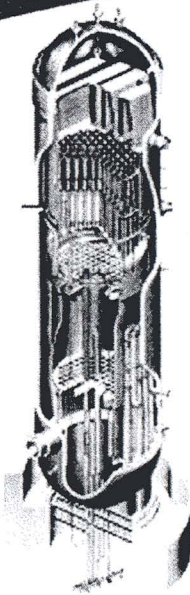


Supplement 1

BWRVIP-135, Revision 3, Cooper Specific Information, 45 pages

BWVRVIP-135, Revision 3: BWVR 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

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Cooper

Representative Surveillance Materials

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

Table 2-22
Target Vessel Materials and ISP Representative Materials for Cooper

Target Vessel Materials		ISP Representative Materials
Weld	27204/12008	20291
Plate	C2307-2	C2307-2

Summary of Available Surveillance Data: Plate

The representative plate material C2307-2 is contained in the following ISP capsules:

Cooper Capsules

Specific surveillance data related to plate heat C2307-2 are summarized in Appendix A-2. Two capsules containing this plate heat have been tested. The Charpy V-notch surveillance results are as follows:

Table 2-23
T₃₀ Shift Results for Plate Heat C2307-2

Capsule	Cu (wt%)	Ni (wt%)	Fluence (10 ¹⁷ n/cm ² , E > 1 MeV)	ΔT ₃₀ (°F)
Cooper 30°	0.21	0.76	2.4	52.2
Cooper 300°			2.8	52.2

The results given in Appendix A-2 show a fitted chemistry factor (CF) of {{ }}, as compared to a value of 164.6°F from the chemistry tables in Reg. Guide 1.99, Rev. 2. The maximum scatter in the fitted data is {{ }} 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 Cooper vessel, and because there are two irradiated data sets for this plate that fall within the 1-sigma scatter band, the ISP surveillance data in Appendix A-2 should be used to determine the projected ART value for the target vessel plate. Recommended guidelines for use of ISP surveillance data are provided in Section 3 of this Data Source Book.

An archival plate heat from the Cooper vessel, Plate Heat C2331-2, was included in the Supplemental Surveillance Program (SSP), and irradiated data from SSP Capsules D, G, E, I, A, and B are provided in Appendix A-19. The credible surveillance data should be considered when a revised ART is calculated for vessel heat C2331-2.

Summary of Available Surveillance Data: Weld

The representative weld material 20291 is contained in the following ISP capsules:

Cooper Capsules

SSP Capsule C

Specific surveillance data related to weld heat 20291 are presented in Appendix B-2 and the results are summarized below. Three capsules containing weld heat 20291 have been tested. The Charpy V-notch surveillance results are as follows:

Table 2-24
T₃₀ Shift Results for Weld Heat 20291

Capsule	Cu (wt%)	Ni (wt%)	Fluence (10 ¹⁷ n/cm ² , E > 1 MeV)	ΔT ₃₀ (°F)
Cooper 30°	0.23	0.75	2.4	60.9
Cooper 300°			2.8	63.8
SSP C			3.29	73.0

The results given in Appendix B-2 show a fitted chemistry factor (CF) of $\left\{ \left\{ \frac{194.5}{\text{CF}} \right\} \right\}$, as compared to a value of 194.5°F from the chemistry tables in Reg. Guide 1.99, Rev. 2. The maximum scatter in the fitted data 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 Cooper 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. Cooper surveillance weld heat 20291 is not in the Cooper vessel beltline. Recommended guidelines for evaluation of ISP surveillance data are provided in Section 3 of this Data Source Book.

A-2 Plate Heat: C2307-2

Summary of Available Charpy V-Notch Test Data

The available Charpy V-notch test data sets for plate heat C2307-2 are listed in Table A-2-1. The source documents for the data are provided, and the capsule designations and fluence values are also provided for irradiated data sets.

Table A-2-1
ISP Capsules Containing Plate Heat C2307-2

Capsule	Fluence ($E > 1 \text{ MeV}, 10^{17} \text{ n/cm}^2$)	Reference
Unirradiated Baseline Data	—	Reference A-2-1
Cooper 300°	2.8	
Cooper 30°	2.4 ¹	Reference A-2-2

¹ From Reference [A-2-1], which updated and superseded the fluence provided by Reference [A-2-2] for this capsule.

The CVN test data for each set taken from the references noted above are presented in Tables A-2-7 through A-2-9. 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-2-3] and the plots are provided in Figures A-2-1 through A-2-3.

Best Estimate Chemistry

Table A-2-2 details the best estimate average chemistry values for plate heat C2307-2 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-2-2
Best Estimate Chemistry of Available Data Sets for Plate Heat C2307-2

Cu (wt%)	Ni (wt%)	P (wt%)	S (wt%)	Si (wt%)	Specimen ID	Source
0.21	0.73	0.010	0.014	0.20	Plate CMTR	Reference A-2-2 and A-2-4
0.22	0.77	0.007	—	—	J64	Reference A-2-2 and A-2-4
0.22	0.78	0.006	—	—	J6L	
0.21	0.76	0.011	—	—	J63	Reference A-2-1
0.21	0.75	0.011	—	—	J6M	
0.21	0.76	0.009	0.014	0.20	← 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-2-5], Table 2 (base metal), is:

$$CF_{(C2307-2)} = 164.6^\circ\text{F}$$

Effects of Irradiation

The radiation induced transition temperature shifts for heat C2307-2 are shown in Table A-2-3. The T_{30} [30 ft-lb Transition Temperature], T_{50} [50 ft-lb Transition Temperature], and $T_{35\text{mil}}$ [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-2-4 compares the predicted shift with the measured ΔT_{30} (°F) taken from Table A-2-3.

Comparison of Actual vs. Predicted Decrease in USE

Table A-2-5 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-2-3.

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-2-6]. The following evaluation is based on the available surveillance data for irradiated plate heat C2307-2. 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.

Table A-2-3
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Plate Heat C2307-2

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)
CPR C2307-2	30°	-43.0	9.2	52.2	-12.8	47.7	60.5	-27.5	7.0	34.5	132.6	124.9	-7.7
	300°	-43.0	9.2	52.2	-12.8	43.9	56.7	-27.5	33.0	60.5	132.6	125.8	-6.8

Table A-2-4
Comparison of Actual Versus Predicted Embrittlement for Plate Heat C2307-2

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
CPR 30°	Plate Heat C2307-2 in Cooper	0.24	52.2	31.7	63.3
CPR 300°	Plate Heat C2307-2 in Cooper	0.28	52.2	34.7	68.7

Notes:

- See Table A-2-3, ΔT₃₀.
- 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 (10¹⁹ n/cm², E > 1.0 MeV).
- Margin = $2\sqrt{(\sigma_i^2 + \sigma_\Delta^2)}$, where σ_i = the standard deviation on initial RT_{NOT} (which is taken to be 0°F), and σ_Δ is the standard deviation on ΔRT_{NOT} (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_{NOT}). 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-2-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Plate Heat C2307-2

Capsule Identity	Material	Fluence ($\times 10^{18}$ n/cm ²)	Cu Content (wt%)	Measured Decrease in USE ¹ (%)	RG 1.99 Rev. 2 Predicted Decrease in USE ² (%)
CPR 30°	Plate Heat C2307-2 in Cooper	0.24	0.21	5.8	12.4
CPR 300°	Plate Heat C2307-2 in Cooper	0.28	0.21	5.1	12.9

Notes:

1. See Table A-2-3, (Change in USE)/(Unirradiated USE).
2. Calculated using equations in Regulatory Guide 1.162 [A-2-7] that accurately model the Charpy upper shelf energy decrease curves in Regulatory Guide 1.99, Revision 2.

