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10 CFR 50.90

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

**SUSQUEHANNA STEAM ELECTRIC STATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION ON TECHNICAL SPECIFICATION CHANGES TO RCS PRESSURE AND TEMPERATURE (P/T) LIMITS
PLA-7299**

**Docket No. 50-387
and No. 50-388**

References: 1. *PPL Letter (PLA-7181), "[Proposed Amendments to] Revise Technical Specification 3.4.10, RCS Pressure and Temperature (P/T) Limits," dated August 11, 2014 (Accession ML14223A780).*

2. *NRC Letter, "Request for Additional Information re: Request to Revise Technical Specification 3.4.10, RCS Pressure and Temperature (P/T) Limits, TAC Nos. MF4597 and MF4598)," dated January 30, 2015 (Accession ML15008A470).*

The purpose of this letter is for PPL Susquehanna, LLC (PPL) to provide the requested additional information (RAI). By Reference 1, PPL submitted a License Amendment Request to revise Technical Specifications (TS) 3.4.10, RCS [reactor coolant system] Pressure and Temperature (P/T) Limits for Units 1 and 2. In Reference 2, the NRC RAI includes two questions that required additional analysis, and for which this response provides revised TS Figures 3.4.10-1 through 3.4.10-3. The associated TS Bases markups are also provided for information. In consideration of the additional analysis required by the RAI, a discussion with the NRC Project Manager resulted in an understanding that this information would be provided to the NRC by April 10, 2015. The additional information is in the Attachments 1 through 5 to this letter.

PPL has reviewed the information supporting a finding of no significant hazards consideration and the environmental consideration provided to the NRC in Reference 1. The additional information provided by this submittal does not affect the bases for concluding that the proposed license amendment does not involve a significant hazards consideration. Furthermore the additional information also does not affect the bases for concluding that neither an environmental impact statement nor an environmental assessment needs to be prepared in connection with the proposed amendment.

There are no new regulatory commitments associated with this response.

If you have any questions or require additional information, please contact Mr. Jeffery N. Grisewood (570) 542-1330.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: April 6, 2015

Sincerely,

J. A. Franke

Attachments:
1. Response to Requested Additional Information
2. Analysis Supporting the Revised TS Figures 3.4.10-1 through 3.4.10-3
3. Technical Justification for Extending the P/T Curves to -100 psig
4. Revised TS Figures 3.4.10-1 through 3.4.10-3, Units 1 and 2
5. Markups to TS Bases, Units 1 and 2 (For Information)

Copy: NRC Region I
Mr. J. Greives, NRC Sr. Resident Inspector
Mr. J. Whited, NRC Project Manager
Mr. L. Winker, PA DEP/BRP

Attachment 1 to PLA-7299

Response to Requested Additional Information

Response to Requested Additional Information

By letter dated August 11, 2014 [(1)] PPL Susquehanna, LLC (PPL), submitted a license amendment request (LAR) to revise Technical Specification (TS) 3.4.10, "RCS Pressure and Temperature (P/T) Limits," for the Susquehanna Steam Electric Station (SSES), Units 1 and 2. Specifically, the proposed LAR was to revise the P/T Limit curves to extend them into the vacuum region to address vacuum fill operations. The NRC requested additional information (RAI) in a letter dated January 30, 2015.[(2)] This Attachment 1 provides the restated RAI 1 and RAI 2, and the PPL responses using the information in Attachments 2 through 5.

RAI 1:

Title 10 of the Code of Federal Regulations Part 50, Appendix G, "Fracture Toughness Requirements," requires that P/T limits be developed to bound all ferritic materials in the reactor vessel (RV). Further, Sections I and IV.A of 10 CFR Part 50, Appendix G specify that all ferritic reactor coolant pressure boundary (RCPB) components outside of the RV must meet the applicable requirements of American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section III, "Rules for Construction of Nuclear Facility Components."

ISSUE

As clarified in Regulatory Information Summary (RIS) 2014-11,[(3)] "Information on Licensing Applications for Fracture Toughness Requirements for Ferritic Reactor Coolant Pressure Boundary Components," P/T limit calculations for ferritic RV components other than those materials with the highest reference temperature, may define curves that are more limiting than those calculated for the RV beltline shell materials because the consideration of stress levels from structural discontinuities (such as nozzles) may produce a lower allowable pressure.

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(1) PPL Letter (PLA-7181), *"[Proposed Amendments to] Revise Technical Specification 3.4.10, RCS Pressure and Temperature (P/T) Limits,"* dated August 11, 2014 (ML14223A780)

(2) NRC Letter, *"Request for Additional Information re: Request to Revise Technical Specification 3.4.10, RCS Pressure and Temperature (P/T) Limits, (TAC Nos. MF4597 and MF4598),"* dated January 30, 2015 (Accession ML15008A470)

(3) NRC Regulatory Issue Summary (RIS) 2014-11, *"Information on Licensing Applications for Fracture Toughness Requirements for Ferritic Reactor Coolant Pressure Boundary Components,"* dated October 14, 2014 (ML14149A165)

REQUEST

Describe how the P/T limit curves for SSES, Units 1 and 2, consider all ferritic pressure boundary components of the reactor vessel that are predicted to experience a neutron fluence exposure greater than 1x10^17 n/cm^2 (E > 1 MeV) at the end of the licensed operating period. If the current P/T limit curves do not consider all ferritic pressure boundary components of the reactor vessel that are predicted to experience a neutron fluence exposure greater than 1x10^17 n/cm^2 (E > 1 MeV) at the end of the licensed operating period, provide appropriately revised P/T limit curves to the NRC staff for review.

PPL's Response to RAI 1:

The requested additional information is provided as follows.

a) Revised P/T limit curves are provided in Attachment 4 to replace the figures in Reference 1, (e.g., TS Figures 3.4.10-1 through 3.4.10-3 for both Units 1 and 2).

b) Analysis supporting use of the revised TS Figures is provided in Attachment 2.

c) Associated TS Bases markups are provided in Attachment 5 for information.

RAI 2:

BACKGROUND

The regulations in 10 CFR 50.36(b) state, in part, that, "The technical specifications will be derived from the analyses and evaluation included in the safety analysis report, and amendments thereto, submitted pursuant to § 50.34."

ISSUE

Page 3 of 7 of the licensee's application states, in part, that:

> The absolute maximum vacuum is assumed to be no greater than 15 psig.

Whereas the licensee's proposed Technical Specifications (TS) change on TS Figures 3.4.10-1 through 3.4.10-3 shows P/T limit curves are extended to -100 psig. Any TS change should be consistent with the technical justification.

REQUEST

Please provide a justification for an extension of the P/T curves to -100 psig, or, TS Figures 3.4.10-1 through 3.4.10-3 should be revised to reflect the maximum vacuum of -15 psig as described in the submittal (i.e., adjusting the axis to end at -15 psig, terminating the P/T curves at -15 psig on the current scale, etc.).

PPL's Response to RAI 2:

The technical justification for allowing an extension of the P/T curves to -100 psig is provided in Attachment 3, which demonstrates that the P/T limits applicable at 0 psig are also applicable at negative pressures and that the RPV maintains structural margin at -100 psig.

The statement on Page 3 of 7 of the application (Reference 1), which states, in part, "The absolute maximum vacuum is assumed to be no greater than 15 psig," recognizes the fact that there is no possibility of drawing the RPV to greater than an absolute vacuum (approximately -14.7 psig). However, as detailed in Attachment 3, it is possible for the RPV to also experience an external pressure of approximately 2 psig due to drywell pressurization. In this case, the effective pressure on the RPV would be -16.7 psig (-14.7 psig - 2 psig). Thus, there is a possibility, albeit remote, for the RPV to experience an effective internal pressure of -16.7 psig, which does exceed an absolute vacuum.

It is also recognized that there is potential variance and uncertainty in the measured steam dome pressure under a vacuum, using the installed instrumentation. By extending the P/T curves to -100 psig, PPL's intention is to avoid future concerns should any vacuum reading ever exceed -15 psig. The extension to -100 psig is expected to cover any reasonably foreseeable variance in steam dome vacuum measurement.

A final point in response to this RAI is that the extension of the P/T curves to -100 psig matches the scale and format of the existing P/T curves (i.e., pressure values are in increments of 100 psig). Furthermore, extending the scale to -100 psig, even though the RPV will never experience such a vacuum, is analogous to the upper limit of 1300 psig on the P/T curves, which would also be unattainable, assuming the RPV safety relief valves operated per design. During startups/heatups, the operators would not pressurize the RPV significantly beyond 1000 psig.

Attachment 2 to PLA-7299

Analysis Supporting the Revised TS Figures 3.4.10-1 Through 3.4.10-3

Analysis Supporting the Revised TS Figures 3.4.10-1 Through 3.4.10-3

Introduction

This attachment documents the revised pressure and temperature (P/T) limit curves developed for the Susquehanna Steam Electric Station (SSES) Unit 1 and Unit 2. The curves 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. The P/T limit curves were developed for 40 EFPY for SSES Unit 1 and Unit 2 and are provided in Figure 1 through Figure 6, and tabulated data for the overall composite curves (by region) is included in Table 1 through Table 6. The adjusted reference temperature (ART) values for the SSES Unit 1 and Unit 2 vessel beltline materials for 40 EFPY are shown in Table 7 and Table 8.

P/T Curve Methodology

The P/T limit curves were derived as follows:

1. The methodology used is in accordance with References [1] and [2], which have been approved by the NRC.

2. The neutron fluence is calculated in accordance with NRC Regulatory Guide 1.190 (RG 1.190) [3], using the RAMA computer code, as documented in Reference [4].

3. The ART values for the limiting beltline materials are calculated in accordance with NRC Regulatory Guide 1.99, Revision 2 (RG 1.99) [5], as documented in Reference [6].

4. 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 References [7, 25].

Operating Limits

The resulting P/T limit curves are based on the geometry, design, and materials information for the SSES Unit 1 and Unit 2 vessels with the following conditions:

- Heat-up/Cool-down rate limit during Hydrostatic Class 1 Leak Testing (Figure 1 and Figure 4: Curve A): ≤ 25°F/hour [(1)].
- Normal Operating Heat-up/Cool-down rate limit (Figure 2 and Figure 5: Curve B - non-nuclear heating, and Figure 3 and Figure 6: Curve C - nuclear heating): ≤ 100°F/hour[(2)].
- 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.

To address the NRC condition regarding lowest service temperature in Reference [1], the minimum temperature is set to 70°F, which is equal to the $RT_{NDT,max}$ + 60°F, for all curves. This value is consistent with the minimum temperature limits specified in the original P/T limit curves from the SSES Units 1 and 2 FSAR, Revision 13, predating initial operation [Figures 5.3-4a and 5.3-4b in Reference 10a]; from FSAR, Revision 35 [Figure 5.3-4a and 5.3-4b in Reference 10b]; and from Technical Specifications [Figure 3.4.6.1-1 in Reference 11].

The revised composite P/T limit curves are extended below 0 psig to -100 psig based on the evaluation documented in Reference [12], which demonstrates that the P/T limit curves are applicable to negative gauge pressures. Although the maximum vacuum is assumed to be no greater than -14.7 psig, a pressure of -100 psig bounds the maximum expected vacuum pressure as well as externally applied pressures the RPV may experience. Since the P/T limit curve calculation methods used do not specifically apply to negative values of pressure, the tabulated results start at 0 psig. However, the maximum analyzed RPV vacuum pressure is -100 psig.

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(1) Interpreted as the temperature change in any 1-hour period is less than or equal to 25°F
(2) Interpreted as the temperature change in any 1-hour period is less than or equal to 100°F.

Discussion

The adjusted reference temperature (ART) of the limiting beltline material is used to adjust the beltline P/T limit curves to account for irradiation effects. RG 1.99 [5] provides the methods for determining the ART. The RG 1.99 methods for determining the limiting material and adjusting the P/T limit curves using ART are discussed in this section.

The vessel beltline copper (Cu) and nickel (Ni) values were obtained from the evaluation of the SSES Unit 1 and Unit 2 vessel plate, weld, and forging materials [9]. 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 chemistry factor (CF) per Paragraph 1.1 of RG 1.99 for plates and forgings. However, for materials where credible surveillance data exists, a fitted CF may be used if it bounds the RG 1.99 CF.

