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2007-333 BWR Vessel & Internals Project (BWRVIP)

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Attention: John Honcharik

Subject: Project No. 704 – BWRVIP-178NP: BWR Vessel and Internals Project, Nonproprietary Report of Materials Test Results from the BWR Integrated Surveillance Program (ISP)

Enclosed are five (5) copies of the non-proprietary report "BWRVIP-178NP: BWR Vessel and Internals Project, Nonproprietary Report of Materials Test Results from the BWR Integrated Surveillance Program (ISP)," EPRI Technical Report 1015504, October 2007. This report is being transmitted to the NRC as a means of exchanging information with the NRC for the purpose of supporting generic regulatory improvements related to surveillance programs for monitoring changes in BWR reactor pressure vessel material properties due to neutron irradiation.

Previous published BWRVIP capsule reports are EPRI proprietary licensed material. This non-proprietary report is issued in order to provide a nonproprietary summary of the capsule test results that may be useful to the industry.

If you have any questions on this subject please contact Chuck Wirtz (FirstEnergy, BWRVIP Integration Committee Technical Chairman) by telephone at 440.280.7665 or by e-mail at cjwirtz@firstenergycorp.com.

Sincerely,

Rick Libra

Rick Libra
Exelon
Chairman, BWR Vessel and Internals Project

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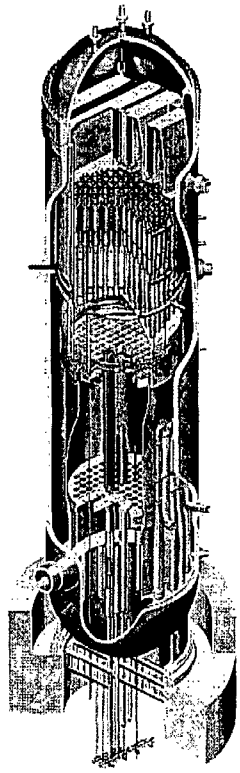
BWRVIP-178NP: BWR Vessel and Internals Project

Nonproprietary Report of Material Test Results from the BWR Integrated Surveillance Program (ISP)



BWRVIP-178NP: BWR Vessel and Internals Project

Nonproprietary Report of Material Test Results from the BWR Integrated Surveillance Program (ISP)

1015504

Final Report, October 2007

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The report is a corporate document that should be cited in the literature in the following manner:

BWRVIP-178NP: BWR Vessel and Internals Project, Nonproprietary Report of Material Test Results from the BWR Integrated Surveillance Program (ISP). EPRI, Palo Alto, CA: 2007. 1015504.

REPORT SUMMARY

In 2002, an Integrated Surveillance Program (ISP) was approved and adopted for the U.S boiling water reactor (BWR) fleet. Instead of each plant continuing to test its own surveillance capsules, the BWR Vessel and Internals Project (BWRVIP) assumed the responsibility to test the remaining capsules of 13 ISP "host plants" and nine capsules from the Supplementary Surveillance Program (SSP). This report provides a summary of the test results obtained from testing of nine SSP capsules and one ISP host plant capsule. Capsule reports were generated for the 10 capsules tested and published per 10 CFR 50 Appendix H. Because the published capsule reports are EPRI proprietary licensed material, this report is issued in order to provide a nonproprietary summary of the capsule test results that may be useful to the industry.

Background

The surveillance materials in the host plant capsules, combined with selected materials from the SSP capsules, represent the BWR fleet beltline materials for the purpose of radiation embrittlement surveillance. To date, all nine SSP capsules have been tested, and one ISP host plant capsule—the River Bend 183 Degree Capsule—has been tested. Testing of other ISP host plant capsules will be conducted over time according to the approved ISP test schedule.

Objective

To summarize the test results for the specimens in the 10 surveillance capsules that have been tested.

Approach

The test results include the best-estimate chemistry values of the surveillance materials, the Charpy V-notch test results for the baseline (unirradiated) and irradiated materials, and associated flux and fluence values for the irradiated specimens. Investigators calculated best-estimate chemistry content of the surveillance materials by averaging the appropriate chemistry measurement data. Charpy V-notch test data for each specimen set was fit to a tanh curve in order to determine transition temperature properties: 30 ft-lb (41 J) transition temperature, 50 ft-lb (68 J) transition temperature, the transition temperature at 35 mils (0.89 mm) lateral expansion, and the upper shelf energy (USE). Investigators conducted a neutron fluence evaluation per Regulatory Guide 1.190 for each capsule in order to determine the fluence of each specimen set. Finally, they calculated the shifts (the difference between the irradiated material transition temperature and the baseline transition temperature), and identified the fluences associated with such shifts.

Results

This report provides an updated, comprehensive summary of the ISP/SSP capsule tests conducted to date. Because it is a nonproprietary summary report, only the summary results are presented; the background test data are reported in the proprietary capsule reports.

EPRI Perspective

This report provides a valuable summary of recent BWR-specific surveillance testing conducted by the BWRVIP ISP. This data may be useful to the industry and provides a nonproprietary reference for future studies of ISP surveillance results as well as research into a BWR-specific trend curve.

Keywords

Reactor Pressure Vessel Integrity
Reactor Vessel Surveillance Program
Radiation Embrittlement
Boiling Water Reactor
Charpy Testing
Mechanical Properties

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1
INTRODUCTION

Test coupons of reactor vessel ferritic beltline materials are irradiated in reactor surveillance capsules to facilitate evaluation of vessel fracture toughness in vessel integrity evaluations. The key values that characterize fracture toughness are the reference temperature of nil-ductility transition (RT_{NDT}) and the upper shelf energy (USE). These are defined in 10CFR50 Appendix G [1] and in Appendix G of the ASME Boiler and Pressure Vessel Code, Section XI [2]. Appendix H of 10CFR50 [1] and ASTM E185-82 [3] establish the methods to be used for testing of surveillance capsule materials.

In the late 1980's the BWR Owners' Group (BWROG) initiated the Supplemental Surveillance Program (SSP) [4] to obtain BWR surveillance data to supplement the individual plant surveillance programs. Nine (9) SSP capsules containing plate and weld test specimens were placed in two host reactors. Three capsules (designated A, B, and C) were placed into the Cooper reactor, and the remaining six capsules (D through I) were placed into the Oyster Creek reactor.

In the late 1990's the BWR Vessel and Internal Project (BWRVIP) initiated the BWRVIP Integrated Surveillance Program (ISP) [5]. The ISP identified thirteen (13) host plants whose capsules will continue to be tested as representative of the BWR fleet; the capsules for other plants were deferred indefinitely. In addition to the capsules from the ISP host plants, the SSP capsules were also included in the ISP because the SSP materials represented a wide range of BWR beltline materials and their baseline properties were well-characterized. The BWRVIP assumed responsibility for testing and evaluation of the SSP capsules.

This report provides a nonproprietary summary of the chemistry and Charpy V-notch test results of the surveillance materials tested to date under the auspices of the BWRVIP ISP. Ten capsules have been tested: nine (9) BWR SSP capsules and the River Bend 183° Capsule. Charpy V-notch (CVN) impact testing was performed to establish the mechanical properties of the irradiated surveillance materials.

Chapter 2 of this report provides a summary of the best estimate chemistry for the surveillance materials in the capsules tested by the ISP. Chapter 3 provides a tabular summary of the Charpy V-notch properties of the materials: 30 ft-lb (41 J) transition temperature, 50 ft-lb (68 J) transition temperature, the transition temperature at 35 mils (0.89 mm) lateral expansion, and the upper shelf energy (USE). Baseline (unirradiated) values of these parameters were also determined, and the shift in each parameter due to irradiation to a specific neutron fluence ($E > 1.0$ MeV) is shown.

Tables 1-1 and 1-2 list the plate and weld materials, respectively, contained in the capsules which have been tested by the BWRVIP and for which data are provided in this report. For each material, a list of the tested ISP capsules that contained that material is provided.

