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Pressure-Temperature Curves
For
Exelon
Dresden Unit 3

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REPORT REVISION STATUS

Revision	Purpose
0	Initial Issue
1	The report was revised to eliminate conservatism in the upper vessel P-T curve. The required shift for this curve was reduced from 44°F to 40°F. Text was changed in Sections 4.3.2.1.3, 4.3.2.1.4, and 5.0. Figures 5-2, 5-6, and 5-9 through 5-14 were revised. Table A-1 in Appendix A was revised. The Appendix B tables were revised.
2	• Proprietary notations have been updated to meet current requirements. • Revision bars have been provided in the right margin of each paragraph denoting change from the previous report. • Discussion regarding a comparison of calculated flux vs. dosimetry results has been deleted from Section 4.2.1.2. • The description of the transients considered in Section 4.3.2.1 has been revised. • Section 4.3.2.1.2 has been revised to reflect a new analysis defining the CRD Penetration (Bottom Head) Core Not Critical P-T Curve; Appendix F provides a detailed discussion of the subject analysis and conclusions. • A clarifying statement has been added to Section 4.3.2.2.4 regarding the use of K_{It} in the Beltline Core Not Critical P-T curves. • Reference 14b has been deleted; all required information from this reference is contained in Reference 14a. Reference 14c has been renumbered to Reference 14b. • Reference 22 has been deleted and replaced with the NRC Safety Evaluation for the Dresden P-T curve reports. • Reference 6 of Appendix E has been deleted; all required information from this reference is contained in Reference 5. • Appendix F has been deleted and replaced with a discussion regarding the CRD (Bottom Head) Core Not Critical evaluation. • Section 5.0 Figures 5-5, 5-12 and 5-14, Appendix G Figures G-5, G-12, and G-14 and all Appendix B and Appendix G Tables have been revised to incorporate changes to the CRD Penetration (Bottom Head) Core Not Critical P-T curves, as defined in Section 4.3.2.1.2 and Appendix F.

IMPORTANT NOTICE

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EXECUTIVE SUMMARY

This report provides the pressure-temperature curves (P-T curves) developed to present steam dome pressure versus minimum vessel metal temperature incorporating appropriate non-beltline limits and irradiation embrittlement effects in the beltline. The methodology used to generate the P-T curves in this report is similar to the methodology used to generate the P-T curves in 2000 [1]; the P-T curves in this report represent 32 and 54 EFPY as determined for a 40- and 60-year life. The P-T curve methodology includes the following: 1) the incorporation of ASME Code Cases N-640 and N-588, and 2) the use of the M_m calculation in the ASME Code paragraph G-2214.1 for a postulated defect normal to the direction of maximum stress. ASME Code Case N-640 allows the use of K_{IC} of Figure A-4200-1 of Appendix A in lieu of Figure G-2210-1 in Appendix G to determine T-RT_{NDT}. ASME Code Case N-588 allows the use of an alternative procedure for calculating the applied stress intensity factors of Appendix G for axial and circumferential welds. This report incorporates a fluence [14a] calculated in accordance with the GE Licensing Topical Report NEDC-32983P, which has been approved by the NRC in a SER [14b], and is in compliance with Regulatory Guide 1.190. Additional detail regarding P-T curve methodology has been submitted in response to NRC questions, and was accepted in the Safety Evaluation for the Dresden Units 2 & 3 P-T curves [22].

CONCLUSIONS

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)

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 this report. 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 apply for both heatup and cooldown and for both the 1/4T and 3/4T locations because the maximum tensile stress for either heatup or cooldown is applied at the 1/4T location. For beltline curves this approach has added conservatism 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.

Composite P-T curves were generated for each of the Pressure Test, Core Not Critical and Core Critical conditions at 32 and 54 effective full power years (EFPY). The composite curves were generated by enveloping the most restrictive P-T limits from the separate bottom head, beltline, upper vessel and closure assembly P-T limits. Separate P-T curves were developed for the upper vessel, beltline (at 32 and 54 EFPY), and bottom head for the Pressure Test and Core Not Critical conditions.

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1.0 INTRODUCTION

The pressure-temperature (P-T) curves included in this report have been developed to present steam dome pressure versus minimum vessel metal temperature incorporating appropriate non-beltline limits and irradiation embrittlement effects in the beltline. Complete P-T curves were developed for 32 and 54 effective full power years (EFPY). The P-T curves are provided in Section 5.0 and a tabulation of the curves is included in Appendix B. This report incorporates a fluence [14a] calculated in accordance with the GE Licensing Topical Report NEDC-32983P, which has been approved by the NRC in a SER [14b], and is in compliance with Regulatory Guide 1.190.

The methodology used to generate the P-T curves in this report is presented in Section 4.3 and is similar to the methodology used to generate the P-T curves in 2000 [1]. The P-T curve methodology includes the following: 1) the incorporation of ASME Code Cases N-640 [4] and N-588 [5], and 2) the use of the M_m calculation in the ASME Code paragraph G-2214.1 [6] for a postulated defect normal to the direction of maximum stress. ASME Code Case N-640 allows the use of K_{IC} of Figure A-4200-1 of Appendix A in lieu of Figure G-2210-1 in Appendix G to determine T-RT_{NDT}. ASME Code Case N-588 allows the use of an alternative procedure for calculating the applied stress intensity factors of Appendix G for axial and circumferential welds. P-T curves are developed using geometry of the RPV shells and discontinuities, the initial RT_{NDT} of the RPV materials, and the adjusted reference temperature (ART) for the beltline materials. Additional detail regarding P-T curve methodology has been submitted in response to NRC questions, and was accepted in the Safety Evaluation for the Dresden Units 2 & 3 P-T curves [22].

The initial RT_{NDT} is the reference temperature for the unirradiated material as defined in Paragraph NB-2331 of Section III of the ASME Boiler and Pressure Vessel Code. The Charpy energy data used to determine the initial RT_{NDT} values are tabulated from the Certified Material Test Report (CMTRs). The data and methodology used to determine initial RT_{NDT} is documented in Section 4.1.

Adjusted Reference Temperature (ART) is the reference temperature when including irradiation shift and a margin term. Regulatory Guide 1.99, Rev. 2 [7] provides the methods for calculating ART. The value of ART is a function of RPV 1/4T fluence and beltline material chemistry. The ART calculation, methodology, and ART tables for 32 and 54 EFPY are included in Section 4.2. The peak ID fluence values of 3.3×10^{17} n/cm^2 (32 EFPY) and 5.7×10^{17} n/cm^2 (54 EFPY) used in this report are discussed in Section 4.2.1.2. Beltline chemistry values are discussed in Section 4.2.1.1.

Comprehensive documentation of the RPV discontinuities that are considered in this report is included in Appendix A. This appendix also includes a table that documents which non-beltline discontinuity curves are used to protect the discontinuities.

Guidelines and requirements for operating and temperature monitoring are included in Appendix C. GE SIL 430, a GE service information letter regarding Reactor Pressure Vessel Temperature Monitoring is included in Appendix D. Appendix E demonstrates that all reactor vessel nozzles are outside the beltline region. Appendix F provides the core not critical calculation for the bottom head (CRD Penetration). Finally, Appendix G provides a set of P-T curves that bound all requirements for both Dresden Unit 2 and Dresden Unit 3.

2.0 SCOPE OF THE ANALYSIS

The methodology used to generate the P-T curves in this report is similar to the methodology used to generate the P-T curves in 2000 [1]. A detailed description of the P-T curve bases is included in Section 4.3. The P-T curve methodology includes the following: 1) the incorporation of ASME Code Cases N-640 and N-588, and 2) the use of the M_m calculation in the ASME Code paragraph G-2214.1 for a postulated defect normal to the direction of maximum stress. ASME Code Case N-640 allows the use of K_{IC} of Figure A-4200-1 of Appendix A in lieu of Figure G-2210-1 in Appendix G to determine T-RT_{NDT}. ASME Code Case N-588 allows the use of an alternative procedure for calculating the applied stress intensity factors to consider attenuation to reference flaw orientation of Appendix G for circumferential welds. This Code Case also provides an alternative procedure for calculating the applied stress intensity factor for axial welds. Other features presented are:

- Generation of separate curves for the upper vessel in addition to those generated for the beltline, and bottom head.
- Comprehensive description of discontinuities used to develop the non-beltline curves (see Appendix A).

The pressure-temperature (P-T) curves are established to the requirements of 10CFR50, Appendix G [8] to assure that brittle fracture of the reactor vessel is prevented. Part of the analysis involved in developing the P-T curves is to account for irradiation embrittlement effects in the core region, or beltline. The method used to account for irradiation embrittlement is described in Regulatory Guide 1.99, Rev. 2 [7].

In addition to beltline considerations, there are non-beltline discontinuity limits such as nozzles, penetrations, and flanges that influence the construction of P-T curves. The non-beltline limits are based on generic analyses that are adjusted to the maximum reference temperature of nil ductility transition (RT_{NDT}) for the applicable Dresden Unit 3 vessel components. The non-beltline limits are discussed in Section 4.3 and are also governed by requirements in [8].

Furthermore, curves are included to allow monitoring of the vessel bottom head and upper vessel regions separate from the beltline region. This refinement could minimize

heating requirements prior to pressure testing. Operating and temperature monitoring requirements are found in Appendix C. Temperature monitoring requirements and methods are available in GE Services Information Letter (SIL) 430 contained in Appendix D. Appendix E demonstrates that all reactor vessel nozzles are outside the beltline region. Appendix F provides the core not critical calculation for the bottom head (CRD Penetration). Finally, Appendix G provides a set of P-T curves that bound all requirements for both Dresden Unit 2 and Dresden Unit 3.

3.0 ANALYSIS ASSUMPTIONS

The following assumptions are made for this analysis:

For end-of-license (54 EFPY) fluence a mixed capacity factor is used to determine the EFPY for a 60-year plant life. An 80% capacity factor is based on the objective to have BWR's available for full power production 80% of the year (refueling outages, etc. ~20% of the year).

For a 60-year license an 80% capacity factor is assumed for up to 19.8 EFPY and to consider recent improvements in plant operation, a 97.5% capacity factor is used beginning at 19.8 EFPY; hence 54 EFPY is assumed to represent 60 years of operation.

The hydrostatic pressure test will be conducted at or below 1105.5 psig.

The shutdown margin, provided in the Dresden Unit 3 Technical Specification, is calculated for a water temperature of 68°F.

The flux is calculated using a pre-EPU and a post-EPU flux [14], both calculated in accordance with Regulatory Guide 1.190. The pre-EPU flux is applied for 19.8 EFPY and the post-EPU flux is applied for 12.2 EFPY and 34.2 EFPY for 32 and 54 EFPY, respectively.

4.0 ANALYSIS

4.1 INITIAL REFERENCE TEMPERATURE

4.1.1 Background

The initial RT_{NDT} values for all low alloy steel vessel components are needed to develop the vessel P-T limits. The requirements for establishing the vessel component toughness prior to 1972 were per the ASME Code Section III, Subsection NB-2300 and are summarized as follows:

a. Test specimens shall be longitudinally oriented CVN specimens.

b. At the qualification test temperature (specified in the vessel purchase specification), no impact test result shall be less than 25 ft-lb, and the average of three test results shall be at least 30 ft-lb.

c. Pressure tests shall be conducted at a temperature at least 60°F above the qualification test temperature for the vessel materials.

The current requirements used to establish an initial RT_{NDT} value are significantly different. For plants constructed according to the ASME Code after Summer 1972, the requirements per the ASME Code Section III, Subsection NB-2300 are as follows:

a. Test specimens shall be transversely oriented (normal to the rolling direction) CVN specimens.

b. RT_{NDT} is defined as the higher of the dropweight NDT or 60°F below the temperature at which Charpy V-Notch 50 ft-lb energy and 35 mils lateral expansion is met.

c. Bolt-up in preparation for a pressure test or normal operation shall be performed at or above the highest RT_{NDT} of the materials in the closure flange region or lowest service temperature (LST) of the bolting material, whichever is greater.

10CFR50 Appendix G [8] states that for vessels constructed to a version of the ASME Code prior to the Summer 1972 Addendum, fracture toughness data and data analyses must be supplemented in an approved manner. GE developed methods for analytically

converting fracture toughness data for vessels constructed before 1972 to comply with current requirements. These methods were developed from data in WRC Bulletin 217 [9] and from data collected to respond to NRC questions on FSAR submittals in the late 1970s. In 1994, these methods of estimating RT_{NDT} were submitted for generic approval by the BWR Owners' Group [10], and approved by the NRC for generic use [11].

4.1.2 Values of Initial RT_{NDT} and Lowest Service Temperature (LST)

To establish the initial RT_{NDT} temperatures for the Dresden Unit 3 vessel per the current requirements, calculations were performed in accordance with the GE method for determining RT_{NDT}. Example RT_{NDT} calculations for vessel plate, weld, HAZ, and forging, and for bolting material LST are summarized in the remainder of this section.

The RT_{NDT} values for the vessel weld materials were not calculated; these values were obtained from other sources (see Section 4.2, Tables 4-3 and 4-4).

For vessel plate material, the first step in calculating RT_{NDT} is to establish the 50 ft-lb transverse test temperature from longitudinal test specimen data (obtained from certified material test reports, CMTRs [12]). For Dresden Unit 3 CMTRs, typically six energy values were listed at a given test temperature, corresponding to two sets of Charpy tests. The lowest energy Charpy value is adjusted by adding 2°F per ft-lb energy difference from 50 ft-lb.

For example, for the Dresden Unit 3 beltline plate heat C1290-2 in the lower-intermediate shell course, the lowest Charpy energy and test temperature from the CMTRs is 45 ft-lb at 10°F. The estimated 50 ft-lb longitudinal test temperature is:

$$T_{50L} = 10°F + [(50 - 45)\ \text{ft-lb} \cdot 2°F/\text{ft-lb}] = 20°F$$

The transition from longitudinal data to transverse data is made by adding 30°F to the 50 ft-lb longitudinal test temperature; thus, for this case above,

$$T_{50T} = 20°F + 30°F = 50°F$$

The initial RT_{NDT} is the greater of nil-ductility transition temperature (NDT) or (T_{50T}- 60°F). Dropweight testing to establish NDT for plate material is listed in the CMTR; the NDT for the case above is 10°F. Thus, the initial RT_{NDT} for plate heat C1290-2 is 10°F.

For the vessel HAZ material, the RT_{NDT} is assumed to be the same as for the base material, since ASME Code weld procedure qualification test requirements and post-weld heat treat data indicate this assumption is valid.

For vessel forging material, such as nozzles and closure flanges, the method for establishing RT_{NDT} is the same as for vessel plate material. For the feedwater nozzle at Dresden Unit 3 (Heat ZT2885-6), the NDT is 30°F and the lowest CVN data is 32 ft-lb at 40°F (transverse Charpy data). The corresponding value of (T_{50T} – 60°F) is:

$$(T_{50T} - 60°F) = \{[40 + (50 - 32)\ \text{ft-lb} \cdot 3°F/\text{ft-lb}]\} - 60°F = 34°F.$$

Therefore, the initial RT_{NDT} is the greater of nil-ductility transition temperature (NDT) or (T_{50T}- 60°F), which is 34°F.

In the bottom head region of the vessel, the vessel plate method is applied for estimating RT_{NDT}. For the bottom head center heat of Dresden Unit 3 (Heat C1173-2), the NDT is 40°F and the lowest CVN data was 33 ft-lb at 40°F. The corresponding value of (T_{50T} - 60°F) was:

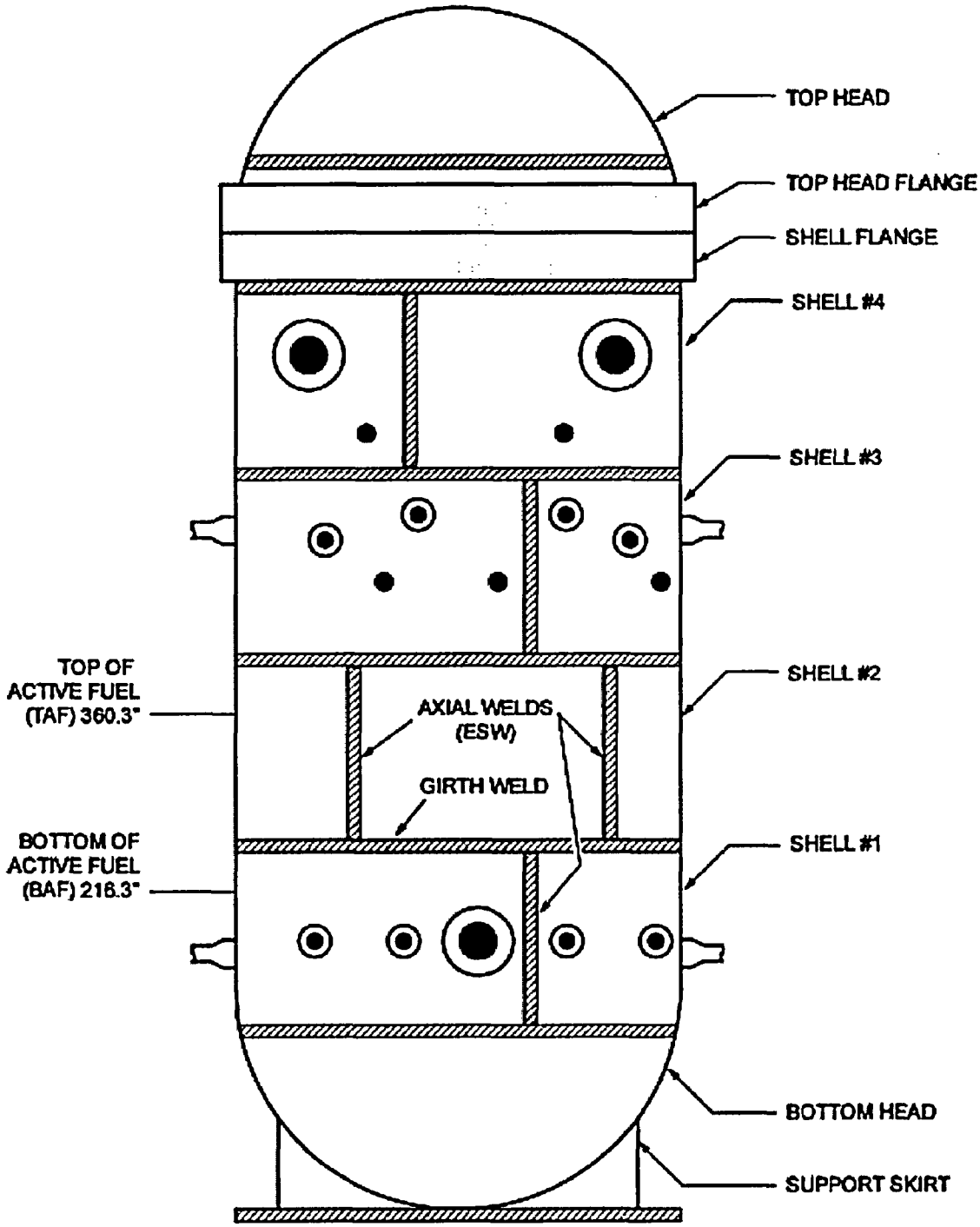
$$(T_{50T} - 60°F) = \{[40 + (50 - 33)\ \text{ft-lb} \cdot 2°F/\text{ft-lb}] + 30°F\} - 60°F = 44°F.$$

Therefore, the initial RT_{NDT} was 44°F.

For bolting material, the current ASME Code requirements define the lowest service temperature (LST) as the temperature at which transverse CVN energy of 45 ft-lb and 25 mils lateral expansion (MLE) were achieved. If the required Charpy results are not met, or are not reported, but the CVN energy reported is above 30 ft-lb, the requirements of the ASME Code Section III, Subsection NB-2300 at construction are applied, namely that the 30 ft-lb test temperature plus 60°F is the LST for the bolting materials. Charpy data for the Dresden Unit 3 closure studs did not all meet the 45 ft-lb, 25 MLE requirements at 10°F. Therefore, the LST for the bolting material is 70°F. The highest RT_{NDT} in the closure flange region is 23.1°F, for the vertical electroslag weld material.

Thus, the higher of the LST and the RT_{NDT} +60°F is 83.1°F, the boltup limit in the closure flange region.

The initial RT_{NDT} values for the Dresden Unit 3 reactor vessel (refer to Figure 4-1 for the Dresden Unit 3 Schematic) materials are listed in Tables 4-1 and 4-2. This tabulation includes beltline, closure flange, feedwater nozzle, and bottom head materials that are considered in generating the P-T curves.



Notes: (1) Refer to Tables 4-1 and 4-2 for reactor vessel components and their heat identifications.
(2) See Appendix E for the definition of the beltline region.

Figure 4-1: Schematic of the Dresden Unit 3 RPV Showing Arrangement of Vessel Plates and Welds

Table 4-1: RT_{NDT} Values for Dresden Unit 3 Vessel Materials

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			(T_{50T}-60) (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
PLATES & FORGINGS:								
Top Head & Flange								
Dollar Plate MK201	C1177-4	40	73	72	74	10	40	40
Top Head Torus MK 202	A0458-2	10	54	60	73	-20	10	10
	C1173-4	10	70	51	74	-20	10	10
	C1177-3	10	54	69	70	-20	10	10
Top Head Flange MK209	5P1127	10	43	75.04	71.92	-6	10	10
MK48	5P1114	10	57	108	106	-20	-10	-10
Shell Courses								
Upper Shell MK60	C1191-1	10	50	43	55	-6	10	10
	C1191-2	10	40	49	52	0	10	10
	B5144-1	10	64	51	62	-20	10	10
Upper Int. Shell MK59	B5144-2	10	65	66	40	0	10	10
	C1516-1	10	39	43	49	2	10	10
	B5159-1	10	83	57	65	-20	10	10
Low-Int. Shell MK58	C1290-2	10	45	60	62	-10	10	10
	A0237-1	10	71	70	59	-20	10	10
	B5118-1	10	66	67	66	-20	10	10
Lower Shell MK57	C1256-2	10	75	70	90	-20	-10	-10
	C1182-2	10	70	61	64	-20	10	10
	B5159-2	10	55	50	65	-20	0	0
Bottom Head								
Dollar Plate MK1	A0284-2	40	54	65	60	10	40	40
Btm Head Torus, Btm Head MK2	A0237-2	40	92	91	109	10	40	40
	C1177-1	40	49	62	74	12	40	40
	C1177-2	40	66	64	83	10	40	40
	C1485-1*							40
Bottom Center, Btm Head MK4	C1173-2	40	49	33	47	44	40	44
	C1173-1	40	41	45	74	28	40	40

*CMTR not available: 40°F RT_{NDT} assumed per purchase specification 21A1109

NOTE: These are minimum Charpy values.

