Enclosure 1 to NG-16-0055

Redacted Non-Proprietary BWRVIP-135 Sections

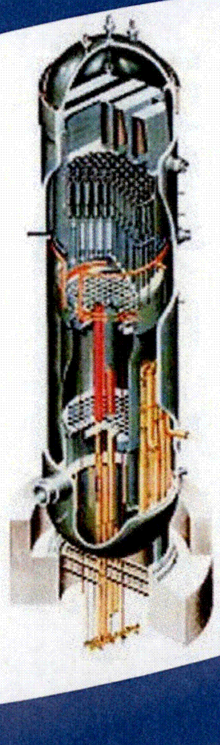
43 pages follow

ELECTRIC POWER RESEARCH INSTITUTE

2014 TECHNICAL REPORT

BWRVIP-135, Revision 3: BWR Vessel and Internals Project

Integrated Surveillance Program (ISP) Data Source Book and Plant Evaluations



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BWRVIP-135, Revision 3: BWR Vessel and Internals Project

Integrated Surveillance Program (ISP) Data Source Book and Plant Evaluations

3002003144

Technical Report, December 2014

EPRI Project Manager
R. Carter

All or a portion of the requirements of the EPRI Nuclear Quality Assurance Program apply to this product.

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Duane Arnold

Representative Surveillance Materials

The ISP Representative Surveillance Materials for the Duane Arnold vessel target weld and plates are shown in the following table.

Table 2-31
Target Vessel Materials and ISP Representative Materials for Duane Arnold

Target Vessel Materials		ISP Representative Materials
Weld	432Z0471	DA1 SMAW
Plate	B0673-1	B0673-1

Summary of Available Surveillance Data: Plate

The representative plate material B0673-1 is contained in the following ISP capsules:

Duane Arnold and SSP Capsule F

Specific surveillance data related to plate heat B0673-1 are summarized in Appendix A-3. Four capsules containing this plate heat have been tested. The Charpy V-notch surveillance results are as follows:

Table 2-32
T_{30} Shift Results for Plate Heat B0673-1

Capsule	Cu (wt%)	Ni (wt%)	Fluence (10^{17} n/cm^2, E > 1 MeV)	ΔT_{30} (°F)
Duane Arnold 288°	0.15	0.65	5.09	41.8
Duane Arnold 36°			11.7	77.0
SSP F			18.699	73.4
Duane Arnold 108°			26.3	94.3

The results given in Appendix A-3 show a fitted chemistry factor (CF) of {{ (E)}}, as compared to a value of 111.25°F from the chemistry tables in Reg. Guide 1.99, Rev. 2. The maximum scatter in the fitted data is {{ (E)}} which is well within the 1-sigma value of 17°F for plates as given in Reg. Guide 1.99, Rev. 2.

Conclusions and Recommendations

Because the representative plate material is the same heat number as the target plate in the Duane Arnold vessel, and because there are four irradiated data sets for this plate that fall within the 1-sigma scatter band, the ISP surveillance data should be used to revise the projected ART value for the target vessel plate with a reduced margin term (Regulatory Position 2.1). Recommended guidelines for use of ISP surveillance data are provided in Section 3 of this Data Source Book.

Summary of Available Surveillance Data: Weld

The representative weld material DA1 SMAW is contained in the following ISP capsules:

Duane Arnold Capsules

SSP Capsule F

Specific surveillance data related to weld heat DA1 SMAW are presented in Appendix B-5 and the results are summarized below. Four capsules containing weld heat DA1 SMAW have been tested. The Charpy V-notch surveillance results are as follows:

Table 2-33
T_{30} Shift Results for Weld Heat DA1 SMAW

Capsule	Cu (wt%)	Ni (wt%)	Fluence (10^{17} n/cm^2, E > 1 MeV)	ΔT_{30} (°F)
Duane Arnold 288°	0.02	0.94	5.09	2.6
Duane Arnold 36°			11.7	16.1
SSP F			19.336	26.3
Duane Arnold 108°			26.3	23.8

The results given in Appendix B-5 show a fitted chemistry factor (CF) of {{ (E)}}, as compared to a value of 27.0°F from the chemistry tables in Reg. Guide 1.99, Rev. 2. The maximum scatter in the fitted data is {{ (E)}} which is well within the 1-sigma value of 28°F for welds as given in Reg. Guide 1.99, Rev. 2.

Conclusions and Recommendations

Because the representative weld material is not the same heat number as the target weld in the Duane Arnold vessel, the utility should use the chemistry factor from the Regulatory Guide 1.99, Rev. 2 tables to determine the projected ART value for the target vessel weld. Recommended guidelines for evaluation of ISP surveillance data are provided in Section 3 of this Data Source Book.

A-3 Plate Heat: B0673-1

Summary of Available Charpy V-Notch Test Data

The available Charpy V-notch test data sets for plate heat B0673-1 are listed in Table A-3-1. The source documents for the data are provided, and the capsule designation and fluence values are also provided for irradiated data sets.

Table A-3-1
ISP Capsules Containing Plate Heat B0673-1

Capsule	Fluence (E> 1 MeV, 10^{17} n/cm^2)	Reference
Unirradiated Baseline Data	—	References A-3-1 and A-3-2
Duane Arnold 288°	5.09	
Duane Arnold 36°	11.7	
SSP Capsule F	18.699	Reference A-3-3
Duane Arnold 108°	26.3	Reference A-3-2

The CVN test data for each set taken from the references noted above are presented in Tables A-3-7 through A-3-11. The BWRVIP ISP uses the hyperbolic tangent (tanh) function as a statistical curve-fit tool to model the transition temperature toughness data. Tanh curve plots for each data set have been generated using CVGRAPH, Version 5 [A-3-4] and the plots are provided in Figures A-3-1 through A-3-5.

Best Estimate Chemistry

Table A-3-2 details the best estimate average chemistry values for plate heat B0673-1 surveillance material. Chemical compositions are presented in weight percent. If there are multiple measurements on a single specimen, those are first averaged to yield a single value for that specimen, and then the different specimens are averaged to determine the heat best estimate.

Table A-3-2
Best Estimate Chemistry of Available Data Sets for Plate Heat B0673-1

Cu (wt%)	Ni (wt%)	P (wt%)	S (wt%)	Si (wt%)	Specimen ID	Source
0.15	0.7	0.006	—	0.07	ETJ	Reference A-3-1
0.15	0.69	0.006	—	0.06	ETK	
0.14	0.62	0.010	—	0.01	EB4	
0.141	0.62	0.014	—	0.02	EBA	
0.145	0.65	0.010	—	0.09	EBE	
0.15	0.61	0.011	—	0.18	Baseline CMTR	Reference A-3-1
0.15	**0.65**	**0.010**	**—**	**0.07**	**←Best Estimate Average**	

Calculation of Chemistry Factor (CF):

The Chemistry Factor (CF) associated with the best estimate chemistry, as determined from U.S. NRC Regulatory Guide 1.99, Revision 2 [A-3-5], Table 2 (base metal), is:

$$\mathbf{CF_{(B0673\text{-}1)} = 111.25°F}$$

Effects of Irradiation

The radiation induced transition temperature shifts for heat B0673-1 are shown in Table A-3-3. The T_{30} [30 ft-lb Transition Temperature], T_{50} [50 ft-lb Transition Temperature], and T_{35mil} [35 mil Lateral Expansion Temperature] have been determined for each Charpy data set, and each irradiated set is compared to the baseline (unirradiated) index temperatures. The change in Upper Shelf Energy (USE) is also shown. The unirradiated and irradiated values are taken from the CVGRAPH fits presented at the back of this sub-appendix (only CVN energy fits are presented).

Comparison of Actual vs. Predicted Embrittlement

A predicted shift in the 30 ft-lb transition temperature (ΔT_{30}) is calculated for each irradiated data set using the Reg. Guide 1.99, Rev. 2, Regulatory Position 1.1 method. Table A-3-4 compares the predicted shift with the measured ΔT_{30} (°F) taken from Table A-3-3.