Table 1-1
Plate and Forging Materials in the ISP Capsules Tested by BWRVIP

Heat / Identity	Material[1]	Capsules Tested by BWRVIP
EP2	Japanese/EPRI Plate (SA533B-1)	SSP Capsules D, E, G, I
A1224-1	Grand Gulf Plate (SA533B-1)	SSP Capsules A, B, D, E, G, I
C2331-2	Cooper Plate (SA533B-1)	SSP Capsules A, B, D, E, G, I
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	SSP Capsules A, B, D, E, G, I
C3278-2	FitzPatrick Plate (SA533B-1)	SSP Capsules A, B, D, E, G, I
B&W-1(BM)	B&W/EPRI Plate (SA302B, Mod)	SSP Capsules F, H
B0673-1	Duane Arnold Plate (SA533B-1)	SSP Capsule C
C1079-1	Millstone 1 Plate (SA302B, Mod)	SSP Capsules C, F, H
A0610-1	Quad Cities 1 Plate (SA302B, Mod)	SSP Capsules C, F, H
A1195-1	HSST-02 Plate (SA533B-1)	SSP Capsules C, F, H
C3985-2	Hatch 1 Plate (SA533B-1)	SSP Capsules C, H
BMF	B&W/EPRI (SA508-2)	SSP Capsule H
A0421	ASTM Standard (SA302B)	SSP Capsule H
C3054-2	River Bend Plate (SA533B-1)	River Bend 183°

1. All plate Charpy test specimens are transverse (TL) except A0421 and B0673-1, which are longitudinal (LT).

Table 1-2
Weld Materials in the ISP Capsules Tested by BWRVIP

Heat / Identity	Material	Capsules
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	SSP Capsules A, B, D, E, G, I
34B009	Millstone 1 Weld (Submerged Arc Weld)	SSP Capsules A, B, D, E, G, I
_P2-21 [1]	Quad Cities 2 Weld (Electroslag Weld)	SSP Capsules A, B, D, E, G, I
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	SSP Capsules A, B, D, E, G, I
B&W-1 (WM)	B&W/EPRI Linde 80 Weld (Submerged Arc Weld)	SSP Capsule F
EE/EK	Duane Arnold Weld (Shielded Metal Arc Weld)	SSP Capsule F
_P2-BW [1]	B&W Linde 80 Weld (Submerged Arc Weld)	SSP Capsules C, F, H
_P2-6 [1]	Humboldt Bay 3 Weld (Submerged Arc Weld)	SSP Capsules C, F, H
5P6756	River Bend Weld (Submerged Arc Weld)	SSP Capsules C, F, and H, and River Bend 183°
20291	Cooper (Submerged Arc Weld)	SSP Capsule C
CE-1(WM)	CE/EPRI Linde 1092 #1 Weld (Submerged Arc Weld)	SSP Capsules D, I
CE-2(WM)	CE/EPRI Linde 1092 #2 Weld (Submerged Arc Weld)	SSP Capsules E, G

1. The underscore is a placeholder for the capsule letter, e.g., for Capsule A the underscore is replaced with the letter A.

Implementation Requirements

The information documented in this report is provided for information only. The implementation requirements of Nuclear Energy Institute (NEI) 03-08, Guideline for the Management of Materials Issues, are not applicable.

2
CHEMICAL COMPOSITIONS

The best estimate chemistry of the surveillance materials irradiated in SSP capsules A through I and the River Bend 183° capsule are summarized in Tables 2-1 and 2-2.

Best Estimate Chemical Compositions

The best estimate chemistry compositions reported in Tables 2-1 and 2-2 are taken from References [6] through [9], and are based on the average of reported measurements.

The materials selected for the BWROG SSP capsules were sourced from several sources. Except for the Duane Arnold and Cooper specimens, most BWR materials were selected by General Electric (GE) from GE archive storage. The ASTM 302B standard plate material was also taken from GE archives. The HSST-02 standard was provided by Oak Ridge National Laboratory, and the B&W Linde 80 weld was provided by B&W from its archives. When the SSP capsules were assembled, GE performed baseline Charpy testing on all those materials; then, chemical content evaluations were performed on a broken Charpy specimen half of each material. The baseline Charpy and chemistry results were reported by GE in Reference [10]. If chemistry test results from an original plant capsule program are available for a BWR surveillance material, then the best estimate given for that material in Table 2-1 or 2-2 also considered that data along with the Reference [10] data.

The Duane Arnold plate and weld, and Cooper weld SSP specimens were provided by those utilities from their own archives. No further testing was conducted by GE, and chemistry data for those materials were obtained from plant data.

Several materials for the SSP capsules were provided by EPRI. Chemistries for the EPRI materials (e.g., B&W/EPRI, CE/EPRI, and Japanese/EPRI plates or welds) were provided by the fabricators. For weld heat B&W-1(WM) in SSF Capsule F, the reported chemistry is from testing commissioned by EPRI [11] on broken Charpy specimens after SSP Capsule F was tested.

Table 2-1
Best Estimate Chemistry Content (wt %) for BWRVIP ISP/SSP Plate Materials

Identity	Material	Cu	Ni	P	S	Si
EP2	Japanese/EPRI Plate (SA533B-1)	0.06	0.59	0.006	0.008	0.22
A1224-1	Grand Gulf Plate (SA533B-1)	0.03	0.65	0.012	0.012	0.28
C2331-2	Cooper Plate (SA533B-1)	0.16	0.62	0.014	0.020	0.24
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	0.172	0.584	0.018	0.028	0.17
C3278-2	FitzPatrick Plate (SA533B-1)	0.11	0.61	0.013	0.018	0.23
B&W-1(BM)	B&W/EPRI Plate (SA302B, Mod)	0.155	0.63	0.012	0.017	0.20
B0673-1	Duane Arnold Plate (SA533B-1)	0.15	0.65	0.010	N/A	0.07
C1079-1	Millstone 1 Plate (SA302B, Mod)	0.22	0.51	0.018	0.028	0.22
A0610-1	Quad Cities 1 Plate (SA302B, Mod)	0.17	0.52	0.015	0.018	0.19
A1195-1	HSST-02 Plate (SA533B-1)	0.15	0.70	0.014	0.020	0.22
C3985-2	Hatch 1 Plate (SA533B-1)	0.11	0.60	0.015	0.017	0.27
BMF	B&W/EPRI (SA508-2)	0.04	0.75	0.006	0.012	0.25
A0421	ASTM Standard (SA302B)	0.19	0.17	0.017	0.025	0.27
C3054-2	River Bend Plate (SA533B-1)	0.08	0.67	0.007	0.016	0.28

Table 2-2
Best Estimate Chemistry Content (wt %) for BWRVIP ISP/SSP Weld Materials

Identity	Material	Cu	Ni	P	S	Si
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	0.01	0.90	0.012	0.017	0.43
34B009	Millstone 1 Weld (Submerged Arc Weld)	0.15	1.81	0.017	0.016	0.21
_P2-21 (1)	Quad Cities 2 Weld (Electroslag Weld)	0.11	0.24	0.015	0.017	0.13
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	0.29	0.69	0.016	0.018	0.47
B&W-1 (WM)	B&W/EPRI Linde 80 Weld (Submerged Arc Weld)	0.28	0.57	0.019	0.008	0.60
_P2-6 (1)	Humboldt Bay 3 Weld (Submerged Arc Weld)	0.27	0.06	0.016	0.016	0.28
5P6756	River Bend Weld (Submerged Arc Weld)	0.06	0.93	0.009	0.015	0.40
_P2-BW (1)	B&W Linde 80 Weld (Submerged Arc Weld)	0.26	0.56	0.014	0.011	0.53
EE/EK	Duane Arnold Weld (Shielded Metal Arc Weld)	0.02	0.93	0.01	N/A	0.14
20291	Cooper (Submerged Arc Weld)	0.23	0.75	0.014	NA	NA
CE-1(WM)	CE/EPRI Linde 1092 #1 Weld (Submerged Arc Weld)	0.22	1.00	0.014	0.009	0.21
CE-2(WM)	CE/EPRI Linde 1092 #2 Weld (Submerged Arc Weld)	0.21	0.86	0.012	0.012	0.23

1. The underscore is a placeholder for the capsule letter, e.g., for Capsule A the underscore is replaced with the letter A.