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-2-8]

For plate material C2307-2, there are 2 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-2-4 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-2-6.

Table A-2-6
Best Fit Evaluation for Surveillance Plate Heat C2307-2

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)
C2307-2	{{ }}	30°	0.192	52.20	{{ }}	{{ }}	Yes
	{{ }}	300°	0.211	52.20	{{ }}	{{ }}	Yes

Table A-2-6 indicates that the scatter is within acceptable range for credible surveillance data. Therefore, plate heat C2307-2 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-2-9] 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 C2307-2, 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-2-7
Unirradiated Charpy V-Notch Results for Surveillance Plate C2307-2 (LT)

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EP4	-100	8	6	9
EPE	-60	10	11	14
EPP	-50	21	20	16
ET4	-40	41	35	28
EPL	-40	33	29	25
EPK	-30	44.5	37	30
EPJ	-20	45.5	40	30
EUK	20	72.5	60	42
ETE	60	108	79	75
EU5	100	114	83	87
EUA	150	132	92	100
EUB	200	133	88	100

Table A-2-8
Charpy V-Notch Results for C2307-2 (LT) in CPR 30° Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EUD	-20	13.5	22.0	10
ETK	0	27.5	31.0	10
EPM	10	32.5	39.0	10
EPC	20	38.5	42.0	15
EPA	40	45.0	49.0	30
ETT	60	55.0	49.0	40
EUC	80	73.0	64.0	50
EU1	120	86.5	64.0	85
EP7	160	112.0	88.0	80
EP3	200	117.7	78.0	90
EU6	300	121.7	93.0	90
ETB	400	125.3	95.0	100

Table A-2-9
Charpy V-Notch Results for C2307-2 (LT) in CPR 300° Capsule

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EP1	-20	18	12	11
EU7	0	24	18	27
EP6	20	42.5	33	25
EPD	60	53.5	46	30
EUJ	100	91	68	63
ETD	150	111	83	83
EU3	200	119	88	100
EU4	300	125	76	100

Tanh Curve Fits of CVN Test Data for Plate Heat C2307-2

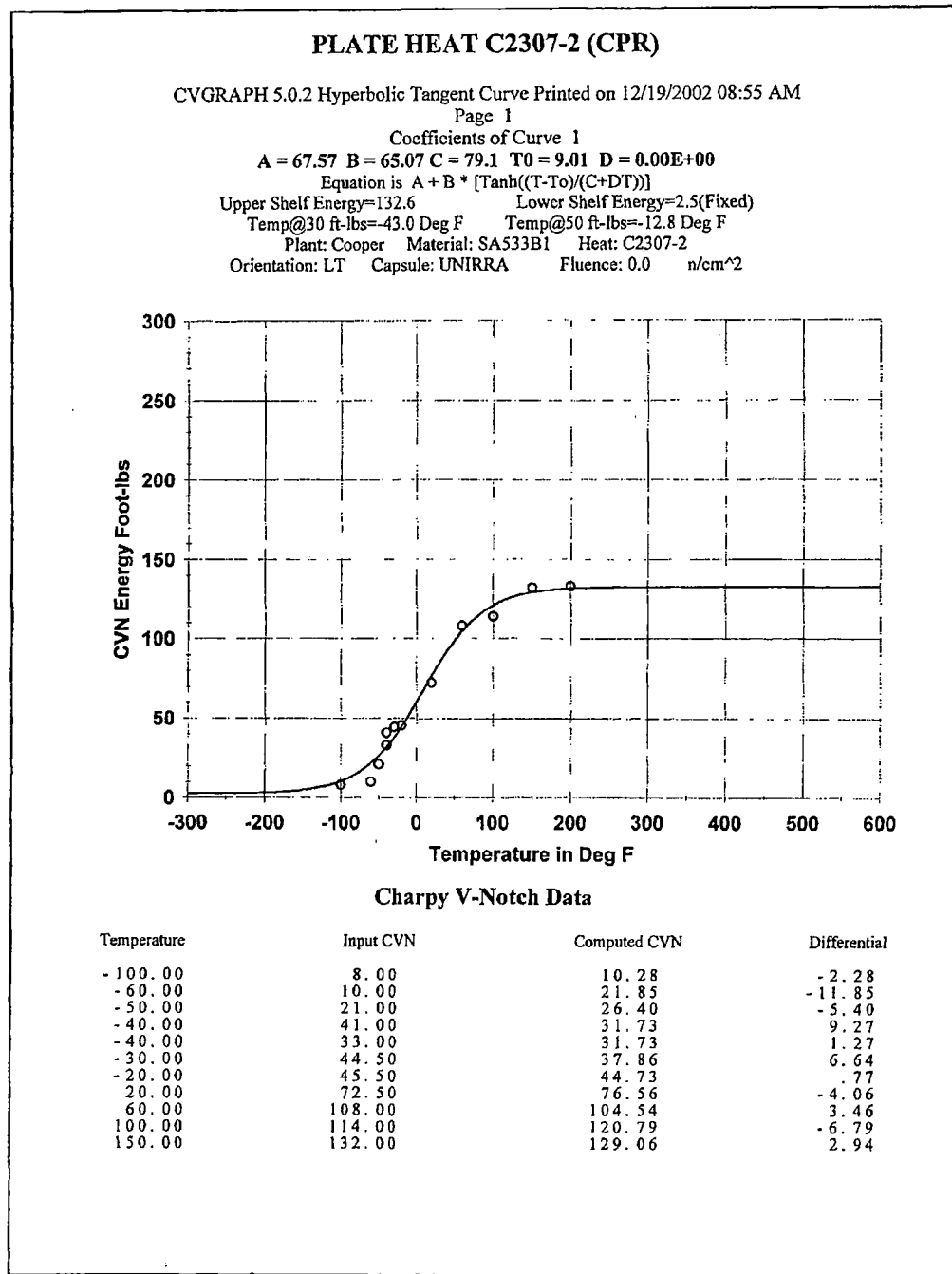


Figure A-2-1
Charpy Energy Data for Plate C2307-2 (LT) Unirradiated

PLATE HEAT C2307-2 (CPR)

Page 2

Plant: Cooper Material: SA533B1 Heat: C2307-2
Orientation: LT Capsule: UNIRRA Fluence: 0.0 n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
200.00	133.00	131.61	1.39

Correlation Coefficient = .992

Figure A-2-1
Charpy Energy Data for Plate C2307-2 (LT) Unirradiated (Continued)

IRRADIATED PLATE HEAT C2307-2 (CPR-30)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/22/2003 08:24 PM

Page 1

Coefficients of Curve 1

A = 63.68 B = 61.18 C = 98.32 T0 = 70.05 D = 0.00E+00

Equation is $A + B * [\text{Tanh}((T-T_0)/(C+DT))]$

Upper Shelf Energy=124.9

Lower Shelf Energy=2.5(Fixed)