For SSES Unit 1, the peak RPV ID fluence value of 9.40×10^{17} n/cm^2 at 40 EFPY was developed in Reference [6] based on linear interpolation between reported fluence values for 23.8 EFPY and 54 EFPY from Reference [4.a], which were calculated in accordance with RG 1.190 [3]. These fluence values for the limiting lower-intermediate shell plate (Heat No. C0776-1) are based upon an attenuation factor of 0.691 for a postulated 1/4t flaw. Consequently, the 1/4t fluence for 40 EFPY for the limiting lower-intermediate shell plate is 6.49×10^{17} n/cm^2 for SSES Unit 1.

For SSES Unit 2, the peak RPV ID fluence value of 1.04×10^{18} n/cm^2 at 40 EFPY was developed in Reference [6] based on linear interpolation between reported fluence values for 32 EFPY and 54 EFPY from Reference [4.b], which were calculated in accordance with RG 1.190 [3]. These fluence values for the limiting lower-intermediate shell plate (Heat No. C-2421-3) are based upon an attenuation factor of 0.691 for a postulated 1/4t flaw. Consequently, the 1/4t fluence for 40 EFPY for the limiting lower-intermediate shell plate is 7.21×10^{17} n/cm^2 for SSES Unit 2.

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 [7, 25]. 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 limiting fluence values are as described in the paragraphs above. Based on the ART evaluation in Reference [6], the recirculation inlet and outlet nozzles do not exist in the beltline region, therefore the only nozzle evaluated for the beltline P/T limits is the WLI nozzle. The feedwater (FW) nozzle is considered in the evaluation of the non-beltline (upper vessel) region P/T limits.

The P/T limit curves for the core not critical and core critical operating condition at a given EFPY apply for both the 1/4t (inside surface flaw) and 3/4t (outside surface flaw) locations. When combining pressure and thermal stresses, it is usually necessary to evaluate stresses at the 1/4t and the 3/4t locations. This is because the thermal gradient tensile stress of interest is in the inner wall during cool-down and is in the outer wall during heat-up. However, as a conservative simplification, the thermal gradient stresses at the 1/4t location are assumed to be tensile for both heat-up and cool-down. This results in the approach of applying the maximum tensile stress at the 1/4t location. This approach is conservative because irradiation effects cause the allowable toughness at 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, which is well above the P/T limits.

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 $E > 1$ MeV) are shown for SSES Unit 1 in Table 7 and for SSES Unit 2 in Table 8 [6].

Per Reference [6] and in accordance with Appendix A of Reference [1], the SSES Unit 1 and Unit 2 representative weld and plate surveillance material data were reviewed from the Boiling Water Reactor Vessel and Internals Project (BWRVIP) Integrated Surveillance Program (ISP) [14, 15, 16, 27].

For SSES Unit 1, the fitted CF for the target beltline plate (Heat No. C2433-1), which is based on credible surveillance data, bounds the RG 1.99 CF [14, 16]. Therefore, the fitted CF is used for the target plate. References [14, 16] contain surveillance capsule test results for the SSES Unit 1 representative weld material. The material heats for the SSES Unit 1 representative surveillance capsule weld material does not match the target weld material, however, the surveillance weld material heat does match the heat number for a beltline weld, and there is no data that identifies which weld wire heat is associated with each specific beltline weld. Consequently, the fitted CF for the representative weld material, which bounds the RG 1.99 CF, is used in the determination of ART values for all beltline welds.

For SSES Unit 2, the representative plate material (Heat No. B0673-1) is contained in the Duane Arnold capsules and Supplemental Surveillance Program (SSP) Capsule F. The representative weld material (Heat No. BP6756) is contained in the River Bend capsules and SSP Capsules C, F, and H. References [14, 27] contains surveillance capsule test results for the SSES Unit 2 representative plate and weld materials; however, the representative plate and weld materials do not match any material heats in the SSES Unit 2 beltline. Therefore, the CF calculated using the RG 1.99 [5] tables is used in the determination of ART values for the SSES Unit 2 target plate and weld materials.

The ANSYS Mechanical and PrepPost, Release 14.5 (with Service Pack 1) [17], finite element computer program was used to develop the stress distributions through the FW nozzle, and these stress distributions were used in the determination of the stress intensity factors for the FW nozzles [18]. At the time that the analyses above were performed, the ANSYS program was controlled under the vendor's 10 CFR 50 Appendix B [19] Quality Assurance Program for nuclear quality-related work.

The plant-specific SSES Unit 1 and Unit 2 FW nozzle analysis [18] was performed to determine stress intensity factors due to through-wall pressure stress distributions and thermal stress distributions due to bounding thermal transients permitted by Technical Specifications [13]. The resulting stress intensity factors are reported in Table 9. Detailed information regarding the analysis can be found in Reference [18]. The following summarizes the development of the thermal and pressure stress intensity factors for the FW nozzle [18]:

- With respect to operating conditions, the thermal transient that would produce the highest tensile stresses at the 1/4t location which is permitted by Technical Specifications is the 100°F/hour shutdown transient [18]. Therefore, the stresses represent the bounding stresses in the FW nozzle associated with 100°F/hour heat-up/cool-down limits associated with the P/T limit curves for the non-beltline region. The thermal stress distribution, corresponding to the limiting time presented in Reference [18], along a linear path through the nozzle corner is used. The BIE/IF methodology presented in Reference [1] is used to calculate the thermal stress intensity factor, K_{IT}, due to the thermal stresses by fitting a third order polynomial equation to the path stress distribution for the thermal load case.

- Boundary conditions and heat transfer coefficients used for the thermal analysis were obtained from Reference [20], based on those used in the FW nozzle design specification [21] and design stress report [22].

- With respect to pressure stress, a unit pressure of 1000 psig was applied to the internal surfaces of the finite element model. The pressure stress distribution was taken along the same path as the thermal stress distribution. The BIE/IF methodology presented in Reference [1] is used to calculate the pressure stress intensity factor, K_{IP}, by fitting a third order polynomial equation to the path stress distribution for the pressure load case. The resulting K_{IP} can be linearly scaled to determine the K_{IP} for various RPV internal pressures.

- A one-quarter symmetric, three-dimensional finite element model of the FW nozzle was constructed. Temperature-dependent material properties were taken from the SSES Code of Construction [23]. For thermal conductivity and thermal diffusivity, the 1971 Code [24] is used, since that was the first Code year that those properties were provided.

References

1. Structural Integrity Associates Report No. SIR-05-044, Revision 1-A, "Pressure-Temperature Limits Report Methodology for Boiling Water Reactors," June 2013.

2. Structural Integrity Associates Report No. 0900876.401, Revision 0-A, "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. Nuclear Regulatory Commission, Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," March 2001.

4. TransWare Fluence Evaluations:
    a. TransWare Report No. EPR-SQ1-001-R-002, Revision 0, "Fluence Evaluation for Susquehanna Unit 1 Reactor Pressure Vessel Using RAMA Fluence Methodology," February 15, 2013.
    b. TransWare Report No. PPL-FLU-002-R-001, Revision 0, "Susquehanna Unit 2 Reactor Pressure Vessel Fluence Evaluation," May 6, 2005.

5. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988.

6. Structural Integrity Associates Calculation No. 1400252.301, Revision 0, "Susquehanna Units 1 and 2 RPV Beltline ART and USE Calculation."

7. Structural Integrity Associates Calculation No. 1400252.303, Revision 0, "Susquehanna Unit 1 P/T Curve Calculation for 40 and 54 EFPY."

8. Code of Federal Regulations, Title 10, Part 50, Section 59, "Changes, tests and experiments," August 28, 2007.

9. General Electric Reports:
    a. GE-NE-523-169-1292, DRF B13-01666, Revision 1, "Susquehanna Steam Electric Station Unit 1 Vessel Surveillance Materials Testing and Fracture Toughness Analysis," October 1993.
    b. GE-NE-523-107-0893, DRF 137-0010-6, Revision 1A, "Susquehanna Steam Electric Station Unit 2 Vessel Surveillance Materials Testing and Fracture Toughness Analysis," October 1993.

10. Susquehanna Units 1 and 2 Final Safety Analysis Report:
    a. Revision 13, November 1979.
    b. Revision 35, July 1984.

11. Letter (PLA-3567), dated 04/18/1991, "Susquehanna Steam Electric Station Proposed Amendments 146 to License No. NPF-14 and 100 to License No. NPF-22: Revision to P/T limit curves and Specimen Withdrawal Schedule," from H. W. Keiser (PP&L) to Dr. W.R. Butler (NRC).

12. Letter (PLA-7299), Attachment 3 of this letter, "Technical Justification for Extending the P/T Curves to -100 psig."

13. Susquehanna Unit 1 Technical Specifications, Section 3.4.10, RCS Pressure and Temperature (P/T) Limits.

14. BWRVIP-135, Revision 2: BWR Vessel and Internals Project, Integrated Surveillance Program (ISP) Data Source Book and Plant Evaluations. EPRI, Palo Alto, CA: 2009. 1020231. **EPRI PROPRIETARY INFORMATION**.

15. EPRI Letter 2010-238, Errata for BWRVIP-135, Revision 2, October 15, 2010. **EPRI PROPRIETARY INFORMATION.**

16. EPRI Letter 2013-193, Evaluation of the Susquehanna 1 120° Surveillance Capsule Data, October 31, 2013. **EPRI PROPRIETARY INFORMATION.**

17. ANSYS Mechanical APDL and PrepPost, Release 14.5 (w/Service Pack 1), September 2012.

18. SI Calculation No. 1400252.302, Revision 0, "Feedwater Nozzle Fracture Mechanics Analysis."

19. Code of Federal Regulations, Title 10, Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," August 28, 2007.

20. Structural Integrity Associates Calculation PPL-02Q-315-1, Revision 0, "Finite Element Model for Susquehanna Feedwater Nozzle."

21. GE Design Specification 22A5536, Revision 3, "Feedwater Nozzle Safe Ends."

22. GE Stress Report 22A5537, Revision 2, "Feedwater Nozzle Safe Ends."

23. ASME Section III, 1968 Edition with Addenda through Summer 1970.

24. ASME Section III, 1971 Edition.

25. Structural Integrity Associates Calculation No. 1400252.304, Revision 0, "Susquehanna Unit 2 P/T Curve Calculation for 40 and 54 EFPY."

26. Code of Federal Regulations, Title 10, Part 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements," January 31, 2008.

27. EPRI Letter 2014-078, Transmittal of New BWRVIP Integrated Surveillance Program (ISP) Data Applicable to Susquehanna Unit 2, May 15, 2014. **EPRI PROPRIETARY INFORMATION.**

28. BWRVIP-275NP: BWR Vessel and Internals Project: Testing and Evaluation of the Susquehanna Unit 1 120° Capsule. EPRI, Palo Alto, CA: 2013: 3002000685.

29. BWRVIP-86, Revision 1: BWR Vessel and Internals Project, Updated BWR Integrated Surveillance Program (ISP) Implementation Plan. EPRI, Palo Alto, CA: 2008. 1016575.

