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2010-208 BWR Vessel & Internals Project (BWRVIP)

September 14, 2010

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U. S. Nuclear Regulatory Commission
11555 Rockville Pike
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Attention: Jonathan Rowley

Subject: Project No. 704 – "BWRVIP-169NP: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C,"

Reference: BWRVIP letter 2007-147 from Rick Libra (BWRVIP Chairman) to Document Control Desk (NRC), "BWRVIP-169: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C," dated May 30, 2007

Enclosed for your information are five (5) copies of the report "BWRVIP-169NP: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C," EPRI Technical Report 1021556, August 2010. This report is a non-proprietary version of the proprietary report transmitted to the NRC staff by the BWRVIP letter referenced above. The technical content of the enclosed report is identical to that in the proprietary version transmitted to the NRC staff by the BWRVIP letter referenced above. The content was re-classified as non-proprietary and is being provided in response to a request from the NRC staff so that the data in the report can be used in the NRC public database of reactor pressure vessel embrittlement data.

Please note that the enclosed report is non-proprietary and is available to the public by request to EPRI.

If you have any questions on this subject please call Randy Schmidt (PSEG Nuclear, BWRVIP Assessment Committee Technical Chairman) at 856-339-3740.

Sincerely,

Dave Czufin
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c: Gary Stevens, NRC
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A004
NRR

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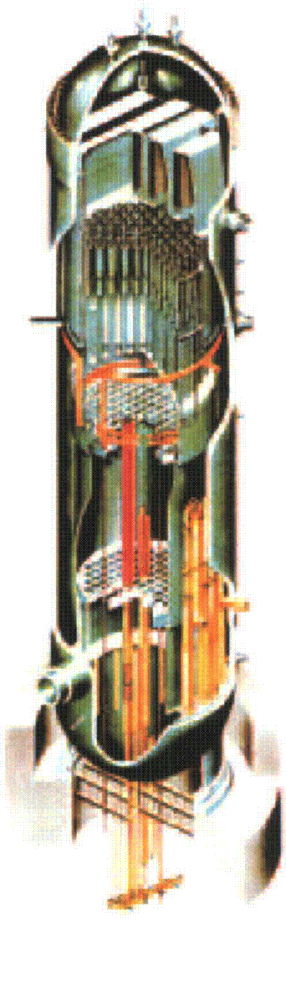
BWRVIP-169NP: BWR Vessel and Internals Project

Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C



BWRVIP-169NP: BWR Vessel and Internals Project

Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C

1021556

Final Report, August 2010

EPRI Project Manager
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Work to develop this product was completed under the EPRI Nuclear Quality Assurance Program in compliance with 10 CFR 50, Appendix B and 10 CFR 21,

✓ (YES) NO

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PRODUCT DESCRIPTION

A Supplemental Surveillance Program (SSP) was developed in the early 1990s to gather additional surveillance data regarding the irradiation embrittlement of BWR vessel materials. In the late 1990s a BWR Vessel and Internals Project (BWRVIP) Integrated Surveillance Program (ISP) assumed responsibility for testing the SSP capsules for use in the integrated program. This report describes testing and evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C. These results will be used to monitor embrittlement as part of the BWRVIP ISP.

Results & Findings

The report includes specimen chemical compositions, capsule neutron exposure, specimen temperatures during irradiation, and Charpy V-notch test results. The project compared irradiated Charpy data for the specimens to unirradiated data to determine the shift in Charpy curves due to irradiation. Results indicate a shift lower than the predictions of Regulatory Guide 1.99, Revision 2, for seventeen of the twenty-four sets of material specimens. Flux wires were measured and fluence was determined for each specimen set within the three capsules.

Challenges & Objectives

Neutron irradiation exposure reduces the toughness of reactor vessel steel plates, welds, and forgings. The objectives of this project were two-fold:

- To document results of the neutron dosimetry and Charpy-V notch ductility tests for materials contained in the SSP capsules A, B, and C
- To compare results with the embrittlement trend prediction of U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guide 1.99, Rev. 2.

Applications, Values & Use

Results of this work will be used in the BWRVIP ISP that integrates individual BWR surveillance programs into a single program. Data generated from the SSP specimens provide significant additional data of high quality to monitor BWR vessel embrittlement. The ISP and the use of the SSP capsule specimen data result in significant cost savings to the BWR fleet and provide more accurate monitoring of embrittlement in BWR vessels.

EPRI Perspective

The BWRVIP ISP represents a major enhancement to the process of monitoring embrittlement for the U.S. fleet of BWRs. The ISP optimizes surveillance capsule tests while at the same time maximizing the quantity and quality of data, thus resulting in a more cost effective program. The BWRVIP ISP provides more representative data that may be used to assess embrittlement in RPV vessel beltline materials and improve trend curves in the BWR range of irradiation conditions.

Approach

The project team inserted capsules into the Cooper reactor in November 1991 at a location of sufficient lead factor to provide the desired fluence. The team used dosimetry to gather information about the neutron fluence accrual of the specimens and placed thermal monitors in the capsules to approximate the highest temperature during irradiation. In March 2003, the team removed the capsules from the reactor and transported them to facilities for testing and evaluation. They performed a neutron transport calculation in accordance with Regulatory Guide 1.190 and compared to the results from the dosimetry. Testing of Charpy V-notch specimens were performed according to ASTM standards.

Keywords

Reactor pressure vessel integrity
Reactor vessel surveillance program
Radiation embrittlement
BWR
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) capsules containing test specimens were placed in two host reactors as part of the SSP. 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 SSP capsules were included in the ISP because the SSP materials represent 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 addresses the final set of SSP capsules (Capsules A, B, and C) to be removed and tested. The three surveillance capsules were installed within the Cooper Nuclear Station (CNS) in November, 1991 and removed in March, 2003. The surveillance capsules contained flux wires for neutron flux monitoring, Charpy V-notch impact test specimens fabricated using materials from a variety of sources, and thermal monitors. The capsules were shipped to MPM Technologies, Inc., for testing. Evaluation of the fluence environment was conducted by TransWare Enterprises, Inc. Final evaluation of the Charpy test data and irradiated material properties and compilation of this report were performed by ATI Consulting. The capsule materials have been tested per ASTM E185-82, and the information and the associated evaluations provided in this report have been performed in accordance with the requirements of 10CFR50 Appendix B.

This report compares the irradiated material properties to the unirradiated properties. The observed embrittlement (as characterized by $\Delta T30$) is compared to that predicted by U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guide 1.99, Rev. 2 [6]. Eleven (11) of the sixteen (16) materials in the three capsules are used or tracked in the BWRVIP ISP. For those materials, other BWRVIP ISP reports will integrate these shift results with other surveillance capsule results for a broader characterization of embrittlement behavior.

1.1 Implementation Requirements

The results documented in this report will be utilized by the BWRVIP ISP and by individual utilities to demonstrate compliance with 10CFR50, Appendix H, Reactor Vessel Material Surveillance Program Requirements. Therefore, the implementation requirements of 10CFR50, Appendix H govern and the implementation requirements of Nuclear Energy Institute (NEI) 03-08, Guideline for the Management of Materials Issues, are not applicable.

2
MATERIALS AND TEST SPECIMEN DESCRIPTION

SSP Capsules A, B, and C were designed and built by GE Nuclear Energy [4]. They contained flux wires for neutron flux monitoring, Charpy V-notch (CVN) impact test specimens fabricated using materials from a variety of sources, and thermal monitors. These monitors and specimens are described in the following sections. Schematics from [4] showing the general layout of SSP Capsules A, B, and C are provided in Figures 2-1, 2-2, and 2-3, respectively. The three capsules were contained in a single capsule holder mounted to the inside wall of the Cooper reactor vessel as shown in Figure 2-4.

2.1 Dosimeters

Each capsule contained a variety of neutron dosimeter materials. Since the surveillance capsules were up to about 20 inches (0.51 m) in axial height, full length copper and iron flux wires were placed in the capsules to provide dosimetry data for each set of 10 Charpy specimens (which were stacked axially). By cutting each wire to lengths corresponding to the locations of each specimen set and analyzing separately, it was possible to determine a fluence for each Charpy specimen set.

All three capsules also contained an additional set of wires and foils placed in gadolinium capsules which are intended for neutron energy spectrum measurements. The spectral dosimetry capsules were irradiated near the bottom of each capsule. The gadolinium dosimetry cylinders in each capsule were identical and included: iron wires (4); copper wire (1); nickel wire (1); niobium wire (1); titanium wire (1); aluminum-cobalt wire (1); and silver foil (1). As designed by GE, the four Fe wires were positioned at 90° intervals around the circumference of the gadolinium capsule for flux gradient determination.

A detailed discussion of the capsule dosimetry, including schematics showing dosimeter wire layout relative to the Charpy test specimens and the results of radiometric analysis, is provided in Appendix C of this report.

2.2 Thermal Monitors

Five thermal monitors were included in Capsule A to provide data needed to bound the peak irradiation temperature. As shown in Figure 2-5, the thermal monitors consist of melt wires which are housed in quartz tubes. The melt wire material is a eutectic material which is designed to melt within 4°F (2.2°C) of a specified temperature. The water temperature in the annulus region of a BWR depends on the feedwater temperature, but typically ranges between 525°F (274°C) and 535°F (279°C). Accordingly, GE designed the melt wire temperatures to cover this range [4], and the target melting temperatures are summarized in Table 2-1. The quartz tube lengths are used to identify the melt wire materials.

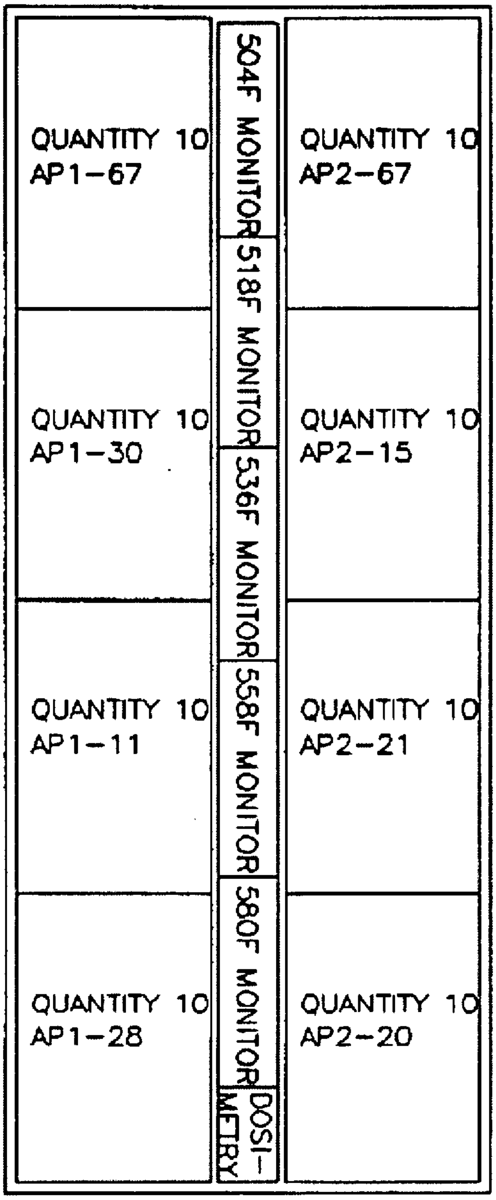

Figure 2-1
Cooper SSP Capsule A

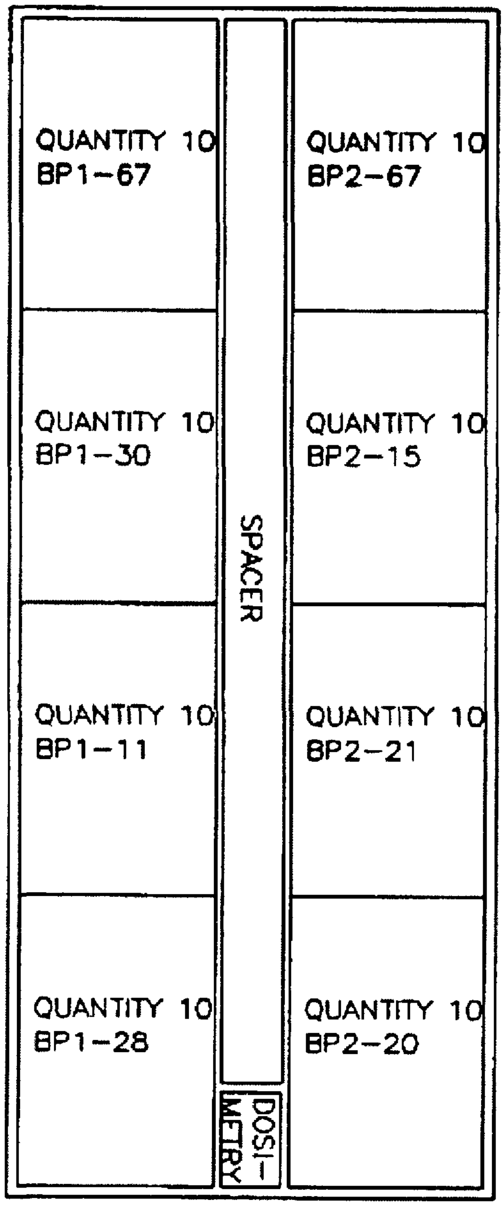

Figure 2-2
Cooper SSP Capsule B

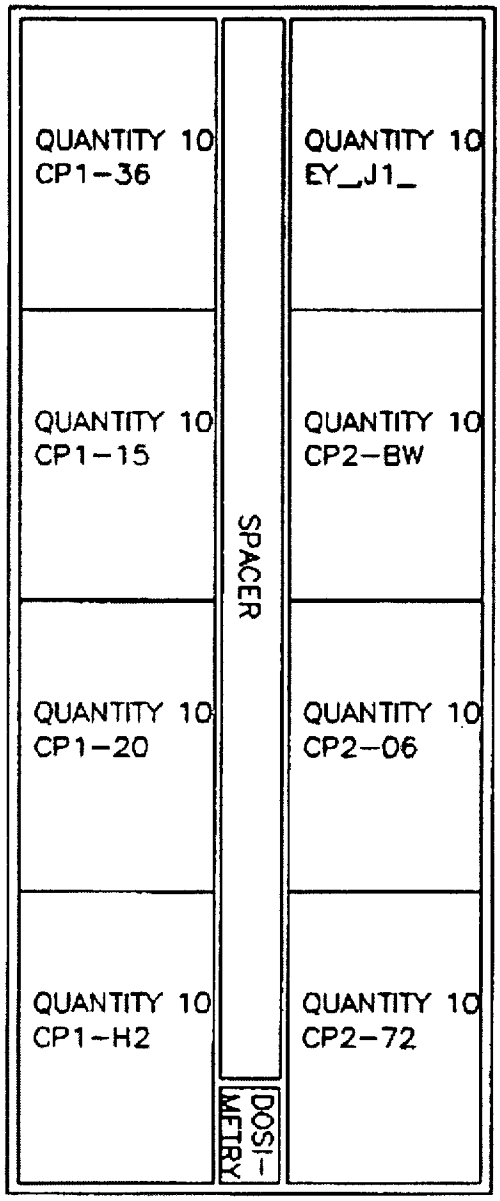

Figure 2-3
Cooper SSP Capsule C

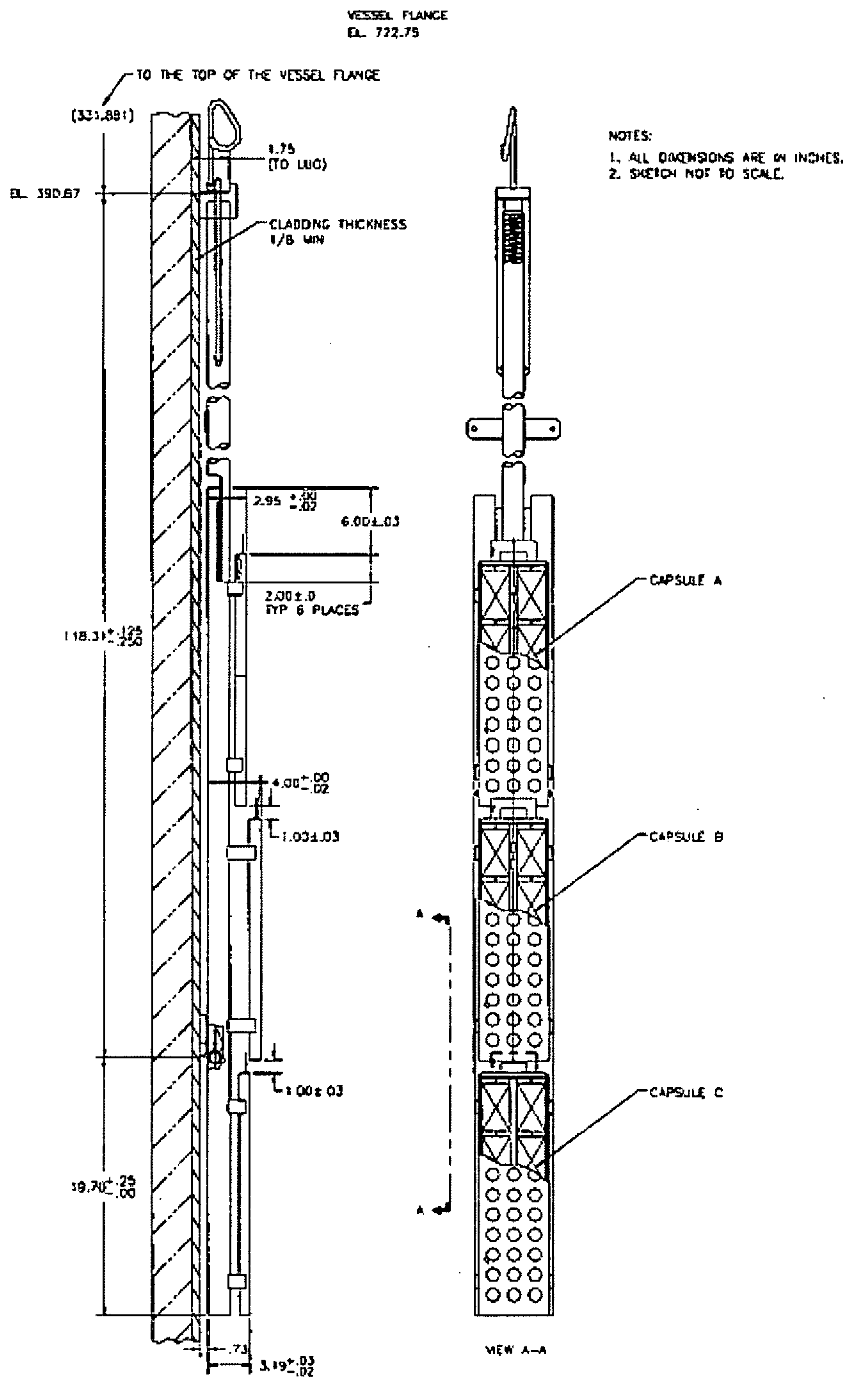

Figure 2-4
Cooper Nuclear Station SSP Capsule Holder

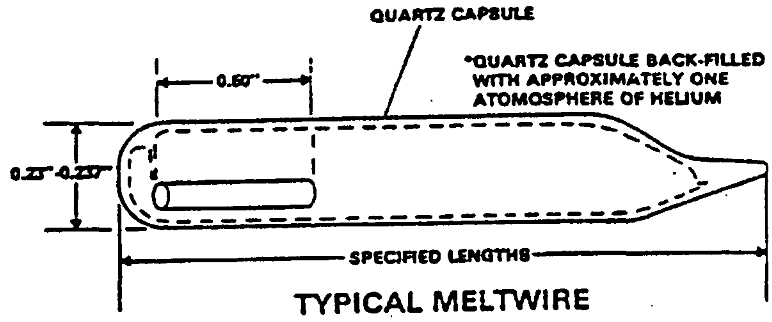

Figure 2-5
Schematic Representation of Thermal Monitor

Table 2-1
Thermal Monitors in SSP Capsule A

Melt Wire Composition (Weight %)	Target Melting Temperature[1] °F (°C)	Quartz Tube Length inches (cm)
73.7 Pb, 25 Sn, 1.3 Sb	504 (262)	1.0 (2.54)
81 Pb, 19 In	518 (270)	1.25 (3.18)
80 Au, 20 Sn	536 (280)	1.5 (3.81)
90 Pb, 5 Ag, 5 Sn	558 (292)	1.75 (4.45)
97.5 Pb, 2.5 Ag	580 (304)	2.0 (5.08)

[1]Melt wires are designed to melt within 4°F (2.2°C) of the specified temperatures.

2.3 Charpy V-Notch Specimens

The Charpy V-notch loading inventory, chemical compositions, material descriptions, and unirradiated (baseline) mechanical properties of the materials irradiated in SSP Capsules A, B, and C are summarized below.

2.3.1 Capsule Loading Inventory

The capsule loading inventory is provided in Table 2-2. Each capsule contained a set of ten (10) Charpy V-notch specimens for eight (8) materials, for a total of 80 CVN specimens in each capsule. The SSP capsules contained no tensile specimens and no CVN specimens for heat-affected zone (HAZ) materials.

Four (4) of the eight materials in each capsule were plate materials and four (4) were weld materials. The material heats loaded into Capsules A and B were identical; a different set of materials was loaded into Capsule C. A total of eight (8) plate materials and eight (8) weld materials were irradiated in SSP Capsules A, B, and C.

Table 2-2
SSP Capsules A, B, and C Charpy V-Notch Specimen Inventory

Surveillance Capsule Charpy Specimen Contents and Identifications[1]					
Capsule	**Source**	**Material Type**	**Heat Number**	**Identification**	**Quantity**
Capsule A	Grand Gulf	SA533B-1	A1224-1	AP1-67	10
	Cooper	SA533B-1	C2331-2	AP1-30	10
	Nine Mile Pt 1	SA302B Mod	P2130-2	AP1-11	10
	Fitzpatrick	SA533B-1	C3278-2	AP1-28	10
	Grand Gulf	SAW[2]	5P6214B	AP2-67	10
	Millstone 1	SAW[2]	34B009	AP2-15	10
	Quad Cities 2	Electroslag	Unknown	AP2-21	10
	Quad Cities 1	SAW	406L44	AP2-20	10
Capsule B	Grand Gulf	SA533B-1	A1224-1	BP1-67	10
	Cooper	SA533B-1	C2331-2	BP1-30	10
	Nine Mile Pt 1	SA302B Mod	P2130-2	BP1-11	10
	Fitzpatrick	SA533B-1	C3278-2	BP1-28	10
	Grand Gulf	SAW[2]	5P6214B	BP2-67	10
	Millstone 1	SAW[2]	34B009	BP2-15	10
	Quad Cities 2	Electroslag	Unknown	BP2-21	10
	Quad Cities 1	SAW[1]	406L44	BP2-20	10
Capsule C	Hatch 1	SA533B-1	C3985-2	CP1-36	10
	Millstone 1	SA302B Mod	C1079-1	CP1-15	10
	Quad Cities 1	SA302B Mod	A0610-1	CP1-20	10
	HSST-02	SA533B-1	A1195-1	CP1-H2	10
	Cooper	SAW[2]	20291	EY_J1_	10
	B&W Linde 80	SAW[2]	Unknown	CP2-BW	10
	Humboldt Bay 3	SAW[2]	Unknown	CP2-06	10
	River Bend	SAW[2]	5P6756	CP2-72	10

[1] The surveillance program does not include tensile specimens. Capsule A had thermal monitors and all three capsules had flux wires and spectral dosimeters.
[2] Submerged Arc Weld

2.3.2 Material Description

SSP capsules A, B, and C contained archive materials from BWR surveillance programs, HSST-02 standard material, and a B&W Linde 80 weld from B&W. All specimens were machined by GE from archive plant material, with the following exceptions: The Cooper weld 20291 specimens were archive specimens fabricated at the same time as the standard Cooper surveillance weld specimens; the B&W Linde 80 weld specimens were fabricated by GE from a block provided by B&W; and the HSST-02 plate specimens were also fabricated by GE from a full thickness block provided by Oak Ridge National Laboratory [5].

Tables 2-3 and 2-4 contain information about the specimens in SSP (Cooper) Capsules A, B, and C including fabricator, and copper and nickel content. Table 2-3 presents plate materials and Table 2-4 describes the weld materials.

Table 2-3
Plate Materials Irradiated in SSP Capsules A, B, and C

Identity (Capsule)	Material Source	Material Type	Cu (wt.%)	Ni (wt.%)	Source (RPV Fabricator)[1]
A1224-1 (A&B)	Grand Gulf	SA533B-1	0.03	0.65	GE (CBIN)
C2331-2 (A&B)	Cooper	SA533B-1	0.16	0.62	GE(CE)
P2130-2 (A&B)	Nine Mile Point 1	SA302B, Mod	0.172	0.584	GE (CE)
C3278-2 (A&B)	FitzPatrick	SA533B-1	0.11	0.61	GE (CE)
C3985-2 (C)	Hatch 1	SA533B-1	0.11	0.60	GE (CE)
C1079-1 (C)	Millstone 1	SA302B, Mod	0.22	0.51	GE (CE)
A0610-1 (C)	Quad Cities 1	SA302B, Mod	0.17	0.52	GE (B&W)
A1195-1 (C)	HSST-02	SA533B-1	0.15	0.70	ORNL (Lukens Steel)

[1]GE = General Electric
CBIN = Chicago Bridge and Iron Nuclear
CE = Combustion Engineering
B&W = Babcock and Wilcox
ORNL = Oak Ridge National Laboratory

Table 2-4
Weld Materials Irradiated in SSP Capsules A, B, and C

Identity (Capsule)	Material Source	Weld Type	Cu (wt.%)	Ni (wt.%)	Source (RPV Fabricator)
5P6214B (A&B)	Grand Gulf	Submerged Arc Weld	0.01	0.90	GE (CBIN)
34B009 (A&B)	Millstone 1	Submerged Arc Weld	0.15	1.81	GE (CE)
AP2-21 & BP2-21 (A&B)	Quad Cities 2	Electroslag Weld	0.11	0.24	GE (B&W)
406L44 (A&B)	Quad Cities 1	Submerged Arc Weld	0.29	0.69	GE (B&W)
20291 (C)	Cooper	Submerged Arc Weld	0.23	0.75	GE(CE)
CP2-BW (C)	B&W	Submerged Arc Weld, Linde 80	0.26	0.56	B&W
CP2-6 (C)	Humboldt Bay 3	Submerged Arc Weld	0.27	0.06	GE (CE)
5P6756 (C)	River Bend	Submerged Arc Weld	0.06	0.93	GE (CBIN)

2.3.3 Chemical Composition

Tables 2-5, 2-6, and 2-7 provide the best estimate chemistry composition of the surveillance materials in SSP Capsules A, B, and C, respectively.

Eleven of the sixteen materials in SSP Capsules A, B, and C are used in the BWRVIP ISP as Representative Surveillance Materials or are tracked by the ISP because they are heats used in the beltlines of BWR plants. For each of those eleven materials, a calculation of the best estimate chemistry is documented in BWRVIP-135 [7], ISP Data Source Book and Plant Evaluations. Each calculation in BWRVIP-135 considered all valid chemistry data for the surveillance material, including GE measurements on the SSP specimens [8] and chemistry measurements by the parent surveillance program from which the archive specimens came to the SSP. Therefore, BWRVIP-135 is used as the source of the best estimate chemistry for those eleven materials. For the other five materials, the best estimate was determined from chemistry measurements conducted by GE on the materials at the time of capsule assembly [8].

Table 2-5
Materials Irradiated in SSP (Cooper) Capsule A

Identity	Material	Cu (wt.%)	Ni (wt.%)	P (wt.%)	S (wt.%)	Si (wt.%)
A1224-1[1]	Grand Gulf Plate (SA533B-1)	0.03	0.65	0.012	0.012	0.28
C2331-2[1]	Cooper Plate (SA533B-1)	0.16	0.62	0.014	0.020	0.24
P2130-2[1]	Nine Mile Point 1 Plate (SA302B, Mod)	0.172	0.584	0.018	0.028	0.17
C3278-2[1]	FitzPatrick Plate (SA533B-1)	0.11	0.61	0.013	0.018	0.23
5P6214B[1]	Grand Gulf Weld (Submerged Arc Weld)	0.01	0.90	0.012	0.017	0.43
34B009[2]	Millstone 1 Weld (Submerged Arc Weld)	0.15	1.81	0.017	0.016	0.21
AP2-21[2]	Quad Cities 2 Weld (Electroslag Weld)	0.11	0.24	0.015	0.017	0.13
406L44[1]	Quad Cities 1 Weld (Submerged Arc Weld)	0.29	0.69	0.016	0.018	0.47

[1] Chemistry data from [7].

[2] Chemistry data from [8].

Table 2-6
Materials Irradiated in SSP (Cooper) Capsule B

Identity	Material	Cu (wt.%)	Ni (wt.%)	P (wt.%)	S (wt.%)	Si (wt.%)
A1224-1[1]	Grand Gulf Plate (SA533B-1)	0.03	0.65	0.012	0.012	0.28
C2331-2[1]	Cooper Plate (SA533B-1)	0.16	0.62	0.014	0.020	0.24
P2130-2[1]	Nine Mile Point 1 Plate (SA302B, Mod)	0.172	0.584	0.018	0.028	0.17
C3278-2[1]	FitzPatrick Plate (SA533B-1)	0.11	0.61	0.013	0.018	0.23
5P6214B[1]	Grand Gulf Weld (Submerged Arc Weld)	0.01	0.90	0.012	0.017	0.43
34B009[2]	Millstone 1 Weld (Submerged Arc Weld)	0.15	1.81	0.017	0.016	0.21
BP2-21[2]	Quad Cities 2 Weld (Electroslag Weld)	0.11	0.24	0.015	0.017	0.13
406L44[1]	Quad Cities 1 Weld (Submerged Arc Weld)	0.29	0.69	0.016	0.018	0.47

[1] Chemistry data from [7].

[2] Chemistry data from [8].

Table 2-7
Materials Irradiated in SSP (Cooper) Capsule C

Identity	Material	Cu (wt.%)	Ni (wt.%)	P (wt.%)	S (wt.%)	Si (wt.%)
C3985-2[1]	Hatch 1 Plate (SA533B-1)	0.11	0.60	0.015	0.017	0.27
C1079-1[1]	Millstone 1 Plate (SA302B, Mod)	0.22	0.51	0.018	0.028	0.22
A0610-1[1]	Quad Cities 1 Plate (SA302B, Mod)	0.17	0.52	0.015	0.018	0.019
A1195-1[2]	HSST-02 Plate (SA533B-1)	0.15	0.70	0.014	0.020	0.22
20291[1]	Cooper (Submerged Arc Weld)	0.23	0.75	0.014	--	--
CP2-BW[2]	B&W Linde 80 Weld (Submerged Arc Weld)	0.26	0.56	0.014	0.011	0.53
CP2-6[2]	Humboldt Bay 3 Weld (Submerged Arc Weld)	0.27	0.06	0.016	0.016	0.28
5P6756[1]	River Bend Weld (Submerged Arc Weld)	0.06	0.93	0.009	0.015	0.40

[1] Chemistry data from [7].

[2] Chemistry data from [8].

2.3.3 CVN Baseline Properties

Tables 2-8, 2-9 and 2-10 provide a summary of the baseline (unirradiated) Charpy V-notch properties of the SSP Capsules A, B, and C materials, respectively. In these tables and throughout this report, T_{30} is the 30 ft-lb (41 J) transition temperature; T_{50} is the 50 ft-lb (68 J) transition temperature; T_{35mil} is the 35 mil (0.89 mm) lateral expansion temperature; and USE is the average energy absorption at full shear fracture appearance.

With the exception of Cooper weld heat 20291, the baseline properties were determined from baseline (unirradiated) Charpy test results documented in [8] and provided by GE in [9]. The Cooper weld heat 20291 baseline Charpy test data was documented in [11]. The baseline test data were fit to a hyperbolic tangent curve using the computer program CVGRAPH [10]. The CVGRAPH curves fits for the baseline data are provided in Appendix B along with the curve fits for the irradiated data for each material. All plate values are transverse orientation.

Table 2-8
Baseline CVN Properties of SSP Capsule A Materials

Material Identity	Material	T_{30} °F (°C)	T_{50} °F (°C)	T_{35mil} °F (°C)	Upper Shelf Energy (USE) ft-lb (J)
A1224-1	Grand Gulf Plate (SA533B-1)	-20.9 (-29.4)	5.9 (-14.5)	10.9 (-11.7)	147.3 (199.7)
C2331-2	Cooper Plate (SA533B-1)	-13.3 (-25.2)	30.1 (-1.1)	34.1 (1.2)	100.0 (135.6)
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	-2.8 (-19.3)	41.6 (5.3)	22.8 (-5.1)	68.2 (92.5)
C3278-2	FitzPatrick Plate (SA533B-1)	-34.4 (-36.9)	5.4 (-14.8)	15.1 (-9.4)	113.3 (153.6)
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	-26.8 (-32.7)	7.0 (-13.9)	9.2 (-12.7)	91.5 (124.1)
34B009	Millstone 1 Weld (Submerged Arc Weld)	-65.0 (-53.9)	-29.5 (-34.2)	-21.0 (-29.4)	104.4 (141.5)
AP2-21	Quad Cities 2 Weld (Electroslag Weld)	-23.1 (-30.6)	17.9 (-7.8)	22.4 (-5.3)	104.0 (141.0)
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	-8.8 (-22.7)	51.1 (10.6)	39.2 (4.0)	73.3 (99.4)

Table 2-9
Baseline CVN Properties of SSP Capsule B Materials

Material Identity	Material	T_{30} °F (°C)	T_{50} °F (°C)	T_{35mil} °F (°C)	Upper Shelf Energy (USE) ft-lb (J)
A1224-1	Grand Gulf Plate (SA533B-1)	-20.9 (-29.4)	5.9 (-14.5)	10.9 (-11.7)	147.3 (199.7)
C2331-2	Cooper Plate (SA533B-1)	-13.3 (-25.2)	30.1 (-1.1)	34.1 (1.2)	100.0 (135.6)
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	-2.8 (-19.3)	41.6 (5.3)	22.8 (-5.1)	68.2 (92.5)
C3278-2	FitzPatrick Plate (SA533B-1)	-34.4 (-36.9)	5.4 (-14.8)	15.1 (-9.4)	113.3 (153.6)
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	-26.8 (-32.7)	7.0 (-13.9)	9.2 (-12.7)	91.5 (124.1)
34B009	Millstone 1 Weld (Submerged Arc Weld)	-65.0 (-53.9)	-29.5 (-34.2)	-21.0 (-29.4)	104.4 (141.5)
BP2-21	Quad Cities 2 Weld (Electroslag Weld)	-23.1 (-30.6)	17.9 (-7.8)	22.4 (-5.3)	104.0 (141.0)
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	-8.8 (-22.7)	51.1 (10.6)	39.2 (4.0)	73.3 (99.4)

Table 2-10
Baseline CVN Properties of SSP Capsule C Materials

Material Identity	Material	T_{30} °F (°C)	T_{50} °F (°C)	T_{35mil} °F (°C)	Upper Shelf Energy (USE) ft-lb (J)
C3985-2	Hatch 1 Plate (SA533B-1)	-11.7 (-24.3)	27.0 (-2.8)	31.1 (-0.5)	112.8 (152.9)
C1079-1	Millstone 1 Plate (SA302B, Mod)	9.7 (-12.4)	76.6 (24.8)	57.1 (13.9)	61.2 (83.0)
A0610-1	Quad Cities 1 Plate (SA302B, Mod)	-33.5 (-36.4)	-4.1 (-20.1)	-1.5 (-18.6)	101.2 (137.2)
A1195-1	HSST-02 Plate (SA533B-1)	39.8 (4.3)	78.7 (25.9)	79.6 (26.4)	99.7 (135.2)
20291	Cooper Weld	-17.8 (-27.7)	13.3 (-10.4)	10.8 (-11.8)	110.0 (149.1)
CP2-BW	B&W Linde 80 Weld (Submerged Arc Weld)	40.0 (4.4)	94.9 (34.9)	80.9 (27.2)	75.8 (102.8)
CP2-6	Humboldt Bay 3 Weld (Submerged Arc Weld)	-74.0 (-58.9)	-29.3 (-34.1)	-24.6 (-31.4)	110.3 (149.5)
5P6756	River Bend Weld (Submerged Arc Weld)	-67.1 (-55.1)	-21.3 (-29.6)	-20.3 (-29.1)	104.4 (141.5)

2.4 Capsule Opening

The surveillance capsules were opened in August, 2005. The outside of the capsules had identification markings which were difficult to read. The capsule identification was determined from the marked Charpy bars inside the capsules. As expected, a total of 80 Charpy V-notch specimens were recovered from each capsule with the identifications listed in Table 2-2.

2.4.1 Condition of Dosimeters

Particular attention was paid to the specimen and dosimeter wire locations during disassembly of the capsules. As shown in Figures 2-6 through 2-9, the Fe and Cu dosimeter wires which extended over the axial length of the capsules were not in the Charpy notches over significant axial distances in all three capsules. GE intended that the dosimetry wires should be irradiated in the Charpy notches. A possible explanation is that the wires were dislodged by the post-irradiation handling. However, the only visible damage on the outside of the capsules was bent U-hooks at the top of the capsules. This damage could have happened when the capsules were removed from service. There were no indications that the capsules had been dropped or otherwise impacted.

Further, several observations point to the conclusion that the wires were not in the Charpy notches during the entire irradiation:

- the capsule outer wrapper is so tight after exposure to the high pressure of the primary system that it is not possible for the wires to move very far
- the external surface of the capsule wrappers (ex, see Figure 2-6) have visible impressions of the wire and have contoured around the wires due to the coolant pressure
- there is a linear mark on the surface of the Charpy specimens showing where the wires were positioned during irradiation
- the wires were not "locked in" at the bottom of the capsules which allowed them to come out of the Charpy notches

These observations point to the capsules being irradiated with the wires out of the notches. It is possible that the wires moved before the initial pressurization in reactor water and then were held in place out of the Charpy notches between the outer stainless steel wrapper and the specimens. It can be difficult to get the stainless steel wrapper tight initially during fabrication. The wires were configured so that they were locked into position at the top of the capsules but not at the bottom. Not locking the wires in at the bottom of the capsule is a serious design deficiency which most likely led to the wires being irradiated out of the Charpy notches over most of the length of the capsules. In cases where there is a large flux variation with azimuthal angle, it is necessary to account for the wire position in the capsule to obtain good agreement between calculation and measurement.

As shown in Figures 2-6 through 2-8, the capsules were opened by removing the top face of the wrapper to reveal the specimens and dosimetry. As discussed in [4], the Charpy specimens were arranged in two parallel columns with four groups of ten specimens in each column. Therefore, the Fe and Cu wires were cut into axial segments which span the group of ten Charpy bars to enable measured fluence determination for each set of Charpy specimens. In addition to the Fe and Cu wire dosimetry, the spectral dosimetry for each of the capsules was successfully recovered along with the thermal monitors from Capsule A.

2.4.2 Condition of Thermal Monitors

The quartz containers were in small metal blocks near the center of Capsule A. A small diameter wire was welded across the hole in the top of each block to hold the quartz container in the block. The retaining wires were removed and the quartz containers were recovered from the blocks. The results are summarized in Table 2-11. Examination of the melt wires has indicated that the peak temperature of the capsule during irradiation was between 536°F (280°C) and 558°F (292°C). If we assume a 4°F (2.2°C) uncertainty for the 536°F (280°C) melt wire, then it is possible that the wire melted at a temperature as low as 532°F (278°C). If this is the case, then the downcomer water would be operating near the high end of the expected temperature range. An alternative explanation is that the capsule internal temperature was above the surrounding water temperature due to radiation heating effects.

Table 2-11
Results of Melt Wire Examination

Melt Wire Composition (Weight %)	Melting Temperature[1] °F (°C)	Post-Irradiation Condition of Melt Wire
73.7 Pb, 25 Sn, 1.3 Sb	504 (262)	Melted
81 Pb, 19 In	518 (270)	Melted
80 Au, 20 Sn	536 (280)	Melted
90 Pb, 5 Ag, 5 Sn	558 (292)	Not Melted
97.5 Pb, 2.5 Ag	580 (304	Not Melted

[1]Melt wires are designed to melt within 4°F (2.2°C) of the specified temperatures.

