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

Peach Bottom Atomic Power Station, Unit 3
Renewed Facility Operating License No. DPR-56
NRC Docket No. 50-278

Subject: Response to Request for Additional Information - License Amendment Request, "Proposed Changes to Extend the Use of Pressure-Temperature Limits Specified in Technical Specifications Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3" (TAC No. MC7519)

References:

(1) Letter from P. B. Cowan, Exelon Generation Company, LLC, to U. S. Nuclear Regulatory Commission, License Amendment Request, "Proposed Changes to Extend the Use of Pressure-Temperature Limits Specified in Technical Specifications Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3," dated July 6, 2005.

(2) Letter from R. V. Guzman, U. S. Nuclear Regulatory Commission, to C. M. Crane, Exelon Generation Company, LLC, "Peach Bottom Power Station Unit No. 3 - Request for Additional Information (RAI) Regarding Proposed Pressure-Temperature Curves (TAC No. MC7519)," dated January 26, 2006.

In Reference 1, Exelon Generation Company, LLC (Exelon), requested a change to Renewed Facility Operating License No. DPR-56 for Peach Bottom Atomic Power Station (PBAPS), Unit 3. The proposed change would allow for extension of the use of the current Pressure-Temperature (P-T) limit curves specified in Technical Specifications (TS) Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3 to 32 effective full power years (EFPY).

In Reference 2, the NRC requested additional information concerning the PBAPS, Unit 3 License Amendment Request (LAR). The attachment to this letter restates the NRC questions and provides Exelon's response to each question.

Exelon has concluded that the information provided in this response does not impact the conclusions of the: (1) Technical Analysis, (2) No Significant Hazards Consideration under the standards set forth in 10 CFR 50.92(c), or (3) Environmental Consideration as provided in the original submittal (Reference 1).

Enclosures 1 and 2 to this letter provide information from two versions of the same General Electric (GE) report. Enclosure 1 to this letter provides information from GE Report GE-NE-B13-02119-00-01a, "Pressure-Temperature Curves for Exelon, Peach Bottom Unit 3," dated February 2002, which is the non-proprietary version of the report. Enclosure 2 to this letter provides information from GE Report GE-NE-B13-02119-00-01, which GE considers to contain proprietary information as defined in 10 CFR 2.390. The proprietary information is identified by a vertical bar in the margin. In each case, the information identified by the vertical bar in the margin is considered "trade secrets" and exempt from disclosure in accordance with the requirements of 10 CFR 2.390(a)(4). Accordingly, GE requests that the proprietary information in Enclosure 2 be withheld from public disclosure in accordance with the requirements of 10 CFR 2.390. An affidavit certifying the basis for this request for withholding, as required by 10 CFR 2.390(b)(1), is provided in Enclosure 3. The non-proprietary version of the information provided in Enclosure 2, which has the proprietary information removed, is included in Enclosure 1. The portions of the information that have been removed are indicated by a vertical bar in the margin.

There are no regulatory commitments contained within this letter. If you have any questions or require additional information, please contact Glenn Stewart at 610-765-5529.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 15th day of March 2006.

Respectfully,

Pamela B. Cowan
Director - Licensing & Regulatory Affairs
Exelon Generation Company, LLC

Attachment: Response to Request for Additional Information
Enclosure 1: Excerpts from GE Report GE-NE-B13-02119-00-01a [Non-Proprietary Information]
Enclosure 2: Excerpts from GE Report GE-NE-B13-02119-00-01 [Proprietary Information]
Enclosure 3: GE Affidavit

cc:	Regional Administrator - NRC Region I	w/ attachments
	NRC Senior Resident Inspector - PBAPS	"
	NRC Project Manager, NRR - PBAPS	"
	Director, Bureau of Radiation Protection - Pennsylvania Department of Environmental Protection	w/o Enclosure 2

ATTACHMENT

PEACH BOTTOM ATOMIC POWER STATION, UNIT 3
DOCKET NO. 50-278

PROPOSED CHANGES TO EXTEND THE USE OF PRESSURE-TEMPERATURE LIMITS SPECIFIED IN TECHNICAL SPECIFICATIONS FIGURES 3.4.9-1, 3.4.9-2, AND 3.4.9-3

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

ATTACHMENT

Peach Bottom Atomic Power Station, Unit 3
Docket No. 50-278

Proposed Changes To Extend the Use of Pressure-Temperature Limits Specified in Technical Specifications Figures 3.4.9-1, 3.4.9-2, And 3.4.9-3

Response to Request for Additional Information

In Reference 1, Exelon Generation Company, LLC (Exelon), requested a change to Renewed Facility Operating License No. DPR-56 for Peach Bottom Atomic Power Station (PBAPS), Unit 3. The proposed change would allow for extension of the use of the current Pressure-Temperature (P-T) limit curves specified in Technical Specifications (TS) Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3 to 32 effective full power years (EFPY).

In Reference 2, the NRC requested additional information concerning the PBAPS, Unit 3 License Amendment Request (LAR). Each NRC question is restated below followed by our response.

Enclosures 1 and 2 to this letter provide information from two versions of the same General Electric (GE) report. Enclosure 1 to this letter provides information from GE Report GE-NE-B13-02119-00-01a, "Pressure-Temperature Curves for Exelon, Peach Bottom Unit 3," dated February, 2002, which is the non-proprietary version of the report. Enclosure 2 to this letter provides information from GE Report GE-NE-B13-02119-00-01, which GE considers to contain proprietary information as defined in 10 CFR 2.390. The proprietary information is identified by a vertical bar in the margin. In each case, the information identified by the vertical bar in the margin is considered "trade secrets" and exempt from disclosure in accordance with the requirements of 10 CFR 2.390(a)(4). Accordingly, GE requests that the proprietary information in Enclosure 2 be withheld from public disclosure in accordance with the requirements of 10 CFR 2.390. An affidavit certifying the basis for this request for withholding, as required by 10 CFR 2.390(b)(1), is provided in Enclosure 3. The non-proprietary version of the information provided in Enclosure 2, which has the proprietary information removed, is included in Enclosure 1. The portions of the information that have been removed are indicated by a vertical bar in the margin.

Question 1.

"Please provide the adjusted reference temperature (ART) calculations for the Peach Bottom Atomic Power Station (Peach Bottom) Unit No. 3 beltline materials at the 1/4T locations of the reactor pressure vessel based on the calculated neutron fluence values for these locations at 32 effective full-power years."

<u>Response</u>
The PBAPS, Unit 3 ART calculations used by General Electric (GE) to develop the latest (i.e., unapproved) P-T curves are provided in Enclosure 1. This information is excerpted from GE Report GE-NE-B13-02119-00-01a, Section 4.2, "Adjusted Reference Temperature for Beltline." This information provides the basis for the calculations and summarizes the results of the ART calculations at the 1/4T location for the calculated fluence at 32 EFPY for all beltline materials, including plate and weld materials. As noted in Section 4.2.1.2 of the enclosed material,

extremely conservative fluence values were used to develop the ART calculations. This enclosure also contains Section 6.0, "References," of the GE report which provides the list of documents referred to in Section 4.2 of the report. This information is considered by GE to be non-proprietary.

Question 2.

"Please provide the pressure-temperature (P-T) calculations over the entire temperature range for the unapproved P-T curves that were based on the K_{IC} equation in Section G-2110 of Appendix G to Section XI of the American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, 2001 Edition. Provide the adjusted pressure value for each temperature value assessed, based on the limiting ART (limiting RT_{NDT}) values for the Peach Bottom Unit No. 3 reactor vessel. Include all parameters used in the calculation (e.g., K_{IT} values, temperature gradients across the wall, K_{IC} values, and any margin included for pressure and/or temperature measurement uncertainty)."

Response
The P-T calculations for the unapproved P-T curves are provided in Enclosure 2. This enclosure contains Section 4.3, "Pressure-Temperature Curve Methodology," of GE Report GE-NE-B13-02119-00-01. The information in Enclosure 2 provides the basis and methodology used for development of the curves, considering all regions of the reactor vessel. This enclosure contains information which GE considers to be proprietary. The non-proprietary version of Section 4.3, which has the proprietary information removed, is provided in Enclosure 1.

Additionally, Enclosure 1 includes Tables B-1 and B-2 from GE Report GE-NE-B13-02119-00-01a. These tables contain the results of the P-T calculations over the entire pressure range of operations for the reactor vessel. These tables are considered by GE to be non-proprietary.

Question 3.

"Please confirm that the P-T curves (as provided in Peach Bottom Unit No. 3 Technical Specifications, Figure 3.4.9-1, “Temperature/Pressure Limits for Inservice Hydrostatic and Inservice Leakage Tests,” Figure 3.4.9-2, “Temperature/Pressure Limits for Non-Nuclear Heatup and Cooldown Following a Shutdown,” and Figure 3.4.9-3, “Temperature/Pressure Limits for Criticality,” which were approved in the Peach Bottom Amendment No. 250), are based on the 1/4T location calculations for cooldown. Also, confirm that these curves are based on the limiting ART for the 1/4T location of the vessel."

Response
The P-T curves, as provided in PBAPS, Unit 3, TS Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3, which were approved in PBAPS, Unit 3, Amendment No. 250, are based on the 1/4T location for cooldown. Additionally, it is confirmed that the curves are based on the limiting ART value for the 1/4T location of the vessel.

References:

(1) Letter from P. B. Cowan, Exelon Generation Company, LLC, to U. S. Nuclear Regulatory Commission, License Amendment Request, "Proposed Changes to Extend the Use of Pressure-Temperature Limits Specified in Technical Specifications Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3," dated July 6, 2005.

(2) Letter from R. V. Guzman, U. S. Nuclear Regulatory Commission, to C. M. Crane, Exelon Generation Company, LLC, "Peach Bottom Power Station Unit No. 3 - Request for Additional Information (RAI) Regarding Proposed Pressure-Temperature Curves (TAC No. MC7519)," dated January 26, 2006.

ENCLOSURE 1

PEACH BOTTOM ATOMIC POWER STATION, UNIT 3
DOCKET NO. 50-278

PROPOSED CHANGES TO EXTEND THE USE OF PRESSURE-TEMPERATURE LIMITS SPECIFIED IN TECHNICAL SPECIFICATIONS FIGURES 3.4.9-1, 3.4.9-2, AND 3.4.9-3

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

GENERAL ELECTRIC (GE) REPORT GE-NE-B13-02119-00-01a, "PRESSURE-TEMPERATURE CURVES FOR EXELON, PEACH BOTTOM UNIT 3" SECTIONS 4.2, 4.3 AND 6.0; TABLES B-1 AND B-2

NON-PROPRIETARY INFORMATION

The information in this enclosure is from the non-proprietary version of the document GE-NE-B13-02119-00-01, which has the proprietary information removed. The portions that have been removed are indicated by a vertical bar in the margin.