Table 4-2: RT_{NDT} Values for Dresden Unit 3 Nozzle and Weld Materials

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			(T_{50T}-60) (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
NOZZLES								
Recirc. Outlet Nozzle MK8 (Transverse data)	ZT2405-1	40	65	74.5	74.5	-20	40	40
Recirc Inlet Nozzle MK7 (Transverse data)	ZT2405-4	40	72.5	65	84	-20	40	40
	ZT2405-3	40	78.5	64	60.5	-20	40	40
(Longitudinal)	ZT2869	40	31	37.5	39	48	30	48
Steam Outlet Nozzle MK14 (Transverse data)	ZT2405-2	40	52.5	42	49	4	40	40
Feedwater Nozzle MK10 (Transverse data)	ZT2405-5	40	52.5	61.5	70.5	-20	40	40
	ZT2885-6	40	32	34	36.5	34	30	34
Core Spray Nozzle MK11	ZT2869-5	40	39	36	44.5	38	30	38
	ZT2782	40	43	42	34	42	30	42
6" Instrumentation, Vent & CRD HSR Nozzle MK206 & 204 & 13	ZT3043	40	102	130	117	10	40	40
Jet Pump Nozzle MK19	EV8446	40	68.5	64	49	12	40	40
Core Diff. Press & Liq. Con. Nozzle Penetration	C1173-2	40	49	33	47	44	40	44
Drain Nozzle	212918	40	238	239	237	10	N/A	10
CRD Penetration	A0284-2	40	54	65	60	10	40	40
Isolation Cond. Nozzle MK15 (Transverse data)	ZT2405-3	40	67	47.5	53.5	-12.5	40	40
WELDS:								
Vertical Welds	ESW							23.1
Girth Welds	299L44/ 8650							-5
STUDS:						LST		
Studs MK61	6720372	10	53	35	58	70		

NOTE: These are minimum Charpy values.

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 performed and summarized in Tables 4-3 and 4-4 for 32 and 54 EFPY, respectively.

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 (13°F for electroslag welds and 20°F for SAW girth 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 13°F for the beltline electroslag weld materials [13d] and 20°F for the beltline SAW girth weld materials [13e].

4.2.1.1 Chemistry

The vessel beltline chemistries were obtained from several sources as detailed below:

- Vessel Plates: Copper – plate manufacturer [13a]; Nickel – highest value from CMTRs [12]
- Submerged Arc Welds: Copper and nickel from separate evaluation [13b & 13c]
- Electroslag Welds: Copper and nickel from separate evaluations [13d & 13c]

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. Best estimate results are used for the beltline electroslag [13d] and submerged arc weld [13e] materials for the initial RT_{NDT}; therefore, the standard deviation (σ_I) is specified.

4.2.1.2 Fluence

A bounding pre-EPU (Extended Power Uprate) and EPU flux [14] for the vessel ID wall are calculated using methods consistent with Regulatory Guide 1.190. The flux in Reference 14 is determined for the pre-EPU power of 2527 MW_t and for the EPU rated power of 2957 MW_t.

The bounding peak fast flux for the RPV inner surface from Reference 14 is 3.12e8 n/cm^2-s for pre-EPU and 3.46e8 n/cm^2-s for EPU conditions.

32 EFPY Fluence

Dresden Unit 3 began EPU operation at 19.8 EFPY, thereby operating for 12.2 EFPY at EPU conditions for 32 EFPY. The RPV ID surface fluence for 32 EFPY is calculated as follows:

3.12e8 n/cm^2-s*1.01e9 s*(19.8/32) + 3.46e8 n/cm^2-s*1.01e9 s*(12.2/32)= 3.3e17 n/cm^2.

This fluence applies to the lower-intermediate plates and axial weld materials. The fluence is adjusted for the lower shell and axial welds, as well as for the lower to lower-intermediate girth weld based upon a peak / lower shell location ratio of 0.71 for pre-EPU conditions and 0.74 for EPU conditions (at an elevation of approximately 258" above vessel "0"); hence the peak ID surface fluence used for these components is 2.4e17 n/cm^2.

The fluence at 1/4T is calculated per Equation 3 of Regulatory Guide 1.99, Revision 2 [7] using the Dresden Unit 3 plant specific fluence and vessel thickness of 6.125". The 32 EFPY 1/4T fluence for the lower-intermediate shell plate and axial welds is:

3.3e17 n/cm^2 * exp (-0.24 * (6.125/4)) = 2.3e17 n/cm^2.

The 32 EFPY 1/4T fluence for the lower shell plate and axial welds and the lower to lower-intermediate girth weld is:

2.4e17 n/cm^2 * exp (-0.24 * (6.125/4)) = 1.6e17 n/cm^2.

54 EFPY Fluence

As stated above, Dresden Unit 3 began EPU operation at 19.8 EFPY, thereby operating for 34.2 EFPY at EPU conditions for 54 EFPY. The RPV ID surface fluence for 54 EFPY is calculated as follows:

3.12e8 n/cm^2-s*1.7e9 s*(19.8/54) + 3.46e8 n/cm^2-s*1.7e9 s*(34.2/54)= 5.7e17 n/cm^2.

This fluence applies to the lower-intermediate plates and axial weld materials. The fluence is adjusted for the lower shell and axial welds, as well as for the lower to lower-intermediate girth weld based upon a peak / lower shell location ratio of 0.71 for pre-EPU conditions and 0.74 for EPU conditions (at an elevation of approximately 258" above vessel "0"); hence the peak ID surface fluence used for these components is 4.1e17 n/cm^2.

The fluence at 1/4T is calculated per Equation 3 of Regulatory Guide 1.99, Revision 2 [7] using the Dresden Unit 3 plant specific fluence and vessel thickness of 6.125". The 54 EFPY 1/4T fluence for the lower-intermediate shell plate and axial welds is:

5.7e17 n/cm^2 * exp (-0.24 * (6.125/4)) = 3.9e17 n/cm^2.

The 54 EFPY 1/4T fluence for the lower shell plate and axial welds and the lower to lower-intermediate girth weld is:

4.1e17 n/cm^2 * exp (-0.24 * (6.125/4)) = 2.9e17 n/cm^2.

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. Tables 4-3 and 4-4 list values of beltline ART for 32 and 54 EFPY, respectively.

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

Lower-Intermediate Plate and Vertical Welds
Thickness = 6.13 inches

32 EFPY Peak I.D. fluence = 3.3E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.3E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.3E+17 n/cm^2

Lower Plate and Vertical Welds and Girth Weld
Thickness = 6.13 inches

32 EFPY Peak I.D. fluence = 2.4E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 1.6E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 1.6E+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:												
Lower												
6-111-2	C1256-2	0.11	0.50	73	-10	1.6E+17	11	0	6	11	22	12
6-111-6	B5159-2	0.24	0.47	153	0	1.6E+17	23	0	12	23	46	46
6-111-7	C1182-2	0.22	0.50	148	10	1.6E+17	22	0	11	22	45	55
Lower-Intermediate												
6-111-3	A0237-1	0.23	0.49	151	10	2.3E+17	28	0	14	28	56	66
6-111-10	B5118-1	0.22	0.49	146	10	2.3E+17	27	0	14	27	54	64
6-111-11	C1290-2	0.15	0.49	104	10	2.3E+17	19	0	10	19	39	49
WELDS:												
Lower-Intermediate												
ES*		0.24	0.37	141	23	2.3E+17	26	13	13	37	63	86
Lower												
ES*		0.24	0.37	141	23	1.6E+17	21	13	11	34	55	78
Girth												
Lower to Lower-Intermediate												
SAW**	299L44/8650	0.34	0.68	221	-5	1.6E+17	34	20	17	52	86	81

* Chemistry values are based on data from BAW-2258, dated January 1996, but adjusted. Values of Initial RTndt and σI are obtained from the same document.
** Chemistry values are based on data from BAW-2325, dated May 1998 and Initial RTndt and σI are obtained from the BAW-1803-1, dated May 1991.

Table 4-4: Dresden Unit 3 Beltline ART Values (54 EFPY)

Lower-Intermediate Plate and Vertical Welds
Thickness = 6.13 inches

54 EFPY Peak I.D. fluence = 5.7E+17 n/cm^2
54 EFPY Peak 1/4 T fluence = 3.9E+17 n/cm^2
54 EFPY Peak 1/4 T fluence = 3.9E+17 n/cm^2

Lower Plate and Vertical Welds and Girth Weld
Thickness = 6.13 inches

54 EFPY Peak I.D. fluence = 4.1E+17 n/cm^2
54 EFPY Peak 1/4 T fluence = 2.9E+17 n/cm^2
54 EFPY Peak 1/4 T fluence = 2.9E+17 n/cm^2

COMPONENT	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	1/4 T Fluence n/cm^2	54 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	54 EFPY Shift °F	54 EFPY ART °F
PLATES:												
Lower												
6-111-2	C1256-2	0.11	0.50	73	-10	2.9E+17	16	0	8	16	31	21
6-111-6	B5159-2	0.24	0.47	153	0	2.9E+17	33	0	16	33	65	65
6-111-7	C1182-2	0.22	0.50	148	10	2.9E+17	32	0	16	32	63	73
Lower-Intermediate												
6-111-3	A0237-1	0.23	0.49	151	10	3.9E+17	39	0	17	34	73	83
6-111-10	B5118-1	0.22	0.49	146	10	3.9E+17	37	0	17	34	71	81
6-111-11	C1290-2	0.15	0.49	104	10	3.9E+17	27	0	13	27	53	63
WELDS:												
Lower-Intermediate												
ES*		0.24	0.37	141	23	3.9E+17	36	13	18	45	81	104
Lower												
ES*		0.24	0.37	141	23	2.9E+17	30	13	15	40	70	93
Girth												
Lower to Lower-Intermediate												
SAW**	299L44/8650	0.34	0.68	221	-5	2.9E+17	47	20	24	62	109	104

* Chemistry values are based on data from BAW-2258, dated January 1996, but adjusted. Values of Initial RTndt and σI are obtained from the same document.
** Chemistry values are based on data from BAW-2325, dated May 1998 and Initial RTndt and σI are obtained from the BAW-1803-1, dated May 1991.

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 to which a pressure-retaining component may be subjected 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 portions 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 4-5:

Table 4-5: 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.

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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 BWR/6 stress analysis bounds for BWR/2 through BWR/5 designs, as will be demonstrated in the following evaluation. 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, and loss of recirculation pump flow. 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 4-6 and 4-7.

Table 4-6: Applicable BWR/3 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 4-7: Applicable BWR/3 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 Dresden 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 Dresden 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.

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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. [[

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

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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:

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

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

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

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]:

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

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

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 $(T - RT_{NDT})$:

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The highest RT_{NDT} for the bottom head plates and welds is 44°F, as shown in Tables 4-1 and 4-2. [[

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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:

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

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 Dresden Unit 3 specific bottom head dimensions are R = 125.7 inches and t =8 inches minimum [19], resulting in:

Dresden Unit 3 specific: $R / (t)^{1/2} = 125.7 / (8)^{1/2} = 44 \text{ inch}^{1/2}$ (4-3)

Since the generic value of $R/(t)^{1/2}$ is larger, the generic P-T curve is conservative when applied to the Dresden 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. [[

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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) · 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 44°F, as shown in Tables 4-1 and 4-2. [[

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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 Table 4-7 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.

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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. [[

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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 $\cdot$ 126.7 inches / (6.1875 inches) = 32,005 psi. The Dead weight and thermal RFE stress of 2.967 ksi is conservatively added yielding $\sigma = 34.97$ 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 $1.5\, \sigma\, (\pi a)^{1/2} \cdot F(a/r_n)$:

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:

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

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

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The highest RT_{NDT} for the feedwater nozzle materials is 40°F as shown in Table 4-2. The generic pressure test P-T curve is applied to the Dresden Unit 3 feedwater nozzle curve by shifting the P vs. (T - RT_{NDT}) values above to reflect the RT_{NDT} value of 40°F.

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Second, the P-T curve is dependent on the K_I value calculated. The Dresden 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:

$a =$	$\frac{1}{4}(t_n^2 + t_v^2)^{1/2}$	=2.35 inches
$t_n =$	thickness of nozzle	= 7.15 inches
$t_v =$	thickness of vessel	= 6.125 inches
$r_n =$	apparent radius of nozzle	$= r_i + 0.29\, r_c$=6.9 inches
$r_i =$	actual inner radius of nozzle	= 6.0 inches
$r_c =$	nozzle radius (nozzle corner radius)	= 3.0 inches

Thus, $a/r_n = 2.35 / 6.9 = 0.34$. 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 $K_I = 1.5 \cdot 35.04 \cdot (\pi \cdot 2.35)^{1/2} \cdot 1.4 = 200$ ksi-in$^{1/2}$

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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, as seen in 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.

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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 inches
σ_{pb} = 0.22 ksi	σ_{sb} = 19.04 ksi	a = 2.36 inches	r_n = 7.09 inches
t_n = 7.125 inches			

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:

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

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

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

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 Dresden Unit 3 is 40°F as shown in Table 4-2. The generic curve is applied to the Dresden Unit 3 upper vessel by shifting the P vs. ($T - RT_{NDT}$) values above to reflect the RT_{NDT} value of 40°F as discussed in Section 4.3.2.1.3.

[[

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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.

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 = 23 + 63 = 86°F (Based on ART values in Table 4-3)
Vessel Height	H = 823 inches
Bottom of Active Fuel Height	B = 216 inches
Vessel Radius (to inside of clad)	R = 125.7 inches
Minimum Vessel Thickness (without clad)	t = 6.125 inches

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

$$P = 1105 \text{ psi} + (H - B)\ 0.0361 \text{ psi/inch} = P \text{ psig} \quad (4\text{-}10)$$
$$= 1105 + (823 - 216)\ 0.0361 = 1127 \text{ psig}$$

Pressure stress:

$$\sigma = PR/t \quad (4\text{-}11)$$
$$= 1.127 \cdot 125.7 / 6.125 = 23.1 \text{ ksi}$$

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, $t^{1/2} = 2.47$. The resulting value obtained was:

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

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

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

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], $K_{Im} = 52.96$, and $K_{It} = 2.29$ for a 20°F/hr coolant heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$\begin{aligned}(T - RT_{NDT}) &= \ln[(1.5 \cdot K_{Im} + K_{It} - 33.2) / 20.734] / 0.02 \qquad (4\text{-}12)\\ &= \ln[(1.5 \cdot 52.96 + 2.29 - 33.2) / 20.734] / 0.02\\ &= 42.5°F\end{aligned}$$

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

$$T = 42.5 + 86 = 128.5°F \qquad \text{for } P = 1105 \text{ psig at 32 EFPY}$$

For Dresden Unit 3, the beltline axial weld is the limiting material at 32 EFPY. However, at 54 EFPY the beltline girth weld becomes limiting by <1°F. However, because the calculated value of K_{Im} is reduced for a girth weld due to implementation of Code Case N-588 (circumferentially oriented defect for circumferential welds), the axial weld bounds the P-T curve beltline region requirements. To demonstrate that by using Code Case N-588, the axial weld has the most limiting temperature for the P-T curves in the beltline region, the stress intensity calculations for both the axial and girth welds at 54 EFPY are presented.

Axial Weld Calculation:

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, $t^{1/2} = 2.47$. The resulting value obtained was:

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

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

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

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], $K_{Im} = 52.96$, and $K_{It} = 2.29$ for a 20°F/hr coolant heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$\begin{aligned}(T - RT_{NDT}) &= \ln[(1.5 \cdot K_{Im} + K_{It} - 33.2) / 20.734] / 0.02 \qquad (4\text{-}12)\\ &= \ln[(1.5 \cdot 52.96 + 2.29 - 33.2) / 20.734] / 0.02\\ &= 42.5°F\end{aligned}$$

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

$T = 42.5 + 104 = 146.5°F$ for P = 1105 psig at 54 EFPY

Girth Weld Calculation:

The value of M_m for an inside circumferential postulated surface flaw from Paragraph G-2214.1 [6] was based on a thickness of 6.125 inches (the minimum thickness without cladding); hence, $t^{1/2} = 2.47$. The resulting value obtained was:

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

$$M_m = 0.926\sqrt{t} \text{ for } 2 \leq \sqrt{t} \leq 3.464 = 1.10$$

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

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} = 25.4, and K_{It} = 2.28 for a 20°F/hr coolant heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$\begin{aligned}(T - RT_{NDT}) &= \ln[(1.5 \cdot K_{Im} + K_{It} - 33.2) / 20.734] / 0.02 \qquad (4\text{-}12)\\ &= \ln[(1.5 \cdot 25.4 + 2.28 - 33.2) / 20.734] / 0.02\\ &= -53°F\end{aligned}$$

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

$$T = -53 + 104 = 51°F \qquad \text{for } P = 1105 \text{ psig at 54 EFPY}$$

As stated above, based on the applied pressure and temperature stress intensity factors, the axial weld flaw bounds the P-T curve in the beltline region for 54 EFPY.

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 (6.3125 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 (=0.2914) can be interpolated from ASME Appendix G, Figure G-2214-2 [6]. Thus the thermal stress intensity factor, $K_{It} = M_t \cdot \Delta T = 11.39$, can

be calculated. The conservative value for thermal diffusivity at 550°F is used for all calculations; therefore, K_{It} is constant for all pressures. 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 $(T - RT_{NDT})$:

$$\begin{aligned}(T - RT_{NDT}) &= \ln[((2 \cdot K_{Im} + K_{It}) - 33.2) / 20.734] / 0.02 \qquad (4\text{-}17)\\ &= \ln[(2 \cdot 52.96 + 11.39 - 33.2) / 20.734] / 0.02\\ &= 70\ °F\end{aligned}$$

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

$T = 70 + 86 = 156\ °F$ for P = 1105 psig at 32 EFPY

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}. Similar to the evaluations performed for the bottom head and upper vessel, a BWR/6 finite element analysis [18] was used to model the flange region. The local stresses were computed for determination of the stress intensity factor, K_I. Using a 1/4T flaw size and the K_{Ic} formulation to determine $T - RT_{NDT}$, for pressures above 312 psig the P-T limits for all flange regions are bounded by the 10 CFR50 Appendix G requirement of RT_{NDT} + 90°F (the largest $T\text{-}RT_{NDT}$ for the flange at 1563 psig is 73°F). For pressures below 312 psig, the flange curve is bounded by RT_{NDT} + 60 (the largest $T - RT_{NDT}$ for the flange at 312 psig is 54°F), therefore, instead of determining a T (temperature) versus pressure curve for the flange (i.e., $T - RT_{NDT}$) the value RT_{NDT} + 60 is used for the closure flange limits.

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 Dresden Unit 3 at low pressures.

The approach used for Dresden Unit 3 for the bolt-up temperature was based on the 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 1/4T flaw size is acceptable. As shown in Tables 4-1 and 4-2, the limiting initial RT_{NDT} for the closure flange region is represented by the electroslag weld materials in the upper shell at 23.1°F, and the LST of the closure studs is 70°F; therefore, the bolt-up temperature value used is 83°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 Dresden 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 83°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 83°F, based on an RT_{NDT} of 23.1°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 1105 psig). The requirement of closure region RT_{NDT} + 160°F causes a temperature shift in Curve C at 312 psig.

5.0 CONCLUSIONS AND RECOMMENDATIONS

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)

For the core not critical and the core critical curve, 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]. 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 apply for both heatup/cooldown and for both the 1/4T and 3/4T locations because the maximum tensile stress for either heatup or cooldown is applied at the 1/4T location. For beltline curves this approach has added conservatism 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.

The following P-T curves were generated for Dresden Unit 3.

- Composite P-T curves were generated for each of the Pressure Test and Core Not Critical conditions at 32 and 54 effective full power years (EFPY). The composite curves were generated by enveloping the most restrictive P-T limits from the separate beltline, upper vessel and closure assembly P-T limits. A separate Bottom Head Limits (CRD Nozzle) curve is also individually included with the composite curve for the Pressure Test and Core Not Critical condition.
- Separate P-T curves were developed for the upper vessel, beltline (at 32 and 54 EFPY), and bottom head for the Pressure Test and Core Not Critical conditions.
- A composite P-T curve was also generated for the Core Critical condition at 32 and 54 EFPY. The composite curves were generated by enveloping the most restrictive P-T limits from the separate beltline, upper vessel, bottom head, and closure assembly P-T limits.

Using the flux from Reference 14, the P-T curves are beltline limited above 1020 psig for Curve A and above 1110 psig for Curve B at 32 EFPY. At 54 EFPY, the P-T curves become beltline limited above 760 psig for Curve A and above 690 psig for Curve B.

Table 5-1 shows the figure numbers for each P-T curve. A tabulation of the curves is presented in Appendix B.