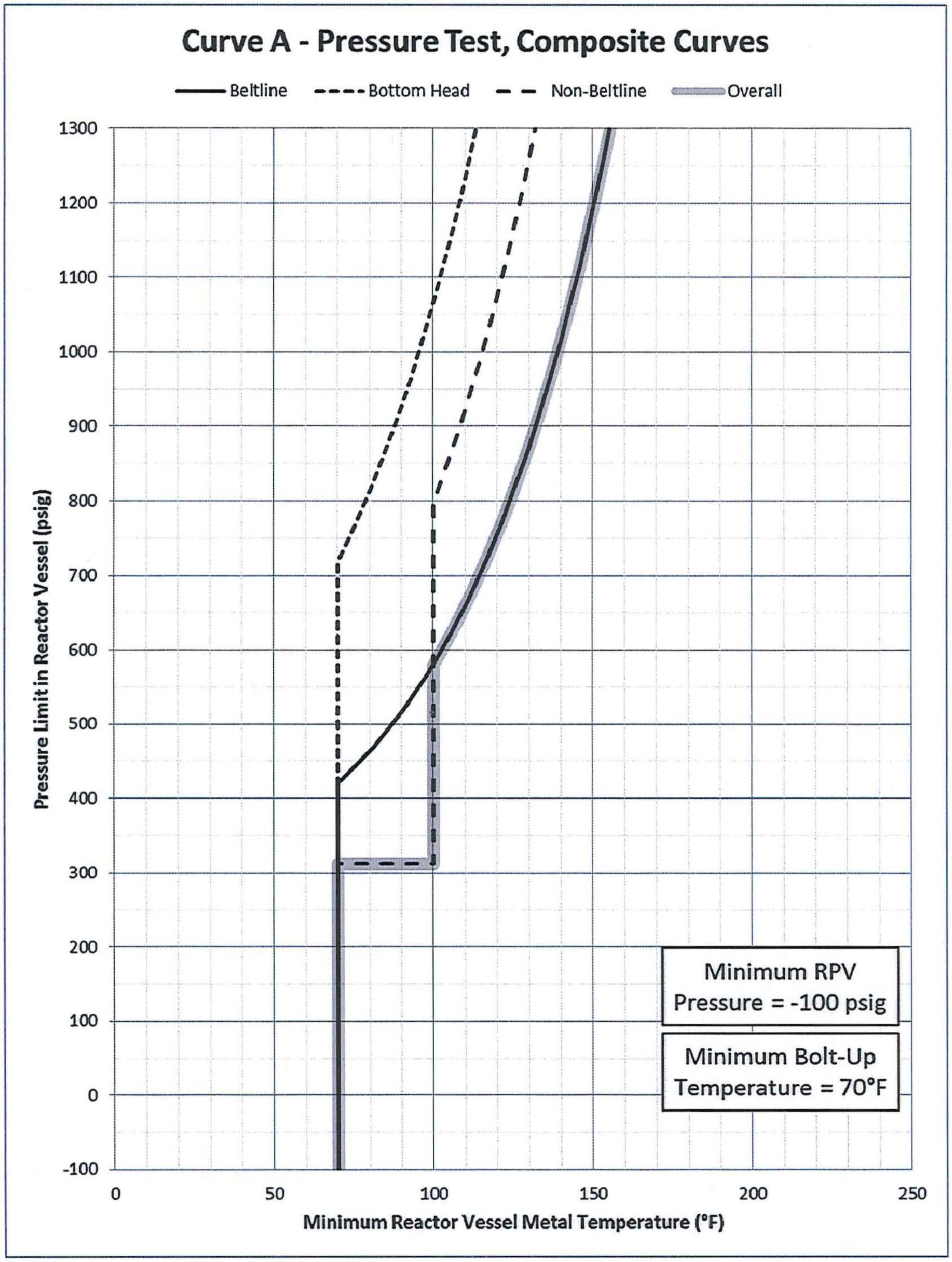

Figure 1: SSES Unit 1 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY

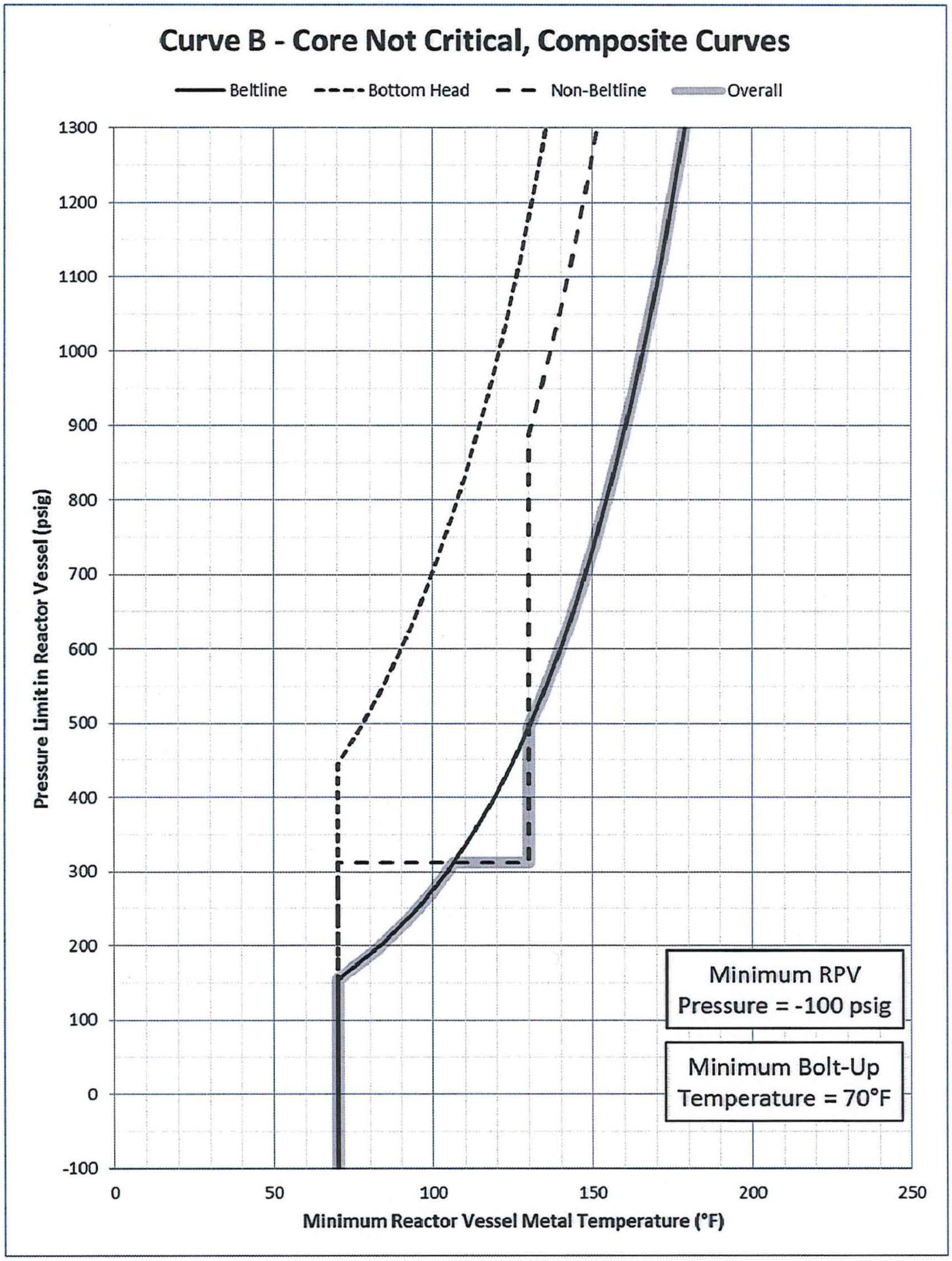

Figure 2: SSES Unit 1 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY

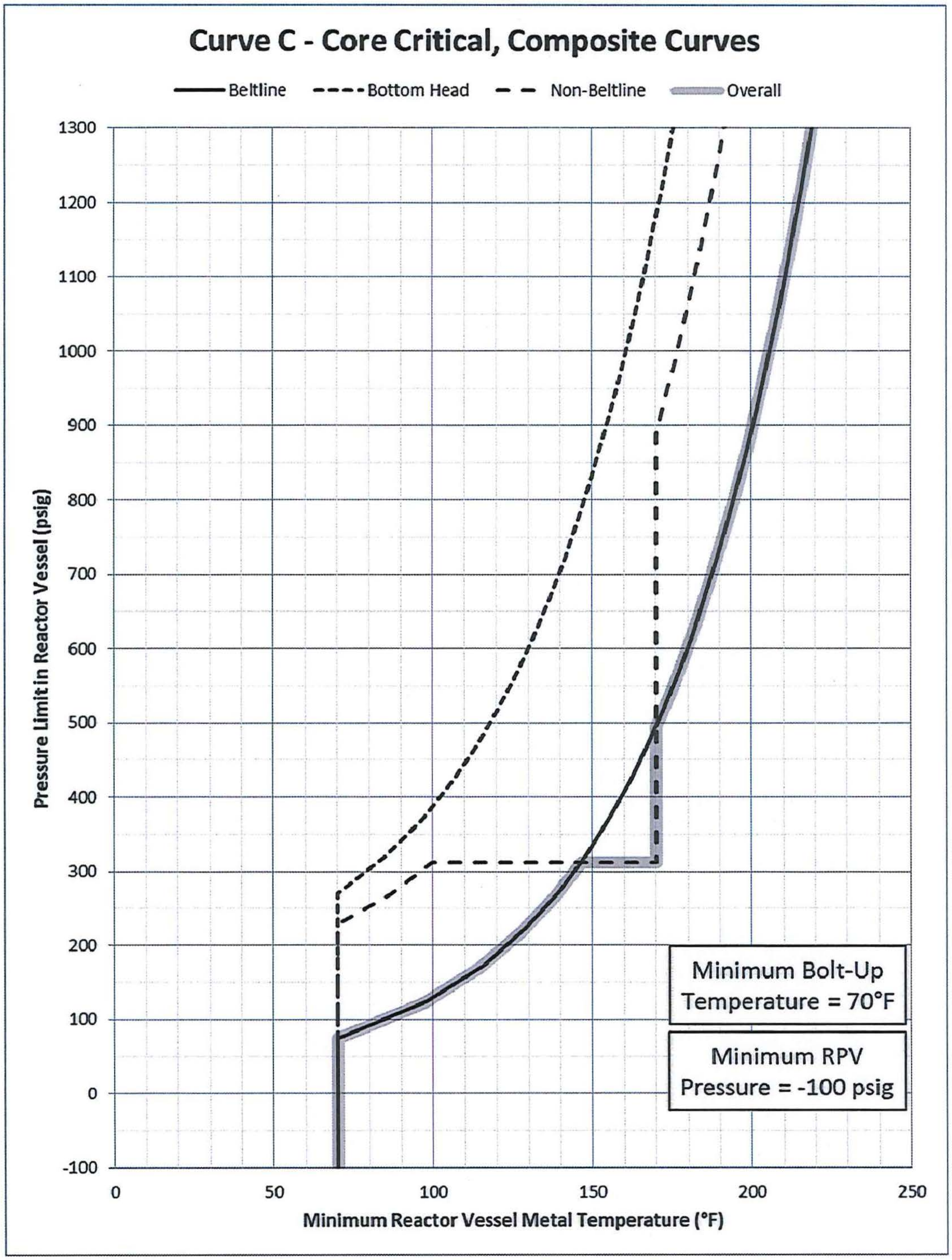

Figure 3: SSES Unit 1 P/T Curve C (Normal Operation – Core Critical), 40 EFPY

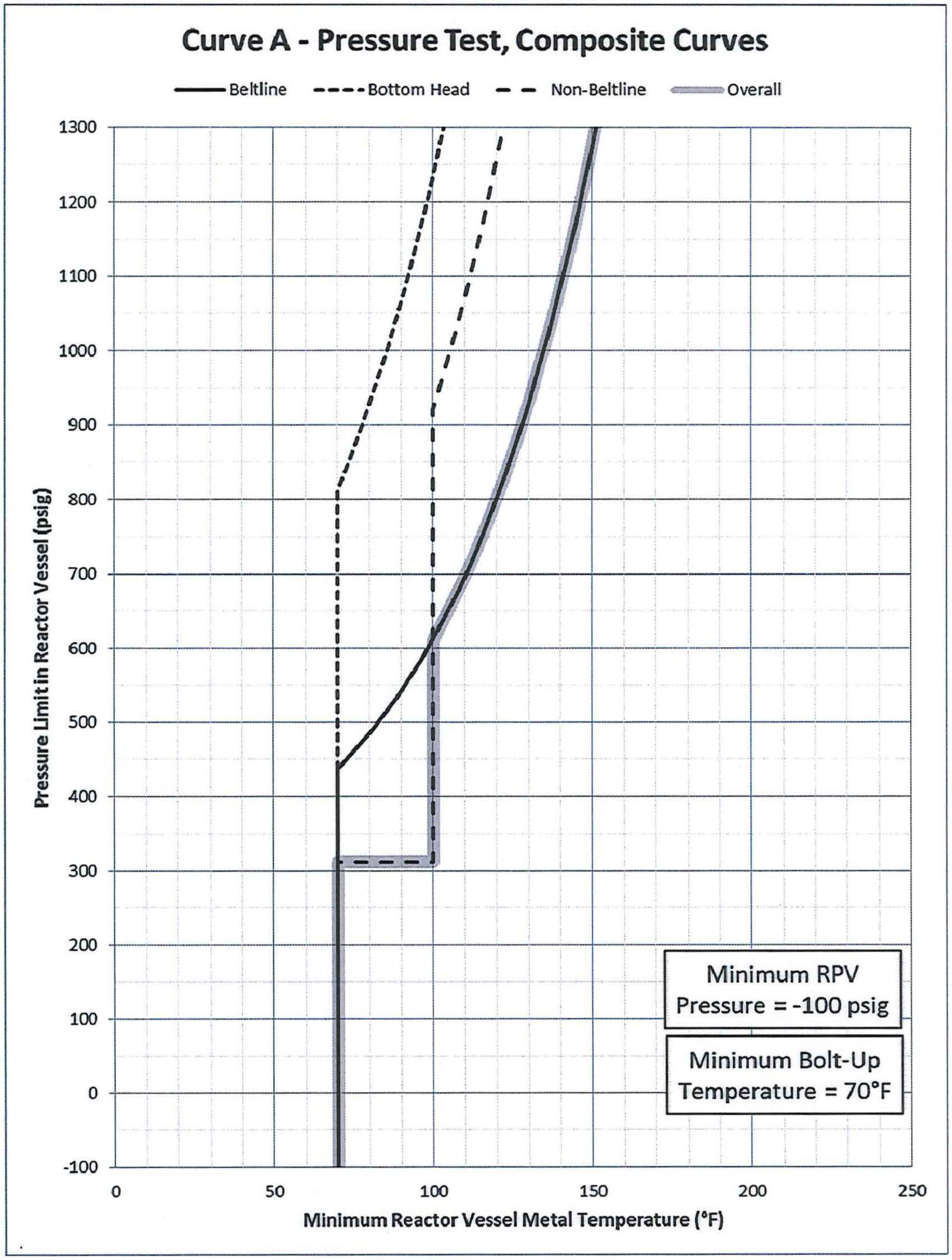

Figure 4: SSES Unit 2 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY

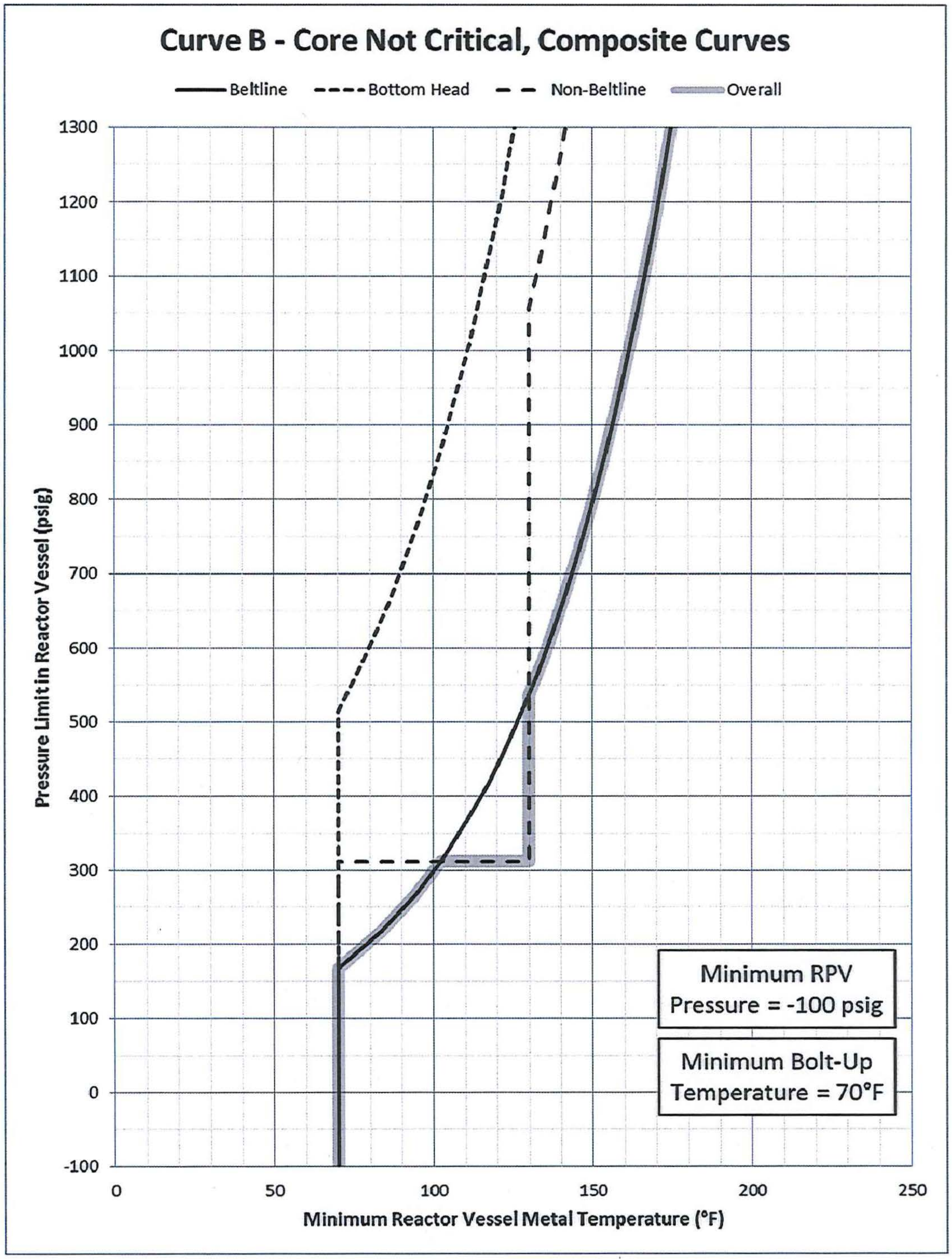

Figure 5: SSES Unit 2 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY

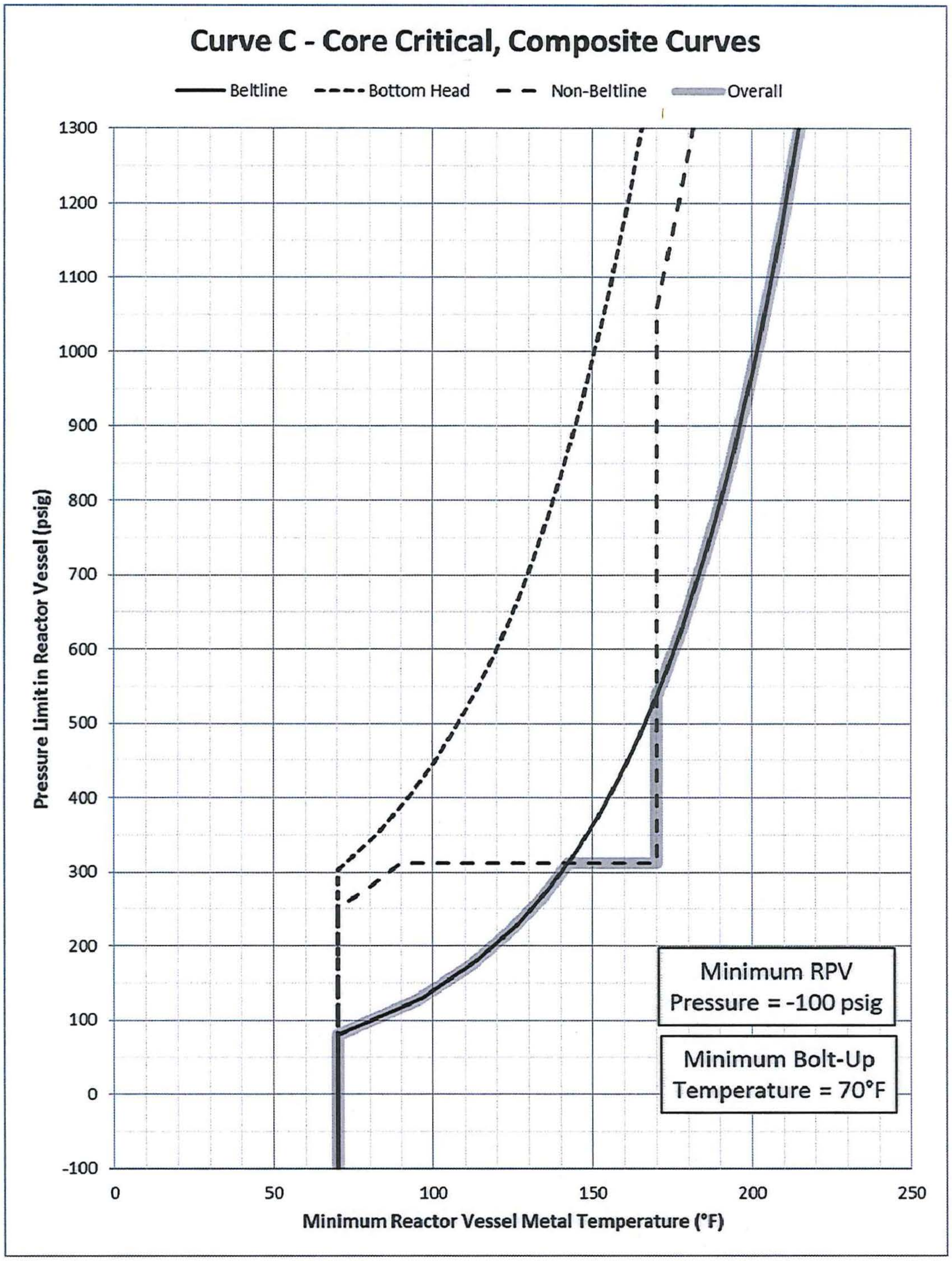

Figure 6: **SSES Unit 2 P/T Curve C (Normal Operation – Core Critical), 40 EFPY**

Table 1: SSES Unit 1 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY)

Beltline Region

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	419.5
81.4	469.2
90.6	518.9
98.4	568.6
105.2	618.3
111.1	668.1
116.4	717.8
121.2	767.5
125.6	817.2
129.6	866.9
133.4	916.7
136.8	966.4
140.1	1016.1
143.1	1065.8
146.0	1115.5
148.7	1165.3
151.3	1215.0
153.7	1264.7
156.1	1314.4

Table 1: SSES Unit 1 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY) (continued)

Non-Beltline Region

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	312.6
100.0	312.6
100.0	796.6
104.1	844.5
107.9	892.4
111.4	940.3
114.7	988.2
117.8	1036.1
120.7	1084.0
123.5	1131.9
126.1	1179.8
128.6	1227.7
130.9	1275.6
133.2	1323.5

Table 1: SSES Unit 1 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY) (concluded)

<u>Bottom Head Region</u>

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	717.9
75.6	767.6
80.6	817.4
85.2	867.1
89.3	916.8
93.2	966.5
96.8	1016.2
100.1	1065.9
103.2	1115.6
106.2	1165.3
