Enclosure 2

Cooper Nuclear Station Pressure and Temperature Limits Report (PTLR) for 54 Effective Full-Power Years (EFPY) (Non-Proprietary)

Cooper Nuclear Station Docket No. 50-298, DPR-46

Engineering Report No. 2016-042 Rev 2
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Engineering Report Cover Sheet

Engineering Report Title:
Cooper Nuclear Station Pressure and Temperature Limits Report (PTLR) for 54 Effective Full-Power Years (EFPY)
(Non-Proprietary)

Engineering Report Type: (3)

New ☐ Revision ☒ Cancelled ☐ Superseded ☐
Superseded by: ______

Revision 1: Removed "Proprietary Brackets" from Table 4 values for Cu and Ni content.

Revision 2: Update information of BWRVIP ISP surveillance capsule data for 120° coupon.

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1.0 Purpose

The purpose of the Cooper Nuclear Station (CNS) Pressure and Temperature Limits Report (PTLR) is to present operating limits relating to:

1. Reactor Coolant System (RCS) Pressure versus Temperature limits during Heatup, Cooldown and Hydrostatic/Class 1 Leak Testing;
2. RCS Heatup and Cooldown rates;
3. RPV head flange boltup temperature limits.

This report has been prepared in accordance with the requirements of Licensing Topical Reports SIR-05-044, Revision 1-A, contained within BWROG-TP-11-022-A, Revision 1 [1], and 0900876.401, Revision 0-A, contained within BWROG-TP-11-023-A, Revision 0 [2].

2.0 Applicability

This report is applicable to the CNS RPV for up to 54 Effective Full-Power Years (EFPY).

The following CNS Technical Specifications (TS) are affected by the information contained in this report:

TS RCS Pressure and Temperature (P-T) Limits

TS Surveillance Requirements

3.0 Methodology

The limits in this report were derived as follows:

- The methodology used is in accordance with Reference [1] and Reference [2], incorporating the NRC Safety Evaluations in References [3] and [4], respectively.
- The neutron fluence is calculated in accordance with NRC Regulatory Guide 1.190 (RG 1.190) [5], using the RAMA computer code, as documented in Reference [6].
- The adjusted reference temperature (ART) values for the limiting beltline materials are calculated in accordance with NRC Regulatory Guide 1.99, Revision 2 [7], as documented in Reference [8].
- The pressure and temperature limits were calculated in accordance with Reference [1], "Pressure – Temperature Limits Report Methodology for Boiling Water Reactors," June 2013, as documented in NPPD Calculation NEDC 07-048, Reference [9].
- This revision of the pressure and temperature limits is to incorporate the following changes:
  - Revision 0 – Initial Issue of PTLR
  - Revision 1 – Update pressure and temperature limits for 54 EFPY.
  - Revision 2 – Update information on BWRVIP ISP surveillance capsule data for CNS representative materials.

Changes to the curves, limits, or parameters within this PTLR, based upon new irradiation fluence data of the RPV, or other plant design assumptions in the Updated Final Safety Analysis Report (UFSAR), can be made pursuant to 10 CFR 50.59 [10], provided the above methodologies are utilized. The revised PTLR shall be submitted to the NRC upon issuance.

Changes to the curves, limits, or parameters within this PTLR, based upon new surveillance capsule data of the RPV or other plant design assumptions modifications in the UFSAR, cannot be made without prior NRC approval. Such analysis and revisions shall be submitted to the NRC for review prior to incorporation into the PTLR.

4.0 Operating Limits

The pressure-temperature (P-T) curves included in this report represent steam dome pressure versus minimum vessel metal temperature and incorporate the appropriate non-beltline limits and irradiation embrittlement effects in the beltline region.

The operating limits for pressure and temperature are required for three categories of operation: (a) hydrostatic pressure tests and leak tests, referred to as Curve A; (b) core not critical operation, referred to as Curve B; and (c) core critical operation, referred to as Curve C.

Complete P-T curves were developed for 54 EFPY for Cooper Nuclear Station, as documented in Reference [9]. The CNS P-T curves for 54 EFPY are provided in Figures 1 through 3, and a tabulation of the curves is included in Tables 1 through 3. The adjusted reference temperature (ART) tables for the CNS vessel beltline materials are shown in Table 4 for 54 EFPY (Reference [8]). The resulting P-T curves are based on the geometry, design and materials information for the CNS vessel with the following conditions:

- Heatup and Cooldown rate limit during Hydrostatic Class 1 Leak Testing (Figure 1: Curve A): **≤ 25°F/hour**[1] [9].

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[1] Interpreted as the temperature change in any 1-hour period is less than or equal to 25°F.

- Normal Operating Heatup and Cooldown rate limit (Figure 2: Curve B – non-nuclear heating, and Figure 3: Curve C – nuclear heating): ≤ **100˚F/hour**[2] [9].
- RPV bottom head coolant temperature to RPV coolant temperature ΔT limit during Recirculation Pump startup: **≤ 145°F**.
- Recirculation loop coolant temperature to RPV coolant temperature ΔT limit during Recirculation Pump startup: **≤ 50°F**.
- RPV flange and adjacent shell temperature limit ≥ **70˚F** [9].

To address the NRC condition regarding lowest service temperature in Reference [3, Section 4.0], the minimum temperature is set to 70°F for Curves A and B, which bounds $RT_{NDT,max}$ and the CNS shutdown margin analysis, and 80°F for Curve C, which is equal to $RT_{NDT,max}$ + 60°F. These values are consistent with the minimum temperature limits approved for use by the NRC in Reference [11].

The composite P-T curves are extended below 0 psig to -14.7 psig based on the evaluation documented in Reference [12], which demonstrates that the P-T curves are applicable to negative gauge pressures. A pressure of -14.7 psig bounds the maximum expected vacuum pressure as well as externally applied pressures the RPV may experience. Since the P-T curve calculation methods used do not specifically apply to negative values of pressure, the tabulated results start at 0 psig. However, the minimum analyzed RPV pressure is -14.7 psig

5.0 Discussion

The adjusted reference temperature (ART) of the limiting beltline material is used to adjust beltline P-T curves to account for irradiation effects. RG 1.99 [7] provides the methods for

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[2] Interpreted as the temperature change in any 1-hour period is less than or equal to 100°F.

determining the ART. The RG 1.99 methods for determining the limiting material and adjusting the P-T curves using ART are discussed in this section.

The vessel beltline copper (Cu) and nickel (Ni) values were obtained from the evaluation of the CNS vessel plate, weld, and forging materials [8]. This evaluation included the results of two surveillance capsules for the representative plate material and three surveillance capsules for the representative weld material. The Cu and Ni values were used with Table 1 of RG 1.99 to determine a chemistry factor (CF) per Paragraph 1.1 of RG 1.99 for welds. The Cu and Ni values were used with Table 2 of RG 1.99 to determine a CF per Paragraph 1.1 of RG 1.99 for plates and forgings. However, the fitted CF for the limiting plate (which is based on credible surveillance data) in the CNS vessel bounds the RG 1.99 CF. Therefore, the fitted CF is used for the limiting beltline plate.

The peak RPV ID fluence value of 2.23×10^{18} n/cm^2 at 54 EFPY used in the P-T curve evaluation were obtained from Reference [6] and are calculated in accordance with RG 1.190 [5]. These fluence values apply to the limiting beltline lower intermediate shell plate (Heat No. C2307-2). The fluence values for the lower intermediate shell plate are based upon an attenuation factor of 0.72 for a postulated 1/4T flaw. As a result, the 1/4T fluence for 54 EFPY for the limiting lower intermediate shell plate is 1.62×10^{18} n/cm^2 for CNS.

The P-T limits are developed to bound all ferritic materials in the RPV, including the consideration of stress levels from structural discontinuities such as nozzles. The water level instrument (WLI) nozzle is located in the lower-intermediate shell beltline plates [9]. The nozzle material is not ferritic, however the effect of the penetration on the adjacent shell is considered according to the methodology in Reference [2]. The RPV ID fluence value of 5.44×10^{17} n/cm^2 at 54 EFPY used in the P-T curve evaluation of the WLI nozzle was obtained from Reference [6] and is calculated in accordance with RG 1.190 [5]. This fluence value applies to the limiting WLI nozzle location (Heat No. EV-26067). The fluence value for the WLI nozzle location is

based upon an attenuation factor of 0.72 for a postulated 1/4T flaw. As a result, the 1/4T fluence for 54 EFPY for the limiting WLI nozzle location is 3.94×10^{17} n/cm^2 for CNS. There are no additional forged or partial penetration nozzles in the extended beltline.

The P-T curves for the core not critical and core critical operating conditions at a given EFPY apply for both the 1/4T and 3/4T locations. When combining pressure and thermal stresses, it is usually necessary to evaluate stresses at the 1/4T location (inside surface flaw) and the 3/4T location (outside surface flaw). This is because the thermal gradient tensile stress of interest is in the inner wall during cooldown and is in the outer wall during heatup. However, as a conservative simplification, the thermal gradient stresses at the 1/4T location are assumed to be tensile for both heatup and cooldown. This results in the approach of applying the maximum tensile stresses at the 1/4T location. This approach is conservative because irradiation effects cause the allowable toughness at the 1/4T to be less than that at 3/4T for a given metal temperature. This approach causes no operational difficulties, since the BWR is at steam saturation conditions during normal operation, and for a given pressure, the coolant saturation temperature is well above the P-T curve limiting temperature. Consequently, the material toughness at a given pressure would exceed the allowable toughness.

For the core not critical curve (Curve B) and the core critical curve (Curve C), the P-T curves specify a coolant heatup and cooldown temperature rate of ≤ 100°F/hour for which the curves are applicable. However, the core not critical and the core critical curves were also developed to bound Service Level A/B RPV thermal transients. For the hydrostatic pressure and leak test curve (Curve A), a coolant heatup and cooldown temperature rate of ≤ 25°F/hour must be maintained. The P-T limits and corresponding limits of either Curve A or B may be applied, if necessary, while achieving or recovering from test conditions. So, although Curve A applies during pressure testing, the limits of Curve B may be conservatively used during pressure testing if the pressure test heatup/cooldown rate limits cannot be maintained.

The initial RT_{NDT}, the chemistry (weight-percent copper and nickel), and ART at the 1/4T location for all RPV beltline materials significantly affected by fluence (i.e., fluence > 10^{17} n/cm^2 for E > 1MeV) are shown in Table 4 for 54 EFPY [8]. Initial RT_{NDT} values were reported in the ART calculation in CNS Amendment 120 [13].

