Constellation Energy

LaSalle County Station Units 1 and 2

Pressure and Temperature Limits Report (PTLR)
up to 54 Effective Full-Power Years (EFPY)

Revision 3

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1.0 Purpose

The purpose of the LaSalle County Station (LSCS) Pressure and Temperature Limits Report (PTLR) is to present operating limits relating to:

1. Reactor Coolant System (RCS) Pressure versus Temperature limits during Heat-up, Cool-down and Hydrostatic/Class 1 Leak Testing;
2. RCS Heat-up and Cool-down 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].

2.0 Applicability

This report is applicable to the LSCS Unit 1 and Unit 2 RPVs for up to 54 Effective Full-Power Years (EFPY).

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

TS 3.4.11 RCS Pressure/Temperature (P/T) Limits

3.0 Methodology

The limits in this report were derived as follows:

1. The methodology used is in accordance with Reference [1], "Pressure – Temperature Limits Report Methodology for Boiling Water Reactors," August 2013, incorporating the NRC Safety Evaluation in Reference [2]. The methodology references BWRVIP-86 Revision A (the NRC-approved version) as an example of a surveillance withdrawal schedule. The methodology is consistent with data input from any withdrawal schedule, and the implementation of the methodology incorporates the schedule within a plant's current license basis.

2. The neutron fluence is calculated in accordance with NRC Regulatory Guide 1.190 (RG 1.190) [3] as documented in Reference [5].

3. The adjusted reference temperature (ART) values for the limiting beltline materials are calculated in accordance with NRC Regulatory Guide 1.99, Revision 2 (RG 1.99, Revision 2) [4], as documented in Reference [5].

4. The pressure and temperature limits, which were calculated in accordance with Reference [1], are documented in Reference [6].

5. This revision of the pressure and temperature limits report is to incorporate the following changes:
    - Changes of ART values [5] from latest fluence reports [12] [13].

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 [8], 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 assumption 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 LSCS, as documented in Reference [6], and are provided in Figure 1 through Figure 3 for LSCS Unit 1 and in Figure 4 through Figure 6 for LSCS Unit 2. A tabulation of the curves is included in Table 1 through Table 3 for LSCS Unit 1 and in Table 4 through Table 6 for LSCS Unit 2. The adjusted reference temperature (ART) tables for 54 EFPY for the LSCS Unit 1 and Unit 2 vessel beltline materials are shown in Table 7 and Table 8, respectively [5].

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

- Heat-up/Cool-down rate limit of the coolant during Hydrostatic Class 1 Leak Testing (Figures 1 and 4: Curve A): **≤ 25˚F/hour**[1] [6].
- Heat-up/Cool-down rate limit of the coolant (Figures 2 and 5: Curve B – non-nuclear heating, and Figures 3 and 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** [1].

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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.

- Recirculation loop coolant temperature to RPV coolant temperature ΔT limit during Recirculation Pump startup: ≤ **50°F** [1].
- RPV flange and adjacent shell temperature limit
  - LSCS Unit 1: > **72°F** [6].
  - LSCS Unit 2: ≥ **86˚F** [6].

Minimum temperature limits are set in accordance with 10 CFR 50, Appendix G [7, Table 1]. An additional 60°F margin above the requirements in Table 1 of 10 CFR 50, Appendix G, is required in the BWR industry. For the LSCS closure flange material, the minimum temperature would be 72°F for Unit 1 (i.e., $RT_{NDT,max}$ of 12°F + 60°F) and 86°F for Unit 2 (i.e., $RT_{NDT,max}$ of 26°F + 60°F) [6]. These values are consistent with the minimum temperature limits and minimum bolt-up temperature in the current docketed P-T curves [9] [10]. These values also bound the lowest service temperatures (LST) for ferritic non-RPV components of the reactor coolant pressure boundary (RCPB) [9] [10], thereby addressing the NRC condition in Reference [2, Section 4.0].

5.0 <u>Discussion</u>

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, Revision 2 [4] provides the methods for determining the ART. The RG 1.99, Revision 2 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 LSCS vessel plate, weld, and forging materials from References [11], [29], [30] and [31]. The Cu and Ni values were used with Table 1 of RG 1.99, Revision 2 to determine a chemistry factor (CF) per Paragraph 1.1 of RG 1.99, Revision 2 for welds. The Cu and Ni values were used with Table 2 of RG 1.99, Revision 2 to determine a CF per Paragraph 1.1 of RG 1.99, Revision 2 for plates and forgings.

Per Reference [5] and in accordance with Appendix A of Reference [1], the LSCS 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 plate material for LSCS Unit 1 (C6345-1) in the ISP is not the same as the target plate material (C5978-2). However, the C6345-1 is a plate heat in LSCS Unit 1 vessel beltline. The fitted CF is used for LSCS Unit 1 ISP plate material. The ISP representative weld material for LSCS Unit 1 (1P3571, flux lot No. 3958) is the same as the target weld material. The fitted CF value for LSCS Unit 1 ISP weld material is adjusted based on the difference between the surveillance weld and vessel weld. Both ISP plate C6345-1 and weld 1P3571 materials are considered in developing the P-T curves for LSCS Unit 1. The ISP representative plate material for LSCS Unit 2 (C3054-2) is not the same heat number as the target plate material (C9404-2), nor does the representative plate heat exist in the LSCS Unit 2 beltline. The ISP representative weld materials for LSCS Unit 2 (402K9171, flux lot No. 411L3071) are not the same as the target weld material (3P4966). Therefore, for LSCS Unit 2 beltline materials, the ISP materials are not considered in developing P-T curves. The CF values are calculated using table values from R.G. 1.99, Revision 2, Position 1.1 [4].

The RPV inside diameter surface (ID) fluence values of 8.23 x 10^{17} n/cm^2 for Unit 1 and 9.11 x 10^{17} n/cm^2 for Unit 2 at 54 EFPY used in the P-T curve evaluations were obtained from Reference [12] and [13]. These fluence values apply to the limiting Integrated Surveillance Program weld heat no. 1P3571 for Unit 1 and plate heat no. C9425-1 for Unit 2. The fluence values for the limiting beltline materials in each unit are based upon attenuation method [4] for a postulated 1/4T flaw. Consequently, the limiting 1/4T fluence for 54 EFPY are 5.70 x 10^{17} n/cm^2 for the LSCS Unit 1 middle shell axial weld and 6.28 x 10^{17} n/cm^2 for the LSCS Unit 2 lower shell assembly plate [5]. The limiting values for ART for beltline plates and welds are 136.3°F for Unit 1 and 85.7°F for Unit 2 [5].

The P-T limits are developed to bound all ferritic materials in the RPV (where the fluence exceeds 1 x 10^{17} n/cm^2), including the consideration of stress levels from structural discontinuities such as nozzles. LSCS Unit 1 and Unit 2 have a set of instrument (N12) nozzles, which are located in the middle shell beltline plates [11]. Additionally, the low pressure coolant injection (LPCI) N6 nozzle is considered in the evaluation of beltline region P-T limits. The feedwater (FW) nozzle is considered in the evaluation of the non-beltline (upper vessel) region P-T limits.

The instrument nozzles have an RPV ID fluence of 2.86 x 10^{17} n/cm^2 for Unit 1 and 3.27 x 10^{17} n/cm^2 for Unit 2 at 54 EFPY, obtained from Reference [12] and [13]. The fluence value for the instrument nozzle location is based upon attenuation method for a postulated 1/4T flaw in the instrument nozzle blend radius. Consequently, the 1/4T fluence for 54 EFPY for the limiting instrument nozzle location is 1.98 x 10^{17} n/cm^2 for Unit 1 and 2.26 x 10^{17} n/cm^2 for Unit 2 [5]. The limiting value for ART for the instrument nozzles is 25.7°F for Unit 1 and 68.3°F for Unit 2 at 54 EFPY [5]. There are no additional forged or partial penetration nozzles in the extended beltline (defined as regions where the fluence exceeds 1 x 10^{17} n/cm^2) at LSCS Units 1 and 2.

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 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 stresses at the 1/4T location. This approach is conservative because irradiation effects cause the allowable fracture toughness at the 1/4T location to be less than that at 3/4T location 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 fracture toughness at a given pressure would exceed the allowable fracture toughness.

The core not critical curve (Curve B) and the core critical curve (Curve C) are prepared considering a coolant heat-up and cool-down temperature rate corresponding to the limiting transient on the RPV thermal cycle diagram, the Single Relief or Safety Valve (SRV) Blowdown event. The Technical Specifications limit operation to ≤100°F/hr. Additionally, for LaSalle, the SRV blowdown event is explicitly classified in the RPV thermal cycles as an Emergency condition. For conservatism, the SRV blowdown event was selected for evaluation as the limiting Service Level A/B transient. For the hydrostatic pressure and leak test curve (Curve A), a coolant heat-up and cool-down temperature rate of ≤ 25°F/hr 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.

The initial RT_{NDT}, 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 in Table 7 and Table 8 for Unit 1 and Unit 2, respectively [5]. Use of initial RT_{NDT} values in the determination of P-T curves for LSCS was approved by the NRC in Reference [11].

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

- ANSYS, Release 14.5 Service Pack 1 [15] for:
    - FW nozzle (non-beltline) through-wall thermal and pressure stress distributions in Reference [17].
- ANSYS, Release 18.1 [16] for:
    - LPCI nozzle thermal and pressure stress distributions in Reference [18].