Table 5-1: Composite and Individual Curves Used To Construct Composite P-T Curves

Curve	Curve Description	Figure Numbers for Presentation of the P-T Curves	Table Numbers for Presentation of the P-T Curves
Curve A			
	Bottom Head Limits (CRD Nozzle)	Figure 5-1	Table B-1 & 3
	Upper Vessel Limits (FW Nozzle)	Figure 5-2	Table B-1 & 3
	Beltline Limits for 32 EFPY	Figure 5-3	Table B-1
	Beltline Limits for 54 EFPY	Figure 5-4	Table B-3
Curve B			
	Bottom Head Limits (CRD Nozzle)	Figure 5-5	Table B-1 & 3
	Upper Vessel Limits (FW Nozzle)	Figure 5-6	Table B-1 & 3
	Beltline Limits for 32 EFPY	Figure 5-7	Table B-1
	Beltline Limits for 54 EFPY	Figure 5-8	Table B-3
Curve C			
	Composite Curve for 32 EFPY**	Figure 5-9	Table B-2
	Composite Curve for 54 EFPY**	Figure 5-10	Table B-4
A & B	**Composite Curves for 32 EFPY**		
	Bottom Head and Composite Curve A for 32 EFPY*	Figure 5-11	Table B-2
	Bottom Head and Composite Curve B for 32 EFPY*	Figure 5-12	Table B-2
A & B	**Composite Curves for 54 EFPY**		
	Bottom Head and Composite Curve A for 54 EFPY*	Figure 5-13	Table B-4
	Bottom Head and Composite Curve B for 54 EFPY*	Figure 5-14	Table B-4

* The Composite Curve A & B curve is the more limiting of three limits: 10CFR50 Bolt-up Limits, Upper Vessel Limits (FW Nozzle), and Beltline Limits. A separate Bottom Head Limits (CRD Nozzle) curve is individually included on this figure.

** The Composite Curve C curve is the more limiting of four limits: 10CFR50 Bolt-up Limits, Bottom Head Limits (CRD Nozzle), Upper Vessel Limits (FW Nozzle), and Beltline Limits.

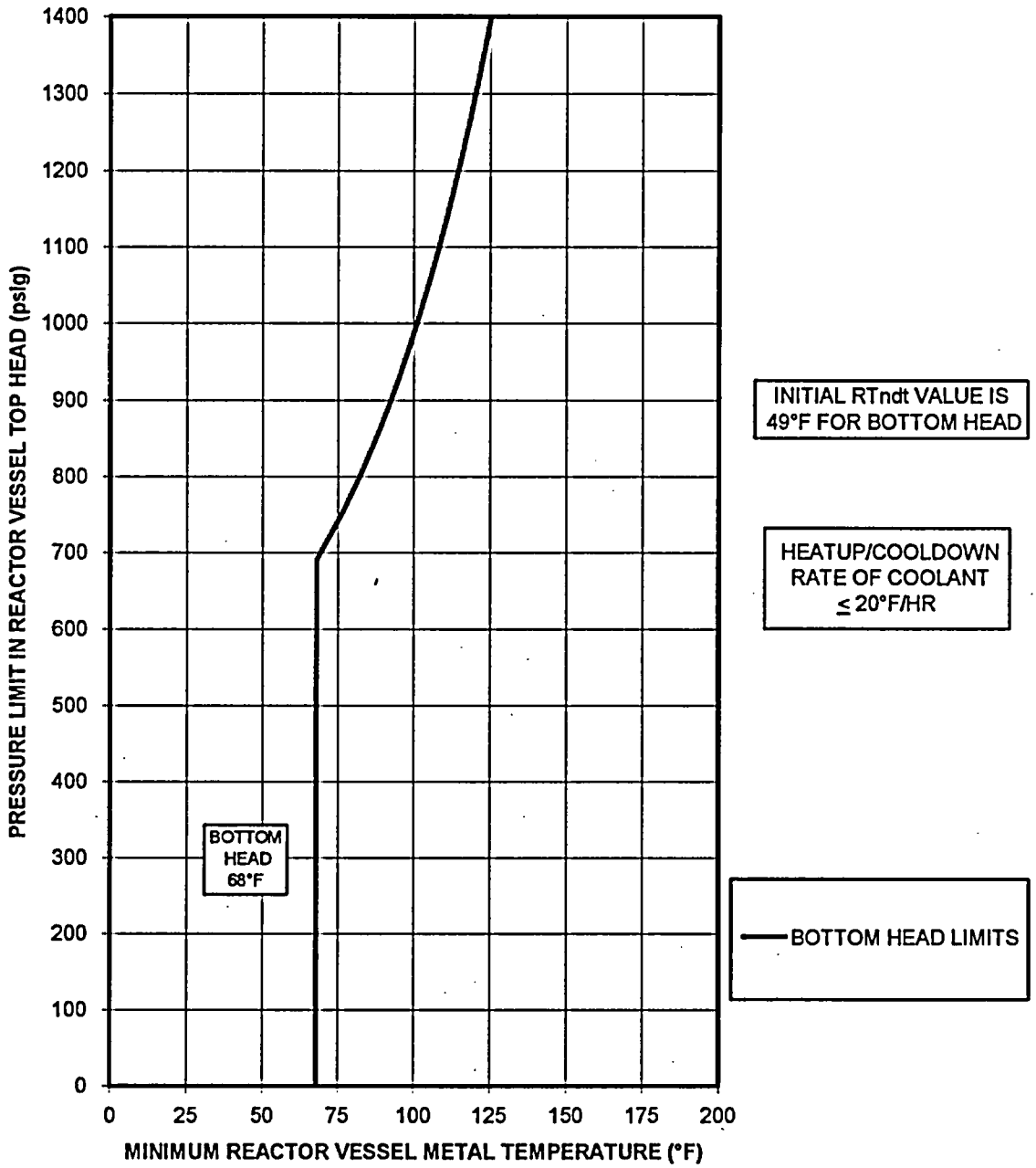

Figure 5-1: Bottom Head P-T Curve for Pressure Test [Curve A]

[20°F/hr or less coolant heatup/cooldown]

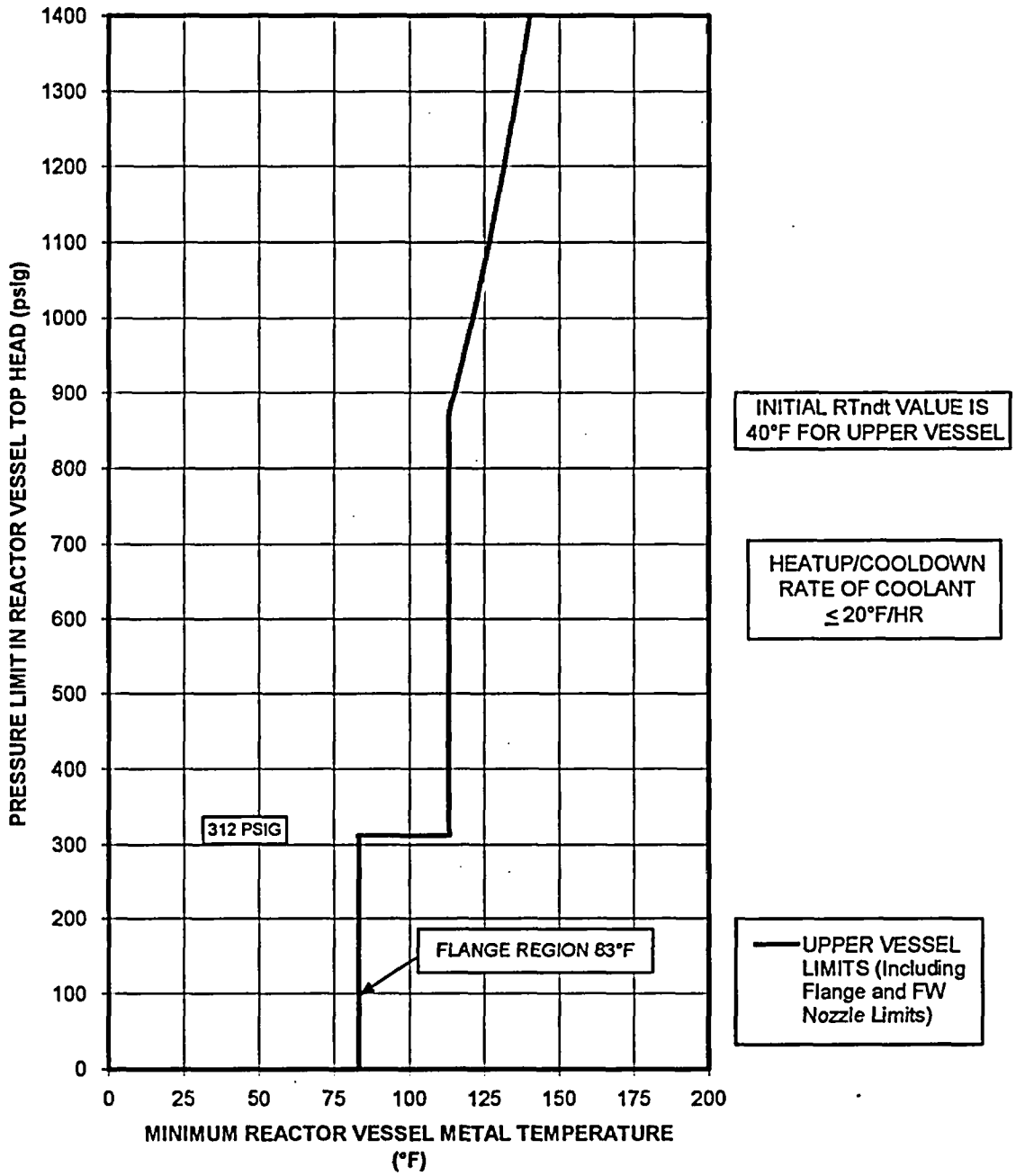

Figure 5-2: Upper Vessel P-T Curve for Pressure Test [Curve A]
[20°F/hr or less coolant heatup/cooldown]

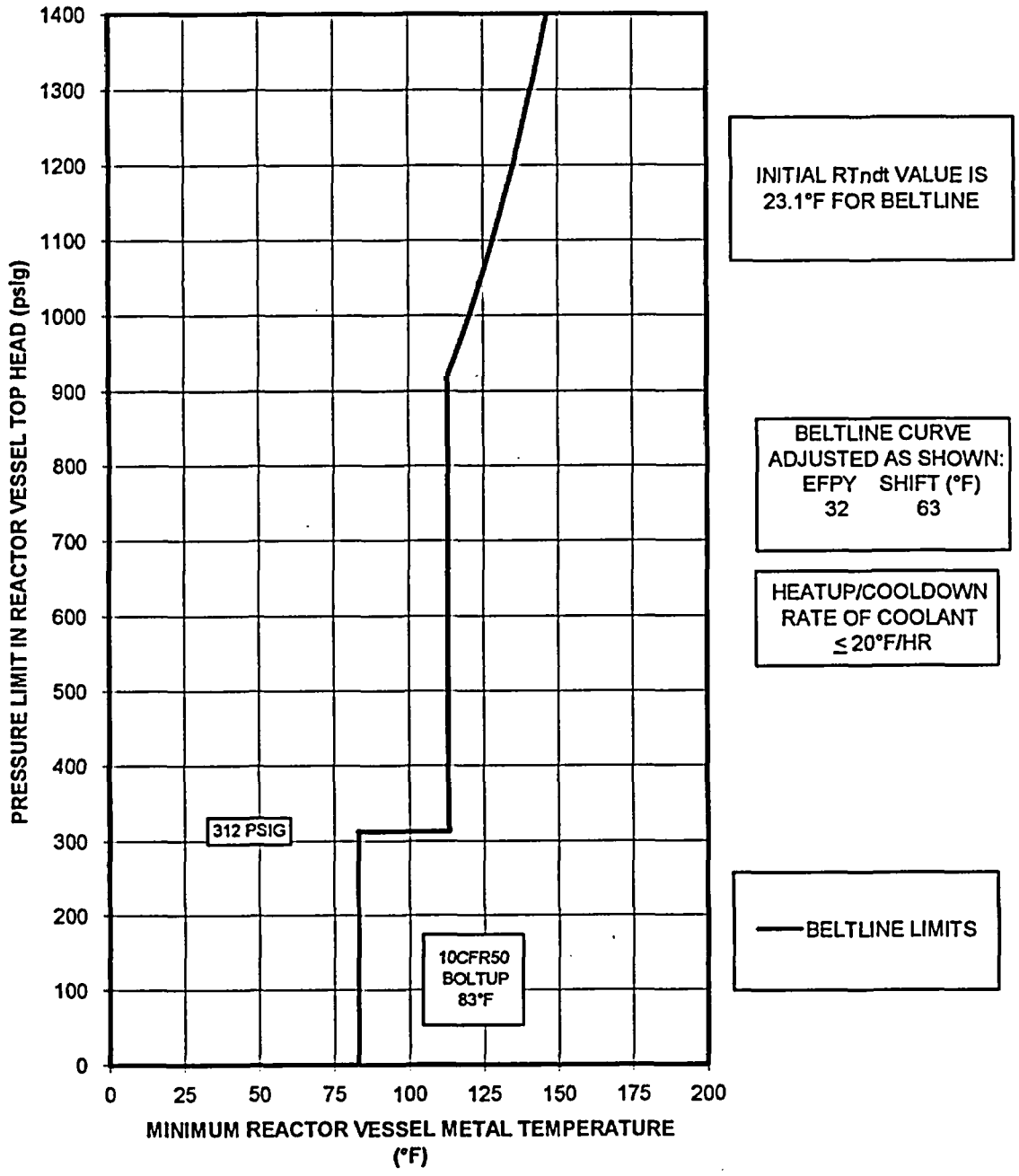

Figure 5-3: Beltline P-T Curve for Pressure Test [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

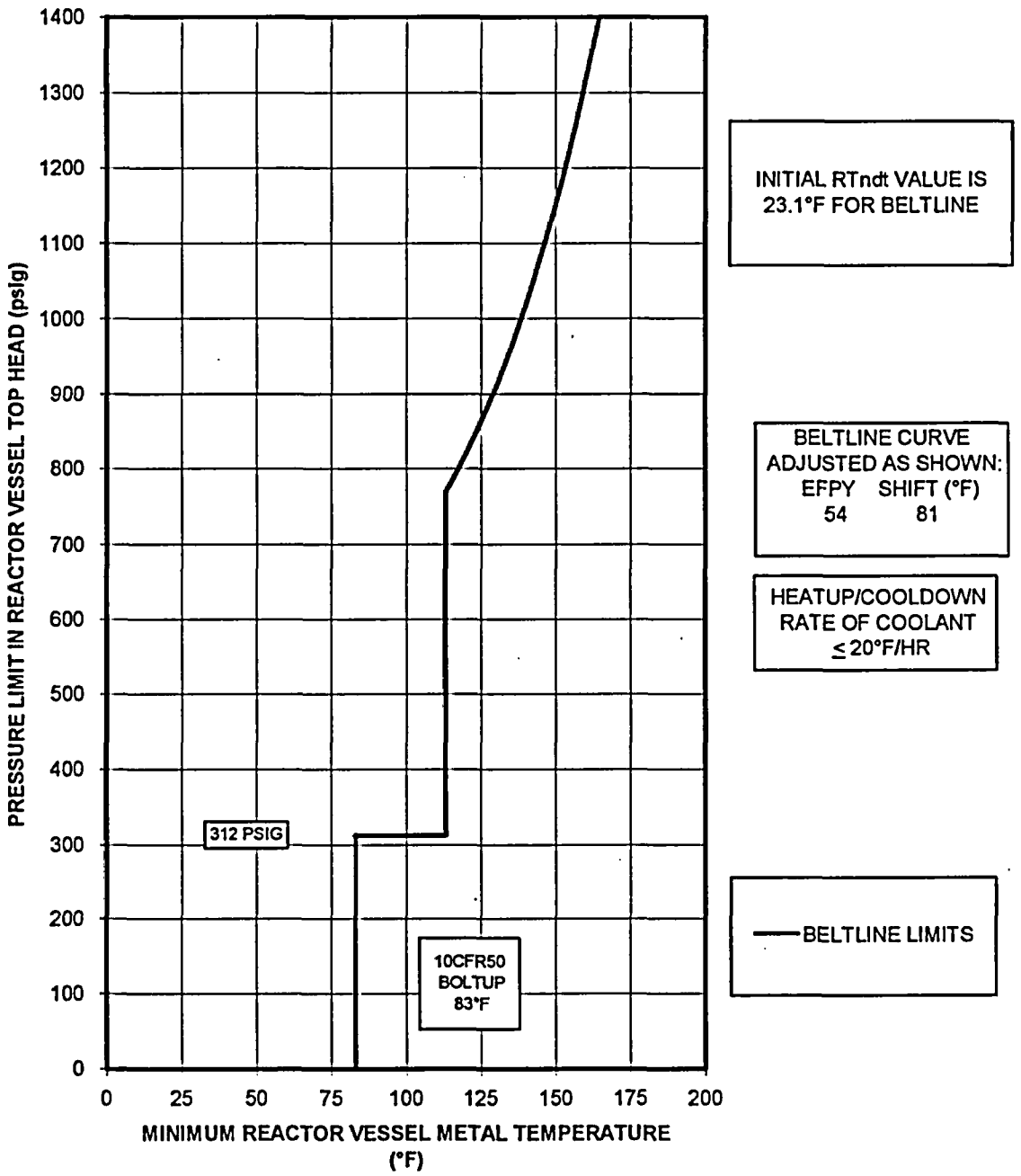

Figure 5-4: Beltline P-T Curve for Pressure Test [Curve A] up to 54 EFPY [20°F/hr or less coolant heatup/cooldown]

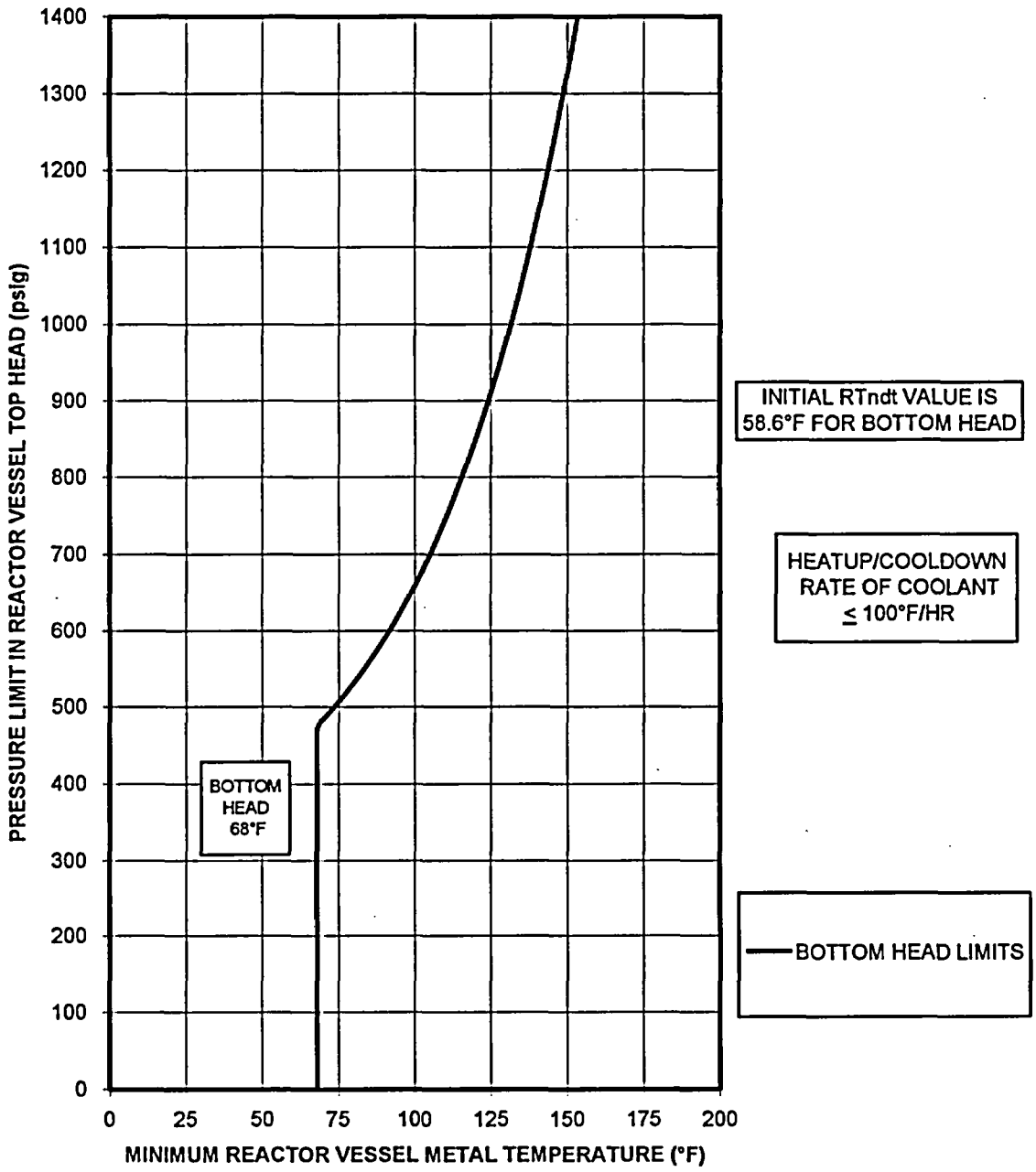

Figure 5-5: Bottom Head P-T Curve for Core Not Critical [Curve B]
[100°F/hr or less coolant heatup/cooldown]

