-01	2.91E-02	6.61E-01	8.26E-01	2.03E-01	7.28E-01	1.21E-02
65W	X COEFF.	288		1.79E+00	1.88E+00	3.27E-02	5.92E-01	1.95E-02	5.04E+00	4.63E+00	3.51E-02	8.38E-01	1.34E-02
65W	STD.ERR.COEF	288		5.51E-01	1.34E+00	6.74E-02	3.35E-01	1.13E-01	3.61E+00	2.13E+00	6.95E-02	5.12E-01	1.21E-01
66W	CONSTANT	30	2	-4.92E+03	-4.24E+03	-1.68E+02	-2.14E+02	-4.75E+02	1.91E+03	1.03E+03	-2.08E+02	-4.94E+02	-5.22E+02
66W	STD.ERR.CNST	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	R SQUARED	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	X COEFF.	30		1.80E+01	1.55E+01	6.00E-01	7.50E-01	1.70E+00	-6.31E+00	-3.29E+00	7.41E-01	1.75E+00	1.87E+00
66W	STD.ERR.COEF	30		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	CONSTANT	150	2										
66W	STD.ERR.CNST	150											
66W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
66W	X COEFF.	150											
66W	STD.ERR.COEF	150											
66W	CONSTANT	288	2	-2.01E+02	1.12E+02	4.47E+01	3.23E+02	6.28E+01	6.69E+02	9.66E+02	4.86E+01	3.56E+02	6.71E+01
66W	STD.ERR.CNST	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	R SQUARED	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
66W	X COEFF.	288		9.90E-01	-1.34E-01	-1.58E-01	-1.14E+00	-2.23E-01	-2.07E+00	-3.13E+00	-1.72E-01	-1.26E+00	-2.38E-01
66W	STD.ERR.COEF	288		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
67W	CONSTANT	30	1										
67W	STD.ERR.CNST	30											
67W	R SQUARED	30		INSUFFICIENT	DATA	FOR	REGRESSION						
67W	X COEFF.	30											
67W	STD.ERR.COEF	30											
67W	CONSTANT	150	2										
67W	STD.ERR.CNST	150											
67W	R SQUARED	150		INSUFFICIENT	DATA	FOR	REGRESSION						
67W	X COEFF.	150											
67W	STD.ERR.COEF	150											
67W	CONSTANT	288	3	-4.43E+01	-1.49E+02	-7.63E+00	-4.10E+01	-4.26E+00	-9.93E+02	-1.03E+03	-1.25E+01	-5.46E+01	-1.67E+00
67W	STD.ERR.CNST	288		2.55E+00	1.90E+00	1.88E-01	4.84E+00	5.33E-02	2.22E+01	2.48E+01	3.13E-01	4.01E+00	1.07E-01
67W	R SQUARED	288		9.60E-01	9.92E-01	9.35E-01	3.83E-01	9.78E-01	9.57E-01	9.49E-01	9.35E-01	6.23E-01	4.89E-01
67W	X COEFF.	288		5.02E-01	8.44E-01	2.85E-02	1.53E-01	1.41E-02	4.18E+00	4.28E+00	4.76E-02	2.07E-01	4.19E-03
67W	STD.ERR.COEF	288		1.02E-01	7.63E-02	7.53E-03	1.94E-01	2.14E-03	8.90E-01	9.97E-01	1.26E-02	1.61E-01	4.28E-03

Table B5. Linear regression estimated radiation-induced tensile properties for HSSI welds 61W through 67W irradiated at 288°C

MAT'L CODE	AVE. NEUT. FLNC.(a)	TEST TEMP. (C)	NUMB OF TSTS	VAL. Y.S. (MPa)	VAL. UTS (MPa)	VAL. U.E. (%)	VAL. R.A. (%)	VAL. T.E. (%)	NRM.V Y.S. (MPa)	NRM.V UTS (MPa)	NRM.V U.E. (%)	NRM.V R.A. (%)	NRM.V T.E. (%)
61W	9.2	30	6	627.6	722.5	8.8	58.5	17.7	613.3	710.8	8.9	58.8	17.7
61W	11.9	150	1	INSUFFICIENT DATA FOR REGRESSION									
61W	9.5	288	2	527.1	646.9	7.7	54.3	16.4	518.3	639.6	7.4	56.3	15.8
62W	11.4	30	5	606.0	697.4	9.7	60.9	19.0	576.7	674.3	9.8	62.3	18.9
62W	10.2	150	2	608.3	698.4	7.9	65.4	13.6	487.6	593.1	9.0	73.1	13.9
62W	9.3	288	2	674.0	726.5	10.4	35.7	16.4	436.4	506.1	10.4	52.2	14.5
63W	9.0	30	6	618.8	709.0	9.4	59.2	16.9	616.1	706.8	9.4	59.8	17.0
63W	13.1	150	1	INSUFFICIENT DATA FOR REGRESSION									
63W	8.3	288	2	522.7	640.0	5.5	56.0	16.9	601.5	712.9	4.3	51.4	16.9
64W	4.6	30	2	596.0	690.6	10.8	56.7	17.1	693.3	773.1	11.6	50.4	15.8
64W	6.4	150	1	INSUFFICIENT DATA FOR REGRESSION									
64W	4.5	288	3	526.0	658.1	7.6	48.6	12.8	601.5	726.1	6.6	47.1	11.0
65W	4.8	30	2	559.5	660.3	10.5	57.0	18.4	677.3	762.5	11.6	48.6	19.0
65W	6.0	150	2	466.8	622.8	9.4	60.7	16.3	497.9	672.7	10.4	58.9	17.1
65W	5.2	288	3	508.4	637.7	8.7	59.4	15.6	567.1	687.3	8.8	62.1	15.5
66W	6.4	30	2	797.0	854.5	12.2	66.0	30.1	621.1	718.4	13.2	73.2	31.2
66W	6.0	150	2	INSUFFICIENT DATA FOR REGRESSION									
66W	7.0	288	2	582.0	683.0	5.7	39.7	10.7	572.5	674.0	5.7	39.7	10.8
67W	1.8	30	1	INSUFFICIENT DATA FOR REGRESSION									
67W	4.8	150	2	INSUFFICIENT DATA FOR REGRESSION									
67W	6.9	288	3	530.5	656.3	8.0	61.0	13.3	642.1	761.5	8.7	62.9	13.1

Table B5.(Continued)

MAT'L CODE	AVE. NEUT. FLNC.(a)	TEST TEMP. (C)	NUMB OF TSTS	V.CH. Y.S. (MPa)	V.CH. UTS (MPa)	V.CH. U.E. (%)	V.CH. R.A. (%)	V.CH. T.E. (%)	NRM.CH Y.S. (MPa)	NRM.CH UTS (MPa)	NRM.CH U.E. (%)	NRM.CH R.A. (%)	NRM.CH T.E. (%)
61W	9.2	30	6	148.3	124.6	-1.5	-7.3	-0.7	134.0	112.9	-1.5	-7.1	-0.7
61W	11.9	150	1	INSUFFICIENT	DATA	FOR	REGRESSION						
61W	9.5	288	2	109.1	110.4	0.6	-9.8	0.5	100.3	103.1	0.3	-7.9	-0.1
62W	11.4	30	5	133.0	106.4	-0.2	-5.1	0.2	103.7	83.3	-0.1	-3.7	0.1
62W	10.2	150	2	180.3	164.9	-1.5	-3.3	-2.3	59.6	59.6	-0.4	4.5	-1.9
62W	9.3	288	2	289.0	213.0	2.4	-27.8	1.7	51.4	-7.4	2.4	-11.3	-0.2
63W	9.0	30	6	137.7	109.5	-0.8	-8.1	-3.5	135.0	107.4	-0.8	-7.6	-3.5
63W	13.1	150	1	INSUFFICIENT	DATA	FOR	REGRESSION						
63W	8.3	288	2	113.2	110.0	-2.2	-7.4	0.3	192.0	182.9	-3.4	-12.1	0.3

(a) In units of 10E18 neutrons/cm^2 (>1 MeV)

Table B6. Unirradiated Charpy V-notch impact results for HSSI weld 61W

V61CS.WK1

UNIRRADIATED HSST 61W CHARPY V-NOTCH.
Impact Test Results

Spec. No.	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
61277	0	-40.0	40.7	0.69	79.4	
61278	0	-28.9	42.0	0.69	69.0	
61279	0	-28.9	44.7	0.69	71.0	
61280	0	-17.8	49.5	0.84	53.0	
61302	0	26.7	82.0	1.32	0.8	
61297	0	37.8	96.9	1.63	0.0	
61303	0	48.9	88.1	1.57	0.0	
61298	0	121.1	92.9	1.57	0.0	
61299	0	176.7	90.8	1.68	0.0	
61304	0	204.4	93.6	1.75	0.0	
61300	0	204.4	91.5	1.69	0.0	
61301	0	287.8	101.7	1.74	0.0	
61269	1	-17.8	42.7	0.74	78.0	40
61273	1	4.4	54.2	0.89	60.0	45
61272	1	26.7	70.5	1.37	30.0	85
61274	1	54.4	83.4	1.47	0.0	100
61270	1	93.3	75.9	1.52	0.0	100
61276	1	93.3	88.8	1.63	0.0	100
61271	1	148.9	82.0	1.68	0.0	100
61275	1	232.2	86.1	1.68	0.0	100

[a]0 = laboratory test.
1 = hot cell test machine.

Table B7. Unirradiated Charpy V-notch impact results for HSSI weld 62W

V62CS.WK1

UNIRRADIATED HSST 62W CHARPY V-NOTCH.
Impact Test Results

Specimen Number	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
62286	0	-28.9	39.3	0.64	70	
62280	0	-17.8	42.0	0.66	43	
62282	0	-12.2	47.5	0.77	60	
62281	0	-12.2	44.7	0.77	52	
62285	0	-6.7	56.3	0.89	50	
62284	0	-6.7	61.0	1.00	42	
62287	0	-1.1	67.8	1.08	37	
62288	0	4.4	67.1	1.09	18	
62289	0	15.6	68.5	1.12	12	
62290	0	32.2	94.2	1.55	17	
62291	0	48.9	105.8	1.68	0	
62292	0	60.0	101.7	1.63	0	
62304	0	71.1	105.1	1.73	0	
62294	0	82.2	108.5	1.80	0	
62295	0	104.4	107.8	1.78	0	
62296	0	115.6	108.5	1.88	0	
62298	0	137.8	109.8	1.82	0	
62299	0	148.9	106.4	1.90	0	
62300	0	176.7	105.1	1.73	0	
62301	0	204.4	119.3	2.03	0	
62302	0	260.0	122.0	1.98	0	
62303	0	287.8	130.2	1.97	0	
62265	1	-45.6	19.0	0.30	87	18
62266	1	-17.8	33.9	0.56	75	40
62221	1	10.0	59.0	1.02	40	80
62269	1	23.9	69.8	1.19	25	95
62264	1	39.4	86.1	1.50		100
62276	1	65.6	86.1	1.55	0	100
62222	1	93.3	90.2	1.63	0	100
62278	1	126.7	92.2	1.75	0	100
62223	1	160.0	90.2	1.68	0	100
62279	1	232.2	95.6	1.55	0	

[a]0 = laboratory test.
1 = hot cell test machine.

Table B8. Unirradiated Charpy V-notch impact results for HSSI weld 63W

V63CS.WK1

UNIRRADIATED HSST 63W CHARPY V-NOTCH.
Impact Test Results

Specimen Number	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
63294	0	-34.4	16.3	0.20	86	
63295	0	-28.9	15.6	0.25	88	
63296	0	-23.3	35.3	0.51	90	
63297	0	-23.3	32.5	0.43	93	
63298	0	-6.7	27.8	0.46	0	
63299	0	15.6	59.7	0.86	52	
63300	0	37.8	71.2	0.51	53	
63301	0	60.0	88.1	1.40	18	
63332	0	60.0	86.8	1.45	0	
63333	0	65.6	92.9	1.55	0	
63302	0	65.6	93.6	1.47	0	
63305	0	71.1	105.8	1.65	0	
63306	0	82.2	99.0	1.55	0	
63334	0	82.2	93.6	1.56	0	
63324	0	104.4	98.3	1.68	0	
63325	0	121.1	96.9	1.65	0	
63326	0	148.9	94.9	1.63	0	
63327	0	176.7	96.9	1.70	0	
63328	0	204.4	101.7	1.71	0	
63329	0	232.2	105.1	1.74	0	
63330	0	260.0	115.2	1.80	0	
63331	0	287.8	115.2	1.85	0	
63288	1	-45.6	33.2	0.43	96	20
63289	1	-17.8	44.7	0.64	81	35
63287	1	4.4	52.9	0.86	68	40
63284	1	26.7	67.8	1.09	34	65
63290	1	51.7	80.7	1.32	0	95
63285	1	71.1	88.8	1.57	0	95
63291	1	98.9	88.8	1.57	0	100
63292	1	135.0	86.1	1.55	0	100
63286	1	160.0	86.1	1.68	0	100
63293	1	232.2	91.5	1.63	0	100

[a]0 = laboratory test.
1 = hot cell test machine.

Table B9. Unirradiated Charpy V-notch impact results for HSSI weld 64W

V64CS.WK1

UNIRRADIATED HSST 64W CHARPY V-NOTCH
Impact Test Results

Specimen Number	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
64242	0	-17.8	30.5	0.51	95	
64252	0	-1.1	44.7	0.69	79	
64254	0	4.4	51.5	0.84	51	
64253	0	4.4	38.6	0.56	73	
64255	0	10.0	50.8	0.86	50	
64256	0	15.6	56.3	0.91	48	
64257	0	32.2	55.6	0.89	42	
64244	0	37.8	69.8	1.14	41	
64260	0	48.9	81.3	1.37	34	
64261	0	54.4	74.6	1.50	27	
64262	0	60.0	103.0	1.80	0	
64263	0	76.7	96.3	1.70	0	
64245	0	93.3	95.6	1.57	0	
64270	0	121.1	105.8	1.65	0	
64271	0	148.9	109.1	1.94	0	
64243	0	176.7	99.0	1.73	0	
64272	0	204.4	107.8	1.90	0	
64273	0	232.2	108.5	1.93	0	
64274	0	260.0	114.6	1.93	0	
64275	0	287.8	122.7	1.93	0	
64246	1	-3.9	29.8	0.33	68	
64251	1	10.0	44.7	0.51	80	
64264	1	24.4	48.8	0.61	78	
64247	1	37.8	73.2	1.02	25	
64248	1	65.6	97.6	1.02	0	
64268	1	65.6	81.3	1.22	15	
64249	1	93.3	94.9	0.97	0	
64269	1	135.0	101.7	1.65	0	
64250	1	176.7	97.6	1.55	0	

[a]0 = laboratory test.
1 = hot cell test machine.

Table B10. Unirradiated Charpy V-notch impact results for HSSI weld 65W

V65CS.WK1

UNIRRADIATED HSST 65W CHARPY V-NOTCH.
Impact Test Results

Specimen Number	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
65309	0	-40.0	27.1	0.42	55	
65310	0	-34.4	43.4	0.69	83	
65312	0	-28.9	43.4	0.66	60	
65313	0	-28.9	43.4	0.71	71	
65315	0	-23.3	33.9	0.58	67	
65285	0	-17.8	45.4	0.71	90	
65316	0	-6.7	50.2	0.84	61	
65318	0	-1.1	53.6	0.91	63	
65319	0	15.6	76.6	1.24	28	
65328	0	21.1	94.9	1.57	15	
65320	0	26.7	81.3	1.42	32	
65329	0	32.2	82.0	1.38	34	
65288	0	37.8	93.6	1.57	0	
65321	0	48.9	92.2	1.57	0	
65289	0	93.3	109.8	1.80	0	
65322	0	121.1	103.0	1.93	0	
65323	0	148.9	96.3	1.71	0	
65286	0	176.7	113.2	2.01	0	
65324	0	204.4	111.2	2.03		
65330	0	232.2	107.8	1.90	0	
65325	0	232.2	103.7	1.98	0	
65326	0	260.0	121.3	2.25	0	
65327	0	287.8	121.3	1.88	0	
65292	1	-23.3	42.0	0.51	92	
65294	1	10.0	81.3	1.17	31	
65295	1	37.8	97.6	1.45	0	
65300	1	65.6	100.3	1.47	0	
65304	1	65.6	105.8	1.57	0	
65301	1	93.3	109.8	1.68	0	
65306	1	135.0	105.8	1.78	0	
65307	1	176.7	105.8	1.63	0	
65303	1	176.7	115.2	1.90	0	

[a]0 = laboratory test.
1 = hot cell test machine.

Table B11. Unirradiated Charpy V-notch impact results for HSSI weld 66W

V66CS.WK1

UNIRRADIATED HSST 66W CHARPY V-NOTCH.
Impact Test Results

Specimen Number	Test[a] Machine	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
66291	0	-17.8	28.5	0.46	95	
66306	0	-1.1	24.4	0.29	50	
66307	0	4.4	39.3	0.65	46	
66308	0	10.0	42.7	0.72	42	
66310	0	15.6	81.3	0.65	57	
66293	0	37.8	63.0	1.12	20	
66311	0	48.9	68.5	1.02	47	
66294	0	93.3	78.6	1.30	0	
66312	0	121.1	74.6	1.19	0	
66313	0	148.9	79.3	1.40	0	
66292	0	176.7	74.6	1.40	0	
66314	0	204.4	78.0	1.40	0	
66315	0	232.2	73.9	1.37	0	
66316	0	260.0	100.3	1.63	0	
66317	0	287.8	95.6	1.45	0	
66295	1	4.4	40.7	0.46	70	
66304	1	37.8	62.4	0.79	15	
66296	1	37.8	47.5	0.61	45	
66302	1	65.6	70.5	0.91	0	
66297	1	65.6	56.9	0.71	17	
66298	1	93.3	73.2	1.04	0	
66301	1	135.0	74.6	1.07	0	
66299	1	176.7	74.6	1.07	0	

[a]0 = laboratory test.
1 = hot cell test machine.

Table B12. Unirradiated Charpy V-notch impact results for HSSI weld 67W

V67CS.WK1

UNIRRADIATED HSST 67W CHARPY V-NOTCH
Impact Test Results

Specimen Number	Test Machine[a]	Test Temp. (C)	Fracture Energy (Joules)	Lateral Expansion (mm)	Fast Load Drop (%)	Fracture Appearance (% Duct)
67206	0	-56.7	11.5	0.18	96	
67228	0	-45.6	0.0	0.42		
67229	0	-40.0	45.4	0.33	87	
67230	0	-34.4	41.4	0.57	82	
67204	0	-17.8	63.7	1.04	55	
67231	0	4.4	63.7	1.03	53	
67236	0	21.1	97.6	1.56	21	
67207	0	37.8	86.8	1.35	10	
67237	0	43.3	97.6	1.63	0	
67238	0	48.9	92.9	1.50	0	
67239	0	54.4	92.9	1.49	0	
67244	0	121.1	101.7	1.73	0	
67245	0	148.9	124.1	1.83	0	
67205	0	176.7	103.7	1.73	0	
67246	0	204.4	101.0		0	
67247	0	232.2	103.7		0	
67252	0	260.0	105.8		0	
67212	1	-40.0	40.7	0.51	77	
67213	1	-17.8	65.1	0.81	49	
67214	1	10.0	73.2	0.84	50	
67223	1	37.8	84.1	1.07	22	
67215	1	37.8	78.6	1.02	9	
67224	1	65.6	94.9	1.42	0	
67220	1	65.6	100.3	1.45	0	
67221	1	93.3	103.0	1.47	0	
67225	1	135.0	103.0	1.50	0	
67222	1	176.7	100.3	1.55	0	

[a]0 = laboratory test.
1 = hot cell test machine.