Per Reference [8] and in accordance with Appendix A of Reference [1], the CNS representative weld and plate surveillance materials data were reviewed from the Boiling Water Reactor Vessel and Internals Project (BWRVIP) Integrated Surveillance Program (ISP) [14]. The representative heat of the plate material (C2307-2) in the ISP is the same as the lower intermediate shell plate material in the vessel beltline region of CNS. For plate heat C2307-2, since the scatter in the fitted results is less than 1-sigma (17°F), the margin term (σ_Δ = 17°F) is cut in half for the plate material when calculating the ART. The representative heat of the weld material (20291) in the ISP is not the same as the limiting weld material in the vessel beltline region of CNS. Therefore, CFs from the tables in RG1.99 were used in the determination of the ART values for all CNS beltline materials except for plate heat C2307-2.

Additionally, the most recent BWRVIP ISP representative weld and plate surveillance material data for CNS have been reviewed. The results of testing of the CNS 120° capsule were published in 2018 in EPRI Letter 2018-064 [28]. The impact of the new surveillance data and updated reactor vessel fluence projections on the 54 EFPY P-T limit curves has been evaluated in Reference [29]. As documented in that evaluation, if the updated CF and fluence projections for plate heat C2307-2 were considered, the 54 EFPY limiting ART value would decrease relative to the limiting ART value in Table 4 (developed in Reference [8]). Therefore, the limiting ART value in Table 4 and the P-T curves in this PTLR remain conservative for 54 EFPY. Consequently, the P-T curves and ART presented in this PTLR have not been revised at this time to incorporate the new surveillance data from Reference [28]

The only computer code used in the determination of the CNS P-T curves was the ANSYS finite element computer program:

- ANSYS, Revision 5.3 [15] for the feedwater (FW) nozzle (non-beltline) pressure and thermal down shock stresses.
- Mechanical and PrepPost, Release 11.0 (Service Pack 1) [16] for the development of the generic WLI nozzle stress intensity factors in [2].
- Mechanical APDL and PrepPost, Release 12.1 [17] for the FW nozzle (non-beltline) thermal ramp stresses and the core differential pressure (DP) nozzle (bottom head) pressure stress distribution.

ANSYS finite element analyses were used to develop the stress distributions through the FW, WLI, and core DP nozzles, and these stress distributions were used in the determination of the stress intensity factors for these nozzles [2, 18, 19, 20]. At the time that each of the analyses above was performed, the ANSYS program was controlled under the vendor's 10 CFR 50 Appendix B [21] Quality Assurance Program for nuclear quality-related work. Benchmarking consistent with NRC GL 83-11, Supplement 1 [22] was performed as a part of the computer program verification by comparing the solutions produced by the computer code to hand calculations for several problems.

The plant-specific CNS FW nozzle analysis was performed to determine through-wall pressure stress distributions and thermal stress distributions due to bounding thermal transients [18, 19]. Detailed information regarding the analysis can be found in References [18] and [19]. The following inputs were used as input to the finite element analysis:

- With respect to operating conditions, stress distributions were developed for two bounding thermal transients. A thermal shock, which represents the maximum thermal shock for the FW nozzle during normal and upset operating conditions [18], and a thermal ramp were analyzed [19]. Potential leakage past the primary and secondary

thermal sleeves is considered in the heat transfer calculations. The thermal down shock of 450°F, which is associated with the turbine roll transient during startup, produces the highest tensile stresses at the 1/4T location. Because operation is along the saturation curve, these stresses are scaled to reflect the worst-case step change due to the available temperature difference. It is recognized that at low temperatures, the available temperature difference is insignificant and could potentially result in a near zero stress distribution. Therefore, a minimum stress distribution is calculated based on the thermal ramp of 100°F/hour, which is associated with the shutdown transient. Therefore, the combination of the thermal down shock and thermal ramp stresses represent the bounding stresses in the FW nozzle associated with 100°F/hour heatup/cooldown limits associated with the P-T curves for the upper vessel FW nozzle region.

- Heat transfer coefficients were given in the CNS FW nozzle design basis stress report and are a function of FW temperature and flow rate. Bounding, or larger, convection coefficients were used in the present P-T curve analysis [18, 19]. Therefore, the heat transfer coefficients used in the analysis bound the actual operating conditions in the FW nozzle at CNS.
- A two-dimensional finite element model of the FW nozzle was constructed (Figure 4). The pressure stresses are multiplied by a factor of 2.5 to account for the 3-D effects [18]. Material properties were taken at 350°F, which is approximately the average temperature for the shutdown transient, from the 1989 ASME Code [23]. The use of temperature independent material properties is consistent with original design basis documents. Use of temperature dependent material properties is expected to have minimal impact on the results of the analysis.

The plant-specific CNS core DP nozzle analysis was performed to determine a through-wall pressure stress distribution [20]. Detailed information regarding the analysis can be found in Reference [20]. The following inputs were used as input to the finite element analysis:

- No thermal transients were analyzed as part of the plant-specific core DP nozzle evaluation. Thermal stresses were addressed generically as specified in [1] with the use of a stress concentration factor of 3.0 to account for the discontinuity in the bottom head.
- A two-dimensional finite element model of the core DP nozzle was constructed (Figure 5). Material properties were taken at 325°F from the vessel stress report [20]. The use of temperature independent material properties is consistent with original design basis documents. Use of temperature dependent material properties is expected to have minimal impact on the results of the analysis.

6.0 References

1. BWROG-TP-11-022-A, Revision 1, Pressure Temperature Limits Report Methodology for Boiling Water Reactors, June 2013.
2. BWROG-TP-11-023-A, Revision 0, Linear Elastic Fracture Mechanics Evaluation of General Electric Boiling Water Reactor Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations, May 2013.
3. U.S. NRC Letter to BWROG dated May 16, 2013, "Final Safety Evaluation for Boiling Water Reactor Owners' Group Topical Report BWROG-TP-11-022, Revision 1, November 2011, 'Pressure-Temperature Limits Report Methodology for Boiling Water Reactors'" (TAC NO. ME7649, ML13277A557).
4. U.S. NRC Letter to BWROG dated March 14, 2013, "Final Safety Evaluation for Boiling Water Reactor Owners" Group Topical Report BWROG-TP-11-023, Revision 0, November 2011, 'Linear Elastic Fracture Mechanics Evaluation of General Electric Boiling Water reactor Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations'" (TAC NO. ME7650, ML13183A017)
5. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence", March 2001.
6. Cooper Nuclear Station Calculation NEDC 07-032, Revision 4, "CNS Review of TransWare Calculations NPP-FLU-003-R-002, Revision 0, NPP-FLU-003-R-004, and NPP-FLU-003-R-005, Reactor Pressure Vessel Fluence Evaluation", August 2019, that incorporated TransWare Enterprises Report No. NPP-FLU-003-R-005, Revision 0, "Non-Proprietary Version of Cooper Nuclear Station Reactor Pressure Vessel Fluence Evaluation," January 2011.
7. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", May 1988.

8. Cooper Nuclear Station Calculation NEDC 07-045, Revision 4, August 2019, "Review of SIA Calculation 1100445.301, Proprietary and Non-Proprietary Versions, ΔRT_{NDT} and ART Evaluation," dated July 2010.

9. Cooper Nuclear Station Calculation, NEDC 07-048, Revision 8, August 2019 , "Review of SIA Calculation 1400473.302 Cooper Updated P-T Curve Calculation for 54 EFPY", dated December 2015.

10. U.S. Code of Federal Regulations, Title 10, Part 50, Section 59, "Changes, tests and experiments," August 29, 2017.

11. Cooper Nuclear Station Amendment 245 as approved by the NRC on February 22, 2013. (ML13032A526)

12. Cooper Nuclear Station Calculation NEDC 16-024, Revision 0, September 2016, "Review of SIA Calculation 1100473.301 Cooper Vacuum Assessment", Revision 0 dated December 2015.

13. Cooper Nuclear Station Amendment 120 as approved by the NRC on April 26, 1988. (ML021360424)

14. BWRVIP-135, Revision 3: BWR Vessel and Internals Project, Integrated Surveillance Program (ISP) Data Source Book and Plant Evaluations. EPRI, Palo Alto, CA: 2014. 3002003144. SI File No. BWRVIP-135P. **EPRI PROPRIETARY INFORMATION**.

15. ANSYS, Revision 5.3, ANSYS Inc., October 1996.

16. ANSYS Mechanical and PrepPost, Release 11.0 (w/ Service Pack 1), ANSYS, Inc., August 2007.

17. ANSYS Mechanical APDL and PrepPost, Release 12.1 x64, ANSYS, Inc., November 2009.

18. Cooper Nuclear Station Calculation No. NEDC99-020, "Review of Structural Integrity Report SIR-99-069 and Calculations No. NPPD-13Q-301, NPPD-13Q-302, NPPD-13-Q-

303," specifically Structural Integrity Associates Calculation No. NPPD-13Q-302, Revision 2, "Feedwater Nozzle Stress Analysis," June 1999.

19. Cooper Nuclear Station Calculation No. NEDC99-020, Structural Integrity Associates Calculation No. 1100445.302, Revision 0, "Finite Element Stress Analysis of Cooper RPV Feedwater Nozzle," June 2011.

20. Cooper Nuclear Station Calculation, NEDC 16-025, "Review of SIA Calculation 1100445.304 Core Differential Pressure Nozzle Finite Element Model and Stress Analysis" dated July 2011.

21. U.S. Code of Federal Regulations, Title 10, Energy, Part 50, Appendix B, "Quality Assurance for Nuclear Power Plants and Fuel Reprocessing Plants".

22. U.S. Nuclear Regulatory Commission, Generic Letter 83-11, Supplement 1, "License Qualification for Performing Safety Analyses", June 24, 1999.

23. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1989 Edition.

24. U.S. Code of Federal Regulations, Title 10, Part 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements," August 29, 2017.

25. Letter NLS2002104 dated December 31, 2002, "License Amendment Request to Adopt an Integrated Reactor Vessel Material Surveillance Program, Cooper Nuclear Station, NRC Docket No. 50-298, DPR-46", from M.T. Coyle (NPPD) to U.S. Nuclear Regulatory Commission, ADAMS Accession No. ML030080070, SI File No. 1400473.202.

26. Cooper Nuclear Station Amendment 201 as approved by the NRC on October 23, 2003. (ML033090607)

27. BWRVIP-86, Revision 1-A: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan. EPRI, Palo Alto, CA: 2012. 1025144. **EPRI PROPRIETARY INFORMATION.**

28. EPRI Letter 2018-064, "Advance Notification of New BWRVIP Integrated Surveillance Program (ISP) Data Applicable to Cooper," June 12, 2018. **EPRI PROPRIETARY INFORMATION**.