ANSYS finite element analyses were used to develop the stress distributions through the FW and LPCI nozzles as well as the vessel shell, and these stress distributions were used in the determination of the stress intensity factors for the FW and LPCI nozzles [17, 18] and vessel shell. 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 [19] Quality Assurance Program for nuclear quality-related work. Benchmarking consistent with NRC GL 83-11, Supplement 1 [20] 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 LSCS FW nozzle analyses were performed to determine through-wall pressure stress distributions and thermal stress distributions due to bounding thermal transients. Detailed information regarding the analyses can be found in Reference [17]. The following summarizes the development of the thermal and pressure stress intensity factors for the FW nozzle:

- A one-quarter symmetric, three-dimensional (3-D) finite element model (FEM) of the FW nozzle was constructed and is shown in Figure 7. Details of the model and material properties are provided in Reference [17]. The Young's modulus and thermal expansion coefficient are taken from the 1968 Edition with 1969 Winter Addenda [21] for Unit 1 and 1970 Winter Addenda [22] for Unit 2. The thermal conductivity and thermal diffusivity are taken from the ASME Code Section II 2001 through addenda 2003 Edition [23].
- Heat transfer coefficients were calculated in Reference [17] and are a function of FW temperature and flow rate.
- With respect to emergency conditions, the thermal transient which represents the maximum thermal ramp for the regions corresponding to the FW nozzles during SRV Blowdown transient and the shutdown vessel flooding transient were analyzed [17]. The thermal stress distributions, corresponding to the limiting times presented in Reference [17], along a linear path through the nozzle corner is used as shown in Figure 8. The boundary integral equation/influence function (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.

- With respect to pressure stress, a unit pressure of 1000 psig was applied to the internal surfaces of the 3-D model in Reference [17]. The pressure stress distribution was taken along a linear path through the nozzle corner as shown in Figure 8. The BIE/IF methodology presented in Reference [1] was used to calculate the applied 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} may be linearly scaled to determine the K_{Ip} for various RPV internal pressures.

The plant-specific LSCS LPCI nozzle analysis was performed to determine through-wall pressure stress distributions and thermal stress distributions due to bounding thermal transients. 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 LPCI nozzle:

- A one-quarter symmetric, 3-D FEM of the LPCI nozzle was constructed and is shown in Figure 9. ASME 1968 Edition with 1970 Winter Addenda [22] is used for Young's Modulus and thermal expansion coefficients. Thermal conductivity and thermal diffusivity were taken from 2001 ASME Code through 2003 Addenda [23].
- A single model was developed to bound both units.
- With respect to operating conditions, the bounding thermal transient for the region corresponding to the LPCI nozzles during normal and upset operating conditions was analyzed [18]. The thermal stress distribution, corresponding to the limiting time in Reference [18], along a linear path through the nozzle corner as shown in Figure 10 is used. The BIE/IF methodology presented in Reference [1] was 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 are described in Reference [18].

- With respect to pressure stress, a unit pressure of 1000 psig was applied to the internal surfaces of the FEM [18]. The pressure stress distribution was taken along the same path as shown in Figure 10 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.

Table 9 summarizes the pressure stress intensity factor and maximum thermal stress intensity factor for both feedwater and LPCI nozzle.

6.0 References

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

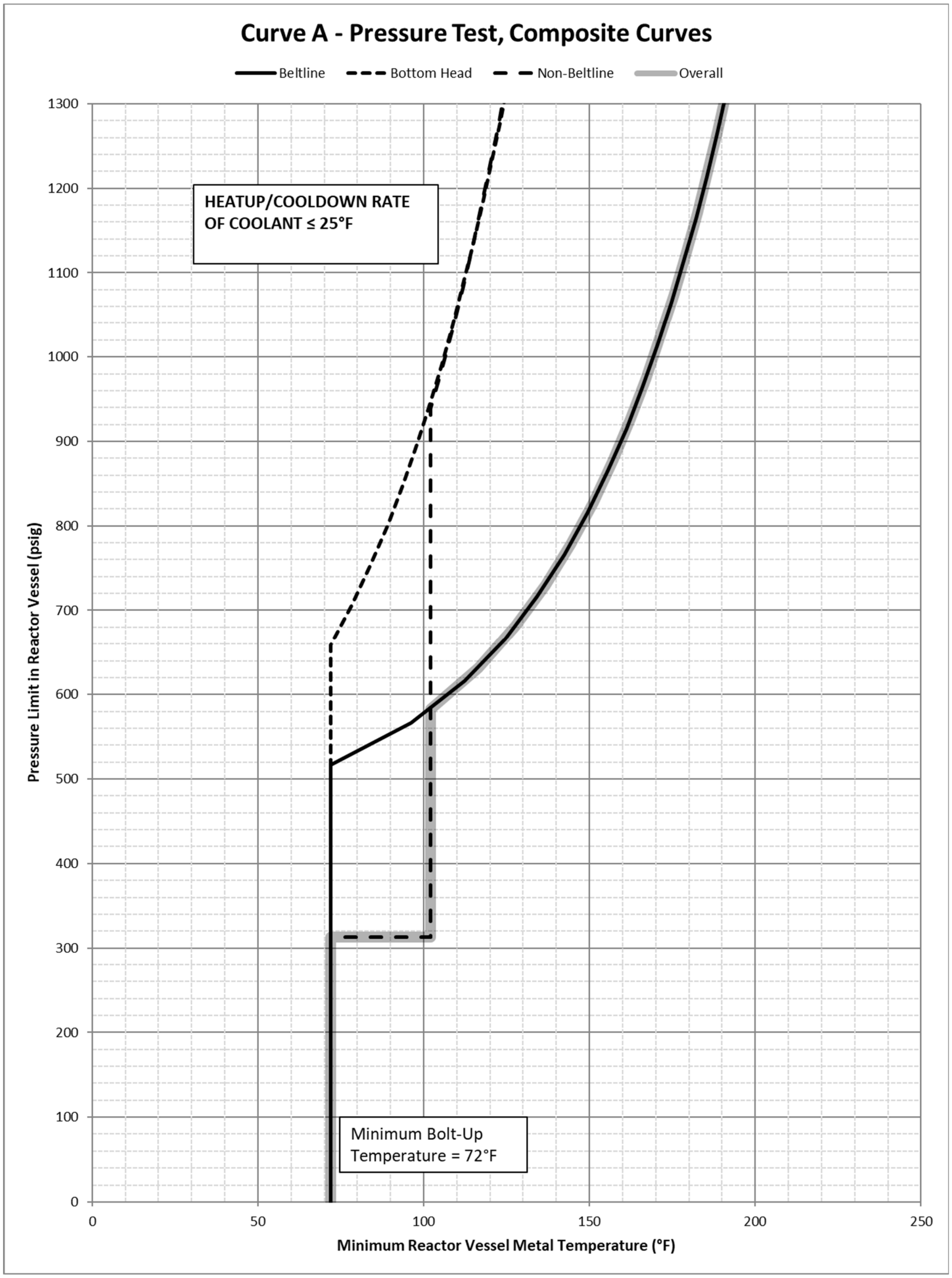


Figure 2: LSCS Unit 1 P-T Curve B (Normal Operation – Core Not Critical) for 54 EFPY