109.0	1215.0
111.6	1264.7
114.1	1314.5

Table 2: SSES Unit 1 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY)

Beltline Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	154.7
84.3	203.3
95.5	251.8
104.6	300.4
112.3	348.9
118.9	397.5
124.8	446.1
130.1	494.6
134.9	543.2
139.2	591.8
143.2	640.3
146.9	688.9
150.3	737.4
153.6	786.0
156.6	834.6
159.5	883.1
162.2	931.7
164.7	980.3
167.2	1028.8
169.5	1077.4
171.7	1125.9
173.8	1174.5
175.9	1223.1
177.8	1271.6
179.7	1320.2

Table 2: SSES Unit 1 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY) (continued)

Non-Beltline Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	312.6
130.0	312.6
130.0	888.6
133.1	936.8
135.9	984.9
138.7	1033.1
141.2	1081.3
143.7	1129.4
146.0	1177.6
148.3	1225.8
150.4	1274.0
152.5	1322.1

Table 2: SSES Unit 1 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY) (concluded)

Bottom Head Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	444.7
77.2	493.3
83.4	541.9
89.0	590.6
94.0	639.2
98.5	687.8
102.7	736.4
106.5	785.0
110.1	833.7
113.5	882.3
116.6	930.9
119.5	979.5
122.3	1028.2
124.9	1076.8
127.4	1125.4
129.8	1174.0
132.1	1222.6
134.3	1271.3
136.3	1319.9

Table 3: **SSES Unit 1 P/T Curve C (Normal Operation – Core Critical), 40 EFPY)**

Beltline Region

Curve C – Core Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	74.2
98.1	123.8
116.0	173.5
129.2	223.1
139.6	272.7
148.2	322.3
155.6	372.0
162.0	421.6
167.6	471.2
172.7	520.9
177.3	570.5
181.6	620.1
185.5	669.7
189.1	719.4
192.5	769.0
195.6	818.6
198.6	868.2
201.4	917.9
204.1	967.5
206.6	1017.1
209.0	1066.7
211.3	1116.4
213.5	1166.0
215.6	1215.6
217.6	1265.2
219.5	1314.9

Table 3: SSES Unit 1 P/T Curve C (Normal Operation – Core Critical), 40 EFPY) (continued)