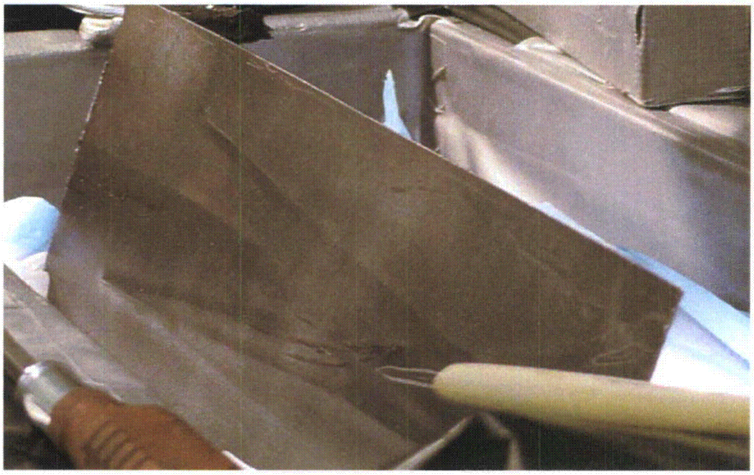

Figure 2-6
Photograph of CNS Capsule A Wrapper Showing Indentations which Indicate that the Capsule was Irradiated with the Dosimetry Wires out of the Charpy Notches

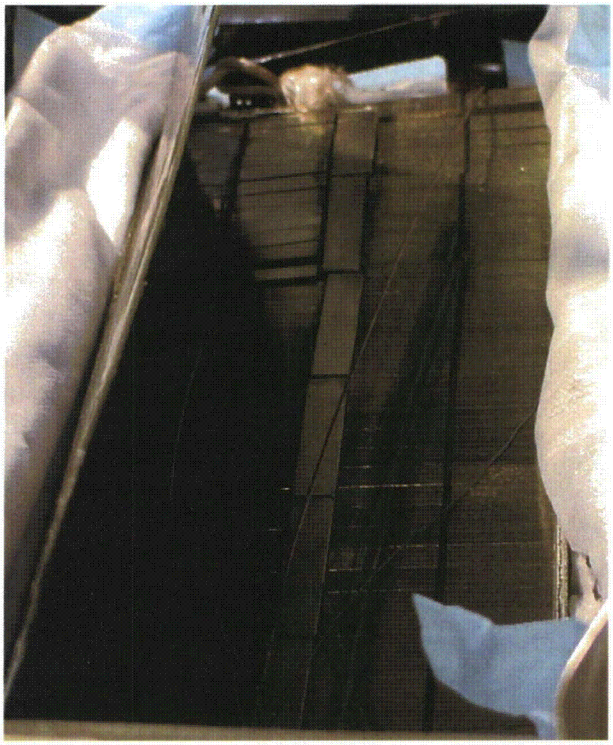

Figure 2-7
Photograph of CNS Capsule A Showing Fe and Cu Wires Out of the Charpy Notches
(Capsule U-Hook is at Top of Photograph)

Figure 2-8
Photograph of CNS Capsule B Showing Fe and Cu Wires Out of the Charpy Notches
(Capsule U-Hook is at Top of Photograph)

Figure 2-9
Photograph of CNS Capsule C Showing Fe and Cu Wires Out of the Charpy Notches
(Capsule U-Hook is at Top of Photograph)

3
NEUTRON FLUENCE CALCULATION

3.1 Description of the Reactor System

This section describes the Cooper Nuclear Station (CNS) design inputs used in the surveillance capsule activation and fluence evaluation performed per the guidance of Regulatory Guide 1.190 [12]. The basic design inputs include component mechanical designs, material compositions, and reactor operating history. Mechanical design drawings and structural material data were provided by Nebraska Public Power District and were used to build the Cooper Nuclear Station RAMA geometry model [13]. Detailed operating history data was provided for this project by Nebraska Public Power District [14] for cycles 15 through 21.

3.1.1 Reactor System Mechanical Design Inputs

The CNS employs a boiling water reactor (BWR) nuclear steam supply system. The reactor is a General Electric BWR/4 class reactor and the reactor core consists of 548 fuel assemblies with a rated thermal power of 2381 MWt.

The CNS is modeled with the RAMA Fluence Methodology [15-19]. The Methodology employs a three-dimensional modeling technique to describe the reactor geometry for the neutron transport calculations. Detailed mechanical design information is used in order to build an accurate three-dimensional RAMA computer model of the reactor system. A summary of the important design inputs is presented in this subsection.

Figure 3-1 illustrates the basic planar geometry configuration of the reactor at the axial elevation corresponding to the core mid-plane elevation. All radial regions comprising the fluence model are illustrated. Beginning at the center of the reactor and projecting outwards, the regions include: the core region, including control rod locations and fuel assembly locations (fuel locations are shown only for the northeast quadrant); core reflector region (bypass water); central shroud wall; downcomer water region including the jet pumps; reactor pressure vessel (RPV) wall; mirror insulation; biological shield (concrete wall); and cavity regions between the RPV and biological shield. Also shown are the azimuthal positions of the surveillance capsules in the downcomer region at 30°, 120°, and 300°. The surveillance capsules are positioned radially near the inner surface of the RPV wall. The azimuthal positions of the jet pump assemblies are illustrated as well at 30°, 60°, 90°, 120°, 150°, 210°, 240°, 270°, 300°, and 330°.

The specimen locations in SSP surveillance capsules A, B, and C, and the capsule holder design showing the positioning of the A, B, and C capsules within the holder (e.g., Figure 2-4), were described in the previous chapter.

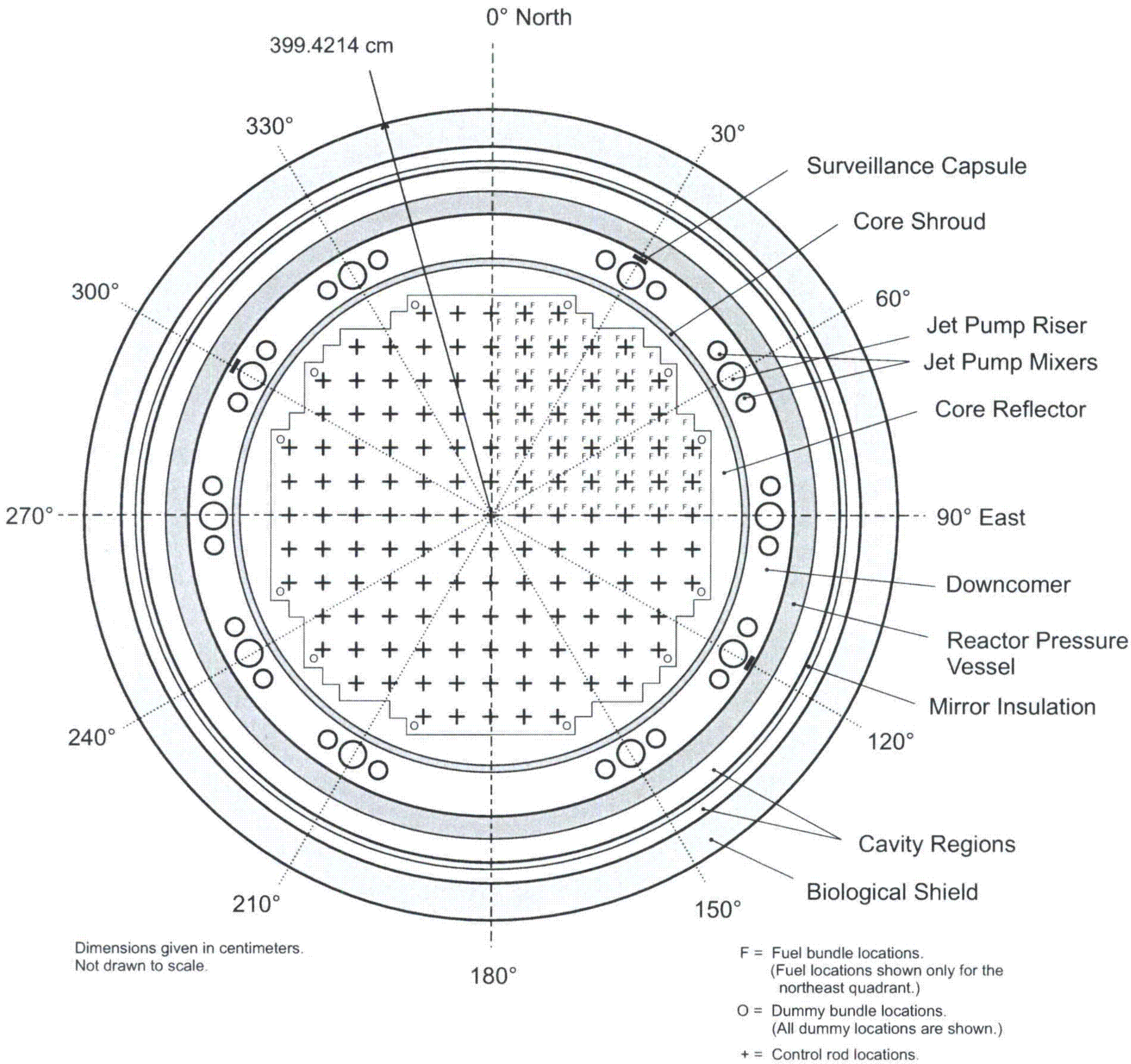

Figure 3-1
Planar View of the Cooper Nuclear Station Reactor

3.1.2 Reactor System Material Compositions

Each region of the reactor is comprised of materials that include reactor fuel, steel, water, insulation, concrete, and air. Accurate material information is essential for the fluence evaluation as the material compositions determine the scattering and absorption of neutrons throughout the reactor system and, thus, affect the determination of neutron fluence in the reactor components.

Table 3-1 provides a summary of the material compositions in the various components and regions of the CNS. The attributes for the steel, insulation, concrete, and air compositions (i.e., material densities and isotopic concentrations) are assumed to remain constant for the operating life of the reactor. The attributes for the ex-core water compositions will vary with the operation of the reactor, but are generally represented at nominal hot operating conditions and are assumed to be constant throughout an operating cycle.

Table 3-1
Summary of Material Compositions by Region for Cooper Nuclear Station

Region	Material Composition
Reactor Core	^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, O_{fuel}, Zr, Water
Core Reflector	Water
Fuel Support Piece	Stainless Steel
Fuel Assembly Lower Tie Plate	Stainless Steel, Zircaloy, Inconel
Fuel Assembly Upper Tie Plate	Stainless Steel, Zircaloy, Inconel
Top Guide	Stainless Steel
Shroud	Stainless Steel
Jet Pump Riser and Mixer Flow Area	Water
Jet Pump Riser and Mixer Metal	Stainless Steel
Downcomer Region	Water
Surveillance Capsule	Carbon Steel
Reactor Pressure Vessel Clad	Stainless Steel
Reactor Pressure Vessel Wall	Carbon Steel
Cavity Regions	Air (Oxygen)
Insulation	Stainless Steel
Biological Shield Clad	Carbon Steel
Biological Shield	Reinforced Concrete

The attributes of the fuel compositions in the reactor core region change continuously during an operating cycle due to changes in power level, fuel burnup, control rod movements, and changing moderator density levels (voids). Because of the dynamics of the fuel attributes with reactor operation, one to several data sets describing the operating state of the reactor core are used for each operating cycle. The number of data sets used in this analysis is presented in Section 3.1.3.2.

3.1.3 Reactor Operating Data Inputs

An accurate evaluation of fluence in the CNS requires an accurate accounting of the reactor operating history. The primary reactor operating parameters that affect neutron fluence evaluations for BWR's include the reactor power level, core power distribution, core void fraction distribution (or equivalently, water density distribution), and fuel material distribution. These items are described in the following subsections.

3.1.3.1 Power History Data

The reactor power history used in the CNS surveillance capsule fluence evaluation was obtained from daily power history edits provided by Nebraska Public Power District for operating cycles 15 through 21 [14]. The daily power values represent step changes in power on a daily basis and are assumed to be representative of the power over the entire day. The surveillance capsule fluence evaluation for the CNS considers the complete daily operating history of the reactor from cycles 15 through 21. Also accounted for in the analysis are the shutdown periods. The shutdowns were primarily due to the refueling outages between cycles. Table 3-2 provides the effective full power years of power generation at the end of each cycle in this capsule fluence evaluation.

3.1.3.2 Reactor State Point Data

CNS operating data for the capsule fluence evaluation was provided as state point data files by Nebraska Public Power District [14]. The state point files provide a best-available representation of the operating conditions of the unit over the operating lifetime of the reactor. The data files include three-dimensional data arrays that describe the fuel materials, moderator densities, and relative power distribution in the core.

A total of 79 state point data files were used to represent operating cycles 15 through 21 of the CNS. Table 3-2 shows the number of state point data files for each cycle used in this capsule fluence evaluation. A separate neutron transport calculation was performed for each state point. The calculated neutron flux for each state point was combined with the appropriate power history data described in Section 3.1.3.1 in order to predict the neutron fluence in the surveillance capsules.

Table 3-2
Number of State-point Data Files for Cooper Nuclear Station Cycles 15-21

Cycle Number	Number of State Point Data Files	Rated Thermal Power MWt	Accumulated Effective Full Power Years (EFPY)
15	13	2381	12.3
16	11	2381	13.6
17	11	2381	14.8
18	12	2381	16.1
19	11	2381	17.2
20	11	2381	18.5
21	10	2381	19.6

3.1.3.3 Core Loading Pattern

It is common in BWRs that more than one fuel assembly design will be loaded in the reactor core in any given operating cycle. For fluence evaluations, it is important to account for the fuel assembly designs that are loaded in the core in order to accurately represent the neutron source distribution at the core boundaries (i.e., peripheral fuel locations, the top fuel nodes, and the bottom fuel nodes).

Three different fuel assembly designs are used in the CNS during cycles 15 through 21. Table 3-3 provides a summary of the fuel designs loaded in the reactor core for these operating cycles. The cycle core loading patterns provided by Nebraska Public Power District are used to identify the fuel assembly designs in each cycle and their location in the core loading pattern. For each cycle, appropriate fuel assembly models are used to build the reactor core region of the RAMA fluence model for the CNS.

Table 3-3
Summary of Cooper Nuclear Station Core Loading Pattern for Cycles 15-21

Cycle	General Electric (GE) 8x8 Fuel Assembly Designs	General Electric (GE) 9x9 Fuel Assembly Designs	General Electric (GE) 10x10 Fuel Assembly Designs	Dominant Peripheral Fuel Design in the RAMA Model
15	X	X		GE 8x8
16	X	X		GE 8x8
17	X			GE 8x8
18	X			GE 8x8
19	X			GE 8x8
20	X		X	GE 8x8
21	X		X	GE 8x8

3.2 Calculation Methodology

The Cooper Nuclear Station fluence evaluations were performed using the RAMA Fluence Methodology software package. The Methodology and the application of the Methodology to the Cooper Nuclear Station reactor are described in this section.

3.2.1 Description of the RAMA Fluence Methodology

The RAMA Fluence Methodology software package is a system of codes that is used to perform fluence evaluations in light water reactor components. The significance of the Methodology is the integration of a three-dimensional arbitrary geometry modeling technique with a deterministic transport method to provide a flexible and accurate platform for determining neutron fluence in light water reactor systems. The Methodology is complemented with model building codes to prepare the three-dimensional models for the transport calculation and a post-processing code to calculate fluence from the neutron flux calculated by the transport code.

The primary inputs for the RAMA Fluence Methodology are mechanical design parameters and reactor operating history data. The mechanical design inputs are obtained from reactor design drawings (or vendor drawings) of the plant. The CNS operating history data is obtained from reactor core simulation calculations, system heat balance calculations, and daily operating logs that describe the operating conditions of the reactor.

The primary outputs from the RAMA Fluence Methodology calculations are neutron flux, neutron fluence, and uncertainty determinations. The RAMA transport code calculates the neutron flux distributions that are used in the determination of neutron fluence. Several transport calculations are typically performed over the operating life of the reactor in order to calculate neutron flux distributions that accurately characterize the operating history of the reactor. The post-processing code (RAFTER) is then used to calculate component fluence and nuclide activations using the neutron flux solutions from the transport calculations and daily operating history data for the plant. The fluence calculated by RAFTER may then be adjusted in accordance with the calculational bias to determine the best estimate fluence and uncertainty in accordance with the intent of U. S. Nuclear Regulatory Guide 1.190.

3.2.2 The RAMA Geometry Model for Cooper Nuclear Station

Figure 3-2 illustrates the planar configuration of the CNS model at an axial elevation near the core mid-plane of the reactor pressure vessel. In the radial dimension the model extends from the center of the RPV to the outside surface of the biological shield (399.4214 cm). Nine radial regions are defined in the CNS model: the core region (comprised of interior and peripheral fuel assemblies), core reflector, shroud, downcomer region with jet pumps, pressure vessel, mirror insulation, biological shield, and inner and outer cavity regions. The RPV has cladding on the wall inner surface. The biological shield has cladding on the inner and outer surfaces.

Figure 3-2 shows that the reactor core region is modeled with rectangular geometry to preserve the shape of the core region. The core region is characterized with two layers: the interior fuel assemblies and the peripheral fuel assemblies. The peripheral fuel assemblies are the primary contributors to the neutron source in the fluence calculation and are modeled to preserve the pin-wise source contribution at the core-core reflector interface.

Each of the components and regions that extend outward from the core region are modeled in their correct geometrical form. The core shroud, downcomer, RPV wall, mirror insulation, biological shield wall, and cavity regions are correctly modeled as cylindrical parts. The jet pump assembly design is properly modeled using cylindrical pipe elements for the jet pump riser and mixer pipes. The riser pipe is correctly situated between the mixer pipes. The surveillance capsule, which is rectangular in design, is modeled as an arc element in the geometry and is correctly positioned near the inner surface of the RPV wall. This model is an acceptable approximation since the capsule is a sufficient distance from the core center that the arc element closely approximates the shape of a rectangular element. Downcomer water surrounds the capsule on all sides.

The jet pumps are shown as modeled at azimuth 30° in the downcomer region. When symmetry is applied to the model, the jet pump assemblies that are positioned azimuthally at 30°, 60°, 120°, 150°, 210°, 240°, 300°, and 330° are represented by the model. Due to model symmetry restrictions, the jet pumps at the 90° and 270° azimuths are not represented. This is a conservative approximation for RPV fluence calculations and is assumed to be applicable to other components. The surveillance capsules are shown as modeled at azimuth 30°. When symmetry is applied to the model, this location represents each of the surveillance capsules loaded at 30°, 120°, and 300° (see Figure 3-1).

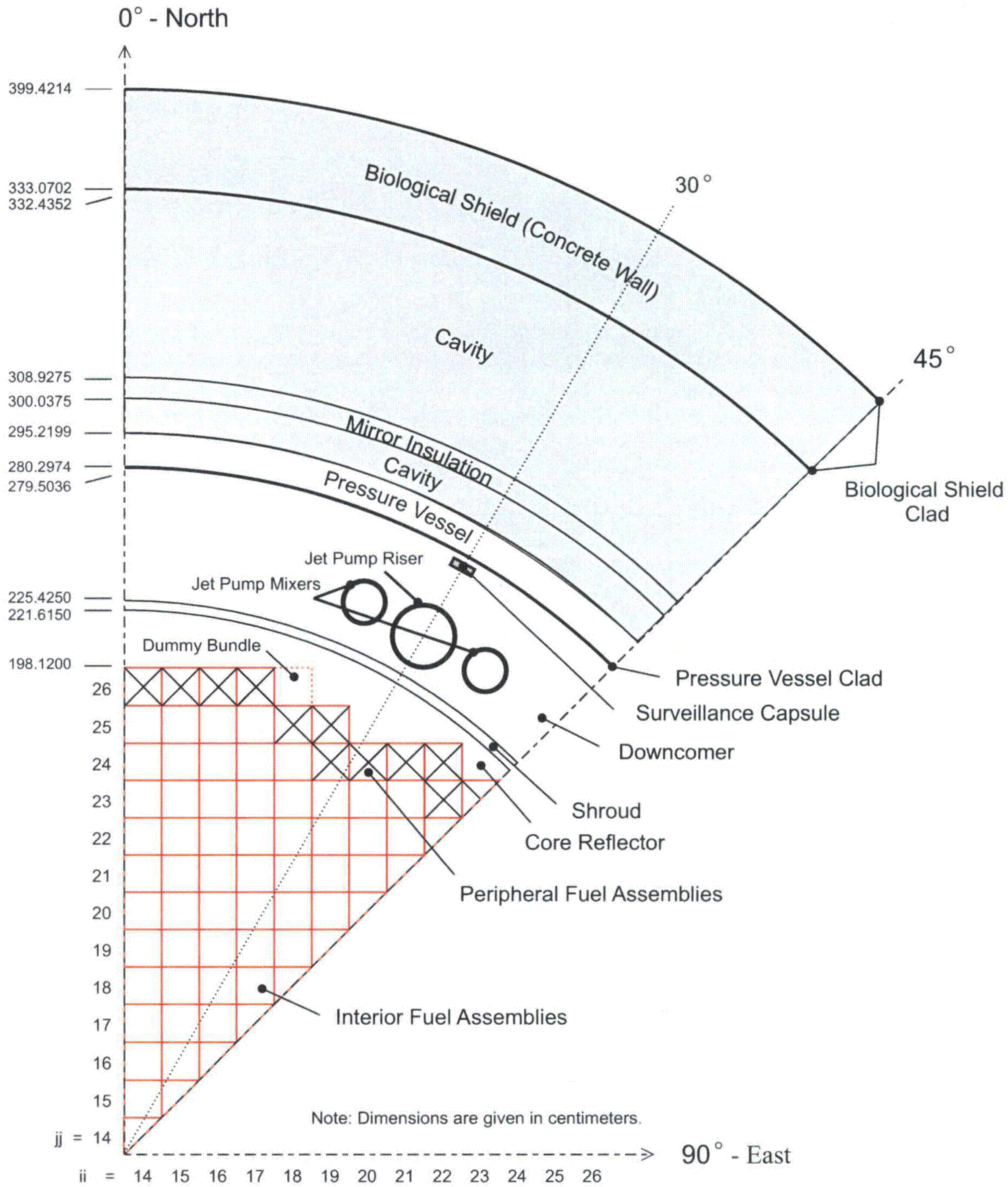

Figure 3-2
Planar View of the Cooper Nuclear Station RAMA Model

As shown in Figure 3-1, the CNS geometry is quadrant symmetric, both in the core region and in the ex-core geometry. The quadrant core symmetry results from the presence of 12 dummy bundles, eight of which are located in octant symmetric locations, and four of which are located in quadrant symmetric locations. The ex-core symmetry results from the presence of ten jet pump assemblies that are located in quadrant-symmetric locations. For computational reasons, the RAMA model of the CNS core and ex-core geometry assumes octant symmetry. In the azimuthal dimension the model spans from 0° to 45° where the 0° azimuth corresponds to the north compass direction that is specified in the reactor design drawings. The selection of this octant is appropriate because the SSP capsules are located at the 30° azimuth.

Figure 3-3 provides an illustration of the axial configuration of the CNS RAMA model for three significant components: a fuel column, the core shroud, and the reactor pressure vessel. Also shown in the figure are the relative axial positioning of the jet pumps, surveillance capsules, and core spray sparger pipes in the reactor model. The axial planes are divided into several groups representing particular component regions of the model as follows: the core region, the top guide, the shroud head flange, the core spray spargers, the fuel support piece, core support plate, and core inlet region. Sub-planar meshing is used in the model, as needed, to properly represent the positioning of reactor components, such as the jet pump rams head and surveillance capsules. The model consists of thousands of mesh regions. In the axial direction, the CNS fluence model spans from below the jet pump riser inlet to above the core shroud head flange for a total of 631.3488 cm (20.7 feet) in length.

There are several key features of the RAMA code system that allow the CNS design to be accurately represented for component fluence evaluations; key features of the model include:

- Rectangular and cylindrical bodies are mixed in the model in order to provide an accurate geometrical representation of the components and regions in the reactor.
- The core geometry is modeled using rectangular bodies to represent the fuel assemblies in the reactor core region.
- Cylindrical bodies are used to represent the components and regions that extend outward from the core region.
- A combination of rectangular and cylindrical bodies is used to describe the transition parts that are required to interface the rectangular core region to the cylindrical outer core regions.
- The top guide is appropriately modeled by including a representation of the vertical fuel assembly parts and top guide plates. The upper fuel assembly parts that extend into the top guide region are modeled in three axial segments: the fuel rod plenum, fuel rod upper end plugs, and fuel assembly upper tie plate.
- The fuel support piece, core support plate, and core inlet regions appropriately include a representation of the cruciform control rod below the core region. The lower fuel assembly parts include representations for the fuel rod lower end plugs, lower tie plate, and nose piece.
- The surveillance capsules are accurately represented in the downcomer region at the correct azimuthal, radial, and axial locations.

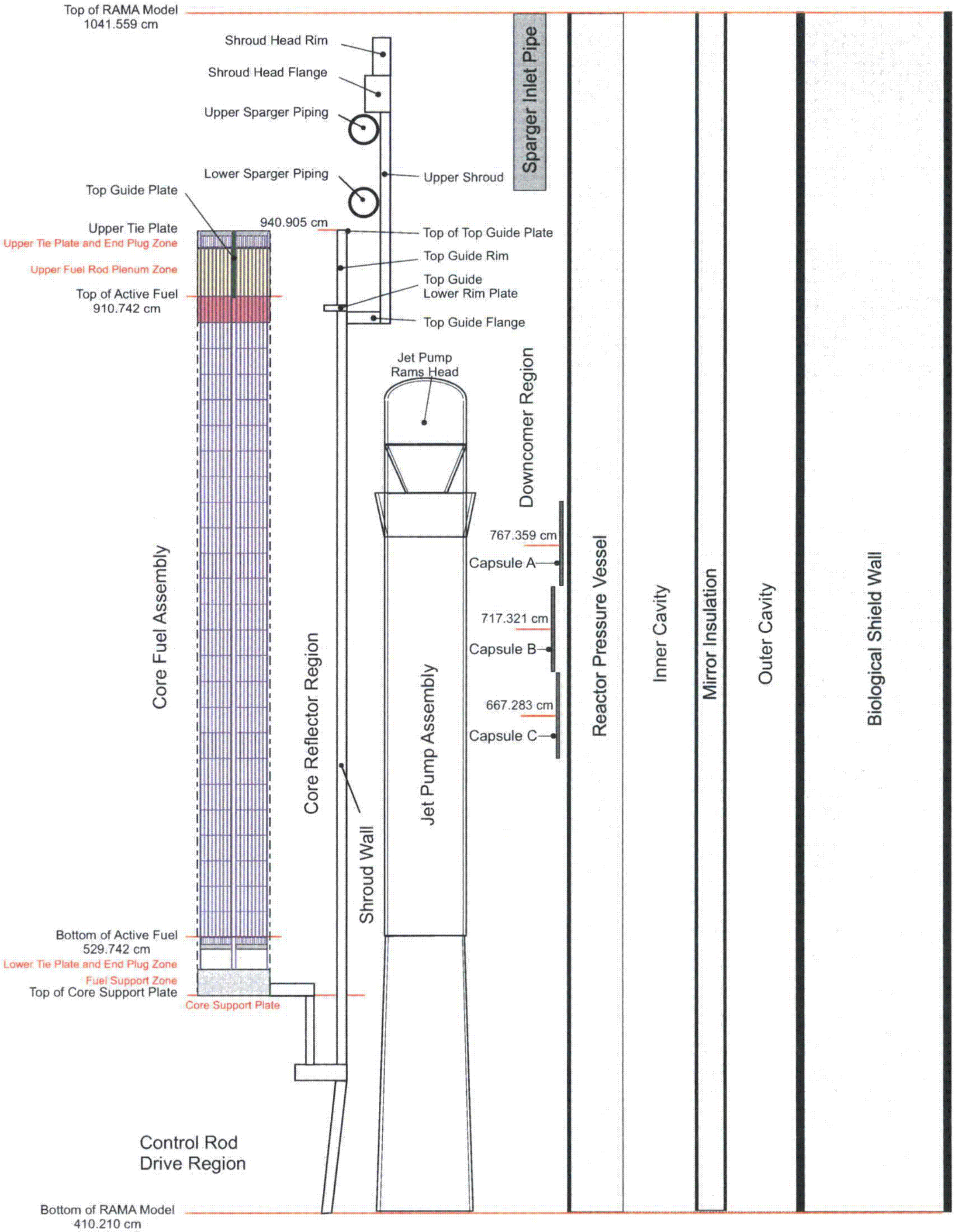

Figure 3-3
Axial View of the Cooper Nuclear Station RAMA Model

3.2.3 RAMA Calculation Parameters

The RAMA transport code uses a three-dimensional deterministic transport method to calculate neutron flux distributions in reactor problems. The transport method is based on a numerical integration technique that uses ray-tracing to form the integration paths through the problem geometry. The integration paths for the rays are determined using four parameters. The distance between parallel rays in the planar dimension is specified as 1.00 cm. The distance between parallel rays in the axial dimension is specified as 5.00 cm. The depth that a ray penetrates a reflective boundary is specified as 10 mean free paths. In accordance with the guidelines provided in [12], the angular quadrature for determining ray trajectories is specified as S8, which provides an acceptable compromise between computational accuracy and performance.

The RAMA transport calculation also uses information from the RAMA nuclear data library to determine the scope of the flux calculation. This information includes the Legendre order of expansion that is used in the treatment of anisotropy of the problem. By default, the RAMA transport calculation uses the maximum order of expansion that is available for each nuclide in the RAMA nuclear data library (i.e., through P_5 scattering for actinide and zirconium nuclides and through P_7 scattering for all other nuclides in the model).

The neutron flux is calculated using an iterative technique to obtain a converged solution for the problem. The convergence criterion used in the evaluation is 0.01 which provides an asymptotic solution.

The impact of these calculation parameter selections on the RAMA capsule fluence evaluation for Cooper Nuclear Station is presented in Section 3.2.6.

3.2.4 RAMA Neutron Source Calculation

The neutron source for the RAMA transport calculation is calculated using the input relative power density factors for the different fuel regions and data from the RAMA nuclear data library.

The core neutron source was determined using the cycle-specific three-dimensional burnup distributions. The source distributions account for the radial power gradient in the fuel assemblies loaded near the core boundary by modeling the pin-wise source distributions in the outer row of fuel assemblies.

3.2.5 RAMA Fission Spectra

RAMA calculates a weighted fission spectrum, based on the relative contributions of the fuel isotopes, that is used in the transport calculation. The fission spectra for ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu that are used in the RAMA transport calculations were taken directly from the latest release of the BUGLE-96 data library.

3.2.6 Parametric Sensitivity Analyses

Several sensitivity analyses were performed to evaluate the stability and accuracy of the RAMA transport calculation for the Cooper Nuclear Station model. Several parameters were evaluated including mesh size and the integration parameters discussed earlier. A summary of the analyses is presented in Table 3-4. As provided for in [12], two-dimensional models consisting of the detailed planar representation at the core mid-plane, typical of the model shown in Figure 3-2, are used to evaluate the sensitivities for those parameters that are insensitive to axial variations. Those parameters that are sensitive to axial variations are evaluated using detailed three-dimensional models typical of the model.

Table 3-4
Sensitivity Analyses

Case Description	Model Geometry	Varied Parameter	Maximum Absolute Deviation in the >1.0 MeV Capsule Flux Relative to the Production Model
Variation of the capsule planar mesh size	2-D	Mesh size is reduced to approximately one-fourth the production model mesh size	<2%
Variation of the distance between planar parallel rays	2-D	Distance between rays is reduced from 1.0 cm in the production model to 0.10 cm	<0.5%
Variation of the distance between axial parallel rays	3-D	Distance between rays is reduced from 5.0 cm in the production model to 3.0 cm	<0.02%
Variation of convergence criterion	2-D	Convergence criterion is reduced from 0.01 in the production model to 0.0001	≤0.02%
Variation of the angular quadrature set	2-D	Angular quadrature set is increased from S8 in the production model to S32	<7%
Variation of the maximum Legendre order of scattering	2-D	Scattering order is decreased from P_7 in the production model to P_3	<0.4%

3.3 RAMA Nuclear Data Library

The nuclear cross section library is an essential element in neutron fluence evaluations. The accuracy of the cross section data is one of the primary factors that affect the accuracy of the neutron fluence prediction in reactor components. The RAMA nuclear data library is based upon the BUGLE-96 library [20] which has been developed exclusively from ENDF/B-VI nuclear data by Oak Ridge National Laboratories.

3.3.1 Nuclear Cross Sections

The RAMA nuclear data library consists of 47 neutron energy groups that span an energy range of 0.1 eV to 17.332 MeV. The group structure is especially well-suited to applications requiring accurate determination of neutron flux with energy >1.0 MeV. This is of primary importance in the evaluation of irradiation damage to reactor components. The RAMA nuclear data library also includes energy group upscattering in the lower (thermal) energy range of <5.04 eV. This significantly improves the prediction of thermal flux. Table 3-5 shows the group structure for the 47 neutron groups in the RAMA nuclear data library. The RAMA nuclear data library contains an extensive set of nuclide cross sections that are pre-shielded and spectrally collapsed using light water reactor flux spectra. The library incorporates improved resonance treatments for steel nuclides that are based on ENDF-B/VI. The resonance treatments are of particular importance in reactor system component fluence evaluations. Except for oxygen in the reactor cavity regions, surveillance capsule evaluations use appropriately pre-shielded and spectrally collapsed cross section data.

The RAMA nuclear data library has been especially developed for the solution of ex-core neutron transport calculations that must account for anisotropic scattering effects. Lighter nuclides contain scattering data for up to P_7 Legendre scattering expansion, while the heavier nuclides contain data for up to P_5 scattering.

Table 3-5
Energy Boundaries for the RAMA Neutron 47-Group Structure

Energy Group	Upper Energy (eV)	Energy Group	Upper Energy (eV)
1	1.7332E+07	25	2.9721E+05
2	1.4191E+07	26	1.8316E+05
3	1.2214E+07	27	1.1109E+05
4	1.0000E+07	28	6.7379E+04
5	8.6071E+06	29	4.0868E+04
6	7.4082E+06	30	3.1828E+04
7	6.0653E+06	31	2.6058E+04
8	4.9659E+06	32	2.4176E+04
9	3.6788E+06	33	2.1875E+04
10	3.0119E+06	34	1.5034E+04
11	2.7253E+06	35	7.1017E+03
12	2.4660E+06	36	3.3546E+03
13	2.3653E+06	37	1.5846E+03
14	2.3457E+06	38	4.5400E+02
15	2.2313E+06	39	2.1445E+02
16	1.9205E+06	40	1.0130E+02
17	1.6530E+06	41	3.7266E+01
18	1.3534E+06	42	1.0677E+01
19	1.0026E+06	43	5.0435E+00
20	8.2085E+05	44	1.8554E+00
21	7.4274E+05	45	8.7643E-01
22	6.0810E+05	46	4.1399E-01
23	4.9787E+05	47	1.0000E-01
24	3.6883E+05	-	1.0000E-05

3.3.2 Activation Response Functions

Response functions are used to calculate nuclear reactions and other integral parameters (e.g., integrated fluxes over various energy ranges) of interest in ex-core calculations. Tables 3-6 and 3-7 list the activation response functions included in the RAMA nuclear data library.

The response function tables are identified in the RAMA nuclear data library with the nuclide identifiers 7001, 7002, 7003, and 7004. Response tables 7001 (Part A) and 7002 (Part B) contain response functions which have a flat weighting corresponding to the in-vessel surveillance capsule location. Response tables 7003 (Part A) and 7004 (Part B) contain response functions which have a weighting corresponding to the 1/4T location in the pressure vessel.

Table 3-6
Row Positions of Response Functions in Tables 7001 and 7003

Row	Response	Row	Response
1	Group upper energy (MeV)	29	I-127 (n,2n) I-126
2	U-235 fission spectrum (chi)	30	Sc-45 (n,γ) Sc-46
3	Li-6 (n,x) He-4	31	Na-23 (n,γ) Na-24
4	B-10 (n,α) Li-7	32	Fe-58 (n,γ) Fe-59
5	Th-232 (n,fission)	33	Co-59 (n,γ) Co-60
6	U-235 (n,fission)	34	Cu-63 (n,γ) Cu-64
7	U-238 (n,fission)	35	In-115 (n,γ) In-116
8	Np-237 (n,fission)	36	Au-197 (n,γ) Au-198
9	Pu-239 (n,fission)	37	Th-232 (n,γ) Th-233
10	Al-27 (n,p) Mg-27	38	U-238 (n,γ) U-239
11	Al-27 (n,α) Na-24	39	$\sqrt{E_{Mid}}\left(MeV^{1/2}\right)$
12	S-32 (n,p) P-32	40	Total neutron flux
13	Ti-46 (n,p) Sc-46	41	U-234 (n,fission)
14	Ti-47 (n,p) Sc-47	42	U-236 (n,fission)
15	Ti-47 (n,n'p) Sc-46	43	Pu-240 (n,fission)
16	Ti-48 (n,p) Sc-48	44	Pu-241 (n,fission)
17	Ti-48 (n,n'p) Sc-47	45	Pu-242 (n,fission)
18	Mn-55 (n,2n) Mn-54	46	Rh-103 (n,n') Rh-103m
19	Fe-54 (n,p) Mn-54	47	Si displacement kerma (eV·b)
20	Fe-56 (n,p) Mn-56	48	U-238 fission spectrum (chi)
21	Co-59 (n,2n) Co-58	49	Pu-239 fission spectrum (chi)
22	Co-59 (n,α) Mn-56	50	E > 1.0 MeV neutron flux
23	Ni-58 (n,p) Co-58	51	E > 0.1 MeV neutron flux
24	Ni-58 (n,2n) Ni-57	52	E < 0.414 eV neutron flux
25	Ni-60 (n,p) Co-60	53	Average energy (MeV)
26	Cu-63 (n,α) Cu-60	54	Delta energy (MeV)
27	Cu-65 (n,2n) Cu-64	55	Delta lethargy
28	In-115 (n,n') In-115m		

Table 3-7
Row Positions of Response Functions in Tables 7002 and 7004

Row	Response
1	Pu-238 (n,fission)
2	U-234 neutrons / fission (nubar)
3	U-235 neutrons / fission (nubar)
4	U-236 neutrons / fission (nubar)
5	U-238 neutrons / fission (nubar)
6	Pu-238 neutrons / fission (nubar)
7	Pu-239 neutrons / fission (nubar)
8	Pu-240 neutrons / fission (nubar)
9	Pu-241 neutrons / fission (nubar)
10	Pu-242 neutrons / fission (nubar)
11	U-234 fission spectrum (chi)
12	U-236 fission spectrum (chi)
13	Pu-238 fission spectrum (chi)
14	Pu-240 fission spectrum (chi)
15	Pu-241 fission spectrum (chi)
16	Pu-242 fission spectrum (chi)

3.4 Surveillance Capsule Activation Results

This section contains the results from the CNS SSP capsules A, B, and C activation analysis. The predicted activations (i.e., specific activities) generated by the RAMA Fluence Methodology were compared to the activation measurements for the capsule flux wires (see Appendix C) and are presented here. CNS SSP capsules A, B, and C were positioned in the reactor at azimuth 30° and were removed at the end of cycle 21 after being irradiated for six cycles for a total of 8.5 effective full power years (EFPY).

Copper and iron flux wires were irradiated in the CNS SSP capsules A, B, and C. Activation measurements were performed following irradiation for the following reactions (see Appendix C): $^{63}Cu(n,\alpha)^{60}Co$ and $^{54}Fe(n,p)^{54}Mn$. Additional activation samples were present in gadolinium dosimetry containers in each capsule. These additional samples included iron and copper wires, as well as wire and foil samples for the following activation reactions: $^{58}Ni(n,p)^{58}Co$, $^{46}Ti(n,p)^{46}Sc$, $^{93}Nb(n,\gamma)^{94}Nb$, $^{59}Co(n,\gamma)^{60}Co$, and $^{109}Ag(n,\gamma)^{110}Ag$. However, the activation levels for the nickel and titanium reactions were too low due to extensive decay of the samples to provide reliable measurement results and are provided for information only in Appendix C. The niobium reaction is not included in the BUGLE-96 based RAMA nuclear data library, so no comparisons are provided for this reaction. Both the cobalt and silver reactions are predominately the result of absorptions in the thermal energy range. The thermal spectrum is attenuated by the gadolinium dosimetry container, however, the RAMA nuclear data library does not include gadolinium so that appropriate attenuation of the thermal spectrum can not be represented in the RAMA evaluation. Accordingly, comparison results are not provided for these reactions in the RAMA activation evaluation.