Table B13. Irradiated Charpy V-notch impact results for HSSI weld 61W

V1RTT

IRRADIATED HSST 61W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	Trans. Temp. Increase vs Lin.Fit (Norm) (C)	Trans. Temp. Increase vs Hyp.Tan. (Obs) (C)	Trans. Temp. Increase vs Hyp.Tan. (Norm) (C)
61224	8.3E+22	296	66	51.5	30	40	68.0	66.9	70.1	68.9
61226	6.1E+22	311	27	38.0	19	62	52.7	60.5	48.2	55.3
61218	1.4E+23	310	54	38.0	19	60	80.4	61.5	75.9	58.1
61220	1.0E+23	310	77	46.1	28	76	88.5	79.0	88.2	78.7
61228	6.7E+22	315	27	46.1	15	61	38.5	42.1	38.2	41.7
61215	9.1E+22	320	29	40.7	24	57	50.2	47.1	46.9	44.0
61216	1.0E+23	320	71	66.4	36	64	47.7	42.7	53.6	48.0
61290	6.6E+22	323	10	16.3	9	74	73.6	81.4	64.5	71.3
61258	7.4E+22	323	27	38.0	21	65	52.7	54.8	48.2	50.1
61291	5.9E+22	323	38	29.8	16	53	77.9	90.5	69.8	81.0
61256	6.5E+22	323	54	58.3	34	33	45.1	49.9	49.9	55.3
61289	7.0E+22	323	54	43.4	26	58	71.0	75.7	68.9	73.5
61235	8.9E+22	329	10	28.5	11	75	52.5	49.8	44.0	41.8
61230	9.7E+22	329	27	42.0	20	57	45.6	41.5	43.2	39.3
61233	9.7E+22	329	28	43.4	23	62	44.3	40.3	42.3	38.4
61236	9.9E+22	329	38	51.5	26	37	40.2	36.2	42.3	38.0
61231	9.1E+22	329	54	66.4	36	20	31.0	29.1	36.9	34.6
61237	9.4E+22	329	71	56.9	32	18	64.1	59.2	68.1	62.9
61250	7.2E+22	345	-12	13.6	8	66	56.1	59.0	48.3	50.7
61251	6.7E+22	345	10	19.0	9	87	68.9	75.4	59.0	64.5
61252	6.0E+22	345	10	28.5	14	70	52.5	60.5	44.0	50.7
61248	6.3E+22	345	27	65.1	24	51	5.6	6.3	11.2	12.6
61246	7.4E+22	345	27	51.5	30	55	29.1	30.2	31.2	32.3
61243	7.4E+22	345	54	58.3	38	12	45.1	47.1	49.9	52.1
Ave.	8.3E+22	296					68.0	66.9	70.1	68.9
Ave.	9.9E+22	310					73.9	67.0	70.8	64.0
Ave.	6.7E+22	315					38.5	42.1	39.2	41.7
Ave.	9.5E+22	320					48.9	44.9	50.3	46.0
Ave.	6.7E+22	323					64.1	70.5	60.3	66.2
Ave.	9.4E+22	329					46.3	42.7	46.1	42.5
Ave.	6.8E+22	345					42.9	46.4	40.6	43.8

$\bar{x} = 8.14$
$\Sigma x^2 = 1672.69$
$\sigma = 1.86$
$\sigma^2 = 3.48$

Table B13. (Continued)

V1RU1

IRRADIATED HSST 61W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
61225	6.7E+22	296	149	70.5	42	0	15.6	17.0	16.4	17.9
61211	8.5E+22	298	177	70.5	49	0	16.0	15.5	16.6	16.1
61209	1.0E+23	298	177	66.4	47	0	20.9	18.7	21.4	19.2
61208	1.1E+23	298	177	56.9	41	0	32.2	27.2	32.6	27.6
61212	8.2E+22	298	177	75.9	50	0	9.6	9.4	10.2	10.0
61210	9.1E+22	298	288	71.9	49	0	16.2	15.2	15.5	14.5
61214	8.5E+22	298	288	73.2	46	0	14.6	14.2	13.9	13.5
61213	8.2E+22	298	288	78.6	57	0	8.3	8.2	7.5	7.4
61223	1.4E+23	310	93	59.7	37	0	27.8	21.3	28.2	21.6
61222	1.1E+23	310	149	67.8	43	0	18.8	16.0	19.6	16.6
61221	1.0E+23	310	149	67.8	42	0	18.8	16.8	19.6	17.5
61227	6.1E+22	311	149	75.9	40	0	9.1	10.4	9.9	11.4
61229	8.3E+22	315	149	86.8	58	0	-3.9	-3.8	-2.9	-2.9
61217	1.1E+23	320	149	67.8	41	0	18.8	15.9	19.6	16.6
61293	7.2E+22	323	77	71.9	43	0	12.8	13.4	12.4	13.0
61292	7.7E+22	323	77	62.4	40	0	24.3	24.8	24.0	24.5
61259	7.6E+22	323	93	70.5	46	0	14.7	15.0	15.1	15.5
61294	6.7E+22	323	121	75.9	48	0	8.6	9.4	9.6	10.4
61260	6.6E+22	323	149	73.2	51	0	12.3	13.6	13.2	14.5
61295	6.1E+22	323	188	74.6	56	0	11.4	13.0	11.8	13.5
61257	6.2E+22	323	232	78.6	54	0	7.3	8.3	7.2	8.2
61296	7.1E+22	323	288	78.6	50	0	8.3	8.8	7.5	8.0
61239	8.2E+22	329	93	81.3	44	0	1.6	1.5	2.1	2.1
61238	8.8E+22	329	93	70.5	43	0	14.7	14.0	15.1	14.5
61240	9.3E+22	329	149	86.8	50	0	-3.9	-3.6	-2.9	-2.7
61232	1.0E+23	329	160	84.1	53	0	-0.4	-0.4	0.4	0.4
61241	8.8E+22	329	188	74.6	46	0	11.4	10.8	11.8	11.3
61234	9.2E+22	329	232	63.7	47	0	24.9	23.2	24.8	23.2
61242	8.3E+22	329	288	70.5	42	0	17.8	17.5	17.1	16.8
61253	7.2E+22	345	71	61.0	37	0	25.8	27.2	25.1	26.4
61249	7.6E+22	345	93	75.9	49	0	8.1	8.3	8.6	8.9
61247	6.9E+22	345	93	77.3	49	0	6.5	7.0	7.0	7.5
61244	6.6E+22	345	149	73.2	52	0	12.3	13.6	13.2	14.5
61254	6.7E+22	345	188	71.9	39	0	14.6	16.0	15.0	16.4
61245	7.8E+22	345	232	78.6	60	0	7.3	7.4	7.2	7.3
Ave.	8.8E+22	297					16.7	15.7	16.7	15.8
Ave.	1.0E+23	310					18.6	16.1	19.3	16.6
Ave.	8.3E+22	315					-3.9	-3.8	-2.9	-2.9
Ave.	1.1E+23	320					18.8	15.9	19.6	16.6

$\bar{x} = 8.32$
$\Sigma x^2 = 2523.82$
$\sigma = 1.70$
$\sigma^2 = 2.89$

Table B13. (Continued)

V1RUT

IRRADIATED HSST 61W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
Ave.	6.9E+22	323					12.5	13.3	12.6	13.5
Ave.	9.0E+22	329					9.4	9.0	9.8	9.3
Ave.	7.1E+22	345					12.5	13.2	12.7	13.5

Table B14. Irradiated Charpy V-notch impact results for HSSI weld 62W

V2RTT

IRRADIATED HSST 62W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Transition Region.

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	vs Lin.Fit (Norm) (C)	vs Hyp.Tan. (Obs) (C)	vs Hyp.Tan. (Norm) (C)
62321	9.2E+22	257	38	24.4	10	85	72.5	67.6	69.8	65.1
62345	7.9E+22	281	16	24.4	8	73	50.3	50.6	47.6	47.9
62342	7.7E+22	281	38	35.3	18		58.8	60.0	57.3	58.4
62346	7.2E+22	281	49	38.0	18	26	66.5	70.1	65.4	68.9
62343	6.9E+22	281	66	47.5	29	42	71.2	76.7	72.6	78.1
62315	1.5E+23	288	49	28.5	14	66	78.5	58.1	75.9	56.2
62320	1.5E+23	288	49	19.0	9	56	90.4	66.9	88.9	65.8
62316	1.2E+23	288	93	52.9	28	19	92.2	75.6	94.8	77.8
62308	9.5E+22	298	38	32.5	16	53	62.2	57.1	60.3	55.3
62312	1.0E+23	297	40	32.5	16	77	64.5	57.1	62.5	55.4
62362	8.3E+22	303	4	27.1	14	61	35.7	35.1	32.9	32.3
62363	7.7E+22	303	21	32.5	15	33	45.6	46.4	43.6	44.5
62357	8.7E+22	303	38	48.8	27		41.7	40.0	43.3	41.5
62364	6.8E+22	303	49	50.2	26	20	51.1	55.5	52.9	57.4
62360	6.8E+22	303	66	70.5	42	16	42.2	45.8	45.6	49.4
62330	1.0E+23	312	38	39.3	21	62	53.7	47.3	52.8	46.5
62332	9.3E+22	312	38	40.7	23	48	52.0	48.2	51.8	48.0
62336	1.0E+23	312	49	47.5	26	14	54.6	48.6	55.9	49.7
62327	1.0E+23	312	66	58.3	39	40	57.6	50.7	61.1	53.8
Ave.	9.2E+22	257					72.5	67.6	69.8	65.1
Ave.	7.4E+22	281					61.7	64.3	60.7	63.3
Ave.	1.4E+23	288					87.0	66.9	86.5	66.6
Ave.	9.8E+22	297					63.3	57.1	61.4	55.3
Ave.	7.7E+22	303					43.3	44.6	43.7	45.0
Ave.	1.0E+23	312					54.5	48.7	55.4	49.5

$\bar{x} = 9.37$
$\Sigma x^2 = 1772.88$
$\sigma = 2.35$
$\sigma^2 = 5.54$

Table B14. (Continued)

V2RUT

IRRADIATED HSST 62W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin. Fit (Obs) (%)	vs Lin. Fit (Norm) (%)	vs Hyp. Tan. (Obs) (%)	vs Hyp. Tan. (Norm) (%)
62322	7.5E+22	257	160	73.2	49	0	20.3	20.9	20.7	21.4
62326	9.2E+22	264	104	67.8	44	0	24.0	22.4	24.7	23.0
62325	7.5E+22	264	232	77.3	53	0	18.8	19.5	18.6	19.2
62324	6.8E+22	274	149	73.2	49	0	19.8	21.5	20.4	22.1
62323	6.8E+22	274	149	70.5	40	0	22.8	24.7	23.3	25.3
62348	8.2E+22	281	82	73.2	39	0	17.0	16.8	17.2	17.0
62349	7.7E+22	281	93	77.3	42	0	12.9	13.1	13.5	13.7
62350	7.0E+22	281	110	77.3	46	0	13.6	14.6	14.4	15.4
62351	6.4E+22	281	121	75.9	34	0	15.6	17.5	16.4	18.4
62352	7.7E+22	281	138	75.9	46	0	16.4	16.7	17.1	17.4
62344	8.5E+22	281	160	85.4	51	0	7.0	6.8	7.5	7.3
62353	7.2E+22	281	193	82.7	44	0	11.4	12.1	11.6	12.2
62347	6.5E+22	281	232	84.1	44	0	11.7	13.0	11.5	12.7
62354	6.6E+22	281	288	88.1	44	0	9.9	10.9	9.0	9.9
62319	1.2E+23	288	121	63.7	36	0	29.2	23.9	29.9	24.5
62317	1.1E+23	288	177	78.6	49	0	15.1	13.0	15.4	13.3
62318	1.1E+23	288	288	75.9	45	0	22.4	19.3	21.6	18.6
62306	1.1E+23	293	177	84.1	51	0	9.2	7.8	9.6	8.1
62305	1.3E+23	293	177	80.0	54	0	13.6	10.9	14.0	11.1
62307	1.0E+23	293	288	78.6	46	0	19.6	17.4	18.8	16.7
62314	1.3E+23	297	104	65.1	38	0	27.1	21.6	27.7	22.1
62313	1.1E+23	297	160	75.9	49	0	17.3	14.6	17.8	15.1
62309	9.2E+22	298	160	78.6	48	0	14.4	13.4	14.9	13.9
62310	9.2E+22	298	177	81.3	46	0	12.2	11.3	12.5	11.7
62311	9.5E+22	298	288	84.1	50	0	14.1	12.9	13.2	12.1
62358	8.0E+22	303	66	70.5	40	0	19.3	19.3	18.5	18.5
62366	8.0E+22	303	93	75.9	45	0	14.4	14.4	15.0	15.0
62355	7.6E+22	303	104	75.9	50	0	14.9	15.3	15.7	16.1
62359	7.5E+22	303	160	84.1	53	0	8.5	8.7	9.0	9.3
62361	8.9E+22	303	177	85.4	56	0	7.8	7.4	8.1	7.7
62356	7.0E+22	303	232	80.0	54	0	16.0	17.1	15.7	16.8
62365	8.7E+22	303	288	84.1	51	0	14.1	13.5	13.2	12.7
62337	9.6E+22	312	82	70.5	40	0	20.0	18.3	20.3	18.5
62338	9.1E+22	312	93	75.9	44	0	14.4	13.5	15.0	14.1
62331	9.8E+22	312	104	75.9	52	0	14.9	13.5	15.7	14.1
62339	1.0E+23	312	132	77.3	46	0	14.6	12.8	15.4	13.5
62328	9.7E+22	312	160	75.9	55	0	17.3	15.7	17.8	16.2
62340	9.7E+22	312	193	86.8	48	0	7.1	6.4	7.3	6.6
62329	1.1E+23	312	232	80.0	54	0	16.0	13.7	15.7	13.5
62341	9.1E+22	312	288	89.5	52	0	8.5	8.0	7.6	7.2

$\bar{x} = 8.93$
$\Sigma x^2 = 3309.74$
$\sigma = 1.73$
$\sigma^2 = 3.00$

Table B14. (Continued)

V2RUT

IRRADIATED HSST 62W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	Ductile Shelf Decrease vs Lin.Fit (Norm) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Obs) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Norm) (%)
Ave.	8.1E+22	261.6					21.04	20.93	21.34	21.21
Ave.	6.8E+22	273.8					21.30	23.10	21.86	23.71
Ave.	7.3E+22	280.8					12.83	13.48	13.13	13.78
Ave.	1.1E+23	290.2					18.19	15.37	18.21	15.37
Ave.	1.0E+23	297.2					16.99	14.77	17.22	14.95
Ave.	8.0E+22	303.0					13.56	13.67	13.60	13.72
Ave.	9.8E+22	312.0					14.11	12.74	14.34	12.95

Table B15. Irradiated Charpy V-notch impact results for HSSI weld 63W

V3RTT

IRRADIATED HSST 63W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	vs Lin.Fit (Norm) (C)	vs Hyp.Tan. (Obs) (C)	vs Hyp.Tan. (Norm) (C)
63258	8.7E+22	282	82	36.6	16	60	117.5	112.6	115.2	110.5
63262	7.1E+22	282	107	56.9	31	11	101.1	107.3	106.7	113.3
63260	6.4E+22	291	93	46.1	25	31	109.3	122.2	110.8	123.9
63281	6.6E+22	303	60	33.9	18	43	100.7	110.9	97.5	107.3
63279	7.8E+22	303	71	38.0	24	39	103.6	104.9	101.6	102.9
63282	6.0E+22	303	82	50.2	34		89.9	103.8	93.2	107.6
63284	7.5E+22	303	93	55.6	27	13	90.0	92.9	95.3	98.5
63283	7.8E+22	303	93	56.9	28	11	87.2	88.3	92.8	94.0
63268	8.4E+22	310	49	27.1	13	75	103.4	100.9	98.9	96.5
63270	9.5E+22	310	60	29.8	12	56	109.0	100.0	105.0	96.4
63264	8.5E+22	310	71	35.3	16	63	109.1	105.8	106.1	102.9
63249	8.2E+22	308	82	55.6	28	13	78.9	77.9	84.2	83.2
63271	9.0E+22	310	93	43.4	27	18	114.8	108.2	115.3	108.7
63265	8.1E+22	310	104	51.5	28	31	107.4	108.7	112.9	112.2
63294	7.1E+22	316	38	24.4	10	60	97.8	103.8	93.3	99.0
63248	7.7E+22	315	51	36.6	19		86.3	88.0	84.1	85.7
63295	6.5E+22	316	60	32.5	12	26	103.5	114.8	100.0	110.9
63302	6.5E+22	316	66	38.0	17		98.0	108.8	96.1	106.6
63290	7.6E+22	316	71	46.1	27	48	87.1	89.3	88.6	90.9
63246	7.5E+22	315	71	48.8	27	44	81.5	84.2	84.1	86.9
63296	8.0E+22	316	93	54.2	30	12	92.7	92.7	97.3	97.3
63242	1.0E+23	320	71	40.7	22	20	98.1	87.3	97.1	86.4
Ave.	7.9E+22	282.2					109.2	109.9	110.9	111.8
Ave.	6.4E+22	290.5					109.2	122.1	110.8	123.9
Ave.	7.1E+22	303.0					94.28	100.1	96.1	102.0
Ave.	8.6E+22	309.6					104.0	100.2	103.7	99.99
Ave.	7.3E+22	315.8					92.42	97.38	91.92	96.76
Ave.	1.0E+23	319.7					98.07	87.28	97.11	86.42

$\bar{x} = 7.75$
$\Sigma x^2 = 1343.67$
$\sigma = 1.01$
$\sigma^2 = 1.01$

Table B15. (Continued)

[illegible]

[illegible] 63W CHARPY V-NOTCH

Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
63263	8.7E+22	282	177	66.4	42	0	25.1	24.0	25.8	24.7
63259	7.1E+22	282	232	67.8	38	0	24.2	25.6	24.6	26.1
63261	6.4E+22	291	121	62.4	37	0	29.1	32.5	29.2	32.6
63256	1.1E+23	291	135	62.4	39	0	29.2	24.6	29.6	24.9
63252	1.4E+23	291	177	65.1	46	0	26.6	20.2	27.3	20.7
63254	1.0E+23	291	177	69.1	45	0	22.0	19.5	22.7	20.1
63257	1.4E+23	291	288	65.1	39	0	27.8	21.1	27.8	21.1
63255	1.0E+23	291	288	67.8	43	0	24.8	21.9	24.8	21.9
63253	1.1E+23	291	288	69.1	42	0	23.3	19.6	23.3	19.6
63277	6.7E+22	303	104	65.1	40	0	25.8	28.2	25.2	27.5
63280	7.1E+22	303	104	62.4	41	0	28.9	30.7	28.3	30.1
63285	6.8E+22	303	121	63.7	36	0	27.5	29.9	27.6	29.9
63286	6.3E+22	303	149	65.1	41	0	26.3	29.6	26.9	30.3
63287	7.9E+22	303	177	67.8	25	0	23.5	23.7	24.2	24.4
63288	7.4E+22	303	204	70.5	39	0	20.8	21.6	21.4	22.3
63278	6.1E+22	303	232	67.8	45	0	24.2	27.7	24.6	28.2
63289	6.5E+22	303	288	69.1	30	0	23.3	25.8	23.3	25.8
63272	8.6E+22	310	121	65.1	35	0	26.0	25.1	26.1	25.1
63250	9.0E+22	308	138	70.5	38	0	20.0	18.9	20.5	19.3
63273	8.2E+22	310	149	65.1	35	0	26.3	26.0	26.9	26.5
63266	9.3E+22	310	160	70.5	41	0	20.3	18.8	21.0	19.5
63274	9.3E+22	310	160	67.8	40	0	23.4	21.7	24.0	22.3
63275	8.8E+22	310	193	67.8	32	0	23.7	22.6	24.4	23.3
63269	8.0E+22	310	232	65.1	45	0	27.2	27.2	27.6	27.6
63267	8.8E+22	310	232	69.1	40	0	22.6	21.6	23.1	22.0
63276	8.3E+22	310	288	70.5	34	0	21.8	21.4	21.8	21.4
63251	1.0E+23	311	288	73.2	35	0	18.8	16.7	18.8	16.7
63293	7.6E+22	316	104	63.7	39	0	27.4	28.1	26.8	27.5
63245	7.7E+22	315	105	67.8	42	0	35.1	35.8	34.6	35.3
63297	7.4E+22	316	121	63.7	38	0	27.5	28.6	27.6	28.7
63298	6.9E+22	316	132	65.1	40	0	26.1	28.1	26.5	28.5
63299	6.3E+22	316	143	66.4	30	0	24.7	27.8	25.2	28.4
63291	6.8E+22	316	160	70.5	46	0	20.3	22.0	21.0	22.8
63300	7.6E+22	316	177	69.1	44	0	22.0	22.6	22.7	23.3
63301	7.0E+22	316	193	67.8	42	0	23.7	25.4	24.4	26.1
63247	7.5E+22	315	232	67.8	46	0	24.2	25.0	24.6	25.4
63292	8.1E+22	316	232	70.5	45	0	21.1	21.0	21.6	21.5
63243	9.0E+22	320	160	65.1	46	0	26.4	24.9	27.1	25.5
63244	8.2E+22	320	232	63.7	47	0	28.7	28.4	29.1	28.8
Ave.	7.9E+22	282.2					24.61	24.84	25.18	25.41

$\bar{x} = 8.34$

$\Sigma x^2 = 2844.08$

$\sigma = 1.82$

$\sigma^2 = 3.31$

Table B15. (Continued)

V3RUT

IRRADIATED HSST 63W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
63263	8.7E+22	282	177	66.4	42	0	25.1	24.0	25.8	24.7
63259	7.1E+22	282	232	67.8	38	0	24.2	25.6	24.6	26.1
63261	6.4E+22	291	121	62.4	37	0	29.1	32.5	29.2	32.6
63256	1.1E+23	291	135	62.4	39	0	29.2	24.6	29.6	24.9
63252	1.4E+23	291	177	65.1	46	0	26.6	20.2	27.3	20.7
63254	1.0E+23	291	177	69.1	45	0	22.0	19.5	22.7	20.1
63257	1.4E+23	291	288	65.1	39	0	27.8	21.1	27.8	21.1
63255	1.0E+23	291	288	67.8	43	0	24.8	21.9	24.8	21.9
63253	1.1E+23	291	288	69.1	42	0	23.3	19.6	23.3	19.6
63277	6.7E+22	303	104	65.1	40	0	25.8	28.2	25.2	27.5
63280	7.1E+22	303	104	62.4	41	0	28.9	30.7	28.3	30.1
63285	6.8E+22	303	121	63.7	36	0	27.5	29.9	27.6	29.9
63286	6.3E+22	303	149	65.1	41	0	26.3	29.6	26.9	30.3
63287	7.9E+22	303	177	67.8	25	0	23.5	23.7	24.2	24.4
63288	7.4E+22	303	204	70.5	39	0	20.8	21.6	21.4	22.3
63278	6.1E+22	303	232	67.8	45	0	24.2	27.7	24.6	28.2
63289	6.5E+22	303	288	69.1	30	0	23.3	25.8	23.3	25.8
63272	8.6E+22	310	121	65.1	35	0	26.0	25.1	26.1	25.1
63250	9.0E+22	308	138	70.5	38	0	20.0	18.9	20.5	19.3
63273	8.2E+22	310	149	65.1	35	0	26.3	26.0	26.9	26.5
63266	9.3E+22	310	160	70.5	41	0	20.3	18.8	21.0	19.5
63274	9.3E+22	310	160	67.8	40	0	23.4	21.7	24.0	22.3
63275	8.8E+22	310	193	67.8	32	0	23.7	22.6	24.4	23.3
63269	8.0E+22	310	232	65.1	45	0	27.2	27.2	27.6	27.6
63267	8.8E+22	310	232	69.1	40	0	22.6	21.6	23.1	22.0
63276	8.3E+22	310	288	70.5	34	0	21.8	21.4	21.8	21.4
63251	1.0E+23	311	288	73.2	35	0	18.8	16.7	18.8	16.7
63293	7.6E+22	316	104	63.7	39	0	27.4	28.1	26.8	27.5
63245	7.7E+22	315	105	56.9	42	0	35.1	35.8	34.6	35.3
63297	7.4E+22	316	121	63.7	38	0	27.5	28.6	27.6	28.7
63298	6.9E+22	316	132	65.1	40	0	26.1	28.1	26.5	28.5
63299	6.3E+22	316	143	66.4	30	0	24.7	27.8	25.2	28.4
63291	6.8E+22	316	160	70.5	46	0	20.3	22.0	21.0	22.8
63300	7.6E+22	316	177	69.1	44	0	22.0	22.6	22.7	23.3
63301	7.0E+22	316	193	67.8	42	0	23.7	25.4	24.4	26.1
63247	7.5E+22	315	232	67.8	46	0	24.2	25.0	24.6	25.4
63292	8.1E+22	316	232	70.5	45	0	21.1	21.0	21.6	21.5
63243	9.0E+22	320	160	65.1	46	0	26.4	24.9	27.1	25.5
63244	8.2E+22	320	232	63.7	47	0	28.7	28.4	29.1	28.8
Ave.	7.9E+22	282.2					24.61	24.84	25.18	25.41

$\bar{x} = 8.34$
$\Sigma x^2 = 2844.08$
$\sigma = 1.82$
$\sigma^2 = 3.31$

Table B15. (Continued)

V3RUT

IRRADIATED HSST 63W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
Ave.	1.1E+23	291.1					26.10	22.76	26.37	22.99
Ave.	6.9E+22	303.0					25.04	27.15	25.19	27.31
Ave.	8.8E+22	309.8					23.00	21.98	23.41	22.37
Ave.	7.3E+22	315.9					25.21	26.43	25.49	26.73
Ave.	8.6E+22	319.7					27.56	26.63	28.09	27.14

Table B16. Irradiated Charpy V-notch impact results for HSSI weld 64W

V4RTT

IRRADIATED HSST 64W CHARPY V-NOTCH.

Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	Trans. Temp. Increase vs Lin.Fit (Norm) (C)	Trans. Temp. Increase vs Hyp.Tan. (Obs) (C)	Trans. Temp. Increase vs Hyp.Tan. (Norm) (C)
64208	4.3E+22	244	66	24.4	2	93	79.6	108.5	78.1	106.5
64201	4.3E+22	238	93	55.6	26	41	66.5	90.7	71.3	97.3
64205	3.7E+22	247	121	51.5	28		99.6	146.5	103.1	151.6
64202	4.0E+22	241	121	55.6	25	4	94.3	133.4	99.1	140.2
64288	4.3E+22	273	66	27.1	12		76.0	103.7	74.1	101.0
64293	4.6E+22	273	82	38.0	21	68	78.5	103.5	78.2	103.2
64289	3.9E+22	273	82	38.0	13	61	78.5	112.4	78.2	112.0
64292	4.4E+22	275	104	43.4	22	40	93.6	126.2	94.4	127.3
64291	4.1E+22	275	121	54.2	30	28	96.1	134.2	100.1	139.8
64290	3.7E+22	273	138	51.5	25	21	116.3	171.0	119.8	176.1
64314	3.9E+22	281	66	35.3	12	60	65.4	93.6	64.6	92.5
64284	3.5E+22	277	77	48.8	22	49	58.7	88.8	61.2	92.5
64315	3.5E+22	281	82	55.6	24	29	55.4	83.8	60.2	91.0
64316	4.2E+22	281	93	51.5	24	34	71.9	99.2	75.3	104.0
64285	3.5E+22	277	93	62.4	31	22	57.7	87.2	63.8	96.5
64319	3.3E+22	281	138	62.4	35	15	102.1	159.0	108.3	168.6
64317	3.9E+22	283	104	42.0	19	55	95.4	136.6	95.9	137.4
64318	3.6E+22	283	121	46.1	20	33	106.7	159.1	108.6	161.9
64303	4.1E+22	287	66	27.1	10	88	76.0	106.2	74.1	103.4
64305	3.6E+22	288	82	38.0	16	44	78.5	117.0	78.2	116.6
64306	3.2E+22	287	93	29.8	16	24	100.2	158.5	98.3	155.5
64307	4.0E+22	287	104	40.7	16	59	97.2	137.4	97.4	137.8
64276	6.3E+22	286	104	43.4	20	45	93.6	105.5	94.4	106.4
Ave.	4.1E+22	242					85.0	119.8	87.9	123.9
Ave.	4.2E+22	274					89.8	125.2	90.8	126.6
Ave.	3.7E+22	279					68.5	101.9	72.2	107.5
Ave.	3.8E+22	283					101.1	147.9	102.3	149.7
Ave.	4.2E+22	287					89.1	124.9	88.5	124.0

$\bar{x} = 4.00$

$\Sigma x^2 = 375.75$

$\sigma = 0.61$

$\sigma^2 = 0.37$

Table B16. (Continued)

V4RUT

IRRADIATED HSST 64W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	Ductile Shelf Decrease vs Lin.Fit (Norm) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Obs) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Norm) (%)
64206	3.8E+22	248	149	67.8	40	0	31.2	45.3	32.3	46.9
64204	3.7E+22	245	149	70.5	35	0	28.4	41.8	29.6	43.5
64200	4.6E+22	234	177	67.8	39	0	31.6	41.6	33.2	43.8
64209	4.6E+22	249	177	67.8	38	0	31.6	41.6	33.2	43.8
64203	3.8E+22	243	260	78.6	44	0	21.9	31.7	24.9	36.2
64207	4.0E+22	248	260	85.4	42	0	15.1	21.4	18.5	26.1
64286	3.8E+22	275	138	67.8	30	0	31.0	45.0	31.9	46.2
64294	4.5E+22	273	149	70.5	38	0	28.4	37.9	29.6	39.5
64297	3.8E+22	273	160	78.6	36	0	20.4	29.5	21.9	31.8
64282	4.3E+22	271	177	70.5	42	0	28.8	39.3	30.5	41.6
64298	4.2E+22	273	177	75.9	48	0	23.3	32.2	25.2	34.7
64299	3.9E+22	273	177	81.3	41	0	17.9	25.6	19.8	28.4
64295	4.2E+22	275	204	78.6	44	0	21.0	29.0	23.4	32.2
64287	4.3E+22	274	232	81.3	45	0	18.7	25.6	21.5	29.4
64283	3.8E+22	274	260	71.9	41	0	28.6	41.5	31.4	45.6
64300	3.6E+22	273	260	84.1	43	0	16.5	24.5	19.7	29.4
64296	4.0E+22	275	288	81.3	48	0	19.6	27.7	23.1	32.7
64320	4.2E+22	281	149	70.5	44	0	28.4	39.2	29.6	40.8
64323	3.2E+22	281	204	78.6	41	0	21.0	33.2	23.4	36.9
64324	3.9E+22	281	232	81.3	42	0	18.7	26.8	21.5	30.8
64325	3.6E+22	281	260	84.1	46	0	16.5	24.5	19.7	29.4
64326	3.3E+22	281	288	86.8	47	0	14.2	22.1	18.0	28.0
64321	3.9E+22	283	160	78.6	44	0	20.4	29.1	21.9	31.4
64322	3.5E+22	283	177	69.1	42	0	30.2	45.6	31.8	48.1
64304	3.8E+22	288	121	61.0	32	0	37.7	54.8	37.9	55.0
64308	3.8E+22	288	138	70.5	43	0	28.3	41.0	29.1	42.3
64309	3.4E+22	288	149	70.5	38	0	28.4	43.6	29.6	45.4
64277	5.6E+22	288	149	78.6	40	0	20.2	24.1	21.5	25.7
64278	5.1E+22	290	160	71.9	34	0	27.2	34.1	28.6	35.9
64310	3.1E+22	287	160	78.6	36	0	20.4	32.7	21.9	35.2
64301	3.9E+22	287	177	71.9	32	0	27.5	39.3	29.2	41.8
64311	3.7E+22	287	177	81.3	44	0	17.9	26.3	19.8	29.1
64279	5.1E+22	290	204	71.9	38	0	27.8	34.9	30.0	37.5
64312	3.5E+22	287	204	78.6	48	0	21.0	31.8	23.4	35.3
64281	6.3E+22	286	232	71.9	40	0	28.2	31.8	30.7	34.6
64302	3.4E+22	287	260	69.1	41		31.3	48.0	34.0	52.1
64280	5.6E+22	288	288	78.6	48	0	22.3	26.6	25.7	30.7
64313	3.1E+22	287	288	93.6.	55	0	7.5	12.1	11.6	18.6

$\bar{x} = 4.05$
$\Sigma x^2 = 642.80$
$\sigma = 0.70$
$\sigma^2 = 0.49$

Table B16. (Continued)

V4RUT

IRRADIATED HSST 64W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	Ductile Shelf Decrease vs Lin.Fit (Norm) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Obs) (%)	Ductile Shelf Decrease vs Hyp.Tan. (Norm) (%)
Ave.	4.1E+22	245					26.6	37.2	28.6	40.0
Ave.	4.0E+22	274					23.1	32.5	25.3	35.6
Ave.	3.6E+22	281					19.8	29.2	22.4	33.2
Ave.	3.7E+22	283					25.3	37.4	26.9	39.8
Ave.	4.2E+22	288					24.7	34.4	26.6	37.1

Table B17. Irradiated Charpy V-notch impact results for HSSI weld 65W

V5RTT

IRRADIATED HSST 65W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	Trans. Temp. Increase vs Lin.Fit (Norm) (C)	Trans. Temp. Increase vs Hyp.Tan. (Obs) (C)	Trans. Temp. Increase vs Hyp.Tan. (Norm) (C)
65250	3.2E+22	273	38	43.4	20	49	60.6	95.8	60.3	95.3
65251	3.1E+22	274	66	61.0	36	18	67.9	109.0	74.6	119.8
65237	3.1E+22	278	16	29.8	12	72	54.1	87.0	50.1	80.4
65281	3.5E+22	279	16	40.7	20	56	41.5	62.8	40.6	61.3
65241	3.4E+22	279	38	38.0	20	51	66.9	102.6	64.8	99.4
65284	3.1E+22	279	38	51.5	22	34	51.1	82.1	54.3	87.2
65255	4.3E+22	283	29	27.1	14	58	70.6	96.3	66.4	90.6
65272	3.3E+22	285	16	31.2	16	66	52.6	81.8	48.6	75.6
65271	3.6E+22	285	40	43.4	22	45	62.8	93.6	62.5	93.2
65243	5.9E+22	287	38	40.7	22	61	63.7	74.2	62.8	73.1
Ave.	3.2E+22	274					64.2	102.4	67.4	107.5
Ave.	3.1E+22	278					54.1	87.0	50.1	80.4
Ave.	3.3E+22	279					53.2	82.5	53.2	82.6
Ave.	4.3E+22	283					70.6	96.3	66.4	90.6
Ave.	3.5E+22	285					57.7	87.7	55.5	84.4
Ave.	5.9E+22	287					63.7	74.2	62.8	73.1

$\bar{x} = 3.65$
$\Sigma x^2 = 140.03$
$\sigma = 0.82$
$\sigma^2 = 0.68$

Table B17. (Continued)

V5RUT

IRRADIATED HSST 65W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
65254	3.7E+22	272	93	75.9	40	2	24.8	36.4	28.4	41.8
65233	4.0E+22	274	135	71.9	50	0	31.2	44.2	33.7	47.6
65253	3.2E+22	273	135	78.6	44	0	24.7	39.1	27.4	43.4
65249	3.7E+22	273	177	74.6	45	0	31.0	45.5	32.4	47.6
65252	3.1E+22	274	260	90.8	54	0	21.1	33.9	20.4	32.8
65236	3.3E+22	278	38	54.2	28		43.6	67.9	44.5	69.3
65240	3.6E+22	278	66	65.1	28		34.0	50.7	37.2	55.4
65242	4.0E+22	277	135	84.1	49		19.5	27.6	22.4	31.7
65234	3.6E+22	276	177	77.3	46	0	28.5	42.4	29.9	44.6
65235	3.4E+22	277	260	81.3	52	0	29.3	45.0	28.7	44.1
65248	5.9E+22	278	288	89.5	42		23.8	27.7	22.5	26.2
65287	3.8E+22	279	66	65.1	34	0	34.0	49.3	37.2	54.0
65238	3.1E+22	279	82	78.6	38		21.4	34.3	25.3	40.7
65290	3.5E+22	280	82	73.2	40	0	26.8	40.5	30.5	46.0
65293	3.2E+22	280	93	84.1	50	0	16.7	26.4	20.8	32.8
65239	3.3E+22	280	93	78.6	42		22.1	34.4	25.9	40.3
65296	2.9E+22	279	93	78.6	47	0	22.1	36.7	25.9	43.0
65299	3.8E+22	279	104	89.5	53	0	12.2	17.7	16.2	23.5
65302	3.5E+22	280	104	94.9	36	0	6.8	10.3	11.1	16.8
65305	3.1E+22	280	177	99.0	62	0	8.4	13.4	10.3	16.5
65308	2.8E+22	279	204	94.9	51	0	14.0	23.7	14.9	25.3
65311	3.5E+22	279	232	94.9	59	0	15.9	23.9	15.9	24.0
65314	3.2E+22	279	260	89.5	56	0	22.3	35.2	21.6	34.1
65317	2.8E+22	279	288	84.1	42	0	28.4	48.1	27.2	45.9
65256	3.7E+22	283	38	58.3	30		39.4	57.9	40.3	59.3
65273	3.0E+22	283	38	51.5	19		46.4	75.9	47.3	77.2
65257	4.8E+22	283	49	67.8	38		30.2	39.0	32.7	42.3
65274	4.0E+22	283	82	74.6	44		25.4	36.0	29.2	41.3
65270	3.9E+22	283	93	69.1	41	0	31.5	45.1	34.8	49.9
65260	3.4E+22	283	93	84.1	53	0	16.7	25.6	20.8	31.9
65262	4.6E+22	283	104	86.8	55		14.8	19.6	18.7	24.7
65277	2.9E+22	283	149	78.6	48	0	25.6	42.5	27.9	46.3
65264	3.3E+22	283	149	90.8	53		14.0	21.8	16.7	26.0
65265	4.4E+22	283	149	89.5	56	0	15.3	20.6	17.9	24.2
65268	3.5E+22	283	177	62.4	35	0	42.3	63.9	43.5	65.7
65266	4.0E+22	283	177	74.6	45	0	31.0	43.8	32.4	45.8
65278	3.7E+22	283	204	86.8	58	0	21.4	31.4	22.2	32.7
65247	5.2E+22	283	232	84.1	32	0	25.4	31.6	25.5	31.6
65279	3.4E+22	283	232	86.8	52	0	23.0	35.3	23.1	35.5
65269	3.2E+22	283	260	65.1	38	0	43.5	68.7	43.0	68.0
65267	3.5E+22	283	260	85.4	50	0	25.8	39.0	25.2	38.0
65280	3.1E+22	283	288	94.9	50	0	19.2	30.8	17.8	28.5
65258	4.4E+22	284	66	84.1	52		14.7	19.9	18.9	25.4

Table B17. (Continued)

V5RUT

IRRADIATED HSST 65W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
65259	4.0E+22	284	82	84.1	52	0	15.9	22.5	20.2	28.5
65261	4.3E+22	284	93	84.1	48		16.7	22.8	20.8	28.3
65275	3.7E+22	285	104	78.6	50		22.8	33.5	26.4	38.7
65263	3.9E+22	284	121	85.4	52	0	17.3	24.8	20.7	29.6
65276	3.2E+22	285	121	81.3	54		21.2	33.6	24.4	38.7
65244	5.2E+22	289	93	70.5	44	0	30.1	37.4	33.5	41.6
65245	4.8E+22	288	149	81.3	51	0	23.0	29.7	25.4	32.8
65246	4.8E+22	288	204	81.3	42		26.3	34.0	27.1	35.0
Ave.	3.5E+22	273					26.6	39.8	28.5	42.6
Ave.	4.0E+22	277					29.8	43.6	30.9	45.2
Ave.	3.3E+22	280					19.3	30.3	21.7	34.1
Ave.	3.8E+22	283					27.3	40.5	28.8	42.7
Ave.	3.9E+22	284					18.1	26.2	21.9	31.5
Ave.	4.9E+22	288					26.5	33.7	29.7	36.5

$\bar{x} = 3.72$
$\Sigma x^2 = 729.79$
$\sigma = 0.67$
$\sigma^2 = 0.44$

Table B18. Irradiated Charpy V-notch impact results for HSSI weld 66W

V6RTT

IRRADIATED HSST 66W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin.Fit (Obs) (C)	Trans. Temp. Increase vs Lin.Fit (Norm) (C)	Trans. Temp. Increase vs Hyp.Tan. (Obs) (C)	Trans. Temp. Increase vs Hyp.Tan. (Norm) (C)
66215	6.3E+22	262	93	32.5	12	40	131.9	148.7	93.3	105.2
66217	5.4E+22	269	116	40.7	19	19	120.4	146.5	103.6	126.0
66229	3.6E+22	279	71	40.7	18	75	75.9	113.2	59.1	88.1
66227	4.7E+22	280	93	38.0	22	50	109.4	142.8	85.3	111.3
66211	6.1E+22	284	116	54.2	26	55	64.1	73.4	82.1	94.0
66214	5.4E+22	284	116	43.4	18	20	109.1	132.8	99.6	121.2
Ave.	6.3E+22	261.9					131.9	148.6	93.33	105.1
Ave.	5.4E+22	269.4					120.3	146.5	103.5	126.0
Ave.	4.2E+22	279.4					92.68	127.9	72.22	99.72
Ave.	5.8E+22	284.4					86.63	103.1	90.80	107.5

$\bar{x} = 5.25$
$\Sigma x^2 = 170.27$
$\sigma = 0.90$
$\sigma^2 = 0.82$

Table B18. (Continued)

V6RUT

IRRADIATED HSST 66W CHARPY V NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin. Fit (Obs) (%)	Ductile Shelf Decrease vs Lin. Fit (Norm) (%)	Ductile Shelf Decrease vs Hyp. Tan. (Obs) (%)	Ductile Shelf Decrease vs Hyp. Tan. (Norm) (%)
66224	6.3E+22	263	177	51.5	28	0	31.4	35.4	30.0	33.8
66223	5.7E+22	265	260	65.1	28	0	16.6	19.6	11.0	13.0
66221	5.1E+22	269	116	55.6	26	0	23.9	30.0	23.7	29.7
66216	5.7E+22	268	135	54.2	26	2	26.5	31.3	26.1	30.9
66222	5.4E+22	268	135	48.8	27	0	33.8	41.2	33.5	40.8
66219	5.0E+22	272	177	54.2	26	0	27.8	35.2	26.3	33.3
66220	5.0E+22	271	218	55.6	30	0	27.4	34.7	24.3	30.7
66218	5.1E+22	271	260	56.9	32	0	27.0	33.8	22.1	27.7
66230	5.3E+22	279	104	56.9	32	0	21.7	26.6	21.3	26.1
66231	4.7E+22	280	121	59.7	34	0	19.6	24.2	19.4	24.0
66228	4.1E+22	280	135	56.9	34	0	22.8	31.8	22.4	31.3
66232	4.0E+22	280	149	61.0	32	0	17.8	25.2	17.0	24.1
66225	4.6E+22	279	177	55.6	34	0	26.0	34.3	24.4	32.2
66233	3.5E+22	279	204	62.4	40	0	18.0	27.3	15.1	22.8
66234	4.8E+22	279	232	65.1	38	0	15.5	20.1	11.2	14.5
66226	5.4E+22	279	260	61.0	37	0	21.8	26.5	16.6	20.2
66290	4.2E+22	279	288	69.1	38	0	12.4	17.1	5.2	7.2
66213	5.8E+22	284	177	67.8	34	0	38.7	45.4	37.3	43.9
66212	6.1E+22	284	177	65.1	34	0	13.4	15.4	11.5	13.2
Ave.	6.0E+22	263.8					24.00	27.52	20.48	23.40
Ave.	5.2E+22	269.6					27.73	34.35	25.99	32.17
Ave.	4.5E+22	279.2					19.39	25.90	16.84	22.48
Ave.	6.0E+22	284.4					26.03	30.38	24.44	28.53

$\bar{x} = 5.04$
$\Sigma x^2 = 492.94$
$\sigma = 0.72$
$\sigma^2 = 0.52$

Table B19. Irradiated Charpy V-notch impact results for HSSI weld 67W

V7RTT

IRRADIATED HSST 67W CHARPY V-NOTCH.