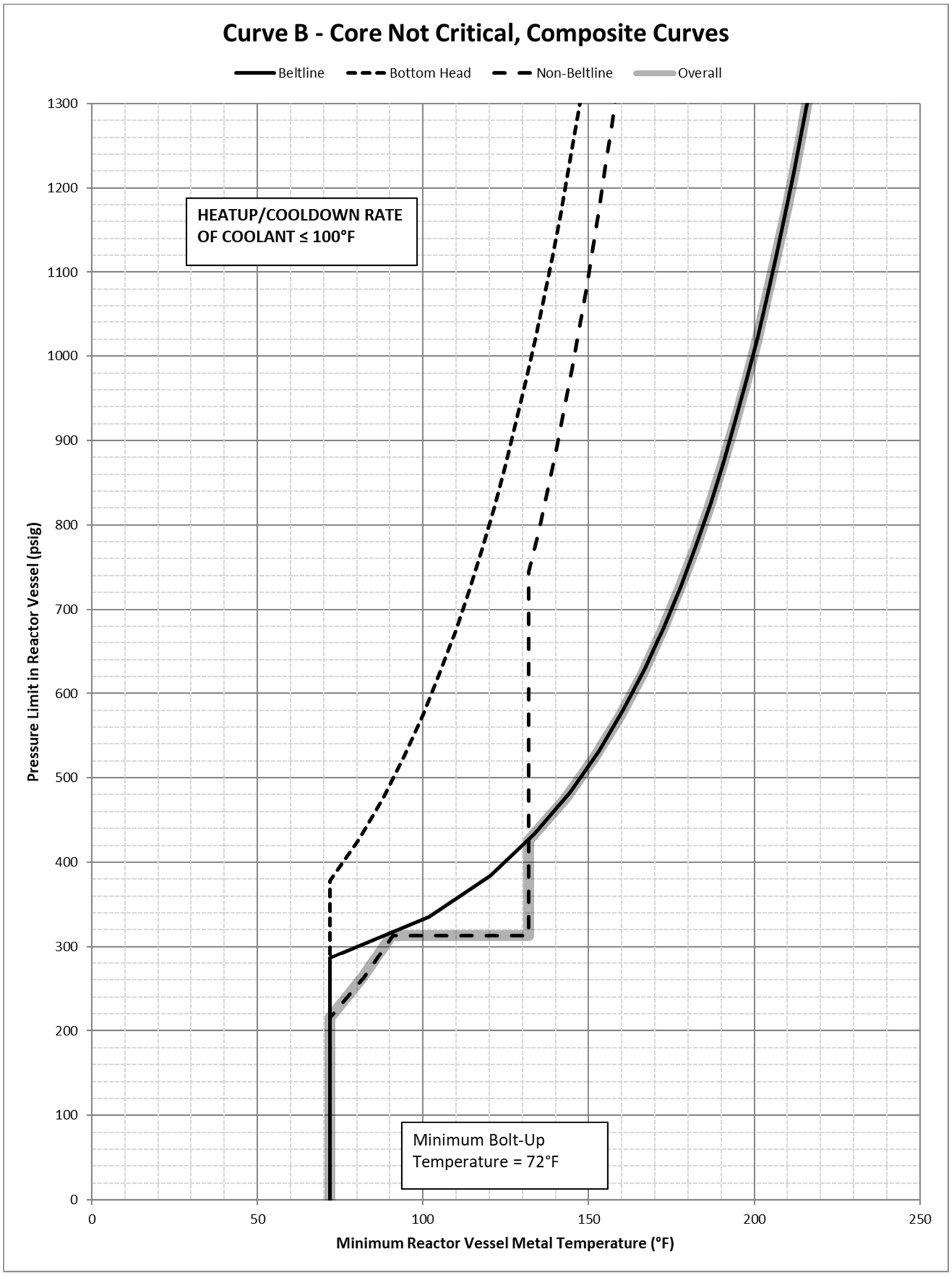


Figure 3: LSCS Unit 1 P-T Curve C (Normal Operation – Core Critical) for 54 EFPY

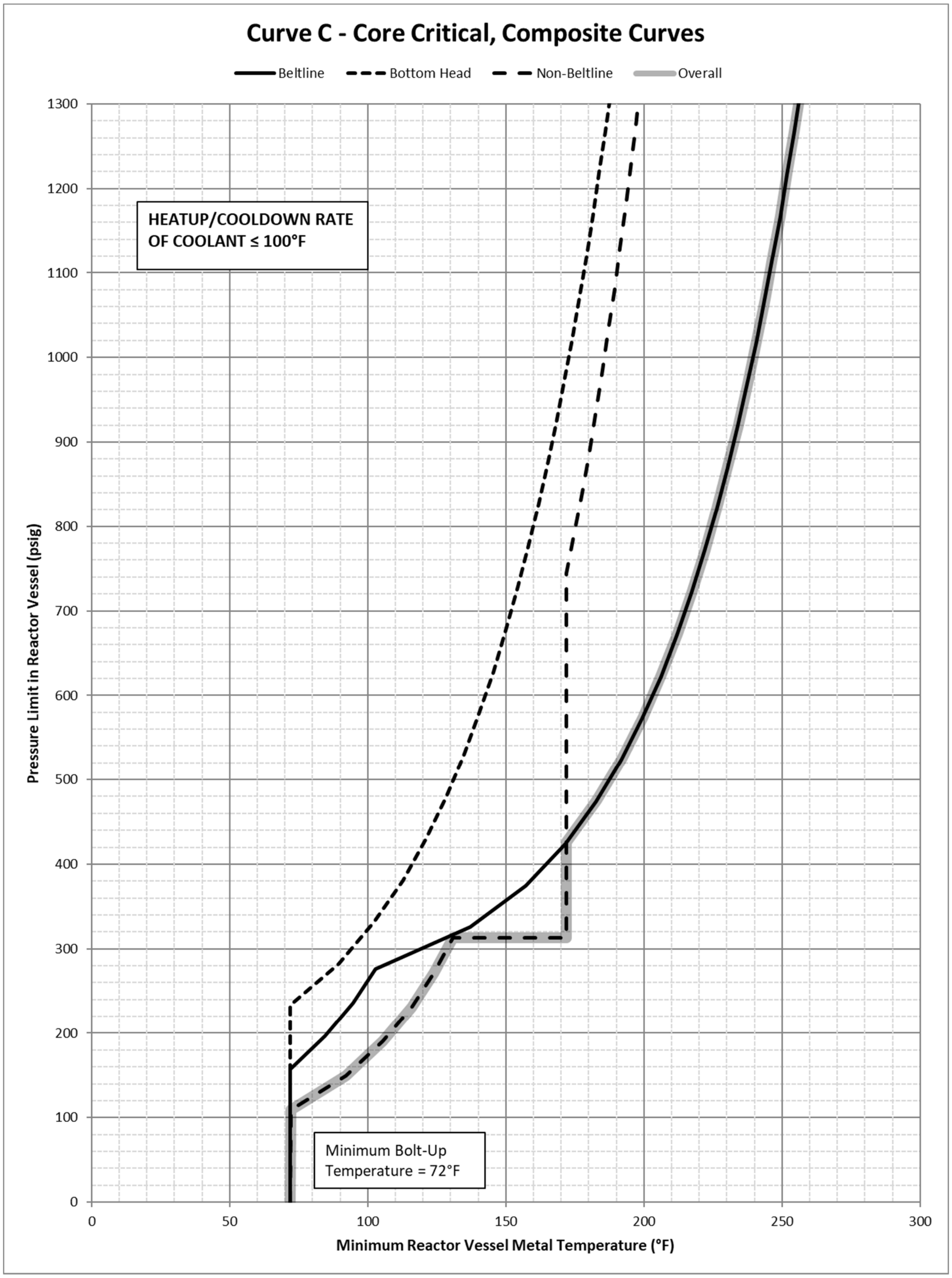


Figure 4: LSCS Unit 2 P-T Curve A (Hydrostatic Pressure and Leak Tests) for 54 EFPY

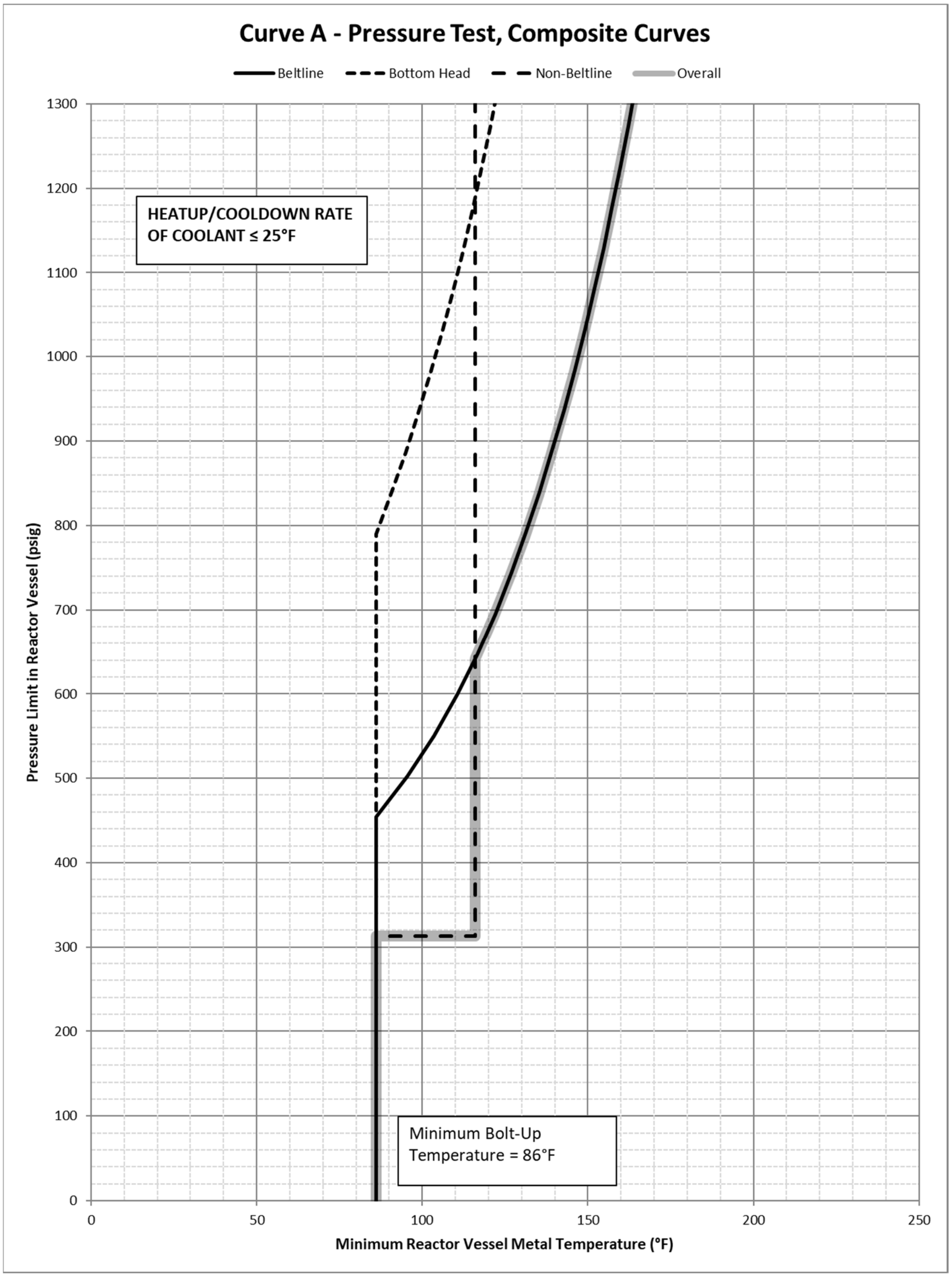


Figure 5: LSCS Unit 2 P-T Curve B (Normal Operation – Core Not Critical) for 54 EFPY