3
FRACTURE TOUGHNESS PROPERTIES

Material Irradiation

To support the evaluation of neutron irradiation on material fracture toughness, the best estimate flux and fluence for each specimen set in each tested capsule were determined according to the guidance of Reg. Guide 1.190 [12]. The results are provided in the following tables.

The fluence evaluation performed for the original capsule report for SSP Capsule D, G, and H, BWRVIP-87 [13], predated and did not conform to Reg. Guide 1.190. A reevaluation was later conducted and reported in BWRVIP-128 [14]. The best estimate flux and fluence values listed in Table 3-1 for materials in SSP Capsules D, G, and H are taken from the updated fluence evaluation in BWRVIP-128.

The best estimate flux and fluence values for the materials in SSP Capsules A, B, and C are from the SSP ABC capsule report, BWRVIP-169 [8]; the values for materials in SSP Capsules E, F, and I are from the EFI capsule report, BWRVIP-111 [7]. The River Bend 183° Capsule flux and fluence (Table 3-2) were reported in BWRVIP-113 [9].

Table 3-1
Best Estimate Flux and Fluence for SSP Capsule Materials

Capsule	Source	Material Type	Heat Number	Specimen ID	Flux ($x\ 10^{10}$, n/cm^2-s, E>1.0MeV)	Fluence ($x\ 10^{17}$, n/cm^2, E>1.0MeV)
SSP Capsule A	Grand Gulf	SA533B-1	A1224-1	AP1-67	0.143	3.80
(Cooper)	Cooper	SA533B-1	C2331-2	AP1-30	0.143	3.82
	Nine Mile Pt 1	SA302B, Mod.	P2130-2	AP1-11	0.142	3.78
	Fitzpatrick	SA533B-1	C3278-2	AP1-28	0.140	3.74
	Grand Gulf	SAW[1]	5P6214B	AP2-67	0.153	4.09
	Millstone 1	SAW[1]	34B009	AP2-15	0.153	4.08
	Quad Cities 2	Electroslag Weld	unknown	AP2-21	0.152	4.06
	Quad Cities 1	SAW[1]	406L44	AP2-20	0.149	3.97
SSP Capsule B	Grand Gulf	SA533B-1	A1224-1	BP1-67	0.184	4.90
(Cooper)	Cooper	SA533B-1	C2331-2	BP1-30	0.180	4.79
	Nine Mile Pt 1	SA302B, Mod.	P2130-2	BP1-11	0.175	4.68
	Fitzpatrick	SA533B-1	C3278-2	BP1-28	0.170	4.54
	Grand Gulf	SAW[1]	5P6214B	BP2-67	0.197	5.26
	Millstone 1	SAW[1]	34B009	BP2-15	0.194	5.17
	Quad Cities 2	Electroslag Weld	unknown	BP2-21	0.189	5.04
	Quad Cities 1	SAW[1]	406L44	BP2-20	0.185	4.93
SSP Capsule C	Hatch 1	SA533B-1	C3985-2	CP1-36	0.117	3.11
(Cooper)	Millstone 1	SA302B, Mod.	C1079-1	CP1-15	0.113	3.02
	Quad Cities 1	SA302B, Mod.	A0610-1	CP1-20	0.110	2.93
	HSST-02	SA533B-1	A1195-1	CP1-H2	0.104	2.79
	Cooper	SAW[1]	20291	EY_,J1_ [2]	0.123	3.29
	B&W Linde 80	SAW[1]	unknown	CP2-BW	0.121	3.22
	Humboldt Bay 3	SAW[1]	unknown	CP2-06	0.118	3.13
	River Bend	SAW[1]	5P6756	CP2-72	0.110	2.93

1. SAW – Submerged Arc Weld
2. The underscore is a placeholder for the specimen number

Table 3-1
Best Estimate Flux and Fluence for SSP Capsule Materials (continued)

Capsule	Source	Material Type	Heat Number	Specimen ID	Flux ($x 10^{10}$, n/cm^2-s, E>1.0MeV)	Fluence ($x 10^{17}$, n/cm^2, E>1.0MeV)
SSP Capsule D	Japanese/EPRI	SA533-1	EP2	EP2-41..83	1.0179	10.044
(Oyster Creek)	Grand Gulf	SA533B-1	A1224-1	DP1-67	1.0301	10.164
	Cooper	SA533B-1	C2331-2	DP1-30	1.0254	10.118
	Nine Mile Pt. 1	SA302B, Mod.	P2130-2	DP1-11	1.0248	10.112
	Fitzpatrick	SA533B-1	C3278-2	DP1-28	1.0065	9.9311
	CE/EPRI Linde 1092 #1	SAW(1)	CE-1 (WM)	C111..C131	1.0338	10.202
	Grand Gulf	SAW(1)	5P6214B	DP2-67	1.0455	10.317
	Millstone 1	SAW(1)	34B009	DP2-15	1.0399	10.261
	Quad Cities 2	Electroslag Weld	unknown	DP2-21	1.0359	10.222
	Quad Cities 1	SAW(1)	406L44	DP2-20	1.0153	10.018
SSP Capsule E	Japanese/EPRI	SA533-1	EP2	EP2-43..84	0.81904	16.988
(Oyster Creek)	Grand Gulf	SA533B-1	A1224-1	EP1-67	0.82521	17.116
	Cooper	SA533B-1	C2331-2	EP1-30	0.82886	17.192
	Nine Mile Pt 1	SA302B, Mod.	P2130-2	EP1-11	0.82936	17.202
	Fitzpatrick	SA533B-1	C3278-2	EP1-28	0.82609	17.135
	CE/EPRI Linde 1092 #2	SAW(1)	CE-2 (WM)	C211..C231	0.84718	17.572
	Grand Gulf	SAW(1)	5P6214B	EP2-67	0.85358	17.704
	Millstone 1	SAW(1)	34B009	EP2-15	0.85737	17.783
	Quad Cities 2	Electroslag Weld	unknown	EP2-21	0.85790	17.794
	Quad Cities 1	SAW(1)	406L44	EP2-20	0.85452	17.724
SSP Capsule F	B&W/EPRI	SA302B, Mod.	B&W-1 (BM)	B01.B10	0.89471	18.558
(Oyster Creek)	Duane Arnold	SA533B-1	B0673-1	ECE..ED2	0.90154	18.699
	Millstone 1	SA302B, Mod.	C1079-1	FP1-15	0.90558	18.783
	Quad Cities 1	SA302B, Mod.	A0610-1	FP1-20	0.90620	18.796
	HSST-02	SA533B-1	A1195-1	FP1-H2	0.90278	18.725
	B&W/EPRI Linde 80	SAW(1)	B&W-1 (WM)	M01 .. 11	0.92517	19.189
	Duane Arnold	SMAW(2)	unknown	EEC..EK1	0.93225	19.336
	B&W Linde 80	SAW(1)	unknown	FP2-BW	0.93644	19.423
	Humboldt Bay 3	SAW(1)	unknown	FP2-6	0.93710	19.437
	River Bend	SAW(1)	5P6756	FP2-72	0.93356	19.364

1. SAW – Submerged Arc Weld
2. SMAW – Shielded Metal Arc Weld

Table 3-1
Best Estimate Flux and Fluence for SSP Capsule Materials (continued)