Irradiation Conditions and Test Results: Transition Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Trans. Temp. Increase vs Lin. Fit (Obs) (C)	Trans. Temp. Increase vs Lin. Fit (Norm) (C)	Trans. Temp. Increase vs Hyp. Tan. (Obs) (C)	Trans. Temp. Increase vs Hyp. Tan. (Norm) (C)
67241	3.8E+22	269	52	48.8	26	57	87.4	126.8	82.2	119.2
67242	4.5E+22	268	93	62.4	32	22	100.7	134.2	104.8	139.8
67266	4.5E+22	282	38	27.1	14	60	119.0	158.7	101.3	135.0
67250	5.0E+22	282	52	38.0	20	23	110.2	139.3	97.7	123.5
67251	4.4E+22	282	66	59.7	34	35	78.6	105.9	81.1	109.3
67207	7.1E+22	285	38	46.1	18	34	79.2	84.1	72.3	76.7
67226	7.1E+22	284	66	65.1	32	10	67.2	71.3	73.1	77.5
Ave.	4.2E+22	269					94.0	130.5	93.5	129.5
Ave.	4.6E+22	282					102.6	134.6	93.3	122.6
Ave.	7.1E+22	285					73.2	77.7	72.7	77.1

$\bar{x} = 5.20$

$\Sigma x^2 = 200.12$

$\sigma = 1.24$

$\sigma^2 = 1.55$

Table B19. (Continued)

V7RUT

IRRADIATED HSST 67W CHARPY V-NOTCH.
Irradiation Conditions and Test Results: Upper Shelf Region

Spec. No.	Fast Neutron Fluence n/m^2 (E>1 Mev)	Mean Irrad. Temp. (C)	Test Temp. (C)	Fract. Energy Joules	Lat. Expan. (mils)	Fast Load Drop (%)	Ductile Shelf Decrease vs Lin.Fit (Obs) (%)	vs Lin.Fit (Norm) (%)	vs Hyp.Tan. (Obs) (%)	vs Hyp.Tan. (Norm) (%)
67234	3.8E+22	270	135	75.9	42	0	25.5	37.0	25.0	36.3
67240	3.5E+22	270	177	81.3	48	0	20.2	30.5	20.8	31.4
67233	4.5E+22	269	177	84.1	50	0	17.5	23.3	18.1	24.2
67235	3.5E+22	270	260	88.1	46	0	13.5	20.4	15.7	23.8
67257	5.6E+22	282	82	70.5	42	0	30.8	36.8	27.6	33.0
67267	3.9E+22	282	93	67.8	36	0	33.5	47.9	31.2	44.7
67258	5.0E+22	282	104	66.4	36	0	34.8	44.0	33.3	42.1
67249	5.6E+22	282	135	74.6	46	0	26.8	32.1	26.4	31.5
67256	3.8E+22	282	177	78.6	45	0	22.8	33.1	23.4	34.0
67259	4.3E+22	282	204	85.4	54	0	16.2	22.1	17.4	23.7
67232	8.8E+22	282	204	86.8	50	0	14.8	14.2	16.1	15.3
67264	3.7E+22	282	232	89.5	54	0	12.2	17.9	13.9	20.5
67243	3.7E+22	279	260	73.2	49	0	28.2	41.4	30.0	44.1
67248	4.8E+22	282	260	89.5	56	0	12.2	15.7	14.4	18.6
67265	5.1E+22	282	288	86.8	38	0	14.8	18.6	17.5	21.9
67206	7.6E+22	284	93	75.9	42	0	25.5	26.2	23.0	23.6
67227	7.6E+22	284	121	71.9	47	0	29.5	30.2	28.6	29.3
67203	8.8E+22	283	149	71.9	44	0	29.5	28.1	29.4	28.1
Ave.	3.8E+22	270					19.2	27.8	19.9	28.9
Ave.	4.9E+22	282					22.5	29.4	22.8	29.9
Ave.	8.0E+22	284					28.2	28.2	27.0	27.0

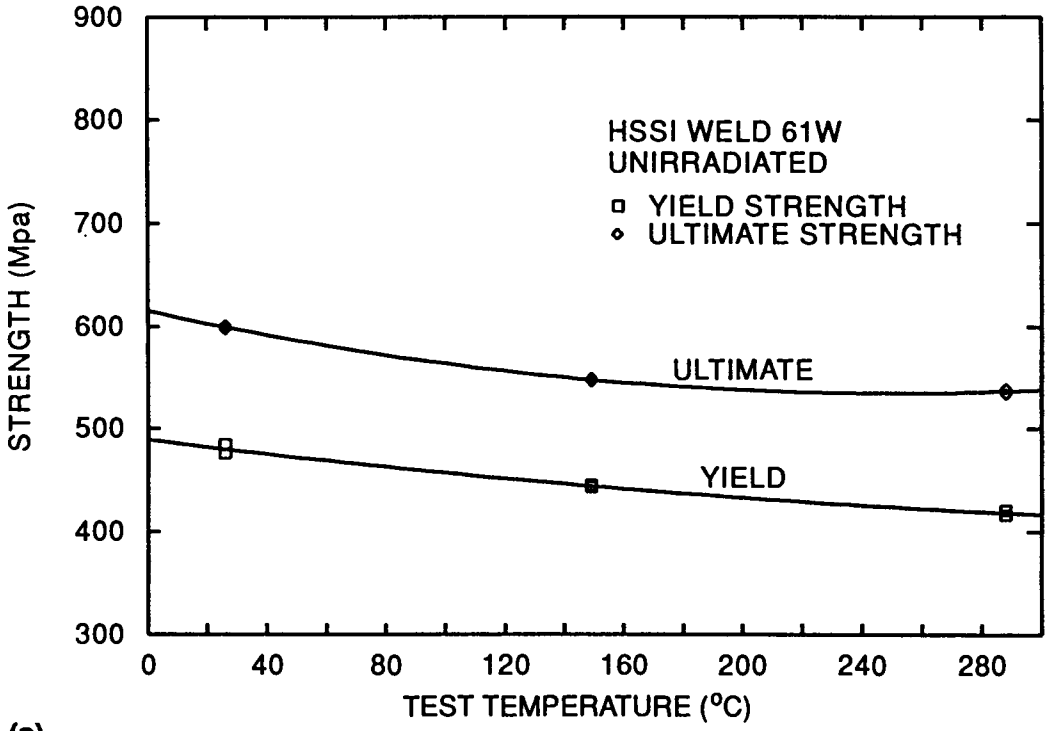
$\bar{x} = 5.20$
$\Sigma x^2 = 541.88$
$\sigma = 1.75$
$\sigma^2 = 3.06$

Table B20. Linear regression results for irradiated Charpy impact energy vs irradiation temperature for HSSI welds 61W through 67W

	MATERIAL:	61W	62W	63W	64W	65W	66W	67W
OBSERVED	CONSTANT "A"	279.6567	206.2232	239.5395	89.0115	135.8206	235.1393	324.9458
TRANSITION	STD.ERR."A"	13.9810	14.2292	8.5050	17.4645	10.5716	16.9980	13.2493
TEMPERATURE	R SQUARED	0.3119	0.2198	0.2521	0.0001	0.0161	0.0913	0.1977
INCREASE	X COEFFICIENT "B"	-0.6962	-0.4962	-0.4570	-0.0106	-0.2750	-0.5348	-0.8498
	STD.ERR.COEFF.	0.2205	0.2267	0.1760	0.2402	0.7609	0.8438	0.7657
NORMALIZED	CONSTANT "A"	232.0108	196.1712	278.9533	110.6092	594.0000	192.3770	739.0000
TRANSITION	STD.ERR."A"	14.8303	9.7373	8.9946	27.4884	14.8000	16.2496	22.0000
TEMPERATURE	R SQUARED	0.2010	0.3573	0.3256	0.0007	0.2640	0.0348	0.3850
INCREASE	X COEFFICIENT "B"	-0.5502	-0.4769	-0.5786	0.0447	-1.8000	-0.3061	-2.2500
	STD.ERR.COEFF.	0.2339	0.1551	0.1862	0.3781	1.0700	0.8066	1.2700
OBSERVED	CONSTANT "A"	46.8567	42.8427	29.4582	41.9891	44.3789	86.1405	-46.5979
UPPER	STD.ERR."A"	6.7013	4.5711	2.6266	5.6242	8.6687	5.9390	6.1462
SHELF	R SQUARED	0.0686	0.0944	0.0088	0.0224	0.0007	0.0790	0.0486
DECREASE	X COEFFICIENT "B"	-0.1108	-0.0968	-0.0230	-0.0561	-0.0569	-0.2573	0.2500
	STD.ERR.COEFF.	0.0711	0.0486	0.0402	0.0617	0.3163	0.2131	0.2765
NORMALIZED	CONSTANT "A"	34.4940	52.5154	7.2708	58.0615	142.3421	84.7029	66.7505
UPPER	STD.ERR."A"	6.0729	3.8880	3.4407	7.9110	13.5586	7.0666	8.7977
SHELF	R SQUARED	0.0376	0.2119	0.0229	0.0202	0.0105	0.0492	0.0070
DECREASE	X COEFFICIENT "B"	-0.0732	-0.1321	0.0491	-0.0748	-0.3569	-0.2378	-0.1326
	STD.ERR.COEFF.	0.0644	0.0413	0.0527	0.0868	0.4948	0.2536	0.3958

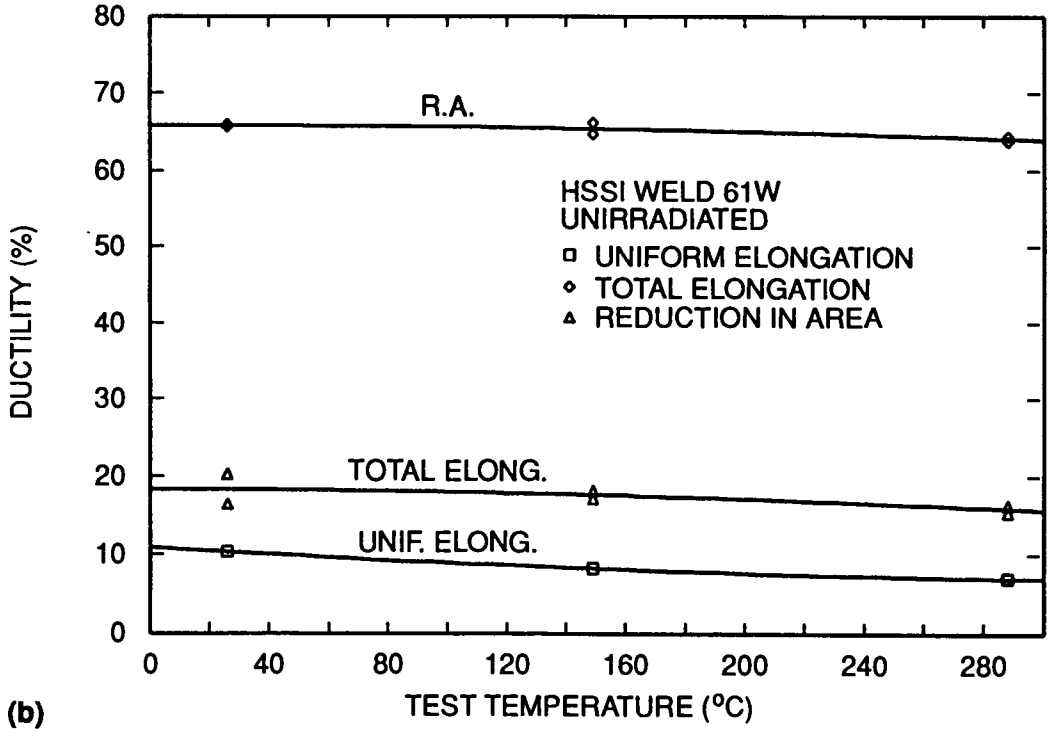
LINEAR FIT EXPRESSION: "CHANGE" = A + B*T
Where: T = Irradiation Temperature (Deg.C)

ORNL-DWG 90Z-17913



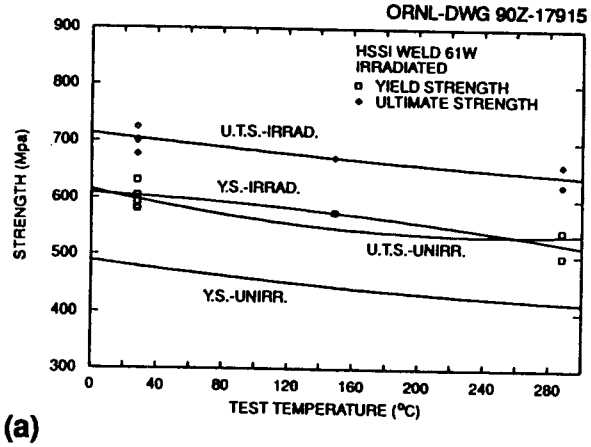
(a)

ORNL-DWG 90Z-17914

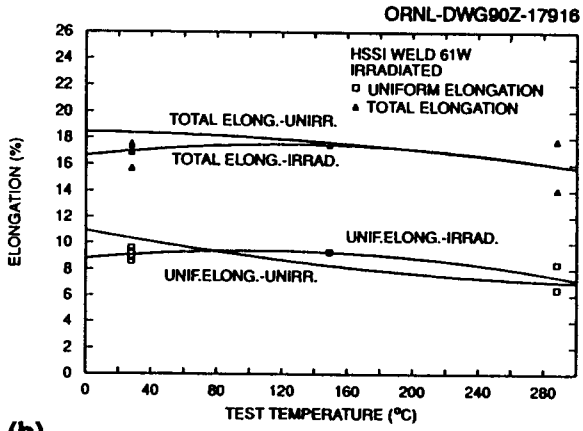


(b)

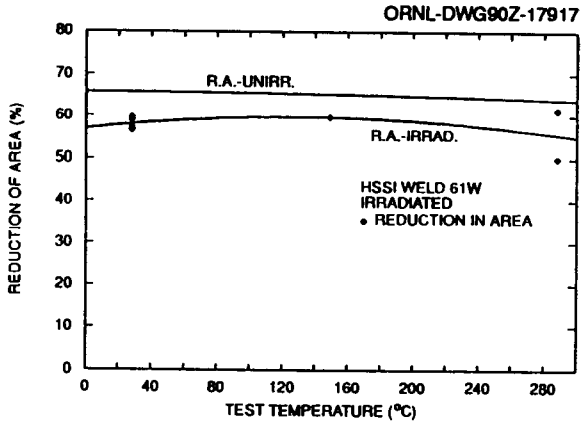
Fig. B1. Unirradiated tensile test results vs test temperature for HSSI weld 61W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.



(a)

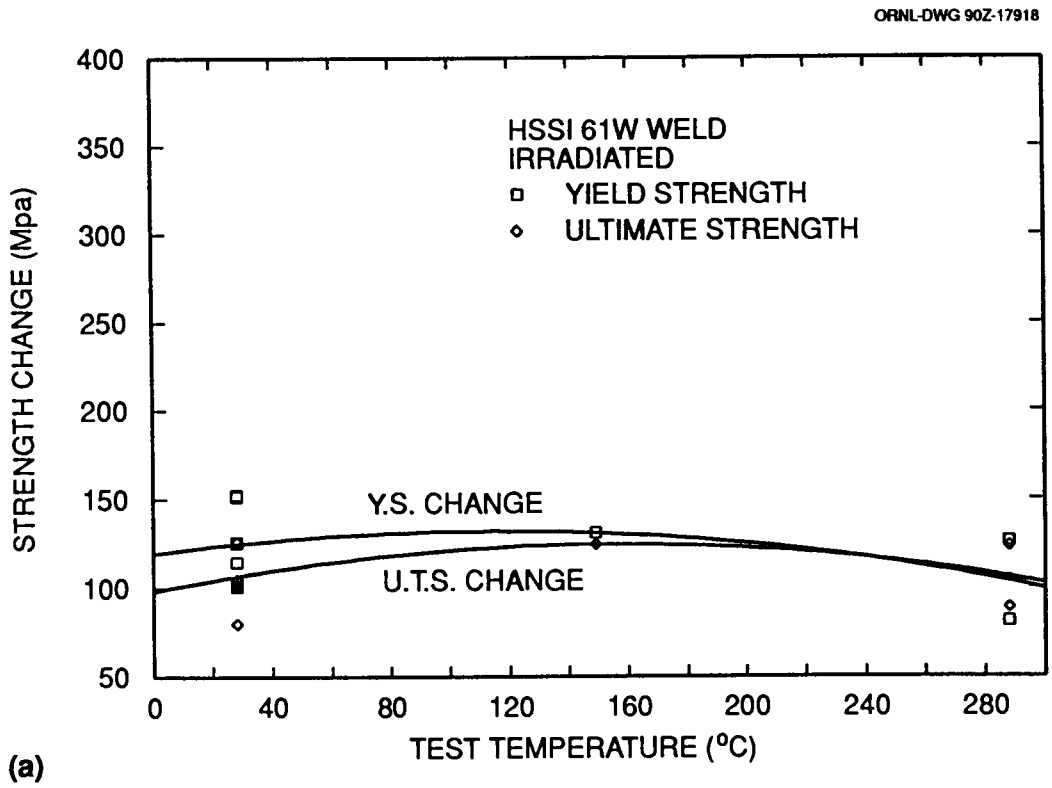


(b)

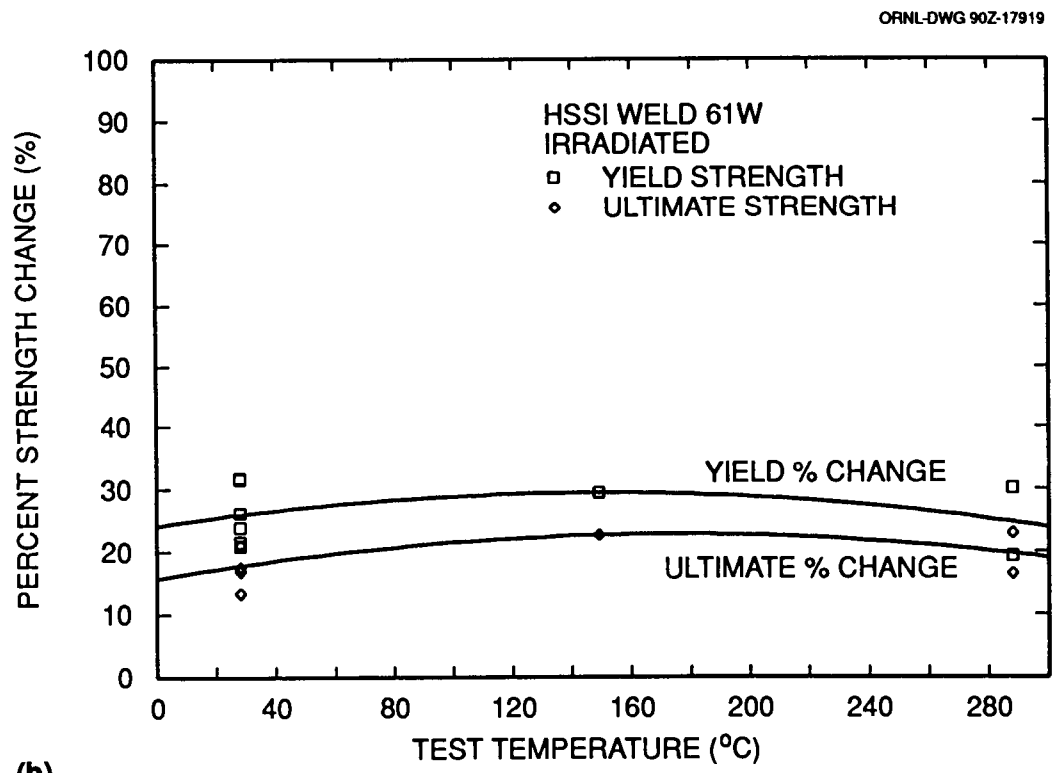


(c)

Fig. B2. Irradiated tensile test results vs test temperature for HSSI weld 61W; (a) yield and ultimate strengths, (b) uniform and total elongations, and (c) reduction of area. Best-fit curves to the unirradiated data are shown for comparison.