GENERAL ELECTRIC (GE) REPORT GE-NE-B13-02119-00-01a,
"PRESSURE-TEMPERATURE CURVES FOR EXELON, PEACH BOTTOM UNIT 3"
SECTION 4.2

4.2 ADJUSTED REFERENCE TEMPERATURE FOR BELTLINE

The adjusted reference temperature (ART) of the limiting beltline material is used to adjust the beltline P-T curves to account for irradiation effects. Regulatory Guide 1.99, Revision 2 (Rev 2) provides the methods for determining the ART. The Rev 2 methods for determining the limiting material and adjusting the P-T curves using ART are discussed in this section. An evaluation of ART for all beltline plates and several beltline welds was made and summarized in Table 4-4 for 32 EFPY and Table 4-5 for 54 EFPY.

4.2.1 Regulatory Guide 1.99, Revision 2 (Rev 2) Methods

The value of ART is computed by adding the SHIFT term for a given value of effective full power years (EFPY) to the initial RT_{NDT}. For Rev 2, the SHIFT equation consists of two terms:

$$SHIFT = \Delta RT_{NDT} + Margin$$

where,

$$\Delta RT_{NDT} = [CF]*f^{(0.28 - 0.10 \log f)}$$

$$Margin = 2(\sigma_I^2 + \sigma_\Delta^2)^{0.5}$$

CF = chemistry factor from Tables 1 or 2 of Rev. 2

f = ¼T fluence / 10^{19}

$$Margin = 2(\sigma_I^2 + \sigma_\Delta^2)^{0.5}$$

σ_I = standard deviation on initial RT_{NDT}, which is taken to be 0°F (16.4°F for electroslag welds).

σ_Δ = standard deviation on ΔRT_{NDT}, 28°F for welds and 17°F for base material, except that σ_Δ need not exceed 0.50 times the ΔRT_{NDT} value.

$$ART = \text{Initial } RT_{NDT} + SHIFT$$

The margin term σ_Δ has constant values in Rev 2 of 17°F for plate and 28°F for weld. However, σ_Δ need not be greater than $0.5 \cdot \Delta RT_{NDT}$. Since the GE/BWROG method of estimating RT_{NDT} operates on the lowest Charpy energy value (as described in Section 4.1.2) and provides a conservative adjustment to the 50 ft-lb. level, the value of

σ_I is taken to be 0°F for the vessel plate and most weld materials, except that σ_I is assumed to be 16.4°F for the beltline electroslag weld materials.

4.2.1.1 Chemistry

The vessel beltline chemistries were obtained from sources including CMTRs [12] and an NRC RAI submittal [13]. The copper (Cu) and nickel (Ni) values were used with Tables 1 and 2 of Rev 2, to determine a chemistry factor (CF) per Paragraph 1.1 of Rev 2 for welds and plates, respectively. As discussed in Section 4.1.2, best estimates results are used for the beltline electroslag for the Initial RT_{NDT} [13], therefore, the standard deviation (σ_I) is specified.

4.2.1.2 Fluence

A bounding Limerick and Peach Bottom flux for the vessel ID wall [14] is calculated using methods consistent with Regulatory Guide 1.190. The flux in Reference 14 is determined for the currently licensed power of 3458 MW_t and is conservatively used from the beginning to the end of the licensing period (i.e., 32 and 54 EFPY). Even using the conservative flux from Reference 14 the P-T curves are only beltline limited above 1230 psig for curve A and 1290 psig for curve B for 32 EFPY. The P-T curves are beltline limited above 830 psig for curve A and 890 psig for curve B for 54 EFPY.

The peak fast flux for the RPV inner surface from Reference 14 is 1.32e9 n/cm^2-s. The peak fast flux for the RPV inner surface determined from surveillance capsule flux wires removed during the outage following Fuel Cycle 7 at a full power of 3293 MW_t is 7.16e8 n/cm^2-s [1]. Linearly scaling the Reference 1 flux by 1.05 to the currently licensed power of 3458 MW_t results in an estimated flux of 7.52e8 n/cm^2-s. Therefore, the Reference 14 flux bounds the flux determined from the surveillance capsule flux wire results by 76%.

The time period 32 EFPY is 1.01e9 sec, therefore the RPV ID surface fluence is as follows: RPV ID surface fluence = 1.32e9 n/cm^2-s*1.01e9 s = 1.33e18 n/cm^2. This fluence of 1.33e18 n/cm^2 applies to Shell #2 and the Vertical Welds for Shell #2.

As shown in Reference 22 the elevation of the girth welds DE and EF are 23.9" above BAF and 138.69" above BAF, respectively. Using Figure 3-2 of Reference 14, the relative flux at 25" above BAF and 138" above BAF is 0.64. Therefore, the fluence for the girth welds and the Shell #1 and #3 welds and plates can be reduced from the peak fluence by a ratio of 0.64. Therefore, the ID fluence for the girth welds and the Shell #1 and #3 welds and plates will be 8.53e17 n/cm^2 and the 1/4T fluence will be 5.9e17 n/cm^2.

The fluence value used in this report for a power level of 3458 MW_t also bounds the fluence value for a thermal optimization power (TPO) level of 3517 MW_t.

4.2.2 Limiting Beltline Material

The limiting beltline material signifies the material that is estimated to receive the greatest embrittlement due to irradiation effects combined with initial RT_{NDT}. Using initial RT_{NDT}, chemistry, and fluence as inputs, Rev 2 was applied to compute ART. Table 4-4 lists values of beltline ART for 32 EFPY and Table 4-5 lists the values for 54 EFPY.

Table 4-4: Peach Bottom Unit 3 Beltline ART Values (32 EFPY)

Shell #2 Plates and Vertical Welds

Thickness in inches = 6.125 Ratio at Location / Peak = 1.00

32 EFPY Peak I.D. fluence = 1.3E+18 n/cm^2
32 EFPY Peak 1/4 T fluence = 9.2E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 9.2E+17 n/cm^2

Shell #1 Plates & Welds, Shell #3 Plates & Welds, and Girth Welds

Thickness in inches= 6.125 Ratio at Location / Peak = 0.64

32 EFPY Peak I.D. fluence = 1.3E+18 n/cm^2
32 EFPY Peak 1/4 T fluence = 9.2E+17 n/cm^2
32 EFPY at Location 1/4 T fluence = 5.9E+17 n/cm^2

COMPONENT	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	1/4 T Fluence n/cm^2	32 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	32 EFPY Shift °F	32 EFPY ART °F
PLATES:												
Shell #1 - Lower												
6-146-1	C4689-2	0.12	0.56	82	-10	5.9E+17	26	0	13	26	53	43
6-146-3	C4684-2	0.13	0.58	90	-20	5.9E+17	29	0	14	29	58	38
6-146-7	C4627-1	0.12	0.57	82	-20	5.9E+17	26	0	13	26	53	33
Shell #2 - Lower-Inter												
6-139-10	C2773-2	0.15	0.49	104	10	9.2E+17	42	0	17	34	76	**86**
6-139-11	C2775-1	0.13	0.46	87	10	9.2E+17	35	0	17	34	69	79
6-139-12	C3103-1	0.14	0.60	100	10	9.2E+17	40	0	17	34	74	84
Shell #3 - Intermediate												
6-146-5	C4608-1	0.12	0.55	82	10	5.9E+17	26	0	13	26	52	62
6-146-4	C4689-1	0.12	0.56	82	10	5.9E+17	26	0	13	26	53	63
6-146-2	C4654-1	0.11	0.55	74	10	5.9E+17	24	0	12	24	47	57
WELDS:												
Vertical Weld												
Shell #1 Seam D1, D2, D3	37C065	0.182	0.181	94.5	-45	5.9E+17	30	16.4	15	45	75	30
Shell #2 Seam E1, E2, E3	37C065	0.182	0.181	94.5	-45	9.2E+17	38	16.4	19	50	88	43
Shell #3 Seam F1, F2, F3	37C065	0.182	0.181	94.5	-45	5.9E+17	30	16.4	15	45	75	30
Girth												
Shell 1 to 2 - Lower to Lower-Intermediate DE	3P4000, Linde 124 Flux Lot 3932	0.020	0.934	27	-50	5.9E+17	9	0	4	9	17	-33
Shell 2 to 3 - Lower-Inter to Intermediate EF	IP4217, Linde 124 Flux Lot 3929	0.102	0.942	137	-50	5.9E+17	44	0	22	44	88	38

Max ART 86

GENERAL ELECTRIC (GE) REPORT GE-NE-B13-02119-00-01a,
"PRESSURE-TEMPERATURE CURVES FOR EXELON, PEACH BOTTOM UNIT 3"
SECTION 4.3

4.3 PRESSURE-TEMPERATURE CURVE METHODOLOGY

4.3.1 Background

Nuclear Regulatory Commission (NRC) 10CFR50 Appendix G [8] specifies fracture toughness requirements to provide adequate margins of safety during the operating conditions that a pressure-retaining component may be subjected to over its service lifetime. The ASME Code (Appendix G of Section XI of the ASME Code [6]) forms the basis for the requirements of 10CFR50 Appendix G. 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) non-nuclear heatup/cooldown and low-level physics tests, referred to as Curve B; and (c) core critical operation, referred to as Curve C.

There are four vessel regions that should be monitored against the P-T curve operating limits; these regions are defined on the thermal cycle diagram [2]:

- Closure flange region (Region A)
- Core beltline region (Region B)
- Upper vessel (Regions A & B)
- Lower vessel (Regions B & C)

The closure flange region includes the bolts, top head flange, and adjacent plates and welds. The core beltline is the vessel location adjacent to the active fuel, such that the neutron fluence is sufficient to cause a significant shift of RT_{NDT}. The remaining portion of the vessel (i.e., upper vessel, lower vessel) include shells, components like the nozzles, the support skirt, and stabilizer brackets; these regions will also be called the non-beltline region.)

For the core not critical and the core critical curves, the P-T curves specify a coolant heatup and cooldown temperature rate of 100°F/hr or less for which the curves are applicable. However, the core not critical and the core critical curves were also developed to bound transients defined on the RPV thermal cycle diagram [2] and the

nozzle thermal cycle diagrams [3]. The bounding transients used to develop the curves are described in the sections below. For the hydrostatic pressure and leak test curve, a coolant heatup and cooldown temperature rate of 20°F/hr or less must be maintained at all times.