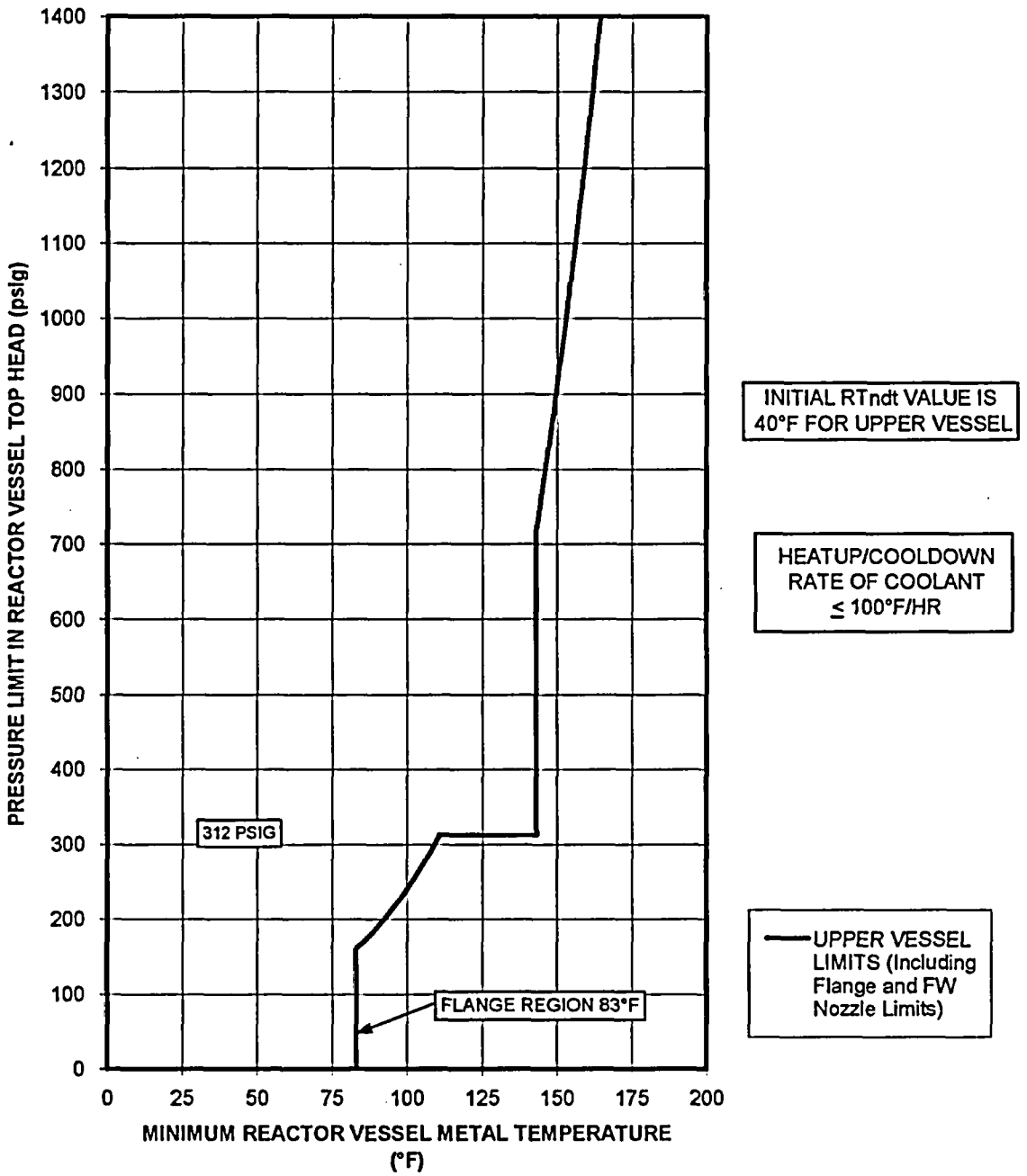

Figure 5-6: Upper Vessel P-T Curve for Core Not Critical [Curve B]
[100°F/hr or less coolant heatup/cooldown]

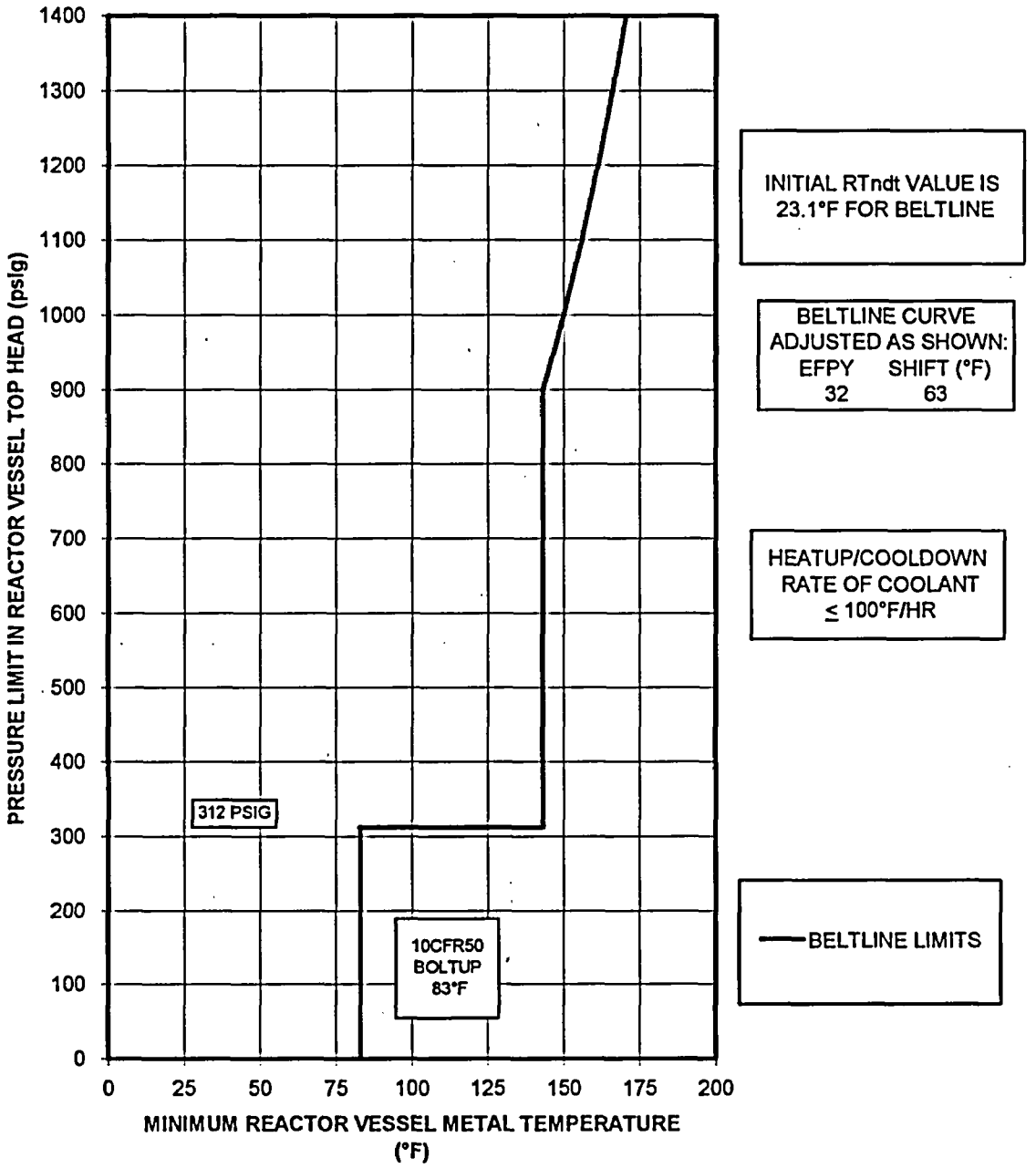

Figure 5-7: Beltline P-T Curve for Core Not Critical [Curve B] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

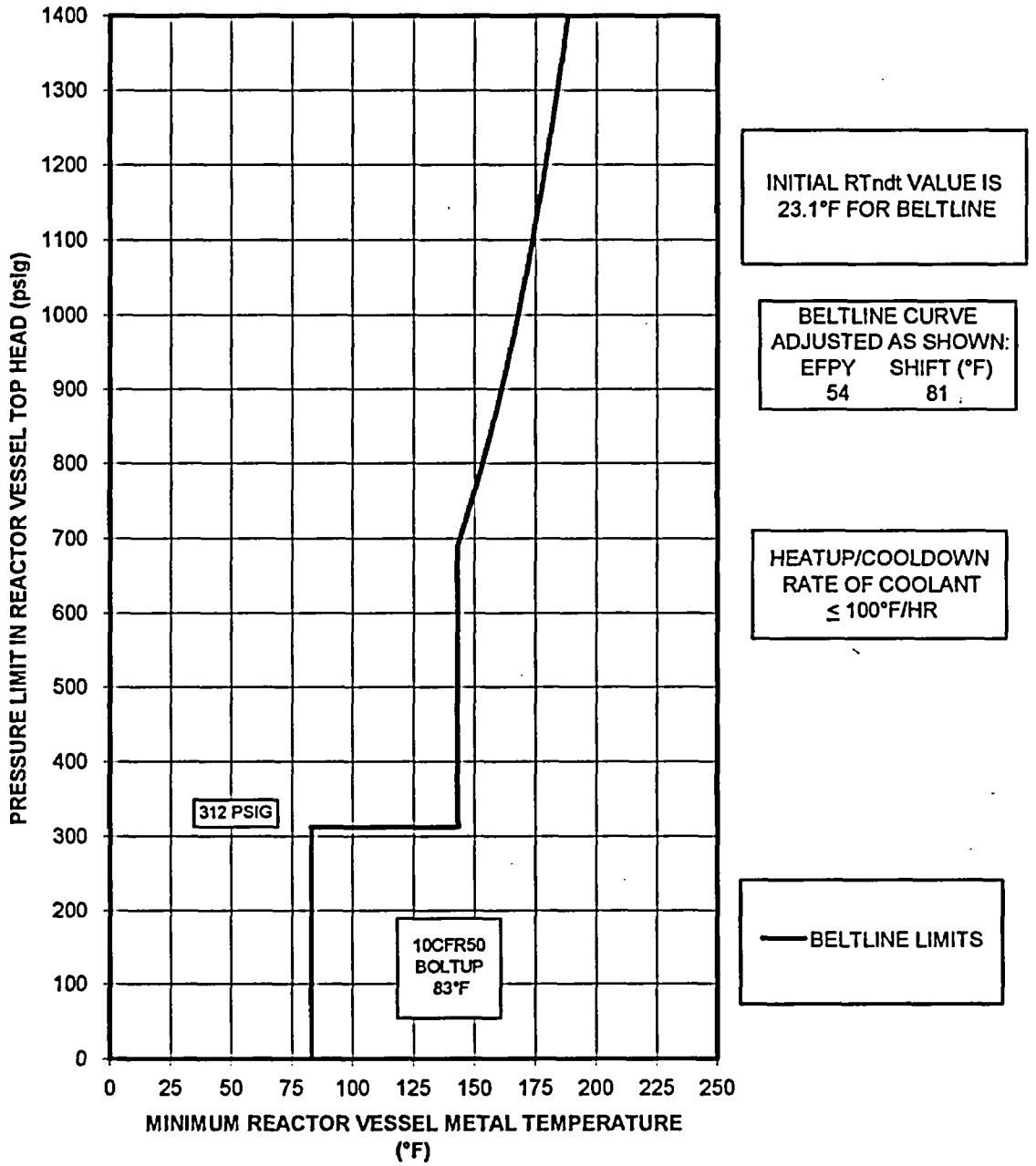

Figure 5-8: Beltline P-T Curve for Core Not Critical [Curve B] up to 54 EFPY [100°F/hr or less coolant heatup/cooldown]

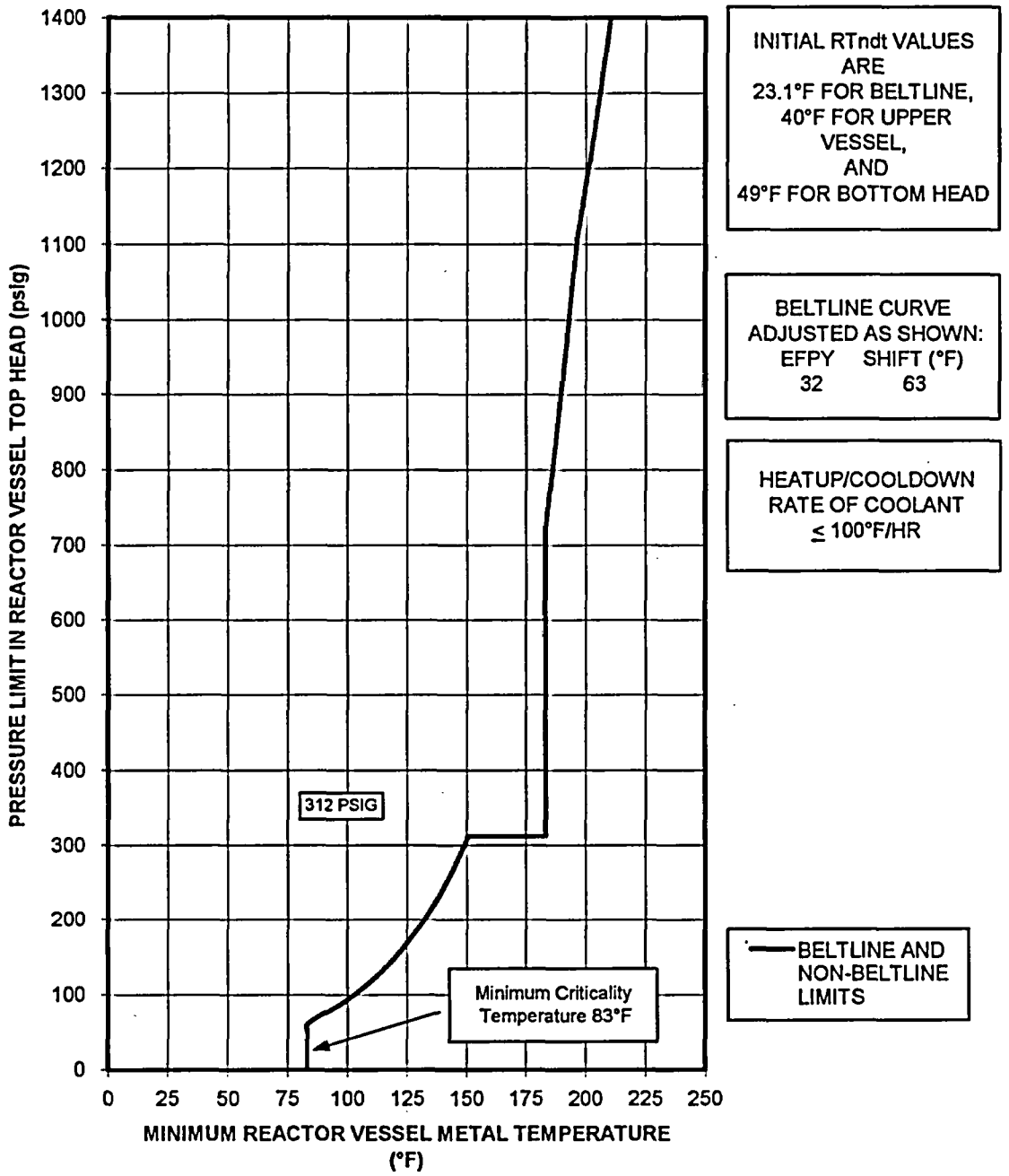

Figure 5-9: Core Critical P-T Curves [Curve C] up to 32 EFPY
[100°F/hr or less coolant heatup/cooldown]

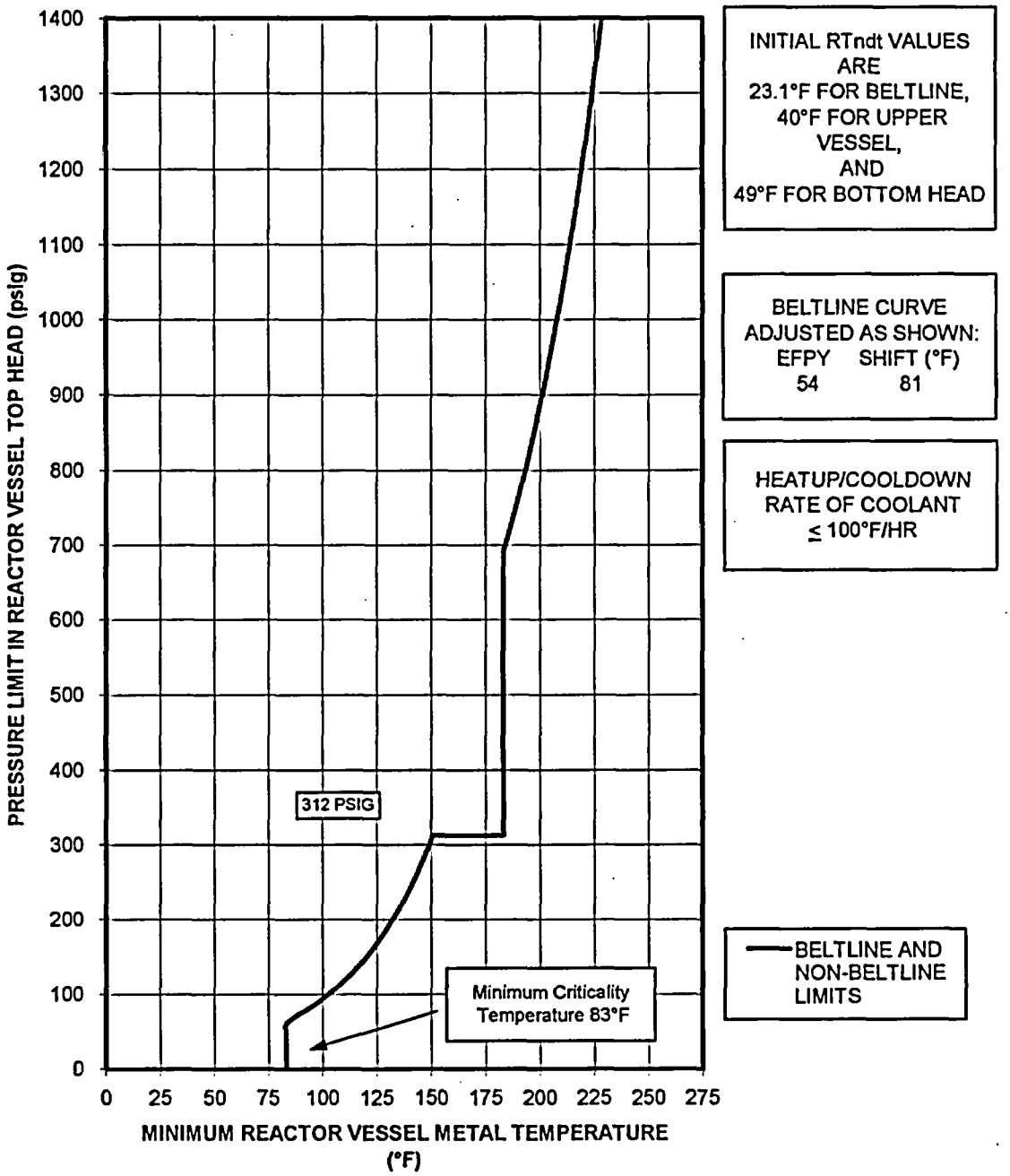

Figure 5-10: Core Critical P-T Curves [Curve C] up to 54 EFPY
[100°F/hr or less coolant heatup/cooldown]

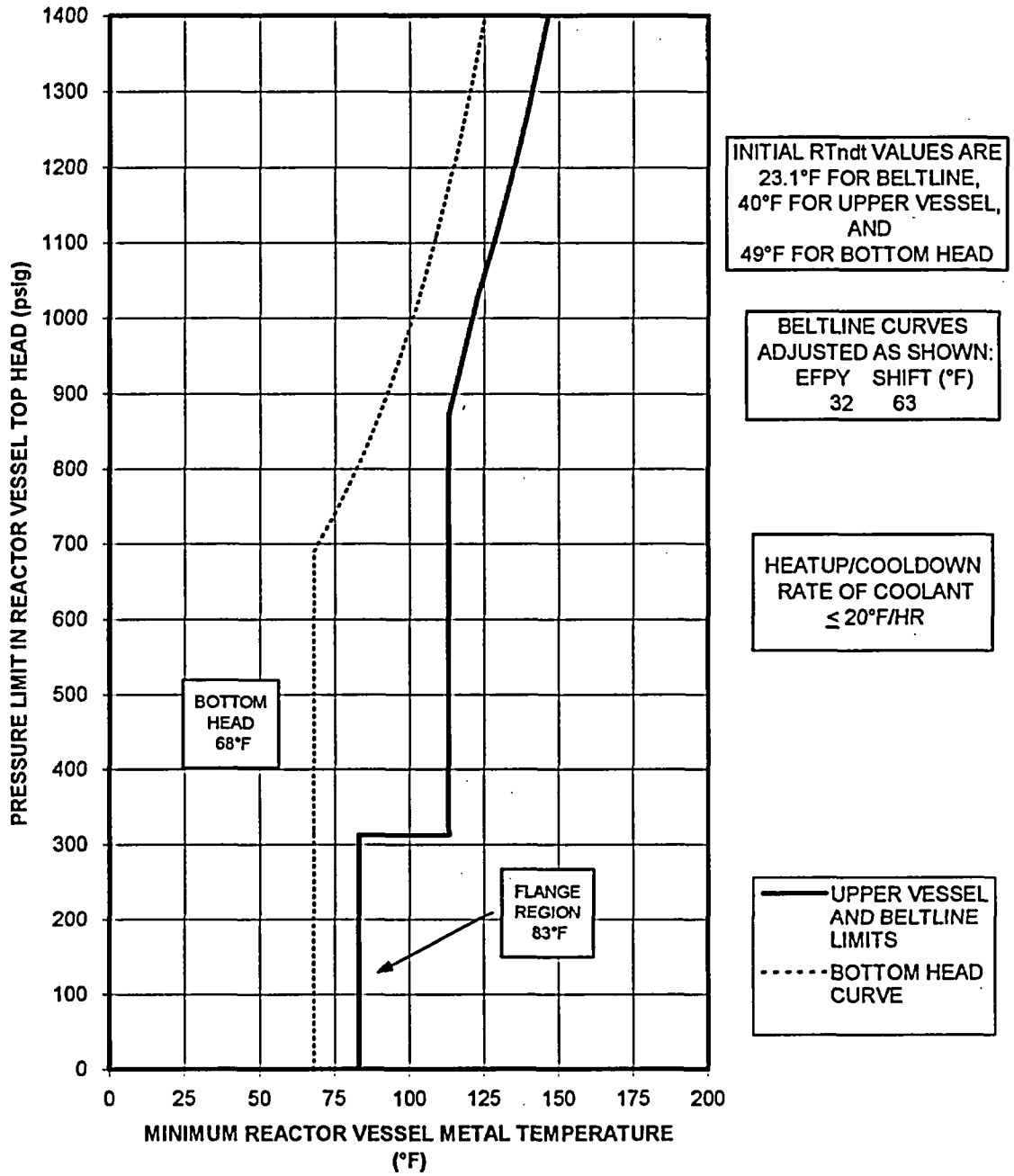

Figure 5-11: Composite Pressure Test P-T Curves [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