It was also observed that the copper and iron flux wires had become displaced from their customary position along the V-groove of the Charpy sample specimens at some point during irradiation. As a result, the specific location of the individual wires within the capsules is not known so the RAMA calculation was performed assuming that the wires were located at the lateral center of the capsules. The potential impact of this assumption was evaluated by comparing the predicted activity at various azimuthal positions to the predicted value from the lateral center of the capsules. For the most sensitive capsule (capsule B), the maximum azimuthal value is about 3% higher than the value at the center of the capsule, and the minimum azimutal value is about 8% lower than the center value. The other two capsules showed maximum and minimum varviations that were about 30% less than those of capsule B. The azimuthal variation is on the order of the measurement standard deviation and is substantially less than the observed bias in the RAMA predictions. As a result, the uncertainty in wire position in the capsules is relatively insignificant.

3.4.1 SSP Capsule A Activation Comparison Results

Table 3-8 provides a comparison of the RAMA calculated specific activities and the measured specific activities for the SSP capsule A flux wire specimens. Capsule A total flux wire average calculated-to-measured (C/M) value is 1.14 with a standard deviation of ±0.11. The capsule A average C/M value for the copper flux wires is 1.06 with a standard deviation of ±0.07. The capsule A average C/M value for the iron flux wires is 1.22 with a standard deviation of ±0.07.

Table 3-8
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule A Flux Wires

Flux Wires	Measured (dps/mg)	Calculated (dps/mg)	Calculated vs. Measured	Standard Deviation
Copper				
AP1-67	19.39	19.51	1.01	
AP1-30	18.14	19.44	1.07	
AP1-11	17.43	19.24	1.10	
AP1-28	16.57	18.98	1.15	
AP2-67	20.28	19.51	0.96	
AP2-15	19.62	19.44	0.99	
AP2-21	17.99	19.24	1.07	
AP2-20	16.77	18.98	1.13	
Average	---	---	**1.06**	**±0.07**
Iron				
AP1-67	146.3	170.9	1.17	
AP1-30	141.2	169.4	1.20	
AP1-11	130.5	166.4	1.27	
AP1-28	124.8	163.7	1.31	
AP2-67	154.5	170.9	1.11	
AP2-15	144.8	169.4	1.17	
AP2-21	135.0	166.4	1.23	
AP2-20	126.5	163.7	1.29	
Average	---	---	**1.22**	**±0.07**
Capsule A Flux Wire Average	---	---	**1.14**	**±0.11**

Table 3-9 provides comparisons of the calculated-to-measured activation for the dosimetry specimens for SSP capsule A. The total SSP capsule A dosimetry average C/M value is 1.36 with a standard deviation of ±0.09.

Table 3-9
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule A Dosimetry

Identification	Measured dps/mg	Calculated dps/mg	C/M
Cu	15.62	18.86	1.21
Fe-0°	117.1	162.9	1.39
Fe-90°	115.3	162.9	1.41
Fe-180°	117.1	162.9	1.39
Fe-270°	116.8	162.9	1.39
Ni	2245	2341	1.04[1]
Ti	65.13	59.89	0.92[1]
Average	---	---	**1.36**
Standard Deviation	---	---	**±0.09**

1) The nickel and titanium activities are too low to provide a reliable measurement due to sample decay and are presented for information purposes only. These values are omitted from the capsule comparison statistics.

The combined C/M for all flux wire and dosimetry samples in capsule A is 1.19 with a standard deviation of ±0.14. Both the flux wire and dosimetry comparisons indicate that the RAMA methodology is consistently over-predicting the neutron flux in SSP capsule A. The relatively small and consistent standard deviations obtained from the individual wire and dosimetry comparisons suggest that the over-prediction is statistically significant and that a bias should be taken into account when predicting the best estimate neutron flux and fluence for capsule A. An appropriate bias is given by the measurement-to-calculated (M/C) ratios (i.e., the inverse of the C/M value) based upon all measurements (wires and dosimetry) determined for capsule A. The resulting bias factor for use in obtaining the best estimate flux and fluence for the capsule Charpy specimens is determined to be 0.84 (= 1/1.19).

3.4.2 SSP Capsule B Activation Comparison Results

Table 3-10 provides a comparison of the RAMA calculated specific activities and the measured specific activities for the SSP capsule B flux wire specimens. Capsule B total flux wire average C/M value is 1.14 with a standard deviation of ±0.11. The capsule B average C/M value for the copper flux wires is 1.04 with a standard deviation of ±0.03. The capsule B average C/M value for the iron flux wires is 1.24 with a standard deviation of ±0.05.

Table 3-10
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule B Flux Wires

Flux Wires	Measured (dps/mg)	Calculated (dps/mg)	Calculated vs. Measured	Standard Deviation
Copper				
BP1-67	24.00	23.67	0.99	
BP1-30	21.76	23.19	1.07	
BP1-11	21.44	22.74	1.06	
BP1-28	20.89	22.25	1.07	
BP2-67	21.98	23.67	1.08	
BP2-15	22.33	23.19	1.04	
BP2-21	22.34	22.74	1.02	
BP2-20	21.98	22.25	1.01	
Average	---	---	1.04	±0.03
Iron				
BP1-67	156.2	208.0	1.33	
BP1-30	160.5	203.3	1.27	
BP1-11	160.2	199.9	1.25	
BP1-28	155.4	196.1	1.26	
BP2-67	164.1	208.0	1.27	
BP2-15	170.5	203.3	1.19	
BP2-21	168.6	199.9	1.19	
BP2-20	163.9	196.1	1.20	
Average	---	---	**1.24**	**±0.05**
Capsule B Flux Wire Average	---	---	**1.14**	**±0.11**

Table 3-11 provides comparisons of the calculated-to-measured activation for the dosimetry specimens for SSP capsule B. The total SSP capsule B dosimetry average C/M value is 1.23 with a standard deviation of ±0.08.

Table 3-11
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule B Dosimetry

Identification	Measured dps/mg	Calculated dps/mg	C/M
Cu	20.09	22.02	1.10
Fe-0°	153.5	193.9	1.26
Fe-90°	156.5	193.9	1.24
Fe-180°	154.3	193.9	1.26
Fe-270°	150.9	193.9	1.28
Ni	2315	2831	1.22[1]
Ti	65.19	72.06	1.18[1]
Average	---	---	**1.23**
Standard Deviation	---	---	**±0.08**

1) The nickel and titanium activities are too low to provide a reliable measurement due to sample decay and are presented for information purposes only. These values are omitted from the capsule comparison statistics.

The combined C/M for all flux wire and dosimetry samples in capsule B is 1.16 with a standard deviation of ±0.11. Both the flux wire and dosimetry comparisons indicate that the RAMA methodology is consistently over-predicting the neutron flux in SSP capsule B. The relatively small and consistent standard deviations obtained from the individual wire and dosimetry comparisons suggest that the over-prediction is statistically significant and that a bias should be taken into account when predicting the best estimate neutron flux and fluence for capsule B. An appropriate bias is given by the measurement-to-calculated (M/C) ratios (i.e., the inverse of the C/M value) based upon all measurements (wires and dosimetry) determined for capsule B. The resulting bias factor for use in obtaining the best estimate flux and fluence for the capsule Charpy specimens is determined to be 0.86 (= 1/1.16).

3.4.3 SSP Capsule C Activation Comparison Results

Table 3-12 provides a comparison of the RAMA calculated specific activities and the measured specific activities for the SSP capsule C flux wire specimens. Capsule C total flux wire average C/M value is 1.35 with a standard deviation of ±0.13. The capsule C average C/M value for the copper flux wires is 1.24 with a standard deviation of ±0.04. The capsule C average C/M value for the iron flux wires is 1.47 with a standard deviation of ±0.05.

Table 3-12
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule C Flux Wires

Flux Wires	Measured (dps/mg)	Calculated (dps/mg)	Calculated vs. Measured	Standard Deviation
Copper				
CP1-36	15.11	17.74	1.17	
CP1-15	14.35	17.26	1.20	
CP1-20	13.49	16.78	1.24	
CP1-H2	12.99	16.09	1.24	
EY-J1	14.85	17.74	1.19	
CP2-BW	13.57	17.26	1.27	
CP2-O6	12.82	16.78	1.31	
CP2-72	12.93	16.09	1.24	
Average	---	---	**1.24**	**±0.04**
Iron				
CP1-36	110.0	153.7	1.40	
CP1-15	104.0	150.4	1.45	
CP1-20	96.37	147.1	1.53	
CP1-H2	98.92	140.7	1.42	
EY-J1	107.0	153.7	1.44	
CP2-BW	102.2	150.4	1.47	
CP2-O6	96.52	147.1	1.52	
CP2-72	93.05	140.7	1.51	
Average	---	---	**1.47**	**±0.05**
Capsule C Flux Wire Average	---	---	**1.35**	**±0.13**

Table 3-13 provides comparisons of the calculated to measured (C/M) activation for the dosimetry specimens for SSP capsule C. The total SSP capsule C dosimetry average C/M value is 1.24 with a standard deviation of ±0.09.

Table 3-13
Comparison of Specific Activities for Cooper Nuclear Station SSP Capsule C Dosimetry

Identification	Measured dps/mg	Calculated dps/mg	C/M
Cu	14.65	15.77	1.08
Fe-0°	107.3	137.4	1.28
Fe-90°	108.8	137.4	1.26
Fe-180°	107.1	137.4	1.28
Fe-270°	106.0	137.4	1.30
Ni	1744	2038	1.17[1]
Ti	65.28	52.92	0.81[1]
Average	---	---	**1.24**
Standard Deviation	---	---	**±0.09**

1) The nickel and titanium activities are too low to provide a reliable measurement due to sample decay and are presented for information purposes only. These values are omitted from the capsule comparison statistics.

The combined C/M for all flux wire and dosimetry samples in capsule C is 1.32 with a standard deviation of ±0.13. Both the flux wire and dosimetry comparisons indicate that the RAMA methodology is consistently over-predicting the neutron flux in SSP capsule C. The relatively small and consistent standard deviations obtained from the individual wire and dosimetry comparisons suggest that the over-prediction is statistically significant and that a bias should be taken into account when predicting the best estimate neutron flux and fluence for capsule C. An appropriate bias is given by the measurement-to-calculated (M/C) ratios (i.e., the inverse of the C/M value) based upon all measurements (wires and dosimetry) determined for capsule C. The resulting bias factor for use in obtaining the best estimate flux and fluence for the capsule Charpy specimens is determined to be 0.75 (= 1/1.32).

3.5 Surveillance Capsule Fluence Results

The best estimate neutron fluence and rated power neutron flux for each of the capsule specimen locations are provided below. Neutron fluence and flux values are provided for >1.0 MeV and >0.1 MeV. The best estimate fluence and flux values are determined by multiplying the RAMA-calculated fluence and flux by the appropriate multiplicative bias factor for each capsule from Section 3.4.

3.5.1 Surveillance Capsule Best Estimate Neutron Fluence and Flux for Energy >1.0 MeV

Tables 3-14 through 3-16 show the best estimate >1.0 MeV neutron fluence and flux at rated thermal power for SSP capsule A, B and C specimen locations, respectively.

Table 3-14
Best Estimate >1.0 MeV Neutron Fluence and Rated Power Flux in SSP Capsule A

Specimen Identifier	Best Estimate Fluence n/cm^2	Best Estimate Rated Power Flux n/cm^2-s
AP1-67	3.80E+17	1.43E+09
AP1-30	3.82E+17	1.43E+09
AP1-11	3.78E+17	1.42E+09
AP1-28	3.74E+17	1.40E+09
AP2-67	4.09E+17	1.53E+09
AP2-15	4.08E+17	1.53E+09
AP2-21	4.06E+17	1.52E+09
AP2-20	3.97E+17	1.49E+09
Average	**3.92E+17**	**1.47E+09**

Table 3-15
Best Estimate >1.0 MeV Neutron Fluence and Rated Power Flux in SSP Capsule B

Specimen Identifier	Best Estimate Fluence n/cm^2	Best Estimate Rated Power Flux n/cm^2-s
BP1-67	4.90E+17	1.84E+09
BP1-30	4.79E+17	1.80E+09
BP1-11	4.68E+17	1.75E+09
BP1-28	4.54E+17	1.70E+09
BP2-67	5.26E+17	1.97E+09
BP2-15	5.17E+17	1.94E+09
BP2-21	5.04E+17	1.89E+09
BP2-20	4.93E+17	1.85E+09
Average	**4.91E+17**	**1.84E+09**

Table 3-16
Best Estimate >1.0 MeV Neutron Fluence and Rated Power Flux in SSP Capsule C

Specimen Identifier	Best Estimate Fluence n/cm²	Best Estimate Rated Power Flux n/cm²-s
CP1-36	3.11E+17	1.17E+09
CP1-15	3.02E+17	1.13E+09
CP1-20	2.93E+17	1.10E+09
CP1-H2	2.79E+17	1.04E+09
EY-J1	3.29E+17	1.23E+09
CP2-BW	3.22E+17	1.21E+09
CP2-06	3.13E+17	1.18E+09
CP2-72	2.93E+17	1.10E+09
Average	**3.05E+17**	**1.14E+09**

3.5.2 Surveillance Capsule Best Estimate Neutron Fluence and Flux for Energy >0.1 MeV

Tables 3-17 through 3-19 show the best estimate >0.1 MeV neutron fluence and flux at rated thermal power for SSP capsule A, B and C specimen locations, respectively. The same bias factors used to determine the >1.0 MeV fluence and flux in Section 3.5.1 are assumed to be applicable to the determination of the best estimate >0.1 MeV fluence and flux as well.

Table 3-17
Best Estimate >0.1 MeV Neutron Fluence and Rated Power Flux in SSP Capsule A

Specimen Identifier	Best Estimate Fluence n/cm²	Best Estimate Rated Power Flux n/cm²-s
AP1-67	6.00E+17	2.25E+09
AP1-30	6.05E+17	2.27E+09
AP1-11	5.96E+17	2.23E+09
AP1-28	5.90E+17	2.21E+09
AP2-67	6.47E+17	2.42E+09
AP2-15	6.48E+17	2.43E+09
AP2-21	6.44E+17	2.41E+09
AP2-20	6.32E+17	2.37E+09
Average	**6.20E+17**	**2.32E+09**

Table 3-18
Best Estimate >0.1 MeV Neutron Fluence and Rated Power Flux in SSP Capsule B

Specimen Identifier	Best Estimate Fluence n/cm^2	Best Estimate Rated Power Flux n/cm^2-s
BP1-67	7.77E+17	2.91E+09
BP1-30	7.60E+17	2.85E+09
BP1-11	7.41E+17	2.78E+09
BP1-28	7.17E+17	2.69E+09
BP2-67	8.37E+17	3.14E+09
BP2-15	8.22E+17	3.08E+09
BP2-21	8.03E+17	3.01E+09
BP2-20	7.84E+17	2.94E+09
Average	**7.80E+17**	**2.92E+09**

Table 3-19
Best Estimate >0.1 MeV Neutron Fluence and Rated Power Flux in SSP Capsule C

Specimen Identifier	Best Estimate Fluence n/cm^2	Best Estimate Rated Power Flux n/cm^2-s
CP1-36	4.89E+17	1.83E+09
CP1-15	4.76E+17	1.78E+09
CP1-20	4.61E+17	1.73E+09
CP1-H2	4.36E+17	1.63E+09
EY-J1	5.18E+17	1.94E+09
CP2-BW	5.08E+17	1.90E+09
CP2-06	4.96E+17	1.86E+09
CP2-72	4.59E+17	1.72E+09
Average	**4.80E+17**	**1.80E+09**

4
CHARPY TEST DATA

4.1 Charpy Test Procedure

Charpy impact tests were conducted in accordance with ASTM Standards E 185-82 and E 23-02. A drawing showing the Charpy test specimen geometry is given in Figure 4-1. The 1982 version of E 185 has been reviewed and approved by NRC for surveillance capsule testing applications. This standard references ASTM E 23. The tests were conducted using a Tinius Olsen Testing Machine Company, Inc. Model 84 impact test machine with a 300 ft-lb (406.75 J) range. The Model 84 is equipped with a dial gage as well as the MPM optical encoder system for accurate absorbed energy measurement. In all cases, the optical encoder measured energy was reported as the impact energy because it is much more accurate than the dial. The optical encoder can resolve the energy to within 0.04 ft-lbs (0.054 J), whereas, for the dial, the resolution is around 0.25 ft-lbs (0.34 J). Therefore, because of the lower accuracy of the dial, and because of the fact that the pendulum was re-weighted to bring the center-of-percussion into close agreement with the center-of-strike, the dial energies were not recorded. The impact energy was corrected for windage and friction for each test performed using the optical encoder measurements. The velocity of the striker at impact was nominally 18 ft/s (5.49 m/s). The encoder system measures the exact impact velocity for every test. Calibration of the machine was verified as specified in E 23 and verification specimens were provided by NIST.

The E 23 procedure for specimen temperature control using an in-situ heating and cooling system was followed. Each specimen was held at the desired test temperature for at least 5 minutes prior to testing and the fracture process zone temperature was held to within ± 1.8 F (± 1 C) up to the instant of strike. Precision calibrated tongs were used for specimen centering on the test machine.

Lateral expansion (LE) was determined from measurements made with a lateral expansion gage. The lateral expansion gage was calibrated using precision gage blocks which are traceable to NIST. The percentage of shear fracture area was determined by integrating the ductile and brittle fracture areas.

The number of Charpy specimens for measurement of the transition region and upper shelf was limited. Therefore, the choice of test temperatures was very important. Prior to testing, the Charpy energy-temperature curve was predicted using fits of the unirradiated data. The first test was then conducted near the middle of the transition region and test temperature decisions were then made based on the test results. Overall, the goal was to perform three tests on the upper shelf and to use the remaining seven specimens to characterize the 30 ft-lb (41 J) index. This approach was successful as illustrated in the next report section.

4.2 Charpy Test Data

A total of 120 irradiated base metal and 120 irradiated weld specimens were tested over the transition region temperature range and on the upper shelf. As shown in Table 2-2, each capsule contained 8 material types (4 base metal and 4 weld), with a total of 10 Charpy specimens for each material type. The irradiated data are summarized in Appendix A, Tables A-1 through A-24. As discussed in [8] and [9], the base metal surveillance specimens have a T-L orientation. In addition to the energy absorbed by the specimen during impact, the measured lateral expansion values and the percentage shear fracture area for each test specimen are listed in the tables. The Charpy energy was read from the optical encoder and has been corrected for windage and friction in accordance with ASTM E 23. The optical encoder and the dial cannot correct for tossing energy and therefore this small amount of additional energy, if present, may be included in the data for some tests.

The lateral expansion is a measure of the transverse plastic deformation produced by the striking edge of the striker during the impact event. Lateral expansion is determined by measuring the maximum change of specimen thickness along the sides of the specimen. Lateral expansion is a measure of the ductility of the specimen. The nuclear industry tracks the embrittlement shift using the 35 mil (0.89 mm) lateral expansion index. In accordance with ASTM E23, the lateral expansion for some specimens, which could be broken after the impact test, should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, when these conditions exist, the value listed in the table is the unbroken measurement and a footnote is included to identify these specimens.

The percentage of shear fracture area is a direct quantification of the transition in the fracture modes as the temperature increases. All metals with a body centered cubic lattice structure, such as ferritic pressure vessel materials, undergo a transition in fracture modes. At low test temperatures, a crack propagates in a brittle manner and cleaves across the grains. As the test temperature increases, the percentage of shear (or ductile) fracture increases. This temperature range is referred to as the transition region and the fracture process is mixed mode. As the temperature increases further, the fracture process is eventually completely ductile (i.e., no brittle component), and this temperature range is referred to as the upper shelf region.

Preparation of P-T operating curves requires the determination of the Charpy 30 ft-lb (41 J) transition temperature shift. This index is determined by fitting the energy-temperature data to find the mean curve. It is also necessary to estimate the upper shelf energy to ensure that the shelf has not dropped below the 10CFR50, Appendix G, 50 ft-lb (68 J) screening criterion. The Charpy data analysis results are provided in the next section of this report. 10CFR50, Appendix H requires that the unirradiated data be included in the surveillance report. Therefore, the base and weld unirradiated data are given in Appendix A, Tables A-25 through A-40.

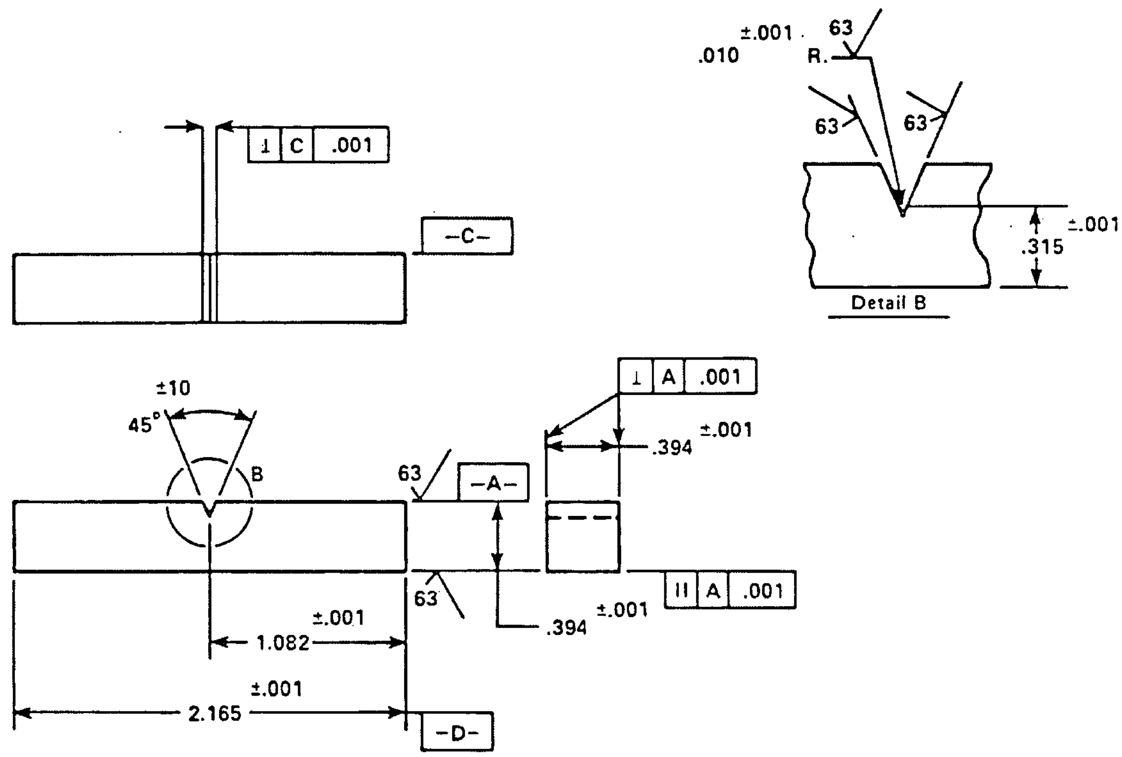

Table 4-1
Drawing Showing the Charpy Test Specimen Geometry

5
CHARPY TEST RESULTS

5.1 Analysis of Impact Test Results

For analysis of the Charpy test data, the BWRVIP ISP has selected the hyperbolic tangent (tanh) function as the statistical curve-fit tool to model the transition temperature toughness data. A hyperbolic tangent curve-fitting program named CVGRAPH [10] developed by ATI Consulting was used to fit the Charpy V-notch energy and lateral expansion data. The impact energy curve-fits from CVGRAPH are provided in Appendix B. Lower shelf energy was fixed at 2.5 ft-lbs (3.4 J) in all cases, consistent with the methodology established for analysis of all ISP Charpy energy data [7]. 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 [3]. 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.

5.2 Irradiated Versus Unirradiated CVN Properties

Tables 5-1, 5-2, and 5-3 summarize the T_{30} [30 ft-lb (41 J) Transition Temperature], T_{50} [50 ft-lb (68 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 change from baseline values for Capsules A, B, and C, respectively. These tables have been sequenced by capsule. The unirradiated and irradiated values are taken from the CVGRAPH fits provided in Appendix B.

Table 5-1
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Capsule A Materials

Material Identity[1]	T_{30}, 30 ft-lb (41 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (68 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)
A1224-1	-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)
C2331-2	-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)
P2130-2	-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)
C3278-2	-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)
5P6214B	-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)
34B009	-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)
Quad Cities 2 ESW	-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)
406L44	-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)

Fluence is unique to each specimen set:
A1224-1 = 3.80×10^{17} n/cm^2 C2331-2 = 3.82×10^{17} n/cm^2 P2130-2 = 3.78×10^{17} n/cm^2 C3278-2 = 3.74×10^{17} n/cm^2
5P6214B = 4.09×10^{17} n/cm^2 34B009 = 4.08×10^{17} n/cm^2 QC2 ESW = 4.06×10^{17} n/cm^2 406L44 = 3.97×10^{17} n/cm^2

Table 5-2
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Capsule B Materials

Material Identity[1]	T_{30}, 30 ft-lb (41 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (68 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)
A1224-1	-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)
C2331-2	-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)
P2130-2	-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)
C3278-2	-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)
5P6214B	-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)
34B009	-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)
Quad Cities 2 ESW	-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)
406L44	-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)

Fluence is unique to each specimen set:

A1224-1 = 4.90×10^{17} n/cm^2 C2331-2 = 4.79×10^{17} n/cm^2 P2130-2 = 4.68×10^{17} n/cm^2 C3278-2 = 4.54×10^{17} n/cm^2

5P6214B = 5.26×10^{17} n/cm^2 34B009 = 5.17×10^{17} n/cm^2 QC2 ESW = 5.04×10^{17} n/cm^2 406L44 = 4.93×10^{17} n/cm^2

Table 5-3
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Capsule C Materials

Material Identity[1]	T_{30}, 30 ft-lb (41 J) Transition Temperature			T_{35mil}, 35 mil (0.89 mm) Lateral Expansion Temperature			T_{50}, 50 ft-lb (68 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)
C3985-2	-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)
C1079-1	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)
A0610-1	-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)
A1195-1	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)
20291	-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)
B&W Linde 80 SAW	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)
Humboldt Bay 3 SAW	-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)
5P6756	-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)

Fluence is unique to each specimen set:
C3985-2 = 3.11×10^{17} n/cm^2 C1079-1 = 3.02×10^{17} n/cm^2 A0610-1 = 2.93×10^{17} n/cm^2 A1195-1 = 2.79×10^{17} n/cm^2
20291 = 3.29×10^{17} n/cm^2 B&W Linde 80 SAW = 3.22×10^{17} n/cm^2 Humboldt Bay 3 SAW = 3.13×10^{17} n/cm^2 5P6756 = 2.93×10^{17} n/cm^2

The materials irradiated in SSP (Cooper) capsules A, B, and C exhibited a wide range of embrittlement sensitivity. All but seven of the materials experienced less embrittlement than predicted using [6] (including margin), based on a unique fluence ($E > 1.0$ MeV) for each set of specimens. Tables 5-4, 5-5, and 5-6 illustrate this comparison for Capsules A, B, and C, respectively. Measured shifts that are greater than predicted shifts (including margin) are shown in bold.

Measured percent decreases in USE are presented in Tables 5-7, 5-8, and 5-9. Note that a negative decrease means an actual increase in the USE.

Table 5-4
Comparison of Actual Versus Predicted Embrittlement of SSP Capsule A Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Measured Shift[1] °F (°C)	RG 1.99 Rev. 2 Predicted Shift[2] °F (°C)	RG 1.99 Rev. 2 Predicted Shift+Margin[2,3] °F (°C)
A1224-1	Grand Gulf Plate (SA533B-1)	0.380	**21.2 (11.8)**	5.0 (2.8)	10.1 (5.6)
C2331-2	Cooper Plate (SA533B-1)	0.382	41.5 (23.1)	29.9 (16.6)	59.8 (33.2)
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	0.378	40.2 (22.3)	31.9 (17.7)	63.7 (35.4)
C3278-2	FitzPatrick Plate (SA533B-1)	0.374	29.9 (16.6)	18.5 (10.3)	37.0 (20.5)
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	0.409	-26.4 (-14.7)	5.2 (2.9)	10.5 (5.8)
34B009	Millstone 1 Weld (Submerged Arc Weld)	0.408	99.0 (55.0)	52.4[4] (29.1[4])	104.7 (58.2)
AP2-21	Quad Cities 2 Weld (Electroslag Weld)	0.406	12.7 (7.1)	19.5 (10.8)	39.0 (21.6)
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	0.397	**121.9 (67.7)**	52.8 (29.4)	105.7 (58.7)

Notes:

1. See Table 5-1, ΔT_{30}.
2. Predicted shift = CF × FF, where CF is a Chemistry Factor taken from tables from USNRC Reg. Guide 1.99, Rev. 2 [6], based on each material's Cu/Ni content, and FF is Fluence Factor, $f^{0.28-0.10 \log f}$, where f = fluence (E > 1.0 MeV) specified.
3. Margin Term is defined as 34°F for plate materials and 56°F for weld materials, or margin equals shift (whichever is less), per Reg. Guide 1.99, Rev. 2 [6].
4. Predicted shift using assumed CF value = 200°F based on Cu = 0.15 wt%, Ni = 1.2 wt%, which is the highest Ni value on the Reg. Guide 1.99, Rev. 2 tables. The actual Ni value for this weld is reported to be 1.81 wt%.

Table 5-5
Comparison of Actual Versus Predicted Embrittlement of SSP Capsule B Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Measured Shift[1] °F (°C)	RG 1.99 Rev. 2 Predicted Shift[2] °F (°C)	RG 1.99 Rev. 2 Predicted Shift+Margin[2,3] °F (°C)
A1224-1	Grand Gulf Plate (SA533B-1)	0.490	-6.8 (-3.8)	5.8 (3.2)	11.6 (6.4)
C2331-2	Cooper Plate (SA533B-1)	0.479	34.7 (19.3)	33.9 (18.8)	67.8 (37.7)
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	0.468	53.4 (29.7)	35.9 (19.9)	69.9 (38.8)
C3278-2	FitzPatrick Plate (SA533B-1)	0.454	**42.9 (23.8)**	20.6 (11.4)	41.2 (22.9)
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	0.526	**15.7 (8.7)**	6.0 (3.3)	12.0 (6.7)
34B009	Millstone 1 Weld (Submerged Arc Weld)	0.517	100.6 (55.9)	59.6[4] (33.1[4])	115.6 (64.2)
BP2-21	Quad Cities 2 Weld (Electroslag Weld)	0.504	11.2 (6.2)	21.9 (12.2)	43.9 (24.4)
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	0.493	**120.6 (67.0)**	59.5 (33.1)	115.5 (64.2)

Notes:

1. See Table 5-2, ΔT_{30}.
2. Predicted shift = CF × FF, where CF is a Chemistry Factor taken from tables from USNRC Reg. Guide 1.99, Rev. 2 [6], based on each material's Cu/Ni content, and FF is Fluence Factor, $f^{0.28-0.10 \log f}$, where f = fluence (E > 1.0 MeV) specified.
3. Margin Term is defined as 34°F for plate materials and 56°F for weld materials, or margin equals shift (whichever is less), per Reg. Guide 1.99, Rev. 2 [6].
4. Predicted shift using assumed CF value = 200°F based on Cu = 0.15 wt%, Ni = 1.2 wt%, which is the highest Ni value on the Reg. Guide 1.99, Rev. 2 tables. The actual Ni value for this weld is reported to be 1.81 wt%.

Table 5-6
Comparison of Actual Versus Predicted Embrittlement of SSP Capsule C Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Measured Shift[1] °F (°C)	RG 1.99 Rev. 2 Predicted Shift[2] °F (°C)	RG 1.99 Rev. 2 Predicted Shift+Margin[2,3] °F (°C)
C3985-2	Hatch 1 Plate (SA533B-1)	0.311	20.5 (11.4)	16.6 (9.2)	33.2 (18.4)
C1079-1	Millstone 1 Plate (SA302, Mod)	0.302	65.4 (36.3)	32.8 (18.2)	65.6 (36.5)
A0610-1	Quad Cities 1 Plate (SA302B, Mod)	0.293	46.0 (25.6)	26.0 (14.5)	52.1 (28.9)
A1195-1	HSST-02 Plate (SA533B-1)	0.279	25.1 (13.9)	23.7 (13.2)	47.4 (26.3)
20291	Cooper Weld (Submerged Arc Weld)	0.329	73.0 (40.6)	45.1 (25.0)	90.1 (50.1)
CP2-BW	B&W Linde 80 Weld (Submerged Arc Weld)	0.322	**85.5 (47.5)**	39.9 (22.2)	79.7 (44.3)
CP2-06	Humboldt Bay 3 Weld (Submerged Arc Weld)	0.313	**58.3 (32.4)**	27.8 (15.5)	55.6 (30.9)
5P6756	River Bend Weld (Submerged Arc Weld)	0.293	23.6 (13.1)	17.8 (9.9)	35.5 (19.7)

Notes:

1. See Table 5-3, ΔT_{30}.
2. Predicted shift = CF × FF, where CF is a Chemistry Factor taken from tables from USNRC Reg. Guide 1.99, Rev. 2 [6], based on each material's Cu/Ni content, and FF is Fluence Factor, $f^{0.28-0.10 \log f}$, where f = fluence (E > 1.0 MeV) specified.
3. Margin Term is defined as 34°F for plate materials and 56°F for weld materials, or margin equals shift (whichever is less), per Reg. Guide 1.99, Rev. 2 [6].

Table 5-7
Percent Decrease in Upper Shelf Energy (USE) of SSP Capsule A Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Cu Content (wt%)	Measured Decrease in USE[1] (%)
A1224-1	Grand Gulf Plate (SA533B-1)	0.380	0.03	-1.0
C2331-2	Cooper Plate (SA533B-1)	0.382	0.16	9.0
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	0.378	0.172	6.3
C3278-2	FitzPatrick Plate (SA533B-1)	0.374	0.11	8.8
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	0.409	0.01	-5.5
34B009	Millstone 1 Weld (Submerged Arc Weld)	0.408	0.15	11.8
AP2-21	Quad Cities 2 Weld (Electroslag Weld)	0.406	0.11	3.2
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	0.397	0.29	20.5

Notes:

1. Calculated from Table 5-1, (Change/Unirradiated) * 100. A positive number indicates a decrease in USE; a negative number indicates the USE increased over the unirradiated value.

Table 5-8
Percent Decrease in Upper Shelf Energy (USE) of SSP Capsule B Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Cu Content (wt%)	Measured Decrease in USE[1] (%)
A1224-1	Grand Gulf Plate (SA533B-1)	0.490	0.03	-8.9
C2331-2	Cooper Plate (SA533B-1)	0.479	0.16	2.3
P2130-2	Nine Mile Point 1 Plate (SA302B, Mod)	0.468	0.172	0.7
C3278-2	FitzPatrick Plate (SA533B-1)	0.454	0.11	11.4
5P6214B	Grand Gulf Weld (Submerged Arc Weld)	0.526	0.01	-6.5
34B009	Millstone 1 Weld (Submerged Arc Weld)	0.517	0.15	5.4
BP2-21	Quad Cities 2 Weld (Electroslag Weld)	0.504	0.11	-5.9
406L44	Quad Cities 1 Weld (Submerged Arc Weld)	0.493	0.29	20.6

Notes:

1. Calculated from Table 5-2, (Change/Unirradiated) * 100. A positive number indicates a decrease in USE; a negative number indicates the USE increased over the unirradiated value.

Table 5-9
Percent Decrease in Upper Shelf Energy (USE) of SSP Capsule C Materials

Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Cu Content (wt%)	Measured Decrease in USE[1] (%)
C3985-2	Hatch 1 Plate (SA533B-1)	0.311	0.11	-2.6
C1079-1	Millstone 1 Plate (SA302, Mod)	0.302	0.22	5.4
A0610-1	Quad Cities 1 Plate (SA302B, Mod)	0.293	0.17	2.4
A1195-1	HSST-02 Plate (SA533B-1)	0.279	0.15	-4.4
20291	Cooper Weld (Submerged Arc Weld)	0.329	0.23	14.9
CP2-BW	B&W Linde 80 Weld (Submerged Arc Weld)	0.322	0.26	14.6
CP2-06	Humboldt Bay 3 Weld (Submerged Arc Weld)	0.313	0.27	9.6
5P6756	River Bend Weld (Submerged Arc Weld)	0.293	0.06	-6.0

Notes:

1. Calculated from Table 5-3, (Change/Unirradiated) * 100. A positive number indicates a decrease in USE; a negative number indicates the USE increased over the unirradiated value.