Capsule	Source	Material Type	Heat Number	Specimen ID	Flux ($x\ 10^{10}$, n/cm^2-s, E>1.0MeV)	Fluence ($x\ 10^{17}$, n/cm^2, E>1.0MeV)
SSP Capsule G	Japanese/EPRI	SA533-1	EP2	EP2-49 .. 85	1.9084	18.831
(Oyster Creek)	Grand Gulf	SA533B-1	A1224-1	GP1-67	1.9010	18.758
	Cooper	SA533B-1	C2331-2	GP1-30	1.8736	18.487
	Nine Mile Pt 1	SA302B, Mod.	P2130-2	GP1-11	1.8407	18.163
	Fitzpatrick	SA533B-1	C3278-2	GP1-28	1.7804	17.569
	CE/EPRI Linde 1092 #2	SAW(1)	CE-2 (WM)	C212 .. 232	1.9764	19.503
	Grand Gulf	SAW(1)	5P6214B	GP2-67	1.9722	19.461
	Millstone 1	SAW(1)	34B009	GP2-15	1.9431	19.173
	Quad Cities 2	Electroslag Weld	unknown	GP2-21	1.9035	18.783
	Quad Cities 1	SAW(1)	406L44	GP2-20	1.8516	18.270
SSP Capsule H	B&W/EPRI	SA302B, Mod.	B&W-1 (BM)	B11..B20	1.6469	16.250
(Oyster Creek)	Hatch 1	SA533B-1	C3985-2	HP1-36	1.6458	16.240
	Millstone 1	SA302B, Mod.	C1079-1	HP1-15	1.6221	16.006
	Quad Cities 1	SA302B, Mod.	A0610-1	HP1-20	1.5931	15.720
	HSST-02	SA533B-1	A1195-1	HP1-H2	1.5429	15.224
	B&W/EPRI	SA508-2	BMF	A01..A10	1.7093	16.867
	ASTM Standard	SA302B	A0421	Y41..Y4C	1.7087	16.861
	B&W Linde 80	SAW(1)	unknown	HP2-BW	1.6838	16.615
	Humboldt Bay 3	SAW(1)	unknown	HP2-6	1.6493	16.275
	River Bend	SAW(1)	5P6756	HP2-72	1.5977	15.766
SSP Capsule I	Japanese/EPRI	SA533-1	EP2	EP2-51..86	1.2543	26.016
(Oyster Creek)	Grand Gulf	SA533B-1	A1224-1	IP1-67	1.2815	26.581
	Cooper	SA533B-1	C2331-2	IP1-30	1.3058	27.085
	Nine Mile Pt 1	SA302B, Mod.	P2130-2	IP1-11	1.3281	27.548
	Fitzpatrick	SA533B-1	C3278-2	IP1-28	1.3479	27.958
	CE/EPRI Linde 1092 #1	SAW(1)	CE-1 (WM)	C112..132	1.2966	26.893
	Grand Gulf	SAW(1)	5P6214B	IP2-67	1.3248	27.478
	Millstone 1	SAW(1)	34B009	IP2-15	1.3500	28.000
	Quad Cities 2	Electroslag Weld	unknown	IP2-21	1.3730	28.479
	Quad Cities 1	SAW(1)	406L44	IP2-20	1.3935	28.903

SAW – Submerged Arc Weld

Table 3-2
Best Estimate Flux and Fluence for River Bend 183° Capsule Materials

Capsule	Source	Material Type	Heat Number	Specimen ID	Flux ($x\ 10^{10}$, n/cm^2-s, E>1.0MeV)	Fluence ($x\ 10^{17}$, n/cm^2, E>1.0MeV)
River Bend	River Bend	SA533-1	C3054-2	B1..B12	0.365	11.6
183 Degree	River Bend	SAW[1]	5P6756	W1..W12	0.365	11.6

1. SAW – Submerged Arc Weld

Charpy V-Notch Testing

Impact Testing

The testing of the Charpy V-notch specimens was performed in accordance with 10CFR50, Appendices G and H [1] and ASTM Specification E185-82 [3].

Analysis of Impact Test Results

A hyperbolic tangent curve-fitting program named CVGRAPH [15] was used to fit the Charpy V-notch test data. For fits of Charpy energy data, lower shelf energy was fixed at 2.5 ft-lbs (3.4 J) in all cases. Upper shelf energy was fixed at the average of all test energies (at least 3) exhibiting shear greater than or equal to 95%, consistent with ASTM Standard E185-82. In cases where there were not three data points exhibiting greater than 95% shear, an engineering judgment was made whether the upper shelf should remain free or be fixed at the average of those points with greater than 95% shear. For fits of lateral expansion data, the lower shelf was fixed at 1.0 mils, and upper shelf lateral expansion was fixed by the same method used for Charpy upper shelf energy.

Irradiated Versus Unirradiated CVN Properties

Tables 3-3 through 3-28 summarize the T_{30} [30 ft-lb (40.7 J) Transition Temperature], T_{50} [50 ft-lb (67.8 J) Transition Temperature], T_{35mil} [35 mil (0.89 mm) Lateral Expansion Temperature], and Upper Shelf Energy for the unirradiated and irradiated materials and show the shift or change from baseline values. The fluence values for each capsule are also presented below each table.

Table 3-3
Effect of Irradiation on the Notch Toughness Properties of Plate Heat EP2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
D	-41.6	-3.6	38.0	-17.9	20.7	38.6	0.7	37.0	36.3	109.5	101.1	-8.4
	(-40.9)	(-19.8)	(21.1)	(-27.7)	(-6.3)	(21.4)	(-17.4)	(2.8)	(20.2)	(148.5)	(137.1)	(-11.4)
E	-41.6	-18.0	23.6	-17.9	15.2	33.1	0.7	24.3	23.6	109.5	94.6	-14.9
	(-40.9)	(-27.8)	(13.1)	(-27.7)	(-9.3)	(18.4)	(-17.4)	(-4.3)	(13.1)	(148.5)	(128.3)	(-20.2)
G	-41.6	-14.5	27.1	-17.9	13.1	31.0	0.7	32.2	31.5	109.5	104.9	-4.6
	(-40.9)	(-25.8)	(15.1)	(-27.7)	(-10.5)	(17.2)	(-17.4)	(0.1)	(17.5)	(148.5)	(142.2)	(-6.3)
I	-41.6	-16.4	25.2	-17.9	19.3	37.2	0.7	20.8	20.1	109.5	97.8	-11.7
	(-40.9)	(-26.9)	(14.0)	(-27.7)	(-7.1)	(20.7)	(-17.4)	(-6.2)	(11.2)	(148.5)	(132.6)	(-15.9)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule D = 1.0044x1018 n/cm2
Capsule E = 1.6988x1018 n/cm2
Capsule G = 1.8831x1018 n/cm2
Capsule I = 2.6016x1018 n/cm2

Table 3-4
Effect of Irradiation on the Notch Toughness Properties of Plate Heat A1224-1

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-20.9 (-29.4)	0.3 (-17.6)	21.2 (11.8)	10.9 (-11.7)	9.7 (-12.4)	-1.2 (-0.7)	5.9 (-14.5)	20.6 (-6.3)	14.7 (8.2)	147.3 (199.7)	148.7 (201.6)	1.4 (1.9)
B	-20.9 (-29.4)	-27.7 (-33.2)	-6.8 (-3.8)	10.9 (-11.7)	-14.7 (-25.9)	-25.6 (-14.2)	5.9 (-14.5)	-0.4 (-18.0)	-6.3 (-3.5)	147.3 (199.7)	160.4 (217.5)	13.1 (17.8)
D	-20.9 (-29.4)	-11.3 (-24.1)	9.6 (5.3)	10.9 (-11.7)	19.6 (-6.9)	8.7 (4.8)	5.9 (-14.5)	23.7 (-4.6)	17.8 (9.9)	147.3 (199.7)	148.0 (200.7)	0.7 (1.0)
E	-20.9 (-29.4)	17.2 (-8.2)	38.1 (21.2)	10.9 (-11.7)	49.8 (9.9)	38.9 (21.6)	5.9 (-14.5)	41.2 (5.1)	35.3 (19.6)	147.3 (199.7)	139.8 (189.5)	-7.5 (-10.2)
G	-20.9 (-29.4)	-0.6 (-18.1)	20.3 (11.3)	10.9 (-11.7)	25.1 (-3.8)	14.2 (7.9)	5.9 (-14.5)	31.3 (-0.4)	25.4 (14.1)	147.3 (199.7)	144.4 (195.8)	-2.9 (-3.9)
I	-20.9 (-29.4)	14.2 (-9.9)	35.1 (19.5)	10.9 (-11.7)	56.5 (13.6)	45.6 (25.3)	5.9 (-14.5)	50.5 (10.3)	44.6 (24.8)	147.3 (199.7)	133.8 (181.4)	-13.5 (-18.3)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule A = 0.380×10^{18} n/cm^2 Capsule B = 0.490×10^{18} n/cm^2
Capsule D = 1.0164×10^{18} n/cm^2 Capsule E = 1.7116×10^{18} n/cm^2
Capsule G = 1.8758×10^{18} n/cm^2 Capsule I = 2.6581×10^{18} n/cm^2