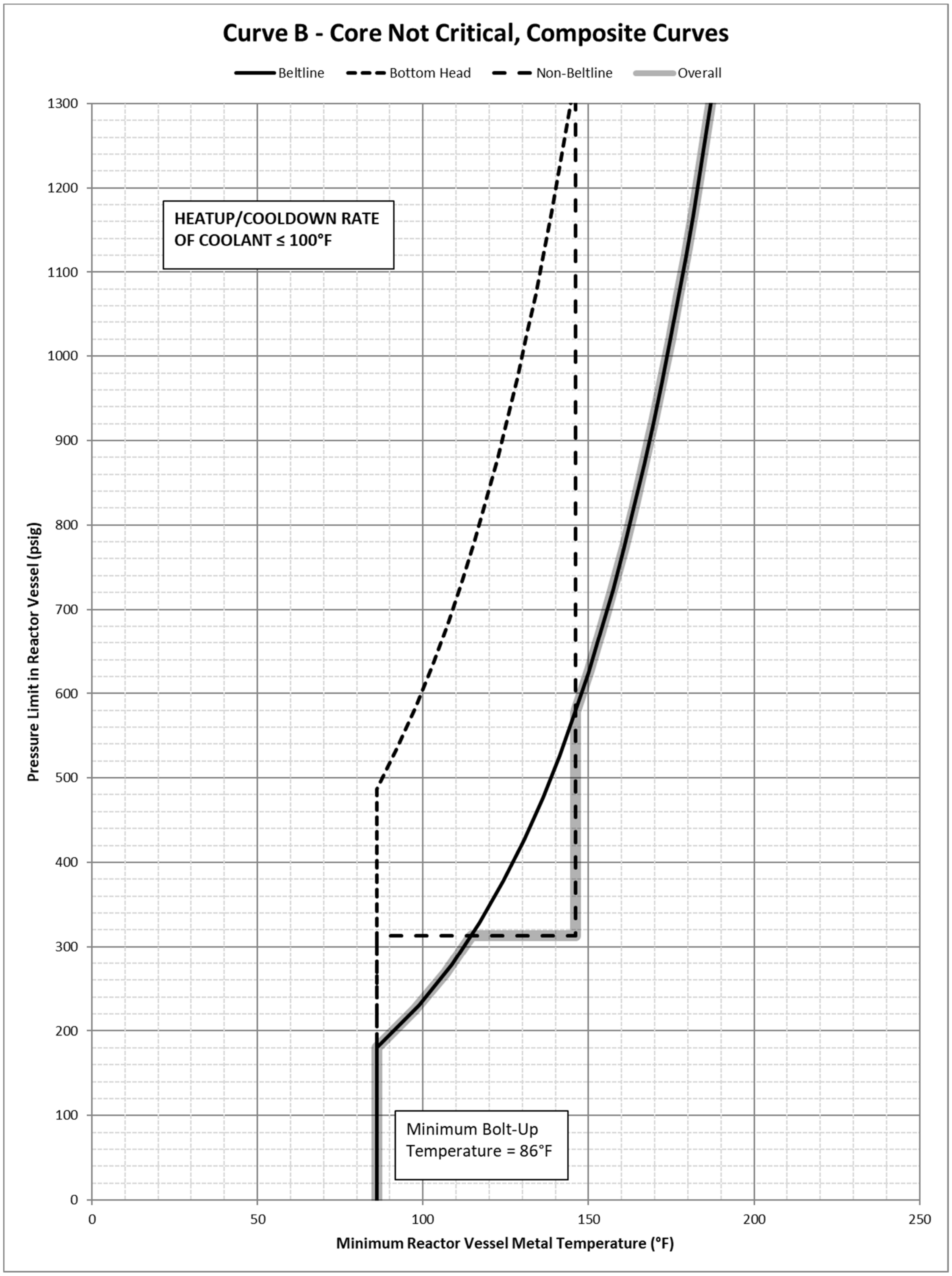


Figure 6: LSCS Unit 2 P-T Curve C (Normal Operation – Core Critical) for 54 EFPY

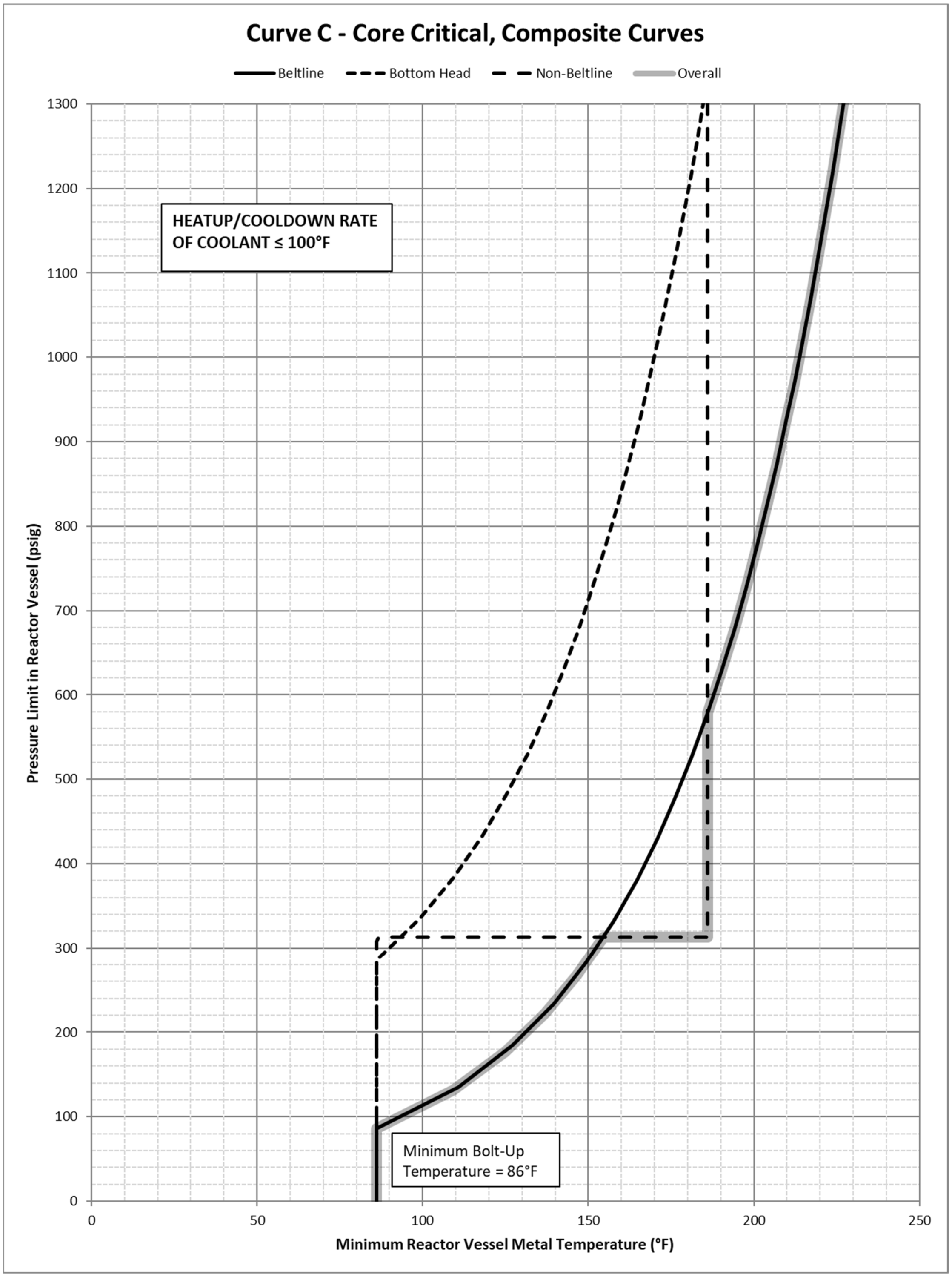
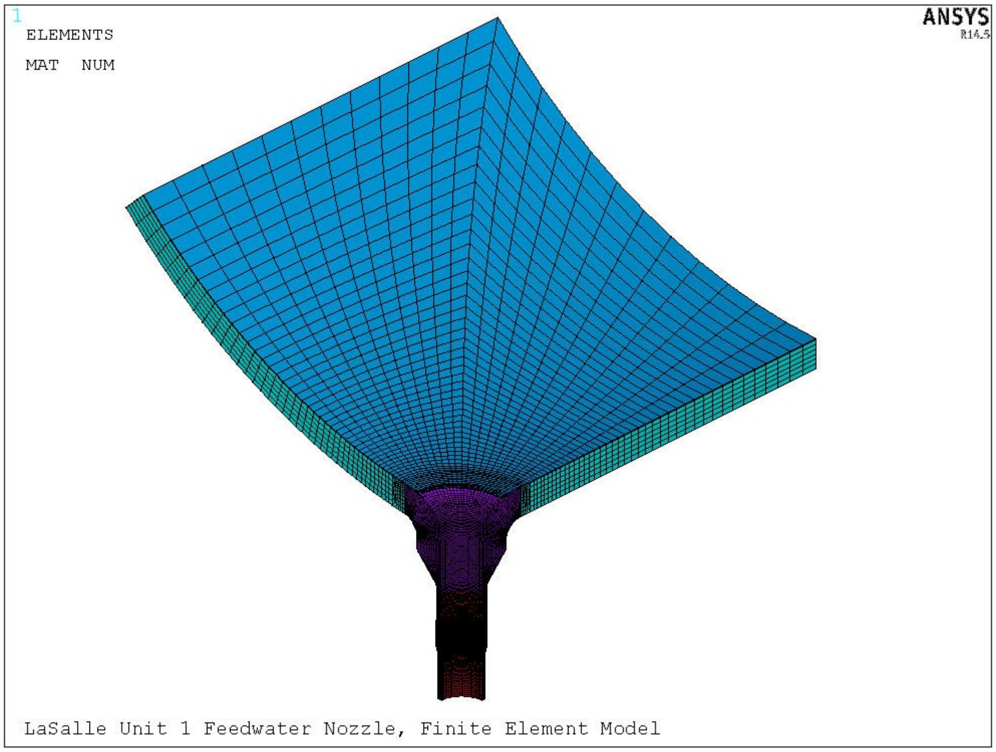