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A
SUMMARY OF CHARPY V-NOTCH TEST DATA

Table A-1
Charpy V-Notch Results for Capsule A Plate A1224-1

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP1-67-8	-30.28 (-34.60)	7.12 (9.65)	9.3	7.0 (0.178)
AP1-67-10	-20.56 (-29.20)	8.33 (11.29)	9.7	10.0 (0.254)
AP1-67-7	0.50 (-17.50)	27.24 (36.93)	16.3	25.5 (0.648)
AP1-67-2	0.86 (-17.30)	31.28 (42.41)	17.1	29.0 (0.737)
AP1-67-9	19.94 (-6.70)	60.26 (81.70)	27.0	52.5 (1.334)
AP1-67-6	39.92 (4.40)	75.99 (103.02)	36.7	60.0 (1.524)
AP1-67-1	68.54 (20.30)	102.88 (139.49)	51.7	75.0 (1.905)
AP1-67-3	199.94 (93.30)	140.00 (189.81)	100.0	94.0 (2.388)
AP1-67-4	300.92 (149.40)	150.03 (203.41)	100.0	93.0 (2.362)
AP1-67-5	399.20 (204.00)	156.02 (211.53)	100.0	86.0 (2.184)

Table A-2
Charpy V-Notch Results for Capsule A Plate Heat C2331-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP1-30-10	-40.36 (-40.20)	10.07 (13.66)	8.3	10.5 (0.267)
AP1-30-8	-20.56 (-29.20)	15.78 (21.39)	11.9	16.0 (0.406)
AP1-30-7	19.94 (-6.70)	30.17 (40.90)	21.0	28.5 (0.724)
AP1-30-9	19.94 (-6.70)	33.14 (44.93)	20.7	30.5 (0.775)
AP1-30-1	67.64 (19.80)	39.22 (53.17)	26.9	39.0 (0.991)
AP1-30-2	110.84 (43.80)	57.99 (78.62)	47.4	52.0 (1.321)
AP1-30-3	160.7 (71.50)	85.95 (116.53)	99.0	73.0 (1.854)
AP1-30-4	250.88 (121.60)	88.94 (120.59)	100.0	77.0 (1.956)
AP1-30-5	300.74 (149.30)	90.17 (122.25)	100.0	73.0 (1.854)
AP1-30-6	399.56 (204.20)	99.00 (134.23)	100.0	76.5 (1.943)

Table A-3
Charpy V-Notch Results for Capsule A Plate Heat P2130-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP1-11-9	0.32 (-17.60)	12.10 (16.41)	22.6	11.0 (0.279)
AP1-11-10	13.82 (-10.10)	28.96 (39.27)	34.2	26.0 (0.660)
AP1-11-8	30.56 (-0.80)	29.68 (40.25)	29.5	27.5 (0.699)
AP1-11-1	68.18 (20.10)	32.40 (43.93)	29.3	31.0 (0.787)
AP1-11-2	68.72 (20.40)	35.74 (48.46)	45.4	35.5 (0.902)
AP1-11-7	90.68 (32.60)	59.89 (81.20)	68.3	48.0 (1.219)
AP1-11-3	109.40 (43.00)	62.12 (84.22)	82.3	54.5 (1.384)
AP1-11-4	150.26 (65.70)	59.15 (80.20)	100.0	54.0 (1.372)
AP1-11-5	229.82 (109.90)	66.24 (89.80)	100.0	58.0 (1.473)
AP1-11-6	301.10 (149.50)	66.40 (90.02)	100.0	67.0 (1.702)

Table A-4
Charpy V-Notch Results for Capsule A Plate Heat C3278-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP1-28-10	-44.50 (-42.50)	13.49 (18.29)	9.6	10.0 (0.254)
AP1-28-4	-29.92 (-34.40)	20.41 (27.68)	11.5	17.5 (0.445)
AP1-28-9	-0.40 (-18.00)	40.93 (55.50)	21.7	31.0 (0.787)
AP1-28-3	0.50 (-17.50)	30.03 (40.72)	18.3	26.0 (0.660)
AP1-28-1	67.64 (19.80)	57.16 (77.49)	39.5	49.0 (1.245)
AP1-28-5	96.08 (35.60)	86.07 (116.70)	73.2	65.0 (1.651)
AP1-28-2	120.92 (49.40)	105.32 (142.79)	98.4	71.0 (1.803)[1]
AP1-28-6	239.90 (115.50)	99.80 (135.31)	100.0	71.5 (1.816)
AP1-28-7	299.66 (148.70)	102.05 (138.36)	100.0	74.5 (1.892)
AP1-28-8	400.28 (204.60)	105.88 (143.55)	100.0	74.0 (1.880)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-5
Charpy V-Notch Results for Capsule A Weld Heat 5P6214B

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP2-67-10	-75.46 (-59.70)	15.56 (21.09)	12.8	11.5 (0.292)
AP2-67-6	-61.24 (-51.80)	22.56 (30.58)	22.8	15.5 (0.394)
AP2-67-9	-50.44 (-45.80)	32.51 (44.07)	22.3	27.0 (0.686)
AP2-67-7	-41.26 (-40.70)	40.63 (55.09)	29.8	32.5 (0.826)
AP2-67-5	-20.2 (-29.00)	53.59 (72.66)	38.0	39.0 (0.991)
AP2-67-8	19.40 (-7.00)	53.70 (72.80)	46.8	44.0 (1.118)
AP2-67-1	68.00 (20.00)	84.12 (114.05)	83.5	67.5 (1.715)
AP2-67-2	180.86 (82.70)	92.02 (124.76)	99.5	78.5 (1.994)
AP2-67-3	300.02 (148.90)	98.39 (133.40)	100.0	87.0 (2.210)
AP2-67-4	400.46 (204.70)	98.96 (134.16)	100.0	84.0 (2.134)

Table A-6
Charpy V-Notch Results for Capsule A Weld Heat 34B009

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP2-15-9	-31.00 (-35.00)	13.35 (18.11)	12.5	8.5 (0.216)
AP2-15-10	-5.08 (-20.60)	16.92 (22.94)	22.5	15.0 (0.381)
AP2-15-8	19.58 (-6.90)	30.37 (41.17)	25.4	25.5 (0.648)
AP2-15-2	39.74 (4.30)	36.94 (50.13)	34.1	31.5 (0.800)
AP2-15-1	67.64 (19.80)	38.03 (51.56)	39.0	32.5 (0.826)
AP2-15-3	120.56 (49.20)	53.33 (72.31)	53.4	42.0 (1.067)
AP2-15-7	150.62 (65.90)	71.43 (96.84)	80.4	65.5 (1.664)
AP2-15-4	240.44 (115.80)	87.85 (119.10)	100.0	75.5 (1.918)
AP2-15-5	299.48 (148.60)	91.24 (123.70)	100.0	74.0 (1.880)
AP2-15-6	399.56 (204.20)	97.33 (131.97)	100.0	82.0 (2.083)

Table A-7
Charpy V-Notch Results for Capsule A Quad Cities 2 Electroslag Weld (Heat unknown)

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP2-21-10	-39.28 (-39.60)	21.85 (29.62)	7.9	16.0 (0.406)
AP2-21-8	-20.74 (-29.30)	25.24 (34.22)	9.5	18.0 (0.457)
AP2-21-9	9.86 (-12.30)	34.51 (46.79)	11.4	27.5 (0.699)
AP2-21-7	20.48 (-6.40)	53.79 (72.93)	26.6	44.0 (1.118)
AP2-21-1	67.28 (19.60)	46.15 (62.58)	30.3	36.5 (0.927)[1]
AP2-21-2	130.46 (54.70)	80.55 (109.22)	69.2	68.5 (1.740)
AP2-21-3	189.50 (87.50)	94.65 (128.33)	94.0	85.0 (2.159)
AP2-21-4	260.24 (126.80)	102.40 (138.84)	100.0	84.0 (2.134)
AP2-21-5	300.20 (149.00)	98.91 (134.10)	100.0	80.0 (2.032)
AP2-21-6	400.46 (204.70)	100.65 (136.46)	100.0	79.0 (2.007)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-8
Charpy V-Notch Results for Capsule A Weld Heat 406L44

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
AP2-20-9	19.58 (-6.90)	11.89 (16.11)	16.1	6.5 (0.165)
AP2-20-8	29.48 (-1.40)	15.24 (20.67)	15.0	8.5 (0.216)
AP2-20-1	67.46 (19.70)	25.38 (34.41)	31.3	17.0 (0.432)
AP2-20-10	120.38 (49.10)	30.03 (40.72)	34.8	22.0 (0.559)
AP2-20-2	130.28 (54.60)	28.87 (39.14)	39.6	22.0 (0.559)
AP2-20-3	179.80 (82.11)	40.53 (54.96)	76.6	34.0 (0.864)
AP2-20-4	220.28 (104.60)	56.00 (75.93)	98.5	48.0 (1.219)
AP2-20-5	280.58 (138.10)	55.64 (75.43)	100.0	52.5 (1.334)
AP2-20-6	350.42 (176.90)	59.85 (81.15)	100.0	46.0 (1.168)
AP2-20-7	410.90 (210.50)	61.71 (83.67)	100.0	48.0 (1.219)

Table A-9
Charpy V-Notch Results for Capsule B Plate Heat A1224-1

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP1-67-9	-60.7 (-51.50)	7.98 (10.82)	7.2	8.0 (0.203)
BP1-67-10	-41.26 (-40.70)	11.00 (14.91)	8.0	12.0 (0.305)[1]
BP1-67-8	-39.82 (-39.90)	43.61 (59.12)	19.1	36.5 (0.927)
BP1-67-3	-19.48 (-28.60)	33.43 (45.33)	11.4	29.5 (0.749)
BP1-67-2	19.40 (-7.00)	73.65 (99.85)	32.8	58.0 (1.473)
BP1-67-1	67.46 (19.70)	104.35 (141.48)	56.2	76.0 (1.930)
BP1-67-4	130.28 (54.60)	163.42 (221.57)	95.5	91.0 (2.311)
BP1-67-5	200.12 (93.40)	160.76 (217.96)	100.0	90.0 (2.286)
BP1-67-6	300.20 (149.00)	156.97 (212.82)	100.0	88.0 (2.235)
BP1-67-7	401.00 (205.00)	201.67 (273.43)	100.0	85.5 (2.172)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-10
Charpy V-Notch Results for Capsule B Plate Heat C2331-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP1-30-8	-20.2 (-29.00)	10.03 (13.60)	9.3	10.0 (0.254)
BP1-30-10	0.32 (-17.60)	27.15 (36.81)	16.6	26.0 (0.660)
BP1-30-7	20.48 (-6.40)	35.30 (47.86)	19.0	31.0 (0.787)
BP1-30-1	68.00 (20.00)	46.36 (62.85)	36.2	39.5 (1.003)
BP1-30-9	89.60 (32.00)	60.70 (82.30)	37.7	55.5 (1.410)
BP1-30-2	120.74 (49.30)	82.25 (111.52)	73.8	66.0 (1.676)[1]
BP1-30-3	180.32 (82.40)	90.96 (123.32)	100.0	72.0 (1.829)
BP1-30-4	249.44 (120.80)	100.08 (135.69)	100.0	81.0 (2.057)
BP1-30-5	299.66 (148.70)	99.12 (134.39)	100.0	77.0 (1.956)
BP1-30-6	400.28 (204.60)	100.70 (136.53)	100.0	74.5 (1.892)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-11
Charpy V-Notch Results for Capsule B Plate Heat P2130-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP1-11-10	-9.40 (-23.00)	8.20 (11.12)	11.7	7.5 (0.191)
BP1-11-9	9.68 (-12.40)	21.30 (28.87)	20.0	16.0 (0.406)
BP1-11-8	29.84 (-1.20)	30.75 (41.70)	29.3	27.0 (0.686)
BP1-11-2	68.36 (20.20)	30.08 (40.78)	41.5	30.5 (0.775)
BP1-11-1	68.72 (20.40)	28.87 (39.14)	38.3	26.0 (0.660)
BP1-11-3	100.04 (37.80)	51.98 (70.47)	62.6	46.5 (1.181)
BP1-11-4	140.00 (60.00)	71.04 (96.32)	87.2	63.0 (1.600)
BP1-11-5	230.54 (110.30)	65.92 (89.38)	100.0	55.0 (1.397)
BP1-11-6	299.66 (148.70)	69.26 (93.90)	100.0	56.0 (1.422)
BP1-11-7	399.74 (204.30)	67.86 (92.00)	100.0	56.0 (1.422)

Table A-12
Charpy V-Notch Results for Capsule B Plate Heat C3278-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP1-28-4	-40.18 (-40.10)	11.49 (15.57)	8.9	10.5 (0.267)
BP1-28-3	-9.4 (-23.00)	12.82 (17.38)	13.2	15.0 (0.381)
BP1-28-10	0.32 (-17.60)	33.48 (45.40)	19.1	22.5 (0.572)
BP1-28-9	10.04 (-12.20)	34.91 (47.33)	22.0	28.0 (0.711)
BP1-28-2	19.04 (-7.20)	39.23 (53.18)	25.2	38.0 (0.965)
BP1-28-1	68.54 (20.30)	54.27 (73.58)	48.4	44.5 (1.130)
BP1-28-5	110.12 (43.40)	78.57 (106.52)	84.2	61.5 (1.562)
BP1-28-6	240.26 (115.70)	103.74 (140.65)	100.0	72.0 (1.829)
BP1-28-7	299.66 (148.70)	96.66 (131.05)	100.0	68.0 (1.727)
BP1-28-8	400.46 (204.70)	100.92 (136.83)	100.0	71.5 (1.816)

Table A-13
Charpy V-Notch Results for Capsule B Weld Heat 5P6214B

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP2-67-4	-70.78 (-57.10)	7.20 (9.76)	16.6	5.0 (0.127)
BP2-67-3	-30.64 (-34.80)	19.72 (26.73)	32.0	16.0 (0.406)
BP2-67-10	-20.20 (-29.00)	14.84 (20.11)	27.8	13.5 (0.343)
BP2-67-9	-9.76 (-23.20)	31.87 (43.21)	32.7	28.5 (0.724)
BP2-67-2	9.32 (-12.60)	53.43 (72.44)	50.9	41.0 (1.041)
BP2-67-8	39.74 (4.30)	66.35 (89.96)	62.5	50.0 (1.270)
BP2-67-1	67.28 (19.60)	69.47 (94.19)	63.0	52.5 (1.334)
BP2-67-5	219.56 (104.20)	95.76 (129.83)	100.0	78.0 (1.981)
BP2-67-6	300.74 (149.30)	93.85 (127.25)	100.0	75.0 (1.905)
BP2-67-7	400.82 (204.90)	102.49 (138.96)	100.0	71.0 (1.803)

Table A-14
Charpy V-Notch Results for Capsule B Weld Heat 34B009

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP2-15-3	-39.82 (-39.90)	4.51 (6.11)	8.0	4.0 (0.102)
BP2-15-2	-0.22 (-17.90)	13.44 (18.23)	15.9	11.0 (0.279)
BP2-15-9	19.94 (-6.70)	32.80 (44.47)	28.7	26.5 (0.673)
BP2-15-8	39.56 (4.20)	31.29 (42.42)	25.6	25.0 (0.635)
BP2-15-1	68.00 (20.00)	44.12 (59.81)	39.2	33.0 (0.838)
BP2-15-4	110.66 (43.70)	65.07 (88.22)	63.5	49.5 (1.257)
BP2-15-10	141.26 (60.70)	70.83 (96.03)	68.0	56.0 (1.422)
BP2-15-5	239.54 (115.30)	92.57 (125.51)	100.0	73.0 (1.854)
BP2-15-6	300.20 (149.00)	101.37 (137.44)	100.0	80.0 (2.032)
BP2-15-7	399.56 (204.20)	102.55 (139.04)	100.0	76.0 (1.930)

Table A-15
Charpy V-Notch Results for Capsule B Quad Cities 2 Electroslag Weld (Heat unknown)

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP2-21-9	-70.96 (-57.20)	20.50 (27.80)	6.0	16.5 (0.419)
BP2-21-10	-41.26 (-40.70)	4.89 (6.63)	2.3	2.5 (0.064)
BP2-21-8	-40.72 (-40.40)	30.41 (41.23)	12.1	29.5 (0.749)
BP2-21-7	0.32 (-17.60)	41.44 (56.19)	15.0	31.0 (0.787)
BP2-21-1	66.56 (19.20)	51.88 (70.34)	29.4	40.0 (1.016)
BP2-21-2	109.94 (43.30)	100.54 (136.31)	73.5	69.5 (1.765)
BP2-21-3	150.08 (65.60)	97.84 (132.66)	86.1	75.0 (1.905)
BP2-21-4	249.44 (120.80)	106.68 (144.64)	100.0	80.0 (2.032)
BP2-21-5	325.94 (163.30)	104.65 (141.89)	100.0	70.0 (1.778)
BP2-21-6	399.56 (204.20)	119.06 (161.42)	100.0	80.0 (2.032)

Table A-16
Charpy V-Notch Results for Capsule B Weld Heat 406L44

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
BP2-20-10	29.84 (-1.20)	22.55 (30.58)	16.8	16.0 (0.406)
BP2-20-1	66.74 (19.30)	20.79 (28.18)	19.4	15.0 (0.381)
BP2-20-8	100.58 (38.10)	21.99 (29.82)	28.3	16.0 (0.406)
BP2-20-2	120.56 (49.20)	33.88 (45.94)	42.0	26.5 (0.673)
BP2-20-9	145.22 (62.90)	28.77 (39.01)	45.3	22.5 (0.572)
BP2-20-3	170.96 (77.20)	46.21 (62.65)	69.5	38.5 (0.978)
BP2-20-4	219.38 (104.10)	50.48 (68.44)	90.1	43.0 (1.092)
BP2-20-5	280.58 (138.10)	56.37 (76.43)	100.0	44.5 (1.130)
BP2-20-6	349.16 (176.20)	59.43 (80.58)	100.0	48.0 (1.219)
BP2-20-7	400.46 (204.70)	58.64 (79.50)	100.0	48.0 (1.219)

Table A-17
Charpy V-Notch Results for Capsule C Plate Heat C3985-2

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP1-36-10	-20.56 (-29.20)	27.38 (37.13)	17.0	24.0 (0.610)
CP1-36-8	-9.40 (-23.00)	30.03 (40.71)	17.0	25.0 (0.635)
CP1-36-7	19.76 (-6.80)	32.12 (43.54)	23.5	24.0 (0.737)[1]
CP1-36-6	20.12 (-6.60)	25.67 (34.80)	28.5	22.0 (0.559)
CP1-36-9	49.46 (9.70)	58.21 (78.92)	34.6	46.5 (1.219)[1]
CP1-36-1	66.74 (19.30)	54.58 (74.00)	35.8	49.5 (1.257)
CP1-36-2	120.20 (49.00)	94.25 (127.79)	58.8	78.5 (1.994)
CP1-36-3	200.66 (93.70)	117.19 (158.89)	100.0	82.0 (2.083)
CP1-36-4	301.10 (149.50)	118.55 (160.73)	100.0	84.0 (2.134)
CP1-36-5	400.28 (204.60)	111.75 (151.51)	100.0	79.5 (2.019)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-18
Charpy V-Notch Results for Capsule C Plate Heat C1079-1

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP1-15-9	-9.40 (-23.00)	11.97 (16.23)	12.8	8.0 (0.203)
CP1-15-8	19.94 (-6.70)	16.28 (22.08)	16.8	12.5 (0.318)
CP1-15-1	66.74 (19.30)	29.45 (39.92)	28.1	27.0 (0.686)
CP1-15-2	67.46 (19.70)	26.14 (35.45)	31.6	25.5 (0.648)
CP1-15-10	94.82 (34.90)	33.29 (45.13)	32.5	29.0 (0.737)
CP1-15-3	118.58 (48.10)	42.90 (58.16)	40.2	39.0 (0.991)[1]
CP1-15-4	170.06 (76.70)	50.84 (68.92)	96.7	44.5 (1.1130)
CP1-15-5	219.74 (104.30)	54.48 (73.86)	100.0	48.0 (1.219)
CP1-15-6	300.38 (149.10)	60.38 (81.86)	100.0	53.5 (1.359)
CP1-15-7	400.28 (204.60)	65.87 (89.31)	100.0	55.0 (1.397)

[1]In accordance with ASTM E23, the lateral expansion for this specimen (which could be broken after the impact test) should not be reported as broken since the lateral expansion of the unbroken specimen is less than that for the broken specimen. Therefore, the value listed is the unbroken measurement.

Table A-19
Charpy V-Notch Results for Capsule C Plate Heat A0610-1

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP1-20-9	-20.74 (-29:30)	19.68 (26.68)	14.6	14.5 (0.368)
CP1-20-10	0.86 (-17.30)	23.31 (31.61)	17.8	19.0 (0.483)
CP1-20-8	19.94 (-6.70)	32.11 (43.54)	26.9	29.5 (0.749)
CP1-20-7	40.46 (4.70)	55.78 (75.63)	37.9	40.0 (1.0016)
CP1-20-1	68.00 (20.00)	38.88 (52.71)	43.1	37.0 (0.940)
CP1-20-2	109.40 (43.00)	76.81 (104.14)	60.5	56.0 (1.422)
CP1-20-3	150.26 (65.70)	89.50 (121.35)	92.5	67.5 (1.715)
CP1-20-4	219.38 (104.10)	91.79 (124.45)	100.0	68.5 (1.740)
CP1-20-5	299.30 (148.50)	98.90 (134.08)	100.0	65.5 (1.664)
CP1-20-6	400.46 (204.70)	105.59 (143.16)	100.0	58.5 (1.486)

Table A-20
Charpy V-Notch Results for Capsule C Plate HSST-02 Heat A1195-1

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP1-H2-9	-0.22 (-17.90)	10.21 (13.84)	12.3	7.5 (0.191)
CP1-H2-10	20.12 (-6.60)	13.44 (18.22)	17.9	10.5 (0.267)
CP1-H2-8	28.94 (-1.70)	25.43 (34.47)	20.0	19.0 (0.483)
CP1-H2-1	68.00 (20.00)	28.25 (38.30)	28.4	22.0 (0.559)
CP1-H2-2	68.00 (20.00)	34.27 (46.46)	26.0	26.5 (0.673)
CP1-H2-3	120.20 (49.00)	51.04 (69.20)	44.0	42.0 (1.067)
CP1-H2-4	169.16 (76.20)	81.59 (110.62)	75.8	63.0 (1.600)
CP1-H2-5	260.60 (127.00)	96.60 (130.97)	100.0	72.0 (1.829)
CP1-H2-6	329.90 (165.50)	107.00 (145.07)	100.0	71.5 (1.816)
CP1-H2-7	400.46 (204.70)	108.70 (147.38)	100.0	67.0 (1.702)

Table A-21
Charpy V-Notch Results for Capsule C Weld Heat 20291

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
EY_J1_-8	19.40 (-7.00)	10.78 (14.61)	13.4	9.0 (0.229)
EY_J1_-9	35.60 (2.00)	25.81 (34.99)	22.3	23.0 (0.584)
EY_J1_-10	55.22 (12.90)	26.00 (35.25)	24.3	22.0 (0.559)
EY_J1_-1	66.38 (19.10)	30.21 (40.96)	30.8	24.0 (0.610)
EY_J1_-2	66.38 (19.10)	45.03 (61.05)	42.1	35.5 (0.902)
EY_J1_-3	119.48 (48.60)	68.13 (92.37)	76.7	49.0 (1.245)
EY_J1_-4	180.5 (82.50)	85.79 (116.31)	91.8	68.0 (1.727)
EY_J1_-5	250.34 (121.30)	92.46 (125.36)	99.2	75.0 (1.905)
EY_J1_-6	300.02 (148.90)	93.91 (127.33)	100.0	77.0 (1.956)
EY_J1_-7	400.64 (204.80)	94.31 (127.86)	100.0	74.0 (1.880)

Table A-22
Charpy V-Notch Results for Capsule C B&W Linde 80 Weld (Heat unknown)

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP2-BW-7	50.18 (10.10)	19.26 (26.11)	20.6	12.5 (0.318)
CP2-BW-1	66.56 (19.20)	17.51 (23.74)	19.2	13.0 (0.330)
CP2-BW-2	110.12 (43.40)	24.30 (32.94)	28.8	19.0 (0.483)
CP2-BW-8	140.72 (60.40)	33.34 (45.20)	46.5	30.0 (0.762)
CP2-BW-3	170.06 (76.70)	37.33 (50.62)	47.6	32.0 (0.813)
CP2-BW-10	209.12 (98.40)	52.91 (71.74)	95.5	46.5 (1.181)
CP2-BW-4	279.86 (137.70)	52.50 (71.18)	93.9	45.5 (1.156)
CP2-BW-5	350.60 (177.00)	65.92 (89.38)	100.0	53.0 (1.346)
CP2-BW-9	385.52 (196.40)	68.13 (92.37)	100.0	64.0 (1.626)
CP2-BW-6	419.18 (215.10)	71.70 (97.21)	100.0	59.0 (1.499)

Table A-23
Charpy V-Notch Results for Capsule C Humboldt Bay 3 Weld (Heat unknown)

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP2-06-7	-50.44 (-45.80)	5.91 (8.02)	8.8	2.0 (0.051)
CP2-06-5	-10.66 (-23.70)	24.20 (32.80)	22.5	18.5 (0.470)
CP2-06-9	-10.30 (-23.50)	41.78 (56.64)	26.9	31.0 (0.787)
CP2-06-8	-0.04 (-17.80)	44.00 (59.66)	27.8	35.0 (0.889)
CP2-06-6	9.68 (-12.40)	43.85 (59.46)	31.2	34.0 (0.864)
CP2-06-1	66.38 (19.10)	61.13 (82.88)	50.5	49.0 (1.245)
CP2-06-10	119.84 (48.80)	79.99 (108.45)	84.3	65.5 (1.664)
CP2-06-2	240.26 (115.70)	99.17 (134.46)	100.0	79.5 (2.019)
CP2-06-3	300.92 (149.40)	96.82 (131.26)	100.0	74.0 (1.880)
CP2-06-4	400.64 (204.80)	103.22 (139.95)	100.0	74.0 (1.880)

Table A-24
Charpy V-Notch Results for Capsule C Weld Heat 5P6756

Specimen Identification	Test Temperature F (C)	Impact Energy ft-lb (J)	Fracture Appearance (% Shear Area)	Lateral Expansion mils (mm)
CP2-72-6	-80.14 (-62.30)	14.11 (19.13)	14.2	12.0 (0.305)
CP2-72-5	-50.44 (-45.80)	22.46 (30.45)	22.8	21.0 (0.533)
CP2-72-9	-40.36 (-40.20)	38.92 (52.77)	26.5	32.0 (0.813)
CP2-72-8	-20.2 (-29.00)	36.38 (49.33)	33.8	32.0 (0.813)
CP2-72-10	0.14 (-17.70)	54.52 (73.92)	47.9	44.0 (1.118)
CP2-72-7	19.58 (-6.90)	60.79 (82.42)	54.8	49.0 (1.245)
CP2-72-1	67.28 (19.60)	77.81 (105.50)	76.8	59.0 (1.499)
CP2-72-2	149.18 (65.10)	102.51 (138.98)	100.0	71.5 (1.816)
CP2-72-3	300.38 (149.10)	112.54 (152.58)	100.0	81.0 (2.057)
CP2-72-4	399.74 (204.30)	117.01 (158.64)	100.0	70.0 (1.778)

Table A-25
Charpy V-Notch Results for Unirradiated SSP Plate Heat A1224-1

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	6.0 (8.1)	2.0 (0.051)	3
-60	12.0 (16.3)	3.5 (0.089)	0
-40	8.5 (11.5)	1.0 (0.025)	9
-20	20.5 (27.8)	9.0 (0.229)	16
-20	42.0 (56.9)	22.0 (0.559)	21
0	24.0 (32.5)	12.5 (0.318)	14
20	84.0 (113.9)	56.0 (1.422)	39
20	71.0 (96.3)	45.5 (1.156)	35
40	97.5 (132.2)	62.5 (1.588)	57
60	83.0 (112.5)	53.0 (1.346)	52
80	115.0 (155.9)	73.0 (1.854)	67
100	120.0 (162.7)	65.0 (1.651)	77
180	143.0 (193.9)	86.0 (2.184)	100
300	154.0 (208.8)	71.0 (1.803)	100
400	145.0 (196.6)	74.0 (1.880)	100

Table A-26
Charpy V-Notch Results for Unirradiated SSP Plate Heat C2331-2

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	12.0 (16.3)	5.0 (0.127)	3
-60	15.5 (21.0)	5.0 (0.127)	0
-40	24.5 (33.2)	12.5 (0.318)	19
-20	20.0 (27.1)	13.0 (0.330)	16
-20	31.5 (42.7)	20.0 (0.508)	20
0	43.5 (59.0)	28.5 (0.724)	23
20	46.0 (62.4)	29.5 (0.749)	30
40	52.5 (71.2)	32.5 (0.826)	49
60	53.5 (72.5)	37.0 (0.940)	47
60	49.5 (67.1)	37.0 (0.940)	44
80	91.5 (124.1)	67.5 (1.715)	87
100	86.0 (116.6)	63.0 (1.600)	89
180	97.0 (131.5)	70.0 (1.778)	100
300	97.0 (131.5)	73.0 (1.854)	100
400	106.0 (143.7)	73.5 (1.867)	100

Table A-27
Charpy V-Notch Results for Unirradiated SSP Plate Heat P2130-2

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	3.5 (4.7)	0.0 (0.000)	5
-60	13.5 (18.3)	9.0 (0.229)	8
-40	21.5 (29.2)	13.5 (0.343)	16
-20	17.5 (23.7)	14.5 (0.368)	20
-20	35.5 (48.1)	23.5 (0.597)	30
0	30.0 (40.7)	25.5 (0.648)	20
20	34.0 (46.1)	26.5 (0.673)	30
40	48.0 (65.1)	35.5 (0.902)	62
60	61.0 (82.7)	45.5 (1.156)	60
100	77.0 (104.4)	59.0 (1.499)	100
100	63.5 (86.1)	55.0 (1.397)	76
180	60.0 (81.3)	58.0 (1.473)	100
180	62.0 (84.1)	54.5 (1.384)	100
300	72.5 (98.3)	60.5 (1.537)	100
400	68.0 (92.2)	57.0 (1.448)	100

Table A-28
Charpy V-Notch Results for Unirradiated SSP Plate Heat C3278-2

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	19.0 (25.8)	11.5 (0.292)	8
-60	24.0 (32.5)	11.5 (0.292)	0
-60	17.0 (23.0)	5.5 (0.140)	18
-40	36.5 (49.5)	20.5 (0.521)	18
-20	25.5 (34.6)	13.0 (0.330)	20
-20	48.0 (65.1)	27.0 (0.686)	24
0	40.5 (54.9)	25.5 (0.648)	23
20	67.0 (90.8)	44.5 (1.130)	37
20	40.0 (54.2)	27.0 (0.686)	30
60	77.0 (104.4)	52.5 (1.334)	44
60	89.0 (120.7)	55.5 (1.410)	71
100	102.0 (138.3)	64.5 (1.638)	94
180	105.0 (142.4)	65.5 (1.664)	100
300	120.0 (162.7)	72.0 (1.829)	100
400	115.0 (155.9)	69.5 (1.765)	100

Table A-29
Charpy V-Notch Results for Unirradiated SSP Plate Heat C3985-2

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	8.0 (10.8)	4.5 (0.114)	4
-60	9.0 (12.2)	1.0 (0.025)	8
-40	16.0 (21.7)	5.5 (0.140)	14
-20	36.0 (48.8)	20.0 (0.508)	11
0	42.0 (56.9)	26.0 (0.660)	25
20	50.5 (68.5)	35.5 (0.902)	34
40	54.0 (73.2)	31.5 (0.800)	40
60	62.5 (84.7)	43.0 (1.092)	42
60	57.0 (77.3)	41.5 (1.054)	42
80	84.5 (114.6)	63.0 (1.600)	62
100	96.5 (130.8)	65.5 (1.664)	64
100	88.0 (119.3)	65.0 (1.651)	86
180	114.0 (154.6)	74.0 (1.880)	100
300	116.0 (157.3)	70.5 (1.791)	100
400	108.5 (147.1)	71.0 (1.803)	100

Table A-30
Charpy V-Notch Results for Unirradiated SSP Plate Heat C1079-1

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	12.5 (16.9)	10.5 (0.267)	10
-60	11.5 (15.6)	2.5 (0.064)	5
-40	19.0 (25.8)	12.5 (0.318)	23
-20	21.0 (28.5)	12.5 (0.318)	14
0	25.0 (33.9)	17.5 (0.445)	24
20	31.0 (42.0)	23.5 (0.597)	23
20	32.0 (43.4)	20.5 (0.521)	39
40	34.5 (46.8)	26.5 (0.673)	56
60	50.0 (67.8)	38.0 (0.965)	52
80	52.0 (70.5)	43.0 (1.092)	89
100	58.0 (78.6)	43.0 (1.092)	97
140	62.5 (84.7)	51.5 (1.308)	98
180	61.5 (83.4)	52.5 (1.334)	100
300	62.0 (84.1)	52.0 (1.321)	100
400	62.0 (84.1)	51.0 (1.295)	100

Table A-31
Charpy V-Notch Results for Unirradiated SSP Plate Heat A0610-1

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	9.5 (12.9)	10.0 (0.254)	8
-60	17.0 (23.0)	8.0 (0.203)	11
-40	37.5 (50.8)	22.5 (0.572)	21
-20	34.0 (46.1)	22.5 (0.572)	18
-20	39.5 (53.6)	25.0 (0.635)	49
0	45.0 (61.0)	34.5 (0.876)	23
20	69.0 (93.6)	44.5 (1.130)	42
60	98.0 (132.9)	67.0 (1.702)	90
60	82.5 (111.9)	59.0 (1.499)	76
100	96.0 (130.2)	71.0 (1.803)	99
180	109.0 (147.8)	79.0 (2.007)	100
180	105.0 (142.4)	69.5 (1.765)	100
300	100.0 (135.6)	70.5 (1.791)	100
400	92.0 (124.7)	64.0 (1.626)	100
400	105.0 (142.4)	74.0 (1.880)	100

Table A-32
Charpy V-Notch Results for Unirradiated SSP Heat A1195-1

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-60	3.5 (4.7)	0.0 (0.000)	0
-40	11.5 (15.6)	3.5 (0.089)	11
-20	10.5 (14.2)	3.0 (0.076)	9
0	14.5 (19.7)	5.5 (0.140)	14
20	30.0 (40.7)	21.5 (0.546)	26
40	37.5 (50.8)	23.0 (0.584)	25
60	39.5 (53.6)	23.0 (0.584)	30
60	28.0 (38.0)	19.5 (0.495)	37
80	51.0 (69.1)	41.0 (1.041)	52
100	61.0 (82.7)	38.5 (0.978)	48
100	60.0 (81.3)	46.0 (1.168)	62
140	80.0 (108.5)	56.5 (1.435)	87
180	98.5 (133.5)	80.5 (2.045)	100
300	100.5 (136.3)	76.0 (1.930)	100
400	100.0 (135.6)	67.0 (1.702)	100

Table A-33
Charpy V-Notch Results for Unirradiated SSP Weld 5P6214B

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	7.5 (10.2)	1.5 (0.038)	7
-60	19.0 (25.8)	13.5 (0.343)	23
-40	17.0 (23.0)	10.5 (0.267)	25
-20	31.5 (42.7)	22.5 (0.572)	34
-20	45.0 (61.0)	26.5 (0.673)	43
0	41.5 (56.3)	26.0 (0.660)	31
20	61.0 (82.7)	44.0 (1.118)	56
20	56.0 (75.9)	39.0 (0.991)	57
40	68.0 (92.2)	51.0 (1.295)	72
60	76.0 (103.0)	54.5 (1.384)	85
80	82.0 (111.2)	61.5 (1.562)	84
100	86.0 (116.6)	69.0 (1.753)	99
180	93.0 (126.1)	79.0 (2.007)	100
300	93.0 (126.1)	73.5 (1.867)	100
400	94.0 (127.4)	70.0 (1.778)	100

Table A-34
Charpy V-Notch Results for Unirradiated SSP Weld 34B009

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-100	20.0 (27.1)	9.5 (0.241)	13
-80	27.5 (37.3)	16.5 (0.419)	18
-60	36.5 (49.5)	23.0 (0.584)	23
-40	41.0 (55.6)	22.5 (0.572)	40
-20	55.0 (74.6)	35.5 (0.902)	54
0	57.5 (78.0)	37.5 (0.953)	42
20	75.0 (101.7)	52.5 (1.334)	74
40	86.5 (117.3)	59.5 (1.511)	88
60	100.0 (135.6)	70.5 (1.791)	99
60	100.0 (135.6)	69.5 (1.765)	94
80	101.5 (137.6)	77.5 (1.969)	99
100	102.0 (138.3)	70.5 (1.791)	100
180	104.5 (141.7)	74.5 (1.892)	100
300	106.5 (144.4)	71.0 (1.803)	100
400	112.0 (151.9)	76.0 (1.930)	100

Table A-35
Charpy V-Notch Results for Unirradiated SSP Quad Cities 2 Electroslag Weld (Heat unknown)

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-100	2.0 (2.7)	0.0 (0.000)	4
-80	7.0 (9.5)	8.0 (0.203)	3
-60	25.5 (34.6)	12.5 (0.318)	9
-40	25.0 (33.9)	14.5 (0.368)	12
-20	42.5 (57.6)	27.0 (0.686)	15
-20	26.0 (35.3)	13.0 (0.330)	17
0	39.0 (52.9)	23.0 (0.584)	13
20	49.0 (66.4)	34.5 (0.876)	23
40	60.0 (81.3)	39.5 (1.003)	42
60	66.5 (90.2)	48.5 (1.232)	46
80	84.5 (114.6)	60.0 (1.524)	68
100	88.0 (119.3)	65.5 (1.664)	51
180	104.0 (141.0)	79.5 (2.019)	100
300	104.0 (141.0)	72.0 (1.829)	100
400	104.0 (141.0)	74.0 (1.880)	100

Table A-36
Charpy V-Notch Results for Unirradiated SSP Weld 406L44

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	23.0 (31.2)	15.5 (0.394)	14
-60	13.0 (17.6)	6.5 (0.165)	14
-40	11.0 (14.9)	5.5 (0.140)	20
-20	26.5 (35.9)	16.0 (0.406)	23
-20	36.0 (48.8)	24.5 (0.622)	40
0	33.0 (44.7)	21.0 (0.533)	26
20	34.5 (46.8)	25.0 (0.635)	26
40	47.5 (64.4)	35.0 (0.889)	61
60	45.0 (61.0)	35.0 (0.889)	66
80	64.0 (86.8)	53.5 (1.359)	95
100	61.5 (83.4)	52.5 (1.334)	96
140	75.5 (102.4)	63.0 (1.600)	100
180	70.0 (94.9)	58.5 (1.486)	100
300	75.5 (102.4)	65.5 (1.664)	100
400	72.0 (97.6)	62.0 (1.575)	100

Table A-37
Charpy V-Notch Results for Unirradiated SSP Weld 20291

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-127	4.5 (6.1)	0.0 (0.000)	-
-100	6.7 (9.1)	1.0 (0.025)	-
-75	5.5 (7.5)	0.0 (0.000)	-
-52	13.3 (18.0)	8.5 (0.216)	-
-25	24.0 (32.5)	19.5 (0.495)	-
0	36.6 (49.6)	25.0 (0.635)	-
10	64.0 (86.8)	45.5 (1.156)	-
25	43.8 (59.4)	35.5 (0.902)	-
40	83.0 (112.5)	58.0 (1.473)	-
49	67.5 (91.5)	49.0 (1.245)	-
60	90.0 (122.0)	63.5 (1.613)	-
75	80.0 (108.5)	60.0 (1.524)	-
90	95.0 (128.8)	71.0 (1.803)	-
101	96.0 (130.2)	65.0 (1.651)	-
150	105.0 (142.4)	70.0 (1.778)	-
200	109.0 (147.8)	75.0 (1.905)	-
300	119.0 (161.3)	84.5 (2.146)	-
400	106.0 (143.7)	76.0 (1.930)	-

[1]Not reported in Reference [5-2].

Table A-38
Charpy V-Notch Results for Unirradiated SSP B&W Linde 80 Weld (Heat unknown)

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-80	3.5 (4.7)	5.5 (0.140)	10
-60	6.5 (8.8)	0.0 (0.000)	0
-40	7.5 (10.2)	2.0 (0.051)	11
-20	11.0 (14.9)	4.5 (0.114)	8
0	19.5 (26.4)	11.0 (0.279)	19
20	25.5 (34.6)	16.5 (0.419)	27
40	35.0 (47.5)	24.0 (0.610)	48
60	37.5 (50.8)	28.0 (0.711)	40
80	43.0 (58.3)	38.0 (0.965)	71
100	49.0 (66.4)	38.0 (0.965)	75
140	58.5 (79.3)	47.5 (1.207)	85
180	76.0 (103.0)	66.0 (1.676)	100
300	71.5 (96.9)	65.0 (1.651)	100
300	77.0 (104.4)	65.5 (1.664)	100
400	78.5 (106.4)	66.0 (1.676)	100

Table A-39
Charpy V-Notch Results for Unirradiated SSP Humboldt Bay Weld (Heat unknown)

Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-100	29.0 (39.3)	15.5 (0.394)	12
-80	22.5 (30.5)	14.5 (0.368)	12
-60	45.0 (61.0)	28.5 (0.724)	22
-60	35.0 (47.5)	22.5 (0.572)	29
-20	40.0 (54.2)	26.0 (0.660)	34
-20	55.0 (74.6)	34.5 (0.876)	42
0	63.5 (86.1)	47.0 (1.194)	59
20	73.5 (99.7)	53.0 (1.346)	67
20	75.5 (102.4)	54.5 (1.384)	70
40	95.5 (129.5)	66.5 (1.689)	86
60	82.0 (111.2)	61.0 (1.549)	65
100	102.0 (138.3)	78.0 (1.981)	99
180	110.0 (149.1)	80.0 (2.032)	100
300	113.0 (153.2)	80.0 (2.032)	100
400	116.0 (157.3)	80.0 (2.032)	100

Table A-40
Charpy V-Notch Results for Unirradiated SSP Weld 5P6756

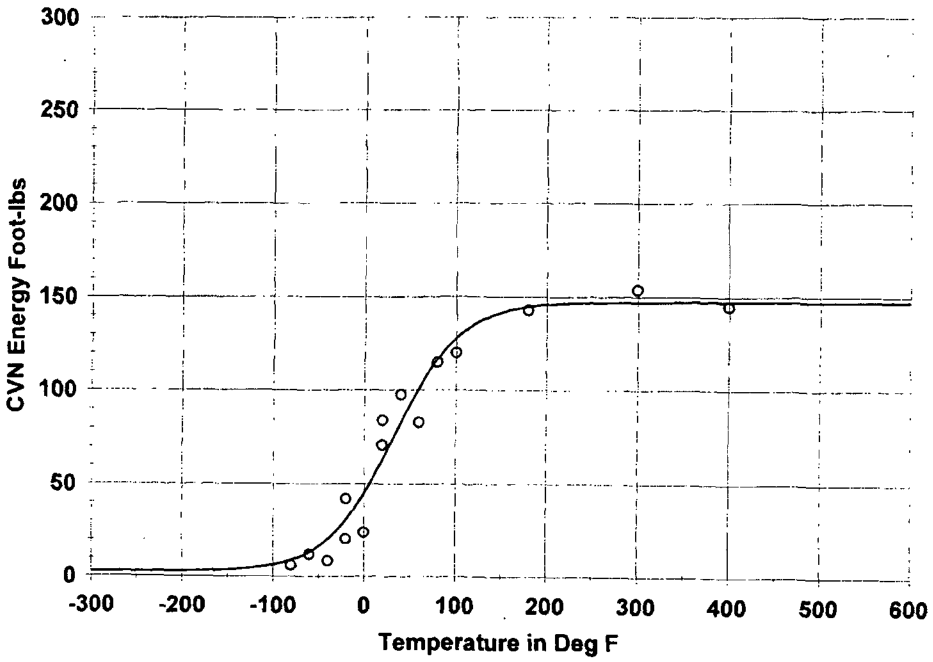
Test Temperature F	Impact Energy ft-lb (J)	Lateral Expansion mils (mm)	Fracture Appearance (% Shear Area)
-100	7.5 (10.2)	0.0 (0.000)	14
-80	22.0 (29.8)	13.5 (0.343)	16
-60	43.0 (58.3)	27.5 (0.699)	26
-60	32.5 (44.1)	23.0 (0.584)	29
-40	47.0 (63.7)	30.5 (0.775)	34
-20	54.5 (73.9)	40.5 (1.029)	28
0	53.5 (72.5)	35.5 (0.902)	51
20	72.5 (98.3)	52.0 (1.321)	69
40	75.5 (102.4)	56.0 (1.422)	72
60	70.0 (94.9)	55.0 (1.397)	66
60	88.0 (119.3)	66.0 (1.676)	90
100	102.0 (138.3)	78.0 (1.981)	100
180	102.0 (138.3)	77.0 (1.956)	100
300	106.0 (143.7)	78.5 (1.994)	100
400	107.5 (145.8)	78.0 (1.981)	100

B
TANH CURVE FIT PLOTS OF CVN TEST DATA

Ten (10) Charpy V-Notch specimens of each irradiated plate and weld material were tested at temperatures selected to define the toughness transition and upper shelf portions of the fracture toughness curves. The absorbed energy and lateral expansion data were fit with the hyperbolic tangent function of CVGRAPH [10]. The absorbed energy data and fit plots are presented in this Appendix. Unirradiated data for the same materials were also fit and are presented for comparison. The curves have been sequenced by material starting with the unirradiated curve, followed by irradiated curve(s).