Non-Beltline Region

Curve C - Core Critical	
P/T Curve Temperature	**P/T Curve Pressure**
°F	*psi*
70.0	0.0
70.0	228.1
87.1	270.4
99.9	312.6
170.0	312.6
170.0	888.6
173.1	936.8
175.9	984.9
178.7	1033.1
181.2	1081.3
183.7	1129.4
186.0	1177.6
188.3	1225.8
190.4	1274.0
192.5	1322.1

Table 3: SSES Unit 1 P/T Curve C (Normal Operation – Core Critical), 40 EFPY) (concluded)

Bottom Head Region

Curve C - Core Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	270.7
85.0	320.4
96.5	370.1
105.9	419.8
113.8	469.5
120.6	519.2
126.6	568.9
131.9	618.6
136.8	668.3
141.2	718.0
145.2	767.7
149.0	817.4
152.4	867.1
155.7	916.8
158.8	966.5
161.6	1016.2
164.4	1065.9
166.9	1115.7
169.4	1165.4
171.7	1215.1
174.0	1264.8
176.1	1314.5

Table 4: **SSES Unit 2 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY)**

Beltline Region

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	436.5
80.4	485.5
89.0	534.5
96.3	583.5
102.7	632.5
108.4	681.4
113.5	730.4
118.1	779.4
122.3	828.4
126.2	877.3
129.9	926.3
133.2	975.3
136.4	1024.3
139.4	1073.2
142.2	1122.2
144.8	1171.2
147.4	1220.2
149.8	1269.1
152.0	1318.1

Table 4: SSES Unit 2 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY) (continued)

Non-Beltline Region

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	312.6
100.0	312.6
100.0	920.4
103.5	969.8
106.8	1019.2
109.8	1068.7
112.7	1118.1
115.4	1167.5
118.0	1217.0
120.5	1266.4
122.8	1315.8

Table 4: SSES Unit 2 P/T Curve A (Hydrostatic Pressure and Leak Test), 40 EFPY) (concluded)

Bottom Head Region

Curve A - Pressure Test	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	811.2
74.4	858.2
78.4	905.2
82.1	952.2
85.6	999.2
88.8	1046.2
91.8	1093.1
94.7	1140.1
97.4	1187.1
100.0	1234.1
102.4	1281.1
104.8	1328.1

Table 5: SSES Unit 2 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY)

Beltline Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	167.5
83.6	217.3
94.3	267.2
103.2	317.0
110.6	366.9
117.2	416.7
122.9	466.5
128.1	516.4
132.8	566.2
137.0	616.0
141.0	665.9
144.6	715.7
148.0	765.6
151.2	815.4
154.2	865.2
157.1	915.1
159.7	964.9
162.3	1014.8
164.7	1064.6
167.0	1114.4
169.2	1164.3
171.3	1214.1
173.3	1264.0
175.3	1313.8

Table 5: SSES Unit 2 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY) (continued)

Non-Beltline Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	312.6
130.0	312.6
130.0	1057.7
132.4	1103.6
134.7	1149.6
136.9	1195.5
139.0	1241.4
141.0	1287.4
142.9	1333.3

Table 5: SSES Unit 2 P/T Curve B (Normal Operation – Core Not Critical), 40 EFPY) (concluded)

Bottom Head Region

Curve B - Core Not Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	514.7
76.1	564.6
81.5	614.5
86.4	664.4
90.8	714.3
94.9	764.3
98.7	814.2
102.2	864.1
105.5	914.0
108.6	963.9
111.5	1013.9
114.2	1063.8
116.8	1113.7
119.3	1163.6
121.7	1213.6
123.9	1263.5
126.1	1313.4

Table 6: SSES Unit 2 P/T Curve C (Normal Operation – Core Critical), 40 EFPY)

Beltline Region

Curve C - Core Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	80.0
96.3	129.4
113.4	178.8
126.2	228.3
136.3	277.7
144.8	327.1
152.0	376.6
158.3	426.0
163.9	475.4
168.9	524.9
173.5	574.3
177.7	623.7
181.5	673.2
185.1	722.6
188.5	772.0
191.6	821.5
194.6	870.9
197.3	920.4
200.0	969.8
202.5	1019.2
204.9	1068.7
207.2	1118.1
209.3	1167.5
211.4	1217.0
213.4	1266.4
215.4	1315.8

Table 6: SSES Unit 2 P/T Curve C (Normal Operation – Core Critical), 40 EFPY) (continued)

Non-Beltline Region

Curve C - Core Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	251.0
80.9	281.8
89.9	312.6
170.0	312.6
170.0	1057.7
172.4	1103.6
174.7	1149.6
176.9	1195.5
179.0	1241.4
181.0	1287.4
182.9	1333.3

Table 6: **SSES Unit 2 P/T Curve C (Normal Operation – Core Critical), 40 EFPY) (concluded)**

Bottom Head Region

Curve C - Core Critical	
P/T Curve Temperature *°F*	**P/T Curve Pressure** *psi*
70.0	0.0
70.0	302.1
82.3	350.6
92.2	399.1
100.5	447.6
107.5	496.1
113.7	544.6
119.2	593.1
124.2	641.6
128.7	690.1
132.9	738.6
136.7	787.1
140.3	835.6
143.6	884.1
146.7	932.5
149.6	981.0
152.4	1029.5
155.0	1078.0
157.5	1126.5
159.9	1175.0
162.1	1223.5
164.3	1272.0
166.4	1320.5

Table 7: SSES Unit 1 ART Table for 40 EFPY

	Part Name & Material	ID No.	Heat No.	Lot No.	Estimated Initial RTNDT (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_i (°F)	EFPY	ART (°F)
Plates	Lower Shell #1	21-1	B5083-1	---	-8	0.14	0.48	94.6	29.4	14.7	0.0	40	50.7
	Lower Shell #2	21-2	C0770-2	---	-20	0.14	0.50	95.5	29.6	14.8	0.0	40	39.3
	Lower Shell #3	21-3	C0814-2	---	-20	0.13	0.51	88.3	27.4	13.7	0.0	40	34.8
	Lower-Int. Shell #1	22-1	C0803-1	---	-10	0.09	0.53	58.0	19.5	9.7	0.0	40	29.0
	Lower-Int. Shell #2	**22-2**	**C0776-1**	**---**	**6**	**0.12**	**0.48**	**80.6**	**27.1**	**13.5**	**0.0**	**40**	**60.2**
	Lower-Int. Shell #3*	***22-3***	***C2433-1***	***---***	***18***	***0.10***	***0.62***	***66.7***	***22.4***	***8.5***	***0.0***	***40***	***57.4***
Welds	Weld #1*	---	629616	L320A27AG	-50	0.04	0.99	135.7	42.1	14.0	0.0	40	20.1
	Weld #2*	---	411L3071	L311A27AF	-50	0.03	0.93	135.7	42.1	14.0	0.0	40	20.1
	Weld #3*	***---***	***494K2351***	***L307A27AD***	***-50***	***0.04***	***1.10***	***135.7***	***42.1***	***14.0***	***0.0***	***40***	***20.1***
	Weld #4*	---	401S0371	B504B27AE	-80	0.03	1.04	135.7	42.1	14.0	0.0	40	-9.9
	Weld #5*	---	402K9171	K315A27AE	-50	0.03	0.98	135.7	42.1	14.0	0.0	40	20.1
	Weld #6*	---	402C4371	C115A27A	-50	0.02	0.92	135.7	42.1	14.0	0.0	40	20.1
	Weld #7*	---	412P3611	J417B27AF	-80	0.03	0.93	135.7	42.1	14.0	0.0	40	-9.9

Fluence Information

	Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$
Plates	Lower Shell #1	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Lower Shell #2	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Lower Shell #3	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Lower-Int. Shell #1	6.16	1.54	40	9.40E+17	0.691	6.49E+17	0.336
	Lower-Int. Shell #2	6.16	1.54	40	9.40E+17	0.691	6.49E+17	0.336
	Lower-Int. Shell #3*	6.16	1.54	40	9.40E+17	0.691	6.49E+17	0.336
Welds	Weld #1*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #2*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #3*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #4*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #5*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #6*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310
	Weld #7*	6.16	1.54	40	8.07E+17	0.691	5.58E+17	0.310

Note: Bold italic text indicates the target beltline plate and weld. Bold underlined text indicates the limiting beltline material at 40 EFPY. An asterisk (*) indicates a CF based on surveillance capsule data was used in ART calculations

Table 8: SSES Unit 2 ART Table for 40 EFPY

	Part Name & Material	ID No.	Heat No.	Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_i (°F)	EFPY	ART (°F)
Plates	Lower Shell #1	21-1	6C956-1-1	---	-20	0.11	0.55	73.5	23.7	11.9	0.0	40	27.4
Plates	Lower Shell #2	21-2	6C980-1-1	---	-20	0.10	0.56	65.0	21.0	10.5	0.0	40	21.9
Plates	Lower Shell #3	21-3	6C1053-1-1	---	10	0.10	0.58	65.0	21.0	10.5	0.0	40	51.9
Plates	***Lower-Int. Shell #1***	***22-1***	***C2421-3***	---	***-10***	***0.13***	***0.68***	***93.0***	***33.0***	***16.5***	***0.0***	***40***	***56.0***
Plates	Lower-Int. Shell #2	22-2	C2929-1	---	-20	0.13	0.64	92.0	32.6	16.3	0.0	40	45.3
Plates	Lower-Int. Shell #3	22-3	C2433-2	---	2	0.10	0.63	65.3	23.2	11.6	0.0	40	48.3
Welds	Weld #1	---	629616	L320A27AG	-50	0.04	0.99	54.0	17.4	8.7	0.0	40	-15.2
Welds	***Weld #2***	---	***624263***	***E204A27A***	***-20***	***0.06***	***0.89***	***82.0***	***26.5***	***13.2***	***0.0***	***40***	***32.9***
Welds	Weld #3	---	09M057	C109A27A	-36	0.03	0.89	41.0	13.2	6.6	0.0	40	-9.5
Welds	Weld #4	---	659N315	F414B27AF	-70	0.04	1.00	54.0	17.4	8.7	0.0	40	-35.2
Welds	Weld #5	---	411L3071	L311A27AF	-50	0.03	0.93	41.0	13.2	6.6	0.0	40	-23.5
Welds	Weld #6	---	494K2351	L307A27AD	-50	0.04	1.10	54.0	17.4	8.7	0.0	40	-15.2
Welds	Weld #7	---	401S0371	B504B27AE	-80	0.03	1.04	41.0	13.2	6.6	0.0	40	-53.5
Welds	Weld #8	---	402K9171	K315A27AE	-50	0.03	0.98	41.0	13.2	6.6	0.0	40	-23.5
Welds	Weld #9	---	402C4371	C115A27A	-50	0.02	0.92	27.0	8.7	4.4	0.0	40	-32.6
Welds	Weld #10	---	412P3611	J417B27AF	-80	0.03	0.93	41.0	13.2	6.6	0.0	40	-53.5

Fluence Information

	Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$
Plates	Lower Shell #1	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Plates	Lower Shell #2	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Plates	Lower Shell #3	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Plates	Lower-Int. Shell #1	6.16	1.54	40	1.04E+18	0.691	7.21E+17	0.355
Plates	Lower-Int. Shell #2	6.16	1.54	40	1.04E+18	0.691	7.21E+17	0.355
Plates	Lower-Int. Shell #3	6.16	1.54	40	1.04E+18	0.691	7.21E+17	0.355
Welds	Weld #1	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #2	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #3	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #4	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #5	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #6	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #7	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #8	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #9	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323
Welds	Weld #10	6.16	1.54	40	8.69E+17	0.691	6.00E+17	0.323

Note: Bold italic text indicates the limiting beltline plate and weld.

Table 9: SSES Units 1 and 2 Summary of Nozzle Stress Intensity Factors

Nozzle	Applied Pressure, $K_{Ip\text{-}app}$	Thermal, K_{It} (100°F/hour Ramp Rate)
Feedwater	82.1	7.5
WLI	86.3	26.2

Note: K_I in units of ksi-in$^{0.5}$

Attachment 3 to PLA-7299

Technical Justification for Extending the P/T Curves to -100 psig

Technical Justification for Extending the P/T Curves to -100 psig

1.0 INTRODUCTION

It is possible for boiling water reactors (BWRs) to pull a small vacuum on the reactor pressure vessel (RPV) during startup and, under certain conditions, during shutdown. Previous pressure-temperature (P/T) limit curves for the Susquehanna Steam Electric Station (SSES) Units 1 and 2 did not allow for pressures below 0 psig. The following evaluation demonstrates the applicability of the P/T limit curves to pressures below 0 psig and the structural adequacy of the SSES RPVs at -100 psig.