Comparison of Actual vs. Predicted Decrease in USE

Table A-3-5 compares the actual percent decrease in upper shelf energy (USE) to the predicted decrease. The predicted decrease is estimated from USNRC Regulatory Guide 1.99, Rev. 2, Figure 2; the measured percent decrease is calculated from the values presented in Table A-3-3.

Table A-3-3
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Plate Heat B0673-1

Material Identity	Capsule ID	T_{30}, 30 ft-lb Transition Temperature			T_{50}, 50 ft-lb Transition Temperature			T_{35mil}, 35 mil Lateral Expansion Temperature			CVN Upper Shelf Energy (USE)		
		Unirrad (°F)	Irrad (°F)	ΔT_{30} (°F)	Unirrad (°F)	Irrad (°F)	ΔT_{50} (°F)	Unirrad (°F)	Irrad (°F)	ΔT_{35mil} (°F)	Unirrad (ft-lb)	Irrad (ft-lb)	Change (ft-lb)
DA1 and SSP B0673-1	288°	-35.5	6.3	41.8	-7.3	42.4	49.7	-23.6	18.6	42.2	158.1	158.8	0.7
	36°	-35.5	41.5	77.0	-7.3	70.7	78.0	-23.6	55.7	79.3	158.1	137.0	-21.1
	SSP F	-35.5	37.9	73.4	-7.3	66.9	74.2	-23.6	57.8	81.4	158.1	133.0	-25.1
	108°	-35.5	58.8	94.3	-7.3	91.4	98.7	-23.6	87.1	110.7	158.1	131.3	-26.8

Table A-3-4
Comparison of Actual Versus Predicted Embrittlement for Plate Heat B0673-1

Capsule Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Measured Shift[1] °F	RG 1.99 Rev. 2 Predicted Shift[2] °F	RG 1.99 Rev. 2 Predicted Shift+Margin[2,3] °F
DA 288°	Plate Heat B0673-1 in Duane Arnold	0.509	41.8	32.9	65.8
DA 36°	Plate Heat B0673-1 in Duane Arnold	1.17	77.0	50.0	84.0
SSP F	Plate Heat B0673-1 in SSP	1.8699	73.4	61.6	95.6
DA 108°	Plate Heat B0673-1 in Duane Arnold	2.63	94.3	70.8	104.8

Notes:

1. See Table A-3-3 ΔT_{30}.
2. Predicted shift = CF × FF, where CF is a Chemistry Factor taken from tables from USNRC Reg. Guide 1.99, Rev. 2, based on each material's Cu/Ni content, and FF is Fluence Factor, $f^{0.28-0.10 \log f}$, where f = fluence (10^{19} n/cm^2, E > 1.0 MeV).
3. Margin = $2\sqrt{(\sigma_I^2 + \sigma_\Delta^2)}$, where σ_I = the standard deviation on initial RT_{NDT} (which is taken to be 0°F), and σ_Δ is the standard deviation on ΔRT_{NDT} (28°F for welds and 17°F for base materials, except that σ_Δ need not exceed 0.50 times the mean value of ΔRT_{NDT}). Thus, margin 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.

Table A-3-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Plate Heat B0673-1

Capsule Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Cu Content (wt%)	Measured Decrease in USE[1] (%)	RG 1.99 Rev. 2 Predicted Decrease in USE[2] (%)
DA 288°	Plate Heat B0673-1 in Duane Arnold	0.509	0.15	—[3]	11.9
DA 36°	Plate Heat B0673-1 in Duane Arnold	1.17	0.15	13.3	14.4
SSP F	Plate Heat B0673-1 in SSP	1.8699	0.15	15.9	16.1
DA 108°	Plate Heat B0673-1 in Duane Arnold	2.63	0.15	17.0	17.5

Notes:

1. See Table A-3-3, (Change in USE)/(Unirradiated USE).
2. Calculated using equations in Regulatory Guide 1.162 [A-3-6] that accurately model the Charpy upper shelf energy decrease curves in Regulatory Guide 1.99, Revision 2.
3. Less than zero.

Credibility of Surveillance Data

The credibility of the surveillance data is determined according to the guidance of Regulatory Guide 1.99, Rev. 2 and 10 CFR 50.61, as supplemented by the NRC staff [A-3-7]. The following evaluation is based on the available surveillance data for irradiated plate heat B0673-1. The applicability of this evaluation to a particular BWR plant must be confirmed on a plant-by-plant basis to verify there are no plant-specific exceptions to the following evaluation.

Per Regulatory Guide 1.99, Revision 2 and 10 CFR 50.61, there are 5 criteria for the credibility assessment.

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

> In order to satisfy this criterion, the representative surveillance material heat number must match the material in the vessel.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and upper shelf energy unambiguously.

> Plots of Charpy energy versus temperature for the unirradiated and irradiated condition are presented in this sub-appendix. Based on engineering judgment, the scatter in these plots is small enough to permit the determination of the 30 ft-lb temperature and the upper shelf energy. Hence, this criterion is met.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 17°F for plates. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice that value. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82 [A-3-8].

> For plate material B0673-1, there are 4 surveillance capsule data sets currently available. The functional form of the least squares fit method as described in Regulatory Position 2.1 is utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 17°F for plates. Figure A-3-6 presents the best-fit line as described in Regulatory Position 2.1 utilizing the shift prediction routine from CVGRAPH, Version 5.0.2.
>
> The scatter of ΔRT_{NDT} values about the functional form of the best-fit line drawn as described in Regulatory Position 2.1 is presented in Table A-3-6.

Table A-3-6
Best Fit Evaluation for Surveillance Plate Heat B0673-1

Material	Fitted CF (°F)	Capsule	FF	Measured ΔRT_{NDT} (30 ft-lb) (°F)	Best Fit ΔRT_{NDT} (°F)	Scatter of ΔRT_{NDT} (°F)	<17°F (Base Metal) <28°F (Weld metal)
B0673-1	{{ (E)}}	288°	0.290	41.8	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	36°	0.436	77.0	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	SSP F	0.553	73.4	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	108°	0.637	94.3	{{ (E)}}	{{ (E)}}	Yes

Table A-3-6 indicates that the scatter is within acceptable range for credible surveillance data. Therefore, plate heat B0673-1 meets this criterion.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within + / - 25°F.

BWRVIP-78 [A-3-9] established the similarity of BWR plant environments in the BWR fleet. The annulus between the wall and the core shroud in the region of the surveillance capsules contains a mix of water returning from the core and feedwater. Depending on feedwater temperature, this annulus region is between 525°F and 535°F. This location of specimens with respect to the reactor vessel beltline is designed so that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperature will not differ by more than 25°F. Any plant-specific exceptions to this generic analysis should be evaluated.

Criterion 5: The surveillance data for the correlation monitor material in the capsule should fall within the scatter band of the database for that material.

Few ISP capsules contain correlation monitor material. Generally, this criterion is not applicable.

For plate heat B0673-1, these criteria are satisfied (or not applicable). The surveillance data are nominally credible because the scatter criterion is met. Prior to application of the data, a plant should verify that no plant-specific exceptions to these criteria exist.