PLATE HEAT A1224-1 (SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 09/09/2002 08:32 AM
Page 1
Coefficients of Curve 1
A = 74.9 B = 72.4 C = 73.25 T0 = 32.16 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=147.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-20.9 Deg F Temp@50 ft-lbs=5.9 Deg F
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	6.00	8.97	-2.97
-60.00	12.00	13.32	-1.32
-40.00	8.50	20.22	-11.72
-20.00	20.50	30.59	-10.09
-20.00	42.00	30.59	11.41
.00	24.00	45.01	-21.01
20.00	84.00	62.99	21.01
20.00	71.00	62.99	8.01
40.00	97.50	82.62	14.88
60.00	83.00	101.17	-18.17
80.00	115.00	116.44	-1.44

Figure B-1
Charpy Energy Data for A1224-1 Grand Gulf Plate Unirradiated

PLATE HEAT A1224-1 (SSP)

Page 2
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

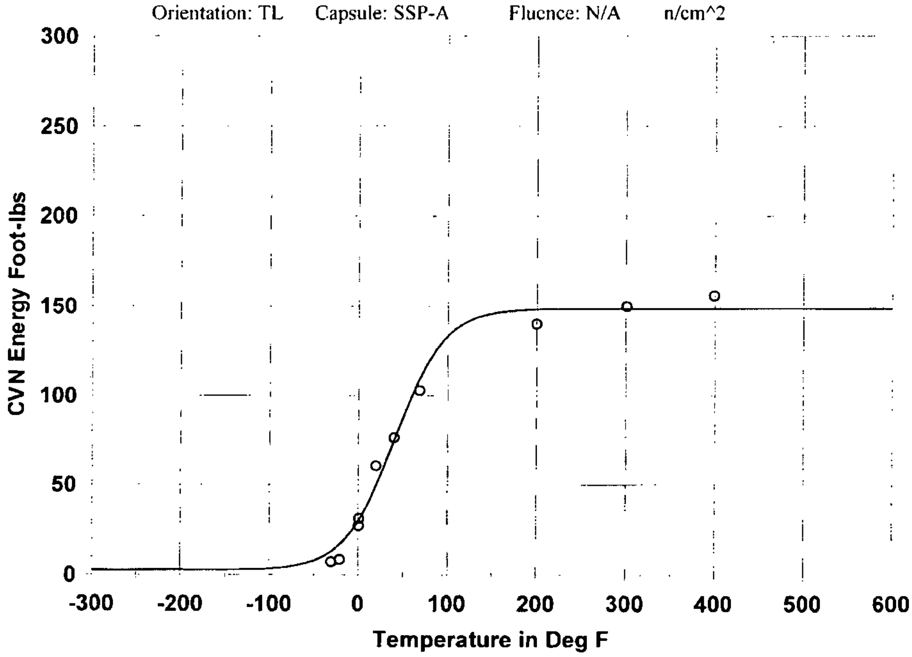
Temperature	Input CVN	Computed CVN	Differential
100.00	120.00	127.67	-7.67
180.00	143.00	144.79	-1.79
300.00	154.00	147.20	6.80
400.00	145.00	147.29	-2.29

Correlation Coefficient = .975

Figure B-1 (continued)
Charpy Energy Data for A1224-1 Grand Gulf Plate Unirradiated

Plate Heat A1224-1 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:04 PM
Page 1
Coefficients of Curve 1
A = 75.6 B = 73.1 C = 55.61 T0 = 40.86 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=148.7(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=.3 Deg F Temp@50 ft-lbs=20.6 Deg F
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: SSP-A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-30.28	7.12	13.00	-5.88
-20.56	8.33	16.96	-8.63
.50	27.24	30.24	-3.00
.86	31.28	30.53	.75
19.94	60.26	49.32	10.94
39.92	75.99	74.36	1.63
68.54	102.88	109.25	-6.37
199.94	140.00	148.22	-8.22
300.92	150.03	148.69	1.34

Figure B-2
Charpy Energy Data for A1224-1 Grand Gulf Plate Irradiated in Capsule A

Plate Heat A1224-1 in SSP Capsule A

Page 2
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: SSP-A Fluence: N/A n/cm^2

Charpy V-Notch Data

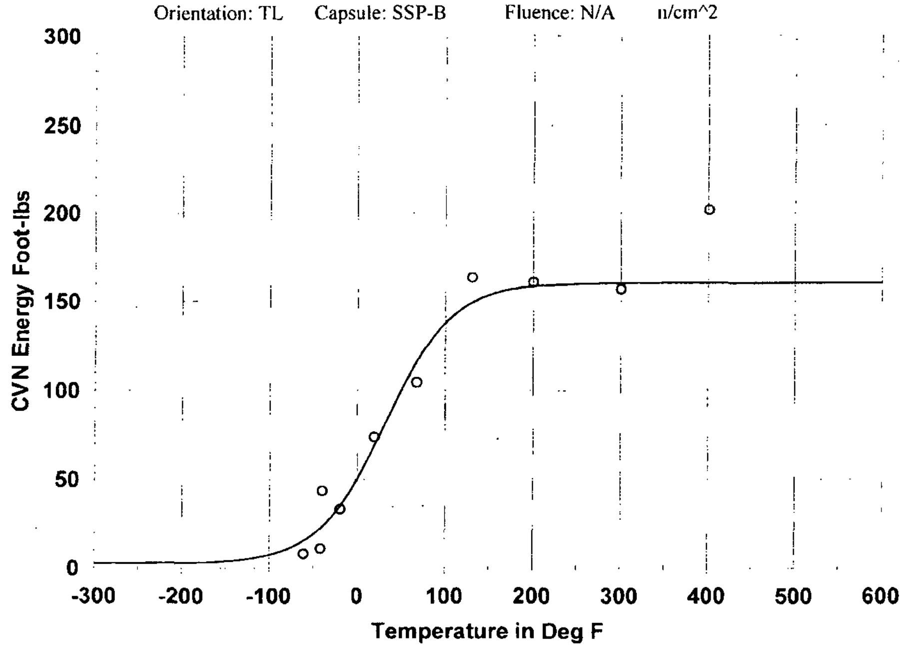
Temperature	Input CVN	Computed CVN	Differential
399.20	156.02	148.70	7.32

Correlation Coefficient = .994

Figure B-2 (continued)
Charpy Energy Data for A1224-1 Grand Gulf Plate Irradiated in Capsule A

Plate Heat A1224-1 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:07 PM
Page 1
Coefficients of Curve 1
A = 81.45 B = 78.95 C = 76.65 T0 = 31.89 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=160.4(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-27.7 Deg F Temp@50 ft-lbs=-.4 Deg F
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: SSP-B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-60.70	7.98	15.44	-7.46
-41.26	11.00	22.89	-11.89
-39.82	43.61	23.56	20.05
-19.48	33.43	35.25	-1.82
19.40	73.65	68.70	4.95
67.46	104.35	115.67	-11.32
130.28	163.42	149.15	14.27
200.12	160.76	158.47	2.29
300.20	156.97	160.26	-3.29

Figure B-3
Charpy Energy Data for A1224-1 Grand Gulf Plate Irradiated in Capsule B

Plate Heat A1224-1 in SSP Capsule B

Page 2
Plant: SSP Material: SA533B1 Heat: A1224-1
Orientation: TL Capsule: SSP-B Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
401.00	201.67	160.39	41.28

Correlation Coefficient = .976

Figure B-3 (continued)
Charpy Energy Data for A1224-1 Grand Gulf Plate Irradiated in Capsule B

UNIRRADIATED PLATE HEAT C2331-2

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/23/2003 03:05 PM

Page 1

Coefficients of Curve 1

A = 51.25 B = 48.75 C = 98.29 T0 = 32.52 D = 0.00E+00

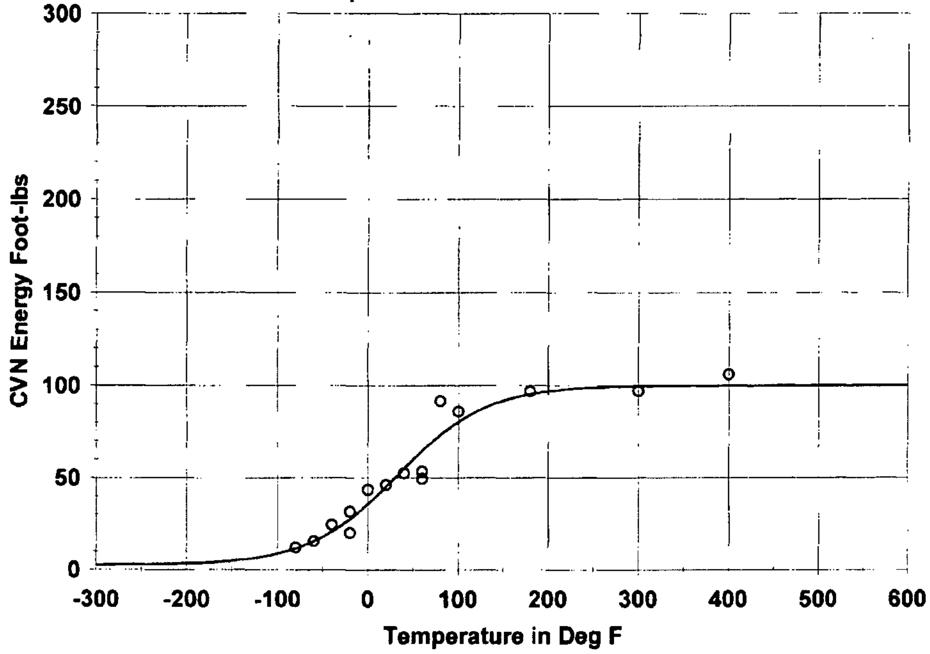
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=100.0(Fixed)   Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=-13.3 Deg F   Temp@50 ft-lbs=30.1 Deg F

Plant: Cooper   Material: SA533B1   Heat: C2331-2

Orientation: TL   Capsule: UNIRRA   Fluence: 0   n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	12.00	11.47	.53
-60.00	15.50	15.38	.12
-40.00	24.50	20.64	3.86
-20.00	20.00	27.43	-7.43
-20.00	31.50	27.43	4.07
.00	43.50	35.68	7.82
20.00	46.00	45.07	.93
40.00	52.50	54.95	-2.45
60.00	53.50	64.53	-11.03

Figure B-4
Charpy Energy Data for C2331-2 Cooper Plate Unirradiated

UNIRRADIATED PLATE HEAT C2331-2

Page 2
Plant: Cooper Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
60.00	49.50	64.53	-15.03
80.00	91.50	73.12	18.38
100.00	86.00	80.29	5.71
180.00	97.00	95.38	1.62
300.00	97.00	99.58	-2.58
400.00	106.00	99.94	6.06

Correlation Coefficient = .969

Figure B-4 (continued)
Charpy Energy Data for C2331-2 Cooper Plate Unirradiated

Plate Heat C2331-2 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:13 PM
Page 1
Coefficients of Curve 1

A = 46.75 B = 44.25 C = 105.31 T0 = 70.12 D = 0.00E+00

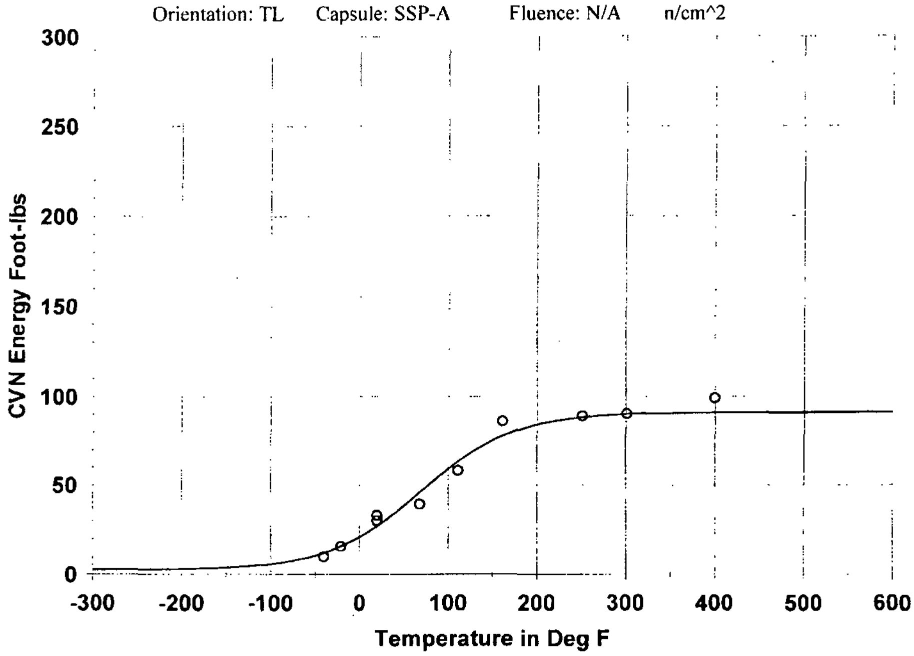
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=91.0(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=28.2 Deg F Temp@50 ft-lbs=77.9 Deg F

Plant: COOPER Material: SA533B1 Heat: C2331-2

Orientation: TL Capsule: SSP-A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-40.36	10.07	12.17	-2.10
-20.56	15.78	15.92	-.14
19.94	30.17	27.13	3.04
19.94	33.14	27.13	6.01
67.64	39.22	45.71	-6.49
110.84	57.99	63.06	-5.07
160.70	85.95	77.56	8.39
250.88	88.94	88.23	.71
300.74	90.17	89.91	.26

Figure B-5
Charpy Energy Data for C2331-2 Cooper Plate Irradiated in Capsule A

Plate Heat C2331-2 in SSP Capsule A

Page 2
Plant: COOPER Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-A Fluence: N/A n/cm^2

Charpy V-Notch Data

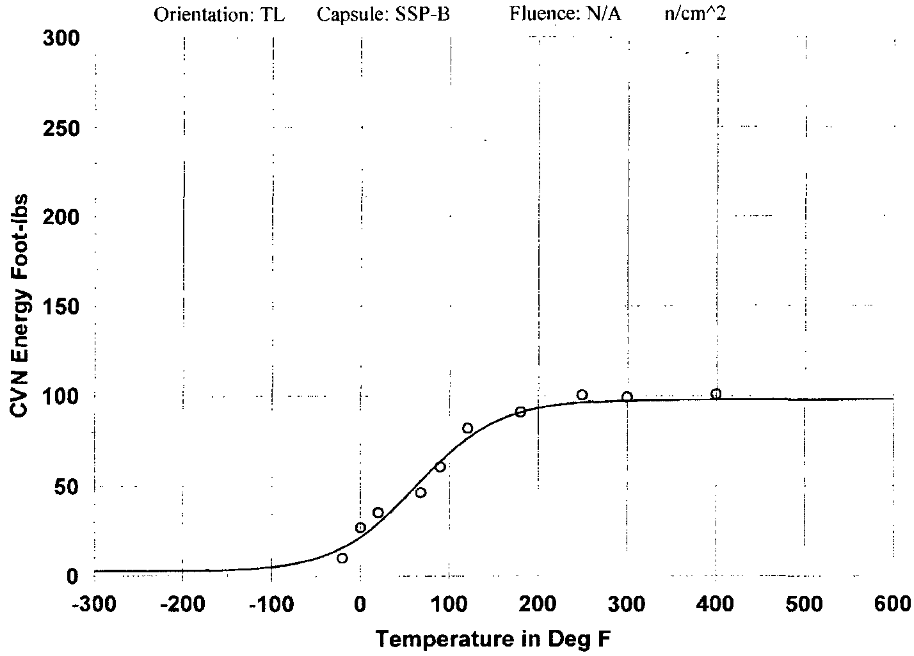
Temperature	Input CVN	Computed CVN	Differential
399.56	99.00	90.83	8.17

Correlation Coefficient = .989

Figure B-5 (continued)
Charpy Energy Data for C2331-2 Cooper Plate Irradiated in Capsule A

Plate Heat C2331-2 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:17 PM
Page 1
Coefficients of Curve 1
A = 50.1 B = 47.6 C = 91.63 T0 = 62.66 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=97.7(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=21.4 Deg F Temp@50 ft-lbs=62.5 Deg F
Plant: COOPER Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.20	10.03	15.90	-5.87
.32	27.15	21.93	5.22
20.48	35.30	29.61	5.69
68.00	46.36	52.87	-6.51
89.60	60.70	63.70	-3.00
120.74	82.25	76.79	5.46
180.32	90.96	90.92	.04
249.44	100.08	96.11	3.97
299.66	99.12	97.16	1.96

Figure B-6
Charpy Energy Data for C2331-2 Cooper Plate Irradiated in Capsule B

Plate Heat C2331-2 in SSP Capsule B

Page 2
Plant: COOPER Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-B Fluence: N/A n/cm^2

Charpy V-Notch Data

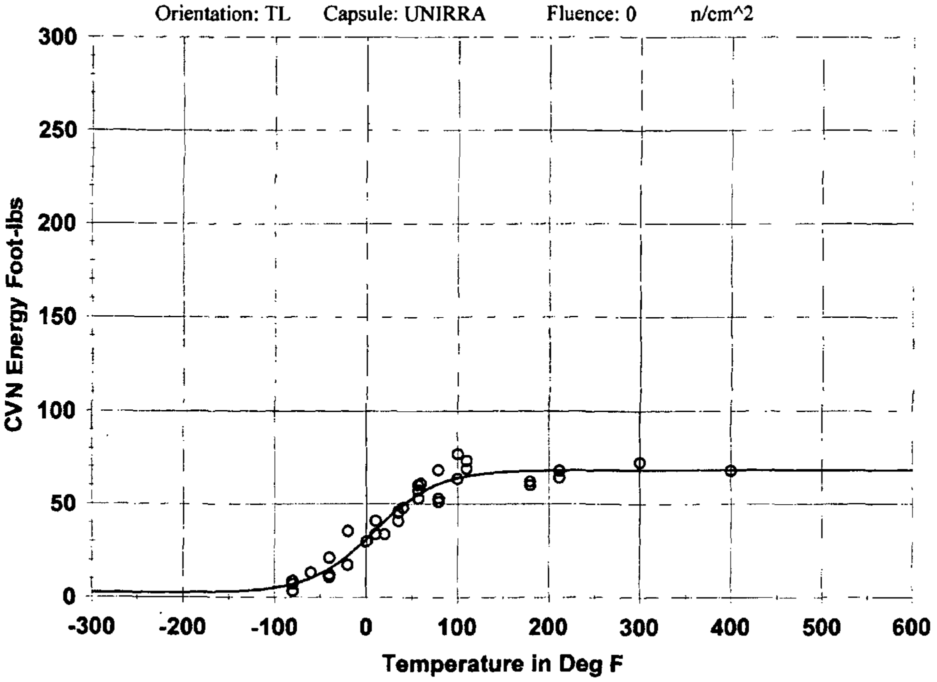
Temperature	Input CVN	Computed CVN	Differential
400.28	100.70	97.64	3.06

Correlation Coefficient = .991

Figure B-6 (continued)
Charpy Energy Data for C2331-2 Cooper Plate Irradiated in Capsule B

UNIRRADIATED PLATE HEAT P2130-2

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/20/2003 04:52 PM
Page 1
Coefficients of Curve 1
A = 35.35 B = 32.85 C = 69.02 T0 = 8.45 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=68.2(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-2.8 Deg F Temp@50 ft-lbs=41.6 Deg F
Plant: Nine Mile Point 1 Material: SA302BM Heat: P2130-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	3.50	7.20	-3.70
-60.00	13.50	10.45	3.05
-40.00	21.50	15.46	6.04
-20.00	17.50	22.53	-5.03
-20.00	35.50	22.53	12.97
.00	30.00	31.35	-1.35
20.00	34.00	40.80	-6.80
40.00	48.00	49.40	-1.40
60.00	61.00	56.15	4.85

Figure B-7
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Unirradiated

UNIRRADIATED PLATE HEAT P2130-2

Page 2
Plant: Nine Mile Point 1 Material: SA302BM Heat: P2130-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	77.00	63.88	13.12
100.00	63.50	63.88	-.38
180.00	60.00	67.75	-7.75
180.00	62.00	67.75	-5.75
300.00	72.50	68.19	4.31
400.00	68.00	68.20	-.20
-80.00	7.30	7.20	.10
-80.00	9.00	7.20	1.80
-40.00	11.00	15.46	-4.46
-40.00	12.20	15.46	-3.26
10.00	33.90	36.09	-2.19
10.00	41.00	36.09	4.91
35.00	41.00	47.40	-6.40
35.00	45.50	47.40	-1.90
57.00	60.10	55.27	4.83
57.00	53.10	55.27	-2.17
57.00	57.20	55.27	1.93
79.00	53.00	60.67	-7.67
79.00	51.20	60.67	-9.47
79.00	68.30	60.67	7.63
110.00	69.00	64.91	4.09
110.00	73.30	64.91	8.39
212.00	68.00	68.02	-.02
212.00	64.00	68.02	-4.02

Correlation Coefficient = .967

Figure B-7 (continued)
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Unirradiated

Plate Heat P2130-2 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:22 PM
Page 1
Coefficients of Curve 1

A = 33.2 B = 30.7 C = 71.88 T0 = 44.86 D = 0.00E+00

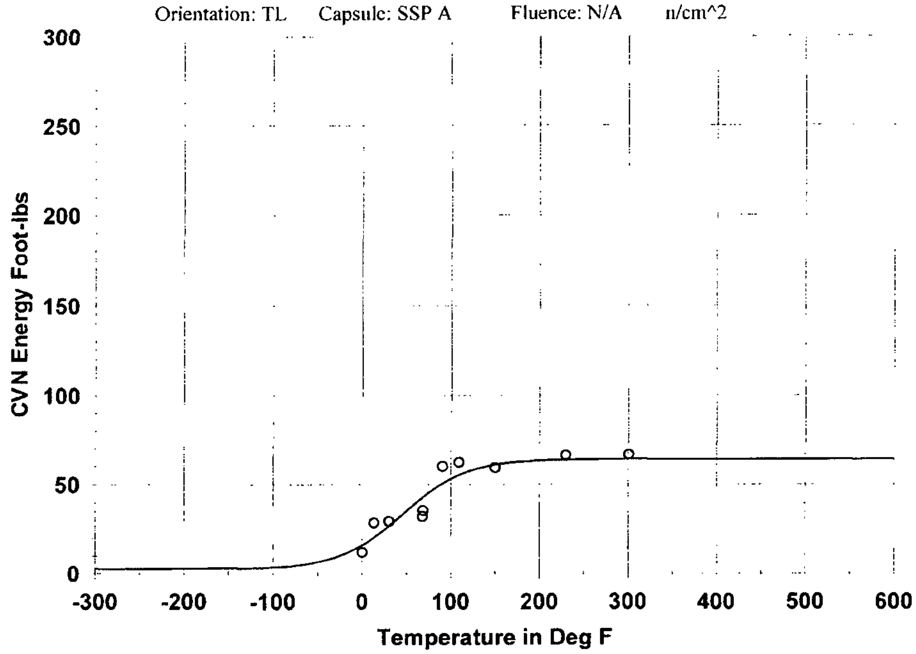
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=63.9(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=37.4 Deg F Temp@50 ft-lbs=89.1 Deg F

Plant: COOPER Material: SA302BM Heat: P2130-2

Orientation: TL Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.32	12.10	16.29	-4.19
13.82	28.96	20.71	8.25
30.56	29.68	27.17	2.51
68.18	32.40	42.83	-10.43
68.72	35.74	43.03	-7.29
90.68	59.89	50.49	9.40
109.40	62.12	55.16	6.96
150.26	59.15	60.80	-1.65
229.82	66.24	63.54	2.70

Figure B-8
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Irradiated in Capsule A

Plate Heat P2130-2 in SSP Capsule A

Page 2
Plant: COOPER Material: SA302BM Heat: P2130-2
Orientation: TL Capsule: SSP A Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
301.10	66.40	63.85	2.55

Correlation Coefficient = .941

Figure B-8 (continued)
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Irradiated in Capsule A

Plate Heat P2130-2 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:25 PM
Page 1
Coefficients of Curve 1

A = 35.1 B = 32.6 C = 77.33 T0 = 62.76 D = 0.00E+00

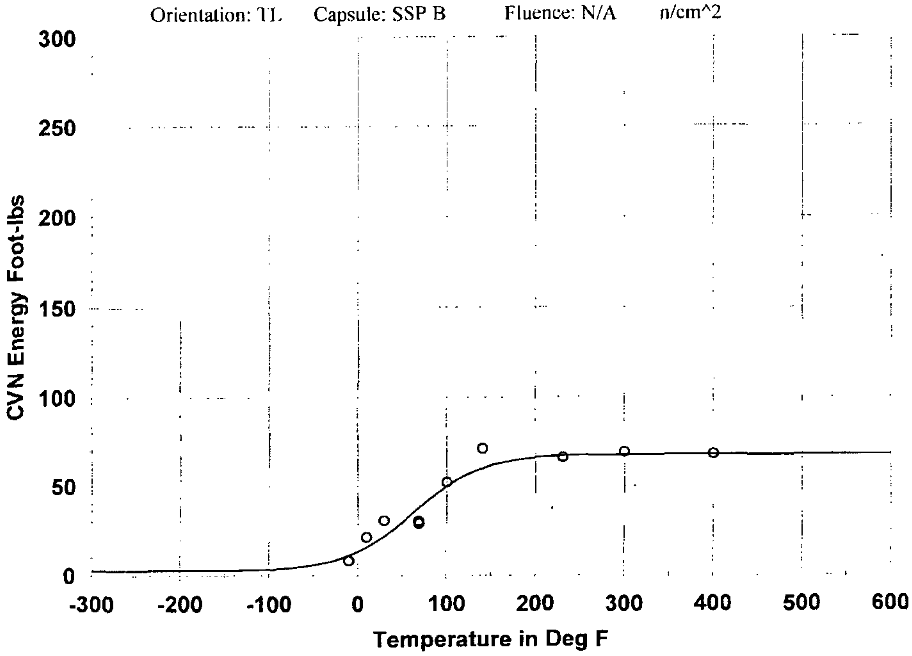
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=67.7(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=50.6 Deg F Temp@50 ft-lbs=101.0 Deg F

Plant: COOPER Material: SA302BM Heat: P2130-2

Orientation: TL Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-9.40	8.20	11.24	-3.04
9.68	21.30	15.68	5.62
29.84	30.75	22.00	8.75
68.36	30.08	37.46	-7.38
68.72	28.87	37.61	-8.74
100.04	51.98	49.70	2.28
140.00	71.04	59.91	11.13
230.54	65.92	66.86	-.94
299.66	69.26	67.56	1.70

Figure B-9
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Irradiated in Capsule B

Plate Heat P2130-2 in SSP Capsule B

Page 2
Plant: COOPER Material: SA302BM Heat: P2130-2
Orientation: TL Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

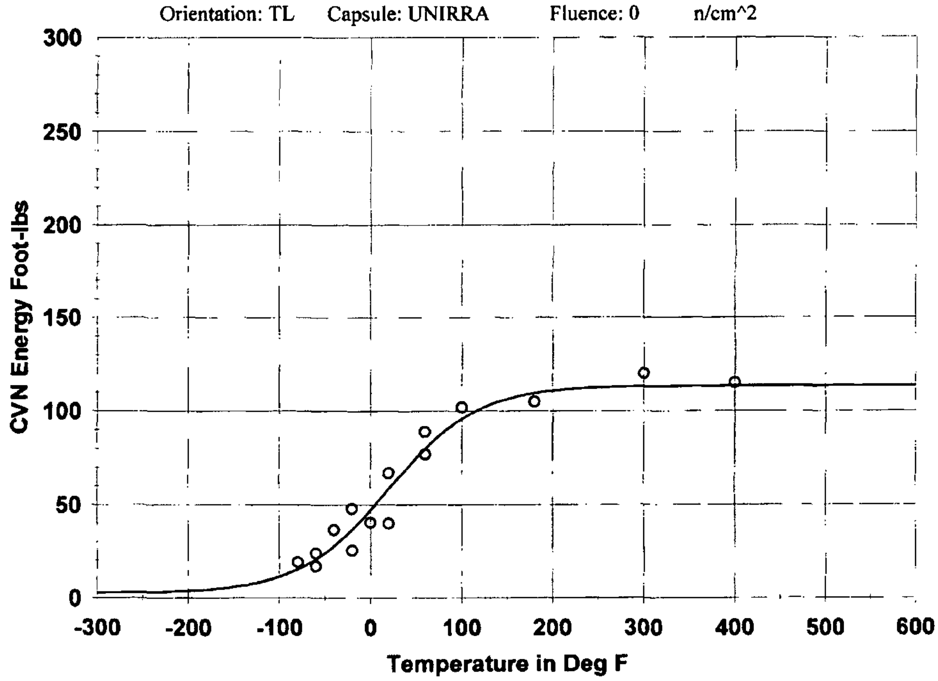
Temperature	Input CVN	Computed CVN	Differential
399.74	67.86	67.69	.17

Correlation Coefficient = .961

Figure B-9 (continued)
Charpy Energy Data for P2130-2 Nine Mile Point 1 Plate Irradiated in Capsule B

UNIRRADIATED PLATE HEAT C3278-2 (TL)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/23/2003 03:07 PM
Page 1
Coefficients of Curve 1
A = 57.9 B = 55.4 C = 96.87 T0 = 19.24 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=113.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-34.4 Deg F Temp@50 ft-lbs=5.4 Deg F
Plant: FitzPatrick Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	19.00	15.15	3.85
-60.00	24.00	20.56	3.44
-60.00	17.00	20.56	-3.56
-40.00	36.50	27.70	8.80
-20.00	25.50	36.61	-11.11
-20.00	48.00	36.61	11.39
.00	40.50	47.04	-6.54
20.00	67.00	58.33	8.67
20.00	40.00	58.33	-18.33

Figure B-10
Charpy Energy Data for C3278-2 Fitzpatrick Plate Unirradiated

UNIRRADIATED PLATE HEAT C3278-2 (TL)

Page 2
Plant: FitzPatrick Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2

Charpy V-Notch Data

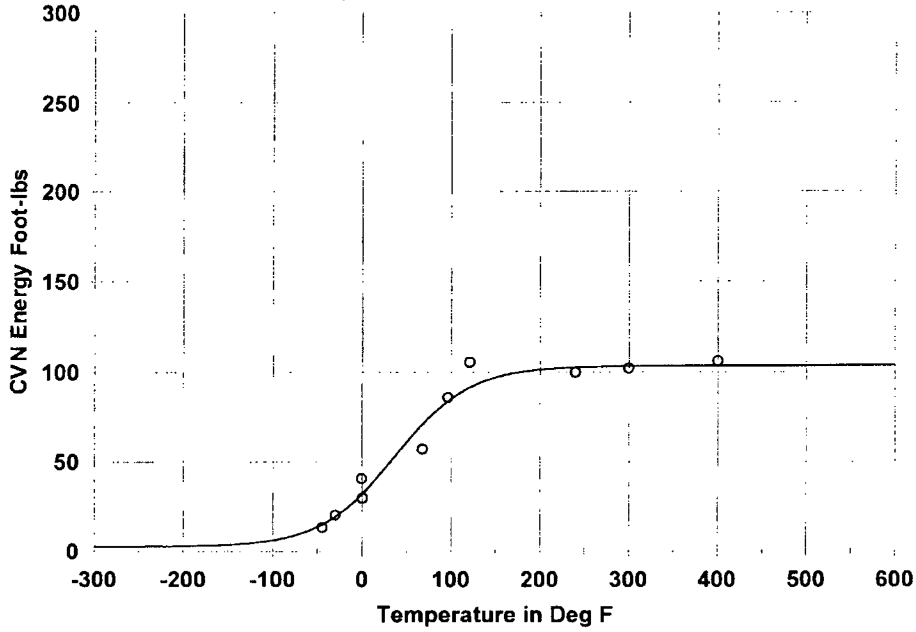
Temperature	Input CVN	Computed CVN	Differential
60.00	77.00	79.92	-2.92
60.00	89.00	79.92	9.08
100.00	102.00	95.71	6.29
180.00	105.00	109.43	-4.43
300.00	120.00	112.96	7.04
400.00	115.00	113.26	1.74

Correlation Coefficient = .973

Figure B-10 (continued)
Charpy Energy Data for C3278-2 Fitzpatrick Plate Unirradiated

Plate Heat C3278-2 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:34 PM
Page 1
Coefficients of Curve 1
A = 52.9 B = 50.4 C = 83.46 T0 = 36.38 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=103.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-4.5 Deg F Temp@50 ft-lbs=31.6 Deg F
Plant: COOPER Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-44.50	13.49	15.19	-1.70
-29.92	20.41	19.59	.82
-.40	40.93	32.02	8.91
.50	30.03	32.48	-2.45
67.64	57.16	70.94	-13.78
96.08	86.07	83.84	2.23
120.92	105.32	91.55	13.77
239.90	99.80	102.54	-2.74
299.66	102.05	103.12	-1.07

Figure B-11
Charpy Energy Data for C3278-2 Fitzpatrick Plate Irradiated in Capsule A

Plate Heat C3278-2 in SSP Capsule A

Page 2
Plant: COOPER Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: SSP A Fluence: N/A n/cm^2

Charpy V-Notch Data

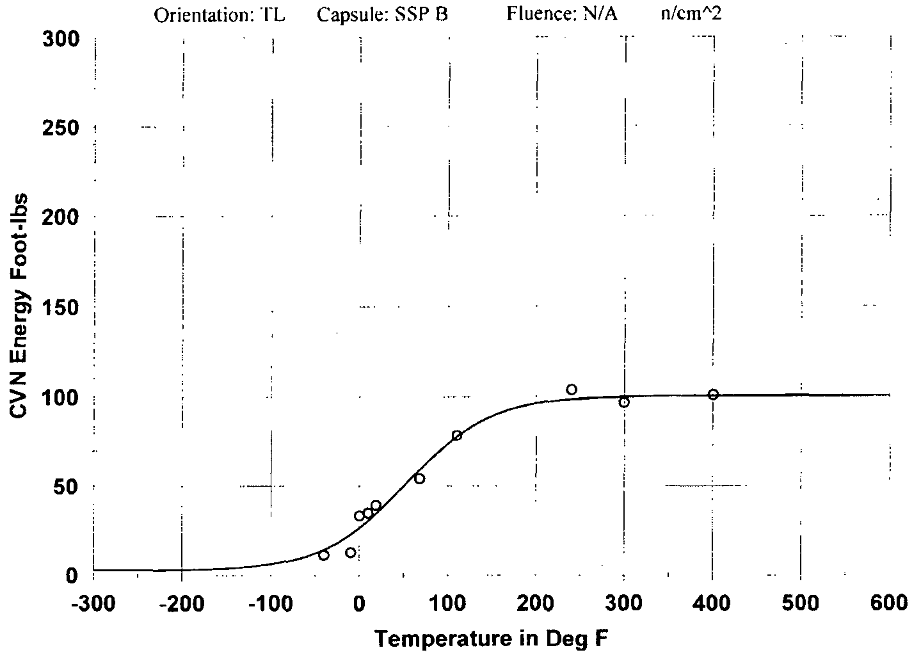
Temperature	Input CVN	Computed CVN	Differential
400.28	105.88	103.28	2.60

Correlation Coefficient = .981

Figure B-11 (continued)
Charpy Energy Data for C3278-2 Fitzpatrick Plate Irradiated in Capsule A

Plate Heat C3278-2 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:36 PM
Page 1
Coefficients of Curve 1
A = 51.45 B = 48.95 C = 94.5 T0 = 52.85 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=100.4(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=8.5 Deg F Temp@50 ft-lbs=50.1 Deg F
Plant: COOPER Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-40.18	11.49	14.49	-3.00
-9.40	12.82	23.18	-10.36
.32	33.48	26.73	6.75
10.04	34.91	30.68	4.23
19.04	39.23	34.65	4.58
68.54	54.27	59.50	-5.23
110.12	78.57	77.95	.62
240.26	103.74	98.58	5.16
299.66	96.66	99.88	-3.22

Figure B-12
Charpy Energy Data for C3278-2 Fitzpatrick Plate Irradiated in Capsule B

Plate Heat C3278-2 in SSP Capsule B

Page 2
Plant: COOPER Material: SA533B1 Heat: C3278-2
Orientation: TL Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

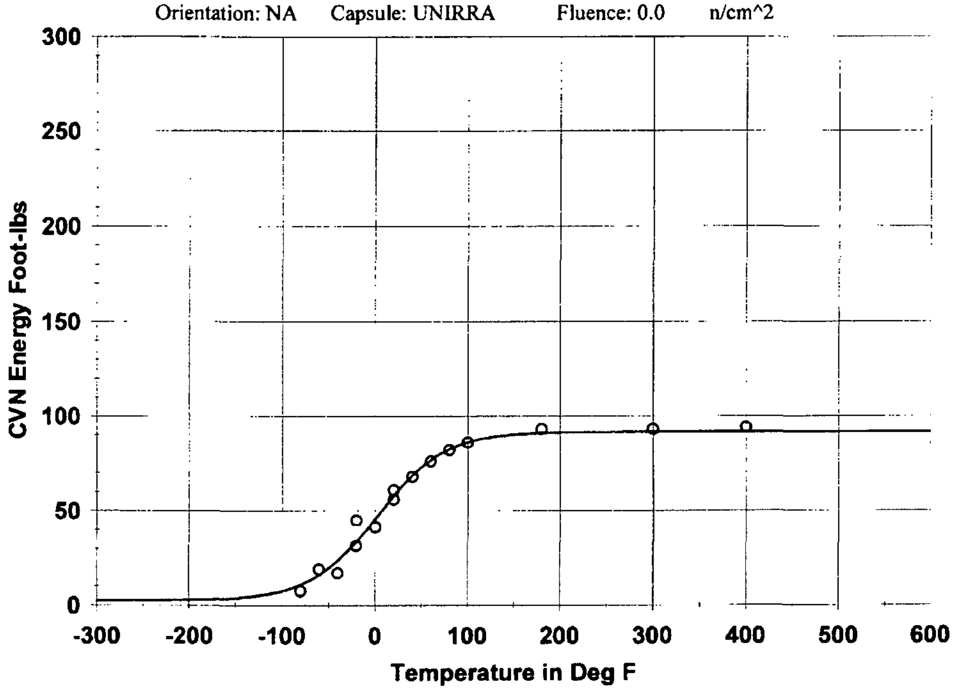
Temperature	Input CVN	Computed CVN	Differential
400.46	100.92	100.34	.58

Correlation Coefficient = .989

Figure B-12 (continued)
Charpy Energy Data for C3278-2 Fitzpatrick Plate Irradiated in Capsule B

WELD HEAT 5P6214B (SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/08/2003 12:59 PM
Page 1
Coefficients of Curve 1
A = 47. B = 44.5 C = 71.84 T0 = 2.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=91.5(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-26.8 Deg F Temp@50 ft-lbs=7.0 Deg F
Plant: SSP Material: SAW Heat: 5P6214B
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	7.50	10.72	-3.22
-60.00	19.00	15.93	3.07
-40.00	17.00	23.56	-6.56
-20.00	31.50	33.75	-2.25
-20.00	45.00	33.75	11.25
.00	41.50	45.72	-4.22
20.00	61.00	57.89	3.11
20.00	56.00	57.89	-1.89
40.00	68.00	68.53	-.53

Figure B-13
Charpy Energy Data for 5P6214B Grand Gulf Weld Unirradiated

WELD HEAT 5P6214B (SSP)

Page 2
Plant: SSP Material: SAW Heat: 5P6214B
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