Table 3-5
Effect of Irradiation on the Notch Toughness Properties of Plate Heat C2331-2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-13.3 (-25.2)	28.2 (-2.1)	41.5 (23.1)	34.1 (1.2)	44.4 (6.9)	10.3 (5.7)	30.1 (-1.1)	77.9 (25.5)	47.8 (26.6)	100.0 (135.6)	91.0 (123.4)	-9.0 (-12.2)
B	-13.3 (-25.2)	21.4 (-5.9)	34.7 (19.3)	34.1 (1.2)	39.2 (4.0)	5.1 (2.8)	30.1 (-1.1)	62.5 (16.9)	32.4 (18.0)	100.0 (135.6)	97.7 (132.5)	-2.3 (-3.1)
D	-13.3 (-25.2)	48.7 (9.3)	62.0 (34.4)	34.1 (1.2)	86.3 (30.2)	52.2 (29.0)	30.1 (-1.1)	92.8 (33.8)	62.7 (34.8)	100.0 (135.6)	89.3 (121.1)	-10.7 (-14.5)
E	-13.3 (-25.2)	62.8 (17.1)	76.1 (42.3)	34.1 (1.2)	124.2 (51.2)	90.1 (50.1)	30.1 (-1.1)	105.8 (41.0)	75.7 (42.1)	100.0 (135.6)	82.3 (111.7)	-17.7 (-23.9)
G	-13.3 (-25.2)	78.7 (25.9)	92.0 (51.1)	34.1 (1.2)	118.2 (47.9)	84.1 (46.7)	30.1 (-1.1)	127.2 (52.9)	97.1 (53.9)	100.0 (135.6)	81.6 (110.6)	-18.4 (-25.0)
I	-13.3 (-25.2)	80.4 (26.9)	93.7 (52.1)	34.1 (1.2)	128.3 (53.5)	94.2 (52.3)	30.1 (-1.1)	128.8 (53.8)	98.7 (54.8)	100.0 (135.6)	80.3 (108.9)	-19.7 (-26.7)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.382×10^{18} n/cm^2 Capsule B = 0.479×10^{18} n/cm^2
Capsule D = 1.0118×10^{18} n/cm^2 Capsule E = 1.7192×10^{18} n/cm^2
Capsule G = 1.8487×10^{18} n/cm^2 Capsule I = 2.7085×10^{18} n/cm^2

Table 3-6
Effect of Irradiation on the Notch Toughness Properties of Plate Heat P2130-2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-2.8 (-19.3)	37.4 (3.0)	40.2 (22.3)	22.8 (-5.1)	58.9 (14.9)	36.1 (20.1)	41.6 (5.3)	89.1 (31.7)	47.5 (26.4)	68.2 (92.5)	63.9 (86.6)	-4.3 (-5.8)
B	-2.8 (-19.3)	50.6 (10.3)	53.4 (29.7)	22.8 (-5.1)	69.9 (21.1)	47.1 (26.2)	41.6 (5.3)	101.0 (38.3)	59.4 (33.0)	68.2 (92.5)	67.7 (91.8)	-0.5 (-0.7)
D	-2.8 (-19.3)	50.1 (10.1)	52.9 (29.4)	22.8 (-5.1)	67.2 (19.6)	44.4 (24.7)	41.6 (5.3)	90.2 (32.3)	48.6 (27.0)	68.2 (92.5)	74.6 (101.1)	6.4 (8.7)
E	-2.8 (-19.3)	77.1 (25.1)	79.9 (44.4)	22.8 (-5.1)	120.2 (49.0)	97.4 (54.1)	41.6 (5.3)	168.7 (75.9)	127.1 (70.6)	68.2 (92.5)	55.5 (75.2)	-12.7 (-17.2)
G	-2.8 (-19.3)	75.1 (23.9)	77.9 (43.3)	22.8 (-5.1)	93.7 (34.3)	70.9 (39.4)	41.6 (5.3)	124.9 (51.6)	83.3 (46.3)	68.2 (92.5)	64.3 (87.2)	-3.9 (-5.3)
I	-2.8 (-19.3)	92.2 (33.4)	95.0 (52.8)	22.8 (-5.1)	121.2 (49.6)	98.4 (54.7)	41.6 (5.3)	141.0 (60.6)	99.4 (55.2)	68.2 (92.5)	62.1 (84.2)	-6.1 (-8.3)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.378×10^{18} n/cm^2 Capsule B = 0.468×10^{18} n/cm^2
Capsule D = 1.0112×10^{18} n/cm^2 Capsule E = 1.7202×10^{18} n/cm^2
Capsule G = 1.7569×10^{18} n/cm^2 Capsule I = 2.7548×10^{18} n/cm^2

Table 3-7
Effect of Irradiation on the Notch Toughness Properties Plate Heat C3278-2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-34.4 (-36.9)	-4.5 (-20.3)	29.9 (16.6)	15.1 (-9.4)	18.6 (-7.4)	3.5 (1.9)	5.4 (-14.8)	31.6 (-0.2)	26.2 (14.6)	113.3 (153.6)	103.3 (140.1)	-10.0 (-13.6)
B	-34.4 (-36.9)	8.5 (-13.1)	42.9 (23.8)	15.1 (-9.4)	31.1 (-0.5)	16.0 (8.9)	5.4 (-14.8)	50.1 (10.1)	44.7 (24.8)	113.3 (153.6)	100.4 (136.1)	-12.9 (-17.5)
D	-34.4 (-36.9)	1.2 (-17.1)	35.6 (19.8)	15.1 (-9.4)	49.9 (9.9)	34.8 (19.3)	5.4 (-14.8)	52.1 (11.2)	46.7 (25.9)	113.3 (153.6)	104.1 (141.1)	-9.2 (-12.5)
E	-34.4 (-36.9)	23.3 (-4.8)	57.7 (32.1)	15.1 (-9.4)	87.1 (30.6)	72.0 (40.0)	5.4 (-14.8)	67.6 (19.8)	62.2 (34.6)	113.3 (153.6)	95.3 (129.2)	-18.0 (-24.4)
G	-34.4 (-36.9)	-7.2 (-21.8)	27.2 (15.1)	15.1 (-9.4)	33.8 (1.0)	18.7 (10.4)	5.4 (-14.8)	39.4 (4.1)	34.0 (18.9)	113.3 (153.6)	99.0 (134.2)	-14.3 (-19.4)
I	-34.4 (-36.9)	34.0 (1.1)	68.4 (38.0)	15.1 (-9.4)	77.6 (25.3)	62.5 (34.7)	5.4 (-14.8)	67.6 (19.8)	62.2 (34.6)	113.3 (153.6)	94.5 (128.1)	-18.8 (-25.5)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.374×10^{18} n/cm^2 Capsule B = 0.454×10^{18} n/cm^2
Capsule D = 0.9931×10^{18} n/cm^2 Capsule E = 1.7135×10^{18} n/cm^2
Capsule G = 1.7569×10^{18} n/cm^2 Capsule I = 2.7958×10^{18} n/cm^2

Table 3-8
Effect of Irradiation on the Notch Toughness Properties of Plate Heat B&W-1(BM)

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
F	-0.7	43.1	43.8	32.9	80.8	47.9	40.4	86.5	46.1	124.8	94.5	-30.3
	(-18.2)	(6.2)	(24.3)	(0.5)	(27.1)	(26.6)	(4.7)	(30.3)	(25.6)	(169.2)	(128.1)	(-41.1)
H	-0.7	53.6	54.3	32.9	75.1	42.2	40.4	87.7	47.3	124.8	102.8	-22.0
	(-18.2)	(12.0)	(30.2)	(0.5)	(23.9)	(23.4)	(4.7)	(30.9)	(26.3)	(169.2)	(139.4)	(-29.8)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule F = 1.8558×10^{18} n/cm^2
Capsule H = 1.6250×10^{18} n/cm^2