Table A-3-7
Unirradiated Charpy V-Notch Results for Surveillance Plate B0673-1 (LT)

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
ED4	-100	6.5	7.0	0
ED1	-80	4.2	5.0	0
ECT	-40	9.0	14.0	10
EDK	-40	24.0	30.0	5
ED7	-30	38.0	35.0	5
EDT	-30	49.0	30.0	5
ED6	-20	47.0	43.0	10
ED5	-10	43.0	43.0	20
ECP	0	56.5	49.0	25
ECM	40	98.5	73.0	40
ECL	120	134.5	73.0	80
ECK	200	158.5	93.0	85
EDY	300	163.5	81.0	90
EDA	400	No Break	No Break	No Break

Table A-3-8
Charpy V-Notch Results for B0673-1 (LT) in Duane Arnold 288 Deg Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EBU	-60	4.0	4.0	0
EBP	-20	15.0	19.0	0
EBT	10	15.5	26.0	40
EC1	20	49.5	45.0	40
EBK	40	60.0	49.0	40
EBJ	120	101.5	70.0	70
EBL	200	144.5	95.0	90
EBY	400	160.0	98.0	90

Table A-3-9
Charpy V-Notch Results for B0673-1 (LT) in Duane Arnold 36 Deg Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EBD	-50	5.0	5.0	1
EB1	0	18.5	15.0	41
EB2	13	27.7	24.0	10
EB3	25	13.7	13.0	27
EBC	32	15.4	23.0	24
EB6	40	15.4	16.0	32
EB4	49	59.2	48.0	32
EB5	81	51.5	43.0	44
EBA	120	92.9	69.0	78
EB7	202	127.8	82.0	100
EBE	250	142.8	84.0	100
EBB	400	140.5	94.0	100

Table A-3-10
Charpy V-Notch Results for B0673-1 (LT) in SSP Capsule F

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EDJ	0	12.5	9.0	0
ECU	30	25.5	22.0	20
EDD	50	24.5	21.0	20
ECY	50	34.5	26.0	30
EDM	70	71.5	54.0	45
EDP	150	103.5	78.0	75
EDB	175	113.5	82.0	85
ED2	200	139.0	89.0	100
ECJ	300	134.5	91.0	100
ECE	400	125.5	85.0	100

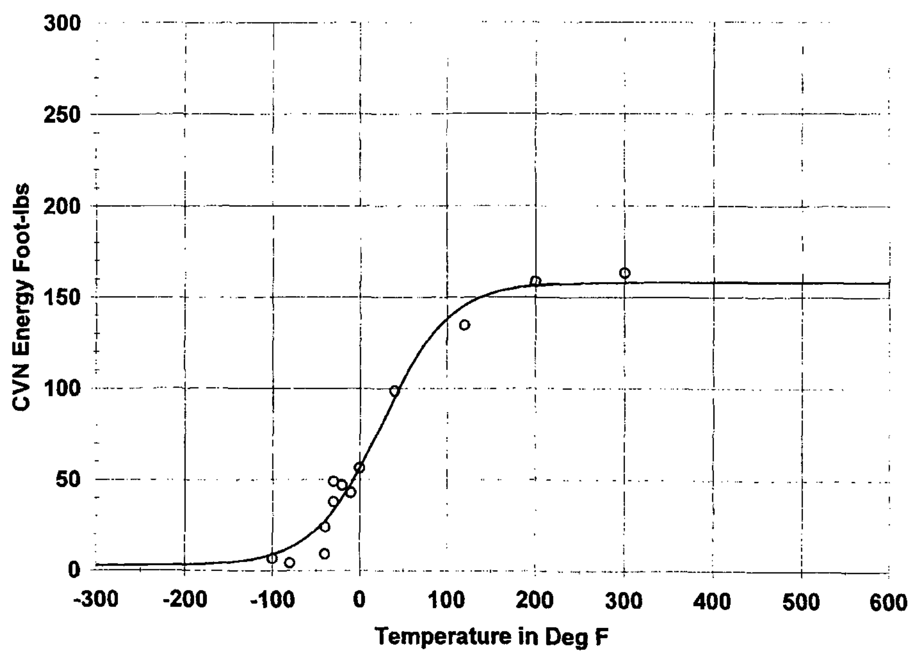
Table A-3-11
Charpy V-Notch Results for B0673-1 (LT) in Duane Arnold 108° Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
ECB	-1.3	4.2	5.0	4.2
ECC	35.8	23.88	17.3	10.4
EC3	69.1	42.06	30.4	17.6
EC7	128.7	63.71	48.5	38.6
ECD	160.5	111.06	76.2	67.2
ECA	191.5	110.36	76.0	84.1
EC4	252.0	129.48	91.0	100.0
EC5	400.8	133.11	92.9	100.0

Tanh Curve Fits of CVN Test Data for Plate Heat B0673-1

PLATE HEAT B0673-1 (DA AND SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 09/09/2002 08:29 AM
Page 1
Coefficients of Curve 1
A = 80.31 B = 77.81 C = 78.77 T0 = 25.02 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=158.1 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-35.5 Deg F Temp@50 ft-lbs=-7.3 Deg F
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	6.50	8.75	-2.25
-80.00	4.20	12.61	-8.41
-40.00	9.00	27.56	-18.56
-40.00	24.00	27.56	-3.56
-30.00	38.00	33.36	4.64
-30.00	49.00	33.36	15.64
-20.00	47.00	40.12	6.88
-10.00	43.00	47.83	-4.83
.00	56.50	56.40	.10
40.00	98.50	94.93	3.57
120.00	134.50	145.31	-10.81

Figure A-3-1
Charpy Energy Data for Plate B0673-1 (LT) Unirradiated

PLATE HEAT B0673-1 (DA AND SSP)

Page 2
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

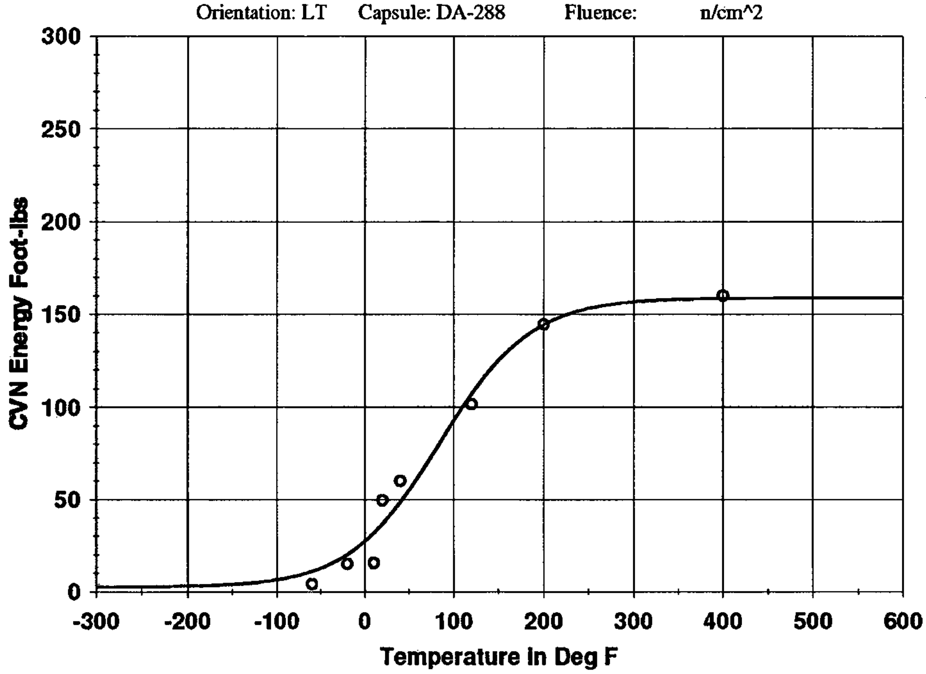
Temperature	Input CVN	Computed CVN	Differential
200.00	158.50	156.31	2.19
300.00	163.50	157.97	5.53

Correlation Coefficient = .988

Figure A-3-1
Charpy Energy Data for Plate B0673-1 (LT) Unirradiated (Continued)

Irradiated Plate Heat B0673-1 (DA1-288)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 01:33 PM
Page 1
Coefficients of Curve 1
A = 80.66 B = 78.16 C = 101.16 T0 = 84.32 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=158.8 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=6.3 Deg F Temp@50 ft-lbs=42.4 Deg F
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: DA-288 Fluence: n/cm^2