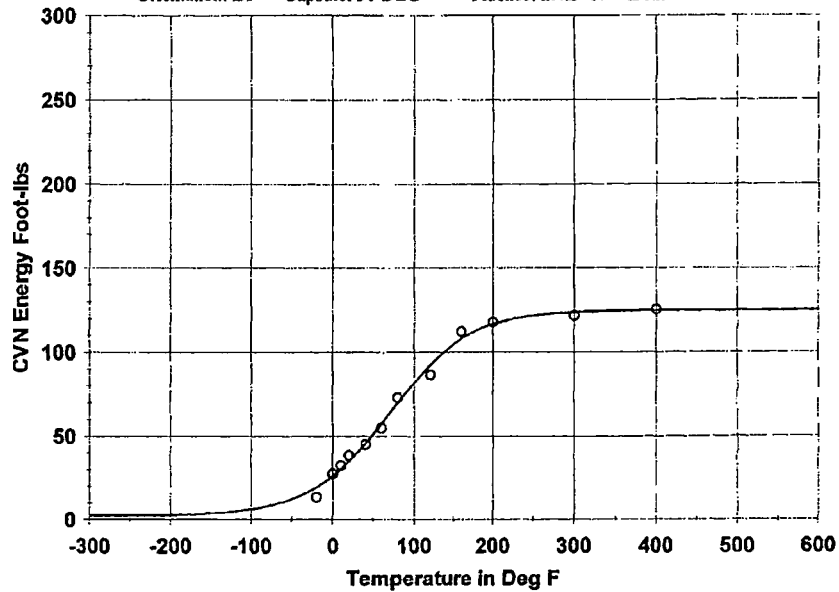
Temp@30 ft-lbs=9.2 Deg F

Temp@50 ft-lbs=47.7 Deg F

Plant: COOPER Material: SAS33B1 Heat: C2307-2

Orientation: LT Capsule: 30 DEG

Fluence: 2.4E+17 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.00	13.50	19.39	-5.89
0.00	27.50	26.22	1.28
10.00	32.50	30.36	2.14
20.00	38.50	34.97	3.53
40.00	45.00	45.54	-0.54
60.00	55.00	57.45	-2.45
80.00	73.00	69.85	3.15
120.00	86.50	92.34	-5.84
160.00	112.00	107.94	4.06

Figure A-2-2

Charpy Energy Data for Plate C2307-2 (LT) in CPR 30° Capsule

IRRADIATED PLATE HEAT C2307-2 (CPR-30)

Page 2

Plant: COOPER Material: SA533B1 Heat: C2307-2
Orientation: LT Capsule: 30 DEG Fluence: 2.4E+17 n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
200.00	117.70	116.73	.97
300.00	121.70	123.73	-2.03
400.00	125.30	124.71	.59

Correlation Coefficient = .997

Figure A-2-2
Charpy Energy Data for Plate C2307-2 (LT) in CPR 30° Capsule (Continued)

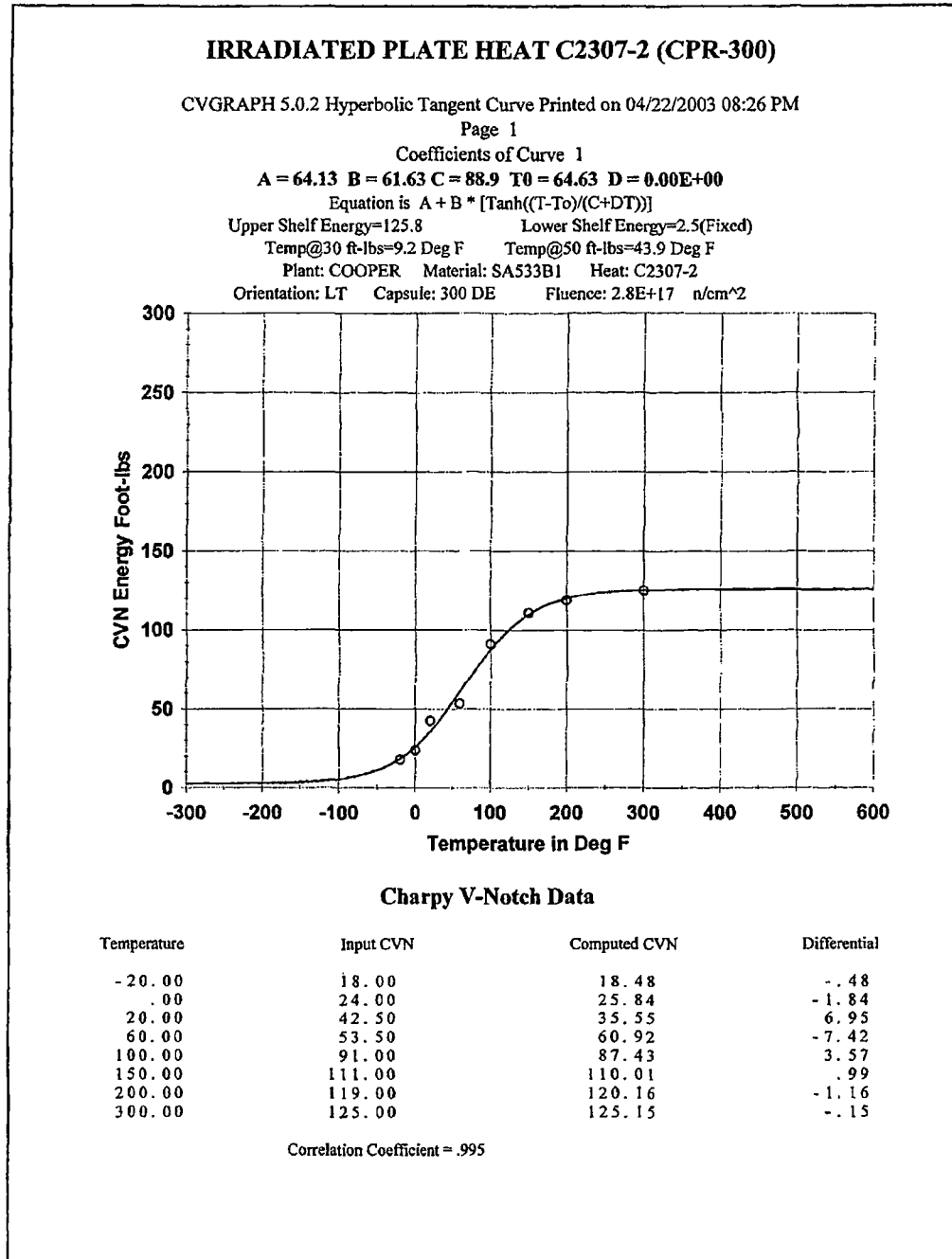


Figure A-2-3
Charpy Energy Data for Plate C2307-2 (LT) in CPR 300° Capsule

{{

(E)}}}

Figure A-2-4
Fitted Surveillance Results for Plate Heat C2307-2

References

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- A-2-2. "Cooper Nuclear Station Reactor Pressure Vessel Surveillance Materials Testing and Fracture Toughness Analysis," T.A. Caine, B.J. Branlund, and S. Ranganath, General Electric, MDE-103-0986, DRF B13-01389, May 1987.
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- A-2-4. Letter from G.R. Horn (NPPD) to USNRC, "Response to Generic Letter 92-01, Revision 1, Cooper Nuclear Station, NRC Docket No. 50-298, DPR-44," Nebraska Public Power District, NSD920629, dated July 1, 1992.
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- A-2-6. 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-2-7. "Format and Content of Report for Thermal Annealing of Reactor Pressure Vessels," USNRC Regulatory Guide 1.162, February 1996.
- A-2-8. 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-2-9. *BWR Vessel and Internals Project: BWR Integrated Surveillance Program Plan (BWRVIP-78)*. EPRI, Palo Alto, CA and BWRVIP: 1999. TR-114228.