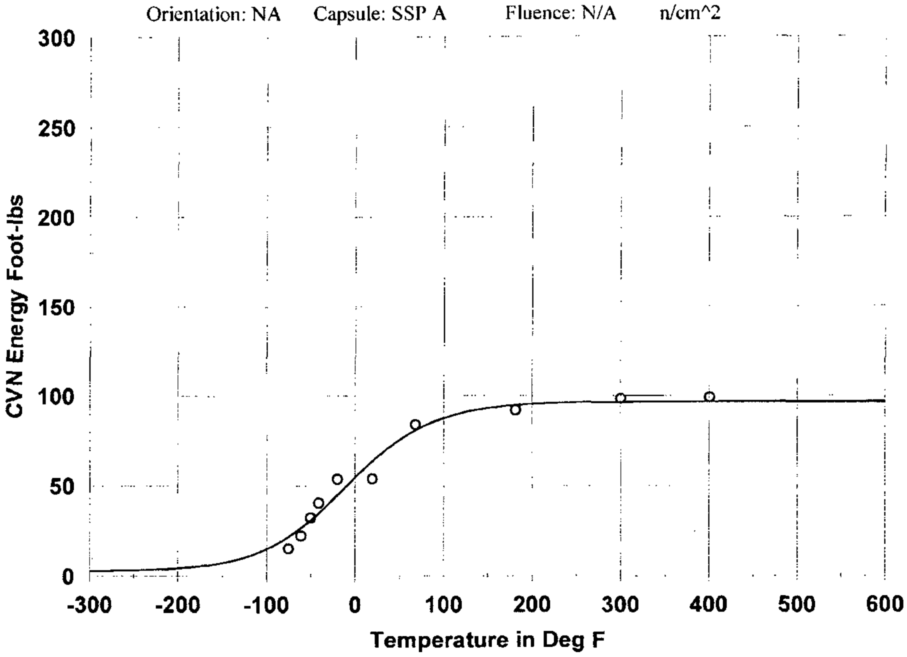
Temperature	Input CVN	Computed CVN	Differential
60.00	76.00	76.71	-.71
80.00	82.00	82.38	-.38
100.00	86.00	86.03	-.03
180.00	93.00	90.88	2.12
300.00	93.00	91.48	1.52
400.00	94.00	91.50	2.50

Correlation Coefficient = .991

Figure B-13 (continued)
Charpy Energy Data for 5P6214B Grand Gulf Weld Unirradiated

Weld Heat 5P6214B in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:38 PM
Page 1
Coefficients of Curve 1
A = 49.5 B = 47. C = 97.12 T0 = -10.4 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=96.5(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-53.2 Deg F Temp@50 ft-lbs=-9.3 Deg F
Plant: COOPER Material: SAW Heat: 5P6214B
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-75.46	15.56	22.01	-6.45
-61.24	22.56	26.92	-4.36
-50.44	32.51	31.15	1.36
-41.26	40.63	35.05	5.58
-20.20	53.59	44.78	8.81
19.40	53.70	63.49	-9.79
68.00	84.12	80.90	3.22
180.86	92.02	94.70	-2.68
300.02	98.39	96.34	2.05

Figure B-14
Charpy Energy Data for 5P6214B Grand Gulf Weld Irradiated in Capsule A

Weld Heat 5P6214B in SSP Capsule A

Page 2
Plant: COOPER Material: SAW Heat: 5P6214B
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2

Charpy V-Notch Data

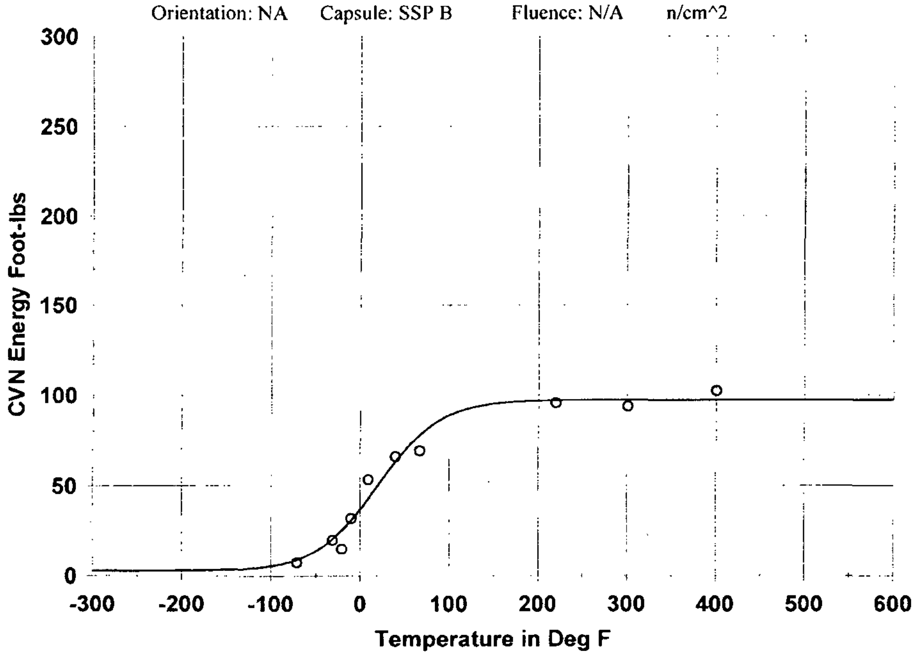
Temperature	Input CVN	Computed CVN	Differential
400.46	98.96	96.48	2.48

Correlation Coefficient = .984

Figure B-14 (continued)
Charpy Energy Data for 5P6214B Grand Gulf Weld Irradiated in Capsule A

Weld Heat 5P6214B in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:41 PM
Page 1
Coefficients of Curve 1
A = 49.95 B = 47.45 C = 68.8 T0 = 19.72 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=97.4(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-11.1 Deg F Temp@50 ft-lbs=19.8 Deg F
Plant: COOPER Material: SAW Heat: 5P6214B
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-70.78	7.20	8.88	-1.68
-30.64	19.72	20.33	-.61
-20.20	14.84	25.14	-10.30
-9.76	31.87	30.78	1.09
9.32	53.43	42.83	10.60
39.74	66.35	63.38	2.97
67.28	69.47	78.36	-8.89
219.56	95.76	97.12	-1.36
300.74	93.85	97.37	-3.52

Figure B-15
Charpy Energy Data for 5P6214B Grand Gulf Weld Irradiated in Capsule B

Weld Heat 5P6214B in SSP Capsule B

Page 2
Plant: COOPER Material: SAW Heat: 5P6214B
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.82	102.49	97.40	5.09

Correlation Coefficient = .985

Figure B-15 (continued)
Charpy Energy Data for 5P6214B Grand Gulf Weld Irradiated in Capsule B

Unirradiated Weld Heat 34B009

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 03/25/2006 11:25 AM
Page 1
Coefficients of Curve 1

A = 53.45 B = 50.95 C = 82.53 T0 = -23.95 D = 0.00E+00

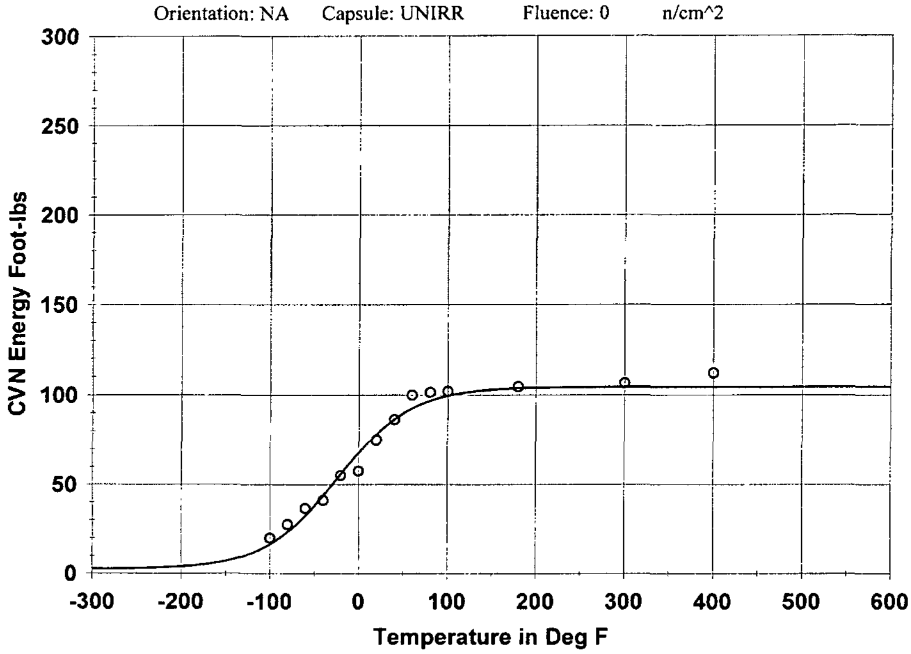
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=104.4(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=-65.0 Deg F Temp@50 ft-lbs=-29.5 Deg F

Plant: OYSTER CREEK Material: SAW Heat: 34B009

Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	20.00	16.43	3.57
-80.00	27.50	23.34	4.16
-60.00	36.50	32.51	3.99
-40.00	41.00	43.67	-2.67
-20.00	55.00	55.89	-.89
.00	57.50	67.84	-10.34
20.00	75.00	78.28	-3.28
40.00	86.50	86.56	-.06
60.00	100.00	92.62	7.38

Figure B-16
Charpy Energy Data for 34B009 Millstone 1 Weld Unirradiated

Unirradiated Weld Heat 34B009

Page 2
Plant: OYSTER CREEK Material: SAW Heat: 34B009
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
60.00	100.00	92.62	7.38
80.00	101.50	96.81	4.69
100.00	102.00	99.59	2.41
180.00	104.50	103.68	.82
300.00	106.50	104.36	2.14
400.00	112.00	104.40	7.60

Correlation Coefficient = .989

Figure B-16 (continued)
Charpy Energy Data for 34B009 Millstone 1 Weld Unirradiated

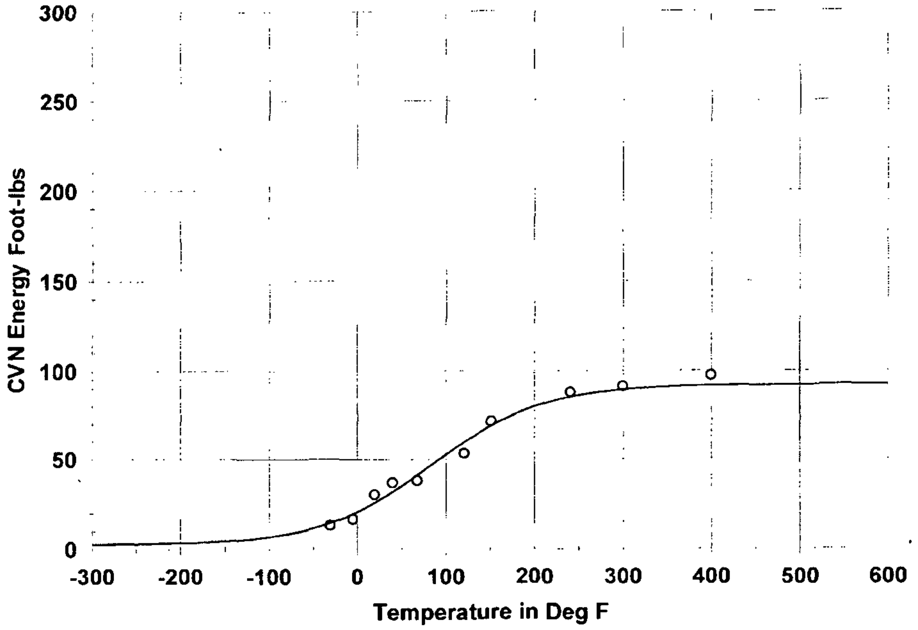
Weld Heat 34B009 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:48 PM
Page 1
Coefficients of Curve 1

A = 47.32 B = 44.82 C = 125.7 T0 = 85.14 D = 0.00E+00

Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=92.1(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=34.0 Deg F Temp@50 ft-lbs=92.7 Deg F
Plant: COOPER Material: SAW Heat: 34B009
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-31.00	13.35	14.70	-1.35
-5.08	16.92	19.73	-2.81
19.58	30.37	25.85	4.52
39.74	36.94	31.80	5.14
67.64	38.03	41.12	-3.09
120.56	53.33	59.63	-6.30
150.62	71.43	68.76	2.67
240.44	87.85	85.16	2.69
299.48	91.24	89.27	1.97

Figure B-17
Charpy Energy Data for 34B009 Millstone 1 Weld Irradiated in Capsule A

Weld Heat 34B009 in SSP Capsule A

Page 2
Plant: COOPER Material: SAW Heat: 34B009
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2

Charpy V-Notch Data

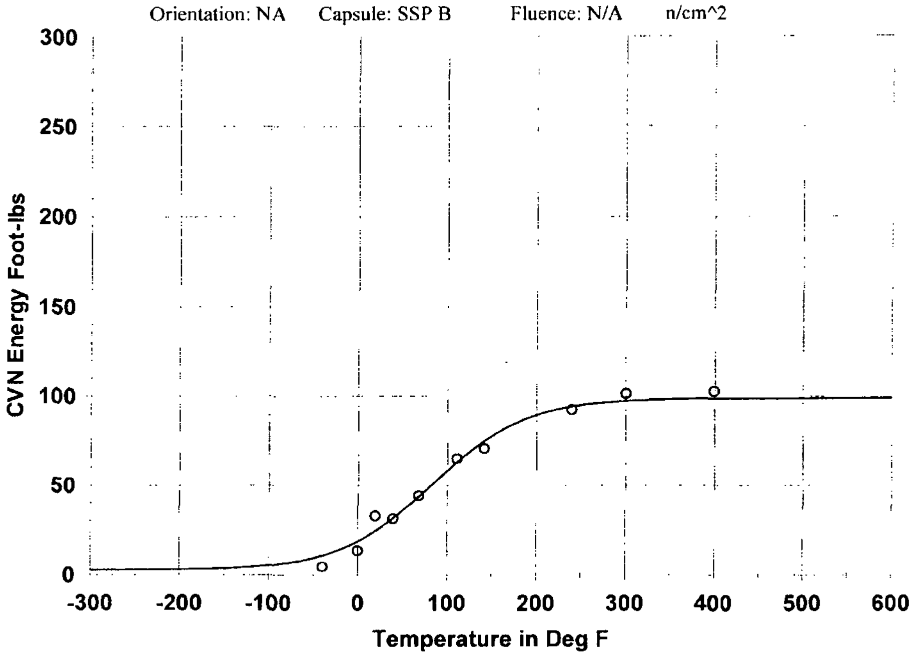
Temperature	Input CVN	Computed CVN	Differential
399.56	97.33	91.54	5.79

Correlation Coefficient = .992

Figure B-17 (continued)
Charpy Energy Data for 34B009 Millstone 1 Weld Irradiated in Capsule A

Weld Heat 34B009 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:50 PM
Page 1
Coefficients of Curve 1
A = 50.67 B = 48.17 C = 104.07 T0 = 83.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=98.8(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=35.6 Deg F Temp@50 ft-lbs=81.9 Deg F
Plant: COOPER Material: SAW Heat: 34B009
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-39.82	4.51	10.77	-6.26
-.22	13.44	18.62	-5.18
19.94	32.80	24.50	8.30
39.56	31.29	31.54	-.25
68.00	44.12	43.64	.48
110.66	65.07	63.05	2.02
141.26	70.83	75.03	-4.20
239.54	92.57	94.27	-1.70
300.20	101.37	97.36	4.01

Figure B-18
Charpy Energy Data for 34B009 Millstone 1 Weld Irradiated in Capsule B

Weld Heat 34B009 in SSP Capsule B

Page 2
Plant: COOPER Material: SAW Heat: 34B009
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

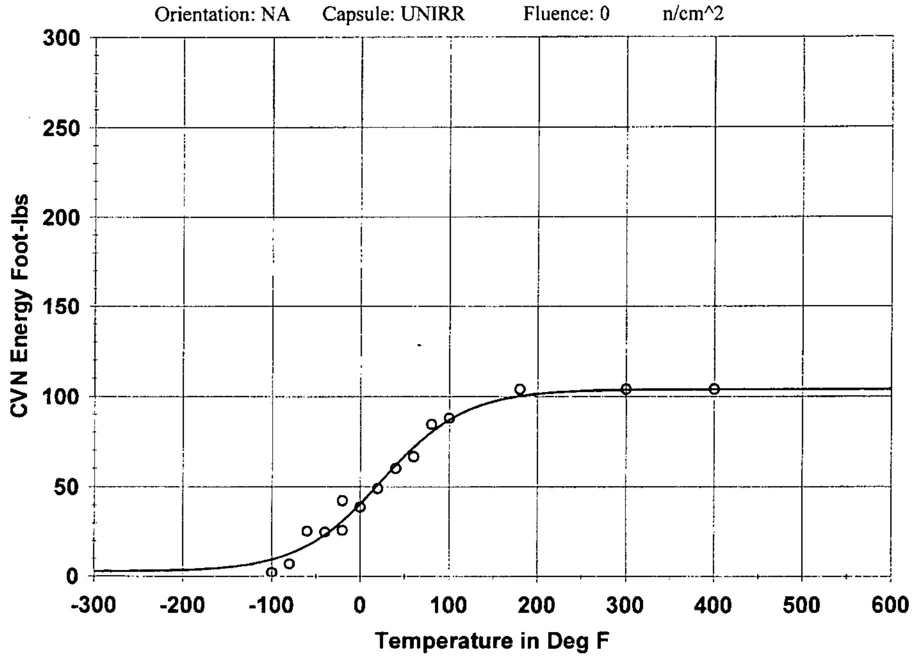
Temperature	Input CVN	Computed CVN	Differential
399.56	102.55	98.61	3.94

Correlation Coefficient = .992

Figure B-18 (continued)
Charpy Energy Data for 34B009 Millstone 1 Weld Irradiated in Capsule B

Unirradiated Quad Cities 2 ESW

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 03/25/2006 11:34 AM
Page 1
Coefficients of Curve 1
A = 53.25 B = 50.75 C = 95.05 T0 = 23.9 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=104.0(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-23.1 Deg F Temp@50 ft-lbs=17.9 Deg F
Plant: OYSTER CREEK Material: ESW Heat: QUAD CITIES
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	2.00	9.47	-7.47
-80.00	7.00	12.75	-5.75
-60.00	25.50	17.33	8.17
-40.00	25.00	23.49	1.51
-20.00	42.50	31.35	11.15
-20.00	26.00	31.35	-5.35
.00	39.00	40.75	-1.75
20.00	49.00	51.17	-2.17
40.00	60.00	61.77	-1.77

Figure B-19
Charpy Energy Data for AP2-21 Quad Cities 2 Weld Unirradiated

Unirradiated Quad Cities 2 ESW

Page 2
Plant: OYSTER CREEK Material: ESW Heat: QUAD CITIES
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
60.00	66.50	71.65	-5.15
80.00	84.50	80.15	4.35
100.00	88.00	86.97	1.03
180.00	104.00	100.34	3.66
300.00	104.00	103.70	.30
400.00	104.00	103.96	.04

Correlation Coefficient = .989

Figure B-19 (continued)
Charpy Energy Data for AP2-21 Quad Cities 2 Weld Unirradiated

Quad Cities 2 ESW in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:55 PM

Page 1

Coefficients of Curve 1

A = 51.58 B = 49.08 C = 126.82 T0 = 49.36 D = 0.00E+00

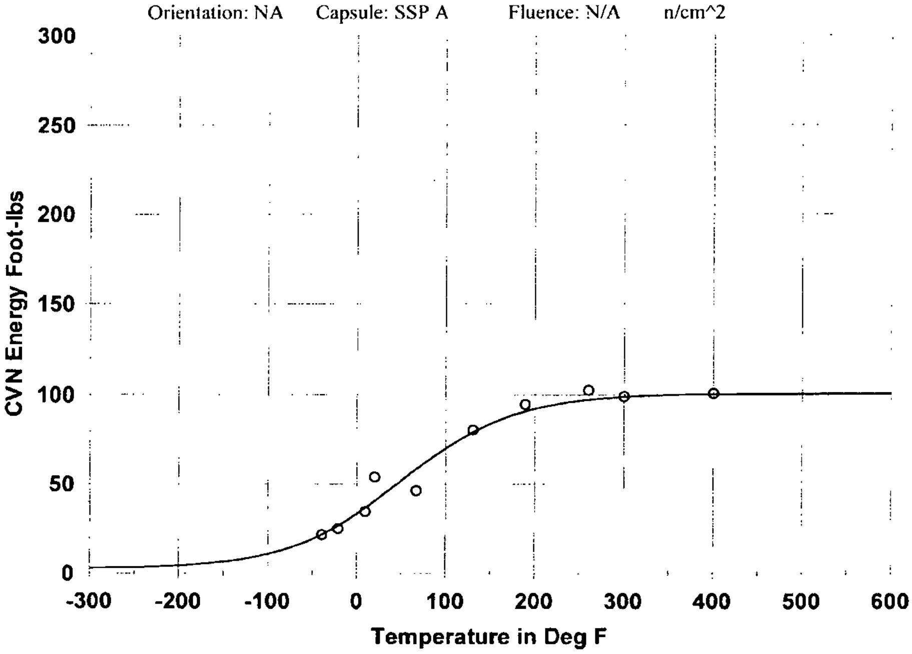
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=100.7(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=-10.4 Deg F Temp@50 ft-lbs=45.3 Deg F

Plant: COOPER Material: ESW Heat: QC2 ESW

Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-39.28	21.85	21.95	-.10
-20.74	25.24	26.91	-1.67
9.86	34.51	36.76	-2.25
20.48	53.79	40.59	13.20
67.28	46.15	58.46	-12.31
130.46	80.55	79.28	1.27
189.50	94.65	90.95	3.70
260.24	102.40	97.24	5.16
300.20	98.91	98.81	.10

Figure B-20
Charpy Energy Data for AP2-21 Quad Cities 2 Weld Irradiated in Capsule A

Quad Cities 2 ESW in SSP Capsule A

Page 2
Plant: COOPER   Material: ESW   Heat: QC2 ESW
Orientation: NA   Capsule: SSP A   Fluence: N/A   n/cm^2

Charpy V-Notch Data

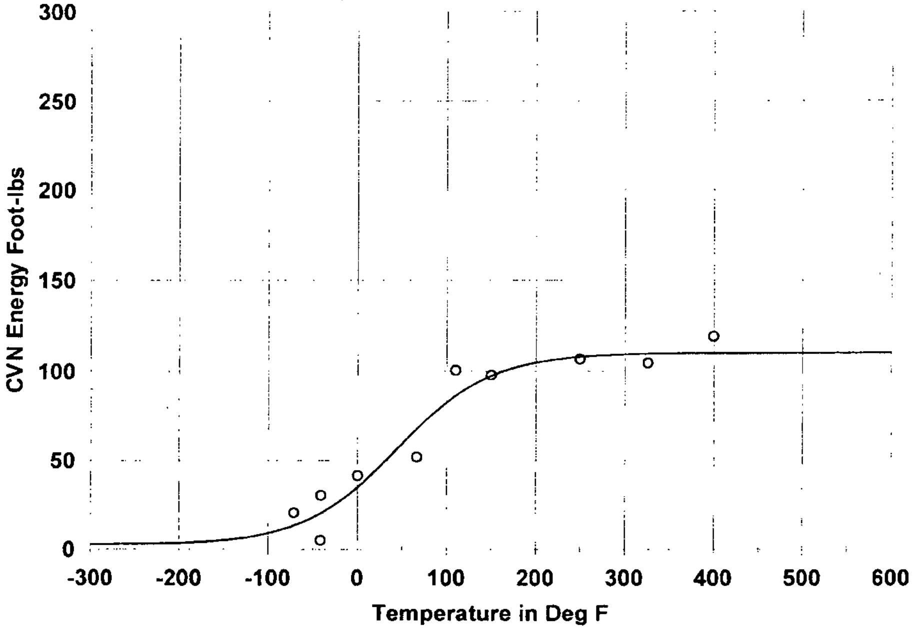
Temperature	Input CVN	Computed CVN	Differential
400.46	100.65	100.27	.38

Correlation Coefficient = .981

Figure B-20 (continued)
Charpy Energy Data for AP2-21 Quad Cities 2 Weld Irradiated in Capsule A

Quad Cities 2 ESW in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 12:58 PM
Page 1
Coefficients of Curve 1
A = 56.31 B = 53.81 C = 104.9 T0 = 44.16 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=110.1(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-11.9 Deg F Temp@50 ft-lbs=31.8 Deg F
Plant: COOPER Material: ESW Heat: QC2 ESW
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-70.96	20.50	13.29	7.21
-41.26	4.89	20.16	-15.27
-40.72	30.41	20.31	10.10
.32	41.44	35.05	6.39
66.56	51.88	67.64	-15.76
109.94	100.54	86.24	14.30
150.08	97.84	97.52	.32
249.44	106.68	108.02	-1.34
325.94	104.65	109.63	-4.98

Figure B-21
Charpy Energy Data for BP2-21 Quad Cities 2 Weld Irradiated in Capsule B

Quad Cities 2 ESW in SSP Capsule B

Page 2
Plant: COOPER Material: ESW Heat: QC2 ESW
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
399.56	119.06	110.01	9.05

Correlation Coefficient = .969

Figure B-21 (continued)
Charpy Energy Data for BP2-21 Quad Cities 2 Weld Irradiated in Capsule B

UNIRRADIATED WELD HEAT 406L44

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/23/2003 02:03 PM
Page 1
Coefficients of Curve 1

A = 37.9 B = 35.4 C = 102.68 T0 = 14.47 D = 0.00E+00

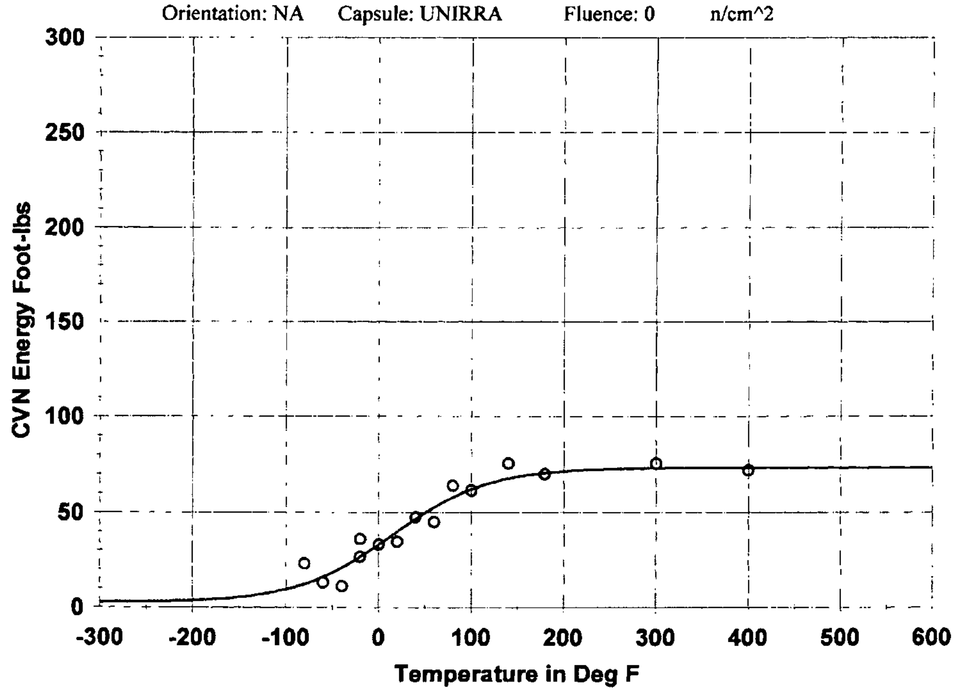
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=73.3(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=-8.8 Deg F Temp@50 ft-lbs=51.1 Deg F

Plant: Quad Cities 1 Material: SAW Heat: 406L44

Orientation: NA Capsule: UNIRRA Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	23.00	12.20	10.80
-60.00	13.00	15.95	-2.95
-40.00	11.00	20.71	-9.71
-20.00	26.50	26.44	.06
-20.00	36.00	26.44	9.56
.00	33.00	32.95	.05
20.00	34.50	39.81	-5.31
40.00	47.50	46.53	.97
60.00	45.00	52.64	-7.64

Figure B-22
Charpy Energy Data for 406L44 Quad Cities 1 Weld Unirradiated

UNIRRADIATED WELD HEAT 406L44

Page 2
Plant: Quad Cities 1 Material: SAW Heat: 406L44
Orientation: NA Capsule: UNIRRA Fluence: 0 n/cm^2

Charpy V-Notch Data

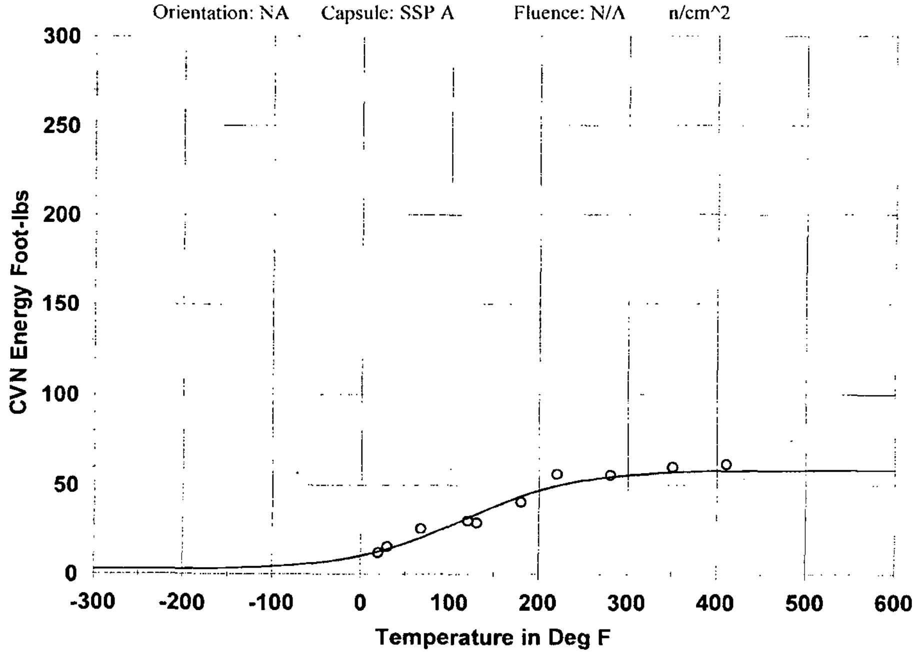
Temperature	Input CVN	Computed CVN	Differential
80.00	64.00	57.85	6.15
100.00	61.50	62.05	-.55
140.00	75.50	67.65	7.85
180.00	70.00	70.59	-.59
300.00	75.50	73.03	2.47
400.00	72.00	73.26	-1.26

Correlation Coefficient = .965

Figure B-22 (continued)
Charpy Energy Data for 406L44 Quad Cities 1 Weld Unirradiated

Weld Heat 406L44 in SSP Capsule A

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:02 PM
Page 1
Coefficients of Curve 1
A = 30.4 B = 27.9 C = 125.05 T0 = 114.81 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=58.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=113.1 Deg F Temp@50 ft-lbs=223.9 Deg F
Plant: COOPER Material: SAW Heat: 406L44
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
19.58	11.89	12.49	-.60
29.48	15.24	13.85	1.39
67.46	25.38	20.31	5.07
120.38	30.03	31.64	-1.61
130.28	28.87	33.84	-4.97
179.80	40.53	43.72	-3.19
220.28	56.00	49.59	6.41
280.58	55.64	54.62	1.02
350.42	59.85	57.04	2.81

Figure B-23
Charpy Energy Data for 406L44 Quad Cities 1 Weld Irradiated in Capsule A

Weld Heat 406L44 in SSP Capsule A

Page 2
Plant: COOPER Material: SAW Heat: 406L44
Orientation: NA Capsule: SSP A Fluence: N/A n/cm^2

Charpy V-Notch Data

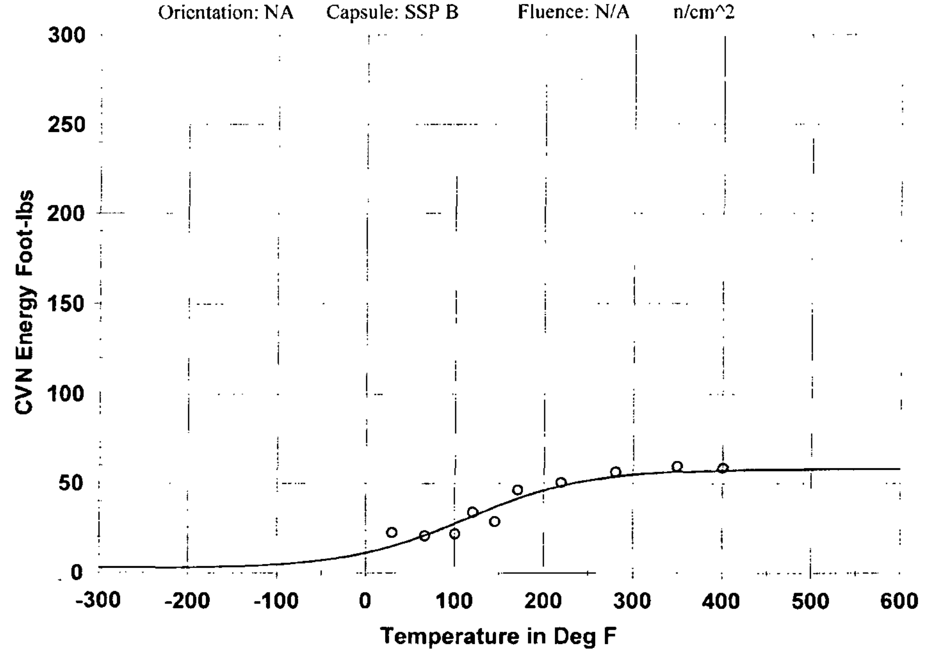
Temperature	Input CVN	Computed CVN	Differential
410.90	61.71	57.81	3.90

Correlation Coefficient = .982

Figure B-23 (continued)
Charpy Energy Data for 406L44 Quad Cities 1 Weld Irradiated in Capsule A

Weld Heat 406L44 in SSP Capsule B

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:05 PM
Page 1
Coefficients of Curve 1
A = 30.33 B = 27.83 C = 135.74 T0 = 113.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=58.2(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=111.8 Deg F Temp@50 ft-lbs=233.0 Deg F
Plant: COOPER Material: SAW Heat: 406L44
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
29.84	22.55	15.09	7.46
66.74	20.79	21.14	-.35
100.58	21.99	27.72	-5.73
120.56	33.88	31.81	2.07
145.22	28.77	36.75	-7.98
170.96	46.21	41.48	4.73
219.38	50.48	48.51	1.97
280.58	56.37	53.79	2.58
349.16	59.43	56.48	2.95

Figure B-24
Charpy Energy Data for 406L44 Quad Cities 1 Weld Irradiated in Capsule B

Weld Heat 406L44 in SSP Capsule B

Page 2
Plant: COOPER Material: SAW Heat: 406L44
Orientation: NA Capsule: SSP B Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.46	58.64	57.35	1.29

Correlation Coefficient = .958

Figure B-24 (continued)
Charpy Energy Data for 406L44 Quad Cities 1 Weld Irradiated in Capsule B

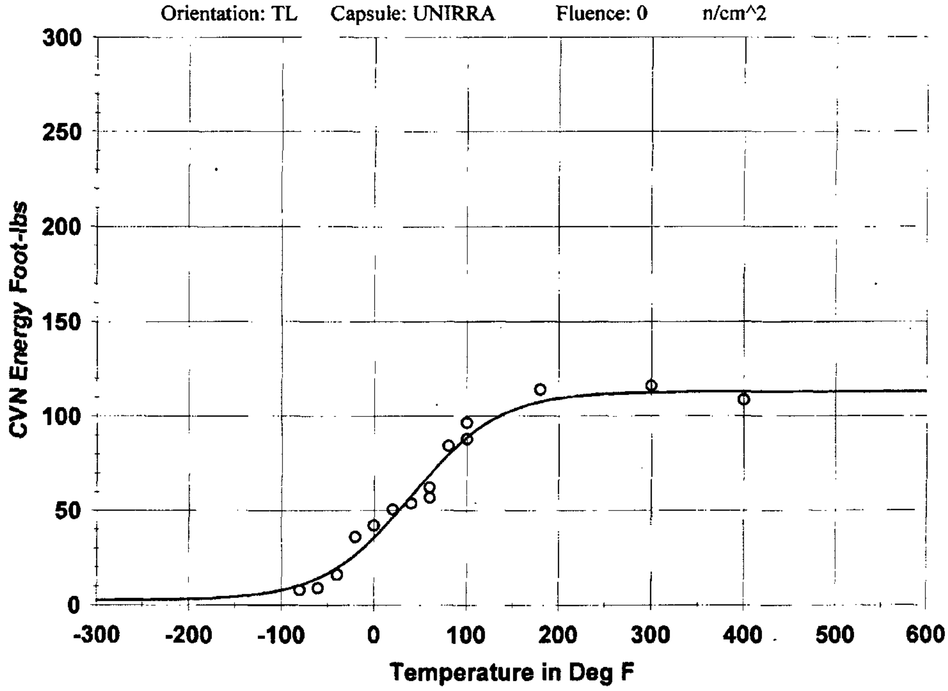
UNIRRADIATED PLATE HEAT C3985-2

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/23/2003 03:10 PM
Page 1
Coefficients of Curve 1

A = 57.65 B = 55.15 C = 94. T0 = 40.03 D = 0.00E+00

Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=112.8(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-11.7 Deg F Temp@50 ft-lbs=27.0 Deg F
Plant: Hatch 1 Material: SA533B1 Heat: C3985-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	8.00	10.46	-2.46
-60.00	9.00	14.23	-5.23
-40.00	16.00	19.50	-3.50
-20.00	36.00	26.55	9.45
.00	42.00	35.49	6.51
20.00	50.50	46.07	4.43
40.00	54.00	57.63	-3.63
60.00	62.50	69.19	-6.69
60.00	57.00	69.19	-12.19

Figure B-25
Charpy Energy Data for C3985-2 Hatch 1 Plate Unirradiated

UNIRRADIATED PLATE HEAT C3985-2

Page 2
Plant: Hatch 1 Material: SA533B1 Heat: C3985-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
80.00	84.50	79.78	4.72
100.00	96.50	88.73	7.77
100.00	88.00	88.73	-.73
180.00	114.00	107.46	6.54
300.00	116.00	112.36	3.64
400.00	108.50	112.75	-4.25

Correlation Coefficient = .986

Figure B-25 (continued)
Charpy Energy Data for C3985-2 Hatch 1 Plate Unirradiated

Plate Heat C3985-2 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:08 PM
Page 1
Coefficients of Curve 1

A = 59.17 B = 56.67 C = 92.84 T0 = 61.55 D = 0.00E+00

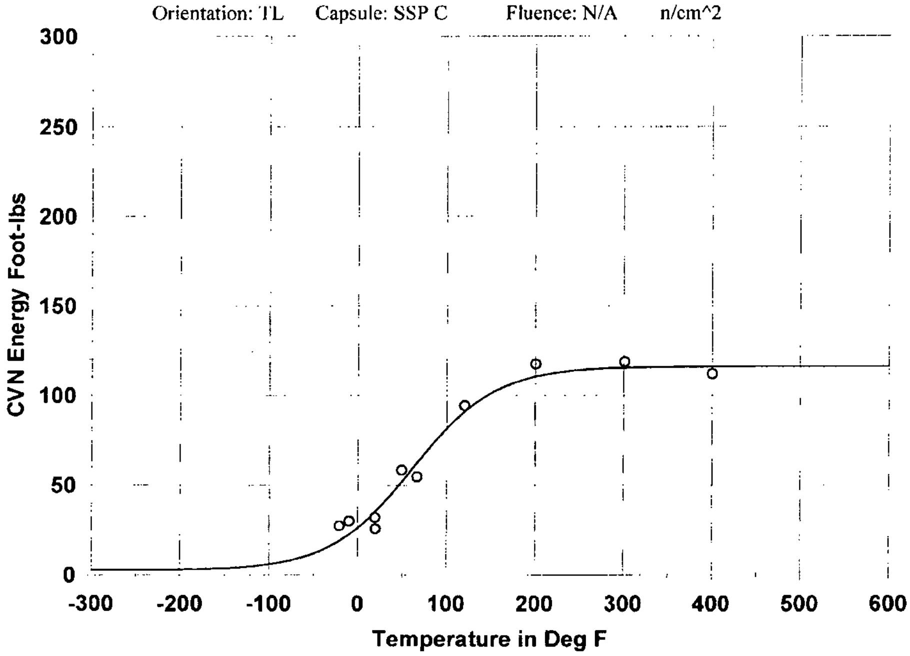
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=115.8(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=8.8 Deg F Temp@50 ft-lbs=46.4 Deg F