2.0 OBJECTIVES

1. Qualitatively assess the applicability of the P/T limit curves to negative gauge pressure values.

2. Calculate the allowable external pressure for the cylindrical and spherical portions of the RPV, and determine if there is adequate structural margin considering vessel operation under a vacuum.

3.0 TECHNICAL APPROACH

A vacuum on the inside of a pressure vessel creates a pressure differential across the vessel wall. The pressure on the inside of the vessel is lower than the pressure on the outside of the vessel. Therefore, the internal vacuum condition can be considered as an externally applied pressure. The applicability of the P/T limit curves to negative gauge pressure values is qualitatively assessed by discussing the impact of an external pressure on the postulated 1/4T flaw used to develop the P/T limit curves.

The allowable external pressure is calculated using the methods provided in Section III, Article NB-3133 of the ASME Code [1.a] and the SSES-specific RPV dimensions and material. The use of the 2007 edition of the ASME Code with 2008 addenda is appropriate because it provides current guidance for evaluating external pressure, and it contains methods that are valid for the SSES RPV material. The cylindrical and spherical sections of the RPV are evaluated separately.

4.0 ASSUMPTIONS

The following assumptions are used in this evaluation:

1. A temperature of 550°F is used for determining the "B" factor from NB-3133.3 Steps 4 and 5.

   This assumption is appropriate because higher temperatures provide lower "B" factors and consequently result in lower allowable external pressures. The value of 550°F conservatively bounds any temperature at which the vessel could see a negative gauge pressure, since the boiling water reactor (BWR) operates on the steam saturation curve. Further, 550°F bounds the normal operating fluid temperature from the RPV thermal cycle diagram [2].

2 A vacuum pressure of -100 psig is assumed for comparison to the calculated allowable external pressure values. This represents a pressure difference across the RPV wall for a vacuum condition that is higher than any anticipated pressures and allows for potentially significant instrumentation uncertainties at negative pressures.

   This assumption is conservative because it bounds the maximum vacuum that could be applied to the RPV (-14.7 psig) and the maximum drywell pressure, which is approximately 2 psig [3, 4], as demonstrated in the following calculation:

$$-14.7\text{ psig} - 2\text{ psig} = -16.7\text{ psig} < -100\text{ psig}$$

5.0 DESIGN INPUTS

The following design inputs are used in this evaluation:

- RPV material: SA 508, Cl. 2; SA 533 Gr. B, Cl. 1 [5, 6, 7, 8]
- RPV inner diameter (ID): 253.38 inches [9]
- RPV thickness: 6.19 inches [9] *(thinner shell)*
- Bottom head inner radius: 126.69 inches [7]
- Bottom head thickness: 6.19 inches [7] *(thinner shell)*
- Top head inner radius: 125.5 inches [8]
- Top head thickness: 3.25 inches [8] *(thinner shell)*
- Tangent length: 618.3 inches [9] (745 - 126.69)

Note: The tangent length is taken as the elevation of the RPV closure flange minus the inside radius of the bottom head.

6.0 ASSESSMENT OF P/T LIMIT CURVE APPLICABILITY

10 CFR 50 Appendix G [10] requires that operating limits on RPV metal temperature and internal pressure be developed such that adequate margin against non-ductile failure exists for all normal operating conditions and anticipated operating occurrences. The methods of the ASME Boiler and Pressure Vessel Code, Section XI, Non-mandatory Appendix G [1.c] are cited in 10CFR50 Appendix G as being acceptable to demonstrate the required margins against non-ductile failure. These methods require the conservative postulation of a ¼ wall thickness flaw with aspect ratio (length to depth) of 6:1. Additionally, only internal pressure and through-wall thermal gradients must be considered when calculating the driving force acting on the postulated flaws.

Some plants can be operated in a manner such that the RPV experiences a small vacuum. Pulling a vacuum on the RPV is conceptually similar to applying an external pressure. When the RPV experiences a small vacuum it will experience compressive loading caused by the ambient external pressure being larger than the internal pressure. Consequently, the driving force acting on the tip of the postulated flaw will be reduced from that calculated for the 0 psig point on the P/T limit curves. In other words, the applied stress intensity factor at the postulated crack tip, when the RPV experiences a small vacuum, is less than the applied stress intensity factor when the RPV experiences a positive internal pressure. Thus, the RPV metal temperature required for a RPV internal pressure of 0 psig is applicable for RPV operation with a small vacuum. Additionally, since the tensile stress field at a crack tip is reduced, the effect is independent of the heatup or cooldown conditions and will not affect the limiting flaw (i.e. ID or OD connected).

7.0 ALLOWABLE EXTERNAL PRESSURE CALCULATIONS

The RPV cylinder, bottom head and top head locations are evaluated separately.

7.1 RPV Cylinder

The RPV cylinder is evaluated using the methods of ASME Section III, NB-3133.3 for cylindrical shells with an outer diameter, Do, to thickness, T, ratio equal to or greater than 10. The outer diameter of the RPV is the inner diameter plus two times the thickness.

$$Do = 253.38 \text{ in.} + 2\,(6.19 \text{ in.}) = 265.8 \text{ in.}$$

For the SSES Units 1 and 2 RPVs, the Do/T ratio = 265.8 / 6.19 = 42.9

The total length, L, is defined as the tangent length plus 1/3 of the depth of each head for a cylinder without stiffening rings. The depth of each head is taken as the head inner radius of each head. The total length is calculated as follows:

$$L = 618.3 \text{ in.} + [(126.69 \text{ in.} + 125.5 \text{ in.}) / 3] = 702.4 \text{ in.}$$

In order to use the material charts in ASME Section II, Part D, Subpart 3 [1.b], the ratio L/Do must be determined.

$$L/Do = 702.4 \text{ in.} / 265.8 \text{ in.} = 2.6$$

From Figure G of ASME Section II, Part D, Subpart 3 [1.b], the A-factor can be determined using the calculated Do/T and L/Do ratios.

$$A \approx 0.0015$$

From Figure CS-5, which is applicable for the RPV material, the B-factor can be determined using the A- factor and the assumed temperature of 550°F.

$$B \approx 16000$$

The allowable pressure, Pa, is then calculated as follows:

$$Pa = 4 \cdot B / 3 \cdot (Do/T) = (4 \cdot 16000) / (3 \cdot 42.9) = 497 \text{ psia}$$

Comparing the assumed maximum vacuum of -100 psig to the calculated allowable external pressure of 497 psia (482 psig), the allowable pressure exceeds the maximum vacuum by a factor of 4.8.

7.2 Bottom Head

The bottom head side plates and dollar plates differ in thickness. Therefore, the limiting lower thickness for the side plates is used to bound the entire bottom head. The bottom head is evaluated using the methods of ASME Section III, NB-3133.4 for spherical shells. The A-factor is calculated using the bottom head radius, R, and thickness, T, as follows:

$$A = 0.125 / R/T = 0.125 / (126.69 \text{ in.} / 6.19 \text{ in.}) = 0.006$$

From Figure CS-5, which is applicable for the RPV material, the B-factor can be determined using the A- factor and the assumed temperature of 550°F.

$$B \approx 19000$$

The allowable pressure, Pa, is then calculated as follows:

$$Pa = B / R/T = 19000 / (126.69 \text{ in.} / 6.19 \text{ in.}) = 928 \text{ psia}$$

Comparing the assumed maximum vacuum of -100 psig to the calculated allowable external pressure of 928 psia (913 psig), the allowable pressure exceeds the maximum vacuum by a factor of 9.

7.3 Top Head

The top head plates vary in thickness. Therefore, the limiting lower thickness for the top head dollar plate is used to bound the entire top head. The top head is evaluated using the methods of ASME Section III, NB-3133.4 for spherical shells. The A-factor is calculated using the top head radius, R, and thickness, T, as follows:

$$A = 0.125 / R/T = 0.125 / (125.5 \text{ in.} / 3.25 \text{ in.}) = 0.003$$

From Figure CS-5, which is applicable for the RPV material, the B-factor can be determined using the A- factor and the assumed temperature of 550°F.

$$B \approx 18000$$

The allowable pressure, Pa, is then calculated as follows:

$$Pa = B / R/T = 18000 / (125.5 \text{ in.} / 3.25 \text{ in.}) = 466 \text{ psia}$$

Comparing the assumed maximum vacuum of -100 psig to the calculated allowable external pressure of 466 psia (451 psig), the allowable pressure exceeds the maximum vacuum by a factor of 4.5.

8.0 CONCLUSIONS

The results of this evaluation support the following conclusions:

1. The P/T limit curves remain applicable for values of negative gauge pressure and may be extended to -100 psig (i.e., the permissible temperature at 0 psig applies through -100 psig).

2. The RPV can withstand significant external pressures, and the RPV cylinder, bottom head and top head locations have adequate structural margin for values of negative gauge pressure in excess of -100 psig, which greatly exceeds any vacuum that could be pulled on the RPV.

9.0 REFERENCES

1. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code:
   a. Section III, 2007 Edition with 2008 Addenda.
   b. Section II, 2007 Edition with 2008 Addenda.
   c. Section XI, 2007 Edition with 2008 Addenda.

2. PPL Drawing No. FF113010, Sheets 8901 and 8902, Revision 2, IDCN 1, "Reactor Vessel Thermal Cycles."

3. SSES Unit 1, Technical Specification (pg. 3.6-17), Amendment No. 178, ADAMS Accession No. ML093290169.

4. SSES Unit 2, Technical Specification (pg. 3.6-17), Amendment No. 151, ADAMS Accession No. ML093290177.

5. PPL Drawing No. FF113013, Sheet 4201, Revision 1, "Shell Ring Assemblies & Flanges, Weld Seam & Plate Identification."

6. PPL Drawing No. FF113013, Sheet 7101, Revision 1, "Shell Ring Assemblies & Flanges, Weld Seam & Plate Identification."

7. PPL Drawing No. FF113010, Sheet 7601, Revision 7, "Bottom Head Assembly."

8. PPL Drawing No. FF113010, Sheet 8401, Revision 3, "Top Head Assembly."

9. PPL Drawing No. FF113011, Sheet 8801, Revision 3, "Vessel Outline."

10. Title 10 Code of Federal Regulations Part 50, Appendix G, "Fracture Toughness Requirements," December 12, 2013.

Attachment 4 to PLA-7299

Revised TS Figures 3.4.10-1 Through 3.4.10-3, Units 1 and 2

Note: This Attachment replaces Attachment 1 to PLA-7181, (Reference 1).