A-19 Plate Heat: C2331-2

Summary of Available Charpy V-Notch Test Data

The available Charpy V-notch test data sets for plate heat C2331-2 are listed in Table A-19-1. The source documents for the data are provided, and the capsule designation and fluence values are also provided for irradiated data sets.

Table A-19-1
ISP Capsules Containing Plate Heat C2331-2

Capsule	Fluence ($E > 1 \text{ MeV}, 10^{17} \text{ n/cm}^2$)	Reference
Unirradiated Baseline Data	—	Reference A-19-1
SSP D	10.118	Reference A-19-2
SSP G	18.487	
SSP E	17.192	Reference A-19-3
SSP I	27.085	
SSP A	3.82	Reference A-19-12
SSP B	4.79	Reference A-19-12

The CVN test data for each set taken from the references noted above are presented in Tables A-19-7 through A-19-13. 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-19-4] and the plots are provided in Figures A-19-1 through A-19-7.

Best Estimate Chemistry

Table A-19-2 details the best estimate average chemistry values for plate heat C2331-2 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-19-2
Best Estimate Chemistry of Available Data Sets for Plate Heat C2331-2

Cu (wt%)	Ni (wt%)	P (wt%)	S (wt%)	Si (wt%)	Specimen ID	Source
0.17	0.58	0.01	0.017	0.22	CMTR	Reference A-19-5
0.15	0.69	0.022	0.023	0.25	SSP	Reference A-19-1
0.15	0.64	0.012	—	—	SSP	
0.15	0.665	0.017	0.023	0.25	SSP Average	
0.16	0.62	0.014	0.020	0.24	←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-19-6], Table 2 (base metal), is:

$$CF_{(C2331-2)} = 118.5^{\circ}\text{F}$$

Effects of Irradiation

The radiation induced transition temperature shifts for heat C2331-2 are shown in Table A-19-3. The T_{30} [30 ft-lb Transition Temperature], T_{50} [50 ft-lb Transition Temperature], and $T_{35\text{mil}}$ [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 end 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-19-4 compares the predicted shift with the measured ΔT_{30} ($^{\circ}\text{F}$) taken from Table A-19-3.

Decrease in USE

Table A-19-5 shows the percent decrease in upper shelf energy (USE). The measured percent decrease is calculated from the values presented in Table A-19-3.

Table A-19-3
Effect of Irradiation (E>1.0 MeV) on the Notch Toughness Properties of Plate Heat C2331-2

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)
CPR C2331-2	SSP D	-13.3	48.7	62.0	30.1	92.8	62.7	34.1	86.3	52.2	100.0	89.3	-10.7
	SSP G	-13.3	78.7	92.0	30.1	127.2	97.1	34.1	118.2	84.1	100.0	81.6	-18.4
	SSP E	-13.3	62.8	76.1	30.1	105.8	75.7	34.1	124.2	90.1	100.0	82.3	-17.7
	SSP I	-13.3	80.4	93.7	30.1	128.8	98.7	34.1	128.3	94.2	100.0	80.3	-19.7
	SSP A	-13.3	28.2	41.5	30.1	77.9	47.8	34.1	44.4	10.3	100.0	91.0	-9.0
	SSP B	-13.3	21.4	34.7	30.1	62.5	32.4	34.1	39.2	5.1	100.0	97.7	-2.3

Table A-19-4
Comparison of Actual Versus Predicted Embrittlement for Plate Heat C2331-2

Capsule Identity	Material	Fluence (x10 ¹⁸ n/cm ²)	Fluence Factor	Measured Shift ¹ °F	RG 1.99 Rev. 2 Predicted Shift ² °F	RG 1.99 Rev. 2 Predicted Shift+Margin ^{2,3} °F
SSP D	Plate Heat C2331-2 from Cooper	1.0118	0.419	62.0	49.7	83.7
SSP G		1.8487	0.551	92.0	65.3	99.3
SSP E		1.7192	0.534	76.1	63.3	97.3
SSP I		2.7085	0.644	93.7	76.3	110.3
SSP A		0.382	0.252	41.5	29.9	59.8
SSP B		0.479	0.286	34.7	33.9	67.8

Notes:

- See Table A-19-3, ΔT₃₀.
- 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, $f^{0.22-0.10 \log f}$, where f = fluence (10¹⁹ n/cm², E > 1.0 MeV).
- 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-19-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Plate Heat C2331-2

Capsule Identity	Material	Fluence ($\times 10^{18}$ n/cm ²)	Cu Content (wt%)	Measured Decrease in USE ¹ (%)	RG 1.99 Rev. 2 Predicted Decrease in USE ² (%)
SSP D	Plate Heat C2331-2 in Cooper	1.0118	0.16	10.7	14.5
SSP G		1.8487	0.16	18.4	16.8
SSP E		1.7192	0.16	17.7	16.5
SSP I		2.7085	0.16	19.7	18.3
SSP A		0.382	0.16	9.0	11.5
SSP B		0.479	0.16	2.3	12.2

Notes:

1. See Table A-19-3, (Change in USE)/(Unirradiated USE).
2. Calculated using equations in Regulatory Guide 1.162 [A-19-7] that accurately model the Charpy upper shelf energy decrease curves in Regulatory Guide 1.99, Revision 2.

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-19-8]. The following evaluation is based on the available surveillance data for irradiated plate heat C2331-2. 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 Figures A-19-1 through A-19-7. 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-19-9].

For plate material C2331-2, there are 6 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-19-8 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-19-6.

Table A-19-6
Best Fit Evaluation for Surveillance Plate Heat C2331-2

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)
C2331-2	{ }	SSP D	0.419	62.0	{ }	{ }	Yes
		SSP G	0.551	92.0	{ }	{ }	Yes
		SSP E	0.534	76.1	{ }	{ }	Yes
		SSP I	0.644	93.7	{ }	{ }	Yes
		SSP A	0.252	41.5	{ }	{ }	Yes
		SSP B	0.286	34.7	{ }	{ }	Yes

Table A-19-6 indicates that the scatter is within acceptable range for credible surveillance data. Therefore, plate heat C2331-2 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-19-11] 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 C2331-2, 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-19-7
Unirradiated Charpy V-Notch Results for Surveillance Plate C2331-2 (TL)

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
SSP 1	-80	12.0	5.0	3
SSP 2	-60	15.5	5.0	0
SSP 3	-40	24.5	12.5	19
SSP 4	-20	20.0	13.0	16
SSP 5	-20	31.5	20.0	20
SSP 6	0	43.5	28.5	23
SSP 7	20	46.0	29.5	30
SSP 8	40	52.5	32.5	49
SSP 9	60	53.5	37.0	47
SSP 10	60	49.5	37.0	44
SSP 11	80	91.5	67.5	87
SSP 12	100	86.0	63.0	89
SSP 13	180	97.0	70.0	100
SSP 14	300	97.0	73.0	100
SSP 15	400	106.0	73.5	100

Table A-19-8
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule D

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
1	0	9	8	5
2	25	24.5	21	10
3	50	28	19	15
4	75	50.5	39	20
5	100	49	37	40
6	150	68	51	90
7	200	83.75	57	100
8	250	92.5	65	100
9	300	94	71	100
10	400	87	71	100

Table A-19-9
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule G

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
1	25	18.5	15	5
2	75	33.5	24	20
3	100	35.5	27	10
4	125	41.5	35	35
5	140	51.5	37	40
6	150	63.5	47	70
7	200	76	57	100
8	250	84.5	58	100
9	300	83	70	100
10	400	83	65	100