Plant: COOPER Material: SA533B1 Heat: C3985-2

Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.56	27.38	19.01	8.37
-9.40	30.03	22.70	7.33
19.76	32.12	35.25	-3.13
20.12	25.67	35.43	-9.76
49.46	58.21	51.83	6.38
66.74	54.58	62.33	-7.75
120.20	94.25	90.86	3.39
200.66	117.19	110.44	6.75
301.10	118.55	115.18	3.37

Figure B-26
Charpy Energy Data for C3985-2 Hatch 1 Plate Irradiated in Capsule C

Plate Heat C3985-2 in SSP Capsule C

Page 2
Plant: COOPER Material: SA533B1 Heat: C3985-2
Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

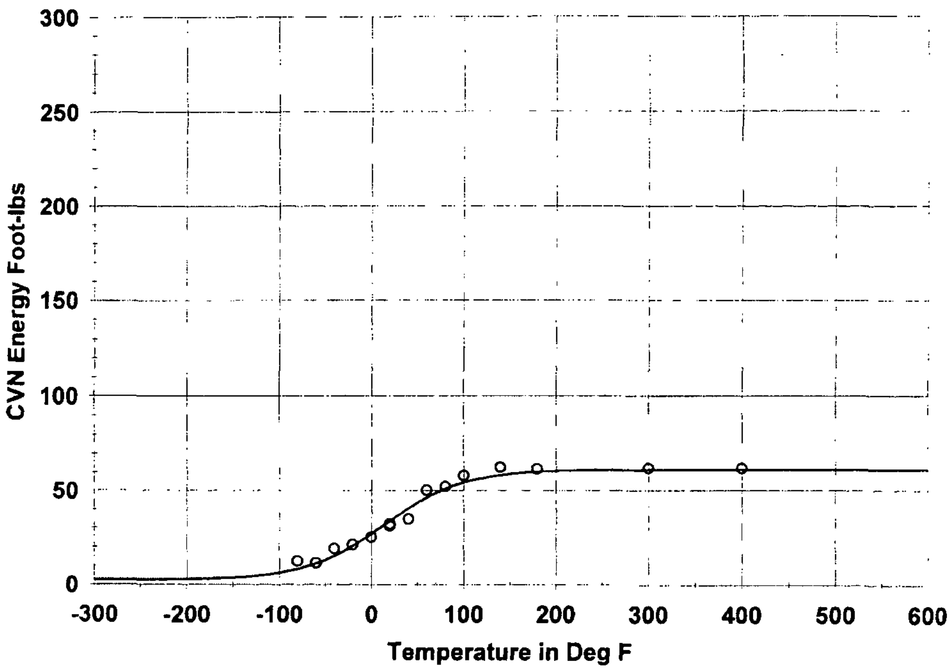
Temperature	Input CVN	Computed CVN	Differential
400.28	111.75	115.75	-4.00

Correlation Coefficient = .986

Figure B-26 (continued)
Charpy Energy Data for C3985-2 Hatch 1 Plate Irradiated in Capsule C

PLATE HEAT C1079-1 (SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 09/09/2002 08:32 AM
Page 1
Coefficients of Curve 1
A = 31.85 B = 29.35 C = 85.19 T0 = 14.98 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=61.2(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=9.7 Deg F Temp@50 ft-lbs=76.6 Deg F
Plant: SSP Material: SA302BM Heat: C1079-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	12.50	8.20	4.30
-60.00	11.50	11.11	.39
-40.00	19.00	15.16	3.84
-20.00	21.00	20.43	.57
.00	25.00	26.74	-1.74
20.00	31.00	33.58	-2.58
20.00	32.00	33.58	-1.58
40.00	34.50	40.23	-5.73
60.00	50.00	46.06	3.94
80.00	52.00	50.72	1.28
100.00	58.00	54.18	3.82

Figure B-27
Charpy Energy Data for C1079-1 Millstone 1 Plate Unirradiated

PLATE HEAT C1079-1 (SSP)

Page 2
Plant: SSP Material: SA302BM Heat: C1079-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
140.00	62.50	58.24	4.26
180.00	61.50	60.01	1.49
300.00	62.00	61.13	.87
400.00	62.00	61.19	.81

Correlation Coefficient = .989

Figure B-27 (continued)
Charpy Energy Data for C1079-1 Millstone 1 Plate Unirradiated

Plate Heat C1079-1 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:10 PM
Page 1
Coefficients of Curve 1

A = 30.19 B = 27.69 C = 99.53 T0 = 75.78 D = 0.00E+00

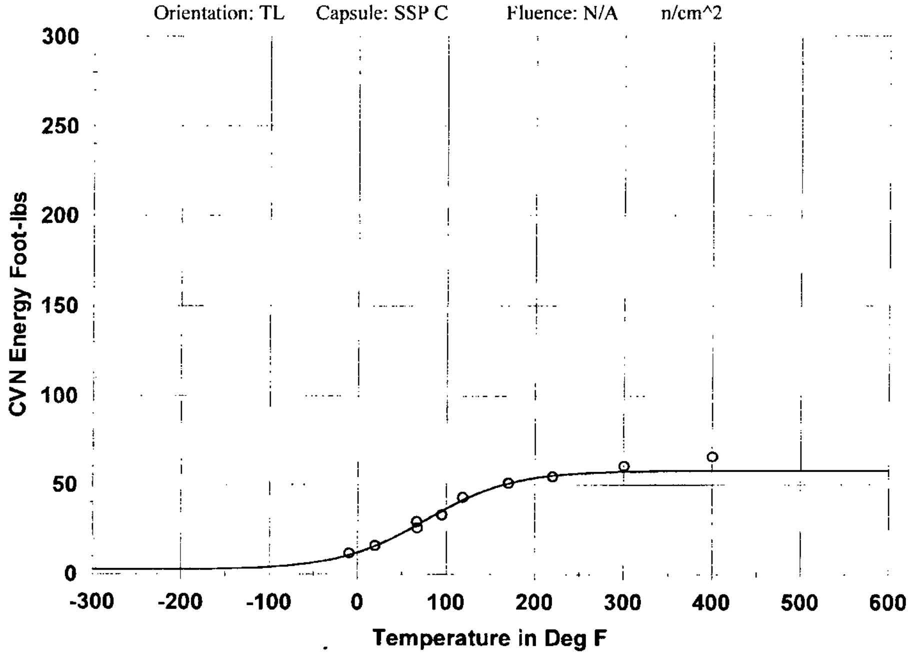
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=57.9(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=75.1 Deg F Temp@50 ft-lbs=165.2 Deg F

Plant: COOPER Material: SA302BM Heat: C1079-1

Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-9.40	11.97	10.97	1.00
19.94	16.28	16.11	.17
66.74	29.45	27.69	1.76
67.46	26.14	27.89	-1.75
94.82	33.29	35.43	-2.14
118.58	42.90	41.42	1.48
170.06	50.84	50.65	.19
219.74	54.48	54.98	-.50
300.38	60.38	57.29	3.09

Figure B-28
Charpy Energy Data for C1079-1 Millstone 1 Plate Irradiated in Capsule C

Plate Heat C1079-1 in SSP Capsule C

Page 2
Plant: COOPER Material: SA302BM Heat: C1079-1
Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

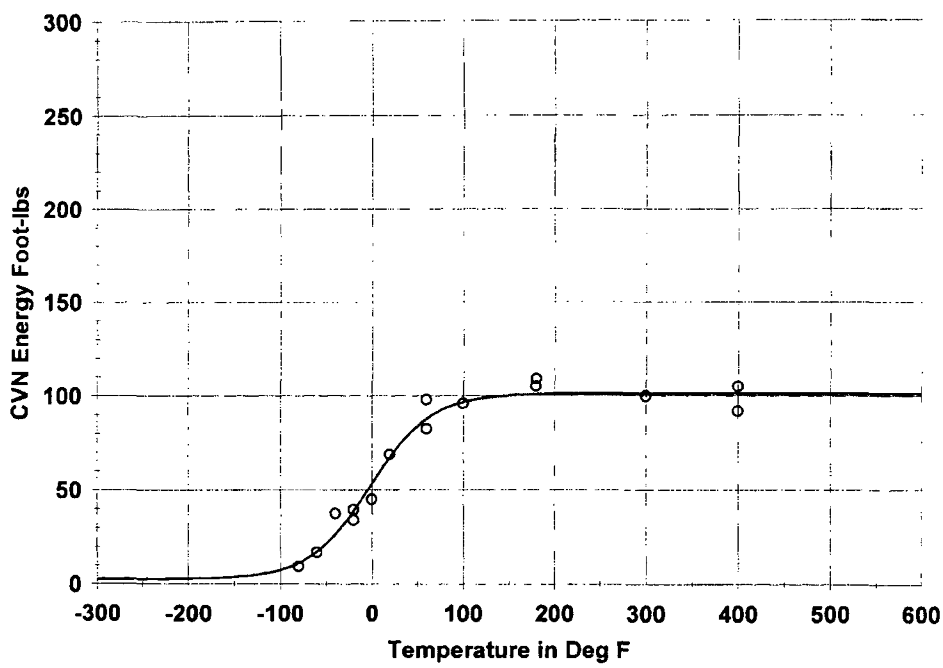
Temperature	Input CVN	Computed CVN	Differential
400.28	65.87	57.81	8.06

Correlation Coefficient = .990

Figure B-28 (continued)
Charpy Energy Data for C1079-1 Millstone 1 Plate Irradiated in Capsule C

PLATE HEAT A0610-1 (SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 09/09/2002 08:32 AM
Page 1
Coefficients of Curve 1
A = 51.85 B = 49.35 C = 67.03 T0 = -1.66 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=101.2(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-33.5 Deg F Temp@50 ft-lbs=-4.1 Deg F
Plant: SSP Material: SA302BM Heat: A0610-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	9.50	11.19	-1.69
-60.00	17.00	17.23	-.23
-40.00	37.50	26.34	11.16
-20.00	34.00	38.67	-4.67
-20.00	39.50	38.67	.83
.00	45.00	53.07	-8.07
20.00	69.00	67.26	1.74
60.00	98.00	87.67	10.33
60.00	82.50	87.67	-5.17
100.00	96.00	96.66	-.66
180.00	109.00	100.76	8.24

Figure B-29
Charpy Energy Data for A0610-1 Quad Cities 1 Plate Unirradiated

PLATE HEAT A0610-1 (SSP)

Page 2
Plant: SSP Material: SA302BM Heat: A0610-1
Orientation: TL Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
180.00	105.00	100.76	4.24
300.00	100.00	101.19	-1.19
400.00	92.00	101.20	-9.20
400.00	105.00	101.20	3.80

Correlation Coefficient = .985

Figure B-29 (continued)
Charpy Energy Data for A0610-1 Quad Cities 1 Plate Unirradiated

Plate Heat A0610-1 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:12 PM

Page 1

Coefficients of Curve 1

A = 50.63 B = 48.13 C = 101.16 T0 = 58.83 D = 0.00E+00

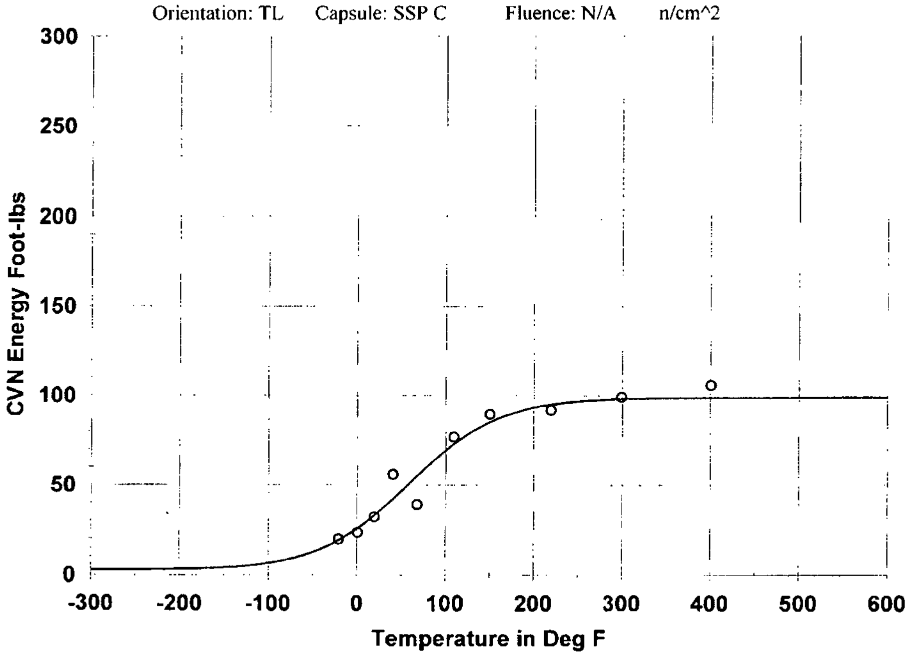
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=98.8(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=12.5 Deg F Temp@50 ft-lbs=57.6 Deg F

Plant: COOPER Material: SA302BM Heat: A0610-1

Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.74	19.68	19.03	.65
.86	23.31	25.72	-2.41
19.94	32.11	32.99	-.88
40.46	55.78	41.98	13.80
68.00	38.88	54.98	-16.10
109.40	76.81	72.87	3.94
150.26	89.50	85.20	4.30
219.38	91.79	94.90	-3.11
299.30	98.90	97.94	.96

Figure B-30
Charpy Energy Data for A0610-1 Quad Cities 1 Plate Irradiated in Capsule C

Plate Heat A0610-1 in SSP Capsule C

Page 2
Plant: COOPER Material: SA302BM Heat: A0610-1
Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

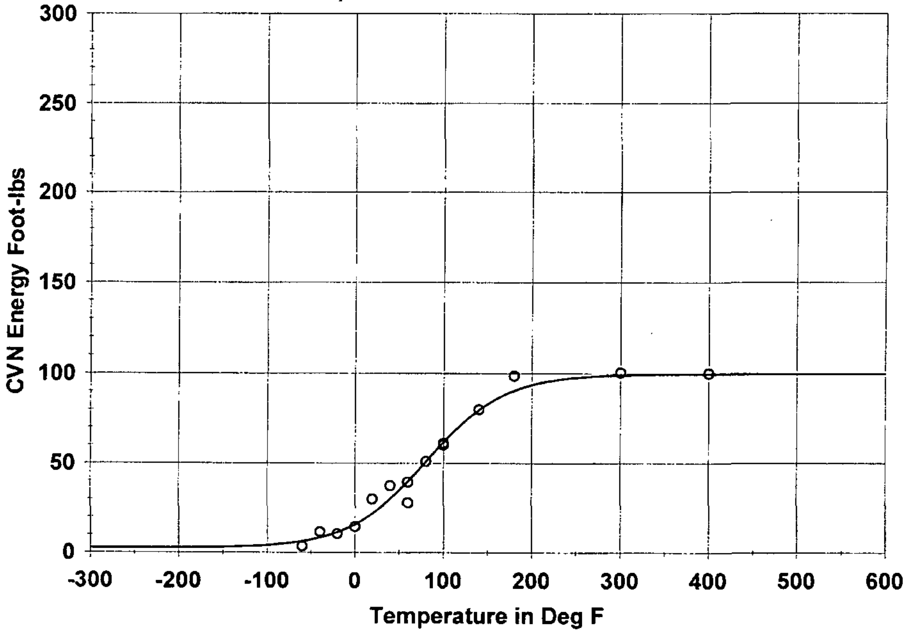
Temperature	Input CVN	Computed CVN	Differential
400.46	105.59	98.65	6.94

Correlation Coefficient = .972

Figure B-30 (continued)
Charpy Energy Data for A0610-1 Quad Cities 1 Plate Irradiated in Capsule C

Unirradiated Plate Heat A1195-1

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 03/25/2006 11:41 AM
Page 1
Coefficients of Curve 1
A = 51.1 B = 48.6 C = 88.01 T0 = 80.68 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.7(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=39.8 Deg F Temp@50 ft-lbs=78.7 Deg F
Plant: OYSTER CREEK Material: SA533B1 Heat: A1195-1
Orientation: LT Capsule: UNIRR Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-60.00	3.50	6.32	-2.82
-40.00	11.50	8.38	3.12
-20.00	10.50	11.45	-.95
.00	14.50	15.90	-1.40
20.00	30.00	22.05	7.95
40.00	37.50	30.11	7.39
60.00	39.50	39.88	-.38
60.00	28.00	39.88	-11.88
80.00	51.00	50.72	.28

Figure B-31
Charpy Energy Data for A1195-1 HSST-02 Plate Unirradiated

Unirradiated Plate Heat A1195-1

Page 2
Plant: OYSTER CREEK Material: SA533B1 Heat: A1195-1
Orientation: LT Capsule: UNIRR Fluence: 0 n/cm^2

Charpy V-Notch Data

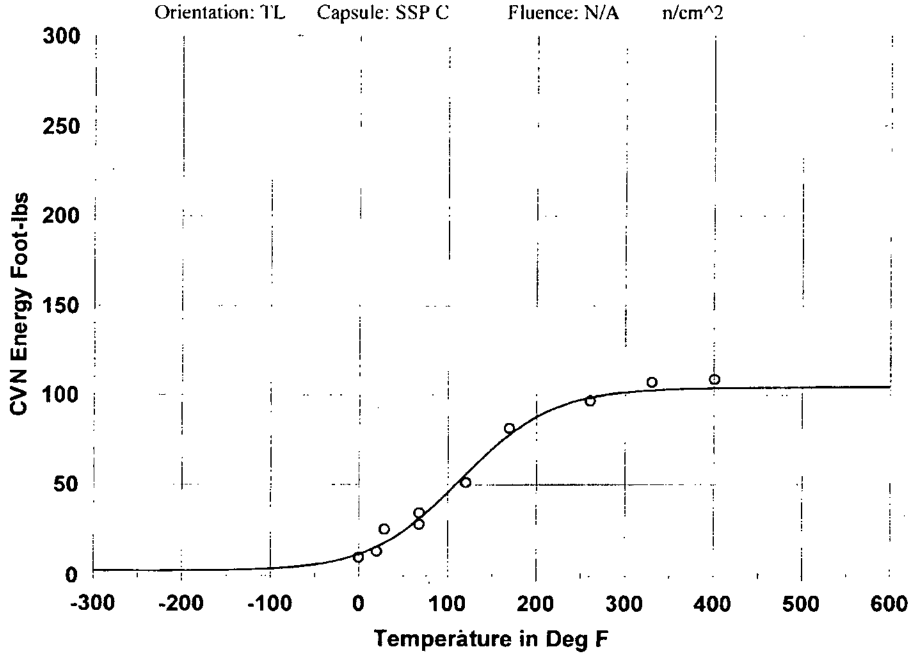
Temperature	Input CVN	Computed CVN	Differential
100.00	61.00	61.60	-.60
100.00	60.00	61.60	-1.60
140.00	80.00	79.66	.34
180.00	98.50	90.49	8.01
300.00	100.50	99.04	1.46
400.00	100.00	99.63	.37

Correlation Coefficient = .989

Figure B-31 (continued)
Charpy Energy Data for A1195-1 HSST-02 Plate Unirradiated

Plate Heat A1195-1 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:14 PM
Page 1
Coefficients of Curve 1
A = 53.3 B = 50.8 C = 101.71 T0 = 115.3 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=104.1(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=64.9 Deg F Temp@50 ft-lbs=108.7 Deg F
Plant: COOPER Material: SA533B1 Heat: A1195-1
Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-.22	10.21	12.00	-1.79
20.12	13.44	16.05	-2.61
28.94	25.43	18.22	7.21
68.00	28.25	31.24	-2.99
68.00	34.27	31.24	3.03
120.20	51.04	55.75	-4.71
169.16	81.59	77.94	3.65
260.60	96.60	98.58	-1.98
329.90	107.00	102.63	4.37

Figure B-32
Charpy Energy Data for A1195-1 HSST-02 Plate Irradiated in Capsule C

Plate Heat A1195-1 in SSP Capsule C

Page 2
Plant: COOPER Material: SA533B1 Heat: A1195-1
Orientation: TL Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

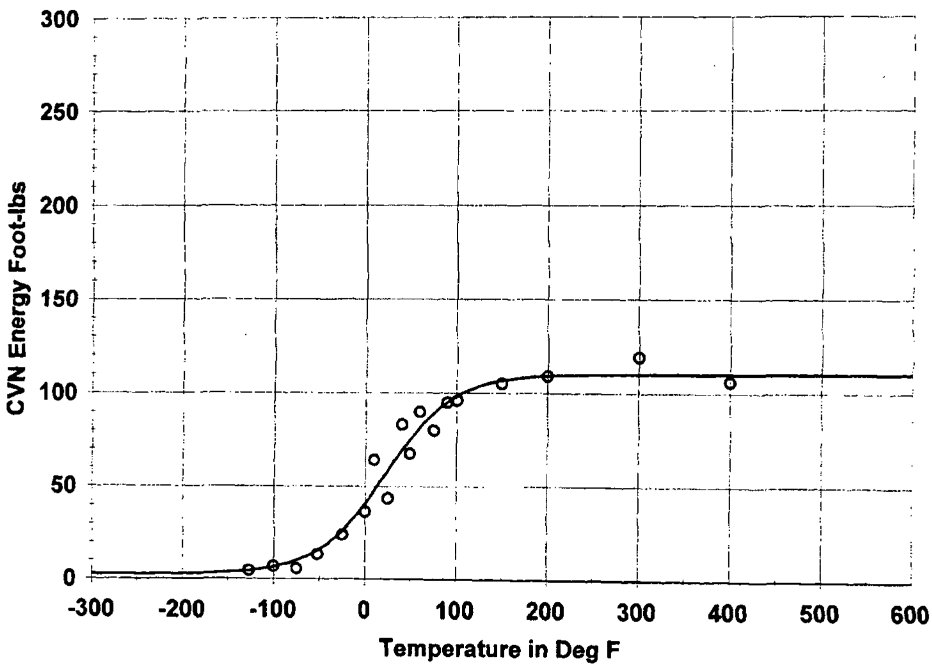
Temperature	Input CVN	Computed CVN	Differential
400.46	108.70	103.73	4.97

Correlation Coefficient = .995

Figure B-32 (continued)
Charpy Energy Data for A1195-1 HSST-02 Plate Irradiated in Capsule C

WELD HEAT 20291 (CPR AND SSP-C)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 11/06/2002 03:47 PM
Page 1
Coefficients of Curve 1
A = 56.25 B = 53.75 C = 74.45 T0 = 21.94 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=110.0 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-17.8 Deg F Temp@50 ft-lbs=13.3 Deg F
Plant: COOPER AND SSP Material: SAW Heat: 20291
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-127.00	4.50	4.43	.07
-100.00	6.70	6.42	.28
-75.00	5.50	9.91	-4.41
-52.00	13.30	15.47	-2.17
-25.00	24.00	26.24	-2.24
.00	36.60	40.86	-4.26
10.00	64.00	47.71	16.29
25.00	43.80	58.46	-14.66
40.00	83.00	69.05	13.95
49.00	67.50	74.98	-7.48
60.00	90.00	81.57	8.43

Figure B-33
Charpy Energy Data for Cooper Weld 20291 Unirradiated

WELD HEAT 20291 (CPR AND SSP-C)

Page 2
Plant: COOPER AND SSP Material: SAW Heat: 20291
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

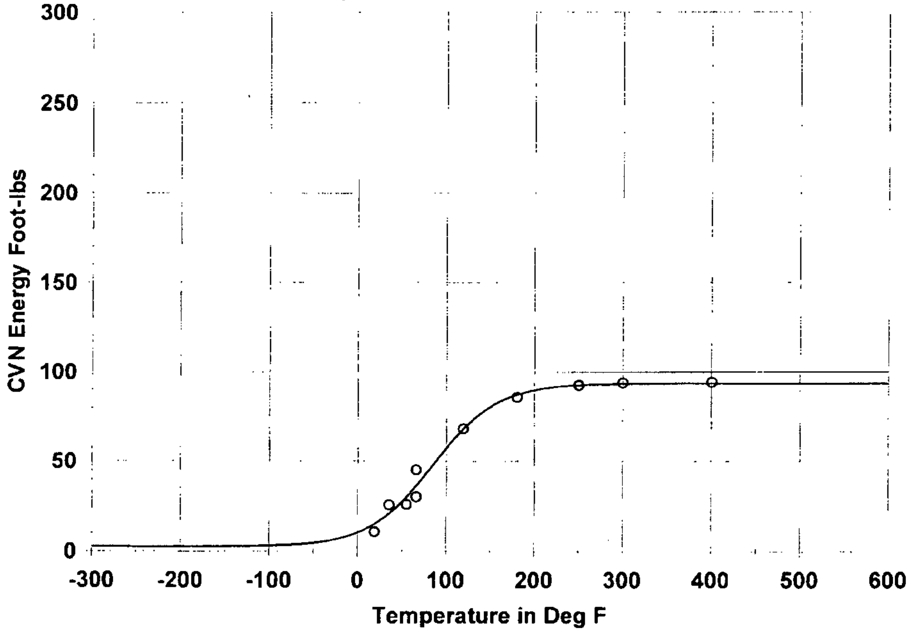
Temperature	Input CVN	Computed CVN	Differential
75.00	80.00	89.17	-9.17
90.00	95.00	95.13	-.13
101.00	96.00	98.53	-2.53
150.00	105.00	106.67	-1.67
200.00	109.00	109.12	-.12
300.00	119.00	109.95	9.05
400.00	106.00	110.00	-4.00

Correlation Coefficient = .981

Figure B-33 (continued)
Charpy Energy Data for Cooper Weld 20291 Unirradiated

Weld Heat 20291 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:17 PM
Page 1
Coefficients of Curve 1
A = 48.03 B = 45.53 C = 72.45 T0 = 85.52 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=93.6(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=55.2 Deg F Temp@50 ft-lbs=88.7 Deg F
Plant: COOPER Material: SAW Heat: 20291
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
19.40	10.78	15.14	-4.36
35.60	25.81	20.83	4.98
55.22	26.00	30.02	-4.02
66.38	30.21	36.27	-6.06
66.38	45.03	36.27	8.76
119.48	68.13	67.93	.20
180.50	85.79	87.39	-1.60
250.34	92.46	92.61	-.15
300.02	93.91	93.32	.59

Figure B-34
Charpy Energy Data for Cooper Weld 20291 Irradiated in Capsule C

Weld Heat 20291 in SSP Capsule C

Page 2
Plant: COOPER   Material: SAW   Heat: 20291
Orientation: NA   Capsule: SSP C   Fluence: N/A   n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.64	94.31	93.54	.77

Correlation Coefficient = .991

Figure B-34 (continued)
Charpy Energy Data for Cooper Weld 20291 Irradiated in Capsule C

Unirradiated SSP B&W Linde 80 Weld (Heat Unk)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 03/25/2006 11:49 AM
Page 1
Coefficients of Curve 1

A = 39.15 B = 36.65 C = 97.99 T0 = 64.97 D = 0.00E+00

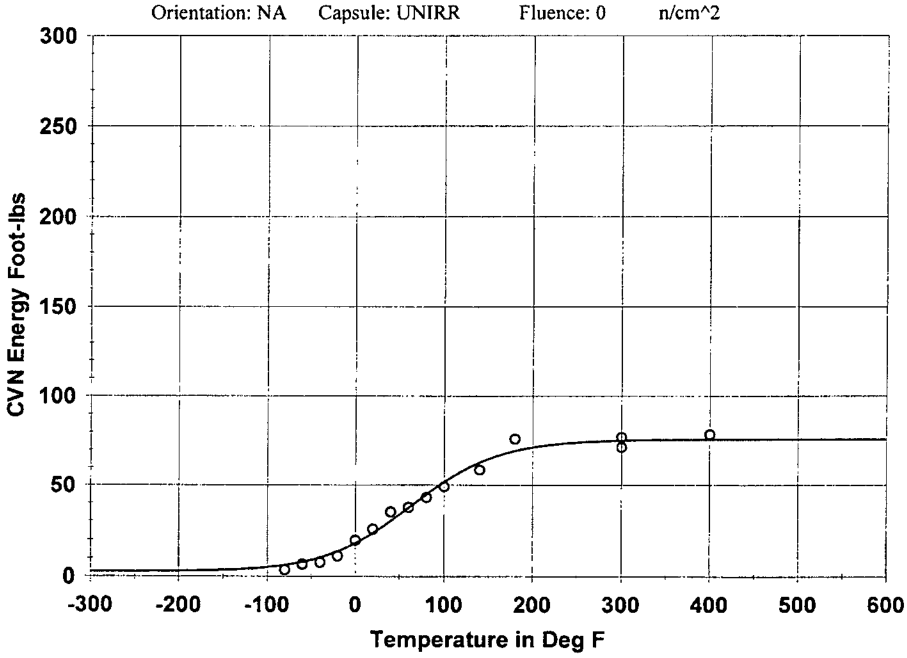
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=75.8(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=40.0 Deg F Temp@50 ft-lbs=94.9 Deg F

Plant: OYSTER CREEK Material: SAW Heat: B&W LINDE 80

Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	3.50	6.11	-2.61
-60.00	6.50	7.81	-1.31
-40.00	7.50	10.20	-2.70
-20.00	11.00	13.50	-2.50
.00	19.50	17.88	1.62
20.00	25.50	23.42	2.08
40.00	35.00	30.01	4.99
60.00	37.50	37.29	.21
80.00	43.00	44.73	-1.73

Figure B-35
Charpy Energy Data for AP2-BW B&W Linde 80 Weld Unirradiated

Unirradiated SSP B&W Linde 80 Weld (Heat Unk)

Page 2
Plant: OYSTER CREEK Material: SAW Heat: B&W LINDE 80
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
100.00	49.00	51.72	-2.72
140.00	58.50	62.77	-4.27
180.00	76.00	69.41	6.59
300.00	71.50	75.20	-3.70
300.00	77.00	75.20	1.80
400.00	78.50	75.72	2.78

Correlation Coefficient = .993

Figure B-35 (continued)
Charpy Energy Data for AP2-BW B&W Linde 80 Weld Unirradiated

B&W Linde 80 SAW in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:20 PM

Page 1

Coefficients of Curve 1

A = 33.58 B = 31.08 C = 130.37 T0 = 140.6 D = 0.00E+00

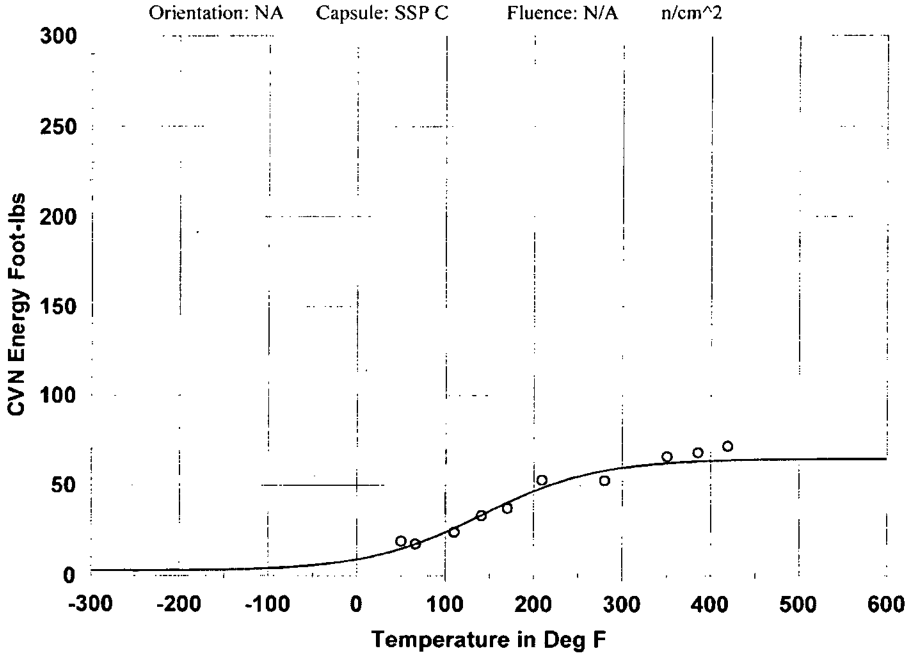
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=64.7(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=125.5 Deg F Temp@50 ft-lbs=217.2 Deg F

Plant: COOPER Material: SAW Heat: BW LINDE 80

Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
50.18	19.26	14.93	4.33
66.56	17.51	17.61	-.10
110.12	24.30	26.45	-2.15
140.72	33.34	33.61	-.27
170.06	37.33	40.49	-3.16
209.12	52.91	48.57	4.34
279.86	52.50	58.10	-5.60
350.60	65.92	62.29	3.63
385.52	68.13	63.25	4.88

Figure B-36
Charpy Energy Data for CP2-BW B&W Linde 80 Weld Irradiated in Capsule C

B&W Linde 80 SAW in SSP Capsule C

Page 2
Plant: COOPER Material: SAW Heat: BW LINDE 80
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

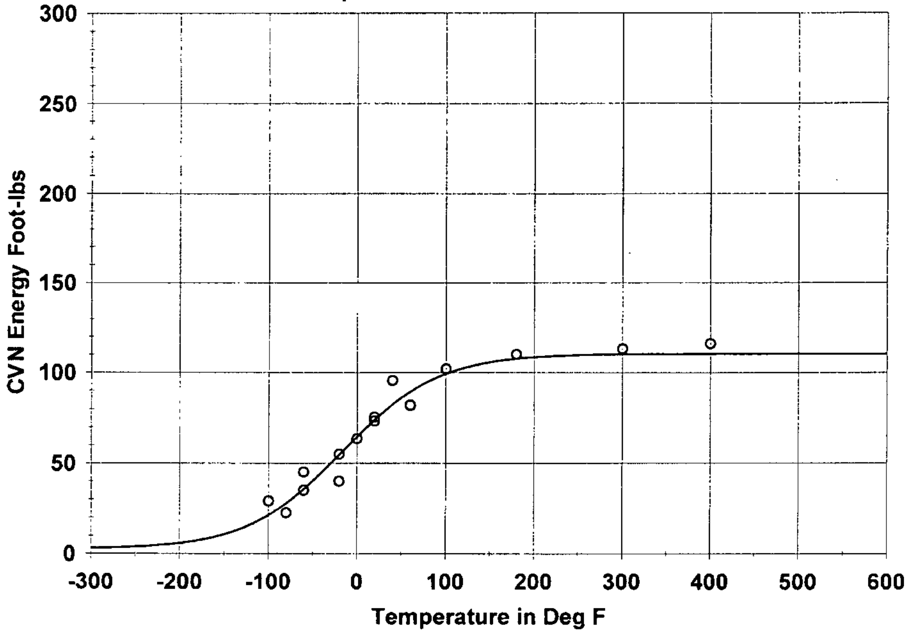
Temperature	Input CVN	Computed CVN	Differential
419.18	71.70	63.82	7.88

Correlation Coefficient = .980

Figure B-36 (continued)
Charpy Energy Data for CP2-BW B&W Linde 80 Weld Irradiated in Capsule C

Unirradiated Humboldt Bay 3 Weld (Heat Unknown)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 03/25/2006 11:44 AM
Page 1
Coefficients of Curve 1
A = 56.4 B = 53.9 C = 107.33 T0 = -16.54 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=110.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-74.0 Deg F Temp@50 ft-lbs=-29.3 Deg F
Plant: OYSTER CREEK Material: SAW Heat: HUMBOLDT BAY
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	29.00	21.29	7.71
-80.00	22.50	27.79	-5.29
-60.00	45.00	35.69	9.31
-60.00	35.00	35.69	-.69
-20.00	40.00	54.66	-14.66
-20.00	55.00	54.66	.34
.00	63.50	64.64	-1.14
20.00	73.50	74.07	-.57
20.00	75.50	74.07	1.43

Figure B-37
Charpy Energy Data for CP2-6 Humboldt Bay 3 Weld Unirradiated

Unirradiated Humboldt Bay 3 Weld (Heat Unknown)

Page 2
Plant: OYSTER CREEK Material: SAW Heat: HUMBOLDT BAY
Orientation: NA Capsule: UNIRR Fluence: 0 n/cm^2

Charpy V-Notch Data

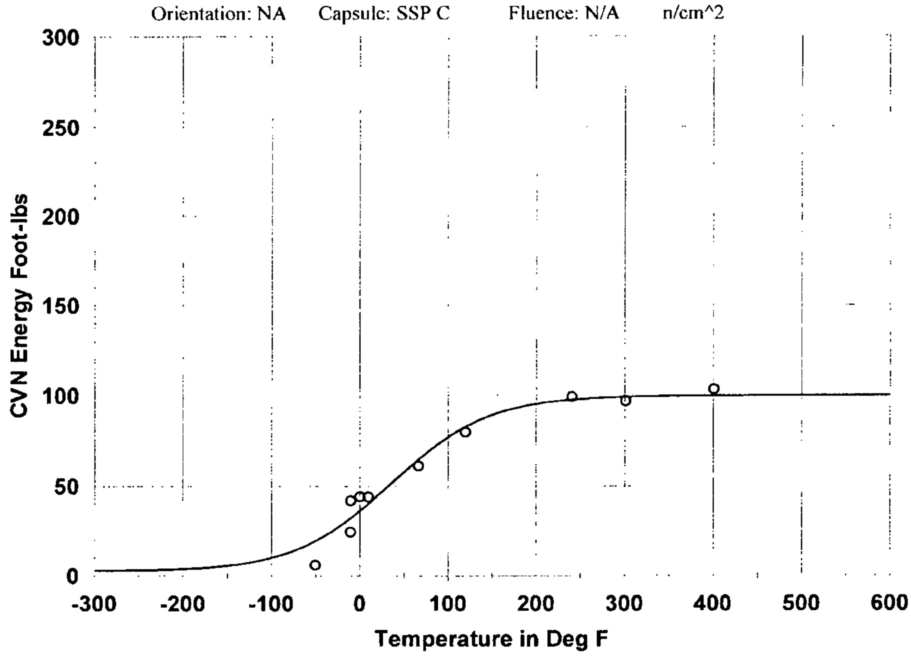
Temperature	Input CVN	Computed CVN	Differential
40.00	95.50	82.43	13.07
60.00	82.00	89.42	-7.42
100.00	102.00	99.27	2.73
180.00	110.00	107.60	2.40
300.00	113.00	110.01	2.99
400.00	116.00	110.25	5.75

Correlation Coefficient = .977

Figure B-37 (continued)
Charpy Energy Data for CP2-6 Humboldt Bay 3 Weld Unirradiated

Humboldt Bay 3 SAW in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:22 PM
Page 1
Coefficients of Curve 1
A = 51.12 B = 48.62 C = 108.78 T0 = 34.88 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.7(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-15.7 Deg F Temp@50 ft-lbs=32.4 Deg F
Plant: COOPER Material: SAW Heat: HUM BAY 3 SA
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.44	5.91	19.27	-13.36
-10.66	24.20	31.88	-7.68
-10.30	41.78	32.01	9.77
-.04	44.00	36.03	7.97
9.68	43.85	40.06	3.79
66.38	61.13	64.82	-3.69
119.84	79.99	82.88	-2.89
240.26	99.17	97.56	1.61
300.92	96.82	99.02	-2.20

Figure B-38
Charpy Energy Data for CP2-6 Humboldt Bay 3 Weld Irradiated in Capsule C

Humboldt Bay 3 SAW in SSP Capsule C

Page 2
Plant: COOPER Material: SAW Heat: HUM BAY 3 SA
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.64	103.22	99.62	3.60

Correlation Coefficient = .978

Figure B-38 (continued)
Charpy Energy Data for CP2-6 Humboldt Bay 3 Weld Irradiated in Capsule C

WELD HEAT 5P6756 (RB AND SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/07/2003 04:46 PM
Page 1
Coefficients of Curve 1