The P-T curves for the heatup and cooldown operating condition at a given EFPY apply for both the 1/4T and 3/4T locations. When combining pressure and thermal stresses, it is usually necessary to evaluate stresses at the 1/4T location (inside surface flaw) and the 3/4T location (outside surface flaw). This is because the thermal gradient tensile stress of interest is in the inner wall during cooldown and is in the outer wall during heatup. However, as a conservative simplification, the thermal gradient stress at the 1/4T location is assumed to be tensile for both heatup and cooldown. 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, K_{Ir}, 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, well above the heatup/cooldown curve limits.

The applicable temperature is the greater of the 10CFR50 Appendix G minimum temperature requirement or the ASME Appendix G limits. A summary of the requirements is as follows in Table 4-6:

Table 4-6: Summary of the 10CFR50 Appendix G Requirements

Operating Condition and Pressure	Minimum Temperature Requirement
I. Hydrostatic Pressure Test & Leak Test (Core is Not Critical) - Curve A	
1. At ≤ 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 60°F*
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 90°F
II. Normal operation (heatup and cooldown), including anticipated operational occurrences	
a. Core not critical - Curve B	
1. At ≤ 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 60°F*
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits or of highest closure flange region initial RT_{NDT} + 120°F
b. Core critical - Curve C	
1. At ≤ 20% of preservice hydrotest pressure, with the water level within the normal range for power operation	Larger of ASME Limits + 40°F or of a.1
2. At > 20% of preservice hydrotest pressure	Larger of ASME Limits + 40°F or of a.2 + 40°F or the minimum permissible temperature for the inservice system hydrostatic pressure test

* 60°F adder is included by GE as an additional conservatism as discussed in Section 4.3.2.3

There are four vessel regions that affect the operating limits: the closure flange region, the core beltline region, and the two regions in the remainder of the vessel (i.e., the upper vessel and lower vessel non-beltline regions). The closure flange region limits are controlling at lower pressures primarily because of 10CFR50 Appendix G [8] requirements. The non-beltline and beltline region operating limits are evaluated according to procedures in 10CFR50 Appendix G [8], ASME Code Appendix G [6], and Welding Research Council (WRC) Bulletin 175 [15]. The beltline region minimum temperature limits are adjusted to account for vessel irradiation.

GE PROPRIETARY INFORMATION DELETED

4.3.2 P-T Curve Methodology

4.3.2.1 Non-Beltline Regions

Non-beltline regions are defined as the vessel locations that are remote from the active fuel and where the neutron fluence is not sufficient (<1.0E17 n/cm^2) to cause any significant shift of RT_{NDT}. Non-beltline components include nozzles (see Appendix E), the closure flanges, some shell plates, the top and bottom head plates and the control rod drive (CRD) penetrations.

Detailed stress analyses of the non-beltline components were performed for the BWR/6 specifically for the purpose of fracture toughness analysis. The analyses took into account all mechanical loading and anticipated thermal transients. Transients considered include 100°F/hr start-up and shutdown, SCRAM, loss of feedwater heaters or flow, loss of recirculation pump flow, and all transients involving emergency core cooling injections. Primary membrane and bending stresses and secondary membrane and bending stresses due to the most severe of these transients were used according to the ASME Code [6] to develop plots of allowable pressure (P) versus temperature relative to the reference temperature (T - RT_{NDT}). Plots were developed for the limiting BWR/6 components: the feedwater nozzle (FW) and the CRD penetration (bottom head). All other components in the non-beltline regions are categorized under one of these two components as described in Tables 4-7 and 4-8.

Table 4-7: Applicable BWR/4 Discontinuity Components for Use With FW (Upper Vessel) Curves A & B

Discontinuity Identification
FW Nozzle
CRD HYD System Return
Core Spray Nozzle
Recirculation Inlet Nozzle
Steam Outlet Nozzle
Main Closure Flange
Support Skirt
Stabilizer Brackets
Shroud Support Attachments
Core ΔP and Liquid Control Nozzle
Steam Water Interface
Jet Pump Instrumentation Nozzle
Shell
CRD and Bottom Head (B only)
Top Head Nozzles (B only)
Recirculation Outlet Nozzle (B only)

Table 4-8: Applicable BWR/4 Discontinuity Components for Use with CRD (Bottom Head) Curves A&B

Discontinuity Identification
CRD and Bottom Head
Top Head Nozzles
Recirculation Outlet Nozzle
Shell**
Support Skirt**
Shroud Support Attachments**
Core ΔP and Liquid Control Nozzle**

** These discontinuities are added to the bottom head curve discontinuity list to assure that the entire bottom head is covered, since separate bottom head P-T curves are provided to monitor the bottom head.

The P-T curves for the non-beltline region were conservatively developed for a large BWR/6 (nominal inside diameter of 251 inches). The analysis is considered appropriate for Peach Bottom Unit 3 as the plant specific geometric values are bounded by the

generic analysis for a large BWR/6, as determined in Section 4.3.2.1.1 through Section 4.3.2.1.4. The generic value was adapted to the conditions at Peach Bottom Unit 3 by using plant specific RT_{NDT} values for the reactor pressure vessel (RPV). The presence of nozzles and CRD penetration holes of the upper vessel and bottom head, respectively, has made the analysis different from a shell analysis such as the beltline. This was the result of the stress concentrations and higher thermal stress for certain transient conditions experienced by the upper vessel and the bottom head.

4.3.2.1.1 Pressure Test - Non-Beltline, Curve A (Using Bottom Head)

In a finite element analysis , the CRD penetration region was modeled to compute the local stresses for determination of the stress intensity factor, K_I. The evaluation was modified to consider the new requirement for M_m as discussed in ASME Code Section XI Appendix G [6] and shown below. The results of that computation were K_I = 143.6 ksi-in$^{1/2}$ for an applied pressure of 1593 psig (1563 psig preservice hydrotest pressure at the top of the vessel plus 30 psig hydrostatic pressure at the bottom of the vessel). The computed value of (T - RT_{NDT}) was 84°F.

The limit for the coolant temperature change rate is 20°F/hr or less.

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [6] was based on a thickness of 8.0 inches; hence, $t^{1/2} = 2.83$. The resulting value obtained was:

$$M_m = 1.85 \text{ for } \sqrt{t} \leq 2$$

$$\mathbf{M_m} = 0.926\ \sqrt{t} \text{ for } 2 \leq \sqrt{t} \leq 3.464 = \mathbf{2.6206}$$

$$M_m = 3.21 \text{ for } \sqrt{t} > 3.464$$

K_{Im} is calculated from the equation in Paragraph G-2214.1 [6] and K_{Ib} is calculated from the equation in Paragraph G-2214.2 [6]:

$$K_{Im} = M_m \cdot \sigma_{pm} = \qquad \text{ksi-in}^{1/2}$$

$$K_{Ib} = (2/3)\ M_m \cdot \sigma_{pb} = \qquad \text{ksi-in}^{1/2}$$

The total K_I is therefore:

$$K_I = 1.5\ (K_{Im} + K_{Ib}) + M_m \cdot (\sigma_{sm} + (2/3) \cdot \sigma_{sb}) = 143.6 \text{ ksi-in}^{1/2}$$

This equation includes a safety factor of 1.5 on primary stress. The method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the K_{Ic} the equation of Paragraph A-4200 in ASME Appendix A [17]:

$$(T - RT_{NDT}) = \ln\ [(K_I - 33.2) / 20.734] / 0.02$$

$$(T - RT_{NDT}) = \ln [(144 - 33.2) / 20.734] / 0.02$$

$$(T - RT_{NDT}) = 84°F$$

The generic curve was generated by scaling 143.6 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated $(T - RT_{NDT})$:

The highest RT_{NDT} for the bottom head plates and welds is 42°F, as shown in Tables 4-1 and 4-3.

Second, the P-T curve is dependent on the calculated K_I value, and the K_I value is proportional to the stress and the crack depth as shown below:

$$K_I \propto \sigma (\pi a)^{1/2} \qquad (4\text{-}1)$$

The stress is proportional to R/t and, for the P-T curves, crack depth, *a*, is t/4. Thus, K_I is proportional to $R/(t)^{1/2}$. The generic curve value of $R/(t)^{1/2}$, based on the generic BWR/6 bottom head dimensions, is:

Generic: $R / (t)^{1/2} = 138 / (8)^{1/2} = 49 \text{ inch}^{1/2}$ (4-2)

The Peach Bottom Unit 3 specific bottom head dimensions are R = 125.5 inches and t =8 inches minimum [19], resulting in:

Peach Bottom Unit 3 specific: $R / (t)^{1/2} = 125.5 / (8)^{1/2} = 44.4 \text{ inch}^{1/2}$ (4-3)

Since the generic value of $R/(t)^{1/2}$ is larger, the generic P-T curve is conservative when applied to the Peach Bottom Unit 3 bottom head.

4.3.2.1.2 Core Not Critical Heatup/Cooldown - Non-Beltline Curve B (Using Bottom Head)

As discussed previously, the CRD penetration region limits were established primarily for consideration of bottom head discontinuity stresses during pressure testing. Heatup/cooldown limits were calculated by increasing the safety factor in the pressure testing stresses (Section 4.3.2.1.1) from 1.5 to 2.0.

The calculated value of K_I for pressure test is multiplied by a safety factor (SF) of 1.5, per ASME Appendix G [6] for comparison with K_{IR}, the material fracture toughness. A safety factor of 2.0 is used for the core not critical. Therefore, the K_I value for the core not critical condition is $(143.6 / 1.5) \cdot 2.0 = 191.5$ ksi-in$^{1/2}$.

Therefore, the method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the K_{Ic} equation of Paragraph A-4200 in ASME Appendix A [17] for the core not critical curve:

$$(T - RT_{NDT}) = \ln [(K_I - 33.2) / 20.734] / 0.02$$

$(T - RT_{NDT}) = \ln [(191.5 - 33.2) / 20.734] / 0.02$

$(T - RT_{NDT}) = 102°F$

The generic curve was generated by scaling 192 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated $(T - RT_{NDT})$:

Core Not Critical CRD Penetration K_I and $(T - RT_{NDT})$ as a Function of Pressure

Nominal Pressure (psig)	K_I (ksi-in$^{1/2}$)	$T - RT_{NDT}$ (°F)
1563	192	102
1400	172	95
1200	147	85
1000	123	73
800	98	57
600	74	33
400	49	-14

The highest RT_{NDT} for the bottom head plates and welds is 42°F, as shown in Tables 4-1 and 4-3.