1. Updated baseline (unirradiated) transition temperatures based on testing report Reference 17.

Table 3-9
Effect of Irradiation on the Notch Toughness Properties of Plate Heat C1079-1

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	9.7 (-12.4)	75.1 (23.9)	65.4 (36.3)	57.1 (13.9)	106.7 (41.5)	49.6 (27.6)	76.6 (24.8)	165.2 (74.0)	88.6 (49.2)	61.2 (83.0)	57.9 (78.5)	-3.3 (-4.5)
F	9.7 (-12.4)	82.8 (28.2)	73.1 (40.6)	57.1 (13.9)	134.6 (57.0)	77.5 (43.1)	76.6 (24.8)	Note 1	Note 1	61.2 (83.0)	49.3 (66.8)	-11.9 (-16.1)
H	9.7 (-12.4)	102.3 (39.1)	92.6 (51.4)	57.1 (13.9)	128.9 (53.8)	71.8 (39.9)	76.6 (24.8)	216.0 (102.2)	139.4 (77.4)	61.2 (83.0)	55.3 (75.0)	-5.9 (-8.0)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.302×10^{18} n/cm^2
Capsule F = 1.8783×10^{18} n/cm^2
Capsule H = 1.6006×10^{18} n/cm^2

This material did not achieve 50 ft-lbs.

Table 3-10
Effect of Irradiation on the Notch Toughness Properties of Plate Heat A0610-1

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	-33.5 (-36.4)	12.5 (-10.8)	46.0 (25.6)	-1.5 (-18.6)	39.5 (4.2)	41.0 (22.8)	-4.1 (-20.1)	57.6 (14.2)	61.7 (34.3)	101.2 (137.2)	98.8 (134.0)	-2.4 (-3.3)
F	-33.5 (-36.4)	51.7 (10.9)	85.2 (47.3)	-1.5 (-18.6)	97.9 (36.6)	99.4 (55.2)	-4.1 (-20.1)	102.5 (39.2)	106.6 (59.3)	101.2 (137.2)	73.0 (99.0)	-28.2 (-38.2)
H	-33.5 (-36.4)	24.9 (-3.9)	58.4 (32.4)	-1.5 (-18.6)	58.0 (14.4)	59.5 (33.1)	-4.1 (-20.1)	67.4 (19.7)	71.5 (39.7)	101.2 (137.2)	85.0 (115.2)	-16.2 (-22.0)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.293×10^{18} n/cm^2
Capsule F = 1.8796×10^{18} n/cm^2
Capsule H = 1.5720×10^{18} n/cm^2

Table 3-11
Effect of Irradiation on the Notch Toughness Properties of Plate Heat A1195-1

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	39.8 (4.3)	64.9 (18.3)	25.1 (13.9)	79.6 (26.4)	93.7 (34.3)	14.1 (7.8)	78.7 (25.9)	108.7 (42.6)	30.0 (16.7)	99.7 (135.2)	104.1 (141.1)	4.4 (6.0)
F	39.8 (4.3)	109.1 (42.8)	69.3 (38.5)	79.6 (26.4)	144.0 (62.2)	64.4 (35.8)	78.7 (25.9)	155.9 (68.8)	77.2 (42.9)	99.7 (135.2)	83.2 (112.8)	-16.5 (-22.4)
H	39.8 (4.3)	104.8 (40.4)	65.0 (36.1)	79.6 (26.4)	137.4 (58.6)	57.8 (32.1)	78.7 (25.9)	151.8 (66.6)	73.1 (40.6)	99.7 (135.2)	91.8 (124.5)	-7.9 (-10.7)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.279×10^{18} n/cm^2
Capsule F = 1.8725×10^{18} n/cm^2
Capsule H = 1.5224×10^{18} n/cm^2

Table 3-12
Effect of Irradiation on the Notch Toughness Properties of Plate Heat B0673-1

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
F	-35.5 (-37.5)	37.9 (3.3)	73.4 (40.8)	-23.6 (-30.9)	57.8 (14.3)	81.4 (45.2)	-7.3 (-21.8)	66.9 (19.4)	74.2 (41.2)	158.1 (214.4)	133.0 (180.3)	-25.1 (-34.0)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule F = 1.8699×10^{18} n/cm^2

Table 3-13
Effect of Irradiation on the Notch Toughness Properties of Plate Heat C3985-2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	-11.7 (-24.3)	8.8 (-12.9)	20.5 (11.4)	31.1 (-0.5)	30.6 (-0.8)	-0.5 (-0.3)	27.0 (-2.8)	46.4 (8.0)	19.4 (10.8)	112.8 (152.9)	115.8 (157.0)	3.0 (4.1)
H	-11.7 (-24.3)	19.4 (-7.0)	31.1 (17.3)	31.1 (-0.5)	55.6 (13.1)	24.5 (13.6)	27.0 (-2.8)	62.5 (16.9)	35.5 (19.7)	112.8 (152.9)	110.5 (149.8)	-2.3 (-3.1)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.311×10^{18} n/cm^2
Capsule H = 1.6240×10^{18} n/cm^2

Table 3-14
Effect of Irradiation on the Notch Toughness Properties of Forging Heat BMF

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
H	-31.5 (-35.3)	-20.0 (-28.9)	11.5 (6.4)	-12.5 (-24.7)	7.2 (-13.8)	19.7 (10.9)	-5.9 (-21.1)	17.2 (-8.2)	23.1 (12.9)	125.8 (170.6)	119.8 (162.4)	-6.0 (-8.2)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule H = 1.6867×10^{18} n/cm^2

Table 3-15
Effect of Irradiation on the Notch Toughness Properties of Plate Heat A0421

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
H	38.1 (3.4)	106.2 (41.2)	68.1 (37.8)	60.2 (15.7)	112.3 (44.6)	52.1 (28.9)	83.2 (28.4)	144.9 (62.7)	61.7 (34.3)	68.8 (93.3)	66.0 (89.5)	-2.8 (-3.8)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule H = 1.6861×10^{18} n/cm^2

Table 3-16
Effect of Irradiation on the Notch Toughness Properties of Plate Heat C3054-2

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
RB 183°	-16.6 (-27.0)	27.4 (-2.6)	44.0 (24.4)	31.7 (-0.2)	68.4 (20.2)	36.7 (20.4)	11.9 (-11.2)	41.2 (5.1)	29.3 (16.3)	95.3 (192.2)	100.6 (136.4)	5.3 (-55.8)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule RB 183° = 1.16×10^{18} n/cm^2

Table 3-17
Effect of Irradiation on the Notch Toughness Properties of Weld Heat 5P6214B

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-26.8 (-32.7)	-53.2 (-47.3)	-26.4 (-14.7)	9.2 (-12.7)	-18.8 (-28.2)	-28.0 (-15.6)	7.0 (-13.9)	-9.3 (-22.9)	-16.3 (-9.1)	91.5 (124.1)	96.5 (130.8)	5.0 (6.8)
B	-26.8 (-32.7)	-11.1 (-23.9)	15.7 (8.7)	9.2 (-12.7)	11.7 (-11.3)	2.5 (1.4)	7.0 (-13.9)	19.8 (-6.8)	12.8 (7.1)	91.5 (124.1)	97.4 (132.1)	5.9 (8.0)
D	-26.8 (-32.7)	-23.7 (-30.9)	3.1 (1.7)	9.2 (-12.7)	7.6 (-13.6)	-1.6 (-0.9)	7.0 (-13.9)	25.9 (-3.4)	18.9 (10.5)	91.5 (124.1)	89.0 (120.7)	-2.5 (-3.4)
E	-26.8 (-32.7)	-22.7 (-30.4)	4.1 (2.3)	9.2 (-12.7)	17.8 (-7.9)	8.6 (4.8)	7.0 (-13.9)	24.0 (-4.4)	17.0 (9.5)	91.5 (124.1)	88.5 (120.0)	-3.0 (-4.1)
G	-26.8 (-32.7)	7.2 (-13.8)	34.0 (18.9)	9.2 (-12.7)	28.5 (-1.9)	19.3 (10.7)	7.0 (-13.9)	40.3 (4.6)	33.3 (18.5)	91.5 (124.1)	85.3 (115.7)	-6.2 (-8.4)
I	-26.8 (-32.7)	-4.3 (-20.2)	22.5 (12.5)	9.2 (-12.7)	42.6 (5.9)	33.4 (18.6)	7.0 (-13.9)	44.9 (7.2)	37.9 (21.1)	91.5 (124.1)	87.7 (118.9)	-3.8 (-5.2)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.409×10^{18} n/cm^2 Capsule B = 0.526×10^{18} n/cm^2
Capsule D = 1.0317×10^{18} n/cm^2 Capsule E = 1.7704×10^{18} n/cm^2
Capsule G = 1.9461×10^{18} n/cm^2 Capsule I = 2.7478×10^{18} n/cm^2