29. SI Report No. 1800664.401, Revision 0, "Evaluation of the Effects of BWRVIP ISP Capsule Test Results on the Cooper Pressure-Temperature Curves," December 19, 2018.

30. *BWRVIP-318NP: BWR Vessel and Internals Project, Testing and Evaluation of the Cooper 120° Surveillance Capsule*. EPRI, Palo Alto, CA: 2018. 3002013102.

31. Cooper Nuclear Station Amendment 256, Cooper Nuclear Station as approved by the NRC on July 25,2016 (ML16158A022)

32. U. S. Nuclear Regulatory Commission, Generic Letter 96-03, "Relocation of the Pressure Temperature Limit Curves and Low Temperature Overpressure Protection System Limits", January 31, 1996.

Figure 1: CNS P-T Curve A (Hydrostatic Pressure and Leak Tests) for 54 EFPY

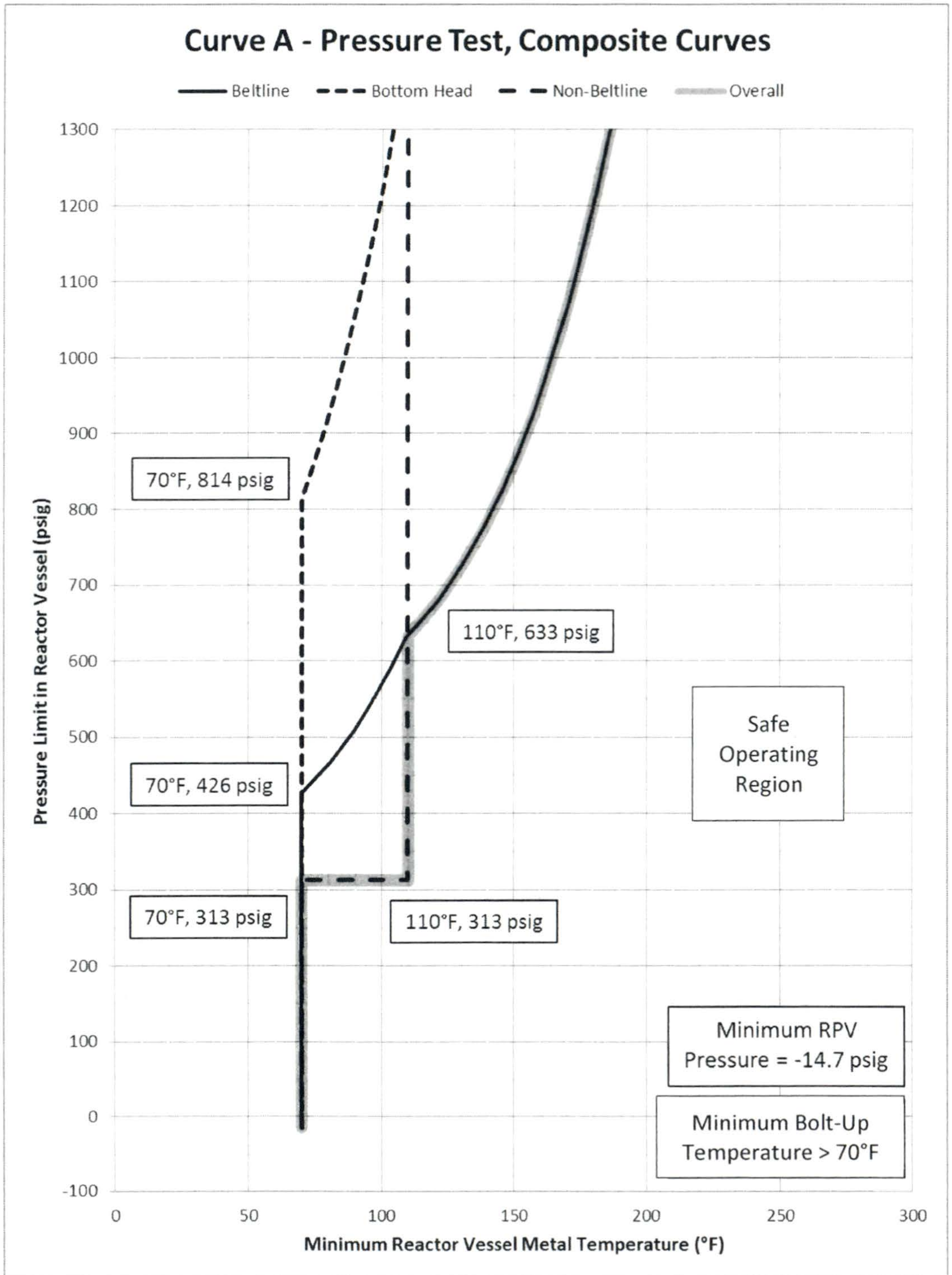


Figure 2: CNS P-T Curve B (Normal Operation – Core Not Critical) for 54 EFPY

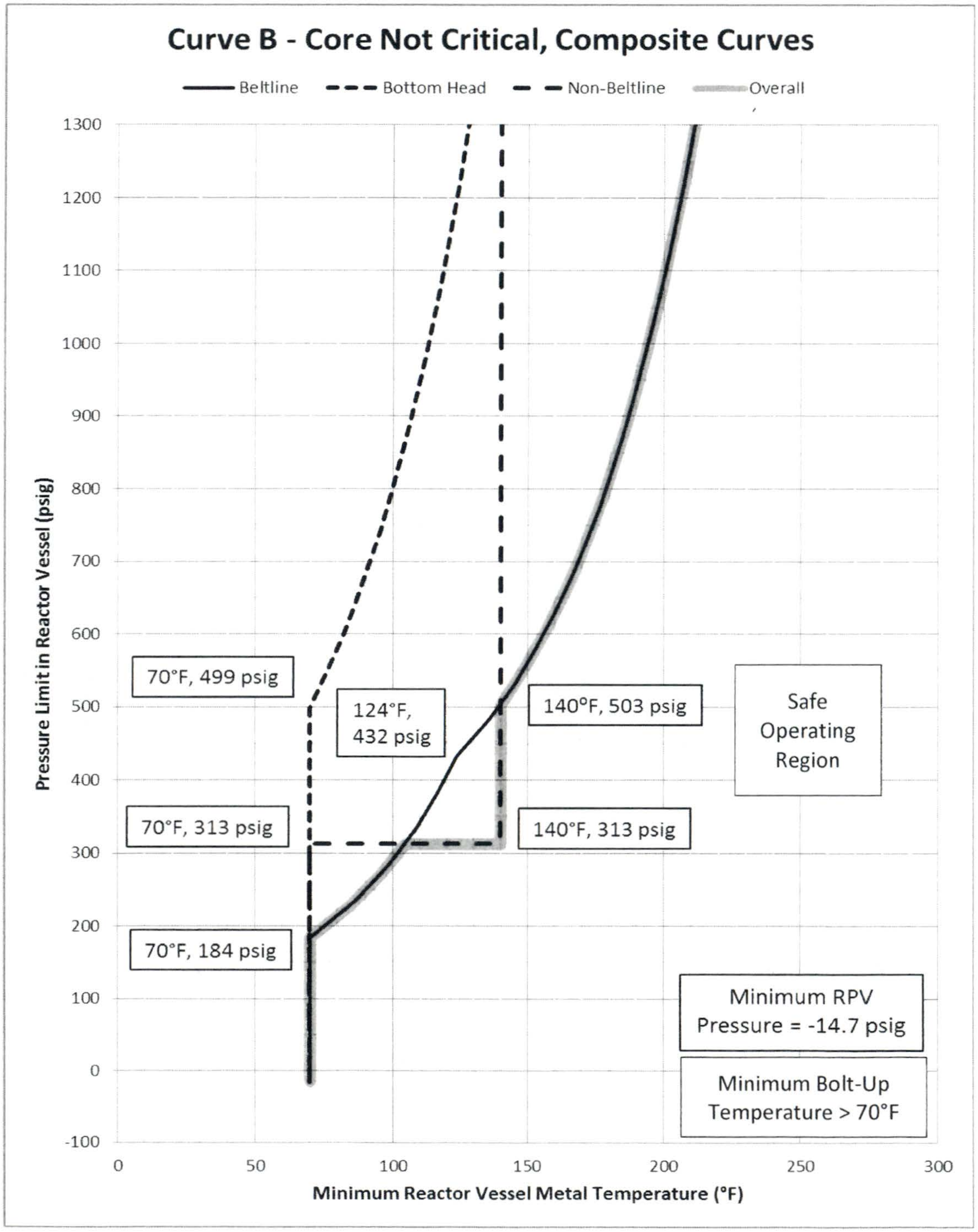


Figure 3: CNS P-T Curve C (Normal Operation – Core Critical) for 54 EFPY

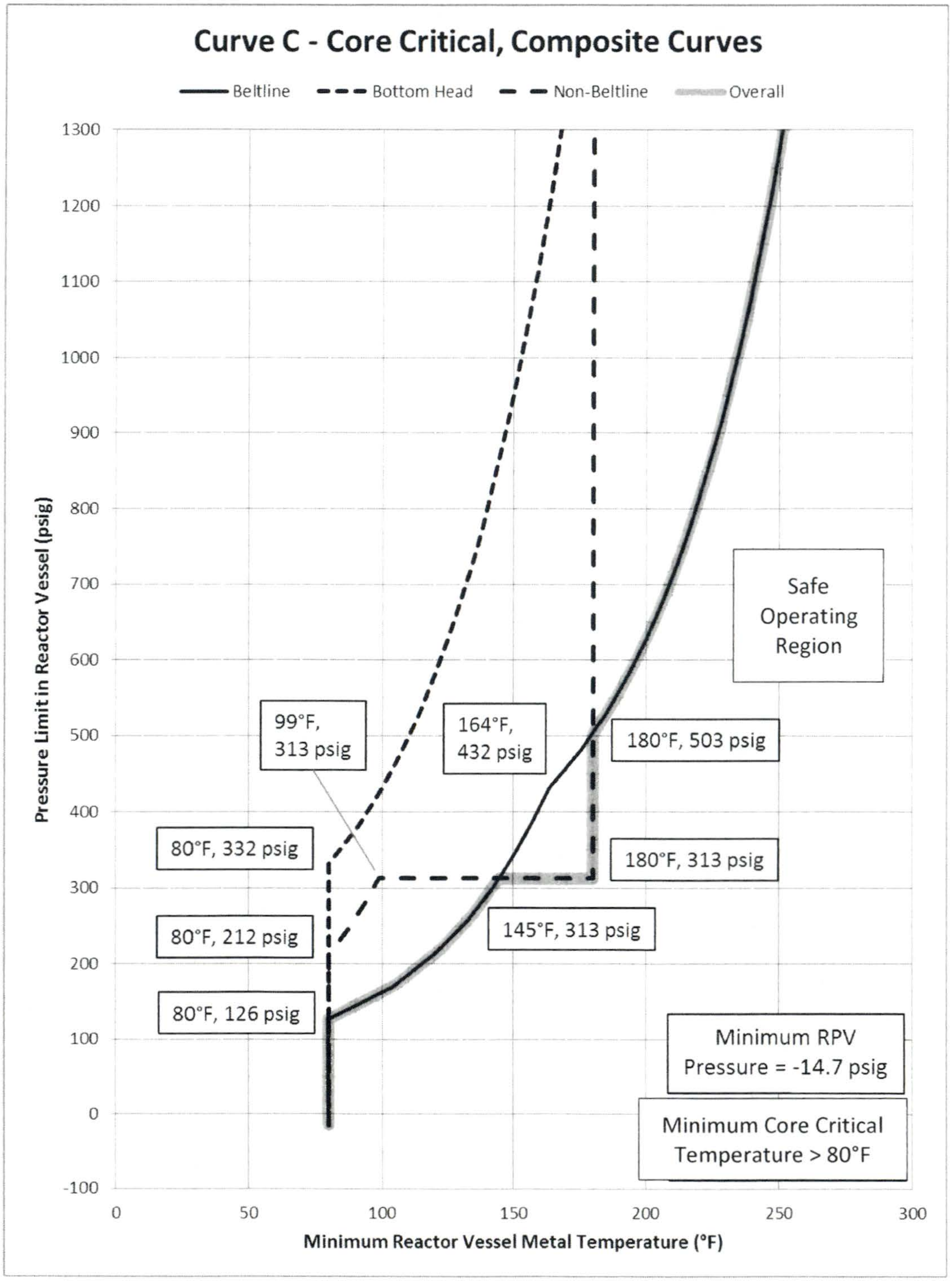


Figure 4: Cooper Feedwater Nozzle Finite Element Model [19]