Figure 7: LSCS Feedwater Nozzle 3-D Finite Element Model [17]



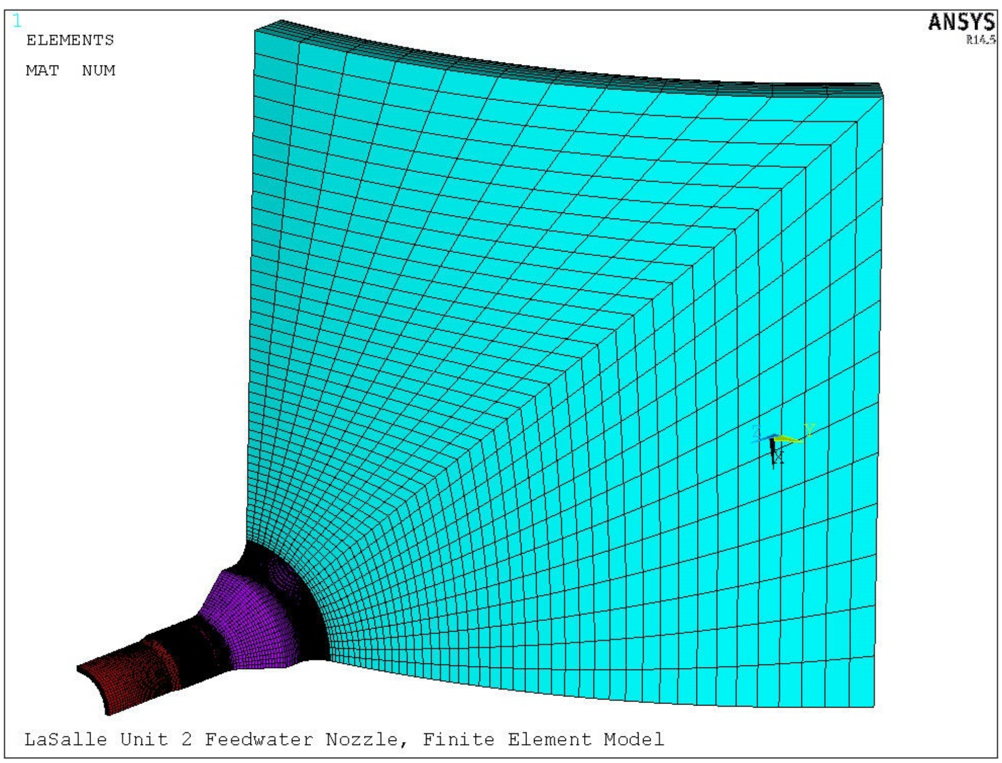
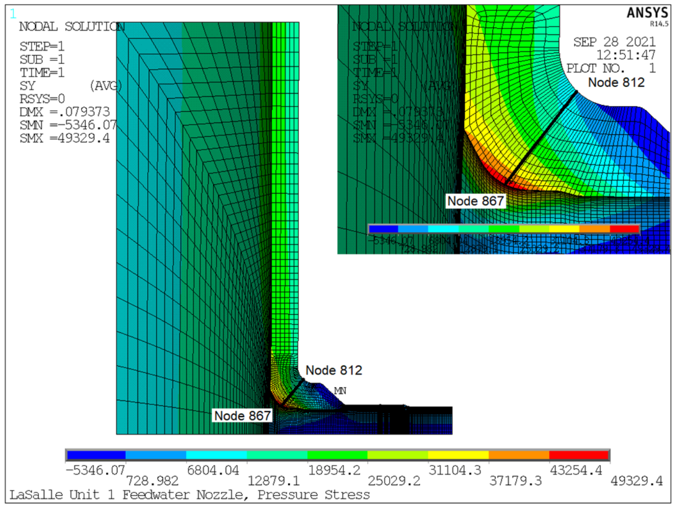
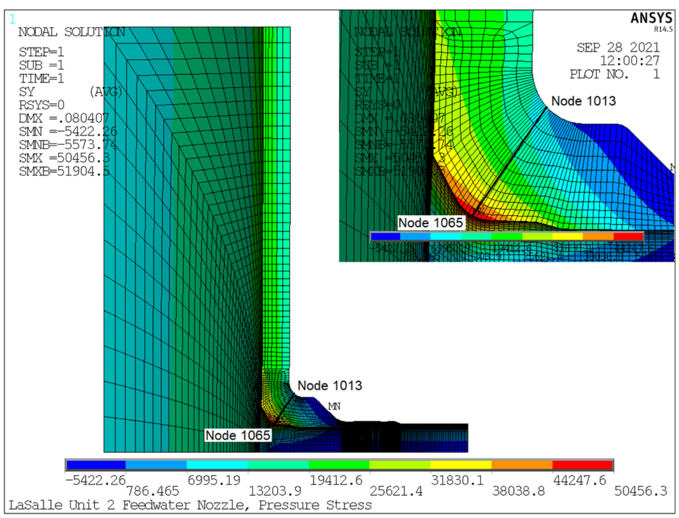


Figure 8: LSCS Feedwater Nozzle Stress Extraction Path [17]



Unit 1



Unit 2

Figure 9: LSCS LPCI Nozzle Finite Element Model [18]

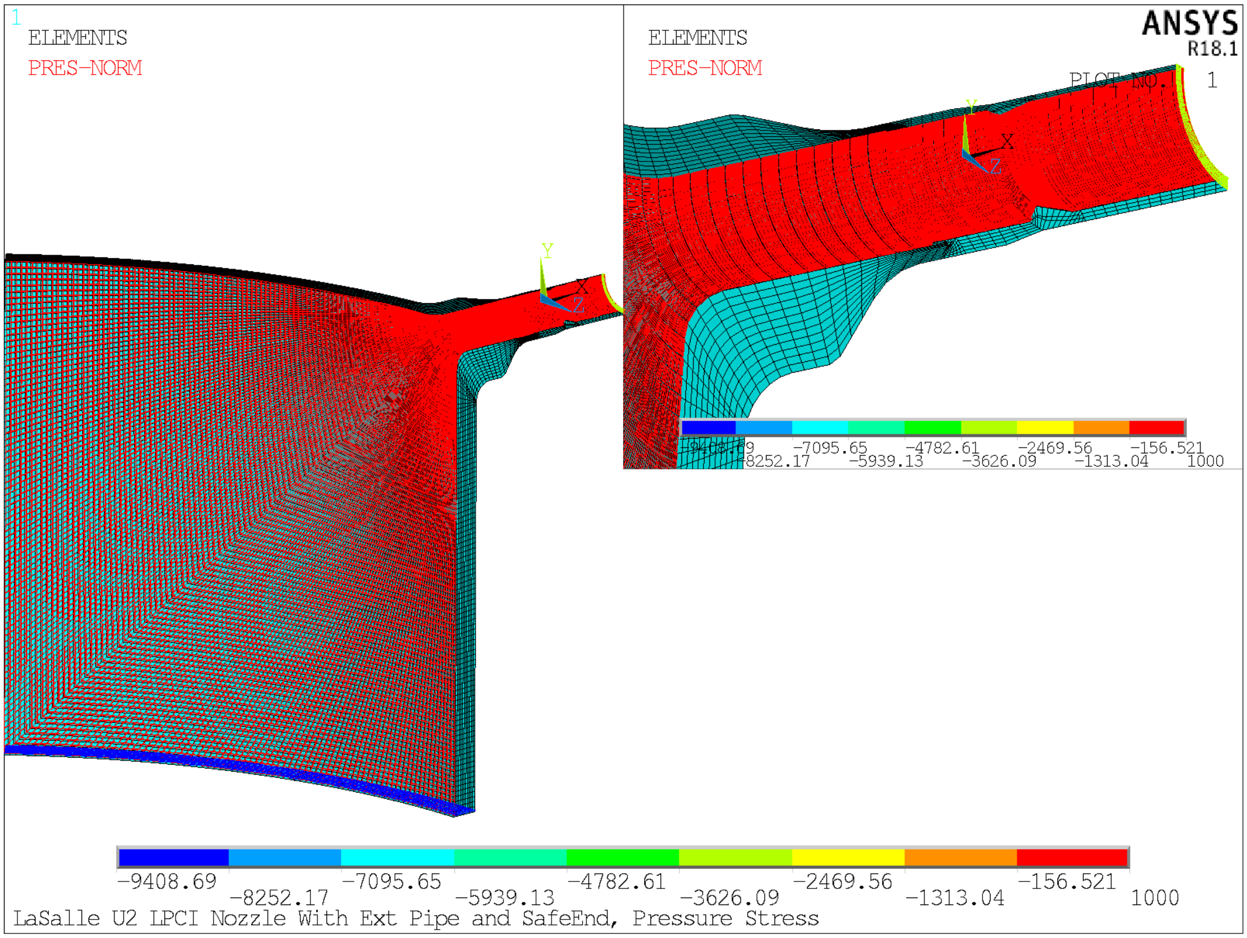


Figure 10: LSCS LPCI Nozzle Stress Extraction Path [18]