Table A-19-10
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule E

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
EP130C	0	10.5	1	0
EP130E	40	28.0	12	15
EP130A	70	27.5	17	30
EP130H	100	49.0	27	55
EP130D	125	54.5	32	50
EP130F	150	68.5	43	90
EP130B	200	80.0	55	100
EP130G	225	82.0	54	100
EP130I	250	81.5	61	100
EP130J	300	85.5	59	100

Table A-19-11
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule I

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
IP130B	0	8.5	2.0	0
IP130J	30	20.0	8.0	5
IP130A	70	27.5	14.0	20
IP130H	100	30.0	18.0	30
IP130G	125	50.5	37.0	55
IP130C	150	60.0	46.0	65
IP130D	200	71.5	54.0	85
IP130I	250	77.5	59.0	100
IP130E	300	83.0	69.0	100
IP130F	400	80.5	64.0	100

Table A-19-12
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule A

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
AP1-30-10	-40.36	10.07	10.5	8.3
AP1-30-8	-20.56	15.78	16.0	11.9
AP1-30-7	19.94	30.17	28.5	21
AP1-30-9	19.94	33.14	30.5	20.7
AP1-30-1	67.64	39.22	39.0	26.9
AP1-30-2	110.84	57.99	52.0	47.4
AP1-30-3	160.70	85.95	73.0	99
AP1-30-4	250.88	88.94	77.0	100
AP1-30-5	300.74	90.17	73.0	100
AP1-30-6	399.56	99.00	76.5	100

Table A-19-13
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule B

Spec ID	Temp (°F)	CVN (ft-lb)	LE (mils)	%Shear
BP1-30-8	-20.20	10.03	10.0	9.3
BP1-30-10	0.32	27.15	26.0	16.6
BP1-30-7	20.48	35.30	31.0	19
BP1-30-1	68.00	46.36	39.5	36.2
BP1-30-9	89.60	60.70	55.5	37.7
BP1-30-2	120.74	82.25	66.0	73.8
BP1-30-3	180.32	90.96	72.0	100
BP1-30-4	249.44	100.08	81.0	100
BP1-30-5	299.66	99.12	77.0	100
BP1-30-6	400.28	100.70	74.5	100

Tanh Curve Fits of CVN Test Data for Plate Heat C2331-2

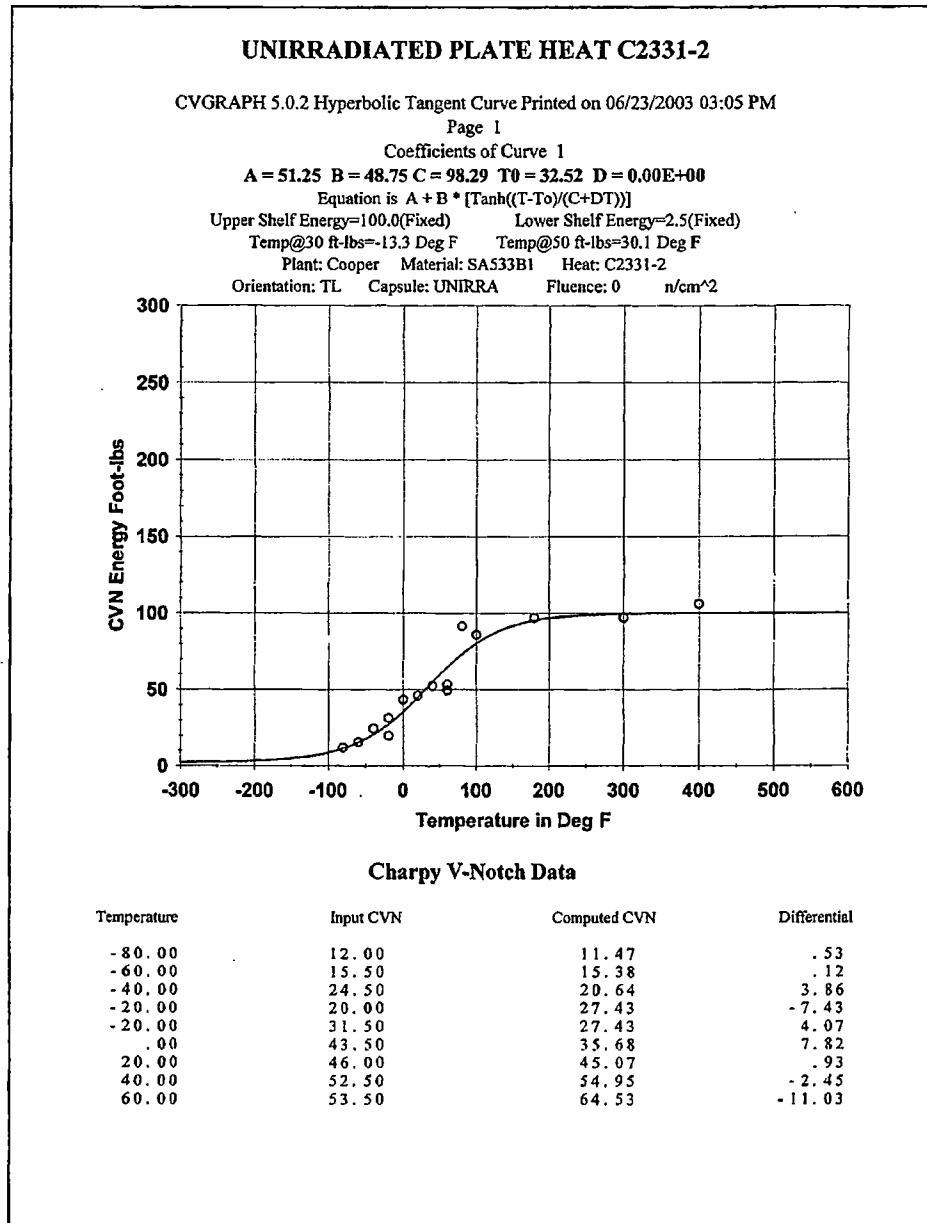


Figure A-19-1
Cooper Unirradiated Plate Heat C2331-2 Charpy Energy Plot

UNIRRADIATED PLATE HEAT C2331-2

Page 2

Plant: Cooper Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: UNIRRA Fluence: 0 n/cm²

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 A-19-1
Cooper Unirradiated Plate Heat C2331-2 Charpy Energy Plot (Continued)