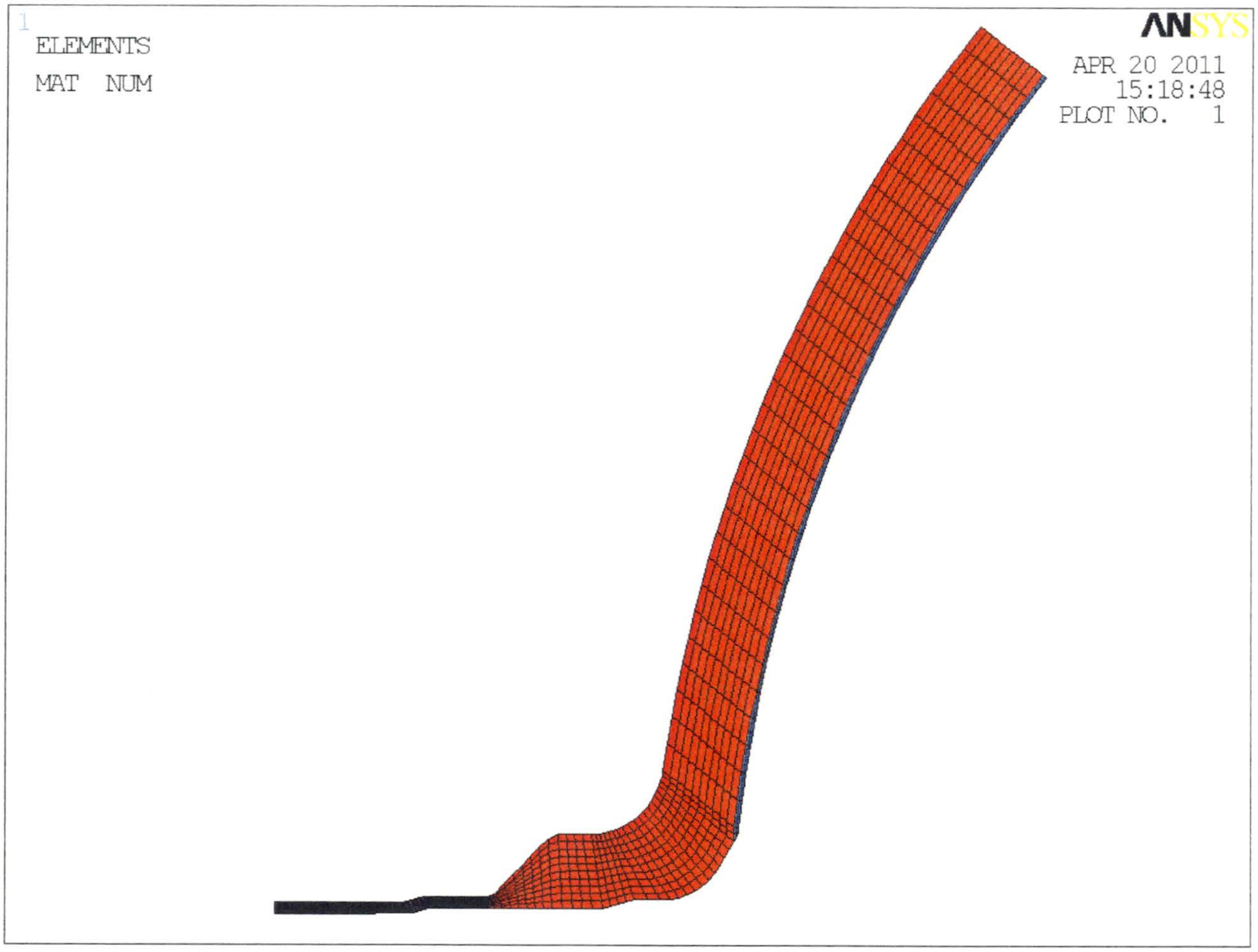


Figure 5: Cooper Core Differential Pressure Nozzle Finite Element Model [20]

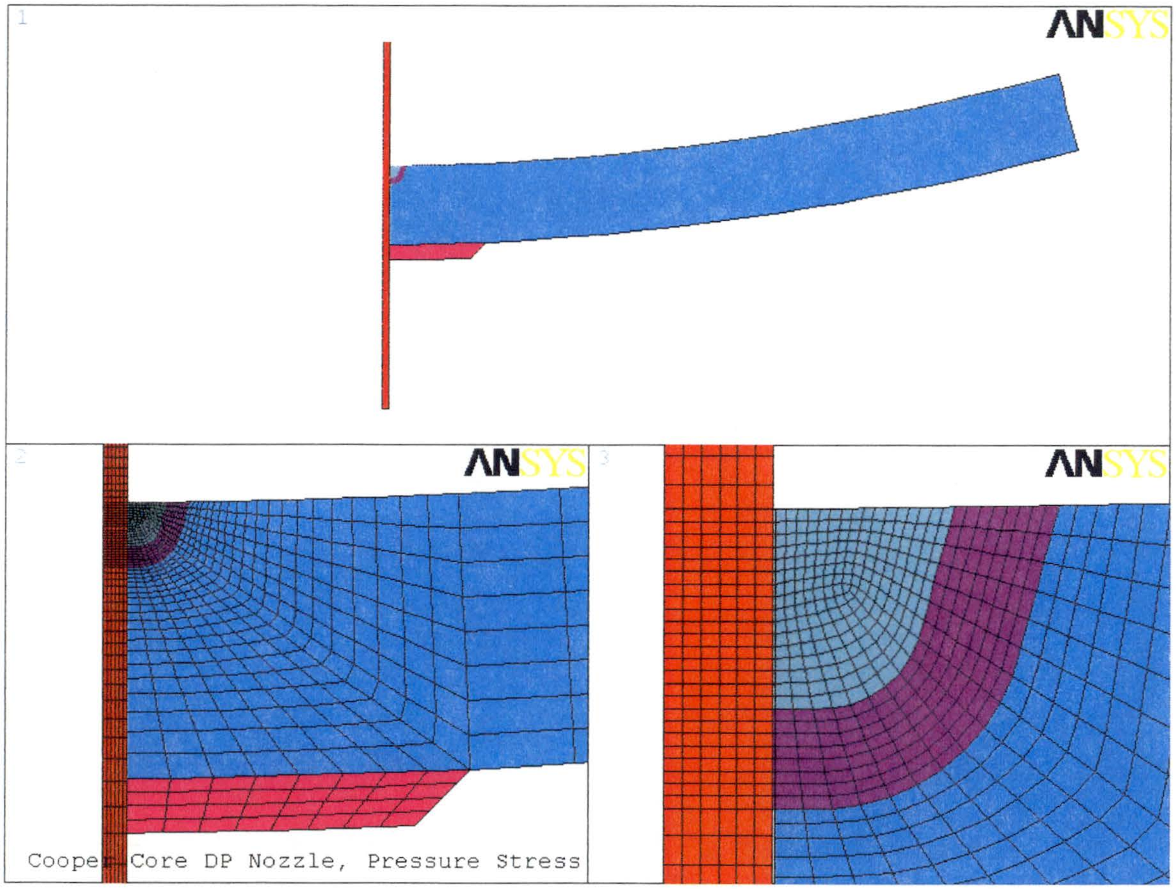


Table 1: CNS Pressure Test (Curve A) P-T Curves for 54 EFPY

Beltline Region

Curve A - Pressure Test	
P-T Curve Temperature	P-T Curve Pressure
°F	*psi*
70.0	0.0
70.0	426.0
80.6	466.6
89.3	507.2
96.8	547.7
103.2	588.3
109.0	628.9
120.9	678.1
130.6	727.2
138.7	776.4
145.6	825.5
151.7	874.7
157.2	923.9
162.1	973.0
166.5	1022.2
170.6	1071.4
174.4	1120.5
178.0	1169.7
181.2	1218.9
184.3	1268.0
187.2	1317.2

Table 1: CNS Pressure Test (Curve A) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve A - Pressure Test	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
70.0	0.0
70.0	312.6
110.0	312.6
110.0	1563.0

Table 1: CNS Pressure Test (Curve A) P-T Curves for 54 EFPY (continued)

Bottom Head Region

Curve A - Pressure Test	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
70.0	0.0
70.0	814.0
74.8	864.0
79.2	913.9
83.3	963.8
87.0	1013.8
90.5	1063.7
93.8	1113.6
96.8	1163.5
99.7	1213.5
102.4	1263.4
105.0	1313.3