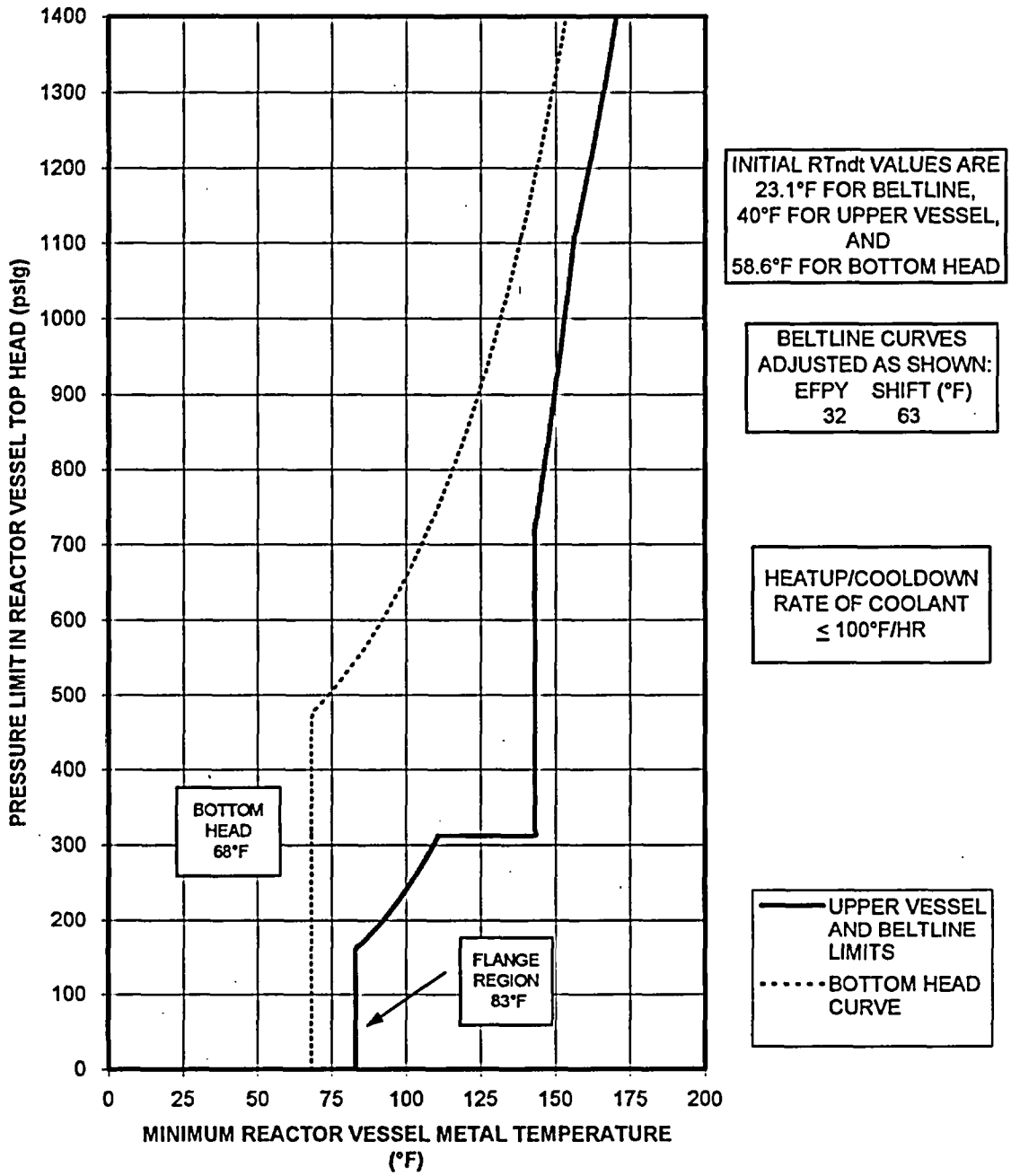

Figure 5-12: Composite Core Not Critical P-T Curves [Curve B] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

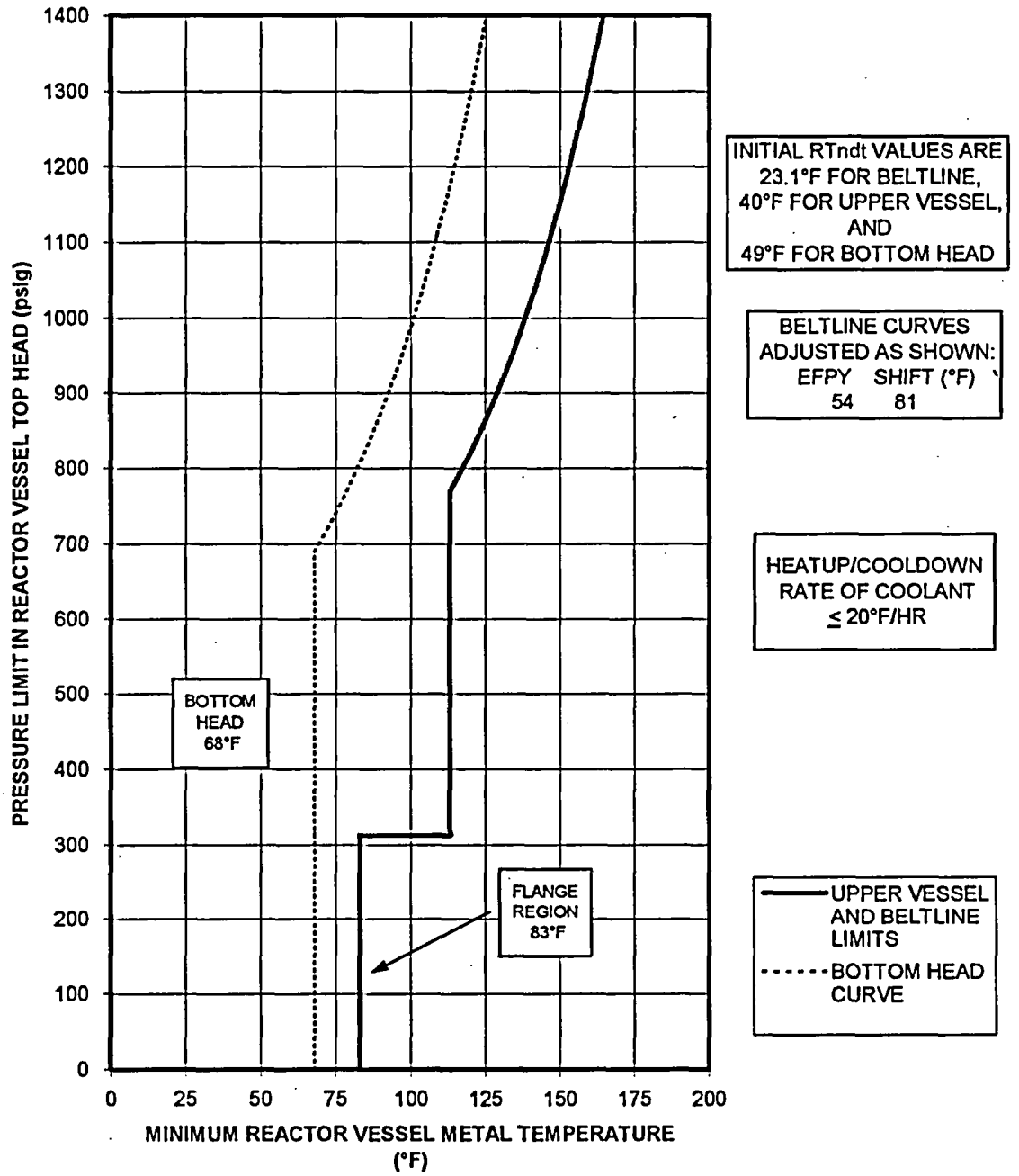

Figure 5-13: Composite Pressure Test P-T Curves [Curve A] up to 54 EFPY [20°F/hr or less coolant heatup/cooldown]

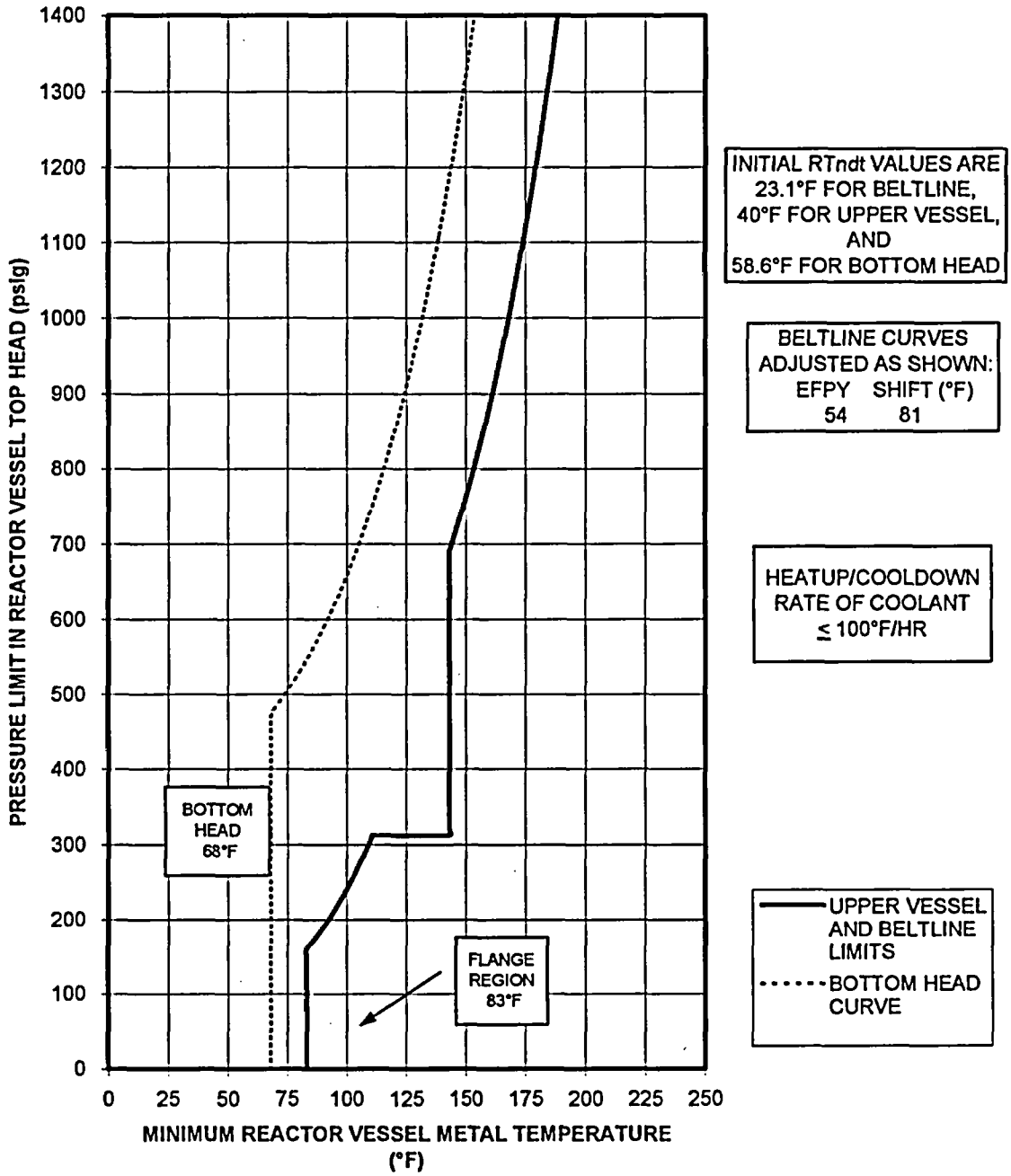

Figure 5-14: Composite Core Not Critical P-T Curves [Curve B] up to 54 EFPY [100°F/hr or less coolant heatup/cooldown]

6.0 REFERENCES

1. R. G. Carey, "Pressure-Temperature Curves for ComEd Dresden Unit 3", GE-NE, San Jose, CA, May 2000 (GE-NE-B13-02057-00-03-R1, Revision 1) (GE Proprietary).

2. GE Drawing Number 921D265, "Reactor Thermal Cycles – Reactor Vessel", GE-APED, San Jose, CA, Revision 1. Dresden and Quad Cities RPV Thermal Cycle Diagram (GE Proprietary).

3. GE Drawing Number 158B7279, "Nozzle Thermal Cycles - Reactor Vessel", GE-APED, San Jose, CA, Revision 1. Dresden and Quad Cities 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.

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:

Dresden 3 – (QA Records & RPV CMTR's Dresden Unit 3 GE PO# 205-55579, Manufactured by B&W), "General Electric Company Atomic Power Equipment Department (APED) Quality Control – Procured Equipment, RPV QC", Barberton, Ohio, Mt. Vernon, Indiana, and Madison, Indiana.

13. a) Letter, J.F. Longnecker (Lukens Steel) to T.A. Caine (GE), "Copper Content of Reactor Vessel Plates", dated August 27, 1985.

b) Howell Letter to NRC dated May 28, 1998, transmitting B&WOG Report, "Response to Request for Additional Information Regarding Reactor Pressure Vessel Integrity", BAW-2325, May 1998.

c) Letter from R.M. Krich to the NRC, "Response to Request for Additional Information Regarding Reactor Pressure Vessel Integrity – Dresden Nuclear Power Station, Units 2 and 3 Facility Operating License Nos. DPR-19 and DPR-25 NRC Docket Nos. 50-237 and 50-249 – LaSalle County Nuclear Power Station, Units 1 and 2 Facility Operating License Nos. NPF-11 and NPF-18 NRC Docket Nos. 50-373 and 50-374 – Quad Cities Nuclear Power Station, Units 1 and 2 Facility Operating License Nos. DPR-29 and DPR-30 NRC Docket Nos. 50-254 and 50-265", Commonwealth Edison Company, Downers Grove, IL, July 30, 1998.

d) "Evaluation of RT_{NDT}, USE and Chemical Composition of Core Region Electroslag Welds for Dresden Units 2 and 3", BAW-2258, January 1996.

e) "Correlations for Predicting the Effects of Nuclear Reactors on Linde 80 Submerged Arc Welds", BAW-1803, Revision 1, May 1991.

14. a) S. Sitaraman, "Dresden and Quad Cities Neutron Flux Evaluation", GE-NE, San Jose, CA, December 2002 (GE-NE-0000-0011-0531-R0, Revision 0)(GE Proprietary Information).

b) Letter, S.A. Richard, USNRC to J.F. Klapproth, GE-NE, "Safety Evaluation for NEDC-32983P, General Electric Methodology for Reactor Pressure Vessel Fast Neutron Flux Evaluation (TAC No. MA9891)", MFN 01-050, September 14, 2001.

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

16. [[

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

18. [[

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19. Bottom Head and Feedwater Nozzle Dimensions: "Final Design Report for General Electric – NED Dresden III", Babcock & Wilcox Co., Mt. Vernon, Indiana, August 1970 (GE VPF 2252-181-1).

20. [[

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

22. Letter, M. Banerjee, USNRC to J.L. Skolds, Exelon Generation Company, LLC, "Dresden Nuclear Power Station, Units 2 and 3 – Issuance of Amendments Regarding Pressure and Temperature Limits (TAC Nos. MB7850 and MB7851)", November 26, 2003 (GE Proprietary).

APPENDIX A

DESCRIPTION OF DISCONTINUITIES

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Table A-2 - Geometric Discontinuities Not Requiring Fracture Toughness Evaluations

Per ASME Code Appendix G, Section G2223 (c), fracture toughness analysis to demonstrate protection against non-ductile failure is not required for portions of nozzles and appurtenances having a thickness of 2.5" or less provided the lowest service temperature is not lower than RT_{NDT} plus 60°F. Also Inconel discontinuities require no fracture toughness evaluations. The RPV penetrations of the nozzles listed in Table A-1 and bound the RPV penetration for the nozzles listed below, therefore, no further fracture toughness evaluation is performed for these nozzles. Nozzles and appurtenances < 2.5" or made from Inconel are not included in Table A-1 and are listed below. The Top Head Lifting Lugs are also not included in Table A-1 because the loads only occur on these components when the reactor is shutdown during an outage. Components not requiring a fracture toughness evaluation are listed below:

Nozzle or Appurtenance Identification	Nozzle or Appurtenance	Material	Reference	RT_{NDT} (°F)	LST (°F)
MK 12	2" Instrumentation ≤ 2.5" Penetration in RPV Shell	Alloy 600	1, 2 & 7	N/A	N/A
MK 22	Drain- Penetration ≤ 2.5" – Bottom Head	SA105-GR 2	1, 2 & 7	40	100
MK 51 - 54	Shroud Support Attachment to RPV Wall Attachment to Bottom Head	Alloy 600	1, 2 & 7	N/A	N/A
MK 74, 75 & 77-84	Insulation Brackets – Shells and Bottom Head Attachment to RPV Shells Attachment to Dollar Plate and RPV Shells	Carbon Steel	1, 2 & 7	N/A	N/A
MK 101-127	Control Rod Drive Stub Tubes – Bottom Head Penetration in Dollar Plate	Alloy 600	2 & 7	N/A	N/A
Mk 139, 141 & 142	High and Low Pressure Seal Leak Detection- Penetration ≃ 1" * - Flange Not a pressure boundary component; therefore requires no fracture toughness evaluation.	Carbon Steel	1 & 7		
Mk 210	Top Head Lifting Lugs (only loads at outage) Attachment to Torus Not a pressure boundary component; therefore requires no fracture toughness evaluation.		1, 2 & 7		

* The high/low pressure leak detector, and the seal leak detector are the same nozzle, these nozzles are the closure flange leak detection nozzles.
** N/A – Not applicable for this material type.

APPENDIX A REFERENCES:

1. RPV Outline or As-Built:
   - Babcock & Wilcox Co. Drawing # 26903F, Revision 2, "General Outline", Babcock & Wilcox Co, Mt. Vernon, Indiana (GE-NE VPF# 2252-139-4) - Dresden Unit 3.
   - Babcock & Wilcox Co. Drawing # 26904F, Revision 3, "Outline Sections", Babcock & Wilcox Co, Mt. Vernon, Indiana (GE-NE VPF# 2252-140-3) - Dresden Unit 3.

2. Certified Stress Report:
   "Certified Design Document for Dresden Unit 3" B&W contract No. 610-0111, GE Order No. 205-55579", Babcock & Wilcox Co, Mt. Vernon, Indiana, August 1970 (GE-NE VPF# 2252-181-1) - Dresden Unit 3.

3. Babcock & Wilcox Co. Drawing #151810E, Revision 2, "Support Skirt Assy & Details", Babcock & Wilcox Co, Mt. Vernon, Indiana (GE-NE VPF# 2252-133-4) - Dresden Unit 3.

4. GE Drawing #104R861, Revision 5, "Reactor Assembly, Nuclear Boiler", GE-NED, San Jose, CA - Dresden Units 2 & 3.

5. Fax Transmittal of NDIT No. SEC-DB-99-163 from Bob Geier to Ray Carey, "Pressure – Temperature (P-T) Curve Limit Re-evaluation for Dresden Units 2 and 3", Commonwealth Edison Company – Dresden Nuclear Station, Morris, IL, 11/2/99.

6. Babcock & Wilcox Co. Drawing #151808E, Revision 1, "Shroud Support", Babcock & Wilcox Co, Mt. Vernon, Indiana (GE-NE VPF# 2252-131-03) - Dresden Unit 3.

7. QA Records & RPV CMTR's:
   Dresden 3 - (QA Records & RPV CMTR's Dresden Unit 3 GE PO# 205-55579, Mfg by B&W)"General Electric Company Atomic Power Equipment Department (APED) Quality Control - Procured Equipment, RPV QC" Project: Dresden 3, Purchase Order: 205-55579, Vendor: Babcock & Wilcox, Location: Mt. Vernon, Indiana.