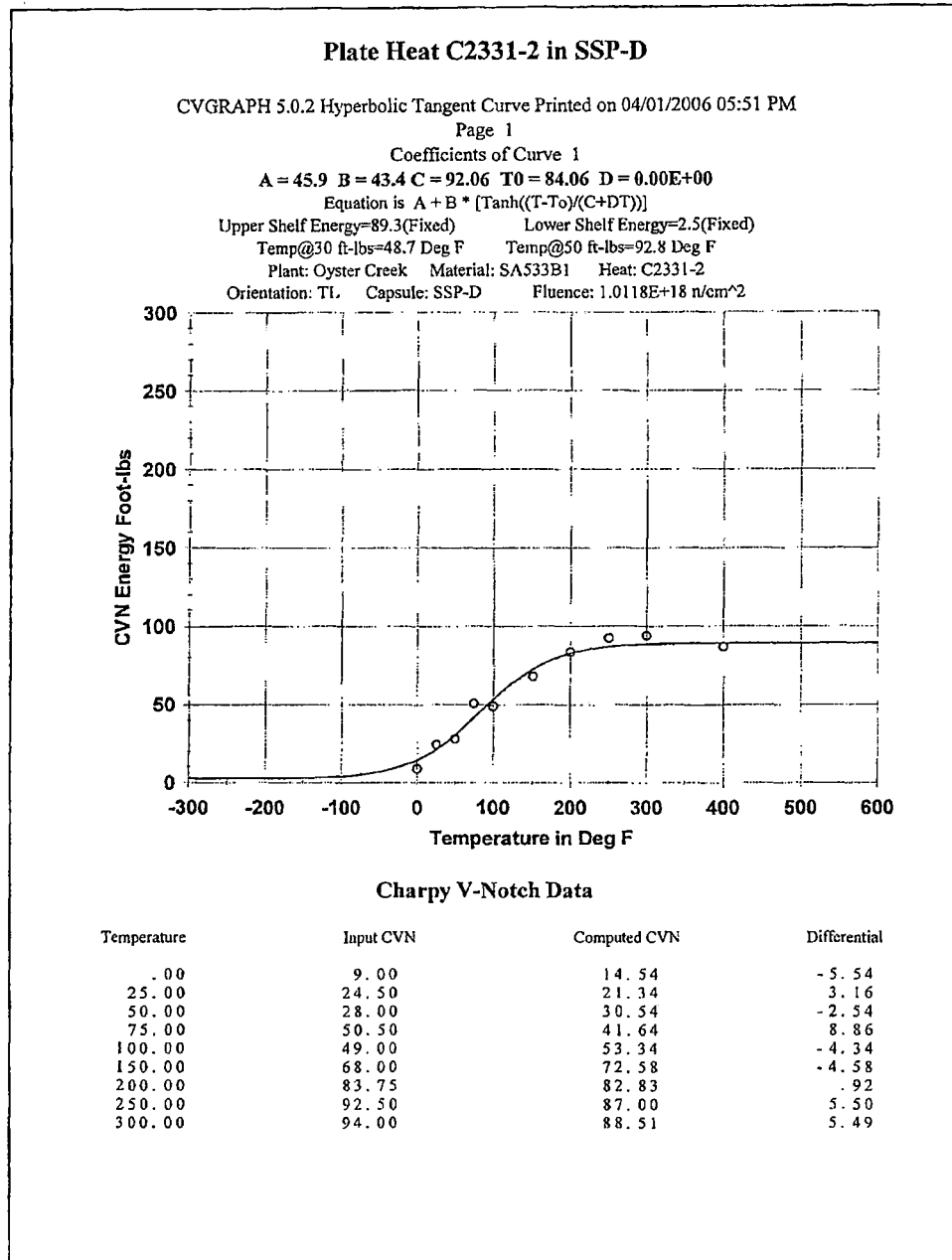


Figure A-19-2
Cooper Irradiated Plate Heat C2331-2 (SSP-D) Charpy Energy Plot

Plate Heat C2331-2 in SSP-D

Page 2

Plant: Oyster Creek Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-D Fluence: 1.0118E+18 n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.00	87.00	89.21	-2.21

Correlation Coefficient = .987

Figure A-19-2
Cooper Irradiated Plate Heat C2331-2 (SSP-D) Charpy Energy Plot (Continued)

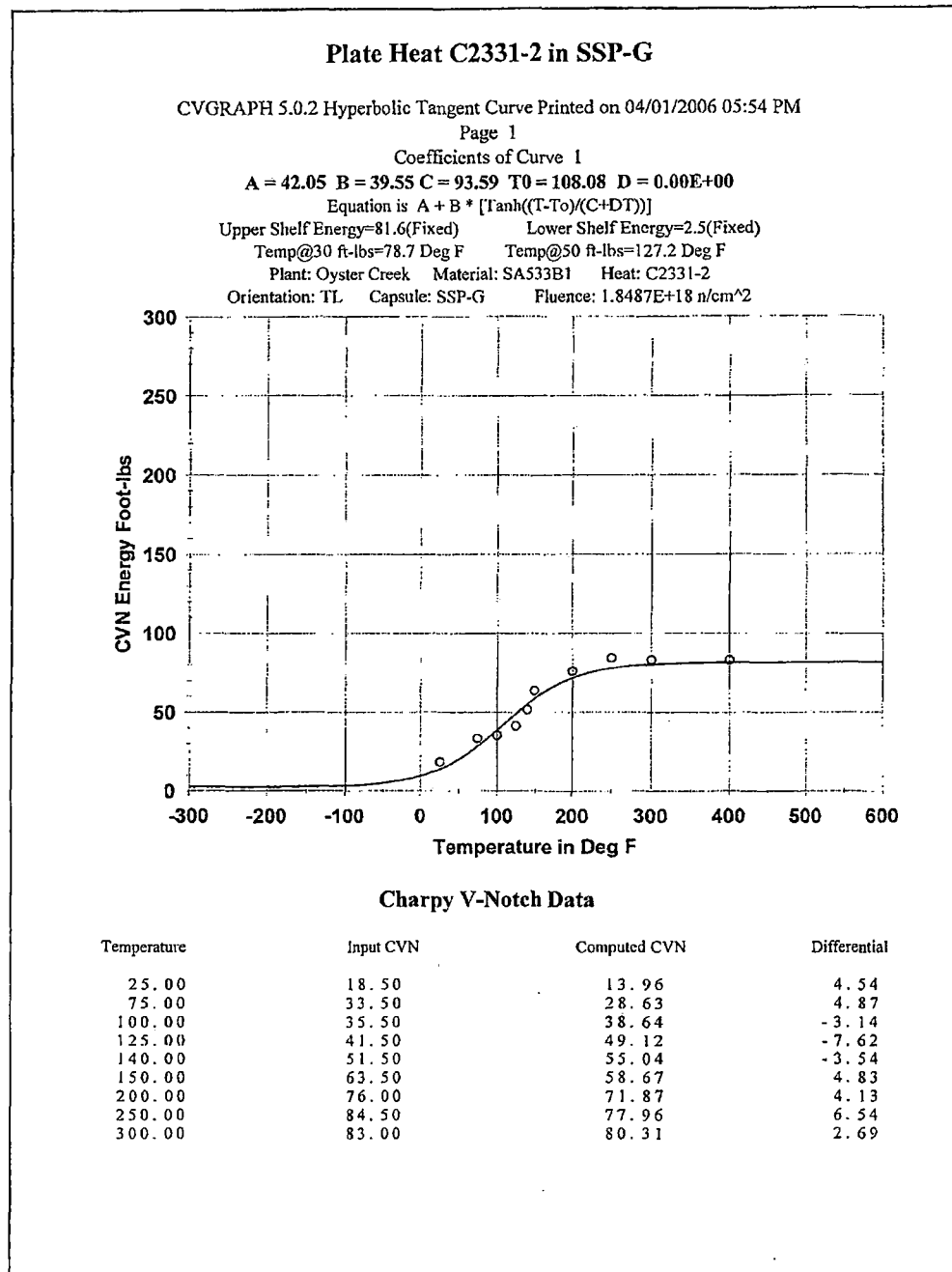


Figure A-19-3
Cooper Irradiated Plate Heat C2331-2 (SSP-G) Charpy Energy Plot

Plate Heat C2331-2 in SSP-G

Page 2

Plant: Oyster Creek Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-G Fluence: $1.8487\text{E}+18$ n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.00	83.00	81.45	1.55