As discussed in Section 4.3.2.1.1 an evaluation is performed to assure that the CRD discontinuity bounds the other discontinuities that are to be protected by the CRD curve with respect to pressure stresses (see Tables 4-7, 4-8, and Appendix A). With respect to thermal stresses, the transients evaluated for the CRD are similar to or more severe than those of the other components being bounded. Therefore, for heatup/cooldown conditions, the CRD penetration provides bounding limits.

4.3.2.1.3 Pressure Test - Non-Beltline Curve A (Using Feedwater Nozzle/Upper Vessel Region)

The stress intensity factor, K_I, for the feedwater nozzle was computed using the methods from WRC 175 [15] together with the nozzle dimension for a generic 251-inch BWR/6 feedwater nozzle. The result of that computation was K_I = 200 ksi-in$^{1/2}$ for an applied pressure of 1563 psig preservice hydrotest pressure.

The respective flaw depth and orientation used in this calculation is perpendicular to the maximum stress (hoop) at a depth of 1/4T through the corner thickness.

To evaluate the results, K_I is calculated for the upper vessel nominal stress, PR/t, according to the methods in ASME Code Appendix G (Section III or XI). The result is compared to that determined by CBIN in order to quantify the K magnification associated with the stress concentration created by the feedwater nozzles. A calculation of K_I is shown below using the BWR/6, 251-inch dimensions:

Vessel Radius, R_v	126.7 inches
Vessel Thickness, t_v	6.1875 inches
Vessel Pressure, P_v	1563 psig

Pressure stress: $\sigma = PR / t$ = 1563 psig · 126.7 inches / (6.1875 inches) = 32,005 psi. The Dead weight and thermal RFE stress of 2.967 ksi is conservatively added yielding σ = 34.97 ksi. The factor F (a/r_n) from Figure A5-1 of WRC-175 is 1.4 where :

a =	$\frac{1}{4}(t_n^2 + t_v^2)^{1/2}$	=2.36 inches
t_n =	thickness of nozzle	= 7.125 inches
t_v =	thickness of vessel	= 6.1875 inches
r_n =	apparent radius of nozzle	= r_i + 0.29 r_c=7.09 inches
r_i =	actual inner radius of nozzle	= 6.0 inches
r_c =	nozzle radius (nozzle corner radius)	= 3.75 inches

Thus, a/r_n = 2.36 / 7.09 = 0.33. The value F(a/r_n), taken from Figure A5-1 of WRC Bulletin 175 for an a/r_n of 0.33, is 1.4. Including the safety factor of 1.5, the stress intensity factor, K_I, is 1.5 σ $(\pi a)^{1/2}$ · F(a/r_n):

Nominal $K_I = 1.5 \quad 34.97 \cdot (\pi \cdot 2.36)^{1/2} \cdot 1.4 = 200$ ksi-in$^{1/2}$

The method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the K_{Ic} equation of Paragraph A-4200 in ASME Appendix A [17] for the pressure test condition:

$$(T - RT_{NDT}) = \ln [(K_I - 33.2) / 20.734] / 0.02$$
$$(T - RT_{NDT}) = \ln [(200 - 33.2) / 20.734] / 0.02$$
$$(T - RT_{NDT}) = 104.2°F$$

The generic pressure test P-T curve was generated by scaling 200 ksi-in$^{1/2}$ by the nominal pressures and calculating the associated $(T - RT_{NDT})$,

The highest RT_{NDT} for the feedwater nozzle materials is 40°F as shown in Table 4-2. However, the RT_{NDT} was increased to 44°F to consider the stresses in the top head nozzle together with the initial RT_{NDT} as described below. The generic pressure test P-T curve is applied to the Peach Bottom Unit 3 feedwater nozzle curve by shifting the P vs. (T - RT_{NDT}) values above to reflect the RT_{NDT} value of 44°F.

Second, the P-T curve is dependent on the K_I value calculated. The Peach Bottom Unit 3 specific vessel shell and nozzle dimensions applicable to the feedwater nozzle location [19] and K_I are shown below:

Vessel Radius, R_v	125.7 inches
Vessel Thickness, t_v	6.125 inches
Vessel Pressure, P_v	1563 psig

Pressure stress: $\sigma = PR / t = 1563$ psig $\cdot$ 125.7 inches / (6.125 inches) = 32,077 psi. The Dead weight and thermal RFE stress of 2.967 ksi is conservatively added yielding $\sigma = 35.04$ ksi. The factor F (a/r_n) from Figure A5-1 of WRC-175 is determined where:

a =	$\frac{1}{4}(t_n^2 + t_v^2)^{1/2}$	=2.32 inches
t_n =	thickness of nozzle	= 6.963 inches
t_v =	thickness of vessel	= 6.125 inches
r_n =	apparent radius of nozzle	= $r_i + 0.29\ r_c$=6.91 inches
r_i =	actual inner radius of nozzle	= 6.0375 inches
r_c =	nozzle radius (nozzle corner radius)	= 3.0 inches

Thus, $a/r_n = 2.32 / 6.91 = 0.34$. The value F($a/r_n$), taken from Figure A5-1 of WRC Bulletin 175 for an a/r_n of 0.34, is 1.4. Including the safety factor of 1.5, the stress intensity factor, K_I, is $1.5\ \sigma\ (\pi a)^{1/2} \cdot F(a/r_n)$:

Nominal $K_I = 1.5 \cdot 35.04 \cdot (\pi \cdot 2.32)^{1/2} \cdot 1.4 = 199$ ksi-in$^{1/2}$

4.3.2.1.4 Core Not Critical Heatup/Cooldown - Non-Beltline Curve B (Using Feedwater Nozzle/Upper Vessel Region)

The feedwater nozzle was selected to represent non-beltline components for fracture toughness analyses because the stress conditions are the most severe experienced in the vessel. In addition to the pressure and piping load stresses resulting from the nozzle discontinuity, the feedwater nozzle region experiences relatively cold feedwater flow in hotter vessel coolant.

Stresses were taken from a finite element analysis done specifically for the purpose of fracture toughness analysis . Analyses were performed for all feedwater nozzle transients that involved rapid temperature changes. The most severe of these was normal operation with cold 40°F feedwater injection, which is equivalent to hot standby, see Figure 4-3.

The non-beltline curves based on feedwater nozzle limits were calculated according to the methods for nozzles in Appendix 5 of the Welding Research Council (WRC) Bulletin 175 [15].

The stress intensity factor for a nozzle flaw under primary stress conditions (K_{IP}) is given in WRC Bulletin 175 Appendix 5 by the expression for a flaw at a hole in a flat plate:

$$K_{IP} = SF \cdot \sigma\,(\pi a)^{1/2} \cdot F(a/r_n) \qquad (4\text{-}4)$$

where SF is the safety factor applied per WRC Bulletin 175 recommended ranges, and $F(a/r_n)$ is the shape correction factor.

Finite element analysis of a nozzle corner flaw was performed to determine appropriate values of $F(a/r_n)$ for Equation 4-4. These values are shown in Figure A5-1 of WRC Bulletin 175 [15].

The stresses used in Equation 4-4 were taken from design stress reports for the feedwater nozzle. The stresses considered are primary membrane, σ_{pm}, and primary bending, σ_{pb}. Secondary membrane, σ_{sm}, and secondary bending, σ_{sb}, stresses are included in the total K_I by using ASME Appendix G [6] methods for secondary portion, K_{Is}:

$$K_{Is} = M_m (\sigma_{sm} + (2/3) \cdot \sigma_{sb}) \quad (4\text{-}5)$$

In the case where the total stress exceeded yield stress, a plasticity correction factor was applied based on the recommendations of WRC Bulletin 175 Section 5.C.3 [15]. However, the correction was not applied to primary membrane stresses because primary stresses satisfy the laws of equilibrium and are not self-limiting. K_{IP} and K_{Is} are added to obtain the total value of stress intensity factor, K_I. A safety factor of 2.0 is applied to primary stresses for core not critical heatup/cooldown conditions.

Once K_I was calculated, the following relationship was used to determine $(T - RT_{NDT})$. The method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the K_{Ic} equation of Paragraph A-4200 in ASME Appendix A [17]. The highest RT_{NDT} for the appropriate non-beltline components was then used to establish the P-T curves.

$$(T - RT_{NDT}) = \ln [(K_I - 33.2) / 20.734] / 0.02 \qquad (4\text{-}6)$$

Example: Core Not Critical Heatup/Cooldown Calculation for Feedwater Nozzle/Upper Vessel Region

The non-beltline core not critical heatup/cooldown curve was based on the feedwater nozzle analysis, where feedwater injection of 40°F into the vessel while at operating conditions (551.4°F and 1050 psig) was the limiting normal or upset condition from a brittle fracture perspective. The feedwater nozzle corner stresses were obtained from finite element analysis. To produce conservative thermal stresses, a vessel and nozzle thickness of 7.5 inches was used in the evaluation. However, a thickness of 7.5 inches is not conservative for the pressure stress evaluation. Therefore, the pressure stress (σ_{pm}) was adjusted for the actual vessel thickness of 6.1875 inches (i.e., σ_{pm} = 20.49 ksi was revised to 20.49 ksi · 7.5 inches/6.1875 inches = 24.84 ksi). These stresses, and other inputs used in the generic calculations, are shown below:

σ_{pm} = 24.84 ksi	σ_{sm} = 16.19 ksi	σ_{ys} = 45.0 ksi	t_v = 6.1875 inch
σ_{pb} = 0.22 ksi	σ_{sb} = 19.04 ksi	a = 2.36 inch	r_n = 7.08 inch
t_n = 7.125 inch			

In this case the total stress, 60.29 ksi, exceeds the yield stress, σ_{ys}, so the correction factor, R, is calculated to consider the nonlinear effects in the plastic region according to

the following equation based on the assumptions and recommendation of WRC Bulletin 175 [15]. (The value of specified yield stress is for the material at the temperature under consideration. For conservatism, the temperature assumed for the crack root is the inside surface temperature.)

$$R = [\sigma_{ys} - \sigma_{pm} + ((\sigma_{total} - \sigma_{ys}) / 30)] / (\sigma_{total} - \sigma_{pm}) \quad (4\text{-}7)$$

For the stresses given, the ratio, R = 0.583. Therefore, all the stresses are adjusted by the factor 0.583, except for σ_{pm}. The resulting stresses are:

σ_{pm} = 24.84 ksi σ_{sm} = 9.44 ksi

σ_{pb} = 0.13 ksi σ_{sb} = 11.10 ksi

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [6] was based on the 4a thickness ; hence, $t^{1/2}$ = 3.072. The resulting value obtained was:

$$M_m = 1.85 \text{ for } \sqrt{t} \leq 2$$

$$\mathbf{M_m} = 0.926\sqrt{t} \text{ for } 2 \leq \sqrt{t} \leq 3.464 = \mathbf{2.845}$$

$$M_m = 3.21 \text{ for } \sqrt{t} > 3.464$$

The value $F(a/r_n)$, taken from Figure A5-1 of WRC Bulletin 175 for an a/r_n of 0.33, is therefore,

$F(a / r_n) = 1.4$

K_{IP} is calculated from Equation 4-4:

$K_{IP} = 2.0 \cdot (24.84 + 0.13) \cdot (\pi \cdot 2.36)^{1/2} \cdot 1.4$

$K_{IP} = 190.4$ ksi-in$^{1/2}$

K_{Is} is calculated from Equation 4-5:

$K_{Is} = 2.845 \cdot (9.44 + 2/3 \cdot 11.10)$

K_{Is} = 47.9 ksi-in$^{1/2}$

The total K_I is, therefore, 238.3 ksi-in$^{1/2}$.