Table 2: CNS Core Not Critical (Curve B) P-T Curves for 54 EFPY

Beltline Region

Curve B - Core Not Critical	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
70.0	0.0
70.0	184.3
86.2	233.8
98.5	283.3
108.3	332.8
116.5	382.3
123.6	431.7
135.5	480.9
145.1	530.1
153.2	579.3
160.1	628.5
166.2	677.7
171.6	726.8
176.5	776.0
181.0	825.2
185.1	874.4
188.9	923.6
192.4	972.8
195.7	1022.0
198.8	1071.1
201.7	1120.3
204.4	1169.5
207.0	1218.7
209.5	1267.9
211.9	1317.1

Table 2: CNS Core Not Critical (Curve B) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve B - Core Not Critical	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
70.0	0.0
70.0	312.6
140.0	312.6
140.0	1563.0

Table 2: CNS Core Not Critical (Curve B) P-T Curves for 54 EFPY (continued)

Bottom Head Region

Curve B - Core Not Critical	
P-T Curve Temperature °F	P-T Curve Pressure psi
70.0	0.0
70.0	498.6
76.2	547.0
81.6	595.4
86.6	643.7
91.1	692.1
95.2	740.5
99.0	788.9
102.5	837.3
105.8	885.7
108.9	934.0
111.8	982.4
114.6	1030.8
117.2	1079.2
119.7	1127.6
122.1	1175.9
124.3	1224.3
126.5	1272.7
128.6	1321.1

Table 3: CNS Core Critical (Curve C) P-T Curves for 54 EFPY

Curve C - Core Critical	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
80.0	0.0
80.0	126.2
104.0	169.8
120.2	213.5
132.4	257.1
142.2	300.8
150.4	344.4
157.4	388.1
163.6	431.7
175.5	480.9
185.1	530.1
193.2	579.3
200.1	628.5
206.2	677.7
211.6	726.8
216.5	776.0
221.0	825.2
225.1	874.4
228.9	923.6
232.4	972.8
235.7	1022.0
238.8	1071.1
241.7	1120.3
244.4	1169.5
247.0	1218.7
249.5	1267.9
251.9	1317.1

Table 3: CNS Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve C - Core Critical	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
80.0	0.0
80.0	211.8
87.3	245.4
93.5	279.0
98.8	312.6
180.0	312.6
180.0	1563.0

Table 3: CNS Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

Bottom Head Region

Curve C - Core Critical	
P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
80.0	0.0
80.0	331.9
90.9	381.1
99.8	430.4
107.4	479.6
113.9	528.9
119.7	578.1
124.9	627.4
129.7	676.6
134.0	725.8
137.9	775.1
141.6	824.3
145.0	873.6
148.2	922.8
151.2	972.1
154.1	1021.3
156.8	1070.6
159.3	1119.8
161.7	1169.0
164.1	1218.3
166.3	1267.5
168.4	1316.8

Table 4: CNS ART Calculations for 54 EFPY

	Beltline ID	Code No.	Heat No.	Flux Type	Initial RT_{NDT}	Cu	Ni	CF	ΔRT_{NDT}	Margin Terms		Total Margin	ART
					(°F)	(wt%)	(wt%)	(°F)	(°F)	σ_Δ (°F)	σ_I (°F)	(°F)	(°F)
Plates	Lower Shell Plate	G-2803-1	C2274-1	-	14.0	0.20	0.68	153.0	69.3	17.0	0.0	34.0	117.3
	Lower Shell Plate	G-2803-2	C2307-1	-	0.0	0.21	0.73	162.8	73.8	17.0	0.0	34.0	107.8
	Lower Shell Plate	G-2803-3	C2274-2	-	-8.0	0.20	0.68	153.0	69.3	17.0	0.0	34.0	95.3
	Lower Int. Shell Plate	G-2802-1	C2331-2	-	10.0	0.16	0.62	{{[redacted](E)}}	77.7	8.5	0.0	17.0	104.7
	Lower Int. Shell Plate	G-2802-2	C2307-2	-	-20.0	0.21	0.76	{{[redacted](E)}}	134.2	8.5	0.0	17.0	131.2
	Lower Int. Shell Plate	G-2801-7	C2407-1	-	-10.0	0.13	0.65	92.3	47.9	17.0	0.0	34.0	71.9
Welds	Lower Shell Axial Welds	2-233A	12420	LINDE 1092	-50.0	0.270	1.035	254.4	114.4	28.0	0.0	56.0	120.4
	Lower Shell Axial Welds	2-233B	12420	LINDE 1092	-50.0	0.270	1.035	254.4	114.4	28.0	0.0	56.0	120.4
	Lower Shell Axial Welds	2-233C	12420	LINDE 1092	-50.0	0.270	1.035	254.4	114.4	28.0	0.0	56.0	120.4
	Lower Int. Shell Axial Welds	1-233A	27204/12008	LINDE 1092	-50.0	0.219	0.996	231.1	92.2	28.0	0.0	56.0	98.2
	Lower Int. Shell Axial Welds	1-233B	27204/12008	LINDE 1092	-50.0	0.219	0.996	231.1	92.2	28.0	0.0	56.0	98.2
	Lower Int. Shell Axial Welds	1-233C	27204/12008	LINDE 1092	-50.0	0.219	0.996	231.1	92.2	28.0	0.0	56.0	98.2
	Lower/Lower Int. Shell Circ Weld	1-240	21935	LINDE 1092	-50.0	0.183	0.704	172.2	80.2	28.0	0.0	56.0	86.2
Nozzles	Nozzle N-16A	G-2822	EV-26067		-10.0	0.13	0.65	92.3	23.7	8.3	0.0	16.5	37.4
	Nozzle N-16B	G-2822	EV-26067		10.0	0.16	0.62	118.5	30.4	10.6	0.0	21.2	70.8

Fluence Data

	Beltline ID	Code No.	Heat No.	Wall Thickness (in.)		Fluence at ID	Attenuation	Fluence at 1/4t	Fluence Factor, FF
				Full	1/4t	(n/cm²)	$e^{-0.24x}$	(n/cm²)	$f^{(0.28 - 0.10 \log f)}$
Plates	Lower Shell Plate	G-2803-1	C2274-1	6.375	1.59	1.75E+18	0.68	1.19E+18	0.453
	Lower Shell Plate	G-2803-2	C2307-1	6.375	1.59	1.75E+18	0.68	1.19E+18	0.453
	Lower Shell Plate	G-2803-3	C2274-2	6.375	1.59	1.75E+18	0.68	1.19E+18	0.453
	Lower Int. Shell Plate	G-2802-1	C2331-2	5.375	1.34	2.23E+18	0.72	1.62E+18	0.520
	Lower Int. Shell Plate	G-2802-2	C2307-2	5.375	1.34	2.23E+18	0.72	1.62E+18	0.520
	Lower Int. Shell Plate	G-2801-7	C2407-1	5.375	1.34	2.23E+18	0.72	1.62E+18	0.520
Welds	Lower Shell Axial Welds	2-233A	12420	6.375	1.59	1.72E+18	0.68	1.17E+18	0.450
	Lower Shell Axial Welds	2-233B	12420	6.375	1.59	1.72E+18	0.68	1.17E+18	0.450
	Lower Shell Axial Welds	2-233C	12420	6.375	1.59	1.72E+18	0.68	1.17E+18	0.450
	Lower Int. Shell Axial Welds	1-233A	27204/12008	5.375	1.34	1.26E+18	0.72	9.13E+17	0.399
	Lower Int. Shell Axial Welds	1-233B	27204/12008	5.375	1.34	1.26E+18	0.72	9.13E+17	0.399
	Lower Int. Shell Axial Welds	1-233C	27204/12008	5.375	1.34	1.26E+18	0.72	9.13E+17	0.399
	Lower/Lower Int. Shell Circ Weld	1-240	21935	5.375	1.34	1.75E+18	0.72	1.27E+18	0.466
Nozzles	Nozzle N-16A	G-2822	EV-26067	5.375	1.34	5.44E+17	0.72	3.94E+17	0.257
	Nozzle N-16B	G-2822	EV-26067	5.375	1.34	5.44E+17	0.72	3.94E+17	0.257

Appendix A

COOPER REACTOR VESSEL MATERIALS SURVEILLANCE PROGRAM

In accordance with 10 CFR 50, Appendix H, Reactor Vessel Material Surveillance Program Requirements [24], two surveillance capsules were removed from the CNS reactor vessel in 1985 at 6.8 EFPY and 1991 at 11.2 EFPY [25, Attachment 3]. The surveillance capsules contained flux wires for neutron fluence measurement, Charpy V-Notch impact test specimens and uniaxial tensile test specimens fabricated using materials from the vessel materials within the core beltline region.

CNS is currently committed to use the BWRVIP ISP, and has made a licensing commitment to use the ISP for CNS during the period of extended operation. The BWRVIP ISP meets the requirements of 10 CFR 50, Appendix H, for Integrated Surveillance Programs, and has been approved by NRC. Nebraska Public Power District committed to use the ISP in place of its existing surveillance programs in the amendments issued by the NRC regarding the implementation of the Boiling Water Reactor Vessel and Internals Project Reactor Pressure Vessel Integrated Surveillance Program, dated October 31, 2003 [26]. Additionally, CNS served as a host plant for three of the nine surveillance capsules irradiated as part of the Supplemental Surveillance Program; the SSP-A, SSP-B, and SSP-C capsules were removed from CNS and tested in 2003 [27] The surveillance capsules contained flux wires for neutron fluence measurement, Charpy V-Notch impact test specimens and uniaxial tensile test specimens fabricated using materials from the vessel materials within the core beltline region. CNS continues to be a host plant under the ISP. One additional standby Cooper capsule is currently scheduled to be removed and tested under the ISP during the license renewal period in approximately 2029 at 40 EFPY [27].

ATTACHMENT 9.3 **TECHNICAL REVIEW COMMENTS AND RESOLUTION FORM**

SHEET 1 OF 1

NPPD
Cooper Nuclear Station

Engineering Report
Technical Review Comments and Resolutions Form

Engineering Report Number	ER2016-042	Rev. 2	Title: Cooper Nuclear Station Pressure and Temperature Limits Report (PTLR) for 54 Effective Full-Power Years (EFPY) (Non-Proprietary)
Quality Related: ☒ Yes ☐ No		**Special Notes or Instructions:**	

Comment Number	Section/ Page No.	Review Comment	Response/Resolution	Reviewer's Accept Initials
N/A	N/A	None	N/A	N/A

Verified/Reviewed By:	[illegible] for PHIL LEININGER*	Date	8-7-19	Resolved By:	
Site/Department:	[illegible]	Ph. 5310		Date:	

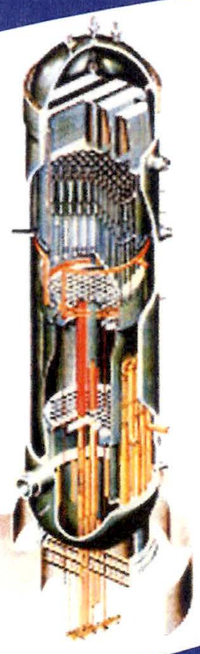
*PER TELCON

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



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.