Correlation Coefficient = .982

Figure A-19-3
Cooper Irradiated Plate Heat C2331-2 (SSP-G) Charpy Energy Plot (Continued)

IRRADIATED PLATE HEAT C2331-2 (SSP-E)

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

Page 1

Coefficients of Curve 1

A = 42.4 B = 39.9 C = 83.62 T0 = 89.63 D = 0.00E+00

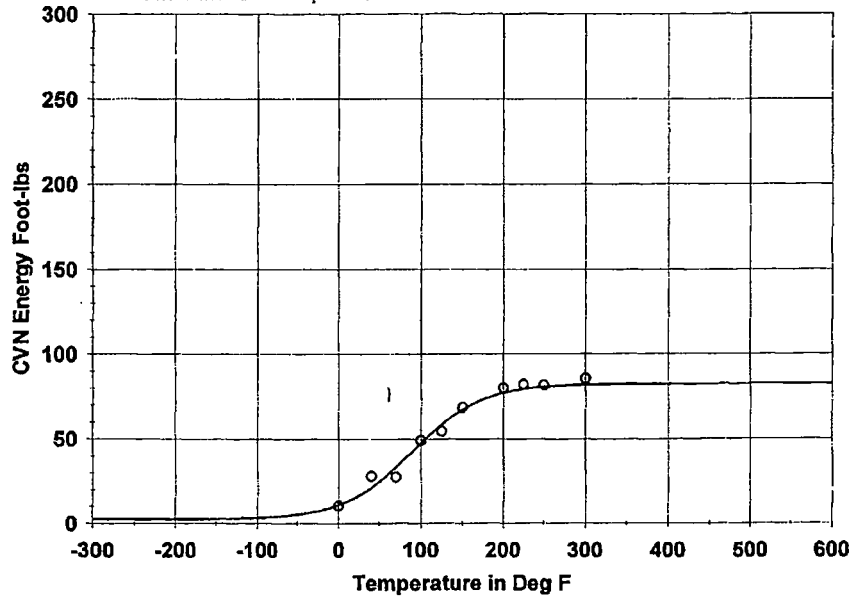
Equation is $A + B * [\text{Tanh}((T - T_0)/(C + DT))]$

Upper Shelf Energy=82.3(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=62.8 Deg F Temp@50 ft-lbs=105.8 Deg F

Plant: Cooper Material: SA533B1 Heat: C2331-2

Orientation: TL Capsule: SSP-E Fluence: 1.7192E+18 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
0.00	10.50	10.87	- .37
40.00	28.00	21.16	6.84
70.00	27.50	33.20	-5.70
100.00	49.00	47.32	1.68
125.00	54.50	58.34	-3.84
150.00	68.50	67.06	1.44
200.00	80.00	76.98	3.02
225.00	82.00	79.29	2.71
250.00	81.50	80.61	.89

Figure A-19-4
Cooper Irradiated Plate Heat C2331-2 (SSP-E) Charpy Energy Plot

IRRADIATED PLATE HEAT C2331-2 (SSP-E)

Page 2

Plant: Cooper Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-E Fluence: $1.7192\text{E}+18$ n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
300.00	85.50	81.78	3.72

Correlation Coefficient = .991

Figure A-19-4
Cooper Irradiated Plate Heat C2331-2 (SSP-E) Charpy Energy Plot (Continued)

IRRADIATED PLATE HEAT C2331-2 (SSP-I)

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

Page 1

Coefficients of Curve 1

A = 41.4 B = 38.9 C = 91.86 T0 = 108.11 D = 0.00E+00

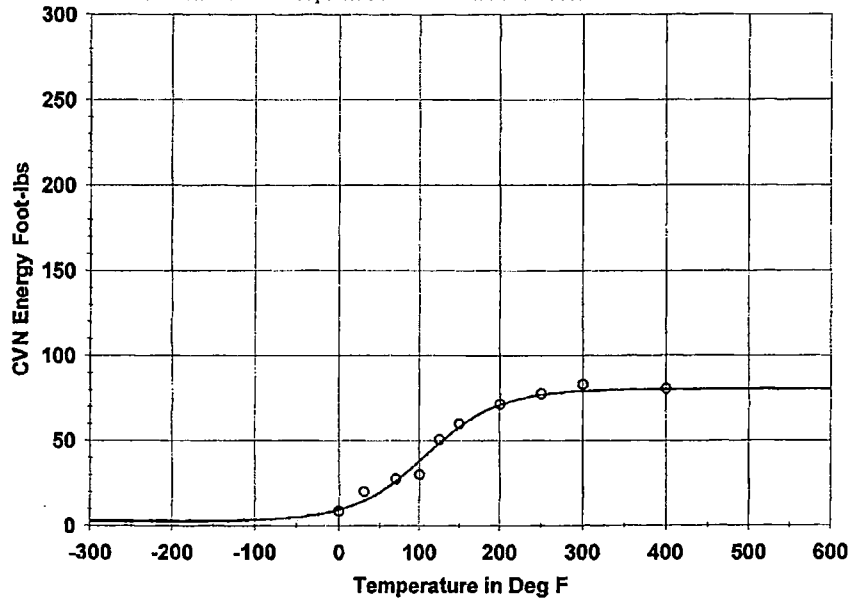
Equation is $A + B * [\text{Tanh}((T-T_0)/(C+DT))]$

Upper Shelf Energy=80.3(Fixed) Lower Shelf Energy=2.5(Fixed)

Temp@30 ft-lbs=80.4 Deg F Temp@50 ft-lbs=128.8 Deg F

Plant: Cooper Material: SA533B1 Heat: C2331-2

Orientation: TL Capsule: SSP-I Fluence: 2.7085E+18 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
0.00	8.50	9.25	- .75
30.00	20.00	14.51	5.49
70.00	27.50	26.13	1.37
100.00	30.00	37.97	- 7.97
125.00	50.50	48.47	2.03
150.00	60.00	58.00	2.00
200.00	71.50	71.03	.47
250.00	77.50	76.91	.59
300.00	83.00	79.13	3.87

Figure A-19-5
Cooper Irradiated Plate Heat C2331-2 (SSP-I) Charpy Energy Plot

IRRADIATED PLATE HEAT C2331-2 (SSP-I)

Page 2

Plant: Cooper Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-I Fluence: $2.7085\text{E}+18$ n/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.00	80.50	80.17	.33

Correlation Coefficient = .992

Figure A-19-5
Cooper Irradiated Plate Heat C2331-2 (SSP-I) Charpy Energy Plot (Continued)