Charpy V-Notch Data

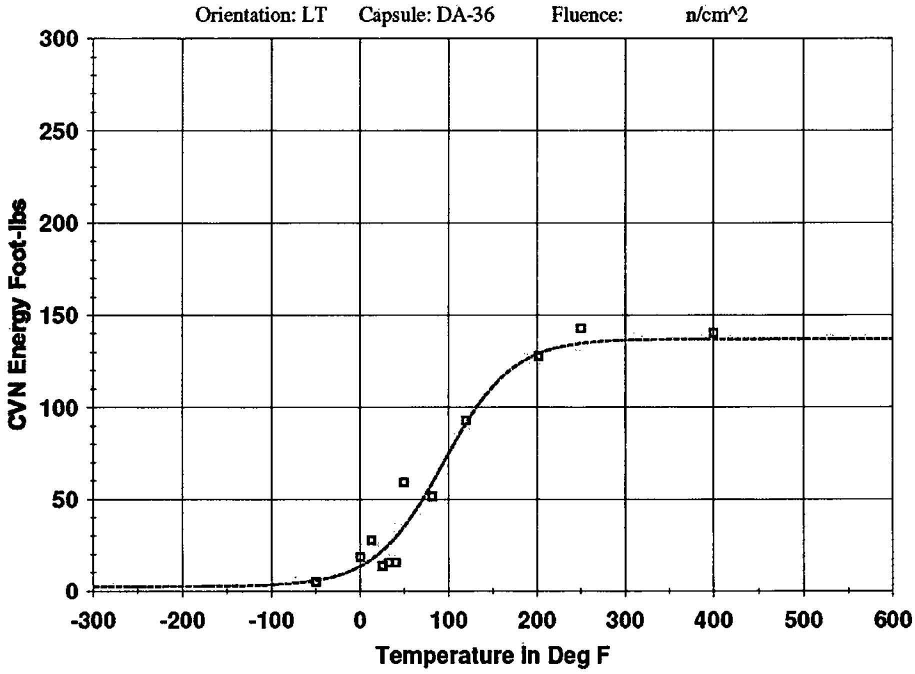
Temperature	Input CVN	Computed CVN	Differential
-60.00	4.00	11.02	-7.02
-20.00	15.00	20.13	-5.13
10.00	15.50	31.74	-16.24
20.00	49.50	36.73	12.77
40.00	60.00	48.45	11.55
120.00	101.50	107.13	-5.63
200.00	144.50	144.40	.10
400.00	160.00	158.51	1.49

Correlation Coefficient = .987

Figure A-3-2
Charpy Energy Data for Plate B0673-1 (LT) in Duane Arnold 288° Capsule

Irradiated Plate Heat B0673-1 (DA1-36)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 01:34 PM
Page 1
Coefficients of Curve 2
A = 69.75 B = 67.25 C = 77.56 T0 = 94.1 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=137.0(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=41.5 Deg F Temp@50 ft-lbs=70.7 Deg F
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: DA-36 Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-50.00	5.00	5.70	-.70
.00	18.50	13.42	5.08
13.00	27.70	17.29	10.41
25.00	13.70	21.88	-8.18
32.00	15.40	25.07	-9.67
40.00	15.40	29.21	-13.81
49.00	59.20	34.53	24.67
81.00	51.50	58.50	-7.00
120.00	92.90	91.41	1.49

Figure A-3-3
Charpy Energy Data for Plate B0673-1 (LT) in Duane Arnold 36° Capsule

Irradiated Plate Heat B0673-1 (DA1-36)

Page 2
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: DA-36 Fluence: n/cm^2

Charpy V-Notch Data

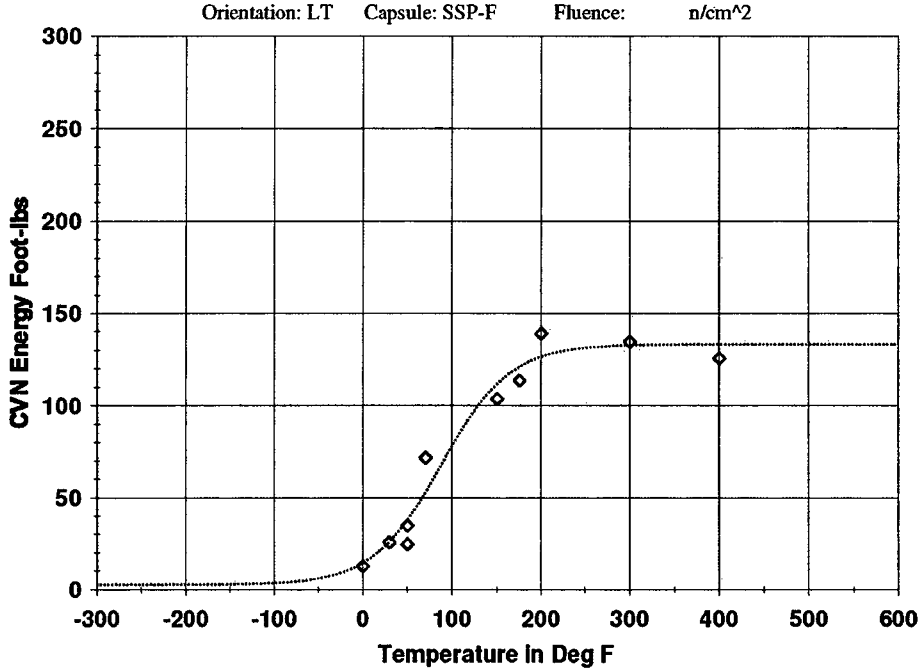
Temperature	Input CVN	Computed CVN	Differential
202.00	127.80	129.16	-1.36
250.00	142.80	134.63	8.17
400.00	140.50	136.95	3.55

Correlation Coefficient = .980

Figure A-3-3
Charpy Energy Data for Plate B0673-1 (LT) in Duane Arnold 36° Capsule (Continued)

Irradiated Plate Heat B0673-1 (SSP-F)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 01:34 PM
Page 1
Coefficients of Curve 3
A = 67.75 B = 65.25 C = 76.12 T0 = 88.09 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=133.0(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=37.9 Deg F Temp@50 ft-lbs=66.9 Deg F
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: SSP-F Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	12.50	14.24	-1.74
30.00	25.50	25.80	-.30
50.00	24.50	37.57	-13.07
50.00	34.50	37.57	-3.07
70.00	71.50	52.53	18.97
150.00	103.50	111.56	-8.06
175.00	113.50	120.93	-7.43
200.00	139.00	126.45	12.55
300.00	134.50	132.50	2.00

Figure A-3-4
Charpy Energy Data for Plate B0673-1 (LT) in SSP Capsule F

Irradiated Plate Heat B0673-1 (SSP-F)

Page 2
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: SSP-F Fluence: n/cm^2

Charpy V-Notch Data

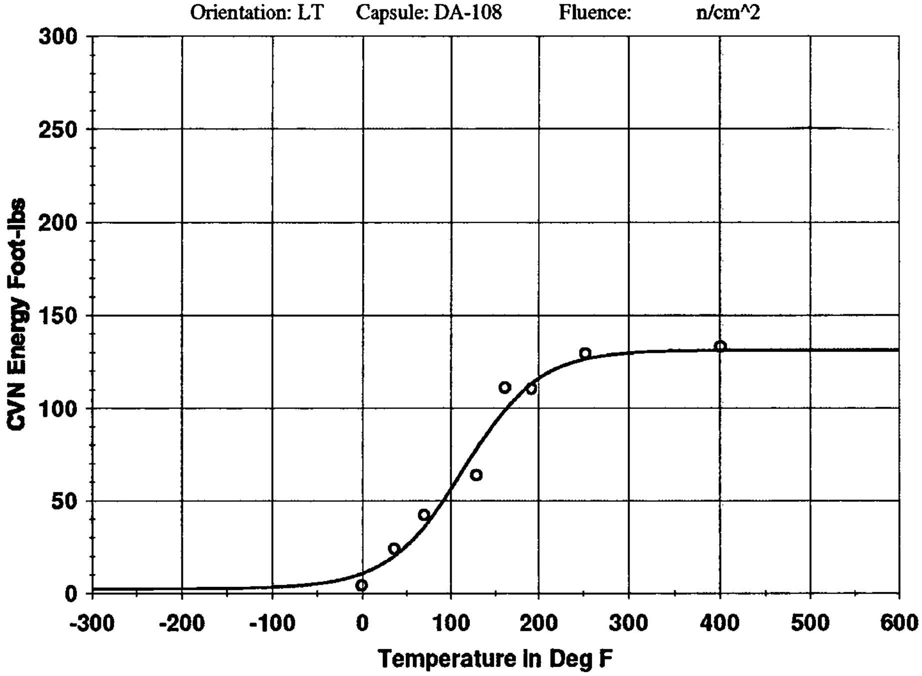
Temperature	Input CVN	Computed CVN	Differential
400.00	125.50	132.96	-7.46