✓ (YES) NO

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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
T_{30} 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 {{ $^{(E)}$}}, 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 {{ $^{(E)}$}} 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 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
T_{30} 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 {{ (E)}}, 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 MeV, 10^{17} 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:

$$CF_{(C2307\text{-}2)} = 164.6°F$$

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_{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-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:

1. See Table A-2-3, 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-2-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Plate Heat C2307-2

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] (%)
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-2-4presents 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	{{ (E)}}	30°	0.192	52.20	{{ (E)}}	{{ (E)}}	Yes
	{{ (E)}}	300°	0.211	52.20	{{ (E)}}	{{ (E)}}	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

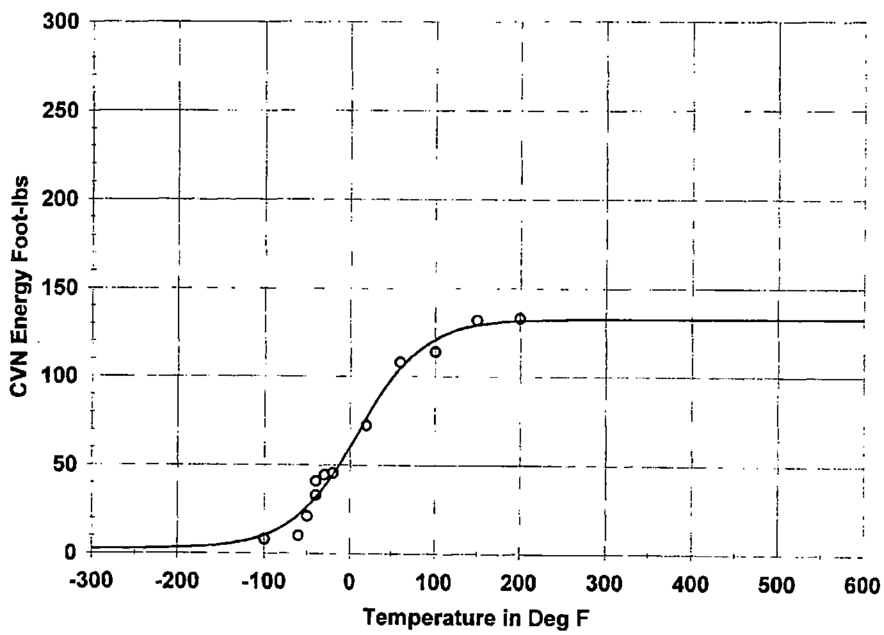
Table A-2-9
Charpy V-Notch Results for C2307-2 (LT) in CPR 300° Capsule

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

PLATE HEAT C2307-2 (CPR)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 12/19/2002 08:55 AM
Page 1
Coefficients of Curve 1
A = 67.57 B = 65.07 C = 79.1 T0 = 9.01 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=132.6 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=-43.0 Deg F Temp@50 ft-lbs=-12.8 Deg F
Plant: Cooper Material: SA533B1 Heat: C2307-2
Orientation: LT Capsule: UNIRRA Fluence: 0.0 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-100.00	8.00	10.28	-2.28
-60.00	10.00	21.85	-11.85
-50.00	21.00	26.40	-5.40
-40.00	41.00	31.73	9.27
-40.00	33.00	31.73	1.27
-30.00	44.50	37.86	6.64
-20.00	45.50	44.73	.77
20.00	72.50	76.56	-4.06
60.00	108.00	104.54	3.46
100.00	114.00	120.79	-6.79
150.00	132.00	129.06	2.94

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/cm^2

Charpy V-Notch Data

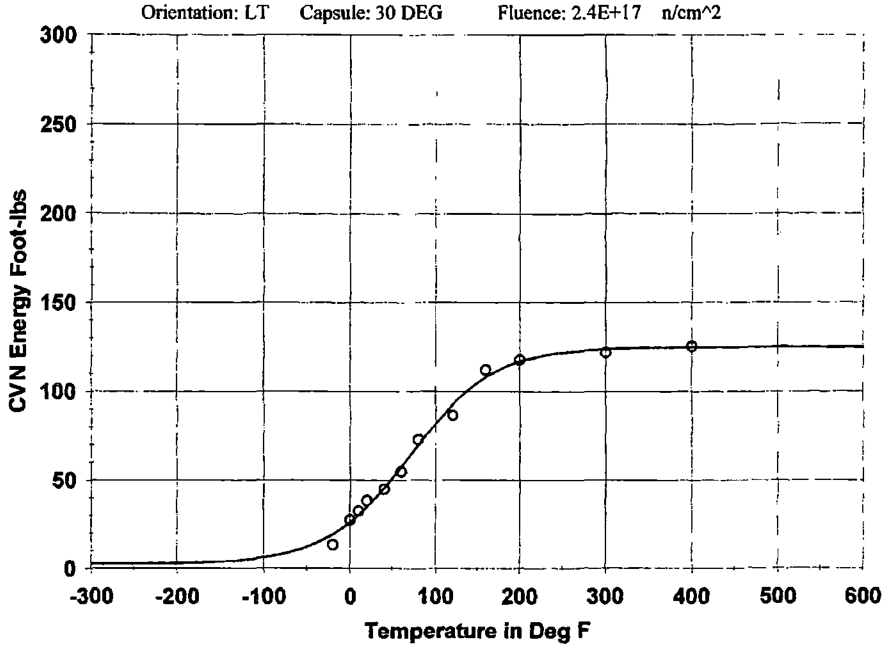
Temperature	Input CVN	Computed CVN	Differential
200.00	133.00	131.61	1.39

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 * [Tanh((T-To)/(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: SA533B1 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
.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	-.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/cm^2

Charpy V-Notch Data

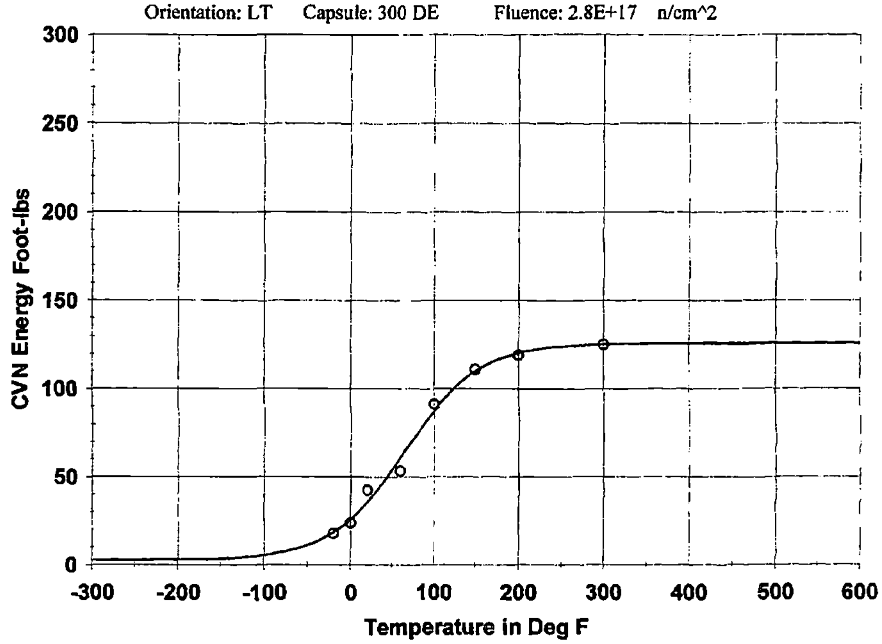
Temperature	Input CVN	Computed CVN	Differential
200.00	117.70	116.73	.97
300.00	121.70	123.73	-2.03
400.00	125.30	124.71	.59

Correlation Coefficient = .997

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

IRRADIATED PLATE HEAT C2307-2 (CPR-300)

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/22/2003 08:26 PM
Page 1
Coefficients of Curve 1
A = 64.13 B = 61.63 C = 88.9 T0 = 64.63 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=125.8 Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=9.2 Deg F Temp@50 ft-lbs=43.9 Deg F
Plant: COOPER Material: SA533B1 Heat: C2307-2
Orientation: LT Capsule: 300 DE Fluence: 2.8E+17 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
-20.00	18.00	18.48	-.48
.00	24.00	25.84	-1.84
20.00	42.50	35.55	6.95
60.00	53.50	60.92	-7.42
100.00	91.00	87.43	3.57
150.00	111.00	110.01	.99
200.00	119.00	120.16	-1.16
300.00	125.00	125.15	-.15

Correlation Coefficient = .995

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

A-2-1. GE Nuclear Energy, "Cooper Nuclear Station Vessel Surveillance Materials Testing and Fracture Toughness Analysis," GE-NE-523-159-1292, February 1993.

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.

A-2-3. CVGRAPH, Hyperbolic Tangent Curve Fitting Program, Developed by ATI Consulting, Version 5.0.2, Revision 1, 3/26/02.

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.