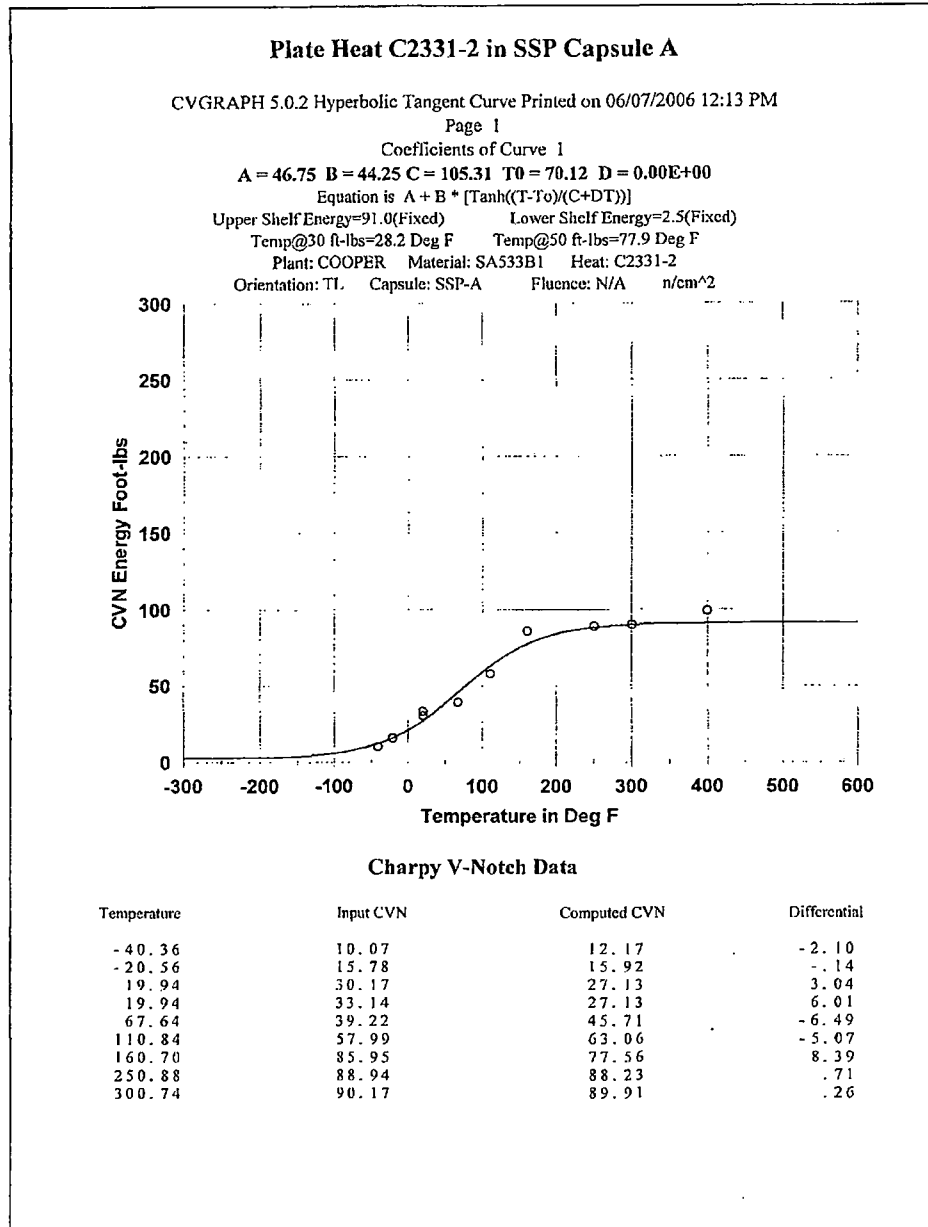


Figure A-19-6
Cooper Irradiated Plate Heat C2331-2 (SSP-A) Charpy Energy Plot

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/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
399.56	99.00	90.83	8.17

Correlation Coefficient = .989

Figure A-19-6
Cooper Irradiated Plate Heat C2331-2 (SSP-A) Charpy Energy Plot (Continued)

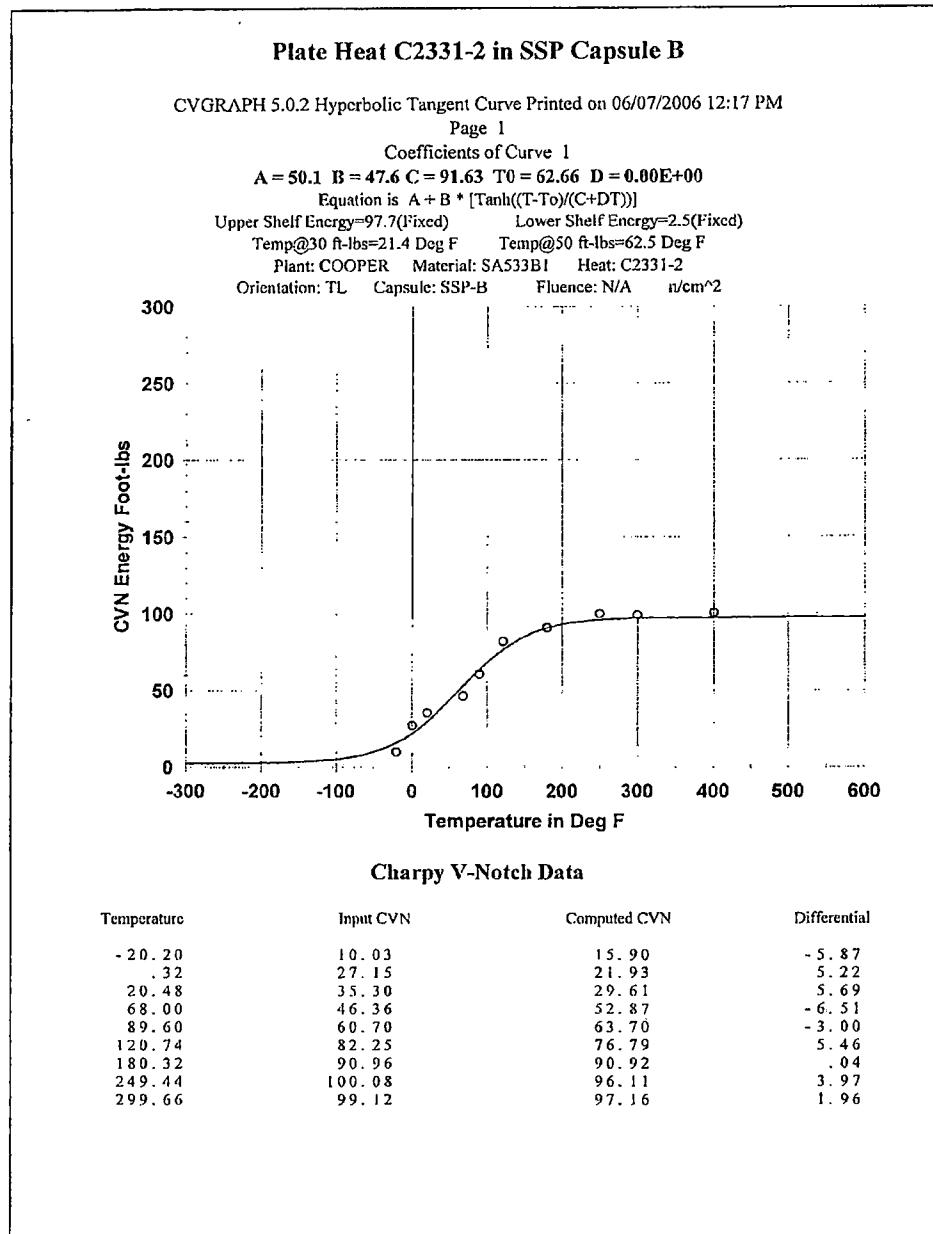


Figure A-19-7
Cooper Irradiated Plate Heat C2331-2 (SSP-B) Charpy Energy Plot

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/cm²

Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
400.28	100.70	97.64	3.06

Correlation Coefficient = .991

Figure A-19-7
Cooper Irradiated Plate Heat C2331-2 (SSP-B) Charpy Energy Plot (Continued)

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(E)}}}

Figure A-19-8
Fitted Surveillance Results for Plate Heat C2331-2

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