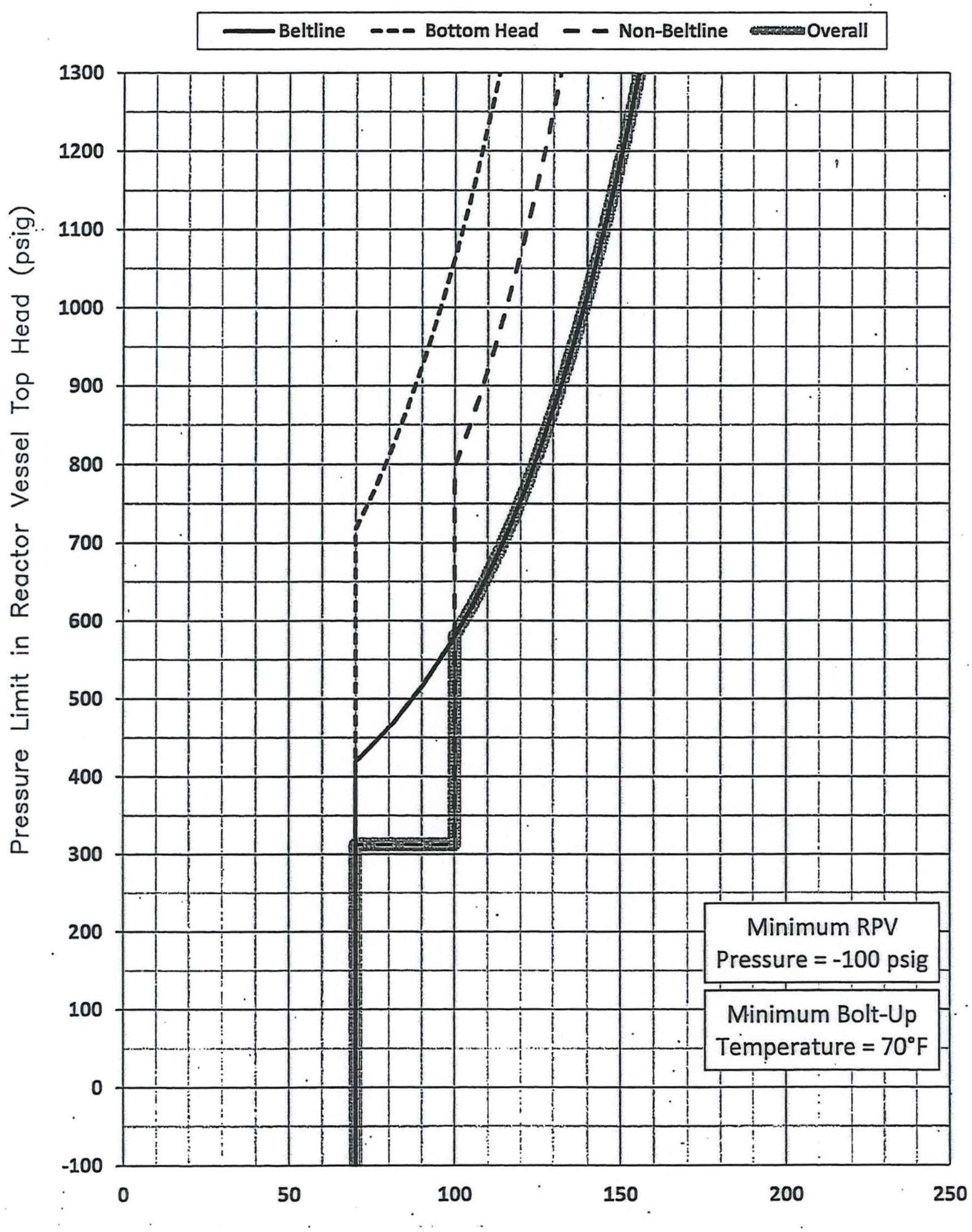

FIGURE 3.4.10-1
System Hydrotest Limit with Fuel in Vessel for ~~35.7~~ 40 EFPY
(Curve A)

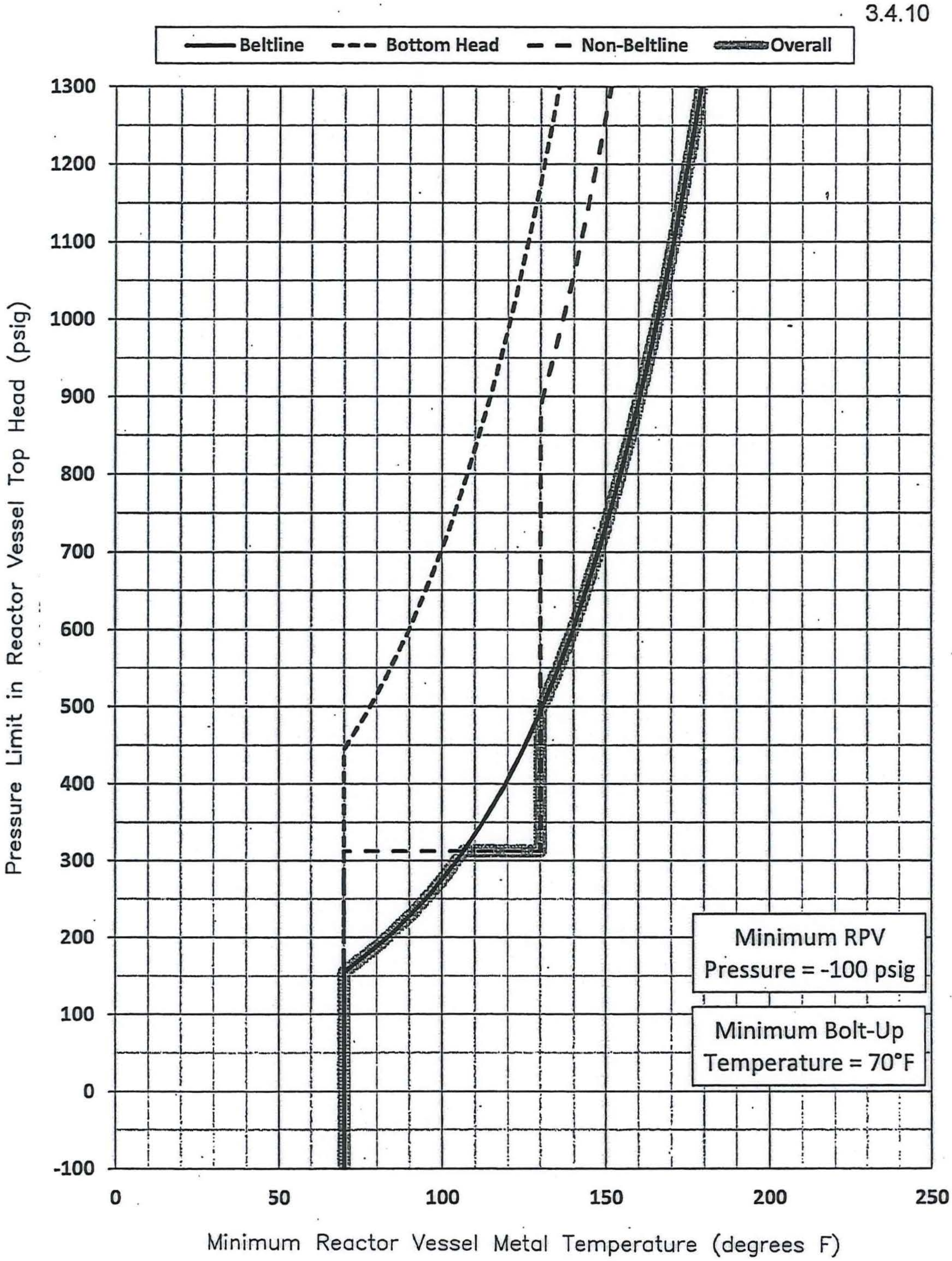

FIGURE 3.4.10–2
Non–Nuclear Heating Limit for ~~35.7~~ 40 EFPY
(Curve B)

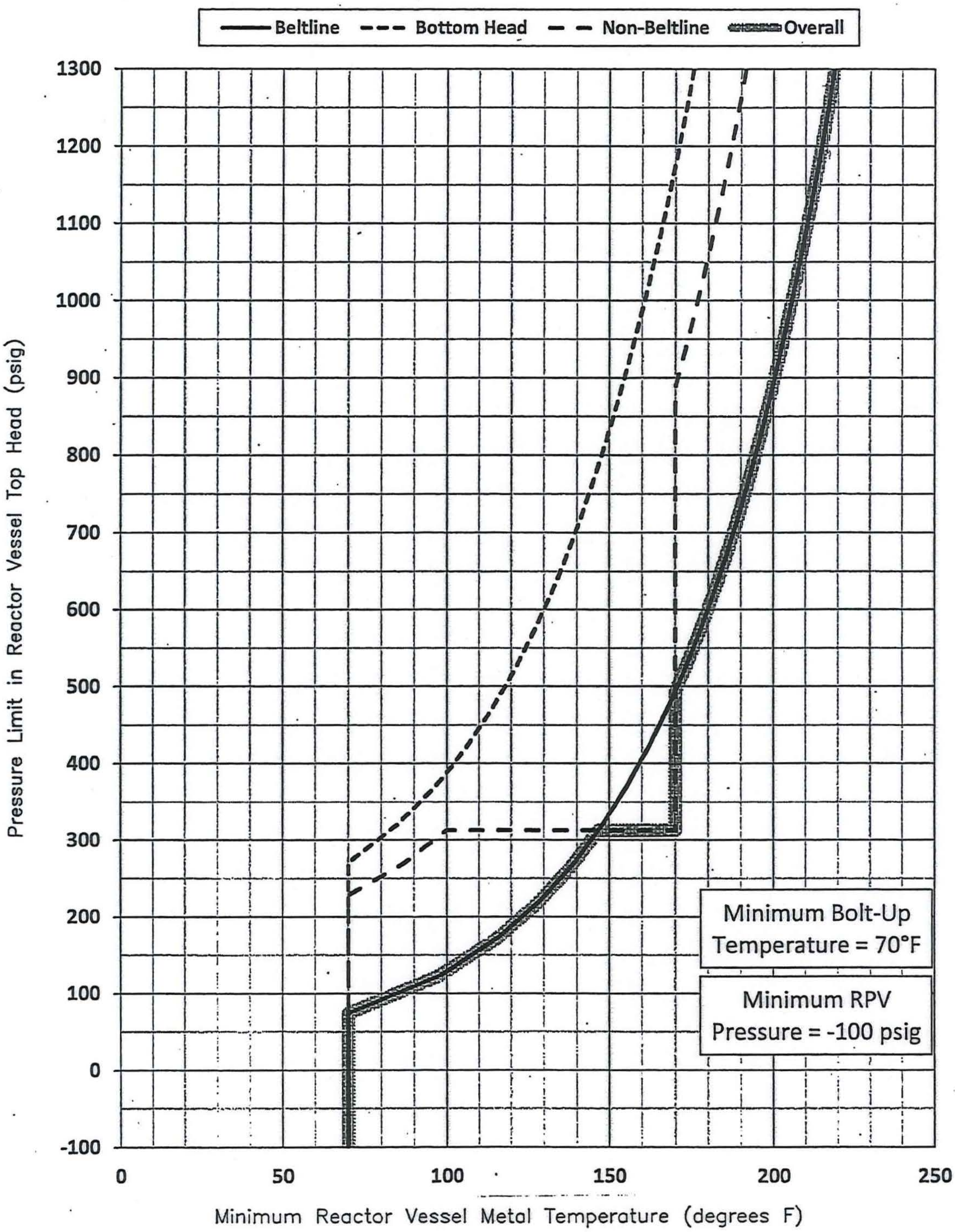

FIGURE 3.4.10–3
Nuclear (Core Critical) Limit for ~~35.7~~ 40 EFPY
(Curve C)

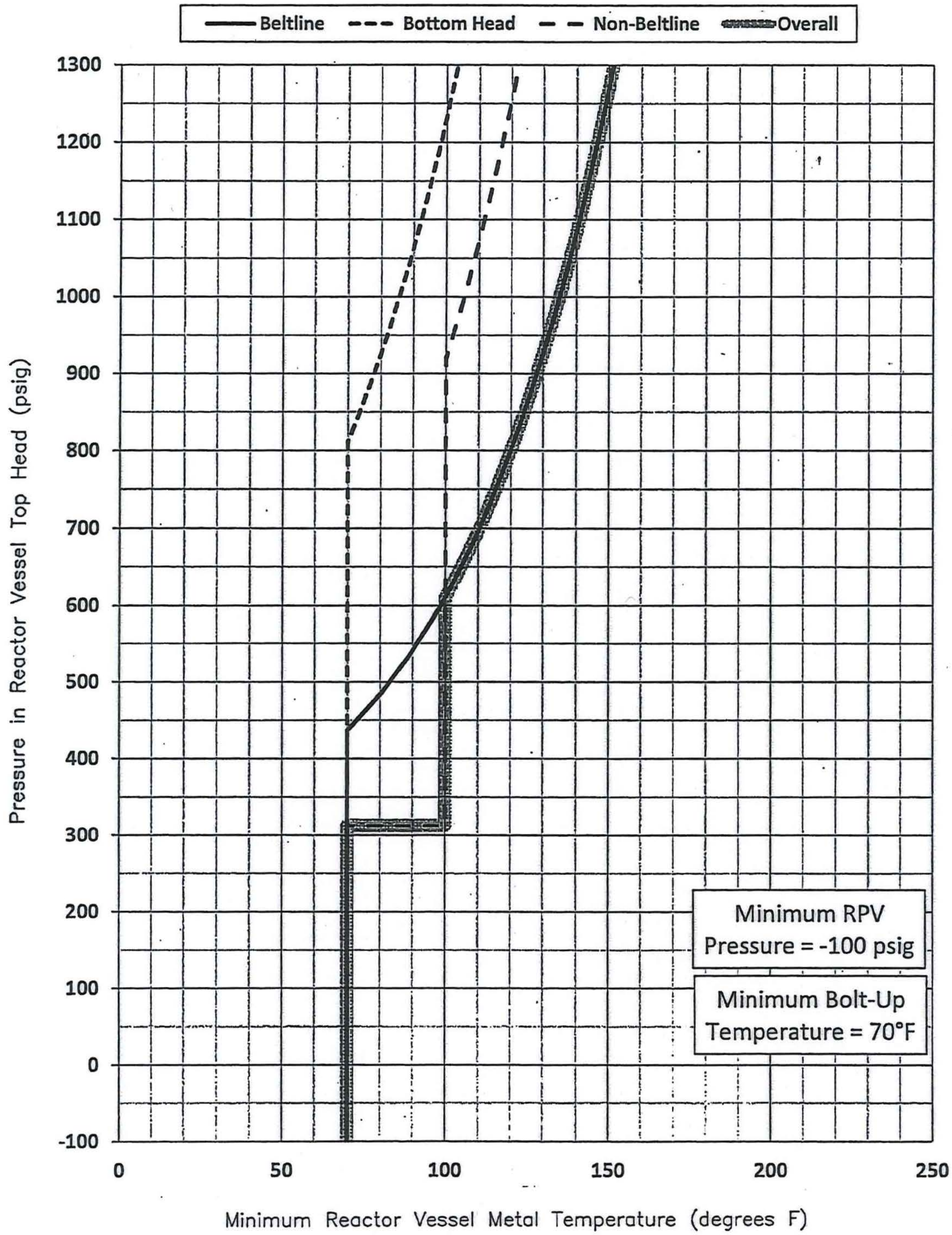

Figure 3.4.10–1
System Hydrotest Limit with Fuel in Vessel for ~~30.2~~ 40 EFPY
(Curve A)