APPENDIX B

PRESSURE TEMPERATURE CURVE DATA TABULATION

TABLE B-1. Dresden 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	83.1	83.1	68.0	83.1	83.1
10	68.0	83.1	83.1	68.0	83.1	83.1
20	68.0	83.1	83.1	68.0	83.1	83.1
30	68.0	83.1	83.1	68.0	83.1	83.1
40	68.0	83.1	83.1	68.0	83.1	83.1
50	68.0	83.1	83.1	68.0	83.1	83.1
60	68.0	83.1	83.1	68.0	83.1	83.1
70	68.0	83.1	83.1	68.0	83.1	83.1
80	68.0	83.1	83.1	68.0	83.1	83.1
90	68.0	83.1	83.1	68.0	83.1	83.1
100	68.0	83.1	83.1	68.0	83.1	83.1
110	68.0	83.1	83.1	68.0	83.1	83.1
120	68.0	83.1	83.1	68.0	83.1	83.1
130	68.0	83.1	83.1	68.0	83.1	83.1
140	68.0	83.1	83.1	68.0	83.1	83.1
150	68.0	83.1	83.1	68.0	83.1	83.1
160	68.0	83.1	83.1	68.0	83.1	83.1
170	68.0	83.1	83.1	68.0	85.5	83.1
180	68.0	83.1	83.1	68.0	87.9	83.1
190	68.0	83.1	83.1	68.0	90.2	83.1
200	68.0	83.1	83.1	68.0	92.3	83.1
210	68.0	83.1	83.1	68.0	94.3	83.1
220	68.0	83.1	83.1	68.0	96.3	83.1
230	68.0	83.1	83.1	68.0	98.1	83.1

TABLE B-1. Dresden 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)
240	68.0	83.1	83.1	68.0	99.9	83.1
250	68.0	83.1	83.1	68.0	101.6	83.1
260	68.0	83.1	83.1	68.0	103.2	83.1
270	68.0	83.1	83.1	68.0	104.8	83.1
280	68.0	83.1	83.1	68.0	106.3	83.1
290	68.0	83.1	83.1	68.0	107.8	83.1
300	68.0	83.1	83.1	68.0	109.2	83.1
310	68.0	83.1	83.1	68.0	110.5	83.1
312.5	68.0	83.1	83.1	68.0	110.9	83.1
312.5	68.0	113.1	113.1	68.0	143.1	143.1
320	68.0	113.1	113.1	68.0	143.1	143.1
330	68.0	113.1	113.1	68.0	143.1	143.1
340	68.0	113.1	113.1	68.0	143.1	143.1
350	68.0	113.1	113.1	68.0	143.1	143.1
360	68.0	113.1	113.1	68.0	143.1	143.1
370	68.0	113.1	113.1	68.0	143.1	143.1
380	68.0	113.1	113.1	68.0	143.1	143.1
390	68.0	113.1	113.1	68.0	143.1	143.1
400	68.0	113.1	113.1	68.0	143.1	143.1
410	68.0	113.1	113.1	68.0	143.1	143.1
420	68.0	113.1	113.1	68.0	143.1	143.1
430	68.0	113.1	113.1	68.0	143.1	143.1
440	68.0	113.1	113.1	68.0	143.1	143.1
450	68.0	113.1	113.1	68.0	143.1	143.1
460	68.0	113.1	113.1	68.0	143.1	143.1
470	68.0	113.1	113.1	68.0	143.1	143.1
480	68.0	113.1	113.1	69.1	143.1	143.1

TABLE B-1. Dresden 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)
490	68.0	113.1	113.1	71.4	143.1	143.1
500	68.0	113.1	113.1	73.6	143.1	143.1
510	68.0	113.1	113.1	75.8	143.1	143.1
520	68.0	113.1	113.1	77.8	143.1	143.1
530	68.0	113.1	113.1	79.8	143.1	143.1
540	68.0	113.1	113.1	81.7	143.1	143.1
550	68.0	113.1	113.1	83.5	143.1	143.1
560	68.0	113.1	113.1	85.3	143.1	143.1
570	68.0	113.1	113.1	87.0	143.1	143.1
580	68.0	113.1	113.1	88.6	143.1	143.1
590	68.0	113.1	113.1	90.2	143.1	143.1
600	68.0	113.1	113.1	91.8	143.1	143.1
610	68.0	113.1	113.1	93.3	143.1	143.1
620	68.0	113.1	113.1	94.7	143.1	143.1
630	68.0	113.1	113.1	96.1	143.1	143.1
640	68.0	113.1	113.1	97.5	143.1	143.1
650	68.0	113.1	113.1	98.8	143.1	143.1
660	68.0	113.1	113.1	100.1	143.1	143.1
670	68.0	113.1	113.1	101.4	143.1	143.1
680	68.0	113.1	113.1	102.7	143.1	143.1
690	68.0	113.1	113.1	103.9	143.1	143.1
700	69.2	113.1	113.1	105.0	143.1	143.1
710	70.7	113.1	113.1	106.2	143.1	143.1
720	72.1	113.1	113.1	107.3	143.1	143.1
730	73.5	113.1	113.1	108.4	143.5	143.1
740	74.8	113.1	113.1	109.5	143.9	143.1
750	76.1	113.1	113.1	110.6	144.2	143.1

TABLE B-1. Dresden 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)
760	77.4	113.1	113.1	111.6	144.6	143.1
770	78.6	113.1	113.1	112.6	145.0	143.1
780	79.8	113.1	113.1	113.6	145.4	143.1
790	81.0	113.1	113.1	114.6	145.8	143.1
800	82.2	113.1	113.1	115.5	146.1	143.1
810	83.3	113.1	113.1	116.5	146.5	143.1
820	84.4	113.1	113.1	117.4	146.9	143.1
830	85.5	113.1	113.1	118.3	147.2	143.1
840	86.5	113.1	113.1	119.2	147.6	143.1
850	87.6	113.1	113.1	120.0	147.9	143.1
860	88.6	113.1	113.1	120.9	148.3	143.1
870	89.6	113.1	113.1	121.7	148.6	143.1
880	90.5	113.6	113.1	122.6	149.0	143.1
890	91.5	114.3	113.1	123.4	149.3	143.1
900	92.4	114.9	113.1	124.2	149.7	143.2
910	93.4	115.6	113.1	125.0	150.0	143.9
920	94.3	116.2	113.1	125.7	150.4	144.6
930	95.1	116.9	114.0	126.5	150.7	145.3
940	96.0	117.5	115.0	127.3	151.0	146.0
950	96.9	118.1	115.9	128.0	151.4	146.7
960	97.7	118.7	116.8	128.7	151.7	147.3
970	98.6	119.3	117.8	129.5	152.0	148.0
980	99.4	119.9	118.7	130.2	152.4	148.6
990	100.2	120.5	119.5	130.9	152.7	149.3
1000	101.0	121.1	120.4	131.6	153.0	149.9
1010	101.7	121.7	121.2	132.2	153.3	150.6
1020	102.5	122.2	122.1	132.9	153.6	151.2

TABLE B-1. Dresden 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)
1030	103.3	122.8	122.9	133.6	154.0	151.8
1040	104.0	123.4	123.7	134.2	154.3	152.4
1050	104.7	123.9	124.5	134.9	154.6	153.0
1060	105.4	124.5	125.3	135.5	154.9	153.6
1070	106.2	125.0	126.1	136.1	155.2	154.2
1080	106.9	125.5	126.8	136.8	155.5	154.8
1090	107.6	126.1	127.6	137.4	155.8	155.3
1100	108.2	126.6	128.3	138.0	156.1	155.9
1105	108.6	126.8	128.7	138.3	156.3	156.2
1110	108.9	127.1	129.0	138.6	156.4	156.4
1120	109.6	127.6	129.7	139.2	156.7	157.0
1130	110.2	128.1	130.5	139.8	157.0	157.5
1140	110.9	128.6	131.2	140.3	157.3	158.1
1150	111.5	129.1	131.8	140.9	157.6	158.6
1160	112.1	129.6	132.5	141.5	157.9	159.1
1170	112.8	130.1	133.2	142.0	158.2	159.7
1180	113.4	130.6	133.8	142.6	158.5	160.2
1190	114.0	131.1	134.5	143.1	158.7	160.7
1200	114.6	131.5	135.1	143.7	159.0	161.2
1210	115.2	132.0	135.8	144.2	159.3	161.7
1220	115.8	132.5	136.4	144.8	159.6	162.2
1230	116.3	132.9	137.0	145.3	159.9	162.7
1240	116.9	133.4	137.6	145.8	160.2	163.2
1250	117.5	133.8	138.2	146.3	160.4	163.7
1260	118.0	134.3	138.8	146.8	160.7	164.2
1270	118.6	134.7	139.4	147.3	161.0	164.6
1280	119.1	135.2	140.0	147.8	161.2	165.1

TABLE B-1. Dresden 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)
1290	119.7	135.6	140.6	148.3	161.5	165.6
1300	120.2	136.0	141.1	148.8	161.8	166.0
1310	120.7	136.5	141.7	149.3	162.1	166.5
1320	121.3	136.9	142.3	149.8	162.3	166.9
1330	121.8	137.3	142.8	150.2	162.6	167.4
1340	122.3	137.7	143.4	150.7	162.8	167.8
1350	122.8	138.1	143.9	151.2	163.1	168.3
1360	123.3	138.6	144.4	151.6	163.4	168.7
1370	123.8	139.0	145.0	152.1	163.6	169.1
1380	124.3	139.4	145.5	152.5	163.9	169.6
1390	124.8	139.8	146.0	153.0	164.1	170.0
1400	125.3	140.2	146.5	153.4	164.4	170.4

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
0	68.0	83.1	68.0	83.1	83.1
10	68.0	83.1	68.0	83.1	83.1
20	68.0	83.1	68.0	83.1	83.1
30	68.0	83.1	68.0	83.1	83.1
40	68.0	83.1	68.0	83.1	83.1
50	68.0	83.1	68.0	83.1	83.1
60	68.0	83.1	68.0	83.1	83.1
70	68.0	83.1	68.0	83.1	87.2
80	68.0	83.1	68.0	83.1	93.2
90	68.0	83.1	68.0	83.1	98.3
100	68.0	83.1	68.0	83.1	102.8
110	68.0	83.1	68.0	83.1	106.9
120	68.0	83.1	68.0	83.1	110.7
130	68.0	83.1	68.0	83.1	114.2
140	68.0	83.1	68.0	83.1	117.4
150	68.0	83.1	68.0	83.1	120.2
160	68.0	83.1	68.0	83.1	122.9
170	68.0	83.1	68.0	85.5	125.5
180	68.0	83.1	68.0	87.9	127.9
190	68.0	83.1	68.0	90.2	130.2
200	68.0	83.1	68.0	92.3	132.3
210	68.0	83.1	68.0	94.3	134.3
220	68.0	83.1	68.0	96.3	136.3

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
230	68.0	83.1	68.0	98.1	138.1
240	68.0	83.1	68.0	99.9	139.9
250	68.0	83.1	68.0	101.6	141.6
260	68.0	83.1	68.0	103.2	143.2
270	68.0	83.1	68.0	104.8	144.8
280	68.0	83.1	68.0	106.3	146.3
290	68.0	83.1	68.0	107.8	147.8
300	68.0	83.1	68.0	109.2	149.2
310	68.0	83.1	68.0	110.5	150.5
312.5	68.0	83.1	68.0	110.9	150.9
312.5	68.0	113.1	68.0	143.1	183.1
320	68.0	113.1	68.0	143.1	183.1
330	68.0	113.1	68.0	143.1	183.1
340	68.0	113.1	68.0	143.1	183.1
350	68.0	113.1	68.0	143.1	183.1
360	68.0	113.1	68.0	143.1	183.1
370	68.0	113.1	68.0	143.1	183.1
380	68.0	113.1	68.0	143.1	183.1
390	68.0	113.1	68.0	143.1	183.1
400	68.0	113.1	68.0	143.1	183.1
410	68.0	113.1	68.0	143.1	183.1
420	68.0	113.1	68.0	143.1	183.1
430	68.0	113.1	68.0	143.1	183.1
440	68.0	113.1	68.0	143.1	183.1
450	68.0	113.1	68.0	143.1	183.1
460	68.0	113.1	68.0	143.1	183.1

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
470	68.0	113.1	68.0	143.1	183.1
480	68.0	113.1	69.1	143.1	183.1
490	68.0	113.1	71.4	143.1	183.1
500	68.0	113.1	73.6	143.1	183.1
510	68.0	113.1	75.8	143.1	183.1
520	68.0	113.1	77.8	143.1	183.1
530	68.0	113.1	79.8	143.1	183.1
540	68.0	113.1	81.7	143.1	183.1
550	68.0	113.1	83.5	143.1	183.1
560	68.0	113.1	85.3	143.1	183.1
570	68.0	113.1	87.0	143.1	183.1
580	68.0	113.1	88.6	143.1	183.1
590	68.0	113.1	90.2	143.1	183.1
600	68.0	113.1	91.8	143.1	183.1
610	68.0	113.1	93.3	143.1	183.1
620	68.0	113.1	94.7	143.1	183.1
630	68.0	113.1	96.1	143.1	183.1
640	68.0	113.1	97.5	143.1	183.1
650	68.0	113.1	98.8	143.1	183.1
660	68.0	113.1	100.1	143.1	183.1
670	68.0	113.1	101.4	143.1	183.1
680	68.0	113.1	102.7	143.1	183.1
690	68.0	113.1	103.9	143.1	183.1
700	69.2	113.1	105.0	143.1	183.1
710	70.7	113.1	106.2	143.1	183.1
720	72.1	113.1	107.3	143.1	183.1

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
730	73.5	113.1	108.4	143.5	183.5
740	74.8	113.1	109.5	143.9	183.9
750	76.1	113.1	110.6	144.2	184.2
760	77.4	113.1	111.6	144.6	184.6
770	78.6	113.1	112.6	145.0	185.0
780	79.8	113.1	113.6	145.4	185.4
790	81.0	113.1	114.6	145.8	185.8
800	82.2	113.1	115.5	146.1	186.1
810	83.3	113.1	116.5	146.5	186.5
820	84.4	113.1	117.4	146.9	186.9
830	85.5	113.1	118.3	147.2	187.2
840	86.5	113.1	119.2	147.6	187.6
850	87.6	113.1	120.0	147.9	187.9
860	88.6	113.1	120.9	148.3	188.3
870	89.6	113.1	121.7	148.6	188.6
880	90.5	113.6	122.6	149.0	189.0
890	91.5	114.3	123.4	149.3	189.3
900	92.4	114.9	124.2	149.7	189.7
910	93.4	115.6	125.0	150.0	190.0
920	94.3	116.2	125.7	150.4	190.4
930	95.1	116.9	126.5	150.7	190.7
940	96.0	117.5	127.3	151.0	191.0
950	96.9	118.1	128.0	151.4	191.4
960	97.7	118.7	128.7	151.7	191.7
970	98.6	119.3	129.5	152.0	192.0
980	99.4	119.9	130.2	152.4	192.4

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
990	100.2	120.5	130.9	152.7	192.7
1000	101.0	121.1	131.6	153.0	193.0
1010	101.7	121.7	132.2	153.3	193.3
1020	102.5	122.2	132.9	153.6	193.6
1030	103.3	122.9	133.6	154.0	194.0
1040	104.0	123.7	134.2	154.3	194.3
1050	104.7	124.5	134.9	154.6	194.6
1060	105.4	125.3	135.5	154.9	194.9
1070	106.2	126.1	136.1	155.2	195.2
1080	106.9	126.8	136.8	155.5	195.5
1090	107.6	127.6	137.4	155.8	195.8
1100	108.2	128.3	138.0	156.1	196.1
1105	108.6	128.7	138.3	156.3	196.3
1110	108.9	129.0	138.6	156.4	196.4
1120	109.6	129.7	139.2	157.0	197.0
1130	110.2	130.5	139.8	157.5	197.5
1140	110.9	131.2	140.3	158.1	198.1
1150	111.5	131.8	140.9	158.6	198.6
1160	112.1	132.5	141.5	159.1	199.1
1170	112.8	133.2	142.0	159.7	199.7
1180	113.4	133.8	142.6	160.2	200.2
1190	114.0	134.5	143.1	160.7	200.7
1200	114.6	135.1	143.7	161.2	201.2
1210	115.2	135.8	144.2	161.7	201.7
1220	115.8	136.4	144.8	162.2	202.2
1230	116.3	137.0	145.3	162.7	202.7

TABLE B-2. Dresden 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 5-9, 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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
1240	116.9	137.6	145.8	163.2	203.2
1250	117.5	138.2	146.3	163.7	203.7
1260	118.0	138.8	146.8	164.2	204.2
1270	118.6	139.4	147.3	164.6	204.6
1280	119.1	140.0	147.8	165.1	205.1
1290	119.7	140.6	148.3	165.6	205.6
1300	120.2	141.1	148.8	166.0	206.0
1310	120.7	141.7	149.3	166.5	206.5
1320	121.3	142.3	149.8	166.9	206.9
1330	121.8	142.8	150.2	167.4	207.4
1340	122.3	143.4	150.7	167.8	207.8
1350	122.8	143.9	151.2	168.3	208.3
1360	123.3	144.4	151.6	168.7	208.7
1370	123.8	145.0	152.1	169.1	209.1
1380	124.3	145.5	152.5	169.6	209.6
1390	124.8	146.0	153.0	170.0	210.0
1400	125.3	146.5	153.4	170.4	210.4

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
0	68.0	83.1	83.1	68.0	83.1	83.1
10	68.0	83.1	83.1	68.0	83.1	83.1
20	68.0	83.1	83.1	68.0	83.1	83.1
30	68.0	83.1	83.1	68.0	83.1	83.1
40	68.0	83.1	83.1	68.0	83.1	83.1
50	68.0	83.1	83.1	68.0	83.1	83.1
60	68.0	83.1	83.1	68.0	83.1	83.1
70	68.0	83.1	83.1	68.0	83.1	83.1
80	68.0	83.1	83.1	68.0	83.1	83.1
90	68.0	83.1	83.1	68.0	83.1	83.1
100	68.0	83.1	83.1	68.0	83.1	83.1
110	68.0	83.1	83.1	68.0	83.1	83.1
120	68.0	83.1	83.1	68.0	83.1	83.1
130	68.0	83.1	83.1	68.0	83.1	83.1
140	68.0	83.1	83.1	68.0	83.1	83.1
150	68.0	83.1	83.1	68.0	83.1	83.1
160	68.0	83.1	83.1	68.0	83.1	83.1
170	68.0	83.1	83.1	68.0	85.5	83.1
180	68.0	83.1	83.1	68.0	87.9	83.1
190	68.0	83.1	83.1	68.0	90.2	83.1
200	68.0	83.1	83.1	68.0	92.3	83.1
210	68.0	83.1	83.1	68.0	94.3	83.1
220	68.0	83.1	83.1	68.0	96.3	83.1
230	68.0	83.1	83.1	68.0	98.1	83.1

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
240	68.0	83.1	83.1	68.0	99.9	83.1
250	68.0	83.1	83.1	68.0	101.6	83.1
260	68.0	83.1	83.1	68.0	103.2	83.1
270	68.0	83.1	83.1	68.0	104.8	83.1
280	68.0	83.1	83.1	68.0	106.3	83.1
290	68.0	83.1	83.1	68.0	107.8	83.1
300	68.0	83.1	83.1	68.0	109.2	83.1
310	68.0	83.1	83.1	68.0	110.5	83.1
312.5	68.0	83.1	83.1	68.0	110.9	83.1
312.5	68.0	113.1	113.1	68.0	143.1	143.1
320	68.0	113.1	113.1	68.0	143.1	143.1
330	68.0	113.1	113.1	68.0	143.1	143.1
340	68.0	113.1	113.1	68.0	143.1	143.1
350	68.0	113.1	113.1	68.0	143.1	143.1
360	68.0	113.1	113.1	68.0	143.1	143.1
370	68.0	113.1	113.1	68.0	143.1	143.1
380	68.0	113.1	113.1	68.0	143.1	143.1
390	68.0	113.1	113.1	68.0	143.1	143.1
400	68.0	113.1	113.1	68.0	143.1	143.1
410	68.0	113.1	113.1	68.0	143.1	143.1
420	68.0	113.1	113.1	68.0	143.1	143.1
430	68.0	113.1	113.1	68.0	143.1	143.1
440	68.0	113.1	113.1	68.0	143.1	143.1
450	68.0	113.1	113.1	68.0	143.1	143.1
460	68.0	113.1	113.1	68.0	143.1	143.1
470	68.0	113.1	113.1	68.0	143.1	143.1
480	68.0	113.1	113.1	69.1	143.1	143.1

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
490	68.0	113.1	113.1	71.4	143.1	143.1
500	68.0	113.1	113.1	73.6	143.1	143.1
510	68.0	113.1	113.1	75.8	143.1	143.1
520	68.0	113.1	113.1	77.8	143.1	143.1
530	68.0	113.1	113.1	79.8	143.1	143.1
540	68.0	113.1	113.1	81.7	143.1	143.1
550	68.0	113.1	113.1	83.5	143.1	143.1
560	68.0	113.1	113.1	85.3	143.1	143.1
570	68.0	113.1	113.1	87.0	143.1	143.1
580	68.0	113.1	113.1	88.6	143.1	143.1
590	68.0	113.1	113.1	90.2	143.1	143.1
600	68.0	113.1	113.1	91.8	143.1	143.1
610	68.0	113.1	113.1	93.3	143.1	143.1
620	68.0	113.1	113.1	94.7	143.1	143.1
630	68.0	113.1	113.1	96.1	143.1	143.1
640	68.0	113.1	113.1	97.5	143.1	143.1
650	68.0	113.1	113.1	98.8	143.1	143.1
660	68.0	113.1	113.1	100.1	143.1	143.1
670	68.0	113.1	113.1	101.4	143.1	143.1
680	68.0	113.1	113.1	102.7	143.1	143.1
690	68.0	113.1	113.1	103.9	143.1	143.1
700	69.2	113.1	113.1	105.0	143.1	144.0
710	70.7	113.1	113.1	106.2	143.1	145.1
720	72.1	113.1	113.1	107.3	143.1	146.0
730	73.5	113.1	113.1	108.4	143.5	147.0
740	74.8	113.1	113.1	109.5	143.9	148.0
750	76.1	113.1	113.1	110.6	144.2	148.9