Correlation Coefficient = .981

Figure A-3-4
Charpy Energy Data for Plate B0673-1 (LT) in SSP Capsule F (Continued)

Irradiated Plate Heat B0673-1 (DA1-108)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/31/2013 09:45 AM
Page 1
Coefficients of Curve 1
A = 66.9 B = 64.4 C = 85.21 T0 = 114.29 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=131.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=58.8 Deg F Temp@50 ft-lbs=91.4 Deg F
Plant: DUANE ARNOLD AND SSP Material: SA533B1 Heat: B0673-1
Orientation: LT Capsule: DA-108 Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-1.30	4.20	10.51	-6.31
35.80	23.88	20.12	3.76
69.10	42.06	35.63	6.43
128.70	63.71	77.69	-13.98
160.50	111.06	98.76	12.30
191.50	110.36	113.22	-2.86
252.00	129.48	126.41	3.07
400.80	133.11	131.15	1.96

Correlation Coefficient = .987

Figure A-3-5
Charpy Energy Data for Plate B0673-1 (LT) in Duane Arnold 108° Capsule

{{

(E)}}

Figure A-3-6
Fitted Surveillance Results for Plate Heat B0673-1

References

A-3-1. GE Nuclear Energy, "Duanc Arnold RPV Surveillance Materials Testing and Analysis," GE-NE-B1100716-01, July 1997.

A-3-2. *BWRVIP-279NP: BWR Vessel and Internals Project, Testing and Evaluation of the Duane Arnold 108° Capsule.* EPRI, Palo Alto, CA: 2014. 3002003134.

A-3-3. *BWRVIP-111NP, Revision 1: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program Capsules E, F and I.* EPRI, Palo Alto, CA: 2010. 1021554.

A-3-4. CVGRAPH, Hyperbolic Tangent Curve Fitting Program, Developed by ATI Consulting, Version 5.0.2, Revision 1, 3/26/02.

A-3-5. "Radiation Embrittlement of Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 2, May 1988.

A-3-6. "Format and Content of Report for Thermal Annealing of Reactor Pressure Vessels," USNRC Regulatory Guide 1.162, February 1996.

A-3-7. K. Wichman, M. Mitchell, and A. Hiser, USNRC, Generic Letter 92-01 and RPV Integrity Workshop Handouts, *NRC/Industry Workshop on RPV Integrity Issues*, February 12, 1998.

A-3-8. ASTM E-185, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," American Society for Testing and Materials, July 1982.

A-3-9. *BWR Vessel and Internals Project: BWR Integrated Surveillance Program Plan (BWRVIP-78).* EPRI, Palo Alto, CA and BWRVIP: 1999. TR-114228.

B-5 Weld Heat: DA1 SMAW

Summary of Available Charpy V-Notch Test Data

The available Charpy V-notch test data sets for weld heat DA1 SMAW are listed in Table B-5-1. The source documents for the data are provided, and the capsule designation and fluence values are also provided for irradiated data sets.

Table B-5-1
ISP Capsules Containing Weld Heat DA1 SMAW

Capsule	Fluence (E> 1 MeV, 10^{17} n/cm^2)	Reference
Unirradiated Baselinc Data	—	References B-5-1 and B-5-2
Duane Arnold 1 288°	5.09	
Duane Arnold 1 36°	11.7	
SSP Capsule F	19.336	Reference B-5-3
Duane Arnold 1 108°	26.3	Reference B-5-2

The CVN test data for each set taken from the references noted above are presented in Tables B-5-7 through B-5-11. The BWRVIP ISP uses the hyperbolic tangent (tanh) function as a statistical curve-fit tool to model the transition temperature toughness data. Tanh curve plots for each data set have been generated using CVGRAPH, Version 5 [Reference B-5-4] and the plots are provided in Figures B-5-1 through B-5-5.

Best Estimate Chemistry

Table B-5-2 details the best estimate average chemistry values for weld heat DA1 SMAW surveillance material. Chemical compositions are presented in weight percent. If there are multiple measurements on a single specimen, those are first averaged to yield a single value for that specimen, and then the different specimens are averaged to determine the heat best estimate.

Table B-5-2
Best Estimate Chemistry of Available Data Sets for Weld Heat DA1 SMAW

Cu (wt%)	Ni (wt%)	P (wt%)	S (wt%)	Si (wt%)	Specimen ID	Source
0.02	1.00	0.011	—	0.32	EU3 irrad	Reference B-5-1
0.02	0.90	0.010	—	0.33	EU6 irrad	
0.025	0.96	0.011	—	0.02	EJM	
0.025	0.94	0.008	—	0.02	EJJ	
0.024	0.88	0.010	—	0.02	EJA	
0.02	0.94	0.010	—	0.14	← Best Estimate Average	

Calculation of Chemistry Factor (CF):

The Chemistry Factor (CF) associated with the best estimate chemistry, as determined from U.S. NRC Regulatory Guide 1.99, Revision 2 [Reference B-5-4], Table 1 (weld metal), is:

$CF_{(DA1\ SMAW)} = 27.0°F$

Effects of Irradiation

The radiation induced transition temperature shifts for heat DA1 SMAW are shown in Table B-5-3. The T_{30} [30 ft-lb Transition Temperature], T_{50} [50 ft-lb Transition Temperature], and T_{35mil} [35 mil Lateral Expansion Temperature] index temperatures have been determined for each Charpy data set, and each irradiated set is compared to the baseline (unirradiated) index temperatures. The change in Upper Shelf Energy (USE) is also shown. The unirradiated and irradiated values are taken from the CVGRAPH fits presented at the back of this sub-appendix (only CVN energy fits are presented).

Comparison of Actual vs. Predicted Embrittlement

A predicted shift in the 30 ft-lb transition temperature (ΔT_{30}) is calculated for each irradiated data set using the Reg. Guide 1.99, Rev. 2, Regulatory Position 1.1 method. Table B-5-4 compares the predicted shift with the measured ΔT_{30} (°F) taken from Table B-5-3.

Comparison of Actual vs. Predicted Decrease in USE

Table B-5-5 compares the actual percent decrease in upper shelf energy (USE) to the predicted decrease. The predicted decrease is estimated from USNRC Regulatory Guide 1.99, Rev. 2, Figure 2; the measured percent decrease is calculated from the values presented in Table B-5-3.

Table B-5-3
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Weld Heat DA1 SMAW

Material Identity	Capsule ID	T_{30}, 30 ft-lb Transition Temperature			T_{50}, 50 ft-lb Transition Temperature			T_{35mil}, 35 mil Lateral Expansion Temperature			CVN Upper Shelf Energy (USE)		
		Unirrad (°F)	Irrad (°F)	ΔT_{30} (°F)	Unirrad (°F)	Irrad (°F)	ΔT_{50} (°F)	Unirrad (°F)	Irrad (°F)	ΔT_{35mil} (°F)	Unirrad (ft-lb)	Irrad (ft-lb)	Change (ft-lb)
DA1 and SSP DA1 SMAW	288°	-45.4	-42.8	2.6	-10.2	-14.2	-4.0	-37.3	-37.2	0.1	99.0	101.7	2.7
	36°	-45.4	-29.3	16.1	-10.2	9.1	19.3	-37.3	-5.5	31.8	99.0	95.6	-3.4
	SSP F	-45.4	-19.1	26.3	-10.2	35.5	45.7	-37.3	14.2	51.5	99.0	99.0	0.0
	108°	-45.4	-21.6	23.8	-10.2	9.1	19.3	-37.3	-2.9	34.4	99.0	119.0	20.0

Table B-5-4
Comparison of Actual Versus Predicted Embrittlement for Weld Heat DA1 SMAW

Capsule Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Measured Shift[1] °F	RG 1.99 Rev. 2 Predicted Shift[2] °F	RG 1.99 Rev. 2 Predicted Shift+Margin[2, 3] °F
DA1 288°	Weld Heat DA1 SMAW in Duane Arnold	0.509	2.6	8.0	16.0
DA1 36°	Weld Heat DA1 SMAW in Duane Arnold	1.17	16.1	12.1	24.2
SSP Capsule F	Weld Heat DA1 SMAW in SSP Capsule F	1.9336	26.3	15.1	30.3
DA1 108°	Weld Heat DA1 SMAW in Duane Arnold	2.63	23.8	17.2	34.4

Notes:

1. See Table B-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, based on each material's Cu/Ni content, and FF is Fluence Factor, $f^{0.28-0.10 \log f}$, where f = fluence (10^{19} n/cm^2, E > 1.0 MeV).
3. Margin = $2\sqrt{(\sigma_i^2 + \sigma_\Delta^2)}$, where σ_i = the standard deviation on initial RT_{NDT} (which is taken to be 0°F), and σ_Δ is the standard deviation on ΔRT_{NDT} (28°F for welds and 17°F for base materials, except that σ_Δ need not exceed 0.50 times the mean value of ΔRT_{NDT}). Thus, margin 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.