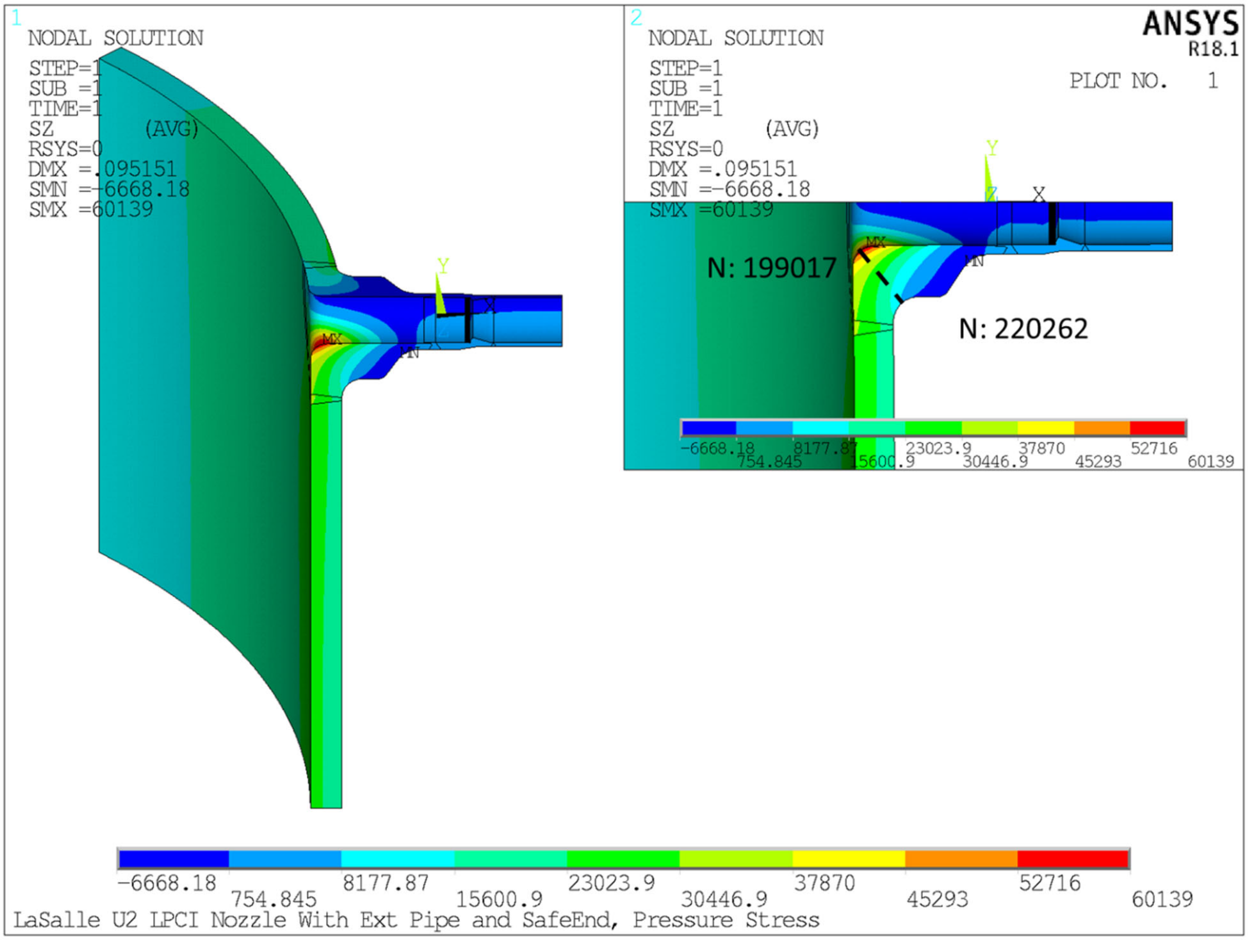


Table 1: LSCS Unit 1 Pressure Test (Curve A) P-T Curves for 54 EFPY

Beltline Region

Curve A - Pressure Test

P-T Curve Temperature	**P-T Curve Pressure**
°F	*psi*
72.0	0.0
72.0	516.5
96.1	566.4
112.2	616.2
124.4	666.0
134.2	715.9
142.4	765.7
149.5	815.5
155.6	865.3
161.1	915.2
166.1	965.0
170.6	1014.8
174.7	1064.7
178.5	1114.5
182.1	1164.3
185.4	1214.2
188.5	1264.0
191.4	1313.8
194.2	1363.7
196.8	1413.5
199.3	1463.3
201.6	1513.2
203.9	1563.0

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

Bottom Head Region

Curve A - Pressure Test

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	658.5
78.4	706.1
84.0	753.7
89.1	801.3
93.7	848.9
98.0	896.5
101.8	944.1
105.5	991.7
108.8	1039.3
112.0	1086.9
114.9	1134.5
117.8	1182.1
120.4	1229.8
122.9	1277.4
125.3	1325.0
127.6	1372.6
129.8	1420.2
131.9	1467.8
133.9	1515.4
135.8	1563.0

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

Non-Beltline Region

Curve A - Pressure Test

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	312.6
102.0	312.6
102.0	939.0
105.5	987.0
108.8	1035.0
111.8	1083.0
114.7	1131.0
117.4	1179.0
120.0	1227.0
122.5	1275.0
124.8	1323.0
127.1	1371.0
129.2	1419.0
131.3	1467.0
133.3	1515.0
135.2	1563.0

Table 2: LSCS Unit 1 Core Not Critical (Curve B) P-T Curves for 54 EFPY

Beltline Region

Curve B - Core Not Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	286.0
101.7	335.2
120.2	384.3
133.7	433.4
144.3	482.5
153.1	531.6
160.5	580.7
167.0	629.8
172.7	679.0
177.9	728.1
182.5	777.2
186.8	826.3
190.7	875.4
194.4	924.5
197.8	973.6
201.0	1022.7
203.9	1071.9
206.8	1121.0
209.4	1170.1
212.0	1219.2
214.4	1268.3
216.7	1317.4
218.9	1366.5
221.0	1415.7
223.0	1464.8
225.0	1513.9
226.8	1563.0

Table 2: LSCS Unit 1 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*
72.0	0.0
72.0	377.8
80.6	427.2
88.0	476.6
94.4	526.0
100.1	575.4
105.2	624.7
109.8	674.1
114.0	723.5
117.9	772.9
121.5	822.3
124.9	871.6
128.1	921.0
131.1	970.4
133.9	1019.8
136.5	1069.2
139.1	1118.6
141.5	1167.9
143.7	1217.3
145.9	1266.7
148.0	1316.1
150.1	1365.5
152.0	1414.9
153.9	1464.2
155.7	1513.6
157.4	1563.0

Table 2: LSCS Unit 1 Core Not Critical (Curve B) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve B - Core Not Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	215.0
82.5	263.8
90.9	312.6
132.0	312.6
132.0	744.2
134.9	792.3
137.6	840.5
140.2	888.7
142.7	936.8
145.0	985.0
147.2	1033.2
149.3	1081.3
151.3	1129.5
153.3	1177.7
155.1	1225.8
156.9	1274.0
158.6	1322.2
160.3	1370.3
161.9	1418.5
163.5	1466.7
165.0	1514.8
166.4	1563.0

Table 3: LSCS Unit 1 Core Critical (Curve C) P-T Curves for 54 EFPY

<u>Beltline Region</u>

Curve C - Core Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	156.8
84.5	196.5
94.6	236.3
102.9	276.0
137.1	325.5
157.2	375.0
171.5	424.5
182.7	474.0
191.7	523.5
199.4	573.0
206.1	622.5
212.0	672.0
217.2	721.5
222.0	771.0
226.3	820.5
230.3	870.0
234.0	919.5
237.5	969.0
240.7	1018.5
243.7	1068.0
246.6	1117.5
249.3	1167.0
251.8	1216.5
254.3	1266.0
256.6	1315.5
258.8	1365.0
260.9	1414.5
263.0	1464.0
264.9	1513.5
266.8	1563.0

Table 3: LSCS Unit 1 Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

<u>Bottom Head Region</u>

Curve C - Core Critical

P-T Curve Temperature *°F*	**P-T Curve Pressure** *psi*
72.0	0.0
72.0	233.3
89.5	282.6
102.4	331.8
112.6	381.1
121.1	430.3
128.4	479.6
134.7	528.8
140.4	578.1
145.4	627.3
150.0	676.6
154.2	725.8
158.1	775.0
161.7	824.3
165.0	873.5
168.2	922.8
171.2	972.0
174.0	1021.3
176.6	1070.5
179.1	1119.8
181.5	1169.0
183.8	1218.3
186.0	1267.5
188.1	1316.8
190.1	1366.0
192.0	1415.3
193.9	1464.5
195.7	1513.8
197.4	1563.0