A = 53.45 B = 50.95 C = 106.52 T0 = -14.17 D = 0.00E+00

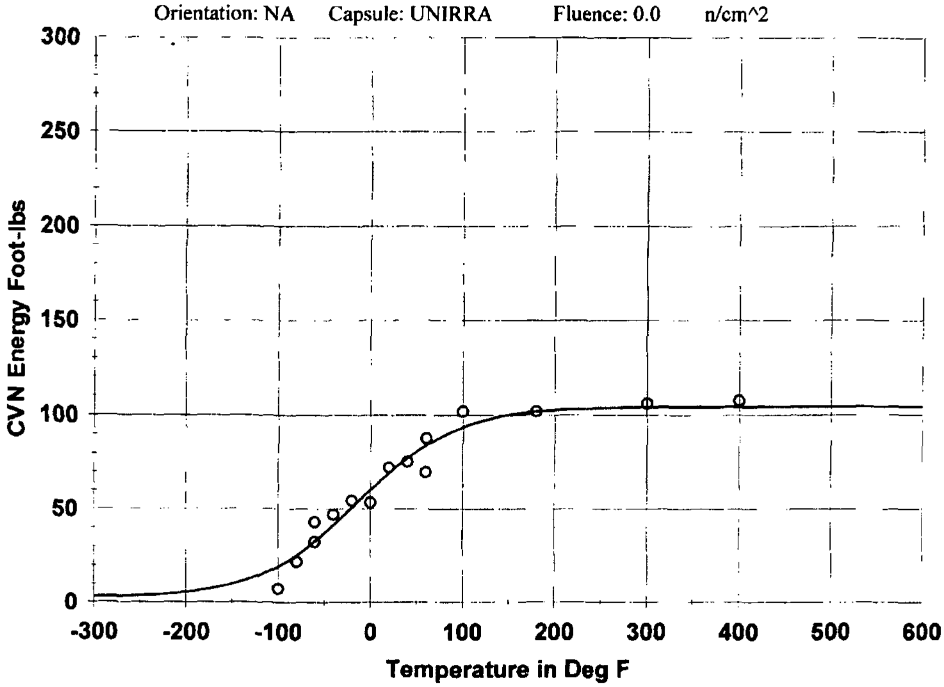
Equation is A + B * [Tanh((T-To)/(C+DT))]

Upper Shelf Energy=104.4(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=-67.1 Deg F Temp@50 ft-lbs=-21.3 Deg F

Plant: RIVER BEND AND SSP Material: SAW Heat: 5P6756

Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	7.50	19.45	-11.95
-80.00	22.00	25.44	-3.44
-60.00	43.00	32.79	10.21
-60.00	32.50	32.79	-.29
-40.00	47.00	41.33	5.67
-20.00	54.50	50.66	3.84
.00	53.50	60.19	-6.69
20.00	72.50	69.25	3.25
40.00	75.50	77.33	-1.83

Figure B-39
Charpy Energy Data for 5P6756 River Bend Weld Unirradiated

WELD HEAT 5P6756 (RB AND SSP)

Page 2
Plant: RIVER BEND AND SSP Material: SAW Heat: 5P6756
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

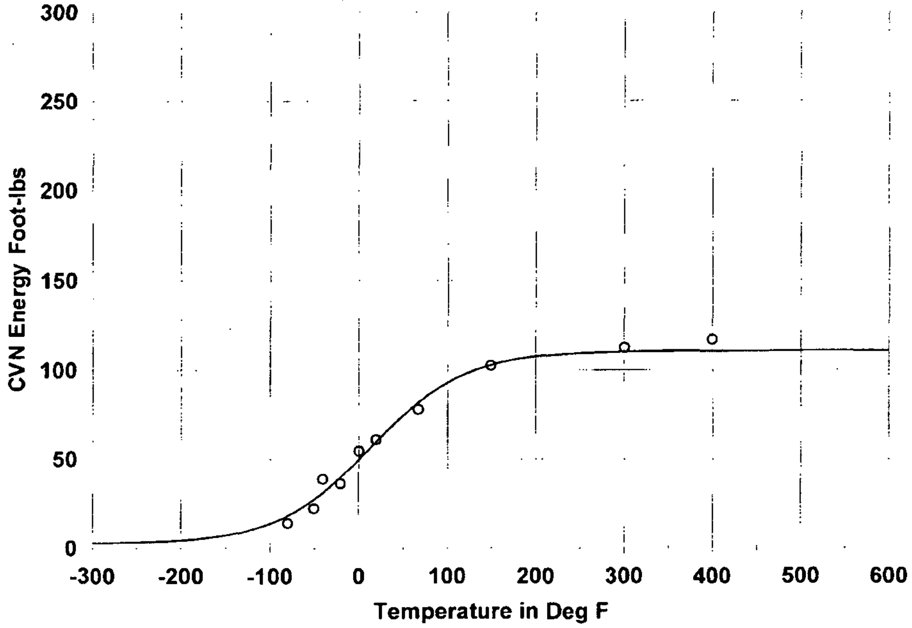
Temperature	Input CVN	Computed CVN	Differential
60.00	70.00	84.12	-14.12
60.00	88.00	84.12	3.88
100.00	102.00	93.71	8.29
180.00	102.00	101.81	.19
300.00	106.00	104.12	1.88
400.00	107.50	104.36	3.14

Correlation Coefficient = .977

Figure B-39 (continued)
Charpy Energy Data for 5P6756 River Bend Weld Unirradiated

Weld Heat 5P6756 in SSP Capsule C

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 06/07/2006 01:26 PM
Page 1
Coefficients of Curve 1
A = 56.6 B = 54.1 C = 106.54 T0 = 13.75 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=110.7(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-43.5 Deg F Temp@50 ft-lbs=.7 Deg F
Plant: COOPER Material: SAW Heat: 5P6756
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.14	14.11	18.35	-4.24
-50.44	22.46	27.45	-4.99
-40.36	38.92	31.26	7.66
-20.20	36.38	39.92	-3.54
.14	54.52	49.72	4.80
19.58	60.79	59.55	1.24
67.28	77.81	81.70	-3.89
149.18	102.51	102.80	-.29
300.38	112.54	110.19	2.35

Figure B-40
Charpy Energy Data for 5P6756 River Bend Weld Irradiated in Capsule C

Weld Heat 5P6756 in SSP Capsule C

Page 2
Plant: COOPER Material: SAW Heat: 5P6756
Orientation: NA Capsule: SSP C Fluence: N/A n/cm^2

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
399.74	117.01	110.61	6.40

Correlation Coefficient = .993

Figure B-40 (continued)
Charpy Energy Data for 5P6756 River Bend Weld Irradiated in Capsule C

C
DOSIMETER ANALYSIS

Dosimeter Material Description

The surveillance capsule contains a variety of neutron dosimeter materials. Since the surveillance capsules were up to about 20 inches (0.51 m) in axial height, full length copper and iron flux wires were placed in the capsules to provide dosimetry data for each collection of 10 Charpy specimens (which were stacked axially). The Cu and Fe wires were cut over the axial length spanned by the sets of 10 Charpy specimens and counted as single wires. Therefore, the wires represent the average over the axial height of the groups of 10 specimens. Figures C-1 through C-3 show the Cu and Fe dosimetry wire identifications and locations relative to the Charpy specimens.

Each capsule also contained an additional set of wires and foils placed in gadolinium capsules which are intended for neutron energy spectrum measurements. As shown in Figures C-1 through C-3, the spectral dosimetry capsules were irradiated near the bottom of each capsule. The gadolinium dosimetry cylinder included: iron wires (4); copper wire (1); nickel wire (1); niobium wire (1); titanium wire (1); aluminum-cobalt wire (1); and silver foil (1). As designed by GE, the four Fe wires were positioned at 90° intervals around the circumference of the gadolinium capsule for flux gradient determination. GE did not track the orientation of the Fe wires in the capsule since they intended the orientation to be determined from the activation results. Accordingly, MPM assigned the angular locations by comparing the pre-irradiation and post-irradiation weights.

Throughout this section of the report we denote the copper and iron wires located near the sets of Charpy test specimens as flux wires, while the neutron energy spectrum measurement materials are referred to as spectral monitors.

Dosimeter Cleaning and Mass Measurement

Upon receipt at the radiometric lab, the wires were visually inspected and inventoried. The wires and spectral monitor capsules were contained in labeled plastic vials. Each of the flux wires were placed in individually marked containers which allowed positive identification of individual dosimeters. The wire segments were examined under a microscope at low magnification. There appeared to be evidence of oxidation and some remaining surface contamination, indicating the need for cleaning. The copper wires were cleaned by immersion in a solution of 2M nitric acid (HNO_3), while the iron wires were treated with 4M hydrochloric (HCl) acid. Most surface corrosion or contamination was removed after 10-20 minutes of immersion. If needed, additional cleaning was performed. The wires were then rinsed with distilled water, wiped with ethanol, and then allowed to dry in air at room temperature. The wires then exhibited a clean, shiny appearance.

The total mass of each wire was measured using a Mettler AX-205 digital balance. The balance was calibrated by a qualified vendor and certified. A daily check of the balance performance was conducted on those days when the balance was used for dosimeter mass measurement using two sets of independent NIST traceable weights. Table C-1 lists the results of these measurements for the flux wires, as well as the identification assigned to each dosimeter. Table C-2 shows similar data for the spectral monitor materials. Each flux wire was wrapped around a thin metal rod to form a coil of approximately 0.50 inch (12.7 mm) diameter, which yields a reasonable approximation to a point source geometry. The coiled wire segments were pressed firmly against a hard surface to flatten the coil.

The spectral monitor capsules were opened and their contents examined. Information provided in the pre-irradiation documentation was used to identify individual dosimeter samples. Some dosimeter materials, such as the silver foil and copper wire, were identifiable by visual inspection and checked by mass and dimensional data. Other materials, such as the niobium wires, were identified by their isotopic content. However, characteristics such as mass and length were used to identify other specimens such as the four iron wires within each gadolinium capsule. Once positive identification was made of all materials, cleaning and radiometric analysis was performed. Some of the spectral monitor dosimeters, such as the copper, iron, and nickel wires, could be cleaned in accordance with the procedures discussed above for the copper and iron flux wires. However, in all cases, dosimeter samples were cleaned with ethanol to remove loose contamination.

Some of the spectral monitor samples were not coiled into 0.5 inch diameter samples because of their physical nature (the silver foil, for example) or small size (the nickel wire, for example, being only 0.25 inches [6.35 mm] long). For these materials, since their maximum extension does not exceed 0.5 inches (12.7 mm), approximation to a point source at the distance from the spectrometer detector chosen for analysis is still valid.

Dosimetry materials from the gadolinium capsules were visually inspected to assure that there was no contamination in the form of dust, dirt, grease, or oil. The wires were also examined for evidence of remaining oxide layers. A low-power inspection microscope was used. The purpose of this inspection was to assure that the radiometric analysis only encompasses materials that were activated by neutron bombardment. Microscopic inspection of the silver foils from gadolinium capsules C1, C2, and C3 showed the foils to have a clean and shiny appearance. This was also true of the cobalt-aluminum wires, which appeared to be a shiny silvery color and were easily malleable and coiled into the desired shape for counting. The titanium wires had a slightly duller appearance, but this is the nature of this material. There was no visual evidence of dirt, oil, or oxide layer. Likewise, the niobium wires have a somewhat duller appearance, which is characteristic of the material. Microscopic examination of the niobium wires did not reveal evidence of a significant layer of oxide. The nickel wires were free of any dust, dirt, grease, or oil. There was no visible oxide layer. One of the three nickel wires had a very slight discoloration.

As an additional check for the possible presence of oxides, the measured masses of the gadolinium capsule wires were compared with those specified by the surveillance capsule manufacturer. Nearly all of the measured masses of the wires agree very closely with those provided in the pre-irradiation documentation. If there were significant oxide layers present after irradiation, the masses would be noticeably higher. There was, however, a measurable difference in the measured masses for the titanium wires in gadolinium capsules C2 and C3. The capsule C2 titanium wire had a pre-irradiation specified mass of 99.6 mg and a post-irradiation measured mass of 101.99 mg, and the capsule C3 titanium wire had a pre-irradiation specified mass of 99.4 mg with a post-irradiation measured mass of 104.11 mg. Based on these measurements, it was concluded that there was a small amount of oxidation present which is sufficient to require further cleaning. The titanium wires in question were lightly sanded with a fine grit sandpaper. Care was taken to avoid removing metal from the wire. Once a clean appearance was attained, the sanding operation was halted. The wires were cleaned in ethanol. The final masses of the wires are provided in Table C-2, which agrees closely with the manufacturer-specified masses. Radiometric results are based on the cleaned wire masses given in the table.

Radiometric Analysis

Radiometric analyses were performed using high-resolution gamma emission spectroscopy. In this method, gamma emissions from the dosimeter materials are detected and quantified using solid-state gamma ray detectors and computer-based signal processing and spectrum analysis. The specifications of the gamma ray spectrometer system (GRSS) are listed in Table C-3. While the overall GRSS features three separate hyperpure germanium (HPGe) detectors, only one was used for this study. The detector is housed in a lead-copper shield (cave) to reduce background count rates.

System calibration was performed using a NIST traceable quasi-point source supplied by Amersham Corporation. The analysis software was procured from Aptec Nuclear, Inc. and provides the capability for energy resolution and efficiency calibration using specified standard source information. Calibration information is stored on magnetic disk for use by the spectrographic analysis software package.

Since detector efficiency depends on the source-detector geometry, a fixed, reproducible geometry/distance must be selected for the gamma spectrographic analysis of the dosimeter materials. For the dosimeter wires, the counting geometry was that of a quasi-point source (coiled wire) placed 5 inches (12.7 cm) vertically from the top surface of the detector shell. In this way, extended sources up to 0.5 inches (12.7 mm) can be analyzed with a good approximation to a point source. The coiled wires were well within the area needed to approximate a point source geometry. The HPGe detector was calibrated for efficiency using the NIST traceable source.

The accuracy of the efficiency calibration was checked using a gamma spectrographic analysis of a NIST traceable gamma source, separate from that used to perform the efficiency calibration, and supplied by a separate vendor. The isotope contained in this check source emits gamma rays which span the energy response of the detector for the dosimeter materials. These measurements show that the efficiency calibration is providing a valid estimate of source activity. The acceptance criteria for these measurements are that the software must yield a valid isotopic identification, and that the quantified activity of each correctly identified isotope must be within the uncertainty specified in the source certification. System performance was verified before beginning the counting studies, and re-verified upon completion of the work to assure that system performance had not changed.

Tables C-4 and C-5 show the counting schedule established for the flux wires and spectral monitor materials, respectively. There was no requirement for order of counting, since the dosimeter materials still contained sufficient quantities of activation products to allow accurate radio assay. Where practical, dosimeter specimens were counted for a time long enough to accumulate at least 10,000 counts above background in the primary emission line(s) of interest. For some samples, counting times of approximately 3,000 to 10,000 seconds of system live time were adequate. Occasionally, counting times of overnight to several days were required to accumulate sufficient counts.

For the titanium and nickel dosimeter materials contained in the spectral monitor gadolinium capsules, excessive decay time prevented accumulation of 10,000 counts above background in the primary emission lines of interest. The half-lives of the induced radionuclides for these materials (^{46}Sc and ^{58}Co, respectively) are relatively short compared with the decay time. The nickel dosimeter wire presented another difficulty for analysis of ^{58}Co content. The gamma photon energy from ^{58}Co decay produces an emission peak in the Compton downscatter region of emission lines from ^{60}Co, which is also present in this material. This makes detection and measurement of the ^{58}Co emission line difficult. The relatively high uncertainties listed for ^{46}Sc and ^{58}Co activity for the titanium and nickel dosimeter wires are a consequence of these difficulties. For information purposes, we list the measured activities and uncertainties as a best-effort attempt to provide data for flux calculations. However, caution is needed in interpreting results based on these measurements because of the uncertainties discussed above.

Neutrons interact with the constituent nuclei of the dosimeter materials, producing radionuclides in varying amounts depending on total neutron fluence and its energy spectrum, and the nuclear properties of the dosimeter materials. Table C-6 lists the reactions of interest and their resultant radionuclide products for each element contained in the dosimeters. These are threshold reactions involving an n-p, n-γ, or n-α interaction.

Finally, Tables C-7 and C-8 present the primary results of interest for flux determination. The activity units are in dps/mg, which normalizes the activity to dosimeter mass. The activities are specified for both the time of the analysis, and a reference date/time, which in this case is the Cooper Nuclear Station shutdown date and time. This was specified as February 24, 2003, at 1:01 ET. These tables also present uncertainty estimates for each of the measurements.

Table C-1
Cooper SSP Capsules A, B and C Wire Dosimeter Masses

Wire Dosimeter ID	Mass (mg)
AP1-11 Cu	639.40
AP1-11 Fe	136.67
AP1-28 Cu	842.99
AP1-28 Fe	163.38
AP1-30 Cu	806.06
AP1-30 Fe	142.96
AP1-67 Cu	836.24
AP1-67 Fe	169.43
AP2-15 Cu	814.27
AP2-15 Fe	148.24
AP2-20 Cu	854.79
AP2-20 Fe	133.12
AP2-21 Cu	722.17
AP2-21 Fe	138.74
AP2-67 Cu	840.33
AP2-67 Fe	151.84
BP1-11 Cu	804.58
BP1-11 Fe	146.56
BP1-28 Cu	731.16
BP1-28 Fe	139.67
BP1-30 Cu	647.02
BP1-30 Fe	157.15
BP1-67 Cu	931.28

Table C-1 (continued)
Cooper SSP Capsules A, B and C Wire Dosimeter Masses

Wire Dosimeter ID	Mass (mg)
BP1-67 Fe	127.75
BP2-15 Cu	755.92
BP2-15 Fe	143.45
BP2-20 Cu	796.14
BP2-20 Fe	139.70
BP2-21 Cu	786.22
BP2-21 Fe	144.43
BP2-67 Cu	695.68
BP2-67 Fe	130.50
CP1-15 Cu	706.54
CP1-15 Fe	148.63
CP1-20 Cu	927.78
CP1-20 Fe	167.72
CP1-36 Cu	725.16
CP1-36 Fe	139.64
CP1-H2 Cu	691.15
CP1-H2 Fe	134.32
CP2-06 Cu	850.39
CP2-06 Fe	156.38
CP2-72 Cu	577.79
CP2-72 Fe	131.64
CP2-BW Cu	717.28
CP2-BW Fe	147.07
EY-J1 Cu	740.45
EY-J1 Fe	134.07

Table C-2
Cooper SSP Capsules A, B and C Spectral Monitor Dosimeter Masses

Spectral Monitor Dosimeter ID	Mass (mg)
C1 Cobalt-Aluminum Wire	77.42
C1 Copper Wire	555.30
C1 0° Iron Wire	49.59
C1 90° Iron Wire	51.17
C1 180° Iron Wire	53.09
C1 270° Iron Wire	54.06
C1 Nickel Wire	11.68
C1 Niobium Wire	86.03
C1 Silver Foil	4.02
C1 Titanium Wire	102.75
C2 Cobalt-Aluminum Wire	76.84
C2 Copper Wire	547.63
C2 0° Iron Wire	45.74
C2 90° Iron Wire	49.71
C2 180° Iron Wire	49.72
C2 270° Iron Wire	52.17
C2 Nickel Wire	11.48
C2 Niobium Wire	83.49
C2 Silver Foil	4.00
C2 Titanium Wire	99.70
C3 Cobalt-Aluminum Wire	76.86
C3 Copper Wire	301.38
C3 0° Iron Wire	47.53
C3 90° Iron Wire	50.76
C3 180° Iron Wire	52.06
C3 270° Iron Wire	53.38
C3 Nickel Wire	21.33
C3 Niobium Wire	88.57
C3 Silver Foil	4.77
C3 Titanium Wire	99.85

Table C-3
GRSS Specifications

System Component	Description and/or Specifications
Detector	Canberra Model GC1420 HPGe
Energy Resolution	1.77 KeV @ 1332.5 KeV
Detector Efficiency (relative to a 3 inch x 3 inch (7.62 cm x 7.62 cm)NaI crystal)	14% at 1332.5 KeV
Amplifier	Aptec Nuclear Inc. Model 6300 Low-Noise Spectroscopy Amplifier
ADC	Aptec Nuclear Inc. Model S5008 PC-ISA card, 8192 Channels, 6 μsec. fixed conversion time, successive approximation conversion method
Computer System	733 MHZ Pentium III-Based PC, 256 MB Main Memory, 40 GB Hard Disk, 17-inch (43.18 cm) Monitor, Lexmark T620 Printer
Software	Aptec Nuclear Inc. OSQ/Professional Version 7.08
Bias Voltage Supply	Mechtronics Model 258

Table C-4
Counting Schedule for the Flux Wire Dosimeter Materials

Dosimeter ID	Count Start Date	Count Start Time (ET)	Count Duration (Live Time Seconds)
AP1-11 Cu	9/29/05	08:18	35471
AP1-11 Fe	9/27/05	16:48	50000
AP1-28 Cu	10/3/05	10:27	9329
AP1-28 Fe	9/26/05	10:21	12277
AP1-30 Cu	9/26/05	15:31	50000
AP1-30 Fe	9/29/05	18:12	50000
AP1-67 Cu	9/27/05	09:11	13141
AP1-67 Fe	9/30/05	16:31	70000
AP2-15 Cu	10/5/05	10:12	3901
AP2-15 Fe	9/28/05	16:44	50000
AP2-20 Cu	10/4/05	12:03	18028
AP2-20 Fe	10/3/05	16:47	60000
AP2-21 Cu	9/30/05	13:09	12009
AP2-21 Fe	10/4/05	17:12	60000
AP2-67 Cu	9/28/05	10:07	23196
AP2-67 Fe	10/5/05	16:34	59534
BP1-11 Cu	10/11/05	09:15	12380
BP1-11 Fe	10/12/05	17:03	17:03
BP1-28 Cu	10/10/05	13:25	12008
BP1-28 Fe	10/11/05	16:46	59415
BP1-30 Cu	10/13/05	09:57	13844
BP1-30 Fe	10/19/05	17:19	56778
BP1-67 Cu	10/19/05	07:58	5131
BP1-67 Fe	11/1/05	13:00	12562
BP2-15 Cu	10/17/05	08:31	9055
BP2-15 Fe	10/13/05	16:40	64037
BP2-20 Cu	10/11/05	12:43	14315
BP2-20 Fe	10/14/05	16:44	70000

Table C-4 (continued)
Counting Schedule for the Flux Wire Dosimeter Materials

Dosimeter ID	Count Start Date	Count Start Time (ET)	Count Duration (Live Time Seconds)
BP2-21 Cu	10/12/05	13:56	11154
BP2-21 Fe	10/18/05	16:47	54536
BP2-67 Cu	10/12/05	09:21	16117
BP2-67 Fe	10/17/05	17:15	58278
CP1-15 Cu	10/6/05	09:47	14411
CP1-15 Fe	9/23/05	16:40	50000
CP1-20 Cu	9/21/05	08:45	28766
CP1-20 Fe	9/8/05	16:44	50000
CP1-36 Cu	10/7/05	09:55	22804
CP1-36 Fe	9/22/05	13:12	50000
CP1-H2 Cu	9/20/05	16:01	50000
CP1-H2 Fe	9/23/05	10:39	21518
CP2-06 Cu	9/21/05	16:52	50000
CP2-06 Fe	10/7/05	16:17	70000
CP2-72 Cu	10/10/05	09:14	14866
CP2-72 Fe	10/6/05	16:59	50000
CP2-BW Cu	10/6/05	13:48	11049
CP2-BW Fe	10/10/05	16:50	58274
EY-J1 Cu	10/26/05	12:11	12823
EY-J1 Fe	10/26/05	17:01	60052

Table C-5
Counting Schedule for the Spectral Monitor Dosimeter Materials

Capsule/Dosimeter ID	Count Start Date	Count Start Time (ET)	Count Duration (Live Time Seconds)
C1 Co-Al Wire	12/5/05	15:34	58938
C1 Cu Wire	11/21/05	10:41	3618
C1 Fe 0° Wire	11/18/05	08:53	27928
C1 Fe 90° Wire	11/21/05	11:43	20485
C1 Fe 180° Wire	11/22/05	08:32	28250
C1 Fe 270° Wire	11/21/05	17:30	54023
C1 Ni Wire	11/17/05	16:50	57385
C1 Nb Wire	11/22/05	16:31	576328
C1 Ag Foil	12/1/05	13:45	67993
C1 Ti Wire	11/18/05	17:06	235849
C2 Co-Al Wire	10/28/05	10:00	25565
C2 Cu Wire	10/27/05	13:09	73908
C2 Fe 0° Wire	10/31/05	07:45	22355
C2 Fe 90° Wire	11/1/05	08:17	16890
C2 Fe 180° Wire	10/31/05	14:00	11906
C2 Fe 270° Wire	10/31/05	17:20	53645
C2 Ni Wire	10/28/05	17:10	228754
C2 Nb Wire	11/1/05	16:31	57491
C2 Ag Foil	10/26/05	15:55	3885
C2 Ti Wire	01/02/06	13:25	328963
C3 Co-Al Wire	11/10/05	08:45	7674
C3 Cu Wire	11/9/05	15:51	5520
C3 Fe 0° Wire	11/17/05	10:00	23616
C3 Fe 90° Wire	11/15/05	12:50	17138
C3 Fe 180° Wire	11/9/05	17:25	55023
C3 Fe 270° Wire	11/16/05	09:03	28638
C3 Ni Wire	11/16/05	17:02	60641
C3 Nb Wire	11/15/05	17:36	55546
C3 Ag Foil	11/2/05	08:33	10665
C3 Ti Wire	12/27/05	14:52	513080

Table C-6
Neutron-Induced Reactions of Interest

Dosimeter Material	Neutron-Induced Reaction	Reaction Product Radionuclide	Primary Gamma Emission Energies (KeV)	Reaction Product Half-Life
Iron	$^{54}Fe(n,p)^{54}Mn$	^{54}Mn	834.8	312.2 Days
Nickel	$^{58}Ni(n,p)^{58}Co$	^{58}Co	810.8	70.78 Days
Copper	$^{63}Cu(n,\alpha)^{60}Co$	^{60}Co	1173.2, 1332.5	5.272 Years
Titanium	$^{46}Ti(n,p)^{46}Sc$	^{46}Sc	889.3, 1120.5	83.83 Days
Cobalt	$^{59}Co(n,\gamma)^{60}Co$	^{60}Co	1173.2, 1332.5	5.272 Years
Silver	$^{109}Ag(n,\gamma)^{110m}Ag$	^{110m}Ag	884.7	250.4 Days
Niobium	$^{93}Nb(n,\gamma)^{94}Nb$	^{94}Nb	702.50	20300 Years

Table C-7
Results of the Radiometric Analysis for the Flux Wires

Dosimeter ID	Isotope ID	Activity At Count Date/Time (dps/mg)	Activity At Reference Date/Time[a] (dps/mg)	Activity Uncertainty (%)
AP1-11 Cu	^{60}Co	12.39	17.43	1.93
AP1-11 Fe	^{54}Mn	15.95	130.5	2.22
AP1-28 Cu	^{60}Co	11.76	16.57	2.05
AP1-28 Fe	^{54}Mn	15.30	124.8	2.43
AP1-30 Cu	^{60}Co	12.90	18.14	1.90
AP1-30 Fe	^{54}Mn	17.18	141.2	2.21
AP1-67 Cu	^{60}Co	13.79	19.39	1.98
AP1-67 Fe	^{54}Mn	17.77	146.3	2.17
AP2-15 Cu	^{60}Co	13.91	19.62	2.22
AP2-15 Fe	^{54}Mn	17.66	144.8	2.20
AP2-20 Cu	^{60}Co	11.90	16.77	1.96
AP2-20 Fe	^{54}Mn	15.25	126.5	2.21
AP2-21 Cu	^{60}Co	12.78	17.99	2.02
AP2-21 Fe	^{54}Mn	16.24	135.0	2.20
AP2-67 Cu	^{60}Co	14.42	20.28	1.93
AP2-67 Fe	^{54}Mn	18.55	154.5	2.19
BP1-11 Cu	^{60}Co	15.18	21.44	1.98
BP1-11 Fe	^{54}Mn	18.94	160.2	2.19
BP1-28 Cu	^{60}Co	14.79	20.89	2.00
BP1-28 Fe	^{54}Mn	18.42	155.4	2.19
BP1-30 Cu	^{60}Co	15.39	21.76	1.99
BP1-30 Fe	^{54}Mn	18.69	160.5	2.19
BP1-67 Cu	^{60}Co	16.94	24.00	2.07
BP1-67 Fe	^{54}Mn	17.68	156.2	2.45
BP2-15 Cu	^{60}Co	15.77	22.33	2.02
BP2-15 Fe	^{54}Mn	20.11	170.5	2.18
BP2-20 Cu	^{60}Co	15.56	21.98	1.96
BP2-20 Fe	^{54}Mn	19.29	163.9	2.18

Table C-7 (continued)
Results of the Radiometric Analysis for the Flux Wires

Dosimeter ID	Isotope ID	Activity At Count Date/Time (dps/mg)	Activity At Reference Date/Time[a] (dps/mg)	Activity Uncertainty (%)
BP2-21 Cu	^{60}Co	15.80	22.34	1.99
BP2-21 Fe	^{54}Mn	19.67	168.6	2.19
BP2-67 Cu	^{60}Co	15.55	21.98	1.97
BP2-67 Fe	^{54}Mn	19.19	164.1	2.19
CP1-15 Cu	^{60}Co	10.17	14.35	2.03
CP1-15 Fe	^{54}Mn	12.82	104.0	2.23
CP1-20 Cu	^{60}Co	9.617	13.49	1.94
CP1-20 Fe	^{54}Mn	12.29	96.37	2.22
CP1-36 Cu	^{60}Co	10.71	15.11	1.97
CP1-36 Fe	^{54}Mn	13.60	110.0	2.23
CP1-H2 Cu	^{60}Co	9.265	12.99	1.92
CP1-H2 Fe	^{54}Mn	12.21	98.92	2.39
CP2-06 Cu	^{60}Co	9.134	12.82	1.92
CP2-06 Fe	^{54}Mn	11.54	96.52	2.20
CP2-72 Cu	^{60}Co	9.155	12.93	2.08
CP2-72 Fe	^{54}Mn	11.15	93.05	2.26
CP2-BW Cu	^{60}Co	9.620	13.57	2.08
CP2-BW Fe	^{54}Mn	12.13	102.2	2.22
EY-J1 Cu	^{60}Co	10.45	14.85	2.04
EY-J1 Fe	^{54}Mn	12.26	107.0	2.22

[a] February 24, 2003 at 01:01 ET is the reference date and time.

Table C-8
Results of the Radiometric Analysis for the Spectral Monitors

Capsule/Dosimeter ID	Isotope ID	Activity At Count Date/Time (dps/mg)	Activity At Reference Date/Time[a] (dps/mg)	Activity Uncertainty (%)
C1 Co-Al Wire	^{60}Co	126.4	182.2	1.90
C1 Cu Wire	^{60}Co	10.89	15.62	2.53
C1 Fe 0° Wire	^{54}Mn	12.76	117.1	2.63
C1 Fe 90° Wire	^{54}Mn	12.48	115.3	2.79
C1 Fe 180° Wire	^{54}Mn	12.65	117.1	2.60
C1 Fe 270° Wire	^{54}Mn	12.63	116.8	2.38
C1 Ni Wire[c]	^{58}Co	0.100	2245	27.37
C1 Nb Wire	^{94}Nb	1.435	1.435	2.29
C1 Ag Foil	^{110m}Ag	453.3	7200	2.39
C1 Ti Wire[b]	^{46}Sc	0.017	65.13	21.37
C2 Co-Al Wire	^{60}Co	154.0	218.9	1.93
C2 Cu Wire	^{60}Co	14.13	20.09	1.90
C2 Fe 0° Wire	^{54}Mn	17.41	153.5	2.63
C2 Fe 90° Wire	^{54}Mn	17.71	156.5	2.71
C2 Fe 180° Wire	^{54}Mn	17.50	154.3	2.93
C2 Fe 270° Wire	^{54}Mn	17.10	150.9	2.33
C2 Ni Wire[c]	^{58}Co	0.103	2315	17.20
C2 Nb Wire	^{94}Nb	1.718	1.718	3.12
C2 Ag Foil	^{110m}Ag	566.4	8479	3.21
C2 Ti Wire[b]	^{46}Sc	0.011	61.19	31.97
C3 Co-Al Wire	^{60}Co	103.1	147.3	2.13

Table C-8 (continued)
Results of the Radiometric Analysis for the Spectral Monitors

Capsule/Dosimeter ID	Isotope ID	Activity At Count Date/Time (dps/mg)	Activity At Reference Date/Time[a] (dps/mg)	Activity Uncertainty (%)
C3 Cu Wire	^{60}Co	10.26	14.65	2.69
C3 Fe 0° Wire	^{54}Mn	11.72	107.3	2.78
C3 Fe 90° Wire	^{54}Mn	11.93	108.8	2.93
C3 Fe 180° Wire	^{54}Mn	11.89	107.1	2.40
C3 Fe 270° Wire	^{54}Mn	11.61	106.0	2.63
C3 Ni Wire[c]	^{58}Co	0.077	1744	16.57
C3 Nb Wire	^{94}Nb	1.218	1.218	3.44
C3 Ag Foil	^{110m}Ag	413.4	6305	2.66
C3 Ti Wire[b]	^{46}Sc	0.012	65.28	21.05

[a] February 24, 2003 at 01:01 ET is the reference date and time.

[b] Total counts for ^{46}Sc were less than 10,000 in the primary emission lines. Activity shown is for information only.

[c] Total counts for ^{58}Co were less than 10,000 in the primary emission lines. Activity shown is for information only.

SSP Capsule A Dosimetry Layout

Specimen ID	Cu Wire ID	Fe Wire ID	Spectral Dosimetry ID	Specimen ID	Cu Wire ID	Fe Wire ID
TOP OF CAPSULE						
AP1-67-1				AP2-67-1		
AP1-67-2				AP2-67-2		
AP1-67-3				AP2-67-3		
AP1-67-4				AP2-67-4		
AP1-67-5	AP1-67Cu	AP1-67Fe		AP2-67-5	AP2-67Cu	AP2-67Fe
AP1-67-6				AP2-67-6		
AP1-67-7				AP2-67-7		
AP1-67-8				AP2-67-8		
AP1-67-9				AP2-67-9		
AP1-67-10				AP2-67-10		
AP1-30-1				AP2-15-1		
AP1-30-2				AP2-15-2		
AP1-30-3				AP2-15-3		
AP1-30-4				AP2-15-4		
AP1-30-5	AP1-30Cu	AP1-30Fe		AP2-15-5	AP2-15Cu	AP2-15Fe
AP1-30-6				AP2-15-6		
AP1-30-7				AP2-15-7		
AP1-30-8				AP2-15-8		
AP1-30-9				AP2-15-9		
AP1-30-10				AP2-15-10		
AP1-11-1				AP2-21-1		
AP1-11-2				AP2-21-2		
AP1-11-3				AP2-21-3		
AP1-11-4				AP2-21-4		
AP1-11-5	AP1-11Cu	AP1-11Fe		AP2-21-5	AP2-21Cu	AP2-21Fe
AP1-11-6				AP2-21-6		
AP1-11-7				AP2-21-7		
AP1-11-8				AP2-21-8		
AP1-11-9				AP2-21-9		
AP1-11-10				AP2-21-10		
AP1-28-1				AP2-20-1		
AP1-28-2				AP2-20-2		
AP1-28-3				AP2-20-3		
AP1-28-4				AP2-20-4		
AP1-28-5	AP1-28-Cu	AP1-28-Fe		AP2-20-5	AP2-20-Cu	AP2-20-Fe
AP1-28-6			C1	AP2-20-6		
AP1-28-7			C1	AP2-20-7		
AP1-28-8			C1	AP2-20-8		
AP1-28-9				AP2-20-9		
AP1-28-10				AP2-20-10		
BOTTOM OF CAPSULE						

Figure C-1
Schematic Representation of the SSP Capsule A Dosimetry Wire Layout Relative to the Charpy Test Specimens

SSP Capsule B Dosimetry Layout

Specimen ID	Cu Wire ID	Fe Wire ID	Spectral Dosimetry ID	Specimen ID	Cu Wire ID	Fe Wire ID
TOP OF CAPSULE						
BP1-67-1				BP2-67-1		
BP1-67-2				BP2-67-2		
BP1-67-3				BP2-67-3		
BP1-67-4				BP2-67-4		
BP1-67-5	BP1-67Cu	BP1-67Fe		BP2-67-5	BP2-67Cu	BP2-67Fe
BP1-67-6				BP2-67-6		
BP1-67-7				BP2-67-7		
BP1-67-8				BP2-67-8		
BP1-67-9				BP2-67-9		
BP1-67-10				BP2-67-10		
BP1-30-1				BP2-15-1		
BP1-30-2				BP2-15-2		
BP1-30-3				BP2-15-3		
BP1-30-4				BP2-15-4		
BP1-30-5	BP1-30Cu	BP1-30Fe		BP2-15-5	BP2-15Cu	BP2-15Fe
BP1-30-6				BP2-15-6		
BP1-30-7				BP2-15-7		
BP1-30-8				BP2-15-8		
BP1-30-9				BP2-15-9		
BP1-30-10				BP2-15-10		
BP1-11-1				BP2-21-1		
BP1-11-2				BP2-21-2		
BP1-11-3				BP2-21-3		
BP1-11-4				BP2-21-4		
BP1-11-5	BP1-11Cu	BP1-11Fe		BP2-21-5	BP2-21Cu	BP2-21Fe
BP1-11-6				BP2-21-6		
BP1-11-7				BP2-21-7		
BP1-11-8				BP2-21-8		
BP1-11-9				BP2-21-9		
BP1-11-10				BP2-21-10		
BP1-28-1				BP2-20-1		
BP1-28-2				BP2-20-2		
BP1-28-3				BP2-20-3		
BP1-28-4				BP2-20-4		
BP1-28-5	BP1-28-Cu	BP1-28-Fe		BP2-20-5	BP2-20-Cu	BP2-20-Fe
BP1-28-6			C2	BP2-20-6		
BP1-28-7			C2	BP2-20-7		
BP1-28-8			C2	BP2-20-8		
BP1-28-9				BP2-20-9		
BP1-28-10				BP2-20-10		
BOTTOM OF CAPSULE						

Figure C-2
Schematic Representation of the SSP Capsule B Dosimetry Wire Layout Relative to the Charpy Test Specimens

SSP Capsule C Dosimetry Layout

Specimen ID	Cu Wire ID	Fe Wire ID	Spectral Dosimetry ID	Specimen ID	Cu Wire ID	Fe Wire ID
TOP OF CAPSULE						
CP1-36-1				EY_J1_-1		
CP1-36-2				EY_J1_-2		
CP1-36-3				EY_J1_-3		
CP1-36-4				EY_J1_-4		
CP1-36-5	CP1-36Cu	CP1-36Fe		EY_J1_-5	EY_J1_Cu	EY_J1_Fe
CP1-36-6				EY_J1_-6		
CP1-36-7				EY_J1_-7		
CP1-36-8				EY_J1_-8		
CP1-36-9				EY_J1_-9		
CP1-36-10				EY_J1_-10		
CP1-15-1				CP2-BW-1		
CP1-15-2				CP2-BW-2		
CP1-15-3				CP2-BW-3		
CP1-15-4				CP2-BW-4		
CP1-15-5	CP1-15Cu	CP1-15Fe		CP2-BW-5	CP2-BWCu	CP2-BWFe
CP1-15-6				CP2-BW-6		
CP1-15-7				CP2-BW-7		
CP1-15-8				CP2-BW-8		
CP1-15-9				CP2-BW-9		
CP1-15-10				CP2-BW-10		
CP1-20-1				CP2-06-1		
CP1-20-2				CP2-06-2		
CP1-20-3				CP2-06-3		
CP1-20-4				CP2-06-4		
CP1-20-5	CP1-20Cu	CP1-20Fe		CP2-06-5	CP2-06Cu	CP2-06Fe
CP1-20-6				CP2-06-6		
CP1-20-7				CP2-06-7		
CP1-20-8				CP2-06-8		
CP1-20-9				CP2-06-9		
CP1-20-10				CP2-06-10		
CP1-H2-1				CP2-72-1		
CP1-H2-2				CP2-72-2		
CP1-H2-3				CP2-72-3		
CP1-H2-4				CP2-72-4		
CP1-H2-5	CP1-H2-Cu	CP1-H2-Fe		CP2-72-5	CP2-72-Cu	CP2-72-Fe
CP1-H2-6			C3	CP2-72-6		
CP1-H2-7			C3	CP2-72-7		
CP1-H2-8			C3	CP2-72-8		
CP1-H2-9				CP2-72-9		
CP1-H2-10				CP2-72-10		
BOTTOM OF CAPSULE						

Figure C-3
Schematic Representation of the SSP Capsule C Dosimetry Wire Layout Relative to the Charpy Test Specimens

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