Table B-5-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Weld Heat DA1 SMAW

Capsule Identity	Material	Fluence ($x10^{18}$ n/cm^2)	Cu Content (wt%)	Measured Decrease in USE[1] (%)	RG 1.99 Rev. 2 Predicted Decrease in USE[2] (%)
DA1 288°	Weld Heat DA1 SMAW in Duane Arnold	0.509	0.02	—[3]	7.9
DA1 36°	Weld Heat DA1 SMAW in Duane Arnold	1.17	0.02	3.4	9.6
SSP Capsule F	Weld Heat DA1 SMAW in SSP Capsule F	1.9336	0.02	0	10.8
DA1 108°	Weld Heat DA1 SMAW in Duane Arnold	2.63	0.02	—[3]	11.7

Notes:

1. See Table B-5-3, (Change in USE)/(Unirradiated USE).
2. Calculated using equations in Regulatory Guide 1.162 [B-5-6] that accurately model the Charpy upper shelf energy decrease curves in Regulatory Guide 1.99, Revision 2.
3. Value less than zero.

Credibility of Surveillance Data

The credibility of the surveillance data is determined according to the guidance of Regulatory Guide 1.99, Rev. 2 and 10 CFR 50.61, as supplemented by the NRC staff [Reference B-5-7]. The following evaluation is based on the available surveillance data for irradiated weld heat DA1 SMAW. The applicability of this evaluation to a particular BWR plant must be confirmed on a plant-by-plant basis to verify there are no plant-specific exceptions to the following evaluation.

Per Regulatory Guide 1.99, Revision 2 and 10 CFR 50.61, there are 5 criteria for the credibility assessment.

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

> In order to satisfy this criterion, the representative surveillance material heat number must match the material in the vessel.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and upper shelf energy unambiguously.

> Plots of Charpy energy versus temperature for the unirradiated and irradiated condition are presented in this sub-appendix. Based on engineering judgment, the scatter in these plots is small enough to permit the determination of the 30 ft-lb temperature and the upper shelf energy. Hence, this criterion is met.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best-fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice that value. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82 [Reference B-5-8].

> For weld material DA1 SMAW, there are 4 surveillance capsule data sets currently available. The functional form of the least squares fit method as described in Regulatory Position 2.1 is utilized to determine a best-fit line for this data and to determine if the scatter of these ΔRT_{NDT} values about this line is less than 28°F for welds. Figure B-5-6 presents the best-fit line as described in Regulatory Position 2.1 utilizing the shift prediction routine from CVGRAPH, Version 5.0.2.
>
> The scatter of ΔRT_{NDT} values about the functional form of the best-fit line drawn as described in Regulatory Position 2.1 is presented in Table B-5-6.

Table B-5-6
Best Fit Evaluation for Surveillance Plate Heat DA1 SMAW

Material	Fitted CF (°F)	Capsule	FF	Measured ΔRT_{NDT} (30 ft-lb) (°F)	Best Fit ΔRT_{NDT} (°F)	Scatter of ΔRT_{NDT} (°F)	<17°F (Base Metal) <28°F (Weld metal)
DA1 SMAW	{{ (E)}}	DA1 288°	0.296	2.6	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	DA1 36°	0.449	16.1	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	SSP F°	0.561	26.3	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	DA1 108°	0.637	23.8	{{ (E)}}	{{ (E)}}	Yes

Table B-5-6 indicates that the scatter is within acceptable range for credible surveillance data. Therefore, weld heat DA1 SMAW meets this criterion.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within +/- 25°F.

BWRVIP-78 [Reference B-5-9] established the similarity of BWR plant environments in the BWR fleet. The annulus between the wall and the core shroud in the region of the surveillance capsules contains a mix of water returning from the core and feedwater. Depending on feedwater temperature, this annulus region is between 525°F and 535°F. This location of specimens with respect to the reactor vessel beltline is designed so that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperature will not differ by more than 25°F. Any plant-specific exceptions to this generic analysis should be evaluated.

Criterion 5: The surveillance data for the correlation monitor material in the capsule should fall within the scatter band of the database for that material.

Few ISP capsules contain correlation monitor material. Generally, this criterion is not applicable.

For weld heat DA1 SMAW, these criteria are satisfied (or not applicable). The surveillance data are nominally credible because the scatter criterion is met. Prior to application of the data, a plant should verify that no plant-specific exceptions to these criteria exist.

Table B-5-7
Unirradiated Charpy V-Notch Results for Surveillance Weld DA1 SMAW

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EET	-100	6.5	11.0	10
EEK	-80	5.5	10.0	15
EK3	-60	16.8	19.0	40
EK4	-50	21.5	22.0	20
EEE	-40	49.0	45.0	20
EK2	-20	58.0	57.0	50
EEL	0	52.5	50.0	30
EEY	40	65.0	61.0	50
EED	120	102.0	88.0	80
EEM	200	94.0	65.0	70
EK5	300	88.2	93.0	60
EK6	400	113.7	96.0	70

Table B-5-8
Charpy V-Notch Results for DA1 SMAW in DA1 288 Deg Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EJ1	-100	6.5	11.0	0
EJ2	-60	15.3	24.0	10
EJ4	-40	22.0	26.0	10
EE5	-20	63.5	54.0	40
EE2	40	75.2	69.0	60
EE3	120	97.2	86.0	80
EE4	200	109.0	90.0	70
EJ3	400	101.0	91.0	100

Table B-5-9
Charpy V-Notch Results for DA1 SMAW in DA1 36 Deg Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EJP	-80	7.2	6.0	25
EJL	-50	23.3	19.0	33
EJM	-25	28.0	24.0	36
EJK	0	48.9	41.0	49
EJJ	33	62.7	51.0	62
EJE	49	74.7	61.0	73
EJA	103	90.2	78.0	91
EJY	120	77.7	61.0	93
EJD	163	84.3	76.0	95
EJT	202	93.4	76.0	100
EJU	250	94.6	69.0	100
EJC	400	110.1	94.0	100

Table B-5-10
Charpy V-Notch Results for DA1 SMAW in SSP Capsule F

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EKB	-40	10.0	9.0	15
EKJ	-40	25.5	17.0	30
EKC	-20	29.5	24.0	35
EKT	0	48.5	39.0	50
EEJ	0	40.5	33.0	50
EK1	70	56.5	49.0	70
EKA	150	86.5	78.0	95
EKE	200	90.0	77.0	100
EEC	300	108.5	89.0	100
EKY	400	98.5	84.0	100