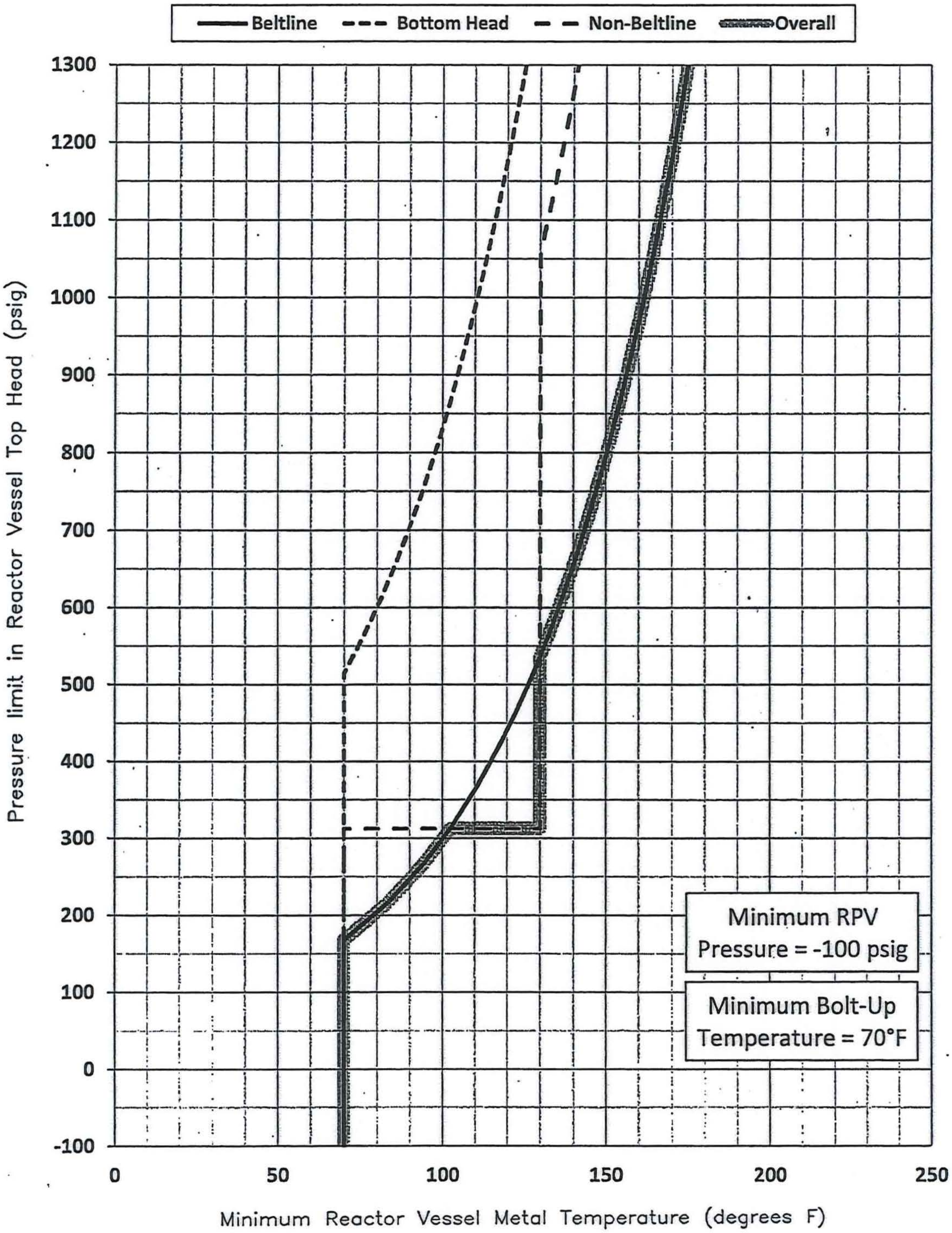

Figure 3.4.10–2
Non–Nuclear Heating Limit for ~~30.2~~ 40 EFPY
(Curve B)

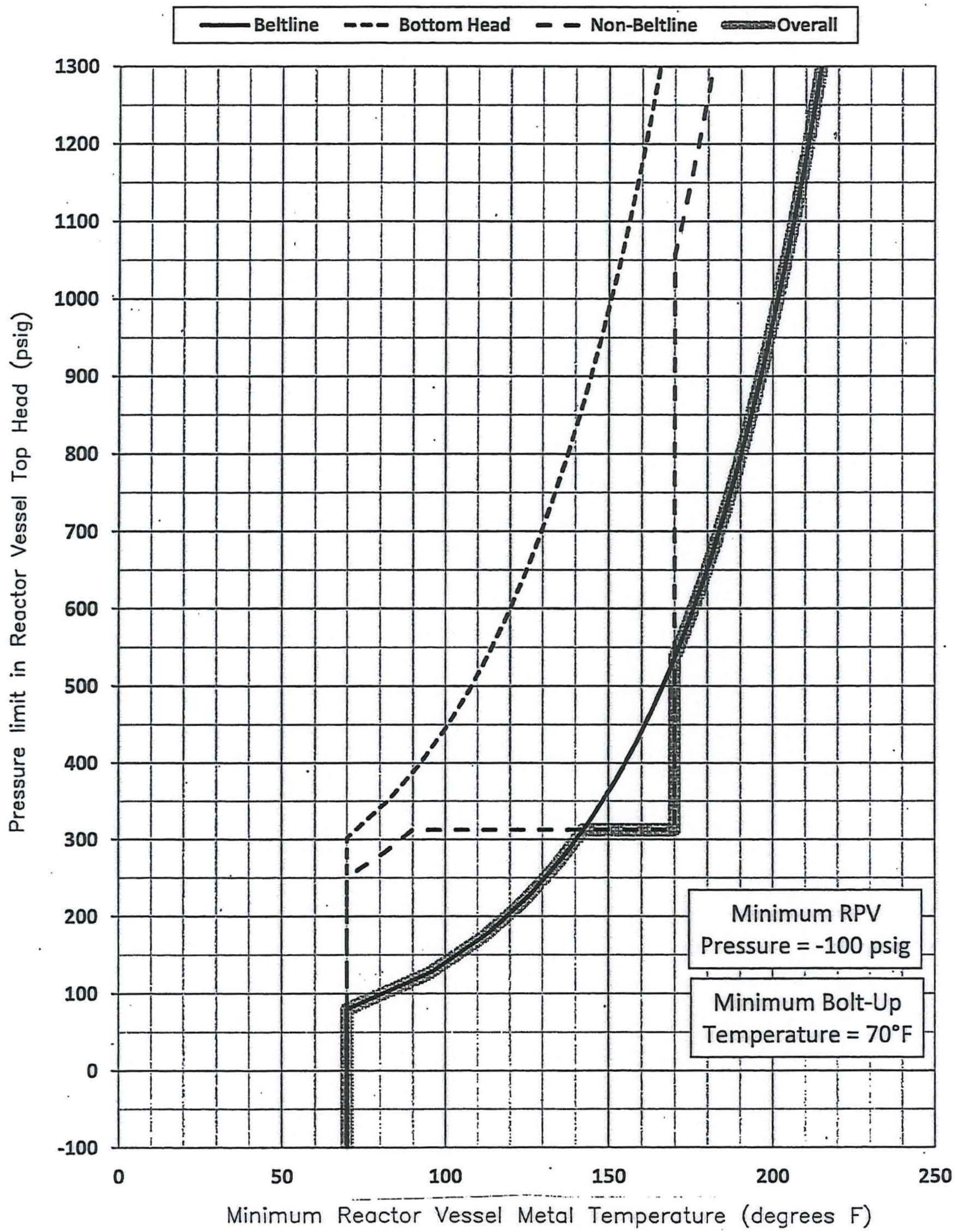

FIGURE 3.4.10−3
Nuclear (Core Critical) Limit for ~~30.2~~ 40 EFPY
(Curve C)

Attachment 5 to PLA-7299

Markups to TS Bases, Units 1 and 2
(For Information)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.4.10.7, SR 3.4.10.8, and SR 3.4.10.9 (continued)

The flange temperatures must be verified to be above the limits 30 minutes before and while tensioning the vessel head bolting studs to ensure that once the head is tensioned the limits are satisfied. When in MODE 4 with RCS temperature ≤ 80°F, 30 minute checks of the flange temperatures are required because of the reduced margin to the limits. When in MODE 4 with RCS temperature ≤ 100°F, monitoring of the flange temperature is required every 12 hours to ensure the temperature is within the specified limits.

The 30 minute Frequency reflects the urgency of maintaining the temperatures within limits, and also limits the time that the temperature limits could be exceeded. The 12 hour Frequency is reasonable based on the rate of temperature change possible at these temperatures.

REFERENCES

1. 10 CFR 50, Appendix G.
2. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix G.
3. ASTM E 185-73.
4. 10 CFR 50, Appendix H.
5. Regulatory Guide 1.99, Revision 2, May 1988.
6. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix E.

INSERT FROM NEXT PAGE

~~7. NEDO 21778-A, December 1978.~~
8. Final Policy Statement on Technical Specifications Improvements, July 22, 1993 (58 FR 39132).
9. PPL Calculation EC-062-0573, "Study to Support the Bases Section of Technical Specification 3.4.10."
10. FSAR, Section 15.4.4.
11. Regulatory Guide 1.190, March 2001.
12. FSAR, Section 4.1.4.5.

INSERT FOR REFERENCE 7

SUSQUEHANNA – UNIT 1

TS / B 3.4-57

7. Licensed Topical Reports:

   a. Structural Integrity Associates Report No. SIR-05-044, Revision 1-A, "Pressure-Temperature Limits Report Methodology for Boiling Water Reactors," June 2013.

   b. Structural Integrity Associates Report No. 0900876.401, Revision 0-A, "Linear Elastic Fracture Mechanics Evaluation of GE BWR Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations," May 2013.

BASES (continued)

REFERENCES

1. 10 CFR 50, Appendix G.
2. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix G.
3. ASTM E 185-73
4. 10 CFR 50, Appendix H.
5. Regulatory Guide 1.99, Revision 2, May 1988.
6. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix E.
7. ~~NEDO-21778-A, December 1978.~~
8. Final Policy Statement on Technical Specifications Improvements, July 22, 1993 (58 FR 39132).
9. PPL Calculation EC-062-0573, "Study to Support the Bases Section of Technical Specification 3.4.10."
10. FSAR, Section 15.4.4.
11. Regulatory Guide 1.190, March 2001.
12 FSAR, Section 4.1.4.5.

7. Licensed Topical Reports:
    a. Structural Integrity Associates Report No. SIR-05-044, Revision 1-A, "Pressure-Temperature Limits Report Methodology for Boiling Water Reactors," June 2013.
    b. Structural Integrity Associates Report No. 0900876.401, Revision 0-A, "Linear Elastic Fracture Mechanics Evaluation of GE BWR Water Level Instrument Nozzles for Pressure-Temperature Curve Evaluations," May 2013.