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
760	77.4	113.1	113.1	111.6	144.6	149.8
770	78.6	113.1	113.3	112.6	145.0	150.7
780	79.8	113.1	114.7	113.6	145.4	151.6
790	81.0	113.1	116.1	114.6	145.8	152.5
800	82.2	113.1	117.4	115.5	146.1	153.3
810	83.3	113.1	118.7	116.5	146.5	154.2
820	84.4	113.1	120.0	117.4	146.9	155.0
830	85.5	113.1	121.2	118.3	147.2	155.8
840	86.5	113.1	122.4	119.2	147.6	156.6
850	87.6	113.1	123.5	120.0	147.9	157.4
860	88.6	113.1	124.7	120.9	148.3	158.2
870	89.6	113.1	125.8	121.7	148.6	158.9
880	90.5	113.6	126.9	122.6	149.0	159.7
890	91.5	114.3	128.0	123.4	149.3	160.4
900	92.4	114.9	129.0	124.2	149.7	161.2
910	93.4	115.6	130.0	125.0	150.0	161.9
920	94.3	116.2	131.0	125.7	150.4	162.6
930	95.1	116.9	132.0	126.5	150.7	163.3
940	96.0	117.5	133.0	127.3	151.0	164.0
950	96.9	118.1	133.9	128.0	151.4	164.7
960	97.7	118.7	134.8	128.7	151.7	165.3
970	98.6	119.3	135.8	129.5	152.0	166.0
980	99.4	119.9	136.7	130.2	152.4	166.6
990	100.2	120.5	137.5	130.9	152.7	167.3
1000	101.0	121.1	138.4	131.6	153.0	167.9
1010	101.7	121.7	139.2	132.2	153.3	168.6
1020	102.5	122.2	140.1	132.9	153.6	169.2

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
1030	103.3	122.8	140.9	133.6	154.0	169.8
1040	104.0	123.4	141.7	134.2	154.3	170.4
1050	104.7	123.9	142.5	134.9	154.6	171.0
1060	105.4	124.5	143.3	135.5	154.9	171.6
1070	106.2	125.0	144.1	136.1	155.2	172.2
1080	106.9	125.5	144.8	136.8	155.5	172.8
1090	107.6	126.1	145.6	137.4	155.8	173.3
1100	108.2	126.6	146.3	138.0	156.1	173.9
1105	108.6	126.8	146.7	138.3	156.3	174.2
1110	108.9	127.1	147.0	138.6	156.4	174.4
1120	109.6	127.6	147.7	139.2	156.7	175.0
1130	110.2	128.1	148.5	139.8	157.0	175.5
1140	110.9	128.6	149.2	140.3	157.3	176.1
1150	111.5	129.1	149.8	140.9	157.6	176.6
1160	112.1	129.6	150.5	141.5	157.9	177.1
1170	112.8	130.1	151.2	142.0	158.2	177.7
1180	113.4	130.6	151.8	142.6	158.5	178.2
1190	114.0	131.1	152.5	143.1	158.7	178.7
1200	114.6	131.5	153.1	143.7	159.0	179.2
1210	115.2	132.0	153.8	144.2	159.3	179.7
1220	115.8	132.5	154.4	144.8	159.6	180.2
1230	116.3	132.9	155.0	145.3	159.9	180.7
1240	116.9	133.4	155.6	145.8	160.2	181.2
1250	117.5	133.8	156.2	146.3	160.4	181.7
1260	118.0	134.3	156.8	146.8	160.7	182.2
1270	118.6	134.7	157.4	147.3	161.0	182.6
1280	119.1	135.2	158.0	147.8	161.2	183.1

TABLE B-3. Dresden Unit 3 P-T Curve Values for 54 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, 5-4,5-5, 5-6 and 5-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
1290	119.7	135.6	158.6	148.3	161.5	183.6
1300	120.2	136.0	159.1	148.8	161.8	184.0
1310	120.7	136.5	159.7	149.3	162.1	184.5
1320	121.3	136.9	160.3	149.8	162.3	184.9
1330	121.8	137.3	160.8	150.2	162.6	185.4
1340	122.3	137.7	161.4	150.7	162.8	185.8
1350	122.8	138.1	161.9	151.2	163.1	186.3
1360	123.3	138.6	162.4	151.6	163.4	186.7
1370	123.8	139.0	163.0	152.1	163.6	187.1
1380	124.3	139.4	163.5	152.5	163.9	187.6
1390	124.8	139.8	164.0	153.0	164.1	188.0
1400	125.3	140.2	164.5	153.4	164.4	188.4

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
0	68.0	83.1	68.0	83.1	83.1
10	68.0	83.1	68.0	83.1	83.1
20	68.0	83.1	68.0	83.1	83.1
30	68.0	83.1	68.0	83.1	83.1
40	68.0	83.1	68.0	83.1	83.1
50	68.0	83.1	68.0	83.1	83.1
60	68.0	83.1	68.0	83.1	83.1
70	68.0	83.1	68.0	83.1	87.2
80	68.0	83.1	68.0	83.1	93.2
90	68.0	83.1	68.0	83.1	98.3
100	68.0	83.1	68.0	83.1	102.8
110	68.0	83.1	68.0	83.1	106.9
120	68.0	83.1	68.0	83.1	110.7
130	68.0	83.1	68.0	83.1	114.2
140	68.0	83.1	68.0	83.1	117.4
150	68.0	83.1	68.0	83.1	120.2
160	68.0	83.1	68.0	83.1	122.9
170	68.0	83.1	68.0	85.5	125.5
180	68.0	83.1	68.0	87.9	127.9
190	68.0	83.1	68.0	90.2	130.2
200	68.0	83.1	68.0	92.3	132.3
210	68.0	83.1	68.0	94.3	134.3
220	68.0	83.1	68.0	96.3	136.3

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
230	68.0	83.1	68.0	98.1	138.1
240	68.0	83.1	68.0	99.9	139.9
250	68.0	83.1	68.0	101.6	141.6
260	68.0	83.1	68.0	103.2	143.2
270	68.0	83.1	68.0	104.8	144.8
280	68.0	83.1	68.0	106.3	146.3
290	68.0	83.1	68.0	107.8	147.8
300	68.0	83.1	68.0	109.2	149.2
310	68.0	83.1	68.0	110.5	150.5
312.5	68.0	83.1	68.0	110.9	150.9
312.5	68.0	113.1	68.0	143.1	183.1
320	68.0	113.1	68.0	143.1	183.1
330	68.0	113.1	68.0	143.1	183.1
340	68.0	113.1	68.0	143.1	183.1
350	68.0	113.1	68.0	143.1	183.1
360	68.0	113.1	68.0	143.1	183.1
370	68.0	113.1	68.0	143.1	183.1
380	68.0	113.1	68.0	143.1	183.1
390	68.0	113.1	68.0	143.1	183.1
400	68.0	113.1	68.0	143.1	183.1
410	68.0	113.1	68.0	143.1	183.1
420	68.0	113.1	68.0	143.1	183.1
430	68.0	113.1	68.0	143.1	183.1
440	68.0	113.1	68.0	143.1	183.1
450	68.0	113.1	68.0	143.1	183.1

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
460	68.0	113.1	68.0	143.1	183.1
470	68.0	113.1	68.0	143.1	183.1
480	68.0	113.1	69.1	143.1	183.1
490	68.0	113.1	71.4	143.1	183.1
500	68.0	113.1	73.6	143.1	183.1
510	68.0	113.1	75.8	143.1	183.1
520	68.0	113.1	77.8	143.1	183.1
530	68.0	113.1	79.8	143.1	183.1
540	68.0	113.1	81.7	143.1	183.1
550	68.0	113.1	83.5	143.1	183.1
560	68.0	113.1	85.3	143.1	183.1
570	68.0	113.1	87.0	143.1	183.1
580	68.0	113.1	88.6	143.1	183.1
590	68.0	113.1	90.2	143.1	183.1
600	68.0	113.1	91.8	143.1	183.1
610	68.0	113.1	93.3	143.1	183.1
620	68.0	113.1	94.7	143.1	183.1
630	68.0	113.1	96.1	143.1	183.1
640	68.0	113.1	97.5	143.1	183.1
650	68.0	113.1	98.8	143.1	183.1
660	68.0	113.1	100.1	143.1	183.1
670	68.0	113.1	101.4	143.1	183.1
680	68.0	113.1	102.7	143.1	183.1
690	68.0	113.1	103.9	143.1	183.1
700	69.2	113.1	105.0	144.0	184.0

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
710	70.7	113.1	106.2	145.1	185.1
720	72.1	113.1	107.3	146.0	186.0
730	73.5	113.1	108.4	147.0	187.0
740	74.8	113.1	109.5	148.0	188.0
750	76.1	113.1	110.6	148.9	188.9
760	77.4	113.1	111.6	149.8	189.8
770	78.6	113.3	112.6	150.7	190.7
780	79.8	114.7	113.6	151.6	191.6
790	81.0	116.1	114.6	152.5	192.5
800	82.2	117.4	115.5	153.3	193.3
810	83.3	118.7	116.5	154.2	194.2
820	84.4	120.0	117.4	155.0	195.0
830	85.5	121.2	118.3	155.8	195.8
840	86.5	122.4	119.2	156.6	196.6
850	87.6	123.5	120.0	157.4	197.4
860	88.6	124.7	120.9	158.2	198.2
870	89.6	125.8	121.7	158.9	198.9
880	90.5	126.9	122.6	159.7	199.7
890	91.5	128.0	123.4	160.4	200.4
900	92.4	129.0	124.2	161.2	201.2
910	93.4	130.0	125.0	161.9	201.9
920	94.3	131.0	125.7	162.6	202.6
930	95.1	132.0	126.5	163.3	203.3
940	96.0	133.0	127.3	164.0	204.0
950	96.9	133.9	128.0	164.7	204.7

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
960	97.7	134.8	128.7	165.3	205.3
970	98.6	135.8	129.5	166.0	206.0
980	99.4	136.7	130.2	166.6	206.6
990	100.2	137.5	130.9	167.3	207.3
1000	101.0	138.4	131.6	167.9	207.9
1010	101.7	139.2	132.2	168.6	208.6
1020	102.5	140.1	132.9	169.2	209.2
1030	103.3	140.9	133.6	169.8	209.8
1040	104.0	141.7	134.2	170.4	210.4
1050	104.7	142.5	134.9	171.0	211.0
1060	105.4	143.3	135.5	171.6	211.6
1070	106.2	144.1	136.1	172.2	212.2
1080	106.9	144.8	136.8	172.8	212.8
1090	107.6	145.6	137.4	173.3	213.3
1100	108.2	146.3	138.0	173.9	213.9
1105	108.6	146.7	138.3	174.2	214.2
1110	108.9	147.0	138.6	174.4	214.4
1120	109.6	147.7	139.2	175.0	215.0
1130	110.2	148.5	139.8	175.5	215.5
1140	110.9	149.2	140.3	176.1	216.1
1150	111.5	149.8	140.9	176.6	216.6
1160	112.1	150.5	141.5	177.1	217.1
1170	112.8	151.2	142.0	177.7	217.7
1180	113.4	151.8	142.6	178.2	218.2
1190	114.0	152.5	143.1	178.7	218.7

TABLE B-4. Dresden Unit 3 Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures 5-10, 5-13 and 5-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
1200	114.6	153.1	143.7	179.2	219.2
1210	115.2	153.8	144.2	179.7	219.7
1220	115.8	154.4	144.8	180.2	220.2
1230	116.3	155.0	145.3	180.7	220.7
1240	116.9	155.6	145.8	181.2	221.2
1250	117.5	156.2	146.3	181.7	221.7
1260	118.0	156.8	146.8	182.2	222.2
1270	118.6	157.4	147.3	182.6	222.6
1280	119.1	158.0	147.8	183.1	223.1
1290	119.7	158.6	148.3	183.6	223.6
1300	120.2	159.1	148.8	184.0	224.0
1310	120.7	159.7	149.3	184.5	224.5
1320	121.3	160.3	149.8	184.9	224.9
1330	121.8	160.8	150.2	185.4	225.4
1340	122.3	161.4	150.7	185.8	225.8
1350	122.8	161.9	151.2	186.3	226.3
1360	123.3	162.4	151.6	186.7	226.7
1370	123.8	163.0	152.1	187.1	227.1
1380	124.3	163.5	152.5	187.6	227.6
1390	124.8	164.0	153.0	188.0	228.0
1400	125.3	164.5	153.4	188.4	228.4

APPENDIX C

OPERATING AND TEMPERATURE MONITORING REQUIREMENTS

C.1 NON-BELTLINE MONITORING DURING PRESSURE TESTS

It is likely that, during leak and hydrostatic pressure testing, the bottom head temperature may be significantly cooler than the beltline. This condition can occur in the bottom head when the recirculation pumps are operating at low speed, or are off, and injection through the control rod drives is used to pressurize the vessel. By using a bottom head curve, the required test temperature at the bottom head could be lower than the required test temperature at the beltline, avoiding the necessity of heating the bottom head to the same requirements of the vessel beltline.

One condition on monitoring the bottom head separately is that it must be demonstrated that the vessel beltline temperature can be accurately monitored during pressure testing. An experiment has been conducted at a BWR-4 that showed that thermocouples on the vessel near the feedwater nozzles, or temperature measurements of water in the recirculation loops provide good estimates of the beltline temperature during pressure testing. Thermocouples on the RPV flange to shell junction outside surface should be used to monitor compliance with upper vessel curve. Thermocouples on the bottom head outside surface should be used to monitor compliance with bottom head curves. A description of these measurements is given in GE SIL 430, attached in Appendix D. First, however, it should be determined whether there are significant temperature differences between the beltline region and the bottom head region.

C.2 DETERMINING WHICH CURVE TO FOLLOW

The following subsections outline the criteria needed for determining which curve is governing during different situations. The application of the P-T curves and some of the assumptions inherent in the curves to plant operation is dependent on the proper monitoring of vessel temperatures. A discussion of monitoring of vessel temperatures can be found in Section 4 of the pressure-temperature curve report prepared in 1989 [1].

C.2.1 Curve A: Pressure Test

Curve A should be used during pressure tests at times when the coolant temperature is changing by ≤20°F per hour. If the coolant is experiencing a higher heating or cooling rate in preparation for or following a pressure test, Curve B applies.

C.2.2 Curve B: Non-Nuclear Heatup/Cooldown

Curve B should be used whenever Curve A or Curve C do not apply. In other words, the operator must follow this curve during times when the coolant is heating or cooling faster than 20°F per hour during a hydrotest and when the core is not critical.

C.2.3 Curve C: Core Critical Operation

The operator must comply with this curve whenever the core is critical. An exception to this principle is for low-level physics tests; Curve B must be followed during these situations.

C.3 REACTOR OPERATION VERSUS OPERATING LIMITS

For most reactor operating conditions, coolant pressure and temperature are at saturation conditions, which are well into the acceptable operating area (to the right of the P-T curves). The operations where P-T curve compliance is typically monitored closely are planned events, such as vessel boltup, leakage testing and startup/shutdown operations, where operator actions can directly influence vessel pressures and temperatures.

The most severe unplanned transients relative to the P-T curves are those that result from SCRAMs, which sometimes include recirculation pump trips. Depending on operator responses following pump trip, there can be cases where stratification of colder water in the bottom head occurs while the vessel pressure is still relatively high. Experience with such events has shown that operator action is necessary to avoid P-T curve exceedance, but there is adequate time for operators to respond.

In summary, there are several operating conditions where careful monitoring of P-T conditions against the curves is needed:

- Head flange boltup
- Leakage test (Curve A compliance)
- Startup (coolant temperature change of less than or equal to 100°F in one hour period heatup)
- Shutdown (coolant temperature change of less than or equal to 100°F in one hour period cooldown)
- Recirculation pump trip, bottom head stratification (Curve B compliance)

APPENDIX C REFERENCES:

1. T.A. Caine, "Pressure-Temperature Curves Per Regulatory Guide 1.99, Revision 2 for the Dresden and Quad Cities Nuclear Power Stations", SASR 89-54, Revision 1, August 1989.

APPENDIX D

GE SIL 430

September 27, 1985 SIL No. 430

REACTOR PRESSURE VESSEL TEMPERATURE MONITORING

Recently, several BWR owners with plants in initial startup have had questions concerning primary and alternate reactor pressure vessel (RPV) temperature monitoring measurements for complying with RPV brittle fracture and thermal stress requirements. As such, the purpose of this Service Information Letter is to provide a summary of RPV temperature monitoring measurements, their primary and alternate uses and their limitations (See the attached table). Of basic concern is temperature monitoring to comply with brittle fracture temperature limits and for vessel thermal stresses during RPV heatup and cooldown. General Electric recommends that BWR owners/operators review this table against their current practices and evaluate any inconsistencies.

TABLE OF RPV TEMPERATURE MONITORING MEASUREMENTS (Typical)

Measurement	Use	Limitations
Steam dome saturation temperature as determined from main steam instrument line pressure	Primary measurement above 212°F for Tech Spec 100°F/hr heatup and cooldown rate.	Must convert saturated steam pressure to temperature.
Recirc suction line coolant temperature.	Primary measurement below 212°F for Tech Spec 100°F/hr heatup and cooldown rate.	Must have recirc flow. Must comply with SIL 251 to avoid vessel stratification.
	Alternate measurement above 212°F.	When above 212°F need to allow for temperature variations (up to 10-15°F lower than steam dome saturation temperature) caused primarily by FW flow variations.

TABLE OF RPV TEMPERATURE MONITORING MEASUREMENTS (CONTINUED)
(Typical)

Measurement	Use	Limitations
	Alternate measurement for RPV drain line temperature (can use to comply with delta T limit between steam dome saturation temperature and bottom head drain line temperature).	
RHR heat exchanger inlet coolant temperature	Alternate measurement for Tech Spec 100°F/hr cooldown rate when in shutdown cooling mode.	Must have previously correlated RHR inlet coolant temperature versus RPV coolant temperature.
RPV drain line coolant temperature	Primary measurement to comply with Tech Spec delta T limit between steam dome saturated temp and drain line coolant temperature.	Must have drain line flow. Otherwise, lower than actual temperature and higher delta T's will be indicated Delta T limit is 100°F for BWR/6s and 145°F for earlier BWRs.
	Primary measurement to comply with Tech Spec brittle fracture limits during cooldown.	Must have drain line flow. Use to verify compliance with Tech Spec minimum metal temperature/reactor pressure curves (using drain line temperature to represent bottom head metal temperature).
	Alternate information only measurement for bottom head inside/ outside metal surface temperatures.	Must compensate for outside metal temperature lag during heatup/cooldown. Should have drain line flow.

TABLE OF RPV TEMPERATURE MONITORING MEASUREMENTS (CONTINUED)
(Typical)

Measurement	Use	Limitations
Closure head flanges outside surface T/Cs	Primary measurement for BWR/6s to comply with Tech Spec brittle fracture metal temperature limit for head boltup.	Use for metal (not coolant) temperature. Install temporary T/Cs for alternate measurement, if required.
	One of two primary measurements for BWR/6s for hydro test.	
RPV flange-to-shell junction outside surface T/Cs	Primary measurement for BWRs earlier than 6s to comply with Tech Spec brittle fracture metal temperature limit for head boltup.	Use for metal (not coolant) temperature. Response faster than closure head flange T/Cs.
	One of two primary measurements for BWRs earlier than 6s for hydro test. Preferred in lieu of closure head flange T/Cs if available.	Use RPV closure head flange outside surface as alternate measurement.
RPV shell outside surface T/Cs	Information only.	Slow to respond to RPV coolant changes. Not available on BWR/6s.
Top head outside surface T/Cs	Information only.	Very slow to respond to RPV coolant changes. Not available on BWR/6s.

TABLE OF RPV TEMPERATURE MONITORING MEASUREMENTS (CONTINUED)

(Typical)

Measurement	Use	Limitations
Bottom head outside surface T/Cs	1 of 2 primary measurements to comply with Tech Spec brittle fracture metal temperature limit for hydro test.	Should verify that vessel stratification is not present for vessel hydro. (see SIL No. 251).
	Primary measurement to comply with Tech Spec brittle fracture metal temperature limits during heatup.	Use during heatup to verify compliance with Tech Spec metal temperature/reactor pressure curves.

Note: RPV vendor specified metal T limits for vessel heatup and cooldown should be checked during initial plant startup tests when initial RPV vessel heatup and cooldown tests are run.

Product Reference: B21 Nuclear Boiler

Prepared By: A.C. Tsang

Approved for Issue:
B.H. Eldridge, Mgr.
Service Information
and Analysis

Issued By:
D.L. Allred, Manager
Customer Service Information

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APPENDIX E

DETERMINATION OF BELTLINE REGION AND IMPACT ON FRACTURE TOUGHNESS

10CFR50, Appendix G defines the beltline region of the reactor vessel as follows:

"The region of the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage."

To establish the value of peak fluence for identification of beltline materials (as discussed above), the 10CFR50 Appendix H fluence value used to determine the need for a surveillance program was used; the value specified is a peak fluence (E>1 MEV) of 1.0e17 n/cm^2. Therefore, if it can be shown that no nozzles are located where the peak neutron fluence is expected to exceed or equal 1.0e17 n/cm^2, then it can be concluded that all reactor vessel nozzles are outside the beltline region of the reactor vessel, and do not need to be considered in the P-T curve evaluation.