Table 3: LSCS Unit 1 Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve C - Core Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
72.0	0.0
72.0	109.0
92.0	149.7
105.5	190.4
115.8	231.1
124.0	271.9
130.9	312.6
172.0	312.6
172.0	744.2
174.9	792.3
177.6	840.5
180.2	888.7
182.7	936.8
185.0	985.0
187.2	1033.2
189.3	1081.3
191.3	1129.5
193.3	1177.7
195.1	1225.8
196.9	1274.0
198.6	1322.2
200.3	1370.3
201.9	1418.5
203.5	1466.7
205.0	1514.8
206.4	1563.0

Table 4: LSCS Unit 2 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*
86.0	0.0
86.0	454.1
95.6	502.3
103.6	550.6
110.5	598.8
116.6	647.0
122.0	695.2
126.9	743.4
131.3	791.6
135.4	839.8
139.2	888.0
142.7	936.2
146.0	984.5
149.1	1032.7
152.0	1080.9
154.7	1129.1
157.3	1177.3
159.8	1225.5
162.1	1273.7
164.4	1321.9
166.5	1370.2
168.6	1418.4
170.6	1466.6
172.5	1514.8
174.3	1563.0

Table 4: LSCS Unit 2 Pressure Test (Curve A) P-T Curves for 54 EFPY (continued)

<u>Bottom Head Region</u>

Curve A - Pressure Test

P-T Curve Temperature *°F*	**P-T Curve Pressure** *psi*
86.0	0.0
86.0	790.2
90.7	838.5
95.1	886.8
99.1	935.1
102.7	983.4
106.2	1031.7
109.4	1080.0
112.4	1128.3
115.3	1176.6
118.0	1224.9
120.5	1273.2
122.9	1321.5
125.3	1369.8
127.5	1418.1
129.6	1466.4
131.6	1514.7
133.6	1563.0

Table 4: LSCS Unit 2 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*
86.0	0.0
86.0	312.6
116.0	312.6
116.0	1563.0

Table 5: LSCS Unit 2 Core Not Critical (Curve B) P-T Curves for 54 EFPY

Beltline Region

Curve B - Core Not Critical

P-T Curve Temperature *°F*	**P-T Curve Pressure** *psi*
86.0	0.0
86.0	180.4
98.7	229.8
108.7	279.2
117.1	328.5
124.3	377.9
130.6	427.3
136.2	476.7
141.2	526.1
145.8	575.4
149.9	624.8
153.8	674.2
157.4	723.6
160.7	772.9
163.8	822.3
166.8	871.7
169.6	921.1
172.2	970.5
174.7	1019.8
177.1	1069.2
179.4	1118.6
181.5	1168.0
183.6	1217.4
185.6	1266.7
187.6	1316.1
189.4	1365.5
191.2	1414.9
192.9	1464.2
194.6	1513.6
196.2	1563.0

Table 5: LSCS Unit 2 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
86.0	0.0
86.0	486.6
92.3	535.6
97.9	584.5
102.9	633.4
107.5	682.3
111.7	731.3
115.5	780.2
119.1	829.1
122.5	878.0
125.6	927.0
128.6	975.9
131.4	1024.8
134.0	1073.7
136.5	1122.7
138.9	1171.6
141.2	1220.5
143.3	1269.4
145.4	1318.4
147.4	1367.3
149.4	1416.2
151.2	1465.1
153.0	1514.1
154.7	1563.0

Table 5: LSCS Unit 2 Core Not Critical (Curve B) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve B - Core Not Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
86.0	0.0
86.0	312.6
146.0	312.6
146.0	1563.0

Table 6: LSCS Unit 2 Core Critical (Curve C) P-T Curves for 54 EFPY

<u>Beltline Region</u>

Curve C - Core Critical

P-T Curve Temperature *°F*	**P-T Curve Pressure** *psi*
86.0	0.0
86.0	86.0
110.7	135.2
127.2	184.5
139.5	233.7
149.4	282.9
157.7	332.2
164.8	381.4
171.0	430.6
176.5	479.9
181.5	529.1
186.0	578.3
190.2	627.6
194.0	676.8
197.5	726.0
200.9	775.3
204.0	824.5
206.9	873.7
209.7	923.0
212.3	972.2
214.8	1021.4
217.2	1070.7
219.4	1119.9
221.6	1169.1
223.7	1218.4
225.7	1267.6
227.6	1316.8
229.4	1366.1
231.2	1415.3
232.9	1464.5
234.6	1513.8
236.2	1563.0

Table 6: LSCS Unit 2 Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

Bottom Head Region

Curve C - Core Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
86.0	0.0
86.0	286.0
99.1	335.1
109.5	384.2
118.1	433.4
125.4	482.5
131.8	531.6
137.5	580.7
142.6	629.8
147.2	678.9
151.4	728.0
155.3	777.2
158.9	826.3
162.3	875.4
165.5	924.5
168.4	973.6
171.2	1022.7
173.9	1071.8
176.4	1121.0
178.8	1170.1
181.1	1219.2
183.3	1268.3
185.4	1317.4
187.4	1366.5
189.3	1415.7
191.2	1464.8
193.0	1513.9
194.7	1563.0

Table 6: LSCS Unit 2 Core Critical (Curve C) P-T Curves for 54 EFPY (continued)

Non-Beltline Region

Curve C - Core Critical

P-T Curve Temperature *°F*	P-T Curve Pressure *psi*
86.0	0.0
86.0	308.3
86.7	312.6
186.0	312.6
186.0	1563.0

Table 7: LSCS Unit 1 1/4T ART Table for 54 EFPY

Component No.	Heat No.	Flux Lot No.	% Cu	% Ni	CF	Initial RT_{NDT} (°F)	54EFPY 1/4T Fluence (n/cm²)	Fluence Factor f	ΔRT_{NDT} (°F)	σ_i (°F)	σ_Δ (°F)	54 EFPY 1/4T ART (°F)
Unit 1 Lower Shell Assembly 307-04 Plates:												
G-5603-1	C5978-1	N/A	0.11	0.58	74	14	2.21E+17	0.183	13.5	0	6.8	41.0
G-5603-2	C5978-2	N/A	0.11	0.59	74	23	2.21E+17	0.183	13.5	0	6.8	50.0
G-5603-3	C5979-1	N/A	0.12	0.66	84	10	2.21E+17	0.183	15.4	0	7.7	40.7
Unit 1 Lower-Intermediate Shell Assembly 308-06 Plates:												
G-5604-1	C6345-1	N/A	0.15	0.49	104	-20	6.77E+17	0.343	35.7	0	17.0	49.7
G-5604-2	C6318-1	N/A	0.12	0.51	81	-20	6.77E+17	0.343	27.9	0	13.9	35.8
G-5604-3	C6345-2	N/A	0.15	0.51	105	-20	6.77E+17	0.343	36.1	0	17.0	50.1
Unit 1 Middle Shell Assembly 308-05 Plates:												
G-5605-1	A5333-1	N/A	0.12	0.54	82	-10	5.85E+17	0.318	26.0	0	13.0	42.1
G-5605-2	B0078-1	N/A	0.15	0.5	105	-10	5.85E+17	0.318	33.3	0	16.6	56.5
G-5605-3	C6123-2	N/A	0.13	0.68	93	-10	5.85E+17	0.318	29.6	0	14.8	49.2
Unit 1 Lower Shell Axial Welds												
2-307 A (BA)	21935 & 12008 (tandem)	3889	0.213	0.867	209	-50	1.96E+17	0.170	35.5	0	17.7	21.0
2-307 B (BB)	21935 & 12008 (tandem)	3889	0.213	0.867	209	-50	1.98E+17	0.171	35.7	0	17.8	21.4
2-307 C (BC)	21935 & 12008 (tandem)	3889	0.213	0.867	209	-50	1.67E+17	0.154	32.0	0	16.0	14.1
Unit 1 Lower-Intermediate Shell Axial Welds:												
4-308 A (BD)	12008 & 305414 (tandem)	3947	0.286	0.792	219	-50	4.97E+17	0.292	64.0	0	28.0	70.0
4-308 B (BE)	12008 & 305414 (tandem)	3947	0.286	0.792	219	-50	4.06E+17	0.261	57.2	0	28.0	63.2
4-308 C (BF)	12008 & 305414 (tandem)	3947	0.286	0.792	219	-50	6.41E+17	0.334	73.2	0	28.0	79.2
Unit 1 Middle Shell Axial Welds:												
3-308 A (BG)	1P3571 (tandem)	3958	0.287	0.756	214	-30	5.70E+17	0.314	67.2	0	28.0	93.2
3-308 B (BH)	1P3571 (tandem)	3958	0.287	0.756	214	-30	4.41E+17	0.273	58.5	0	28.0	84.5
3-308 C (BJ)	1P3571 (tandem)	3958	0.287	0.756	214	-30	3.26E+17	0.231	49.3	0	24.7	68.7
Unit 1 Circumferential Weld Between Lower Shell and Lower-Intermediate Shell:												
1-313 (AB)	4P6519	0653	0.131	0.06	64	-52	2.35E+17	0.190	12.1	0	6.0	-27.8
Unit 1 Circumferential Weld Between Lower-Intermediate Shell and Middle Shell:												
6-308 (AC)	6329637	3999	0.205	0.105	98	-50	5.85E+17	0.318	31.3	0	15.7	12.6