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

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 MeV, 10^{17} 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:

$$\mathbf{CF_{(C2331\text{-}2)} = 118.5°F}$$

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_{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 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} (°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:

1. See Table A-19-3, 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-19-5
Comparison of Actual Versus Predicted Percent Decrease in Upper Shelf Energy (USE) for Plate Heat C2331-2

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] (%)
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	{{ (E)}}	SSP D	0.419	62.0	{{ (E)}}	{{ (E)}}	Yes
		SSP G	0.551	92.0	{{ (E)}}	{{ (E)}}	Yes
		SSP E	0.534	76.1	{{ (E)}}	{{ (E)}}	Yes
		SSP I	0.644	93.7	{{ (E)}}	{{ (E)}}	Yes
		SSP A	0.252	41.5	{{ (E)}}	{{ (E)}}	Yes
		SSP B	0.286	34.7	{{ (E)}}	{{ (E)}}	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

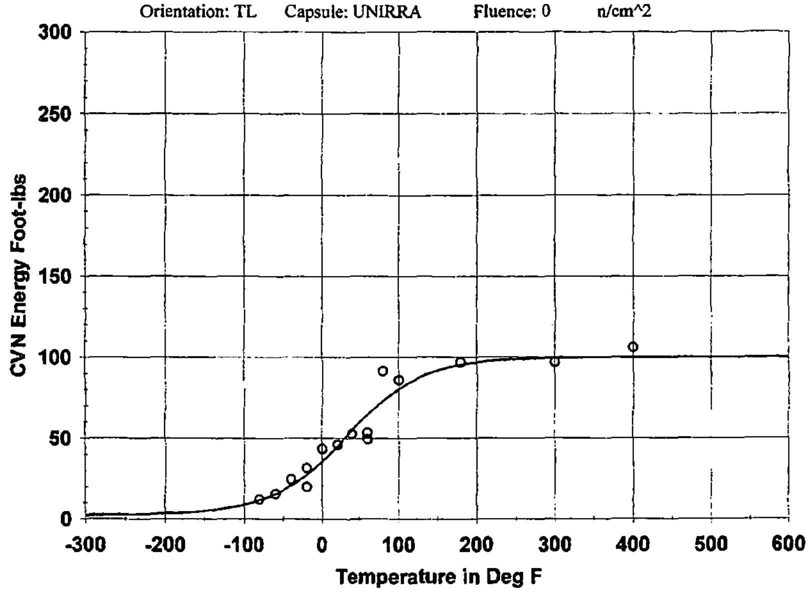
Table A-19-13
Charpy V-Notch Results for C2331-2 (TL) in SSP Capsule B

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

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 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/cm^2

Charpy V-Notch Data

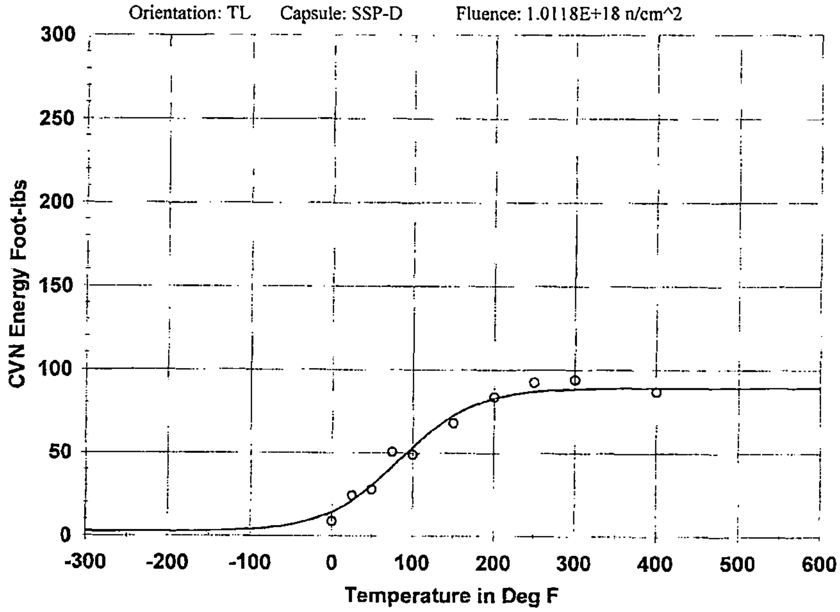
Temperature	Input CVN	Computed CVN	Differential
60.00	49.50	64.53	-15.03
80.00	91.50	73.12	18.38
100.00	86.00	80.29	5.71
180.00	97.00	95.38	1.62
300.00	97.00	99.58	-2.58
400.00	106.00	99.94	6.06

Correlation Coefficient = .969

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

Plate Heat C2331-2 in SSP-D

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/01/2006 05:51 PM
Page 1
Coefficients of Curve 1
A = 45.9 B = 43.4 C = 92.06 T0 = 84.06 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=89.3(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=48.7 Deg F Temp@50 ft-lbs=92.8 Deg F
Plant: Oyster Creek Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-D Fluence: 1.0118E+18 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
.00	9.00	14.54	-5.54
25.00	24.50	21.34	3.16
50.00	28.00	30.54	-2.54
75.00	50.50	41.64	8.86
100.00	49.00	53.34	-4.34
150.00	68.00	72.58	-4.58
200.00	83.75	82.83	.92
250.00	92.50	87.00	5.50
300.00	94.00	88.51	5.49

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/cm^2

Charpy V-Notch Data

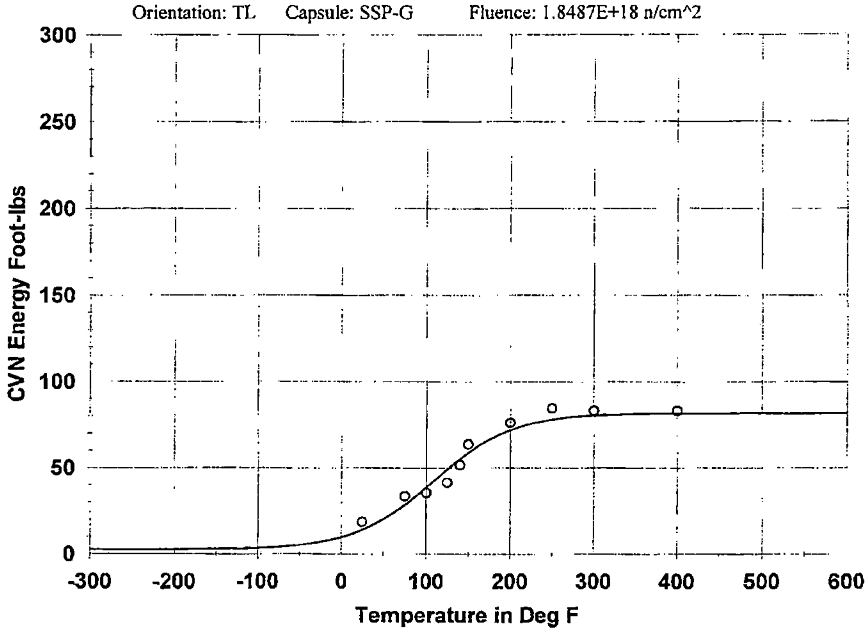
Temperature	Input CVN	Computed CVN	Differential
400.00	87.00	89.21	-2.21

Correlation Coefficient = .987

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

Plate Heat C2331-2 in SSP-G

CVGRAPH 5.0.2 Hyperbolic Tangent Curve Printed on 04/01/2006 05:54 PM
Page 1
Coefficients of Curve 1
A = 42.05 B = 39.55 C = 93.59 T0 = 108.08 D = 0.00E+00
Equation is A + B * [Tanh((T-To)/(C+DT))]
Upper Shelf Energy=81.6(Fixed) Lower Shelf Energy=2.5(Fixed)
Temp@30 ft-lbs=78.7 Deg F Temp@50 ft-lbs=127.2 Deg F
Plant: Oyster Creek Material: SA533B1 Heat: C2331-2
Orientation: TL Capsule: SSP-G Fluence: 1.8487E+18 n/cm^2



Charpy V-Notch Data

Temperature	Input CVN	Computed CVN	Differential
25.00	18.50	13.96	4.54
75.00	33.50	28.63	4.87
100.00	35.50	38.64	-3.14
125.00	41.50	49.12	-7.62
140.00	51.50	55.04	-3.54
150.00	63.50	58.67	4.83
200.00	76.00	71.87	4.13
250.00	84.50	77.96	6.54
300.00	83.00	80.31	2.69

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: 1.8487E+18 n/cm^2

Charpy V-Notch Data

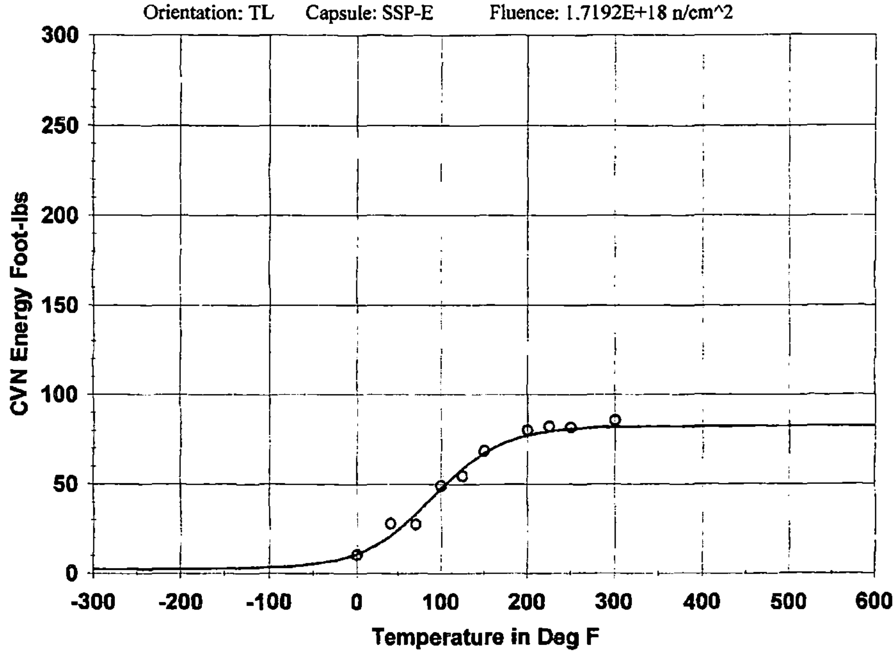
Temperature	Input CVN	Computed CVN	Differential
400.00	83.00	81.45	1.55

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 * [Tanh((T-To)/(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
.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: 1.7192E+18 n/cm^2

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)

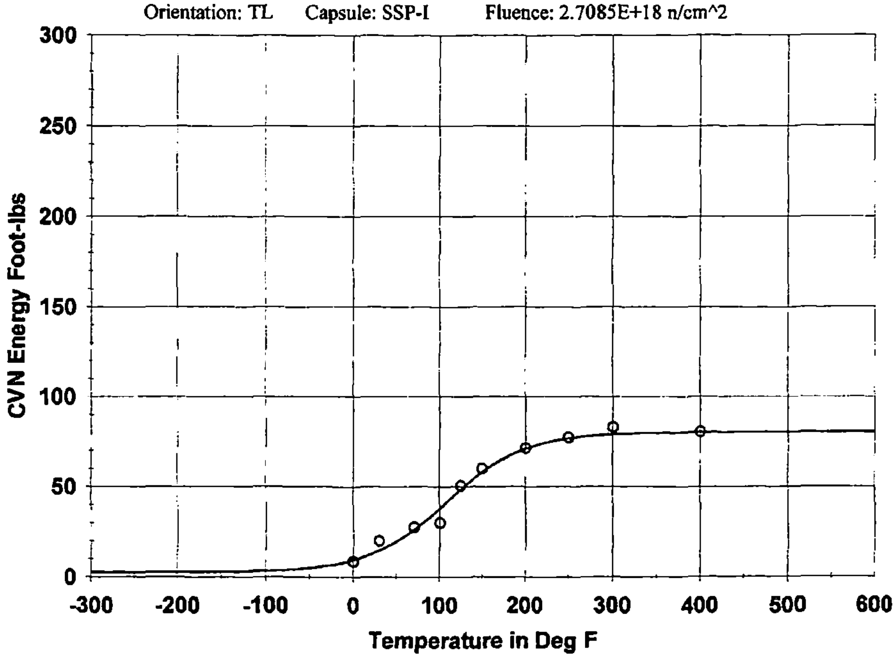
IRRADIATED PLATE HEAT C2331-2 (SSP-I)