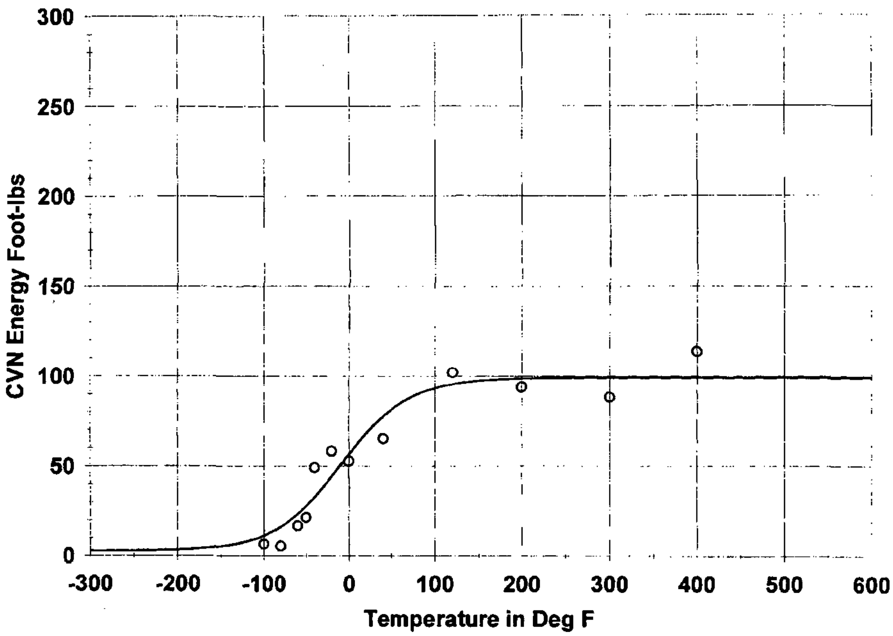
Table B-5-11
Charpy V-Notch Results for DA1 SMAW in DA1 108° Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EE1	-125.5	3.33	1.1	4.3
EE6	-59.3	9.6	11.0	15.0
EEA	-30.3	20.39	18.7	23.6
EEB	-11.4	28.08	24.5	28.4
EE7	-1.7	59.88	48.0	46.0
EJ5	69.3	86.4	67.5	84.1
EJ6	201.7	118.43	88.0	100
EJ7	398.7	119.49	92.5	100

Tanh Curve Fits of CVN Test Data for Weld Heat DA1 SMAW

DA1 SURV WELD HEAT UNK (DA1 AND SSP)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 09/09/2002 08:25 AM
Page 1
Coefficients of Curve 1
A = 50.77 B = 48.27 C = 79.1 T0 = -9. D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.0 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-45.4 Deg F Temp@50 ft-lbs=-10.2 Deg F
Plant: Duane Arnold AND SSP Material: SMAW Heat: SURV WELD HE
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	6.50	11.29	-4.79
-80.00	5.50	16.25	-10.75
-60.00	16.80	23.35	-6.55
-50.00	21.50	27.78	-6.28
-40.00	49.00	32.77	16.23
-20.00	58.00	44.10	13.90
.00	52.50	56.24	-3.74
40.00	65.00	77.36	-12.36
120.00	102.00	95.48	6.52
200.00	94.00	98.56	-4.56
300.00	88.20	99.00	-10.80

Figure B-5-1
Charpy Energy Data for Weld DA1 SMAW Unirradiated

DA1 SURV WELD HEAT UNK (DA1 AND SSP)

Page 2
Plant: Duane Arnold AND SSP Material: SMAW Heat: SURV WELD HE
Orientation: NA Capsule: UNIRRA Fluence: 0.0 n/cm^2

Charpy V-Notch Data

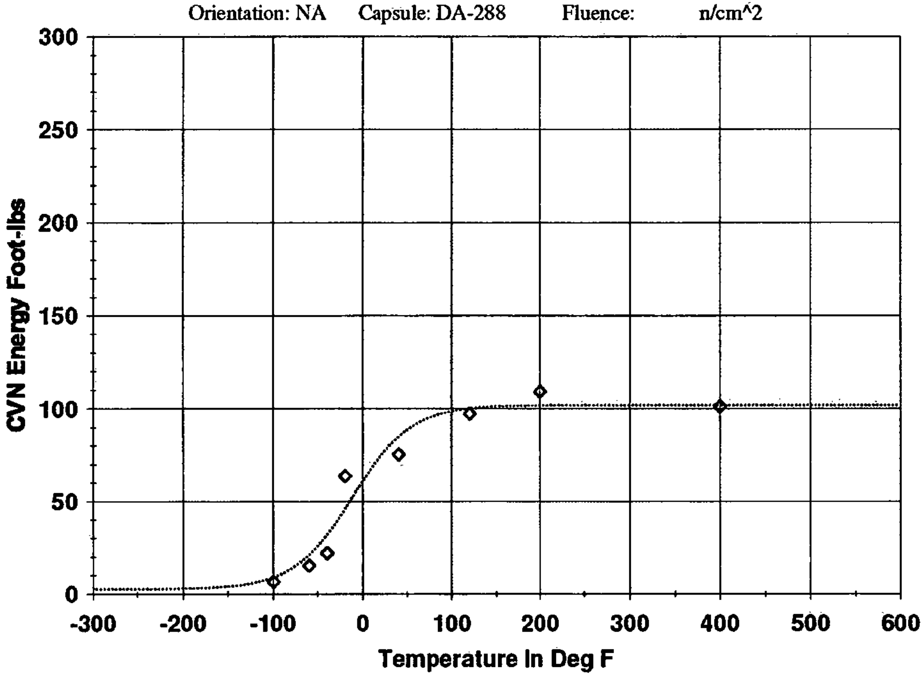
Temperature	Input CVN	Computed CVN	Differential
400.00	113.70	99.04	14.66

Correlation Coefficient = .961

Figure B-5-1
Charpy Energy Data for Weld DA1 SMAW Unirradiated (Continued)

Irradiated Weld Heat DA1 SMAW (DA1-288)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 04:51 PM
Page 1
Coefficients of Curve 3
A = 52.09 B = 49.59 C = 65.48 T0 = -11.49 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=101.7 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-42.8 Deg F Temp@50 ft-lbs=-14.2 Deg F
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: DA-288 Fluence: n/cm^2



Charpy V-Notch Data

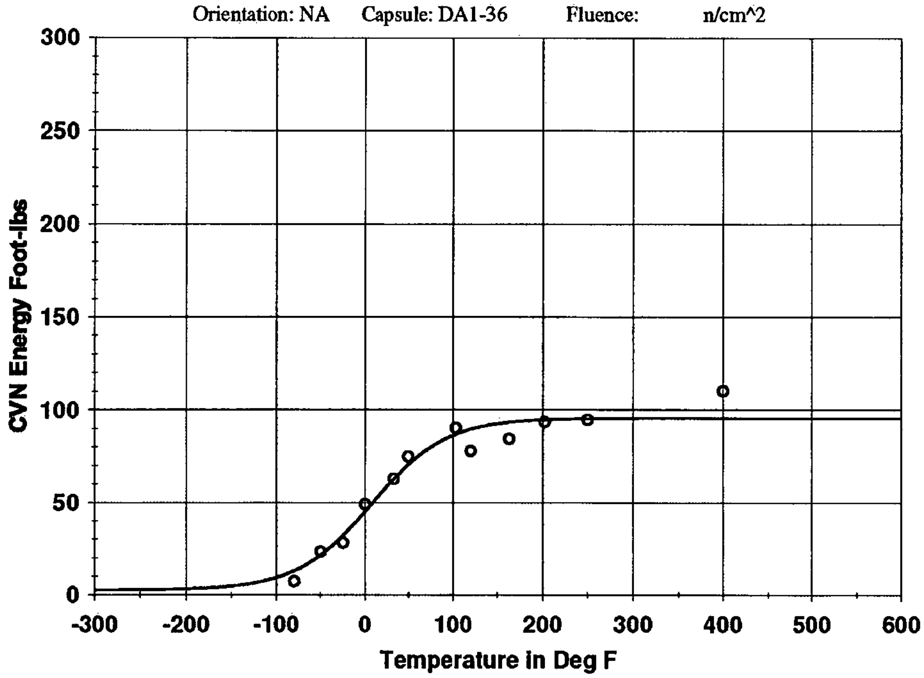
Temperature	Input CVN	Computed CVN	Differential
-100.00	6.50	8.72	-2.22
-60.00	15.30	20.86	-5.56
-40.00	22.00	31.77	-9.77
-20.00	63.50	45.68	17.82
40.00	75.20	84.64	-9.44
120.00	97.20	99.92	-2.72
200.00	109.00	101.52	7.48
400.00	101.00	101.68	-.68