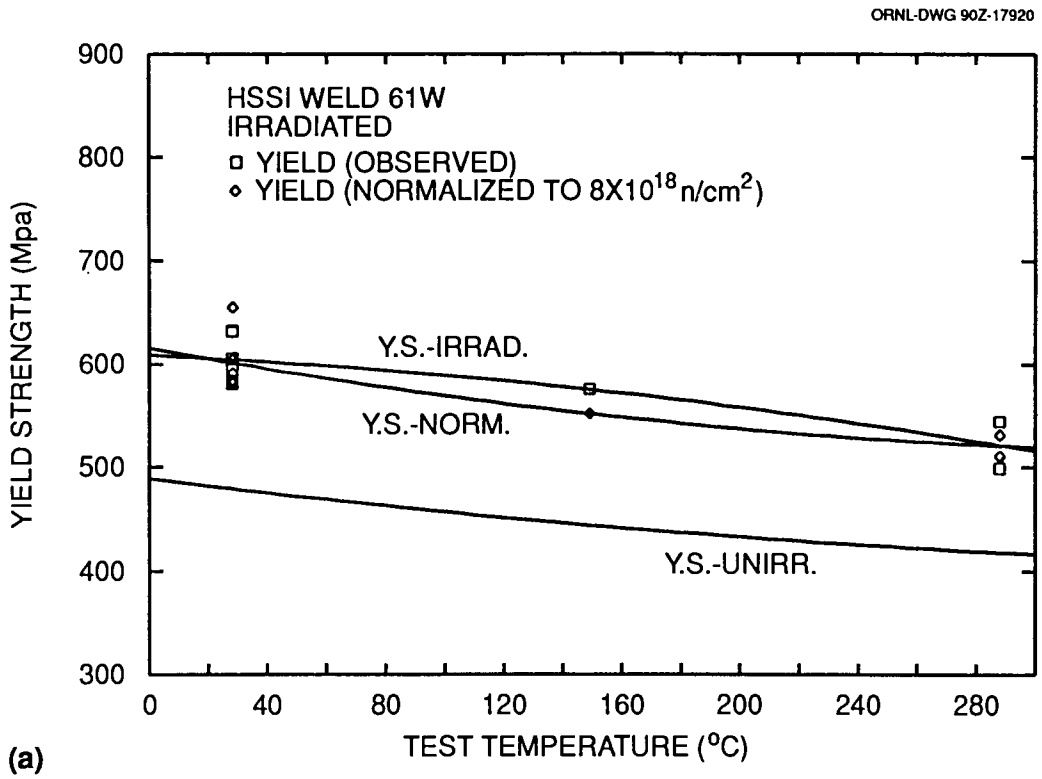


(a)



(b)

Fig. B3. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 61W; (a) increase in property units (MPa), and (b) increase in percent relative to unirradiated strengths.



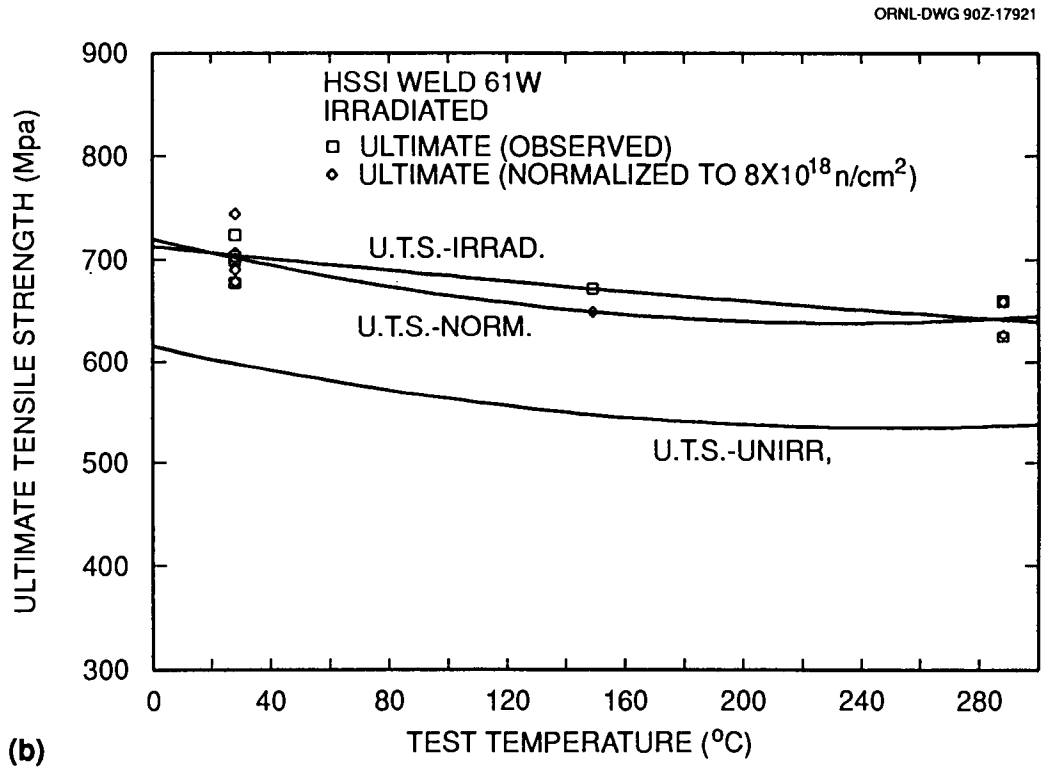
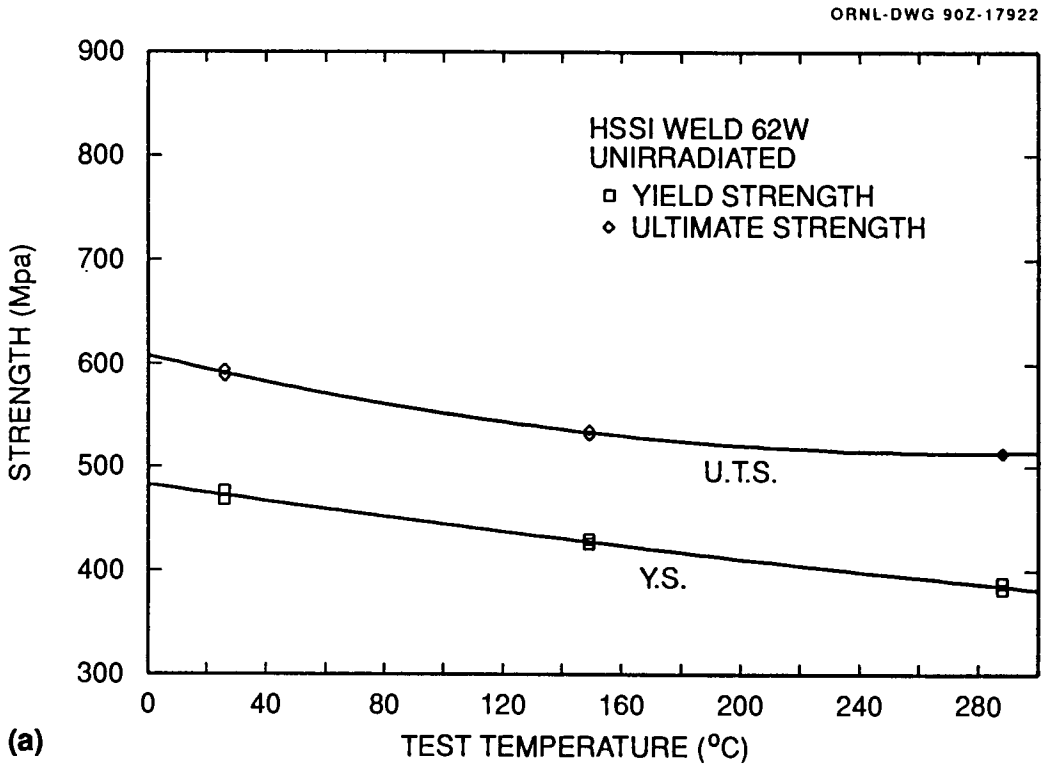


Fig. B4. Irradiated tensile test results vs test temperature for HSSI weld 61W with and without fluence normalized to 8×10^{18} neutrons/cm^2; (a) yield strength, and (b) ultimate strength. Best-fit curves to the unirradiated data are shown for comparison.



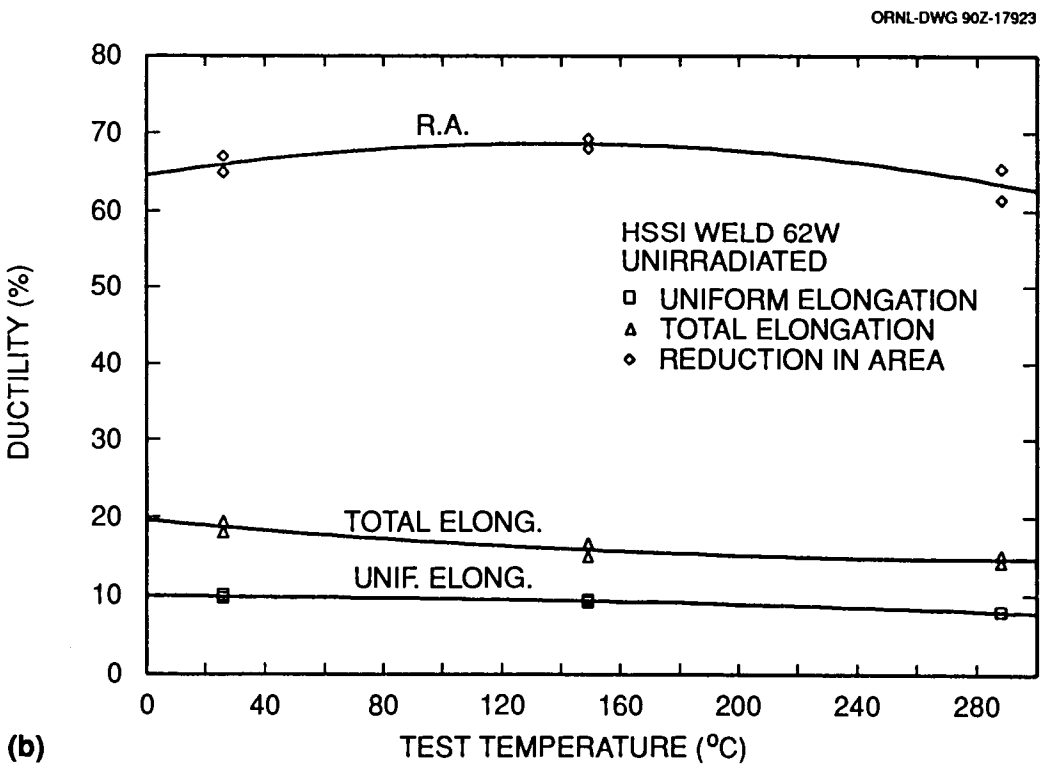


Fig. B5. Unirradiated tensile test results vs test temperature for HSSI weld 62W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

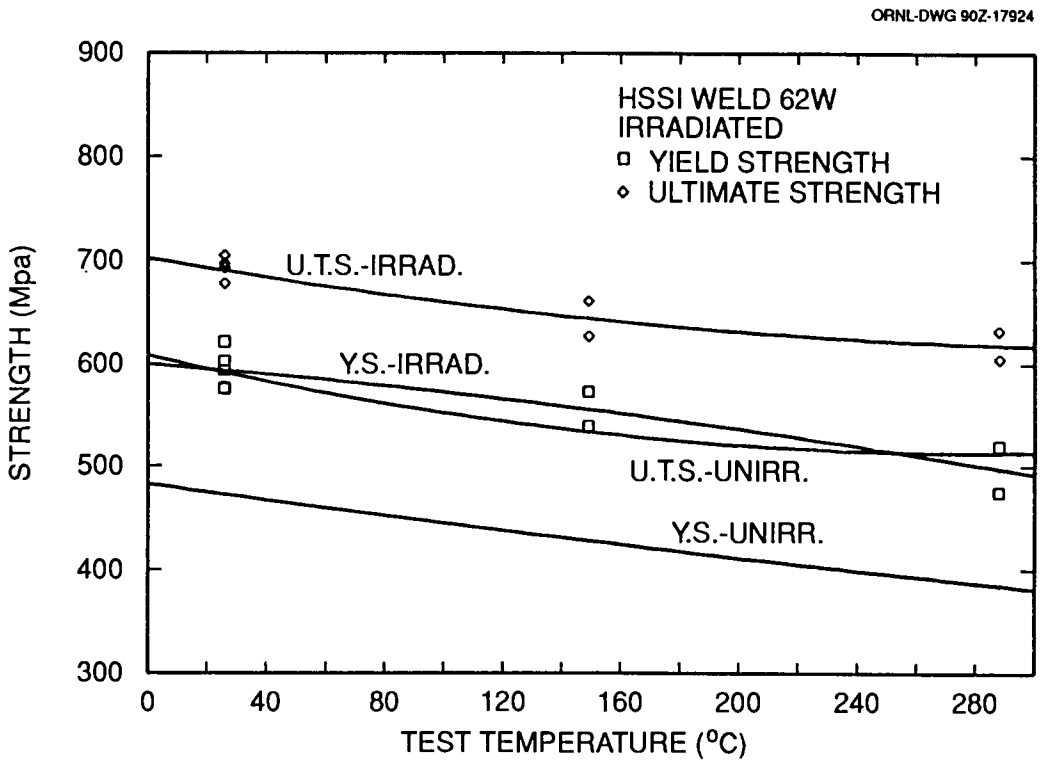


Fig. B6. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 62W. Best-fit curves to the unirradiated data are shown for comparison.

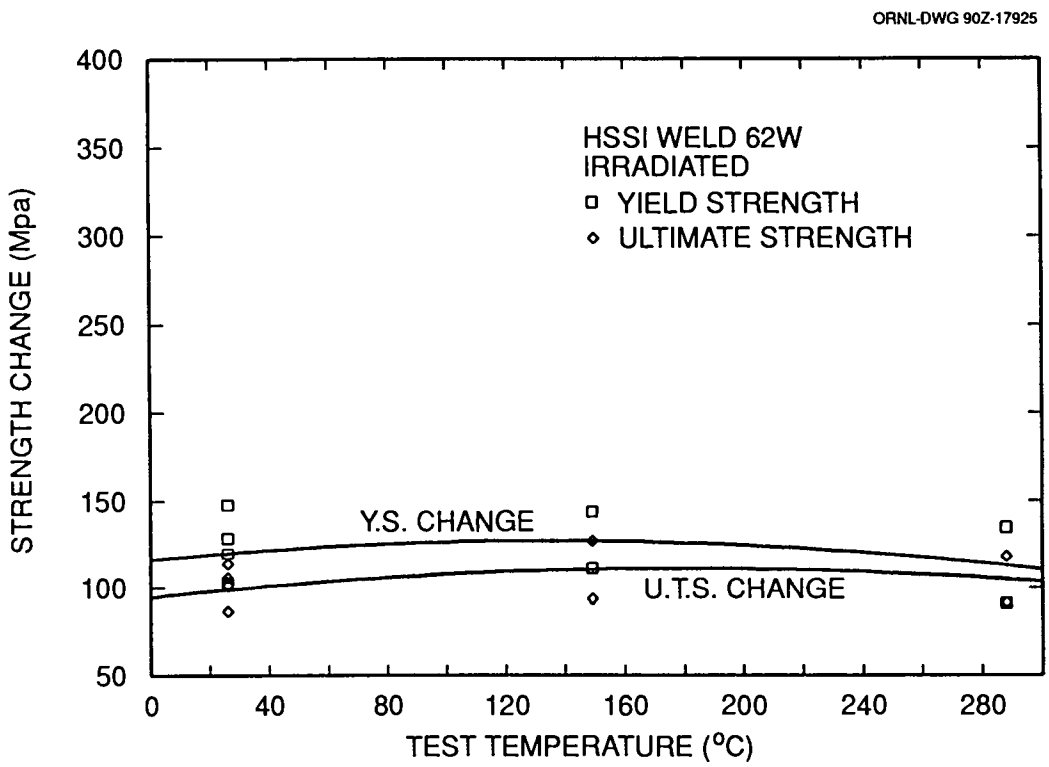
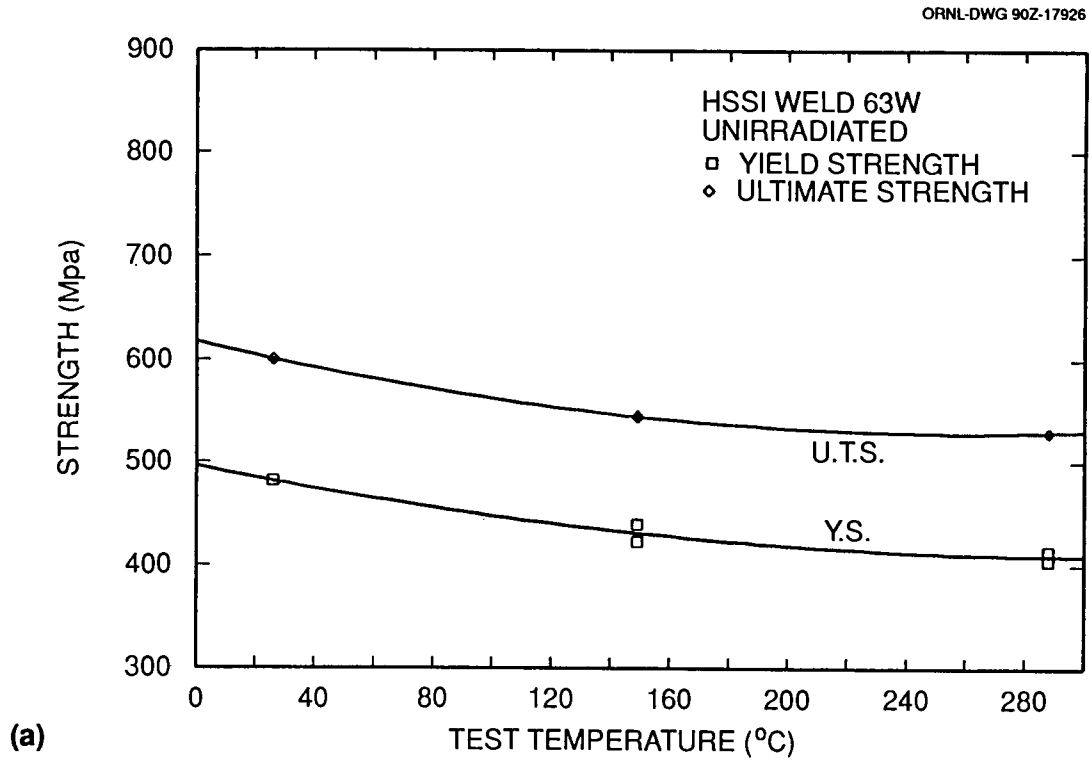
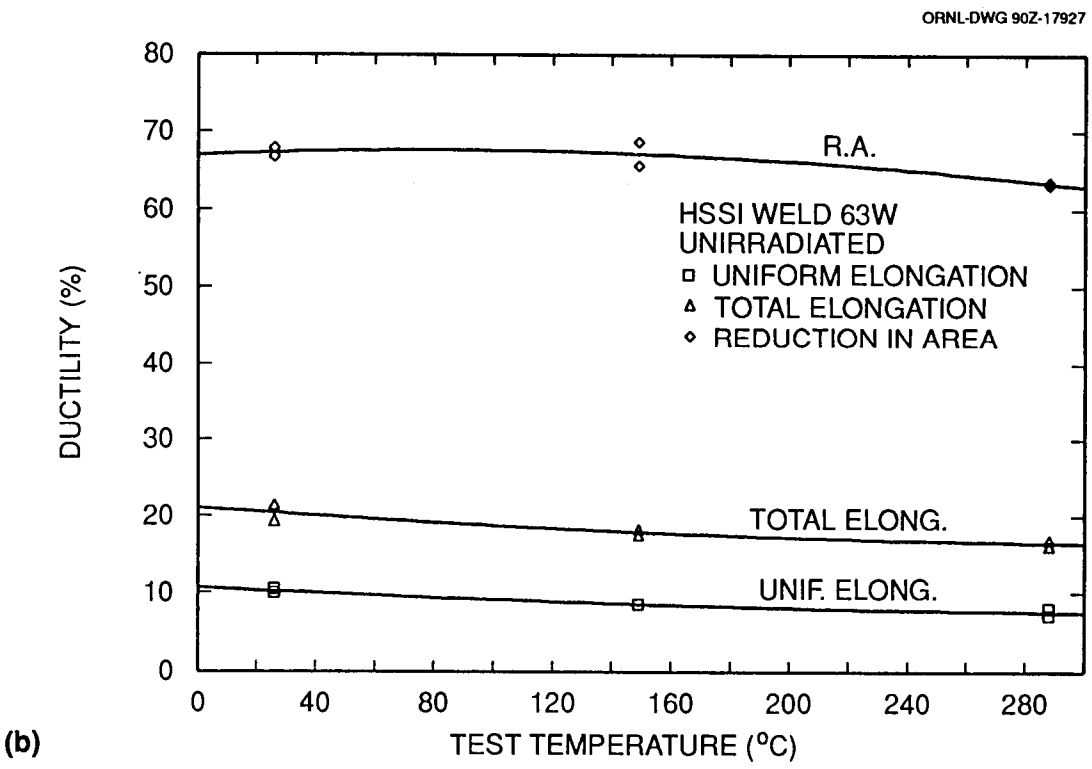


Fig. B7. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 62W.