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 * [Tanh((T-To)/(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
.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: 2.7085E+18 n/cm^2

Charpy V-Notch Data

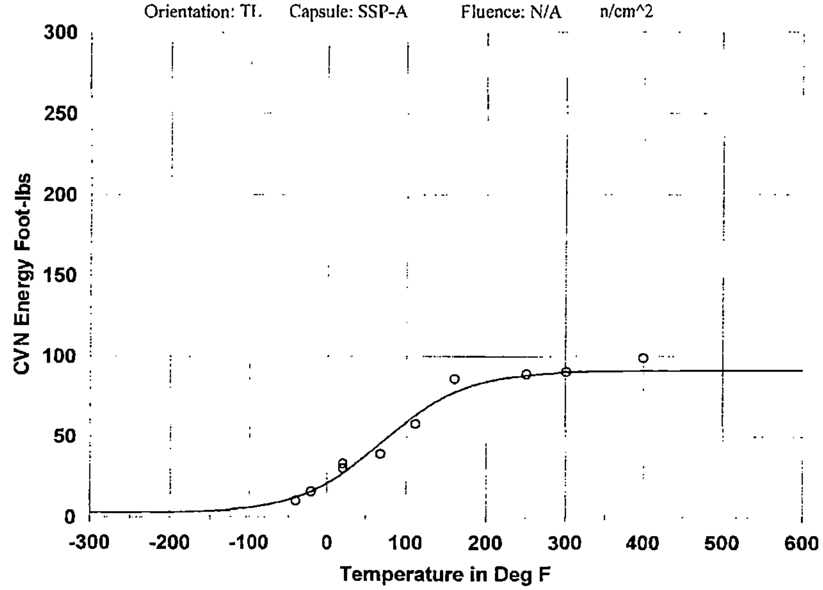
Temperature	Input CVN	Computed CVN	Differential
400.00	80.50	80.17	.33

Correlation Coefficient = .992

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

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 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/cm^2

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)

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

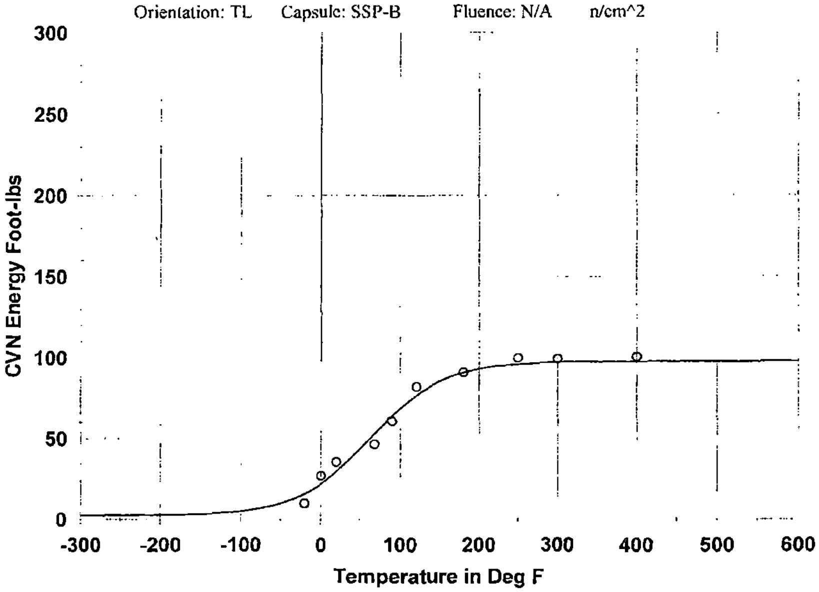
Equation is A + B * [Tanh((T-To)/(C+DT))]

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 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/cm^2

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)

{{

(E)}}

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

References

A-19-1. "Progress Report on Phase 2 of the BWR Owners' Group Supplemental Surveillance Program," T.A. Caine, S. Ranganath, and S.J. Stark, GE Nuclear Energy, GE-NE-523-99-0792, January 1992.

A-19-2. *BWRVIP-87NP, Revision 1: BWR Vessel and Internals Project Testing and Evaluation of BWR Supplemental Surveillance Program Capsules D, G, and H.* EPRI, Palo Alto and BWRVIP: 2010. 1021553.

A-19-3. *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-19-4. CVGRAPH, Hyperbolic Tangent Curve Fitting Program, Developed by ATI Consulting, Version 5.0.2, Revision 1, 3/26/02.

A-19-5. General Electric, "Cooper Nuclear Station Reactor Pressure Vessel Surveillance Materials Testing and Fracture Toughness Analysis," T.A. Caine, B.J. Branlund, and S. Ranganath, MDE-103-0986, May 1987.

A-19-6. "Radiation Embrittlement of Reactor Vessel Materials," USNRC Regulatory Guide 1.99, Revision 2, May 1988.

A-19-7. "Format and Content of Report for Thermal Annealing of Reactor Pressure Vessels," USNRC Regulatory Guide 1.162, February 1996.

A-19-8. 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-19-9. 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-19-10. *BWR Vessel and Internals Project: BWR Integrated Surveillance Program Plan (BWRVIP-78).* EPRI, Palo Alto, CA and BWRVIP: 1999. TR-114228.

A-19-11. Not used.

A-19-12. *BWRVIP-169NP: BWR Vessel and Internals Project, Testing and Evaluation of BWR Supplemental Surveillance Program (SSP) Capsules A, B, and C.* EPRI, Palo Alto, CA: 2010. 1021556.

Enclosure 3

Affidavit for Proprietary Information Contained in the Pressure and Temperature Limits Report (PTLR) for 54 Effective Full-Power Years (EFPY)

Cooper Nuclear Station Docket No. 50-298, DPR-46

ELECTRIC POWER RESEARCH INSTITUTE

AFFIDAVIT

RE: Request for Withholding of the Following Proprietary Information Included In:

NPPD, Cooper Nuclear Station,
Pressure and Temperature Limits Report (PTLR)
for 54 Effective Full Power Years (EFPY),
ER 2016-041, Rev 2

I, Neil Wilmshurst, being duly sworn, depose and state as follows:

I am the Vice President and Chief Nuclear Officer at Electric Power Research Institute, Inc. whose principal office is located at 3420 Hillview Avenue, Palo Alto, California ("EPRI") and I have been specifically delegated responsibility for the above-listed Report which contains EPRI Proprietary Information that is sought under this Affidavit to be withheld "Proprietary Information". I am authorized to apply to the U.S. Nuclear Regulatory Commission ("NRC") for the withholding of the Proprietary Information on behalf of EPRI.

EPRI Proprietary Information is identified in the above referenced report with text inside double brackets. Examples of such identification is as follows:

{{This sentence is an example[(E)]}}

Tables containing EPRI Proprietary Information are identified with double brackets before and after the object. In each case the superscript notation [(E)] refers to this affidavit and all the bases included below, which provide the reasons for the proprietary determination.

EPRI requests that the Proprietary Information be withheld from the public on the following bases:

Withholding Based Upon Privileged And Confidential Trade Secrets Or Commercial Or Financial Information (see e.g. 10 C.F.R. §2.390(a)(4))::

a. The Proprietary Information is owned by EPRI and has been held in confidence by EPRI. All entities accepting copies of the Proprietary Information do so subject to written agreements imposing an obligation upon the recipient to maintain the confidentiality of the Proprietary Information. The Proprietary Information is disclosed only to parties who agree, in writing, to preserve the confidentiality thereof.

b. EPRI considers the Proprietary Information contained therein to constitute trade secrets of EPRI. As such, EPRI holds the information in confidence and disclosure thereof is strictly limited to individuals and entities who have agreed, in writing, to maintain the confidentiality of the Information.

c. The information sought to be withheld is considered to be proprietary for the following reasons. EPRI made a substantial economic investment to develop the Proprietary Information and, by prohibiting public disclosure, EPRI derives an economic benefit in the form of licensing royalties and other additional fees from the confidential nature of the Proprietary Information. If the Proprietary Information were publicly available to consultants and/or other businesses providing services in the electric and/or nuclear power industry, they would be able to use the Proprietary Information for their own commercial benefit and profit and without expending the substantial economic resources required of EPRI to develop the Proprietary Information.

d. EPRI's classification of the Proprietary Information as trade secrets is justified by the Uniform Trade Secrets Act which California adopted in 1984 and a version of which has been adopted by over forty states. The California Uniform Trade Secrets Act, California Civil Code §§3426 – 3426.11, defines a "trade secret" as follows:

> "'Trade secret' means information, including a formula, pattern, compilation, program device, method, technique, or process, that:
>
> (1) Derives independent economic value, actual or potential, from not being generally known to the public or to other persons who can obtain economic value from its disclosure or use; and
>
> (2) Is the subject of efforts that are reasonable under the circumstances to maintain its secrecy."

e. The Proprietary Information contained therein are not generally known or available to the public. EPRI developed the Information only after making a determination that the Proprietary Information was not available from public sources. EPRI made a substantial investment of both money and employee hours in the development of the Proprietary Information. EPRI was required to devote these resources and effort to derive the Proprietary Information. As a result of such effort and cost, both in terms of dollars spent and dedicated employee time, the Proprietary Information is highly valuable to EPRI.

f. A public disclosure of the Proprietary Information would be highly likely to cause substantial harm to EPRI's competitive position and the ability of EPRI to license the Proprietary Information both domestically and internationally. The Proprietary Information and Report can only be acquired and/or duplicated by others using an equivalent investment of time and effort.

I have read the foregoing and the matters stated herein are true and correct to the best of my knowledge, information and belief. I make this affidavit under penalty of perjury under the laws of the United States of America and under the laws of the State of North Carolina.

Executed at 1300 W WT Harris Blvd, Charlotte, NC being the premises and place of business of Electric Power Research Institute, Inc.

Date: 8-6-2019.

[signature]

Neil Wilmshurst

(State of North Carolina)
(County of Mecklenburg)

Subscribed and sworn to (or affirmed) before me on this 6th day of August, 2019 by Neil Wilmshurst, proved to me on the basis of satisfactory evidence to be the person(s) who appeared before me.

Signature Deborah H. Rouse (Seal)

My Commission Expires 2nd day of April, 2021

DEBORAH H. ROUSE
NOTARY PUBLIC
CABARRUS
COUNTY
NORTH CAROLINA