The total K_I is substituted into Equation 4-6 to solve for $(T - RT_{NDT})$:

$(T - RT_{NDT}) = \ln [(238.3 - 33.2) / 20.734] / 0.02$
$(T - RT_{NDT}) = 115°F$

The curve was generated by scaling the stresses used to determine the K_I; this scaling was performed after the adjustment to stresses above yield. The primary stresses were scaled by the nominal pressures, while the secondary stresses were scaled by the temperature difference of the 40°F water injected into the hot reactor vessel nozzle. In the base case that yielded a K_I value of 238 ksi-in$^{1/2}$, the pressure is 1050 psig and the hot reactor vessel temperature is 551.4°F. Since the reactor vessel temperature follows the saturation temperature curve, the secondary stresses are scaled by
$(T_{saturation} - 40) / (551.4 - 40)$. From K_I the associated $(T - RT_{NDT})$ can be calculated:

Core Not Critical Feedwater Nozzle K_I and $(T - RT_{NDT})$ as a Function of Pressure

Nominal Pressure (psig)	Saturation Temp. (°F)	R	K_I* (ksi-in$^{1/2}$)	$(T - RT_{NDT})$ (°F)
1563	604	0.23	303	128
1400	588	0.34	283	124
1200	557	0.48	257	119
1050	551	0.58	238	115
1000	546	0.62	232	113
800	520	0.79	206	106
600	489	1.0	181	98
400	448	1.0	138	81

*Note: For each change in stress for each pressure and saturation temperature condition, there is a corresponding change to R that influences the determination of K_I.

The highest non-beltline RT_{NDT} for the feedwater nozzle at Peach Bottom Unit 3 is 40°F as shown in Table 4-2. The generic curve is applied to the Peach Bottom Unit 3 upper vessel by shifting the P vs. $(T - RT_{NDT})$ values above to reflect the RT_{NDT} value of 44°F as discussed in Section 4.3.2.1.3.

4.3.2.2 CORE BELTLINE REGION

The pressure-temperature (P-T) operating limits for the beltline region are determined according to the ASME Code. As the beltline fluence increases with the increase in operating life, the P-T curves shift to a higher temperature.

The stress intensity factors (K_I), calculated for the beltline region according to ASME Code Appendix G procedures [6], were based on a combination of pressure and thermal stresses for a 1/4T flaw in a flat plate. The pressure stresses were calculated using thin-walled cylinder equations. Thermal stresses were calculated assuming the through-wall temperature distribution of a flat plate; values were calculated for 100°F/hr coolant thermal gradient. The shift value of the most limiting ART material was used to adjust the RT_{NDT} values for the P-T limits.

4.3.2.2.1 Beltline Region - Pressure Test

The methods of ASME Code Section XI, Appendix G [6] are used to calculate the pressure test beltline limits. The vessel shell, with an inside radius (R) to minimum thickness (t_{min}) ratio of 15, is treated as a thin-walled cylinder. The maximum stress is the hoop stress, given as:

$$\sigma_m = PR / t_{min} \tag{4-8}$$

The stress intensity factor, K_{Im}, is calculated using Paragraph G-2214.1 of the ASME Code Case.

The calculated value of K_{Im} for pressure test is multiplied by a safety factor (SF) of 1.5, per ASME Appendix G [6] for comparison with K_{IC}, the material fracture toughness. A safety factor of 2.0 is used for the core not critical and core critical conditions.

The relationship between K_{IC} and temperature relative to reference temperature ($T - RT_{NDT}$) is based on the K_{Ic} equation of Paragraph A-4200 in ASME Appendix A [17] for the pressure test condition:

$$K_{Im} \cdot SF = K_{IC} = 20.734 \exp[0.02 (T - RT_{NDT})] + 33.2 \tag{4-9}$$

This relationship provides values of pressure versus temperature (from K_{IR} and ($T-RT_{NDT}$), respectively).

GE's current practice for the pressure test curve is to add a stress intensity factor, K_{It}, for a coolant heatup/cooldown rate of 20°F/hr to provide operating flexibility. For the core not critical and core critical condition curves, a stress intensity factor is added for a coolant heatup/cooldown rate of 100°F/hr. The K_{It} calculation for a coolant heatup/cooldown rate of 100°F/hr is described in Section 4.3.2.2.3 below.

4.3.2.2.2 Calculations for the Beltline Region - Pressure Test

This sample calculation is for a pressure test pressure of 1105 psig at 32 EFPY. The following inputs were used in the beltline limit calculation:

Adjusted RT_{NDT} = Initial RT_{NDT} + Shift	A = 10 + 76 = 86°F (Based on ART values in Section 4.2)
Vessel Height	H = 874.75 inches
Bottom of Active Fuel Height	B = 216.3 inches
Vessel Radius (to inside of clad)	R = 125.5 inches
Minimum Vessel Thickness (without clad)	t = 6.125 inches

Pressure is calculated to include hydrostatic pressure for a full vessel:

$$P = 1105 \text{ psi} + (H - B)\ 0.0361 \text{ psi/inch} = P \text{ psig} \quad (4\text{-}10)$$
$$= 1105 + (874.75 - 216.3)\ 0.0361 = 1129 \text{ psig}$$

Pressure stress:

$$\sigma = PR/t \quad (4\text{-}11)$$
$$= 1.129 \cdot 125.5 / 6.125 = 23.1 \text{ ksi}$$

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [6] was based on a thickness of 6.125 inches (the minimum thickness without cladding); hence, $t^{1/2} = 2.475$. The resulting value obtained was:

$$M_m = 1.85 \text{ for } \sqrt{t} \leq 2$$

$$\mathbf{M_m} = 0.926\ \sqrt{t} \text{ for } 2 \leq \sqrt{t} \leq 3.464 = \mathbf{2.29}$$

$$M_m = 3.21 \text{ for } \sqrt{t} > 3.464$$

The stress intensity factor for the pressure stress is $K_{Im} = M_m \cdot \sigma$. The stress intensity factor for the thermal stress, K_{It}, is calculated as described in Section 4.3.2.2.4 except that the value of "G" is 20°F/hr instead of 100°F/hr.

Equation 4-9 can be rearranged, and 1.5 K_{Im} substituted for K_{IC}, to solve for $(T - RT_{NDT})$. Using the K_{Ic} equation of Paragraph A-4200 in ASME Appendix A [17], $K_{Im} = 52.9$, and $K_{It} = 2.28$ for a 20°F/hr coolant heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$\begin{aligned}(T - RT_{NDT}) &= \ln[(1.5 \cdot K_{Im} + K_{It} - 33.2) / 20.734] / 0.02 \qquad (4\text{-}12)\\ &= \ln[(1.5 \cdot 52.9 + 2.28 - 33.2) / 20.734] / 0.02\\ &= 42.4°F\end{aligned}$$

T can be calculated by adding the adjusted RT_{NDT}:

$$T = 42.4 + 86 = 128°F \qquad \text{for } P = 1105 \text{ psig}$$

4.3.2.2.3 Beltline Region - Core Not Critical Heatup/Cooldown

The beltline curves for core not critical heatup/cooldown conditions are influenced by pressure stresses and thermal stresses, according to the relationship in ASME Section XI Appendix G [6]:

$$K_{IC} = 2.0 \cdot K_{Im} + K_{It} \qquad (4\text{-}13)$$

where K_{Im} is primary membrane K due to pressure and K_{It} is radial thermal gradient K due to heatup/cooldown.

The pressure stress intensity factor K_{Im} is calculated by the method described above, the only difference being the larger safety factor applied. The thermal gradient stress intensity factor calculation is described below.

The thermal stresses in the vessel wall are caused by a radial thermal gradient that is created by changes in the adjacent reactor coolant temperature in heatup or cooldown conditions. The stress intensity factor is computed by multiplying the coefficient M_t from Figure G-2214-1 of ASME Appendix G [6] by the through-wall temperature gradient ΔT_w, given that the temperature gradient has a through-wall shape similar to that shown in Figure G-2214-2 of ASME Appendix G [6]. The relationship used to compute the through-wall ΔT_w is based on one-dimensional heat conduction through an insulated flat plate:

$$\partial^2 T(x,t) / \partial x^2 = 1 / \beta \, (\partial T(x,t) / \partial t) \qquad (4\text{-}14)$$

where T(x,t) is temperature of the plate at depth x and time t, and β is the thermal diffusivity.

The maximum stress will occur when the radial thermal gradient reaches a quasi-steady state distribution, so that $\partial T(x,t) / \partial t = dT(t) / dt = G$, where G is the coolant heatup/cooldown rate, normally 100°F/hr. The differential equation is integrated over x for the following boundary conditions:

1. Vessel inside surface (x = 0) temperature is the same as coolant temperature, T_0.
2. Vessel outside surface (x = C) is perfectly insulated; the thermal gradient dT/dx = 0.

The integrated solution results in the following relationship for wall temperature:

$$T = Gx^2 / 2\beta - GCx / \beta + T_0 \qquad (4\text{-}15)$$

This equation is normalized to plot $(T - T_0) / \Delta T_w$ versus x / C.