(a)



(b)

Fig. B8. Unirradiated tensile test results vs test temperature for HSSI weld 63W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

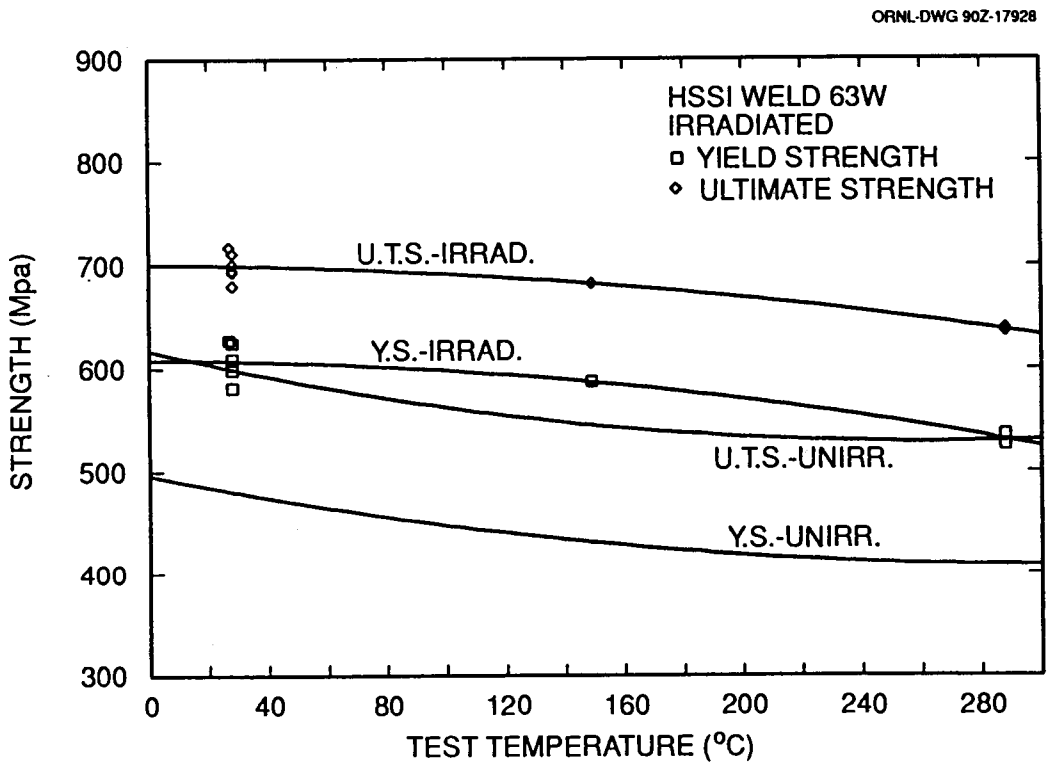


Fig. B9. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 63W. Best-fit curves to the unirradiated data are shown for comparison.

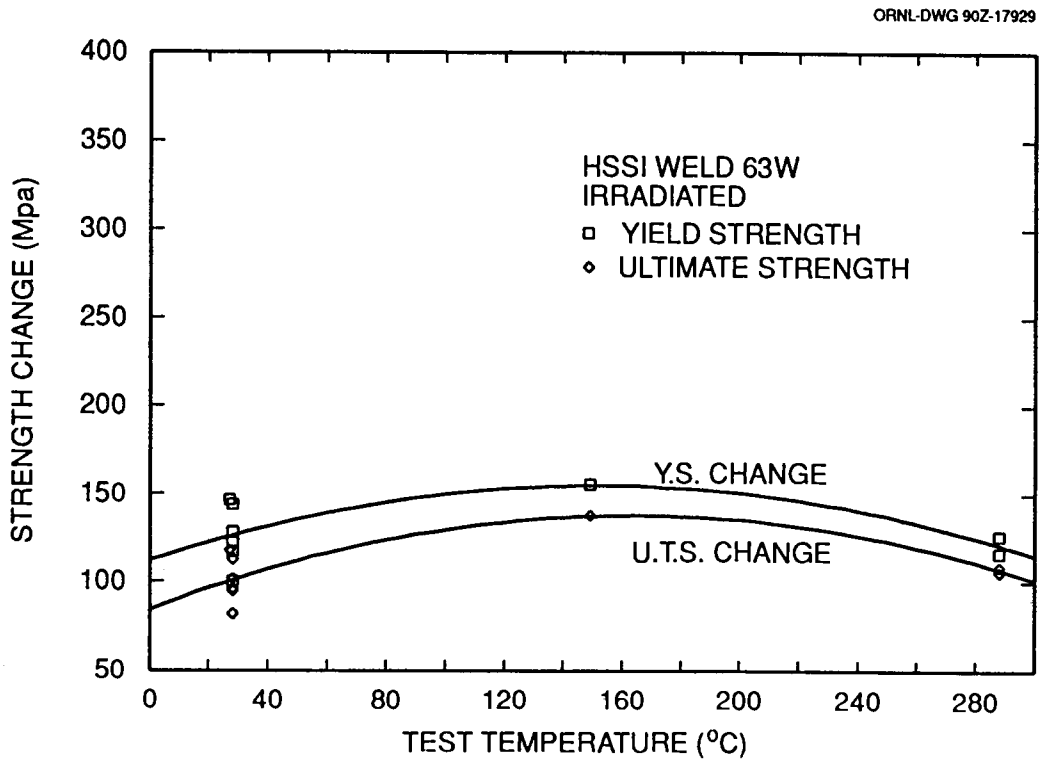
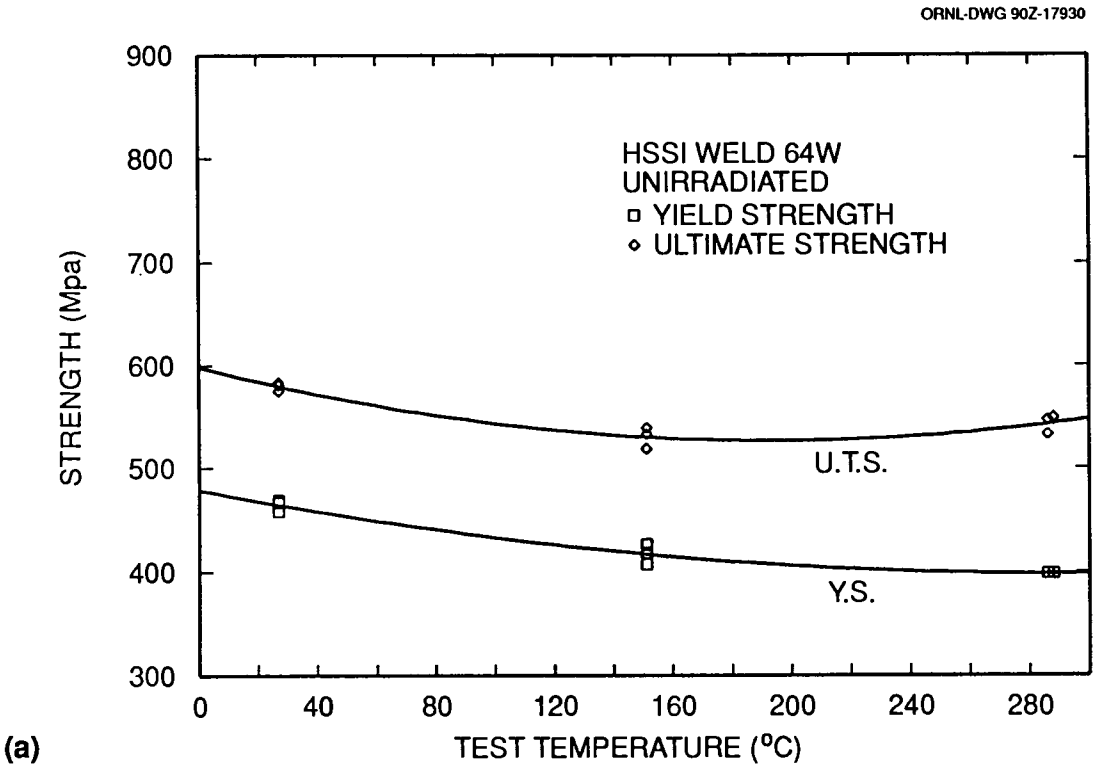


Fig. B10. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 63W.



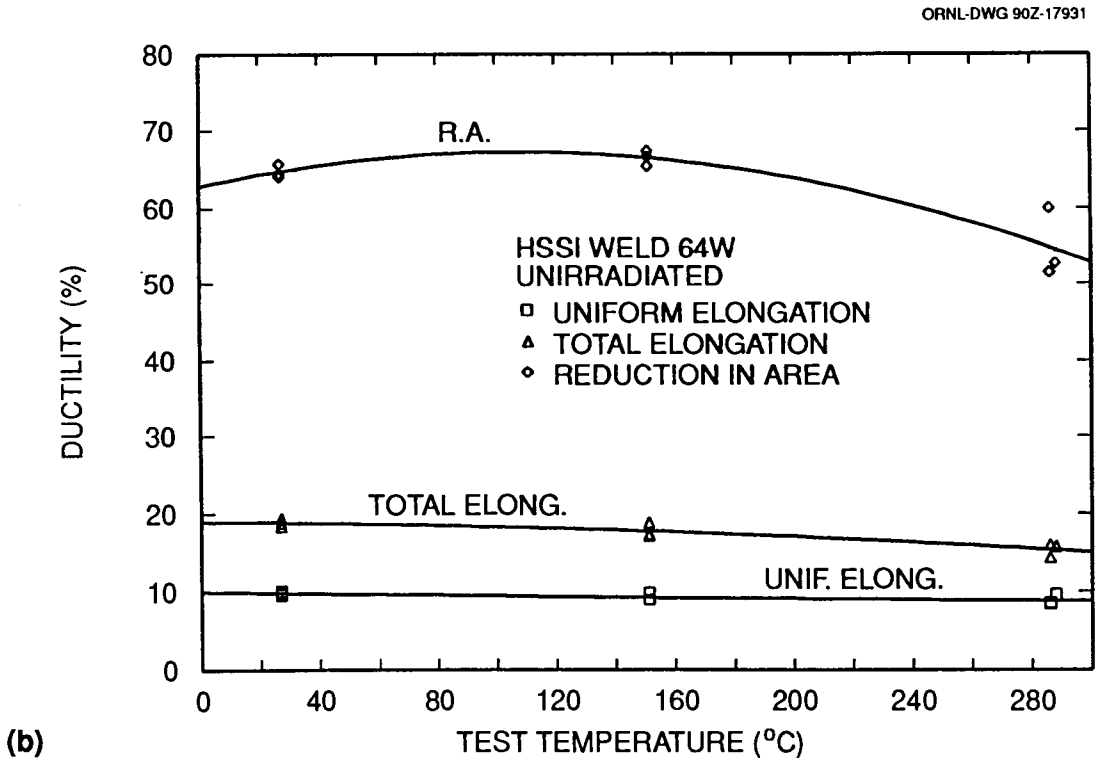


Fig. B11. Unirradiated tensile test results vs test temperature for HSSI weld 64W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

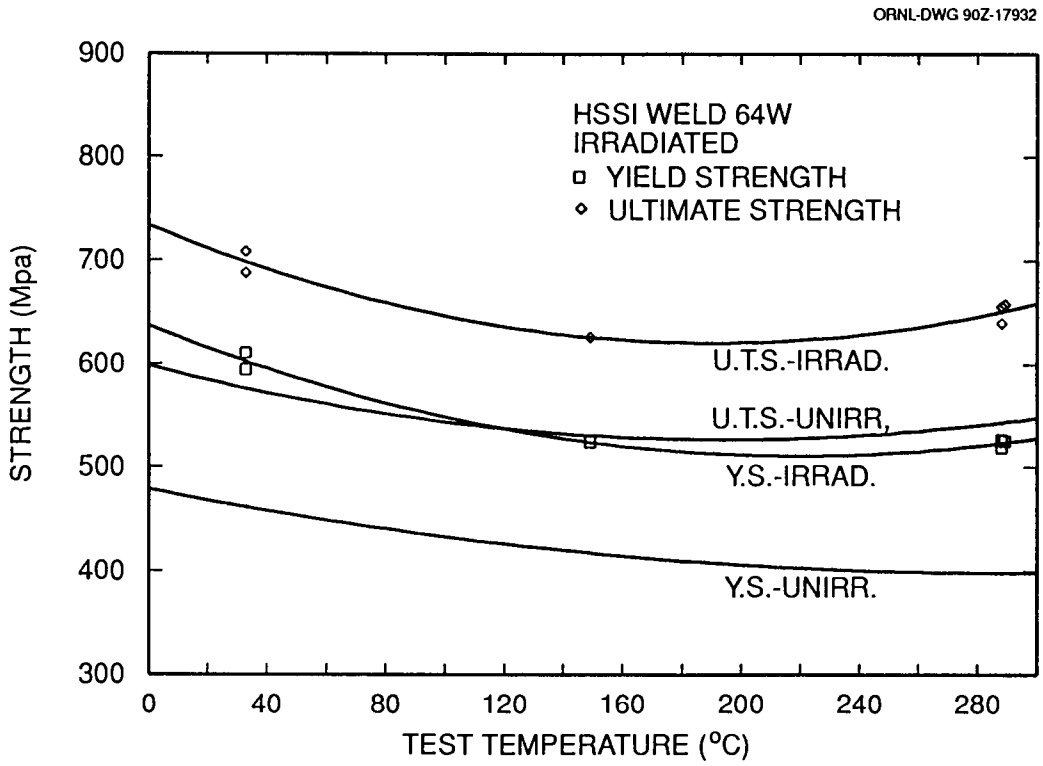


Fig. B12. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 64W. Best-fit curves to the unirradiated data are shown for comparison.

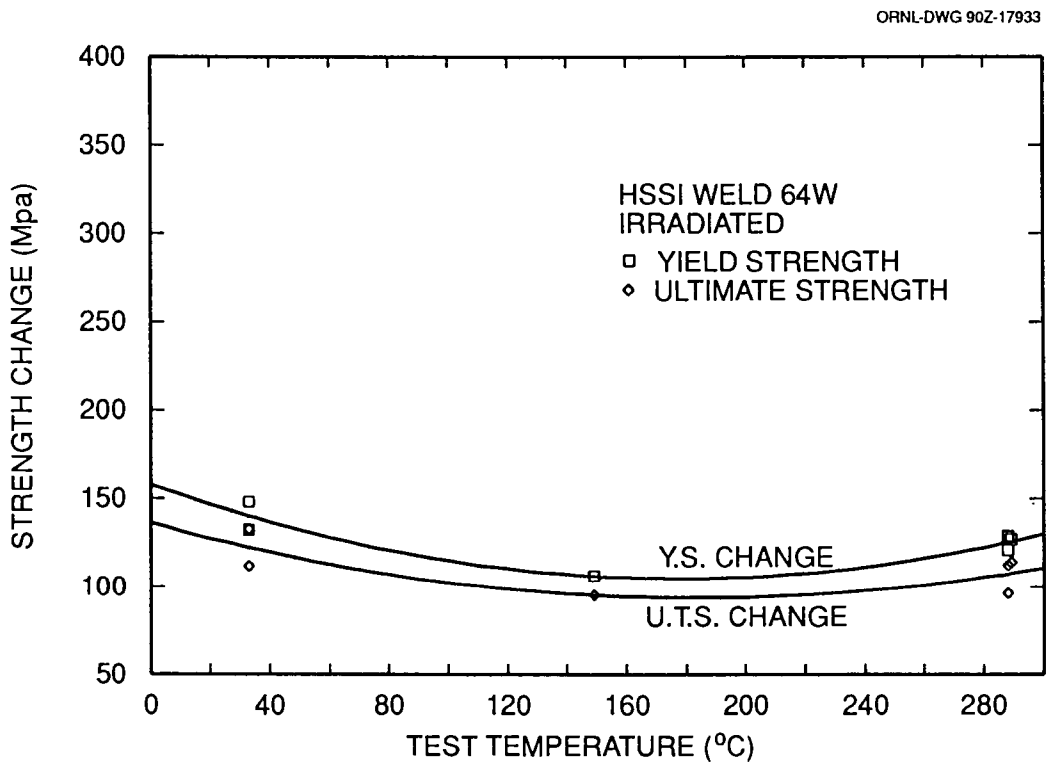
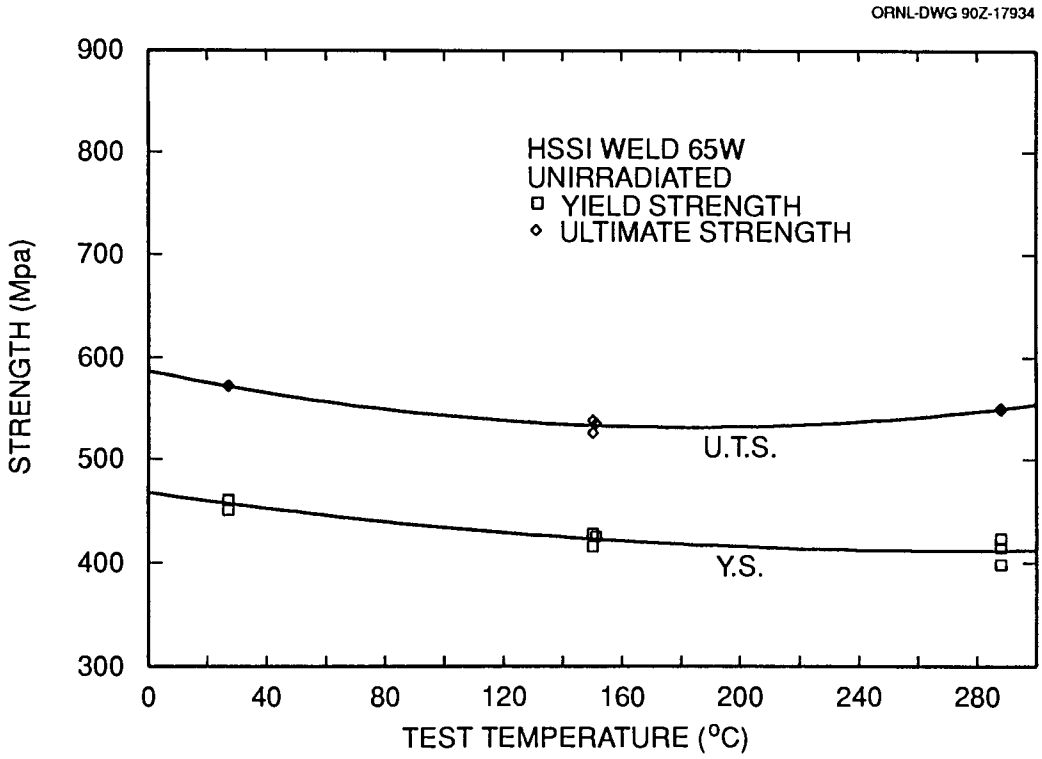
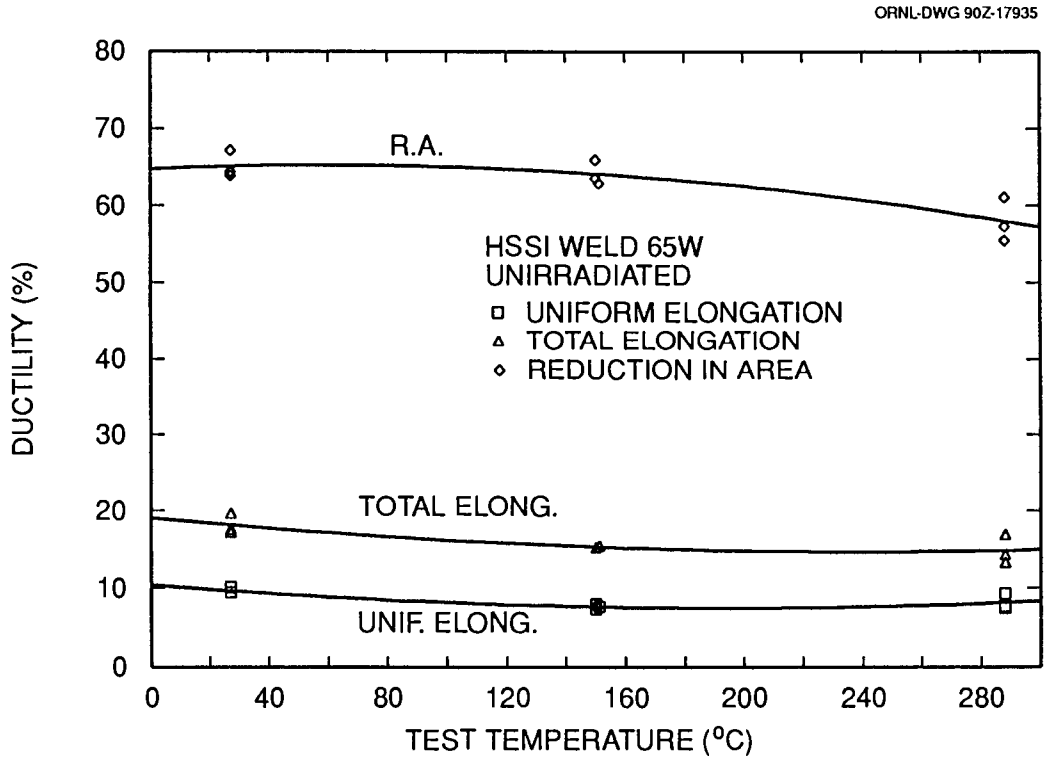


Fig. B13. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 64W.