Table 3-18
Effect of Irradiation on the Notch Toughness Properties of Weld Heat 34B009

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-65.0 (-53.9)	34.0 (1.1)	99.0 (55.0)	-21.0 (-29.4)	67.3 (19.6)	88.3 (49.1)	-29.5 (-34.2)	92.7 (33.7)	122.2 (67.9)	104.4 (141.5)	92.1 (124.9)	-12.3 (-16.7)
B	-65.0 (-53.9)	35.6 (2.0)	100.6 (55.9)	-21.0 (-29.4)	70.2 (21.2)	91.2 (50.7)	-29.5 (-34.2)	81.9 (27.7)	111.4 (61.9)	104.4 (141.5)	98.8 (134.0)	-5.6 (-7.6)
D	-65.0 (-53.9)	37.7 (3.2)	102.7 (57.1)	-21.0 (-29.4)	78.8 (26.0)	99.8 (55.4)	-29.5 (-34.2)	83.1 (28.4)	112.6 (62.6)	104.4 (141.5)	76.7 (104.0)	-27.7 (-37.5)
E	-65.0 (-53.9)	59.5 (15.3)	124.5 (69.2)	-21.0 (-29.4)	97.6 (36.4)	118.6 (65.8)	-29.5 (-34.2)	105.4 (40.8)	134.9 (75.0)	104.4 (141.5)	74.4 (100.9)	-30.0 (-40.7)
G	-65.0 (-53.9)	40.9 (4.9)	105.9 (58.8)	-21.0 (-29.4)	67.8 (19.9)	88.8 (49.3)	-29.5 (-34.2)	69.3 (20.7)	98.8 (54.9)	104.4 (141.5)	104.6 (141.8)	0.2 (0.3)
I	-65.0 (-53.9)	74.0 (23.3)	139.0 (77.2)	-21.0 (-29.4)	112.7 (44.8)	133.7 (74.3)	-29.5 (-34.2)	108.4 (42.4)	137.9 (76.6)	104.4 (141.5)	87.0 (118.0)	-17.4 (-23.6)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.408×10^{18} n/cm^2 Capsule B = 0.517×10^{18} n/cm^2
Capsule D = 1.0261×10^{18} n/cm^2 Capsule E = 1.7783×10^{18} n/cm^2
Capsule G = 1.9173×10^{18} n/cm^2 Capsule I = 2.8000×10^{18} n/cm^2

Table 3-19
Effect of Irradiation on the Notch Toughness Properties of Weld Heat Quad Cities 2 ESW (specimen code _P2-21 [1])

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-23.1 (-30.6)	-10.4 (-23.6)	12.7 (7.1)	22.4 (-5.3)	27.7 (-2.4)	5.3 (2.9)	17.9 (-7.8)	45.3 (7.4)	27.4 (15.2)	104.0 (141.0)	100.7 (136.5)	-3.3 (-4.5)
B	-23.1 (-30.6)	-11.9 (-24.4)	11.2 (6.2)	22.4 (-5.3)	19.4 (-7.0)	-3.0 (-1.7)	17.9 (-7.8)	31.8 (-0.1)	13.9 (7.7)	104.0 (141.0)	110.1 (149.3)	6.1 (8.3)
D	-23.1 (-30.6)	10.2 (-12.1)	33.3 (18.5)	22.4 (-5.3)	50.6 (10.3)	28.2 (15.6)	17.9 (-7.8)	54.8 (12.7)	36.9 (20.5)	104.0 (141.0)	93.8 (127.2)	-10.2 (-13.8)
E	-23.1 (-30.6)	57.5 (14.1)	80.6 (44.8)	22.4 (-5.3)	95.7 (35.4)	73.3 (40.7)	17.9 (-7.8)	94.5 (34.7)	76.6 (42.5)	104.0 (141.0)	94.4 (128.0)	-9.6 (-13.0)
G	-23.1 (-30.6)	55.0 (12.8)	78.1 (43.4)	22.4 (-5.3)	79.7 (26.5)	57.3 (31.8)	17.9 (-7.8)	90.1 (32.3)	72.2 (40.1)	104.0 (141.0)	96.9 (131.4)	-7.1 (-9.6)
I	-23.1 (-30.6)	53.2 (11.8)	76.3 (42.4)	22.4 (-5.3)	98.4 (36.9)	76.0 (42.2)	17.9 (-7.8)	99.8 (37.7)	81.9 (45.5)	104.0 (141.0)	90.7 (123.0)	-13.3 (-18.0)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.406×10^{18} n/cm^2 Capsule B = 0.504×10^{18} n/cm^2
Capsule D = 1.0222×10^{18} n/cm^2 Capsule E = 1.7794×10^{18} n/cm^2
Capsule G = 1.8783×10^{18} n/cm^2 Capsule I = 2.8479×10^{18} n/cm^2

1. The underscore is a placeholder for the capsule letter, e.g., for Capsule A the underscore is replaced with the letter A

Table 3-20
Effect of Irradiation on the Notch Toughness Properties of Weld Heat 406L44

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
A	-8.8 (-22.7)	113.1 (45.1)	121.9 (67.7)	39.2 (4.0)	171.5 (77.5)	132.3 (73.5)	51.1 (10.6)	223.9 (106.6)	172.8 (96.0)	73.3 (99.4)	58.3 (79.0)	-15.0 (-20.3)
B	-8.8 (-22.7)	111.8 (44.3)	120.6 (67.0)	39.2 (4.0)	179.2 (81.8)	140.0 (77.8)	51.1 (10.6)	233.0 (111.7)	181.9 (101.1)	73.3 (99.4)	58.2 (78.9)	-15.1 (-20.5)
D	-8.8 (-22.7)	119.2 (48.4)	128.0 (71.1)	39.2 (4.0)	206.3 (96.8)	167.1 (92.8)	51.1 (10.6)	396.3 (202.4)	345.2 (191.8)	73.3 (99.4)	50.2 (68.1)	-23.1 (-31.3)
E	-8.8 (-22.7)	159.8 (71.0)	168.6 (93.7)	39.2 (4.0)	257.9 (125.5)	218.7 (121.5)	51.1 (10.6)	Note 1	Note 1	73.3 (99.4)	46.8 (63.5)	-26.5 (-35.9)
G	-8.8 (-22.7)	147.9 (64.4)	156.7 (87.1)	39.2 (4.0)	178.8 (81.6)	139.6 (77.6)	51.1 (10.6)	Note 1	Note 1	73.3 (94.4)	49.4 (67.0)	-23.9 (-32.4)
I	-8.8 (-22.7)	179.9 (82.2)	188.7 (104.8)	39.2 (4.0)	328.3 (164.6)	289.1 (160.6)	51.1 (10.6)	Note 1	Note 1	73.3 (99.4)	42.3 (57.4)	-31.0 (-42.0)

Fluence (E > 1.0 MeV) is unique to each specimen set:

Capsule A = 0.397×10^{18} n/cm^2 Capsule B = 0.493×10^{18} n/cm^2
Capsule D = 1.0018×10^{18} n/cm^2 Capsule E = 1.7724×10^{18} n/cm^2
Capsule G = 1.8270×10^{18} n/cm^2 Capsule I = 2.8903×10^{18} n/cm^2