Correlation Coefficient = .975

Figure B-5-2
Charpy Energy Data for Weld DA1 SMAW in DA1 288° Capsule

Irradiated Weld Heat DA1 SMAW (DA1-36)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 04:50 PM
Page 1
Coefficients of Curve 1
A = 49.05 B = 46.55 C = 84.36 T0 = 7.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=95.6(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-29.3 Deg F Temp@50 ft-lbs=9.1 Deg F
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: DA1-36 Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-80.00	7.20	12.92	-5.72
-50.00	23.30	21.52	1.78
-25.00	28.00	32.02	-4.02
.00	48.90	45.00	3.90
33.00	62.70	62.78	-.08
49.00	74.70	70.33	4.37
103.00	90.20	86.86	3.34
120.00	77.70	89.57	-11.87
163.00	84.30	93.33	-9.03

Figure B-5-3
Charpy Energy Data for Weld DA1 SMAW in DA1 36° Capsule

Irradiated Weld Heat DA1 SMAW (DA1-36)

Page 2
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: DA1-36 Fluence: n/cm^2

Charpy V-Notch Data

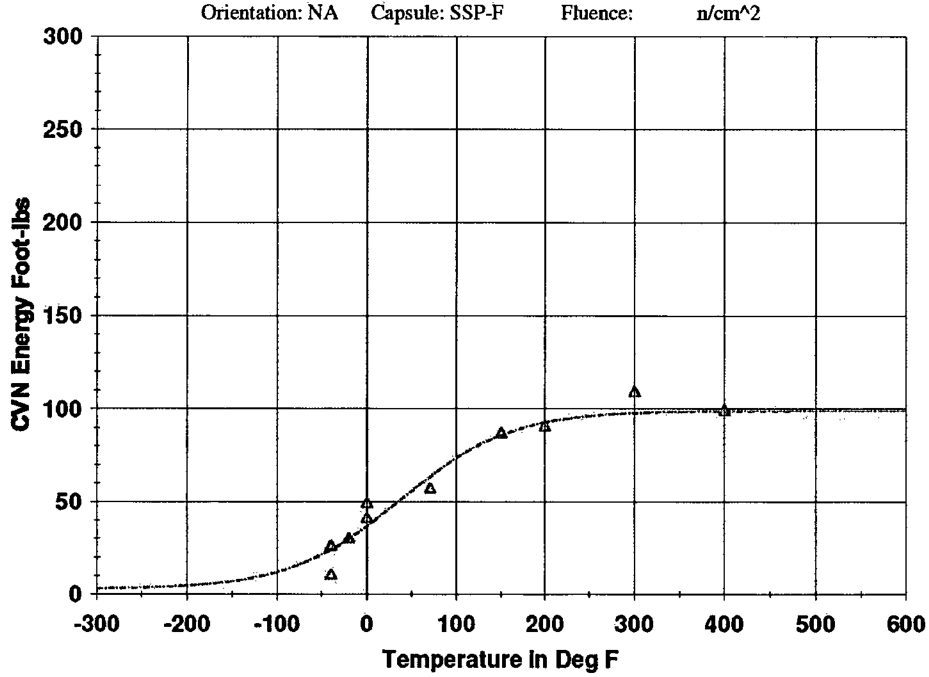
Temperature	Input CVN	Computed CVN	Differential
202.00	93.40	94.69	-1.29
250.00	94.60	95.31	-.71
400.00	110.10	95.59	14.51

Correlation Coefficient = .977

Figure B-5-3
Charpy Energy Data for Weld DA1 SMAW in DA1 36° Capsule (Continued)

Irradiated Weld Heat DA1 SMAW (SSP-F)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/17/2013 04:53 PM
Page 1
Coefficients of Curve 4
A = 50.75 B = 48.25 C = 122.89 T0 = 37.36 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=99.0(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-19.1 Deg F Temp@50 ft-lbs=35.5 Deg F
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: SSP-F Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-40.00	10.00	23.84	-13.84
-40.00	25.50	23.84	1.66
-20.00	29.50	29.73	-.23
.00	48.50	36.52	11.98
.00	40.50	36.52	3.98
70.00	56.50	63.27	-6.77
150.00	86.50	85.70	.80
200.00	90.00	92.61	-2.61
300.00	108.50	97.68	10.82

Figure B-5-4
Charpy Energy Data for Weld DA1 SMAW in SSP Capsule F

Irradiated Weld Heat DA1 SMAW (SSP-F)

Page 2
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: SSP-F Fluence: n/cm^2

Charpy V-Notch Data

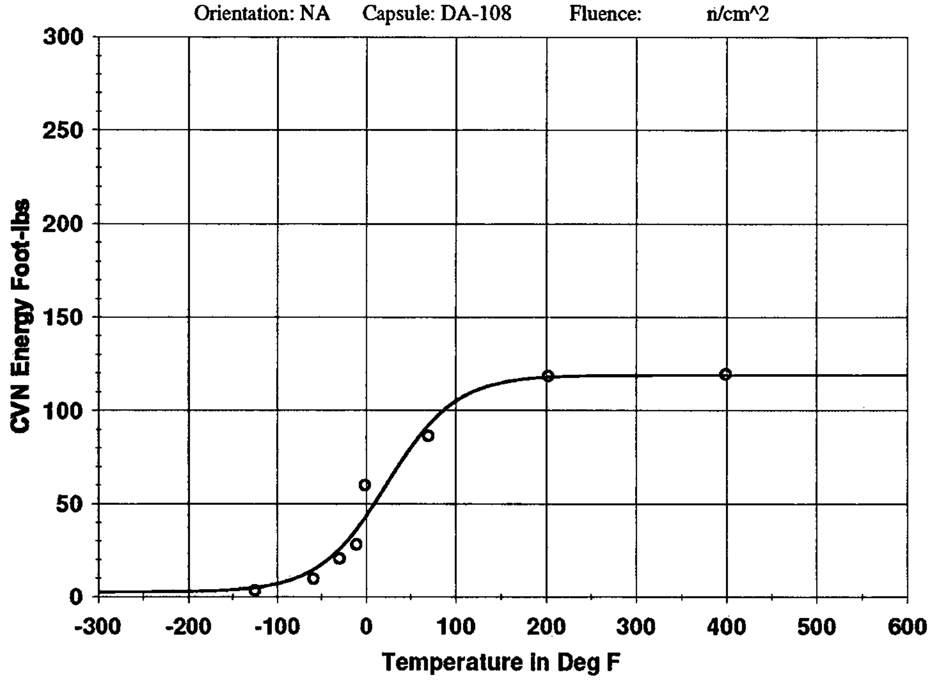
Temperature	Input CVN	Computed CVN	Differential
400.00	98.50	98.74	-.24

Correlation Coefficient = .976

Figure B-5-4
Charpy Energy Data for Weld DA1 SMAW in SSP Capsule F (Continued)

Irradiated Weld Heat DA1 SMAW (DA1-108)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 01/02/2014 10:04 PM
Page 1
Coefficients of Curve 1
A = 60.75 B = 58.25 C = 76.69 T0 = 23.34 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=119.0(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-21.6 Deg F Temp@50 ft-lbs=9.1 Deg F
Plant: DUANE ARNOLD AND SSP Material: SMAW Heat: DA1 SMAW
Orientation: NA Capsule: DA-108 Fluence: n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-125.50	3.33	4.85	-1.52
-59.30	9.60	14.60	-5.00
-30.30	20.39	25.57	-5.18
-11.40	28.08	36.03	-7.95
-1.70	59.88	42.38	17.50
69.30	86.40	92.01	-5.61
201.70	118.43	117.90	.53
398.70	119.49	118.99	.50

Correlation Coefficient = .986

Figure B-5-5
Charpy Energy Data for Weld DA1 SMAW in DA1 108° Capsule

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(E)}}

Figure B-5-6
Fitted Surveillance Results for Weld Heat DA1 SMAW

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