The resulting through-wall gradient compares very closely with Figure G-2214-2 of ASME Appendix G [6]. Therefore, ΔT_w calculated from Equation 4-15 is used with the appropriate M_t of Figure G-2214-1 of ASME Appendix G [6] to compute K_{It} for heatup and cooldown.

The M_t relationships were derived in the Welding Research Council (WRC) Bulletin 175 [15] for infinitely long cracks of 1/4T and 1/8T. For the flat plate geometry and radial thermal gradient, orientation of the crack is not important.

4.3.2.2.4 Calculations for the Beltline Region Core Not Critical Heatup/Cooldown

This sample calculation is for a pressure of 1105 psig for 32 EFPY. The core not critical heatup/cooldown curve at 1105 psig uses the same K_{Im} as the pressure test curve, but with a safety factor of 2.0 instead of 1.5. The increased safety factor is used because the heatup/cooldown cycle represents an operational rather than test condition that necessitates a higher safety factor. In addition, there is a K_{It} term for the thermal stress. The additional inputs used to calculate K_{It} are:

Coolant heatup/cooldown rate, normally 100°F/hr	G = 100 °F/hr
Minimum vessel thickness, including clad thickness	C = 0.526 ft (6.313 inches)
Thermal diffusivity at 550°F (most conservative value)	β = 0.354 ft^2/ hr [21]

Equation 4-15 can be solved for the through-wall temperature (x = C), resulting in the absolute value of ΔT for heatup or cooldown of:

$$\Delta T = GC^2 / 2\beta \qquad (4\text{-}16)$$
$$= 100 \cdot (0.526)^2 / (2 \cdot 0.354) = 39°F$$

The analyzed case for thermal stress is a 1/4T flaw depth with wall thickness of C. The corresponding value of M_t (=0.2916) can be interpolated from ASME Appendix G, Figure G-2214-2 [6]. Thus the thermal stress intensity factor, $K_{It} = M_t \cdot \Delta T = 11.42$, can be calculated. K_{Im} has the same value as that calculated in Section 4.3.2.2.2.

The pressure and thermal stress terms are substituted into Equation 4-9 to solve for $(T - RT_{NDT})$:

$$(T - RT_{NDT}) = \ln[((2 \cdot K_{Im} + K_{It}) - 33.2) / 20.734] / 0.2 \qquad (4\text{-}17)$$
$$= \ln[(2 \cdot 52.9 + 11.42 - 33.2) / 20.734] / 0.02$$
$$= 70\ °F$$

T can be calculated by adding the adjusted RT_{NDT}:

$T = 70 + 86 = 156\ °F$ for P = 1105 psig

4.3.2.3 CLOSURE FLANGE REGION

10CFR50 Appendix G [8] sets several minimum requirements for pressure and temperature in addition to those outlined in the ASME Code, based on the closure flange region RT_{NDT}. In some cases, the results of analysis for other regions exceed these requirements and closure flange limits do not affect the shape of the P-T curves. However, some closure flange requirements do impact the curves, as is true with Peach Bottom Unit 3 at low pressures.

The approach used for Peach Bottom Unit 3 for the bolt-up temperature was based on a conservative value of (RT_{NDT} + 60), or the LST of the bolting materials, whichever is greater. The 60°F adder is included by GE for two reasons: 1) the pre-1971 requirements of the ASME Code Section III, Subsection NA, Appendix G included the

60°F adder, and 2) inclusion of the additional 60°F requirement above the RT_{NDT} provides the additional assurance that a flaw size between 0.1 and 0.24 inches is acceptable. As shown in Tables 4-1 and 4-3, the limiting initial RT_{NDT} for the closure flange region is represented by both the top head and vessel shell flange materials at 10°F, and the LST of the closure studs is 70°F; therefore, the bolt-up temperature value used is 70°F. This conservatism is appropriate because bolt-up is one of the more limiting operating conditions (high stress and low temperature) for brittle fracture.

10CFR50 Appendix G, paragraph IV.A.2 [8] including Table 1, sets minimum temperature requirements for pressure above 20% hydrotest pressure based on the RT_{NDT} of the closure region. Curve A temperature must be no less than (RT_{NDT} + 90°F) and Curve B temperature no less than (RT_{NDT} + 120°F).

For pressures below 20% of preservice hydrostatic test pressure (312 psig) and with full bolt preload, the closure flange region metal temperature is required to be at RT_{NDT} or greater as described above. At low pressure, the ASME Code [6] allows the bottom head regions to experience even lower metal temperatures than the flange region RT_{NDT}. However, temperatures should not be permitted to be lower than 68°F for the reason discussed below.

The shutdown margin, provided in the Peach Bottom Unit 3 Technical Specification, is calculated for a water temperature of 68°F. Shutdown margin is the quantity of reactivity needed for a reactor core to reach criticality with the strongest-worth control rod fully withdrawn and all other control rods fully inserted. Although it may be possible to safely allow the water temperature to fall below this 68°F limit, further extensive calculations would be required to justify a lower temperature. The 70°F limit for the upper vessel and beltline region and the 68°F limit for the bottom head curve apply when the head is on and tensioned and when the head is off while fuel is in the vessel. When the head is not tensioned and fuel is not in the vessel, the requirements of 10CFR50 Appendix G [8] do not apply, and there are no limits on the vessel temperatures.

4.3.2.4 CORE CRITICAL OPERATION REQUIREMENTS OF 10CFR50, APPENDIX G

Curve C, the core critical operation curve, is generated from the requirements of 10CFR50 Appendix G [8], Table 1. Table 1 of [8] requires that core critical P-T limits be 40°F above any Curve A or B limits when pressure exceeds 20% of the pre-service system hydrotest pressure. Curve B is more limiting than Curve A, so limiting Curve C values are at least Curve B plus 40°F for pressures above 312 psig.

Table 1 of 10CFR50 Appendix G [8] indicates that for a BWR with water level within normal range for power operation, the allowed temperature for initial criticality at the closure flange region is (RT_{NDT} + 60°F) at pressures below 312 psig. This requirement makes the minimum criticality temperature 70°F, based on an RT_{NDT} of 10°F. In addition, above 312 psig the Curve C temperature must be at least the greater of RT_{NDT} of the closure region + 160°F or the temperature required for the hydrostatic pressure test (Curve A at 1140 psig). The requirement of closure region RT_{NDT} + 160°F does cause a temperature shift in Curve C at 312 psig.

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SECTION 6.0

6.0 REFERENCES

1. T. A. Caine, "Peach Bottom Atomic Power Station, Unit 3 Vessel Surveillance Materials Testing and Fracture Toughness Analysis," GE-NE, San Jose, CA, July 1995, (SASR 90-50, Revision 1).

2. GE Drawing Number 729E762, "Reactor Vessel Thermal Cycles," GE-APED, San Jose, CA, Revision 0. Peach Bottom Units 2 and 3 RPV Thermal Cycle Diagram (GE Proprietary).

3. GE Drawing Number 135B9990, "Nozzle Thermal Cycles," GE-APED, San Jose, CA, Revision 1. Peach Bottom Units 2 and 3 Nozzle Thermal Cycle Diagram (GE Proprietary).

4. "Alternative Reference Fracture Toughness for Development of P-T Limit Curves Section XI, Division 1," Code Case N-640 of the ASME Boiler & Pressure Vessel Code, Approval Date February 26, 1999

5. "Alternative to Reference Flaw Orientation of Appendix G for Circumferential Welds in Reactor Vessels Section XI, Division 1," Code Case N-588 of the ASME Boiler & Pressure Vessel Code, Approval Date December 12, 1997. (Note this reference is not used in this report because the girth welds are not limiting).

6. "Fracture Toughness Criteria for Protection Against Failure," Appendix G to Section III or XI of the ASME Boiler & Pressure Vessel Code, 1995 Edition with addenda through 1996.

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

8. "Fracture Toughness Requirements," Appendix G to Part 50 of Title 10 of the Code of Federal Regulations, December 1995.

9. Hodge, J. M., "Properties of Heavy Section Nuclear Reactor Steels," Welding Research Council Bulletin 217, July 1976.

10. GE Nuclear Energy, NEDC-32399-P, "Basis for GE RT_{NDT} Estimation Method," Report for BWR Owners' Group, San Jose, California, September 1994 (GE Proprietary).

11. Letter from B. Sheron to R.A. Pinelli,"Safety Assessment of Report NEDC-32399-P, Basis for GE RT_{NDT} Estimation Method, September 1994, " USNRC, December 16, 1994.

12. QA Records & RPV CMTR's and Purchase Specification:

    12.1. Peach Bottom Unit 3 – A Nuclear Vessel Fabricated by One Manufacturer for Another Manufacturer initiated by Babcock and Wilcox (B&W) and completed by BVI Nuclear (CBIN) - (QA Records & RPV CMTR's Peach Bottom Unit 3 GE PO# 205-B1156, Manufactured by B&W and GE PO#205-H4641, Manufactured by CBIN), B&W Contract No. 610-0146-51 and CBI Contract No. 69-5128.

    12.2. GE Document #21A1111, Rev. 9, "Purchase Specification for the Reactor Pressure Vessel," GE-APED, San Jose, CA.

13. a). Letter GL 92-01, Rev.1, Supp. 1 From Garrett D. Edwards, Director-Licensing,To U.S. Nuclear Regulatory Commission, Attn: Document Control Desk, "Peach Bottom Atomic Power Station, Units 2 and 3 Response to Request for Additional Information Concerning Generic Letter 92-01, Revision 1, Supplement 1, "Reactor Vessel Structural Integrity", Dated November 24, 1998

    b). Nuclear Regulatory Commission Letter From Bartholomew C. Buckley, Sr. Project manager, Section 2, Office of Nuclear Reactor Regulation, to James A. Hutton, Director-Licensing, PECO Energy Company, "Closure of TAC Nos MA1203 and MA1204 – Response to the Request for Additional Information to Generic Letter 92-01, Revision 1, Supplement 1, Reactor Vessel Structural Integrity" for Peach Bottom Atomic Power Station, Units 2 and 3.

14. Wu, Tang, "Limerick /Peach Bottom Neutron Flux Evaluation," GE-NE, San Jose, CA, May 2001, (GE-NE-B11-00842-00-01, Rev. 0).

15. "PVRC Recommendations on Toughness Requirements for Ferritic Materials," Welding Research Council Bulletin 175, August 1972.

17. "Analysis of Flaws," Appendix A to Section XI of the ASME Boiler & Pressure Vessel Code, 1995 Edition with addenda through 1996.