(a)



(b)

Fig. B14. Unirradiated tensile test results vs test temperature for HSSI weld 65W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

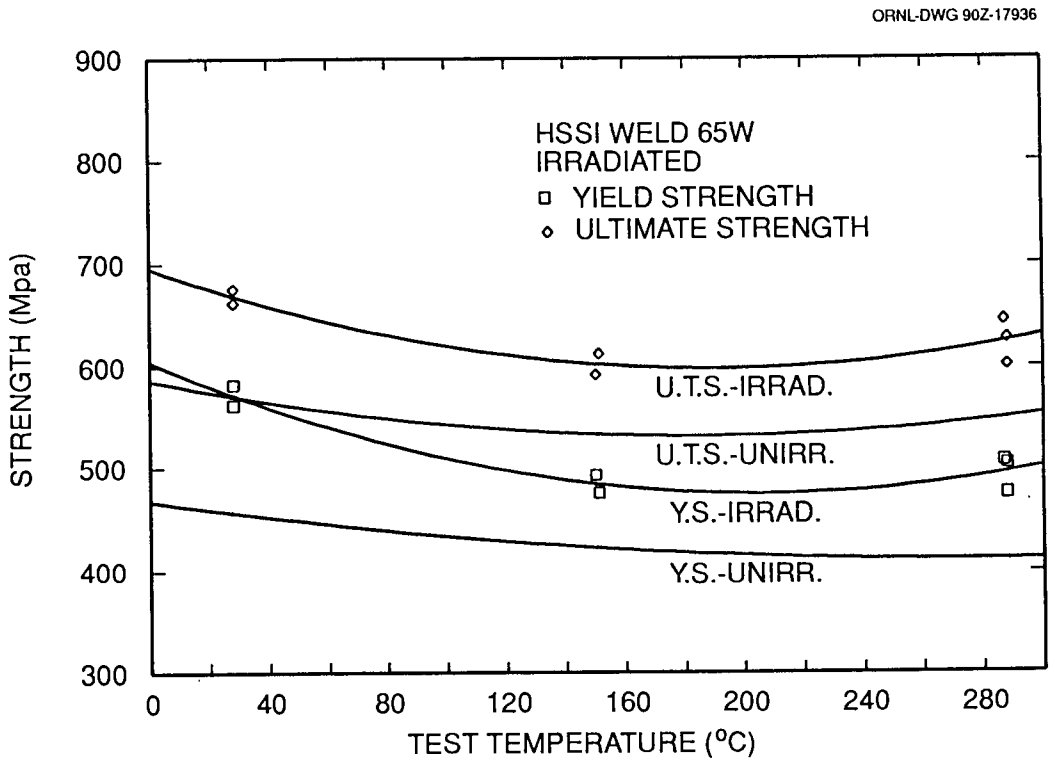


Fig. B15. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 65W. Best-fit curves to the unirradiated data are shown for comparison.

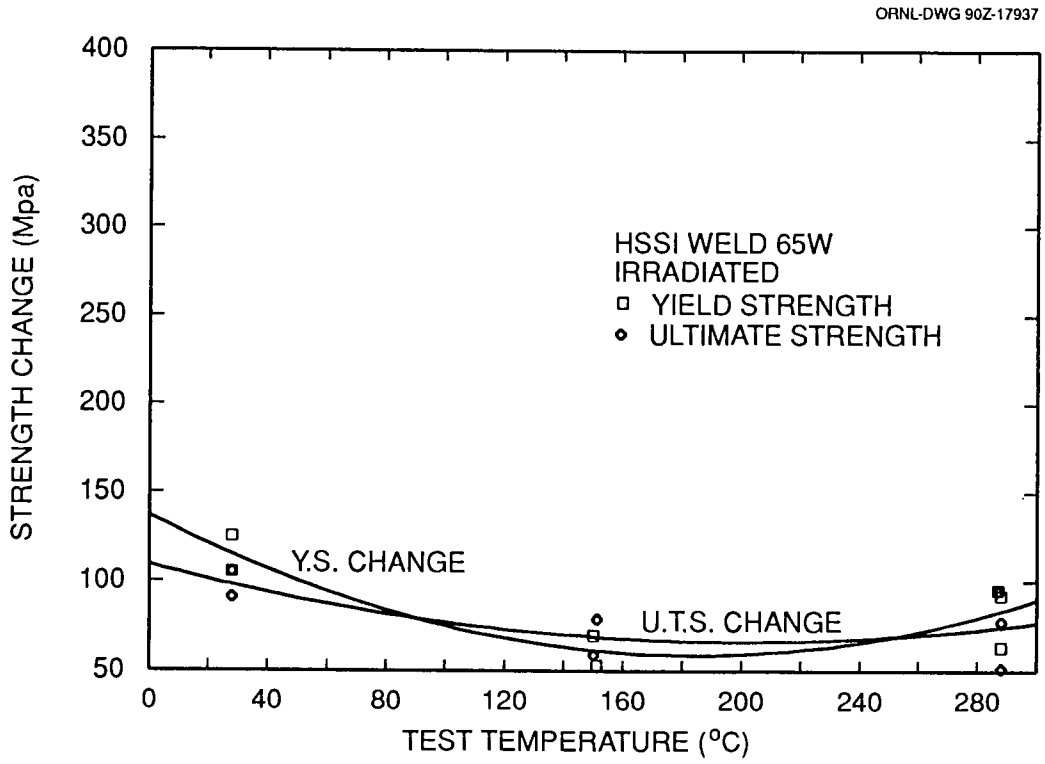
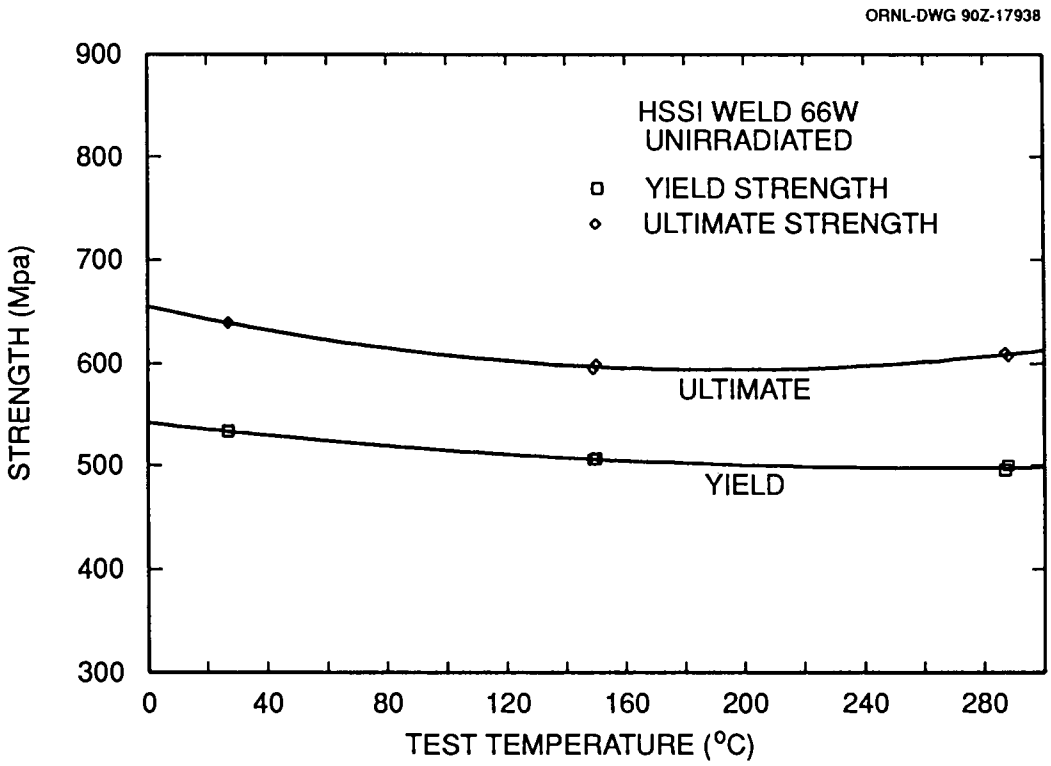
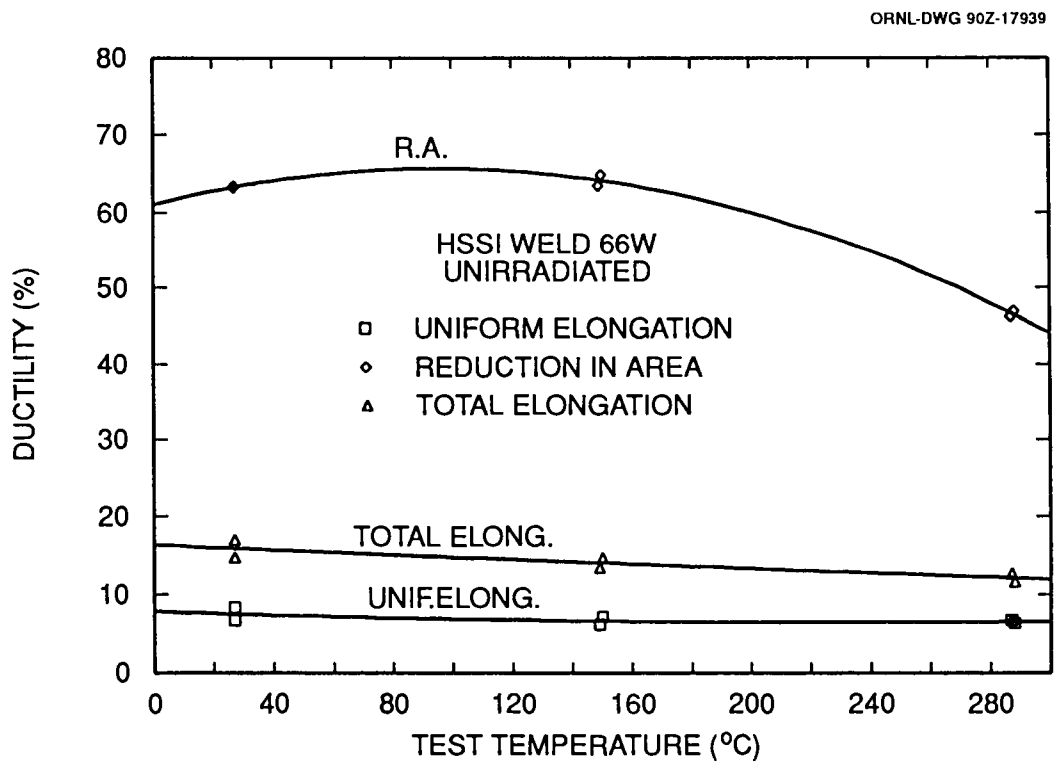


Fig. B16. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 65W.



(a)



(b)

Fig. B17. Unirradiated tensile test results vs test temperature for HSSI weld 66W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

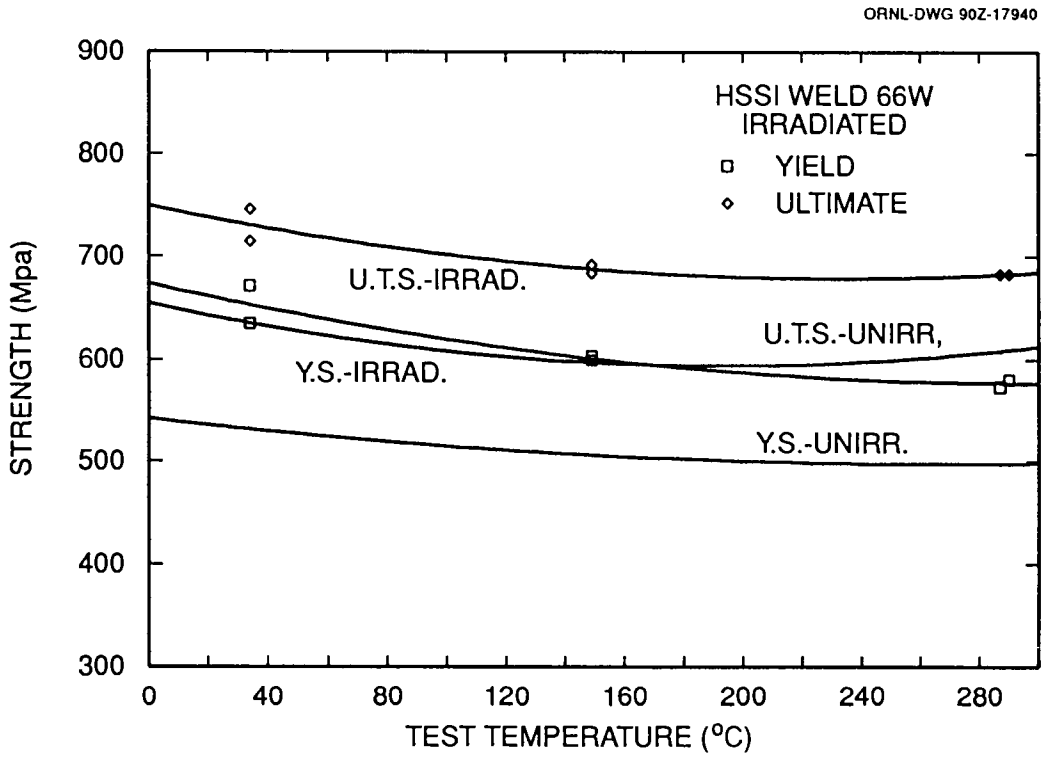


Fig. B18. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 66W. Best-fit curves to the unirradiated data are shown for comparison.

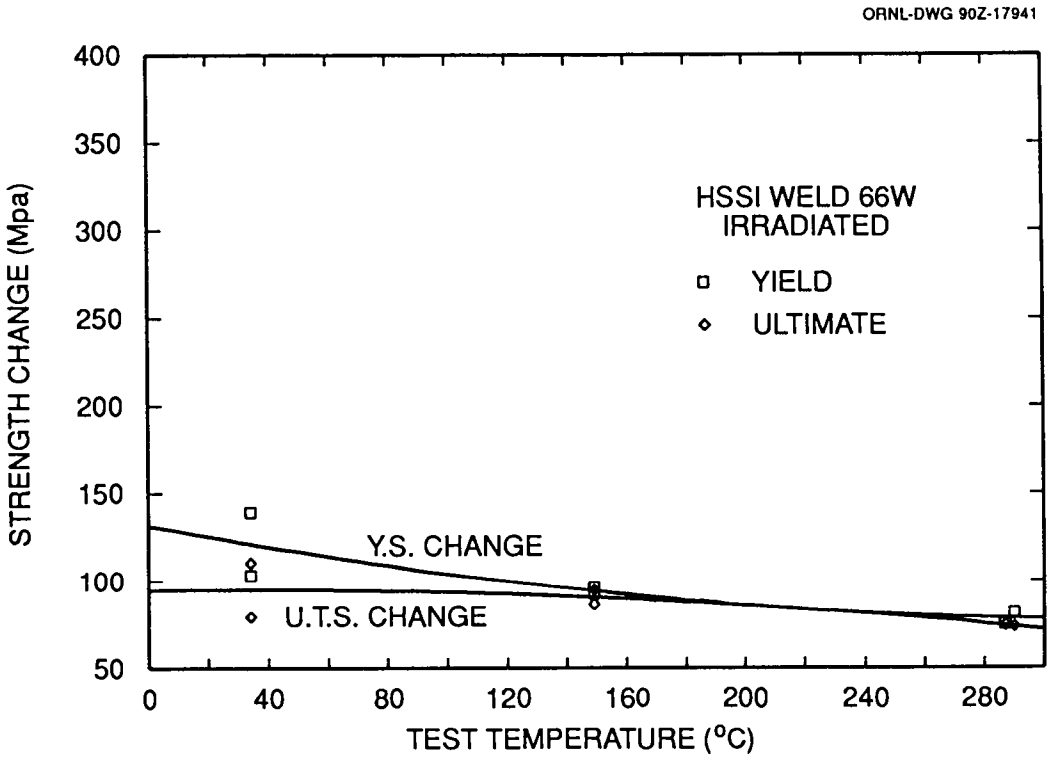
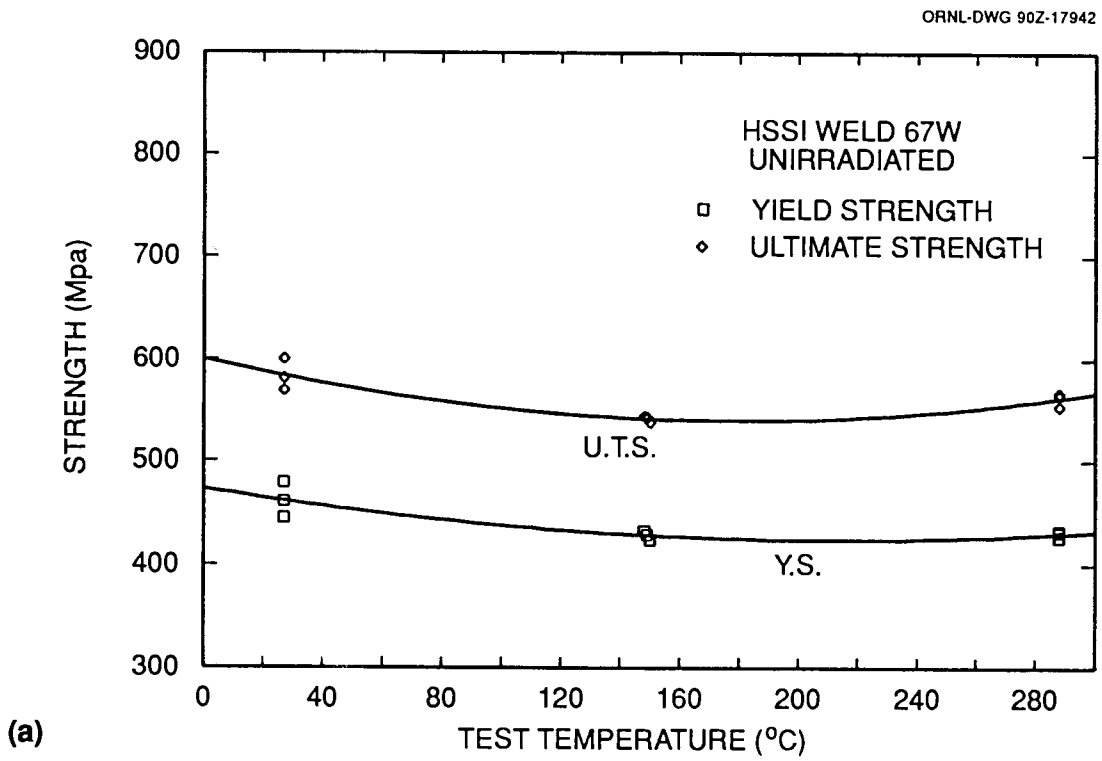
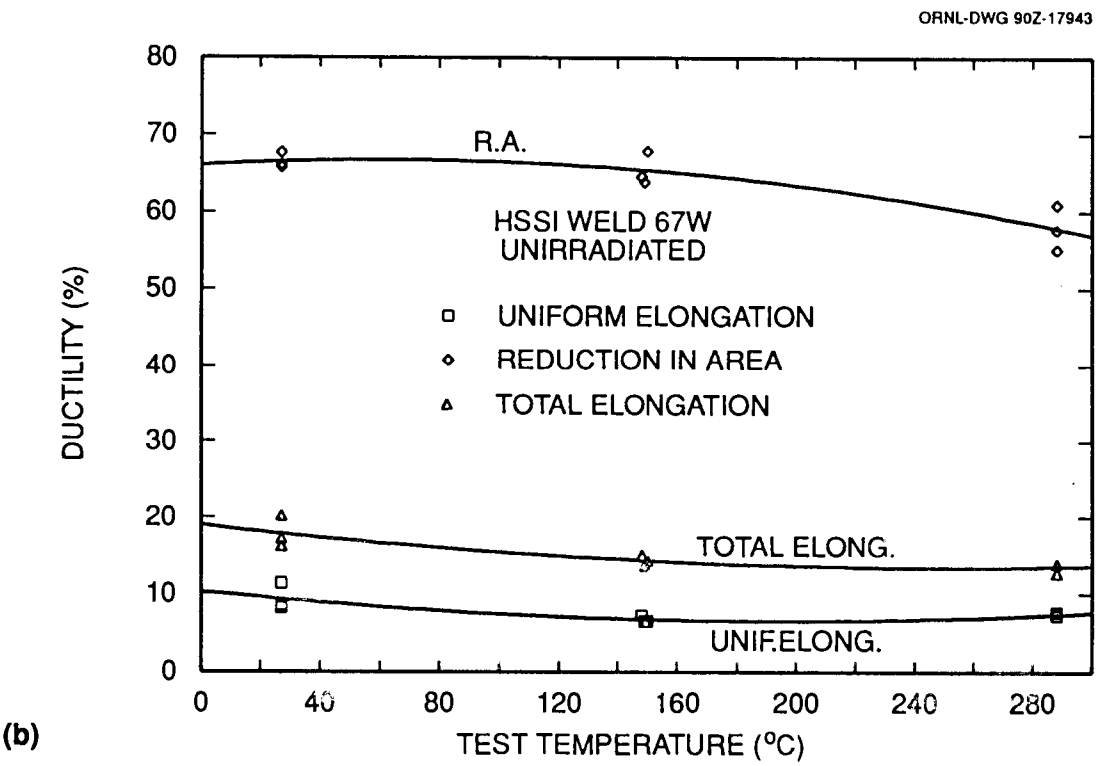


Fig. B19. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 66W.



(a)



(b)

Fig. B20. Unirradiated tensile test results vs test temperature for HSSI weld 67W; (a) yield and ultimate strength, and (b) uniform and total elongations, and reduction of area.