1. This material did not achieve 50 ft-lbs.

Table 3-21
Effect of Irradiation on the Notch Toughness Properties of Weld Heat B&W-1(WM)

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
F	9.6 (-12.4)	149.8 (65.4)	140.2 (77.8)	30.8 (-0.7)	188.0 (86.7)	157.2 (87.4)	69.0 (20.6)	Note 1	Note 1	80.3 (108.9)	47.3 (64.1)	-33.0 (-44.7)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule F = 1.9189×10^{18} n/cm^2

1. This material did not achieve 50 ft-lbs.

Table 3-22
Effect of Irradiation on the Notch Toughness Properties of Humboldt Bay 3 SAW

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	-74.0 (-58.9)	-15.7 (-26.5)	58.3 (32.4)	-24.6 (-31.4)	18.3 (-7.6)	42.9 (23.8)	-29.3 (-34.1)	32.4 (0.2)	61.7 (34.3)	110.3 (149.5)	99.7 (135.2)	-10.6 (-14.4)
F	-74.0 (-58.9)	29.5 (-1.4)	103.5 (57.5)	-24.6 (-31.4)	87.2 (30.7)	111.8 (62.1)	-29.3 (-34.1)	95.3 (35.2)	124.6 (69.2)	110.3 (149.5)	74.8 (101.4)	-35.5 (-48.1)
H	-74.0 (-58.9)	22.3 (-5.4)	96.3 (53.5)	-24.6 (-31.4)	65.2 (18.4)	89.8 (49.9)	-29.3 (-34.1)	84.8 (29.3)	114.1 (63.4)	110.3 (149.5)	80.0 (108.5)	-30.3 (-41.1)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.313×10^{18} n/cm^2
Capsule F = 1.9437×10^{18} n/cm^2
Capsule H = 1.6275×10^{18} n/cm^2

Table 3-23
Effect of Irradiation on the Notch Toughness Properties of Weld Heat 5P6756

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	-67.1 (-55.1)	-43.5 (-41.9)	23.6 (13.1)	-20.3 (-29.1)	-17.4 (-27.4)	2.9 (1.6)	-21.3 (-29.6)	0.7 (-17.4)	22.0 (12.2)	104.4 (141.5)	110.7 (150.1)	6.3 (8.5)
F	-67.1 (-55.1)	-5.2 (-20.7)	61.9 (34.4)	-20.3 (-29.1)	31.7 (-0.2)	52.0 (28.9)	-21.3 (-29.6)	39.5 (4.2)	60.8 (33.8)	104.4 (141.5)	79.3 (107.5)	-25.1 (-34.0)
H	-67.1 (-55.1)	-3.4 (-19.7)	63.7 (35.4)	-20.3 (-29.1)	12.5 (-10.8)	32.8 (18.2)	-21.3 (-29.6)	22.3 (-5.4)	43.6 (24.2)	104.4 (141.5)	84.6 (114.7)	-19.8 (-26.8)
RB 183°	-67.1 (-55.1)	-13.4 (-25.2)	53.7 (29.8)	-20.3 (-29.1)	11.4 (-11.4)	31.7 (17.6)	-21.3 (-29.6)	33.1 (0.6)	54.4 (30.2)	104.4 (141.6)	84.4 (114.4)	-20.0 (-27.1)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.293×10^{18} n/cm^2
Capsule F = 1.9364×10^{18} n/cm^2
Capsule H = 1.5766×10^{18} n/cm^2
Capsule RB183° = 1.16×10^{18} n/cm^2

Table 3-24
Effect of Irradiation on the Notch Toughness Properties of Weld Heat B&W Linde 80 SAW (specimen code _P2-BW [1])

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	40.0 (4.4)	125.5 (51.9)	85.5 (47.5)	80.9 (27.2)	170.9 (77.2)	90.0 (50.0)	94.9 (34.9)	217.2 (102.9)	122.3 (67.9)	75.8 (102.8)	64.7 (87.7)	-11.1 (-15.0)
F	40.0 (4.4)	162.1 (72.3)	122.1 (67.8)	80.9 (27.2)	222.7 (105.9)	141.8 (78.8)	94.9 (34.9)	282.8 (139.3)	187.9 (104.4)	75.8 (102.8)	54.2 (73.5)	-21.6 (-29.3)
H	40.0 (4.4)	196.4 (91.3)	156.4 (86.9)	80.9 (27.2)	252.0 (122.2)	171.1 (95.1)	94.9 (34.9)	347.4 (175.2)	252.5 (140.3)	75.8 (102.8)	53.0 (71.9)	-22.8 (-30.9)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.322×10^{18} n/cm^2
Capsule F = 1.9423×10^{18} n/cm^2
Capsule H = 1.6615×10^{18} n/cm^2

1. The underscore is a placeholder for the capsule letter, e.g., for Capsule A the underscore is replaced with the letter A

Table 3-25
Effect of Irradiation on the Notch Toughness Properties of Weld Heat Duane Arnold SMAW (specimen code EE/EK)

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
F	-45.4 (-43.0)	-19.1 (-28.4)	26.3 (14.6)	-37.3 (-38.5)	14.2 (-9.9)	51.5 (28.6)	-10.2 (-23.4)	35.5 (1.9)	45.7 (25.4)	99.0 (134.2)	99.0 (134.2)	0 (0)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule F = 1.9336×10^{18} n/cm^2

Table 3-26
Effect of Irradiation on the Notch Toughness Properties of Weld Heat 20291

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
C	-17.8 (-27.7)	55.2 (12.9)	73.0 (40.6)	10.8 (-11.8)	81.6 (27.6)	70.8 (39.3)	13.3 (-10.4)	88.7 (31.5)	75.4 (41.9)	110.0 (149.1)	93.6 (126.9)	-16.4 (-22.2)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule C = 0.329×10^{18} n/cm^2

Table 3-27
Effect of Irradiation on the Notch Toughness Properties of Weld Heat CE-1(WM)

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
D	-41.0 (-40.6)	86.8 (30.4)	127.8 (71.0)	-39.7 (-39.8)	111.9 (44.4)	151.6 (84.2)	-5.9 (-21.1)	131.6 (55.3)	137.5 (76.4)	104.3 (141.4)	80.3 (108.9)	-24.0 (-32.5)
I	-41.0 (-40.6)	150.9 (66.1)	191.9 (106.6)	-39.7 (-39.8)	191.9 (88.8)	231.6 (128.7)	-5.9 (-21.1)	219.3 (104.1)	225.2 (125.1)	104.3 (141.4)	64.4 (87.3)	-39.9 (-54.1)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule D = 1.0202×10^{18} n/cm^2
Capsule I = 2.6893×10^{18} n/cm^2

Table 3-28
Effect of Irradiation on the Notch Toughness Properties of Weld Heat CE-2(WM)

Capsule	T_{30}, 30 ft-lb (40.7 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (67.8 J) Transition Temperature			CVN Upper Shelf Energy (USE)		
	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{30} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{35mil} °F (°C)	Unirrad °F (°C)	Irradiated °F (°C)	ΔT_{50} °F (°C)	Unirrad ft-lb (J)	Irradiated ft-lb (J)	Change ft-lb (J)
E	-96.1 (-71.2)	96.6 (35.9)	192.7 (107.1)	-62.9 (-52.7)	142.4 (61.3)	205.3 (114.0)	-45.7 (-43.2)	152.7 (67.1)	198.4 (110.3)	119.3 (161.7)	67.7 (91.8)	-51.6 (-70.0)
G	-96.1 (-71.2)	68.8 (20.4)	164.9 (91.6)	-62.9 (-52.7)	103.5 (39.7)	166.4 (92.4)	-45.7 (-43.2)	126.7 (52.6)	172.4 (95.8)	119.3 (161.7)	70.1 (95.0)	-49.2 (-66.7)

Fluence (E > 1.0 MeV) is unique to each specimen set:
Capsule E = 1.7572×10^{18} n/cm^2
Capsule G = 1.9503×10^{18} n/cm^2

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