Table 7: LSCS Unit 1 1/4T ART Table for 54 EFPY (continued)

Component No.	Heat No.	Flux Lot No.	% Cu	% Ni	CF	Initial RT_{NDT} (°F)	54 EFPY 1/4T Fluence (n/cm^2)	Fluence Factor f	ΔRT_{NDT} (°F)	σ_i (°F)	σ_Δ (°F)	54 EFPY 1/4T ART (°F)
Unit 1 N6 LPCI Nozzle Forgings:												
N6 A,B,&C	Q2Q22 W	N/A	0.10	0.82	67	10	9.76E+16	0.108	7.2	0	3.6	24.5
Unit 1 N6 LPCI Nozzle Welds:												
N6 A,B,&C	ABEA	N/A	0.04	0.98	54	-50	2.89E+17	0.215	11.6	0	5.8	-26.8
N6 A,B,&C	FAGA	N/A	0.03	0.95	41	-50	2.89E+17	0.215	8.8	0	4.4	-32.4
N6 A,B,&C	CCJA	N/A	0.02	0.86	27	-50	2.89E+17	0.215	5.8	0	2.9	-38.4
N6 A,B,&C	FOAA	N/A	0.03	1.00	41	-50	2.89E+17	0.215	8.8	0	4.4	-32.4
N6 A,B,&C	EAIB	N/A	0.12	0.86	155	-50	2.89E+17	0.215	33.4	0	16.7	16.8
Unit 1 N12 Water Level Instrument Nozzle Locations in Middle Shell Assembly 308-05 Plates:												
G-5605-1	A5333-1	N/A	0.12	0.54	82	-10	1.98E+17	0.171	14.0	0	7.0	18.0
G-5605-2	B0078-1	N/A	0.15	0.5	105	-10	1.98E+17	0.171	17.9	0	8.9	25.7
G-5605-3	C6123-2	N/A	0.13	0.68	93	-10	1.98E+17	0.171	15.9	0	8.0	21.8
Unit 1 N12 Water Level Instrument Nozzle Welds:												
Nickel Alloy	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit 1 Best-Estimate Chemistry Values from BWRVIP-135 Revision 4:												
Plate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Weld	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit 1 Integrated Surveillance Program Chemistry Values from BWRVIP-135 Revision 4:												
Plate	C6345-1	N/A	0.14	0.54	152	-20	6.77E+17	0.343	52.3	0	17.0	66.3
Weld	1P3571	3958	0.21	0.75	440	-30	5.70E+17	0.314	138.3	0	14.0	136.3

Table 8: LSCS Unit 2 1/4T ART Table for 54 EFPY

Component No.	Heat No.	Flux Lot No.	% Cu	% Ni	CF	Initial RT_{NDT} (°F)	54EFPY 1/4T Fluence (n/cm^2)	Fluence Factor f	ΔRT_{NDT} (°F)	σ_i (°F)	σ_Δ (°F)	54 EFPY 1/4T ART (°F)
Unit 2 Lower Shell Assembly Plates:												
21-1	C9425-2	N/A	0.12	0.51	81	30	6.28E+17	0.330	26.8	0	13.4	83.7
21-2	C9425-1	N/A	0.12	0.51	81	32	6.28E+17	0.330	26.8	0	13.4	85.7
21-2	C9434-2	N/A	0.09	0.51	58	10	6.28E+17	0.330	19.2	0	9.6	48.3
Unit 2 Lower-Intermediate Shell Assembly Plates:												
22-1	C9481-1	N/A	0.11	0.5	73	10	7.38E+17	0.359	26.2	0	13.1	62.4
22-2	C9404-2	N/A	0.07	0.49	44	52	7.38E+17	0.359	15.8	0	7.9	83.6
22-3	C9601-2	N/A	0.12	0.5	81	10	7.38E+17	0.359	29.1	0	14.5	68.1
Unit 2 Lower Shell Assembly Axial Welds:												
BA	3P4000	3933	0.02	0.93	27	-50	4.46E+17	0.275	7.4	0	3.7	-35.2
BB	3P4000	3933	0.02	0.93	27	-50	4.33E+17	0.270	7.3	0	3.7	-35.4
BC	3P4000	3933	0.02	0.93	27	-50	5.57E+17	0.310	8.4	0	4.2	-33.2
Unit 2 Lower-Intermediate Shell Assembly Axial Welds:												
BD	3P4966	1214	0.026	0.92	35	-6	4.44E+17	0.274	9.7	0	4.9	13.4
BE	3P4966	1214	0.026	0.92	35	-6	6.97E+17	0.349	12.3	0	6.2	18.7
BF	3P4966	1214	0.026	0.92	35	-6	5.46E+17	0.307	10.9	0	5.4	15.7
Unit 2 Circumferential Weld Between Lower Shell and Lower-Intermediate Shell:												
AB	5P6771	0342	0.04	0.94	54	-34	6.28E+17	0.330	17.8	0	8.9	1.7

Table 8: LSCS Unit 2 1/4T ART Table for 54 EFPY (continued)

Component No.	Heat No.	Flux Lot No.	% Cu	% Ni	CF	Initial RT_{NDT} (°F)	54EFPY 1/4T Fluence (n/cm^2)	Fluence Factor f	ΔRT_{NDT} (°F)	σ_i (°F)	σ_Δ (°F)	54 EFPY 1/4T ART (°F)
Unit 2 N6 LPCI Nozzle Forgings:												
N6A,B,&C	Q2Q36W	N/A	0.22	0.83	177	-6	1.05E+17	0.113	20.0	0	10.0	34.0
Unit 2 N6 LPCI Nozzle Welds:												
N6A,B,&C	C3L46C	J0202A27A	0.02	0.87	27	-20	3.15E+17	0.226	6.1	0	3.0	-7.8
N6A,B,&C (single wire)	3P4966	1214/3482	0.02	0.8	27	-30	3.15E+17	0.226	6.1	0	3.0	-17.8
N6A,B,&C (tandem wire)	3P4966	1214/3482	0.02	0.92	27	-48	3.15E+17	0.226	6.1	0	3.0	-35.8
N6A,B,&C	05P018	D211A27A	0.09	0.9	122	-38	3.15E+17	0.226	27.5	0	13.8	17.1
N6A,B,&C	04P046	D217A27A	0.06	0.9	82	-48	3.15E+17	0.226	18.5	0	9.3	-11.0
Unit 2 N12 Water Level Instrument Nozzle Locations in Lower-Intermediate Shell Assembly Plates:												
22-1	C9481-1	N/A	0.11	0.5	73	10	2.26E+17	0.186	13.5	0	6.8	37.1
22-2	C9404-2	N/A	0.07	0.49	44	52	2.26E+17	0.186	8.2	0	4.1	68.3
22-3	C9601-2	N/A	0.12	0.5	81	10	2.26E+17	0.186	15.0	0	7.5	40.1
Unit 2 N12 Water Level Instrument Nozzle Welds:												
N12-1,2,&3	Nickel Alloy	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unit 2 Best-Estimate Chemistry Values from BWRVIP-135 Revision 4:												
Plate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Weld	3P4000	N/A	0.02	0.935	27	-50	5.57E+17	0.310	8.4	0	4.2	-33.2
Weld	3P4966	N/A	0.025	0.913	34	-6	6.97E+17	0.349	11.8	1	5.9	17.9
Weld	5P6771	N/A	0.034	0.934	46	-34	6.28E+17	0.330	15.3	2	7.6	-3.0
Unit 2 Integrated Surveillance Program Chemistry Values from BWRVIP-135 Revision 4:												
Plate	C3054-2	N/A	0.08	0.67	51	52	7.38E+17	0.359	18.3	0	9.2	88.6
Weld	402K9171	411L3071	0.02	0.95	27	-6	6.97E+17	0.349	9.4	0	4.7	12.8

Table 9: Nozzle Stress Intensity Factors

Nozzle	Applied Pressure, K_{Ip-app}	Thermal, K_{It}
Unit 1 Feedwater	72.05	41.74
Unit 2 Feedwater	75.05	41.69
LPCI (N6)	88.35	6.97

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

APPENDIX A

LASALLE REACTOR VESSEL MATERIALS SURVEILLANCE PROGRAM

In accordance with 10 CFR 50, Appendix H, Reactor Vessel Material Surveillance Program Requirements [24], one surveillance capsule has been removed and tested from each of the LSCS Unit 1 and Unit 2 reactor vessels. The first LaSalle Unit 1 capsule was removed at 6.5 EFPY [25] and the first LaSalle Unit 2 capsule was removed at 6.98 EFPY [25]. The second LaSalle Unit 1 capsule was removed at 18.9 EFPY in 2010 [28]. 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. The methods and results of testing are presented in References [25, 26]. There is one remaining capsule in LSCS Unit 1 and two remaining capsules in LSCS Unit 2 which will remain in place to serve as backup surveillance material for the BWRVIP program, or as otherwise needed.

LSCS has replaced the original RPV material surveillance program with the BWRVIP ISP [25]. LSCS is currently committed to use the BWRVIP ISP and has made a licensing commitment to use the ISP for LSCS 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. LSCS committed to use the ISP in place of its existing surveillance programs in the license amendment issued by the NRC regarding the implementation of the BWRVIP ISP. Under the ISP, one further capsule is scheduled for removal from the LSCS Unit 1 vessel in 2030 [28].