19. Bottom Head and Feedwater Nozzle Dimensions:

    19.1. "Lower Hd Bottom Segment Assembly for Peach Bottom III Nuclear Reactor Vessel", Chicago Bridge & Iron Co., Drawing No. 4, Rev. 11, (GE VPF # 2753-5-9)

    19.2. "Exhibit A Fabrication Report Summary Stress Report for Peach Bottom III R.P.V. P.O 205-H4641, Contract 69-5128," GE PO# 205-B1156, Manufactured by B&W and GE PO#205-H4641, Manufactured by CBIN, B&W Contract No. 610-0146-51 and CBI Contract No. 69-5128, (GE VPF # 2753-133-1), Sheet A-1 for the Bottom Head and A-28 for the Feedwater Nozzle.

21. "Materials - Properties," Part D to Section II of the ASME Boiler & Pressure Vessel Code, 1995 Edition with Addenda through 1996.

22. GE VPF # 2752-124-1, "CB&I Heat No's. & Seam Identification for Peach Bottom III Nuclear Reactor Vessel," Chicago Bridge & Iron Company, (CB&I Contract No 69-5128 Drawing #R1, Rev. 6)

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"PRESSURE-TEMPERATURE CURVES FOR EXELON, PEACH BOTTOM UNIT 3"
TABLE B-1

TABLE B-1. Peach Bottom Unit 3 P-T Curve Values for 32 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-1, 5-2, 5-3, 5-5, 5-6, AND 5-7

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	32 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	32 EFPY BELTLINE CURVE B (°F)
0	68.0	70.0	70.0	68.0	70.0	70.0
10	68.0	70.0	70.0	68.0	70.0	70.0
20	68.0	70.0	70.0	68.0	70.0	70.0
30	68.0	70.0	70.0	68.0	70.0	70.0
40	68.0	70.0	70.0	68.0	70.0	70.0
50	68.0	70.0	70.0	68.0	70.0	70.0
60	68.0	70.0	70.0	68.0	70.0	70.0
70	68.0	70.0	70.0	68.0	70.0	70.0
80	68.0	70.0	70.0	68.0	70.0	70.0
90	68.0	70.0	70.0	68.0	70.0	70.0
100	68.0	70.0	70.0	68.0	70.0	70.0
110	68.0	70.0	70.0	68.0	70.9	70.0
120	68.0	70.0	70.0	68.0	74.7	70.0
130	68.0	70.0	70.0	68.0	78.2	70.0
140	68.0	70.0	70.0	68.0	81.4	70.0
150	68.0	70.0	70.0	68.0	84.2	70.0
160	68.0	70.0	70.0	68.0	86.9	70.0
170	68.0	70.0	70.0	68.0	89.5	70.0
180	68.0	70.0	70.0	68.0	91.9	70.0
190	68.0	70.0	70.0	68.0	94.2	70.0
200	68.0	70.0	70.0	68.0	96.3	70.0
210	68.0	70.0	70.0	68.0	98.3	70.0
220	68.0	70.0	70.0	68.0	100.3	70.0
230	68.0	70.0	70.0	68.0	102.1	70.0
240	68.0	70.0	70.0	68.0	103.9	70.0
250	68.0	70.0	70.0	68.0	105.6	70.0
260	68.0	70.0	70.0	68.0	107.2	70.0
270	68.0	70.0	70.0	68.0	108.8	70.0

TABLE B-1. Peach Bottom Unit 3 P-T Curve Values for 32 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-1, 5-2, 5-3, 5-5, 5-6, AND 5-7

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	32 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	32 EFPY BELTLINE CURVE B (°F)
280	68.0	70.0	70.0	68.0	110.3	70.0
290	68.0	70.0	70.0	68.0	111.8	70.0
300	68.0	70.0	70.0	68.0	113.2	70.0
310	68.0	70.0	70.0	68.0	114.5	70.0
312.5	68.0	70.0	70.0	68.0	114.9	70.0
312.5	68.0	100.0	100.0	68.0	130.0	130.0
320	68.0	100.0	100.0	68.0	130.0	130.0
330	68.0	100.0	100.0	68.0	130.0	130.0
340	68.0	100.0	100.0	68.0	130.0	130.0
350	68.0	100.0	100.0	68.0	130.0	130.0
360	68.0	100.0	100.0	68.0	130.0	130.0
370	68.0	100.0	100.0	68.0	130.0	130.0
380	68.0	100.0	100.0	68.0	130.0	130.0
390	68.0	100.0	100.0	68.0	130.0	130.0
400	68.0	100.0	100.0	68.0	130.0	130.0
410	68.0	100.0	100.0	68.0	130.0	130.0
420	68.0	100.0	100.0	68.0	130.0	130.0
430	68.0	100.0	100.0	68.0	130.0	130.0
440	68.0	100.0	100.0	68.0	130.0	130.0
450	68.0	100.0	100.0	68.0	130.1	130.0
460	68.0	100.0	100.0	68.0	131.1	130.0
470	68.0	100.0	100.0	68.0	132.0	130.0
480	68.0	100.0	100.0	68.0	132.9	130.0
490	68.0	100.0	100.0	68.0	133.7	130.0
500	68.0	100.0	100.0	68.0	134.6	130.0
510	68.0	100.0	100.0	68.0	135.4	130.0
520	68.0	100.0	100.0	68.2	136.2	130.0
530	68.0	100.0	100.0	70.2	137.0	130.0
540	68.0	100.0	100.0	72.1	137.8	130.0
550	68.0	100.0	100.0	73.9	138.6	130.0
560	68.0	100.0	100.0	75.7	139.4	130.0

TABLE B-1. Peach Bottom Unit 3 P-T Curve Values for 32 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-1, 5-2, 5-3, 5-5, 5-6, AND 5-7

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	32 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	32 EFPY BELTLINE CURVE B (°F)
570	68.0	100.0	100.0	77.4	140.1	130.0
580	68.0	100.0	100.0	79.0	140.9	130.0
590	68.0	100.0	100.0	80.6	141.6	130.0
600	68.0	100.0	100.0	82.2	142.1	130.0
610	68.0	100.0	100.0	83.7	142.6	130.0
620	68.0	100.0	100.0	85.1	143.0	130.0
630	68.0	100.0	100.0	86.5	143.4	130.0
640	68.0	100.0	100.0	87.9	143.8	130.0
650	68.0	100.0	100.0	89.2	144.2	130.0
660	68.0	100.0	100.0	90.5	144.7	130.0
670	68.0	100.9	100.0	91.8	145.1	130.0
680	68.0	101.9	100.0	93.1	145.5	130.0
690	68.0	102.8	100.0	94.3	145.9	130.0
700	69.2	103.7	100.0	95.4	146.3	130.0
710	70.7	104.6	100.0	96.6	146.7	130.0
720	72.1	105.4	100.0	97.7	147.1	130.0
730	73.5	106.3	100.0	98.8	147.5	130.0
740	74.8	107.1	100.0	99.9	147.9	130.0
750	76.1	108.0	100.0	101.0	148.2	130.9
760	77.4	108.8	100.0	102.0	148.6	131.8
770	78.6	109.6	100.0	103.0	149.0	132.7
780	79.8	110.3	100.0	104.0	149.4	133.6
790	81.0	111.1	100.0	105.0	149.8	134.4
800	82.2	111.9	100.0	105.9	150.1	135.3
810	83.3	112.6	100.7	106.9	150.5	136.1
820	84.4	113.4	101.9	107.8	150.9	136.9
830	85.5	114.1	103.1	108.7	151.2	137.8
840	86.5	114.8	104.3	109.6	151.6	138.6
850	87.6	115.5	105.5	110.4	151.9	139.3
860	88.6	116.2	106.6	111.3	152.3	140.1
870	89.6	116.9	107.7	112.1	152.6	140.9

TABLE B-1. Peach Bottom Unit 3 P-T Curve Values for 32 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-1, 5-2, 5-3, 5-5, 5-6, AND 5-7

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	32 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	32 EFPY BELTLINE CURVE B (°F)
880	90.5	117.6	108.8	113.0	153.0	141.6
890	91.5	118.3	109.9	113.8	153.3	142.4
900	92.4	118.9	110.9	114.6	153.7	143.1
910	93.4	119.6	112.0	115.4	154.0	143.8
920	94.3	120.2	113.0	116.1	154.4	144.5
930	95.1	120.9	113.9	116.9	154.7	145.2
940	96.0	121.5	114.9	117.7	155.0	145.9
950	96.9	122.1	115.9	118.4	155.4	146.6
960	97.7	122.7	116.8	119.1	155.7	147.3
970	98.6	123.3	117.7	119.9	156.0	147.9
980	99.4	123.9	118.6	120.6	156.4	148.6
990	100.2	124.5	119.5	121.3	156.7	149.2
1000	101.0	125.1	120.3	122.0	157.0	149.8
1010	101.7	125.7	121.2	122.6	157.3	150.5
1020	102.5	126.2	122.0	123.3	157.6	151.1
1030	103.3	126.8	122.8	124.0	158.0	151.7
1040	104.0	127.4	123.6	124.6	158.3	152.3
1050	104.7	127.9	124.4	125.3	158.6	152.9
1060	105.4	128.5	125.2	125.9	158.9	153.5
1070	106.2	129.0	126.0	126.5	159.2	154.1
1080	106.9	129.5	126.7	127.2	159.5	154.7
1090	107.6	130.1	127.5	127.8	159.8	155.2
1100	108.2	130.6	128.2	128.4	160.1	155.8
1105	108.6	130.8	128.6	128.7	160.3	156.1
1110	108.9	131.1	128.9	129.0	160.4	156.3
1120	109.6	131.6	129.7	129.6	160.7	156.9
1130	110.2	132.1	130.4	130.2	161.0	157.4
1140	110.9	132.6	131.1	130.7	161.3	158.0
1150	111.5	133.1	131.7	131.3	161.6	158.5
1160	112.1	133.6	132.4	131.9	161.9	159.0
1170	112.8	134.1	133.1	132.4	162.2	159.6

TABLE B-1. Peach Bottom Unit 3 P-T Curve Values for 32 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-1, 5-2, 5-3, 5-5, 5-6, AND 5-7