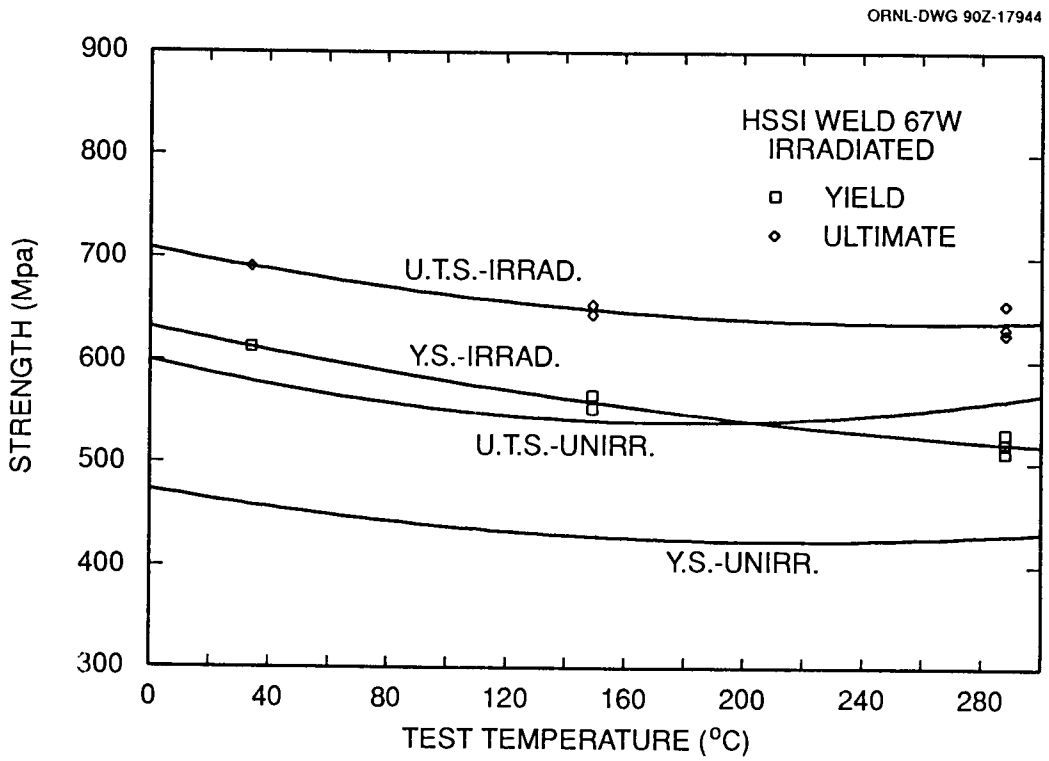


Fig. B21. Irradiated yield and ultimate strength results vs test temperature for HSSI weld 67W. Best-fit curves to the unirradiated data are shown for comparison.

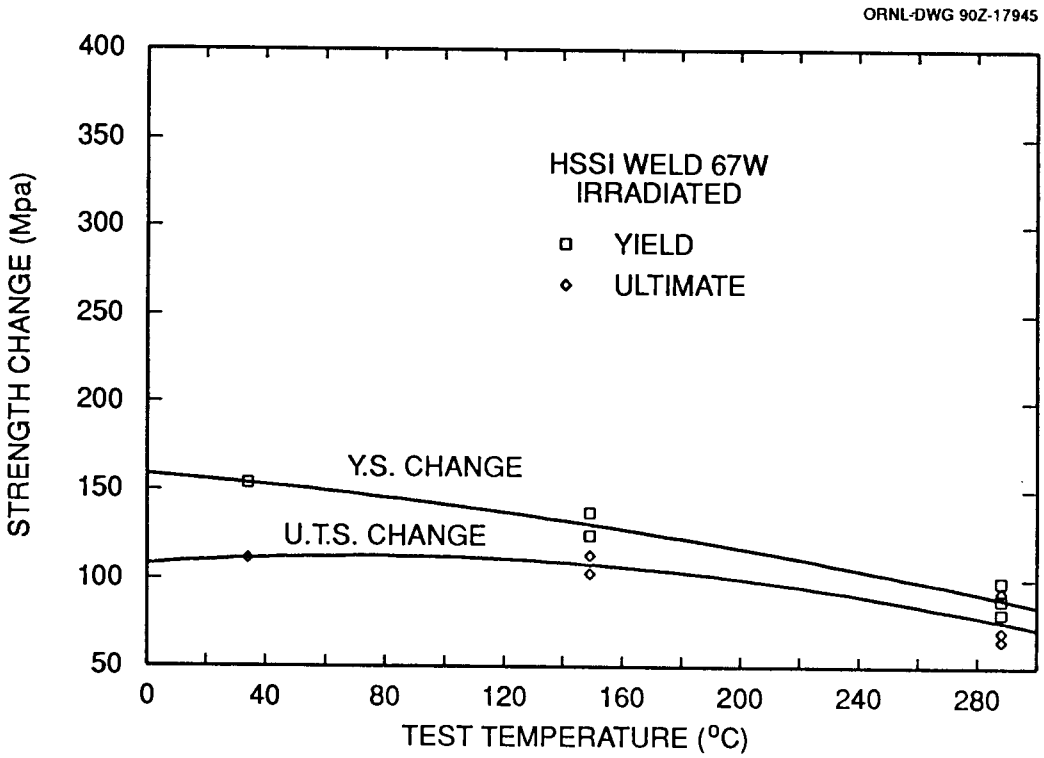
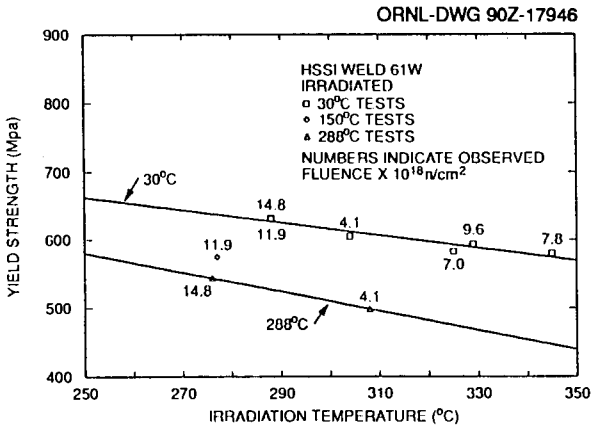
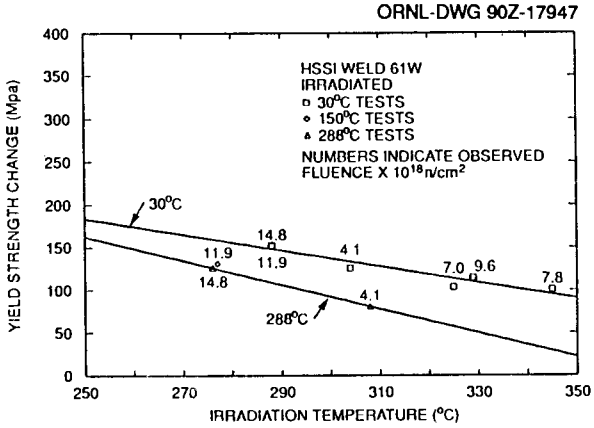


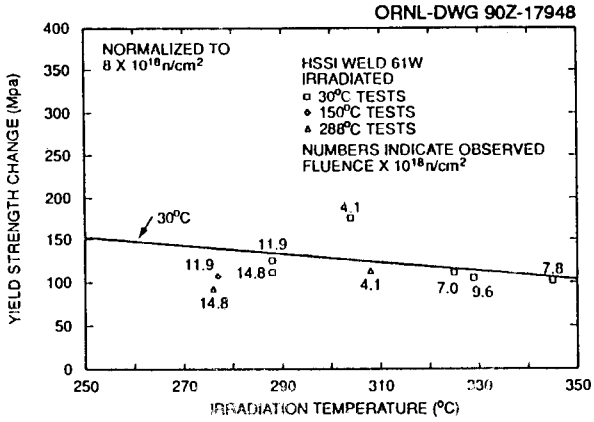
Fig. B22. Radiation-induced changes in the yield and ultimate strengths vs test temperature for HSSI weld 67W.



(a)



(b)



(c)

Fig. B23. Irradiated (a) yield strength, (b) yield strength change, and normalized yield strength change vs irradiation temperature for HSSIweld 61W. The results are shown by test temperature and the fluence [$\times 10^{-18}$ neutrons/cm^2 (>1 MeV)] for each specimen is annotated next to the datum. The data in (c) were normalized to 8×10^{18} neutrons/cm^2 (>1 MeV).

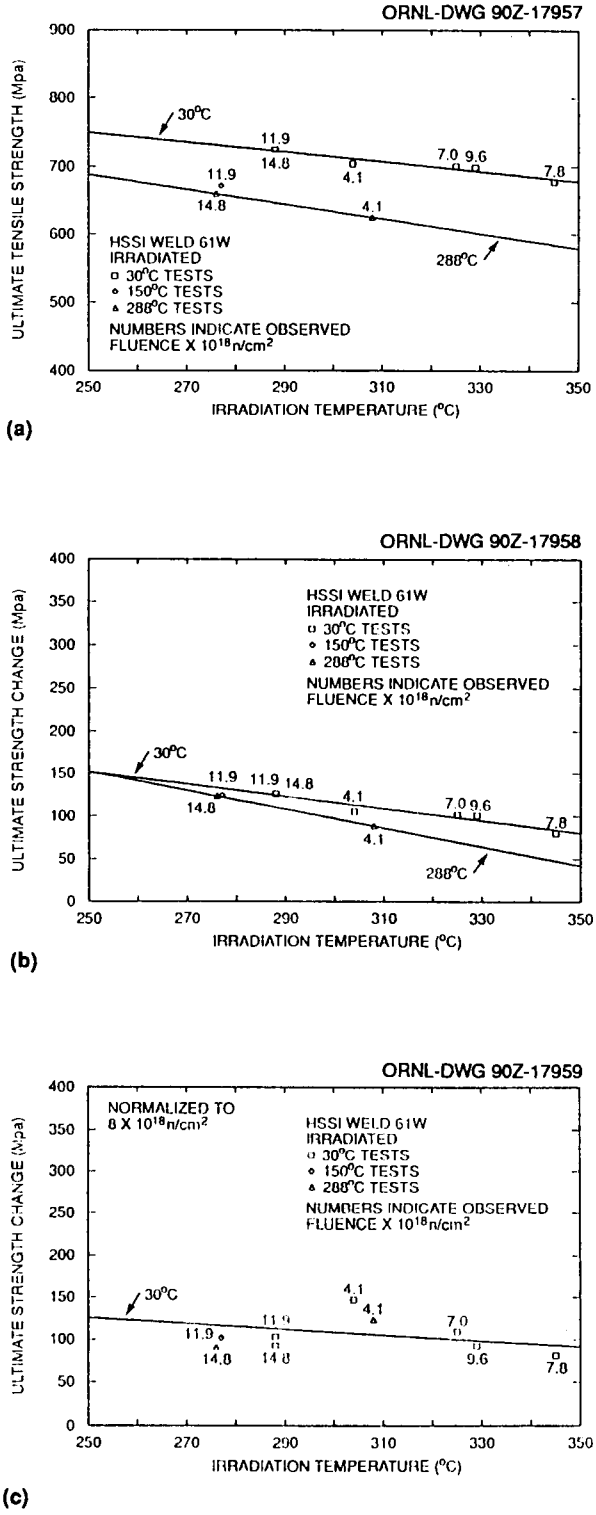


Fig. B24. Irradiated (a) ultimate strength, (b) ultimate strength change, and (c) normalized ultimate strength change vs irradiation temperature for HSSI weld 61W. The results are shown by test temperature and the fluence [$\times 10^{-18}$ neutrons/cm^2 (>1 MeV)] for each specimen is annotated next to the datum. The data in (c) were normalized to 8×10^{18} neutrons/cm^2 (>1 MeV).

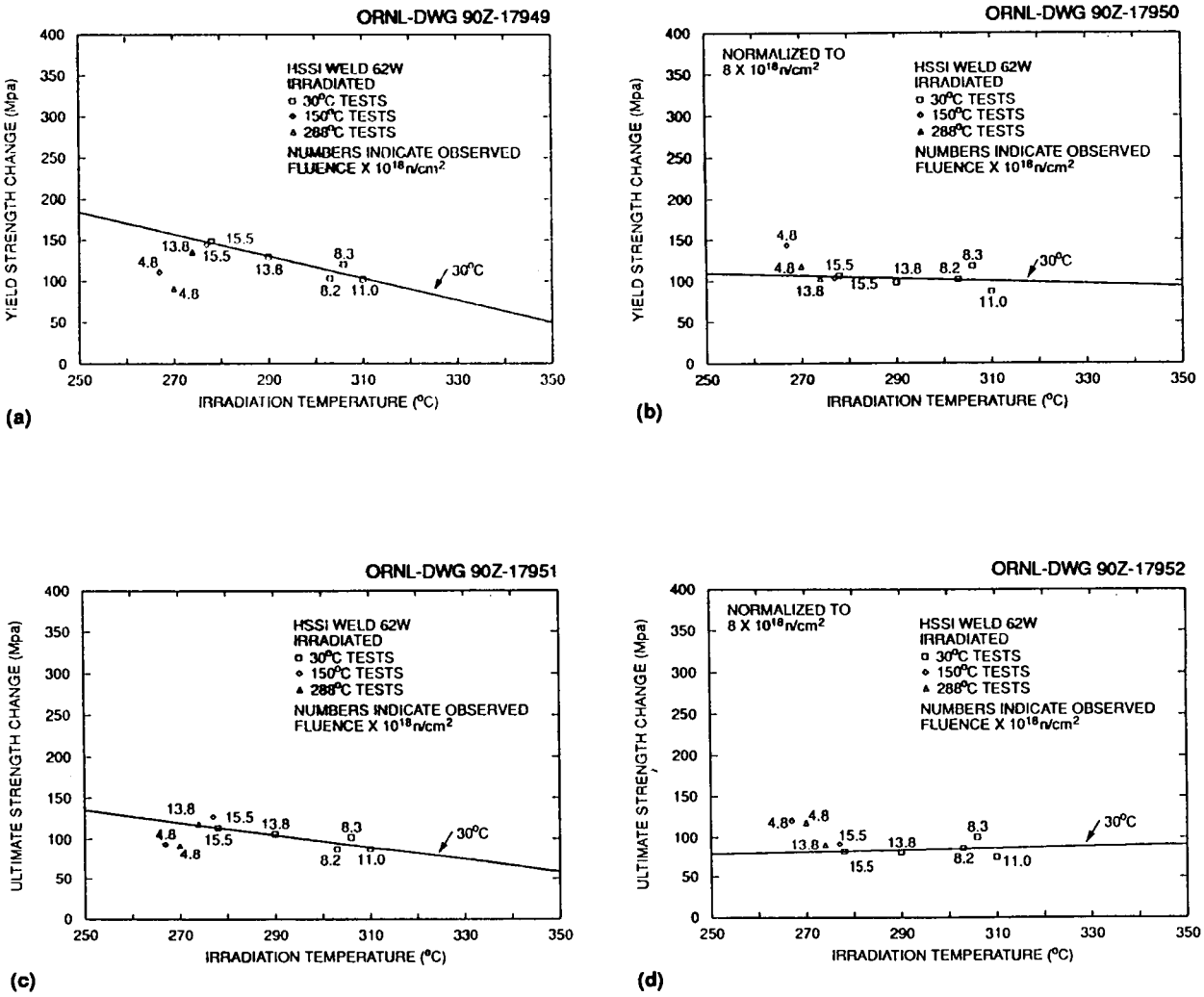


Fig. B25. Radiation-induced changes in the (a) yield strength change, (b) normalized yield strength change, (c) ultimate strength change, and (d) normalized ultimate strength change vs irradiation temperature for HSSI weld 62W. The results are shown by test temperature and the fluence [$\times 10^{-18}$ neutrons/cm^2 (>1 MeV)] for each specimen is annotated next to the datum. The data in (b) and (d) were normalized to 8×10^{18} neutrons/cm^2 (>1 MeV).

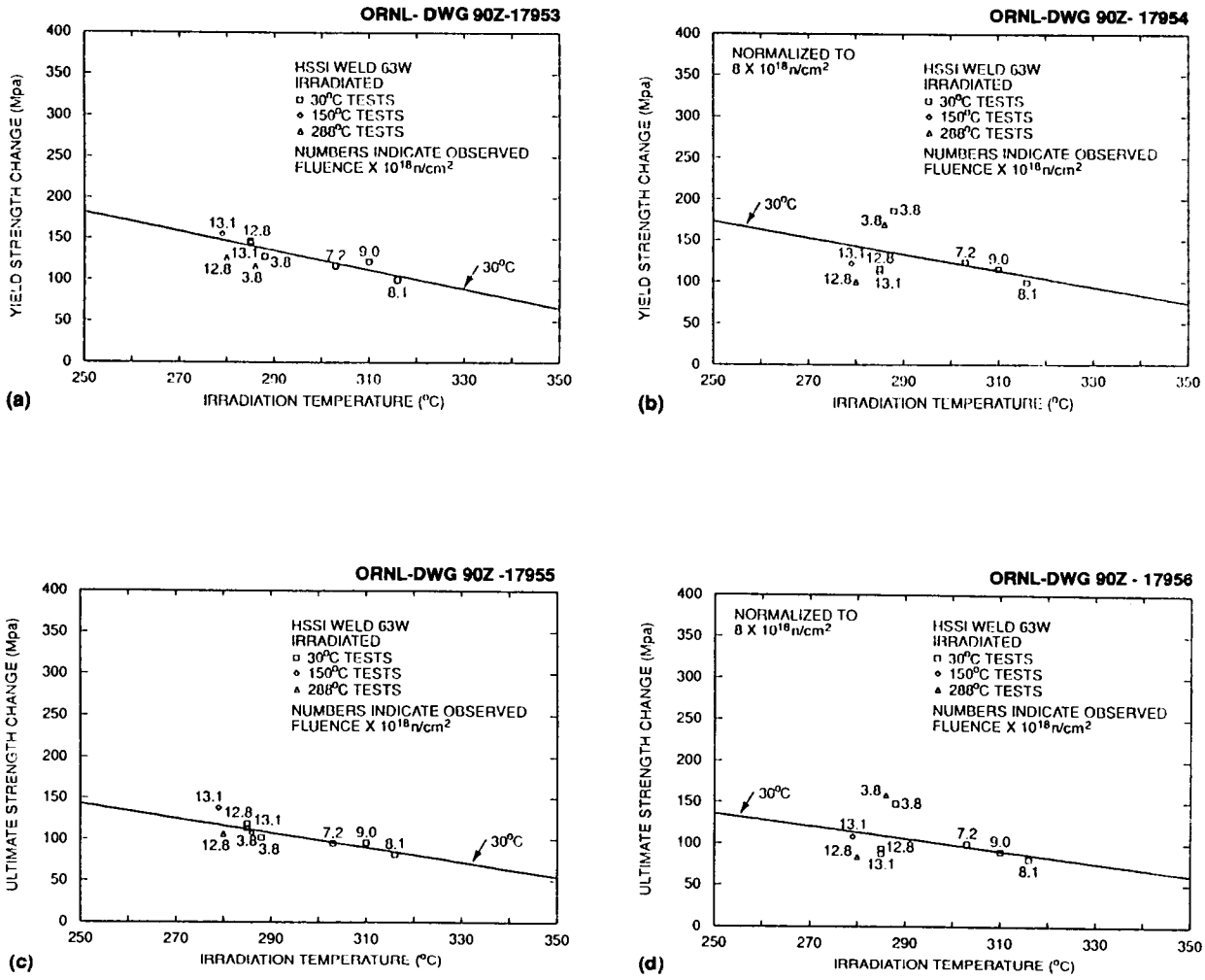


Fig. B26. Radiation-induced changes in the (a) yield strength change, (b) normalized yield strength change, (c) ultimate strength change, and (d) normalized ultimate strength change vs irradiation temperature for HSSI weld 63W. The results are shown by test temperature and the fluence [$\times 10^{-18}$ neutrons/cm^2 (>1 MeV)] for each specimen is annotated next to the datum. The data in (b) and (d) were normalized to 8×10^{18} neutrons/cm^2 (>1 MeV).

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NUREG/CR- 5696
ORNL/TM-11804

2. TITLE AND SUBTITLE

Irradiation Effects on Charpy Impact and Tensile Properties of Low Upper-Shelf Welds, HSSI Series 2 and 3

3. DATE REPORT PUBLISHED

MONTH	YEAR
August	1991

4. FIN OR GRANT NUMBER

L1098

5. AUTHOR(S)

R. K. Nanstad, R. G. Berggren

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

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10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

The objective of the Second and Third Irradiation Series was to investigate the effects of irradiation on the ductile fracture toughness of seven commercially fabricated, low upper-shelf welds. All seven submerged-arc welds were fabricated with copper-coated wire and Linde 80 flux and had average bulk copper contents from 0.21 to 0.42% with nickel levels of about 0.6%. In addition to the fracture toughness specimens which were irradiated at nominally 288°C, Charpy V-notch and tensile specimens were included in the capsules at available locations which were subject to wide variations in irradiation temperature and fluence. This report presents analyses of the Charpy impact and tensile test data. Analyses revealed a dependence of yield strength on irradiation temperature of -1.1 MPa/°C, while the Charpy impact energy dependencies were about -0.5°C/°C for transition temperature shift and -0.06 J/°C for upper-shelf decrease. After adjustment to an irradiation temperature of 288°C and normalization to a fluence of 8×10^{18} neutrons/cm^2 (>1 MeV), the Charpy transition temperature shifts ranged from 59 to 123°C while the upper-shelf energies ranged from 58 to 79 J.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

Charpy V-notch impact
copper content
fracture toughness
irradiation
irradiation temperature
light-water reactors
Linde 80 flux
neutron fluence
reactor pressure vessels
submerged-arc welds
surveillance
tensile strength
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upper-shelf energy drop
yield strength

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page)

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15. NUMBER OF PAGES

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NRC FORM 335 (2-89)