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	32 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	32 EFPY BELTLINE CURVE B (°F)
1180	113.4	134.6	133.7	133.0	162.5	160.1
1190	114.0	135.1	134.4	133.5	162.7	160.6
1200	114.6	135.5	135.0	134.1	163.0	161.1
1210	115.2	136.0	135.7	134.6	163.3	161.6
1220	115.8	136.5	136.3	135.2	163.6	162.1
1230	116.3	136.9	136.9	135.7	163.9	162.6
1240	116.9	137.4	137.5	136.2	164.2	163.1
1250	117.5	137.8	138.1	136.7	164.4	163.6
1260	118.0	138.3	138.7	137.2	164.7	164.0
1270	118.6	138.7	139.3	137.7	165.0	164.5
1280	119.1	139.2	139.9	138.2	165.2	165.0
1290	119.7	139.6	140.5	138.7	165.5	165.5
1300	120.2	140.0	141.0	139.2	165.8	165.9
1310	120.7	140.5	141.6	139.7	166.1	166.4
1320	121.3	140.9	142.1	140.2	166.3	166.8
1330	121.8	141.3	142.7	140.6	166.6	167.3
1340	122.3	141.7	143.2	141.1	166.8	167.7
1350	122.8	142.1	143.8	141.6	167.1	168.2
1360	123.3	142.6	144.3	142.0	167.4	168.6
1370	123.8	143.0	144.8	142.5	167.6	169.0
1380	124.3	143.4	145.4	142.9	167.9	169.4
1390	124.8	143.8	145.9	143.4	168.1	169.9
1400	125.3	144.2	146.4	143.8	168.4	170.3

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TABLE B-2

TABLE B-2. Peach Bottom Unit 3 Composite P-T Curve Values for 32 EFPY
Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-10, 5-11, AND 5-12

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE B (°F)	NON-BELTLINE AND BELTLINE AT 32 EFPY CURVE C (°F)
0	68.0	70.0	68.0	70.0	70.0
10	68.0	70.0	68.0	70.0	70.0
20	68.0	70.0	68.0	70.0	70.0
30	68.0	70.0	68.0	70.0	70.0
40	68.0	70.0	68.0	70.0	70.0
50	68.0	70.0	68.0	70.0	75.1
60	68.0	70.0	68.0	70.0	84.0
70	68.0	70.0	68.0	70.0	91.2
80	68.0	70.0	68.0	70.0	97.2
90	68.0	70.0	68.0	70.0	102.3
100	68.0	70.0	68.0	70.0	106.8
110	68.0	70.0	68.0	70.9	110.9
120	68.0	70.0	68.0	74.7	114.7
130	68.0	70.0	68.0	78.2	118.2
140	68.0	70.0	68.0	81.4	121.4
150	68.0	70.0	68.0	84.2	124.2
160	68.0	70.0	68.0	86.9	126.9
170	68.0	70.0	68.0	89.5	129.5
180	68.0	70.0	68.0	91.9	131.9
190	68.0	70.0	68.0	94.2	134.2
200	68.0	70.0	68.0	96.3	136.3
210	68.0	70.0	68.0	98.3	138.3
220	68.0	70.0	68.0	100.3	140.3
230	68.0	70.0	68.0	102.1	142.1
240	68.0	70.0	68.0	103.9	143.9
250	68.0	70.0	68.0	105.6	145.6
260	68.0	70.0	68.0	107.2	147.2
270	68.0	70.0	68.0	108.8	148.8

TABLE B-2. Peach Bottom Unit 3 Composite P-T Curve Values for 32 EFPY
Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-10, 5-11, AND 5-12

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE B (°F)	NON-BELTLINE AND BELTLINE AT 32 EFPY CURVE C (°F)
280	68.0	70.0	68.0	110.3	150.3
290	68.0	70.0	68.0	111.8	151.8
300	68.0	70.0	68.0	113.2	153.2
310	68.0	70.0	68.0	114.5	154.5
312.5	68.0	70.0	68.0	114.9	154.9
312.5	68.0	100.0	68.0	130.0	170.0
320	68.0	100.0	68.0	130.0	170.0
330	68.0	100.0	68.0	130.0	170.0
340	68.0	100.0	68.0	130.0	170.0
350	68.0	100.0	68.0	130.0	170.0
360	68.0	100.0	68.0	130.0	170.0
370	68.0	100.0	68.0	130.0	170.0
380	68.0	100.0	68.0	130.0	170.0
390	68.0	100.0	68.0	130.0	170.0
400	68.0	100.0	68.0	130.0	170.0
410	68.0	100.0	68.0	130.0	170.0
420	68.0	100.0	68.0	130.0	170.0
430	68.0	100.0	68.0	130.0	170.0
440	68.0	100.0	68.0	130.0	170.0
450	68.0	100.0	68.0	130.1	170.1
460	68.0	100.0	68.0	131.1	171.1
470	68.0	100.0	68.0	132.0	172.0
480	68.0	100.0	68.0	132.9	172.9
490	68.0	100.0	68.0	133.7	173.7
500	68.0	100.0	68.0	134.6	174.6
510	68.0	100.0	68.0	135.4	175.4
520	68.0	100.0	68.2	136.2	176.2
530	68.0	100.0	70.2	137.0	177.0
540	68.0	100.0	72.1	137.8	177.8
550	68.0	100.0	73.9	138.6	178.6

TABLE B-2. Peach Bottom Unit 3 Composite P-T Curve Values for 32 EFPY
Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-10, 5-11, AND 5-12

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE B (°F)	NON-BELTLINE AND BELTLINE AT 32 EFPY CURVE C (°F)
560	68.0	100.0	75.7	139.4	179.4
570	68.0	100.0	77.4	140.1	180.1
580	68.0	100.0	79.0	140.9	180.9
590	68.0	100.0	80.6	141.6	181.6
600	68.0	100.0	82.2	142.1	182.1
610	68.0	100.0	83.7	142.6	182.6
620	68.0	100.0	85.1	143.0	183.0
630	68.0	100.0	86.5	143.4	183.4
640	68.0	100.0	87.9	143.8	183.8
650	68.0	100.0	89.2	144.2	184.2
660	68.0	100.0	90.5	144.7	184.7
670	68.0	100.9	91.8	145.1	185.1
680	68.0	101.9	93.1	145.5	185.5
690	68.0	102.8	94.3	145.9	185.9
700	69.2	103.7	95.4	146.3	186.3
710	70.7	104.6	96.6	146.7	186.7
720	72.1	105.4	97.7	147.1	187.1
730	73.5	106.3	98.8	147.5	187.5
740	74.8	107.1	99.9	147.9	187.9
750	76.1	108.0	101.0	148.2	188.2
760	77.4	108.8	102.0	148.6	188.6
770	78.6	109.6	103.0	149.0	189.0
780	79.8	110.3	104.0	149.4	189.4
790	81.0	111.1	105.0	149.8	189.8
800	82.2	111.9	105.9	150.1	190.1
810	83.3	112.6	106.9	150.5	190.5
820	84.4	113.4	107.8	150.9	190.9
830	85.5	114.1	108.7	151.2	191.2
840	86.5	114.8	109.6	151.6	191.6
850	87.6	115.5	110.4	151.9	191.9

TABLE B-2. Peach Bottom Unit 3 Composite P-T Curve Values for 32 EFPY
Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-10, 5-11, AND 5-12

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE B (°F)	NON-BELTLINE AND BELTLINE AT 32 EFPY CURVE C (°F)
860	88.6	116.2	111.3	152.3	192.3
870	89.6	116.9	112.1	152.6	192.6
880	90.5	117.6	113.0	153.0	193.0
890	91.5	118.3	113.8	153.3	193.3
900	92.4	118.9	114.6	153.7	193.7
910	93.4	119.6	115.4	154.0	194.0
920	94.3	120.2	116.1	154.4	194.4
930	95.1	120.9	116.9	154.7	194.7
940	96.0	121.5	117.7	155.0	195.0
950	96.9	122.1	118.4	155.4	195.4
960	97.7	122.7	119.1	155.7	195.7
970	98.6	123.3	119.9	156.0	196.0
980	99.4	123.9	120.6	156.4	196.4
990	100.2	124.5	121.3	156.7	196.7
1000	101.0	125.1	122.0	157.0	197.0
1010	101.7	125.7	122.6	157.3	197.3
1020	102.5	126.2	123.3	157.6	197.6
1030	103.3	126.8	124.0	158.0	198.0
1040	104.0	127.4	124.6	158.3	198.3
1050	104.7	127.9	125.3	158.6	198.6
1060	105.4	128.5	125.9	158.9	198.9
1070	106.2	129.0	126.5	159.2	199.2
1080	106.9	129.5	127.2	159.5	199.5
1090	107.6	130.1	127.8	159.8	199.8
1100	108.2	130.6	128.4	160.1	200.1
1105	108.6	130.8	128.7	160.3	200.3
1110	108.9	131.1	129.0	160.4	200.4
1120	109.6	131.6	129.6	160.7	200.7
1130	110.2	132.1	130.2	161.0	201.0
1140	110.9	132.6	130.7	161.3	201.3

TABLE B-2. Peach Bottom Unit 3 Composite P-T Curve Values for 32 EFPY
Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A

FOR FIGURES 5-10, 5-11, AND 5-12

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 32 EFPY CURVE B (°F)	NON-BELTLINE AND BELTLINE AT 32 EFPY CURVE C (°F)
1150	111.5	133.1	131.3	161.6	201.6
1160	112.1	133.6	131.9	161.9	201.9
1170	112.8	134.1	132.4	162.2	202.2
1180	113.4	134.6	133.0	162.5	202.5
1190	114.0	135.1	133.5	162.7	202.7
1200	114.6	135.5	134.1	163.0	203.0
1210	115.2	136.0	134.6	163.3	203.3
1220	115.8	136.5	135.2	163.6	203.6
1230	116.3	136.9	135.7	163.9	203.9
1240	116.9	137.5	136.2	164.2	204.2
1250	117.5	138.1	136.7	164.4	204.4
1260	118.0	138.7	137.2	164.7	204.7
1270	118.6	139.3	137.7	165.0	205.0
1280	119.1	139.9	138.2	165.2	205.2
1290	119.7	140.5	138.7	165.5	205.5
1300	120.2	141.0	139.2	165.9	205.9
1310	120.7	141.6	139.7	166.4	206.4
1320	121.3	142.1	140.2	166.8	206.8
1330	121.8	142.7	140.6	167.3	207.3
1340	122.3	143.2	141.1	167.7	207.7
1350	122.8	143.8	141.6	168.2	208.2
1360	123.3	144.3	142.0	168.6	208.6
1370	123.8	144.8	142.5	169.0	209.0
1380	124.3	145.4	142.9	169.4	209.4
1390	124.8	145.9	143.4	169.9	209.9
1400	125.3	146.4	143.8	170.3	210.3