The following dimensions are obtained from the referenced drawings:

Shell # 2 - Top of Active Fuel (TAF): 360.3" (from vessel 0) [1]
Shell # 1 - Bottom of Active Fuel (BAF): 216.3" (from vessel 0) [1]
Top of Recirculation Outlet Nozzle N1 in Shell # 1: 188" (from vessel 0) [2]
Centerline of Recirculation Outlet Nozzle N1 in Shell # 1: 161.5" (from vessel 0) [3]
Top of Recirculation Inlet Nozzle N2 in Shell # 1: 193.3" (from vessel 0) [2]
Centerline of Recirculation Inlet Nozzle N2 in Shell # 1: 181" (from vessel 0) [3]
Girth Weld between Shell Ring #2 and Shell Ring #3: 391.5" (from vessel 0) [3,4]

From [2], it is obvious that the recirculation inlet and outlet nozzles are closest to the beltline region (the top of the recirculation inlet nozzle is ~23" from BAF and the top of the recirculation outlet nozzle is ~28" from BAF), and no other nozzles are within the BAF-TAF region of the reactor vessel. The girth weld between Shell Rings #2 and#3 is ~31" above TAF. Therefore, if it can be shown that the peak fluence at these locations is less than 1.0e17 n/cm^2, it can be safely concluded that all nozzles and welds, other

than those included in Tables 4-3 and 4-4, are outside the beltline region of the reactor vessel.

Based on the bounding 32 and 54 EFPY axial flux profile for pre- and post-EPU [5], the RPV flux level dropped to less than 1e17 n/cm^2 at the same radius at ~1" below the BAF and at ~6" above TAF. The beltline region considered in the development of the P-T curves is adjusted to include the additional 6" above the active fuel region and the additional 1" below the active fuel region. This adjusted beltline region extends from 215.3" to 366.3" above reactor vessel "0" for both 32 and 54 EFPY.

Based on the above, it is concluded that none of the Dresden Unit 3 reactor vessel plates, nozzles or welds, other than those included in Tables 4-3 and 4-4, are in the beltline region.

APPENDIX E REFERENCES:

1. Dresden/Quad Cities LR PT Curves – Data Input Request, Robert Stachniak (Exelon), 4/26/02.
2. Babcock & Wilcox Co. (B&W) Drawing #151803E, Revision 1, "Recirculation Nozzles" (GE-NE VPF# 2252-130-3), Dresden Unit 3.
3. Babcock & Wilcox Co. (B&W) Drawing #26903F, Revision 2, "General Outline" (GE-NE VPF# 2252-139-4), Dresden Unit 3.
4. Babcock & Wilcox Co. (B&W) Drawing # 151797E, Revision 1, "Shell Segment Assembly" (GE-NE VPF# 2252-126-3), Dresden Unit 3.
5. S. Sitaraman, "Dresden and Quad Cities Neutron Flux Evaluation," GE-NE, San Jose, CA, December 2002 (GE-NE-0000-0011-0531-R0, Revision 0)(GE Proprietary Information).

APPENDIX F

CORE NOT CRITICAL CALCULATION FOR THE BOTTOM HEAD (CRD PENETRATION)

TABLE OF CONTENTS

The following outline describes the contents of this Appendix:

F.1 Executive Summary

This Appendix describes the analytical methods used to determine the T-RT_{NDT} value applicable for the Bottom Head Core Not Critical P-T curves. This evaluation uses new finite element fracture mechanics technology developed by the General Electric Company, which is used to augment the methods described in the ASME Boiler and Pressure Vessel Code [1]. [[

]] This method more accurately predicts the expected stress intensity [[

]] The peak stress intensities for the pressure and thermal load cases evaluated are used as inputs into the ASME Code Appendix G evaluation methodology to calculate a T-RT_{NDT}. [[

]]

F.2 Scope

This Appendix describes the analytical methods used to determine the T-RT_{NDT} value applicable for the Bottom Head Core Not Critical P-T curves. This evaluation uses new finite element fracture mechanics technology developed by the General Electric Company, which is used to augment the methods described in the ASME Boiler and Pressure Vessel Code [1]. This Appendix discusses the finite element analysis and the Appendix G [1] calculations separately below.

F.3 Analysis Methods

This section contains technical descriptions of the analytical methods used to perform the BWR Bottom Head fracture mechanics evaluation. The applicability of the current ASME Code, Section XI, Appendix G methods [1] considering the specific bottom head geometry is discussed first, followed by a detailed discussion of the finite element analysis and Appendix G evaluation [1].

F.3.1 Applicability of the ASME Code Appendix G Methods

The methods described in the ASME Code Section XI, Appendix G [1] for demonstrating sufficient margin against brittle fracture in the RPV material are based upon flat plate solutions, which consider uniform stress distributions along the crack tip. The method also suggests that a ¼ wall thickness semi-elliptical flaw with an aspect ratio of 6:1 (length to depth) be considered in the evaluation. When the bottom head specific geometry is considered in more detail the following items become evident:

[[

]]

Noting these items, the applicability of the methods suggested in Appendix G [[

]]. The ASME Code does not preclude using other methods; therefore, a

more detailed [[ ]] finite element fracture mechanics analysis [[ ]] was performed. The stress intensity obtained from this analysis is used in place of that determined using the Appendix G methods [1].

F.3.2 Finite Element Fracture Mechanics Evaluation

An advanced [[ ]] finite element analysis of a BWR bottom head geometry [[ ]] was performed to determine the mode I stress intensity at the tip of a ¼ thickness postulated flaw. [[ ]]

Finite Elements [[ ]]

All Finite Element Analyses were performed using ANSYS Version 6.1 [2]. [[ ]]

Structural Boundary Conditions

The modeled geometry is one-fourth of the Bottom Head hemisphere, so symmetry boundary conditions are used. [[ ]] The mesh is shown in Figure 1.

[[

]]

Material Properties

Two materials are used as per the ASME Code. Material 1 is SA533, which is used to model the vessel. Material 2 [[

]] The ANSYS listing of these materials in (pound-inch-second-°F) units are:

[[

]]

EX is the Young's Modulus, NUXY is the Poisson's Ratio, ALPX is the Thermal Expansion Coefficient, DENS is the Density, KXX is the Thermal Conductivity and C is the Heat Capacity.

Loads

Two loads cases were independently analyzed.

1. Pressure Loading –

   An internal pressure of 1250 psi is applied to the interior of the vessel [[

   ]] In addition, the thin cylindrical shell stress due to this pressure is applied as a blowoff pressure [[ ]] at the upper extremity of the vertical wall of the BWR. Figure 2 shows these loads. [[

   ]]

Figure 2. Pressure Loads

2. [[ ]] Thermal Transient

   [[

   ]]

   Thermal loads are applied to the model as time-dependent convection coefficients and bulk temperatures. Referring to the regions identified in Figure 3, the corresponding values follow. Convection coefficients (h) are in units of BTU/(hr-ft-°F) and temperatures (T) are in °F.

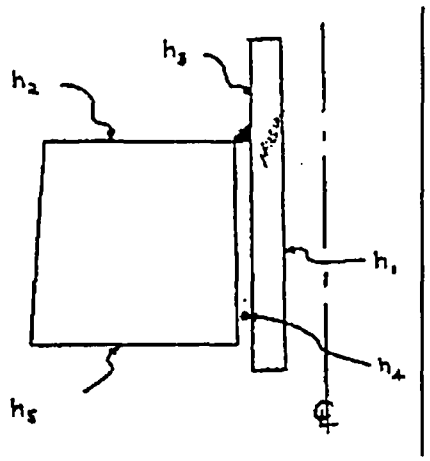

Figure 3. Regions To Which Thermal Loads Are Applied

a. Region 1: h = 25, T = 60

b. Regions 2 and 3:

Time (min)	h_2	h_3	T
0	496	413	[[ ]]
[[ ]]	341	354	[[ ]]
[[ ]]	496	413	[[ ]]
[[ ]]	496	413	[[ ]]
[[ ]] Temperature Plot vs. Time (min.)			

c. Region 4: Adiabatic (exaggerated in size in drawing)

d. Region 5: h = 0.2, T = 100

The peak thermal gradients were used to compute the thermal stresses based on a uniform reference temperature of 70°F.

Crack Configurations

The following four cracks were analyzed:

1. A part through crack, ¼ of the vessel wall thickness deep, measured from inside the vessel, [[

   ]]
2. Same as 1, but depth is measured from outside the vessel
3. Same as 1, [[ ]]
4. Same as 2, [[ ]]

[[

]]

The cracks considered for this analysis [[

]]

[[

]]

[[

]]

Stress Intensity Factor Computation

[[

]]

[[

]]

Benchmarking [[ ]] Methodology

[[

]] The results of these benchmarking studies have demonstrated the accuracy of this method as used for this evaluation.

Pressure Loading Analysis Results

[[

]]

Benchmarking Of Pressure Loading Results

Pressure Loading analyses [[

]]

[[

]]

[[

]]

Thermal Transients Analysis Results

For the thermal transient considered, the inner diameter of the vessel is hotter than the outer diameter; hence the I.D. cracks, [[ ]], close due to the thermal gradient and result in negative Stress Intensity Factors, which is not critical. However, the O.D. cracks open [[ ]]. All results for the thermal transient will consequently be shown for the O.D. [[ ]] crack.

In order to identify the peak gradient, three locations were chosen. [[

]]

[[ ]] Thermal Gradients [[ ]]

Figure 10a is a plot of these three gradients vs. time. Figure 10b is zoomed in to the peaking region.

[[

]]

[[

]]

It can be seen that the peak times and values based on each gradient are:

Gradient	Peak Time (Min.)	Peak Value (°F)
		]]

Stress analyses were performed using the temperature distributions obtained from the thermal analyses at each of these peak times and the Stress Intensity Factors are shown in Figure 11.

[[

]]

F.3.3 ASME Code Appendix G Evaluation

The peak stress intensities for the pressure and thermal load cases evaluated above are used as inputs to the ASME Code Appendix G evaluation methodology [1] to calculate a T-RT_{NDT}. The Core Not Critical Bottom Head P-T curve T-RT_{NDT} is calculated using the formulas listed below:

$$K_I = SF_P \cdot K_{Ip} + SF_T \cdot K_{It}$$

$$SF_p = 2.0$$

$$SF_t = 1.0$$

$$T - RT_{NDT} = \ln\left(\frac{K_I - 33.2}{20.734}\right) \cdot \frac{1}{0.02}$$

Where: KI is the total mode I stress intensity,
KIp is the pressure load stress intensity,
KIt is the thermal load stress intensity,
SFp is the pressure safety factor,
SFt is the thermal safety factor,

Note that the stress intensity is defined in units of: ksi*in$^{1/2}$

F.4 Results

Review of the [[ ]] results above demonstrates that the OD [[ ]] crack exhibits the highest stress intensity for the considered loading. The T-RT_{NDT} to be used in the Core Not Critical Bottom Head P-T curves shall be calculated using the stress intensities obtained at this location. The calculations are shown below:

[[

]]

Note that the pressure stress intensity has been adjusted by the factor [[ ]] to account for the vessel pressure at which the maximum thermal stress occurred. The finite element results summarized above were calculated using a vessel pressure [[ ]]

Comparing the T-RT_{NDT} calculated using the methods described above to that determined using the previous GE methodology, [[ ]]

F.5 Conclusions

For the [[ ]] transient, the appropriate T-RT_{NDT} for use in determining the Bottom Head Core Not Critical P-T curves [[ ]]. Existing Bottom Head Core Not Critical curves developed using the previous GE methodology [[ ]]

F.6 References

1. American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV Code), Section XI, 1998 Edition with Addenda to 2000.

2. ANSYS User's Manual, Version 6.1.

APPENDIX G

BOUNDING P-T CURVES

FOR

DRESDEN UNITS 2 & 3

This appendix contains P-T curves that bound the limiting material characteristics of both Dresden Unit 2 and Dresden Unit 3. Composite and individual curves are presented for both 32 and 54 EFPY similar to those provided within the main body of this report. Table G-1 provides the figure numbers and the corresponding tabulation for each P-T curve presented in this appendix.

Table G-1: Composite and Individual Curves Used To Construct Composite P-T Curves

Curve	Curve Description	Figure Numbers for Presentation of the P-T Curves	Table Numbers for Presentation of the P-T Curves
Curve A			
	Bottom Head Limits (CRD Nozzle)	Figure G-1	Table G-2 & 4
	Upper Vessel Limits (FW Nozzle)	Figure G-2	Table G-2 & 4
	Beltline Limits for 32 EFPY	Figure G-3	Table G-2
	Beltline Limits for 54 EFPY	Figure G-4	Table G-4
Curve B			
	Bottom Head Limits (CRD Nozzle)	Figure G-5	Table G-2 & 4
	Upper Vessel Limits (FW Nozzle)	Figure G-6	Table G-2 & 4
	Beltline Limits for 32 EFPY	Figure G-7	Table G-2
	Beltline Limits for 54 EFPY	Figure G-8	Table G-4
Curve C			
	Composite Curve for 32 EFPY**	Figure G-9	Table G-3
	Composite Curve for 54 EFPY**	Figure G-10	Table G-5
A & B	**Composite Curves for 32 EFPY**		
	Bottom Head and Composite Curve A for 32 EFPY*	Figure G-11	Table G-3
	Bottom Head and Composite Curve B for 32 EFPY*	Figure G-12	Table G-3
A & B	**Composite Curves for 54 EFPY**		
	Bottom Head and Composite Curve A for 54 EFPY*	Figure G-13	Table G-5
	Bottom Head and Composite Curve B for 54 EFPY*	Figure G-14	Table G-5

* The Composite Curve A & B curve is the more limiting of three limits: 10CFR50 Bolt-up Limits, Upper Vessel Limits (FW Nozzle), and Beltline Limits. A separate Bottom Head Limits (CRD Nozzle) curve is individually included on this figure.

** The Composite Curve C curve is the more limiting of four limits: 10CFR50 Bolt-up Limits, Bottom Head Limits (CRD Nozzle), Upper Vessel Limits (FW Nozzle), and Beltline Limits.

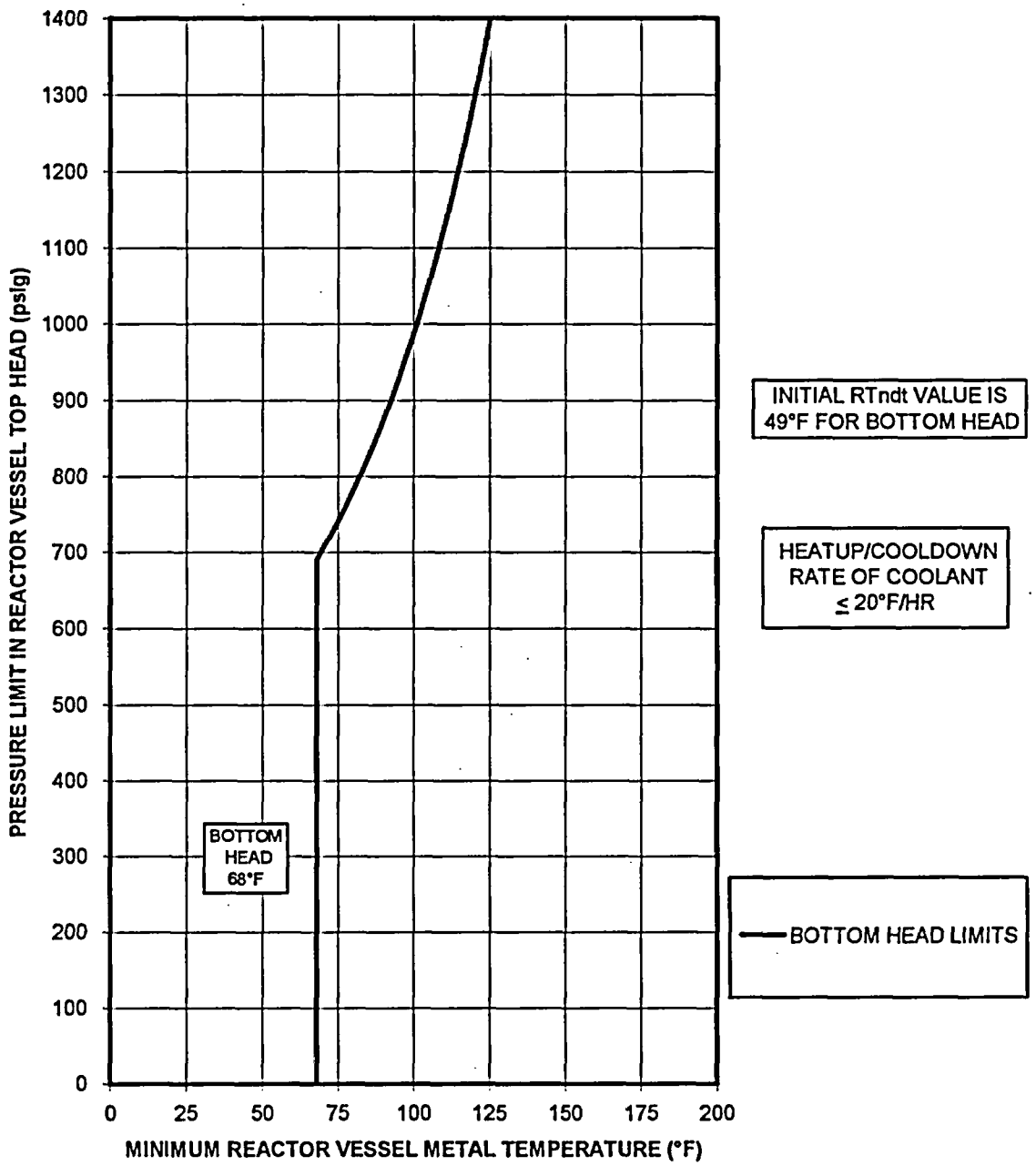

Figure G-1: Bounding Dresden 2&3 Bottom Head P-T Curve for Pressure Test [Curve A]
[20°F/hr or less coolant heatup/cooldown]

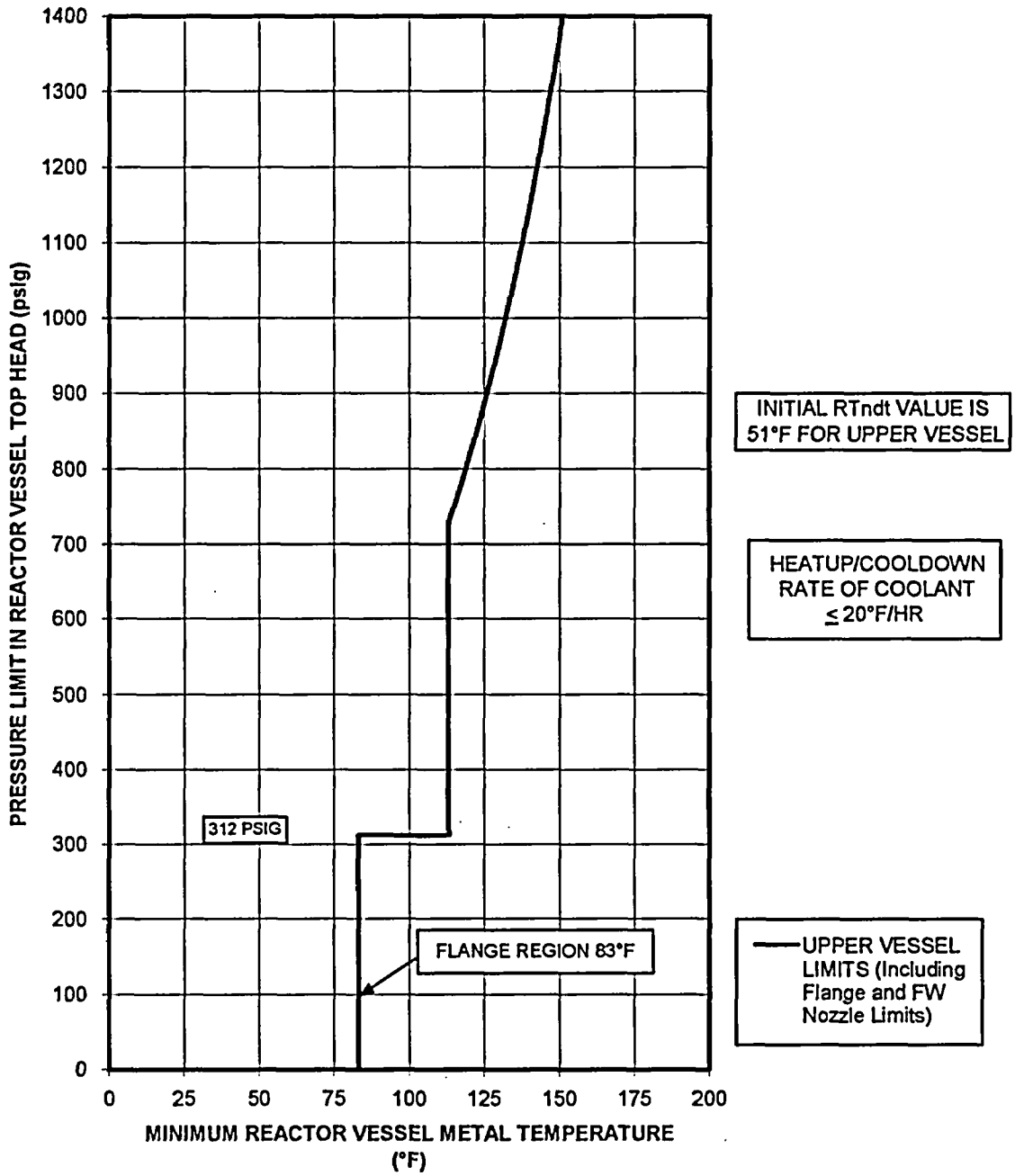

Figure G-2: Bounding Dresden 2&3 Upper Vessel P-T Curve for Pressure Test [Curve A]
[20°F/hr or less coolant heatup/cooldown]

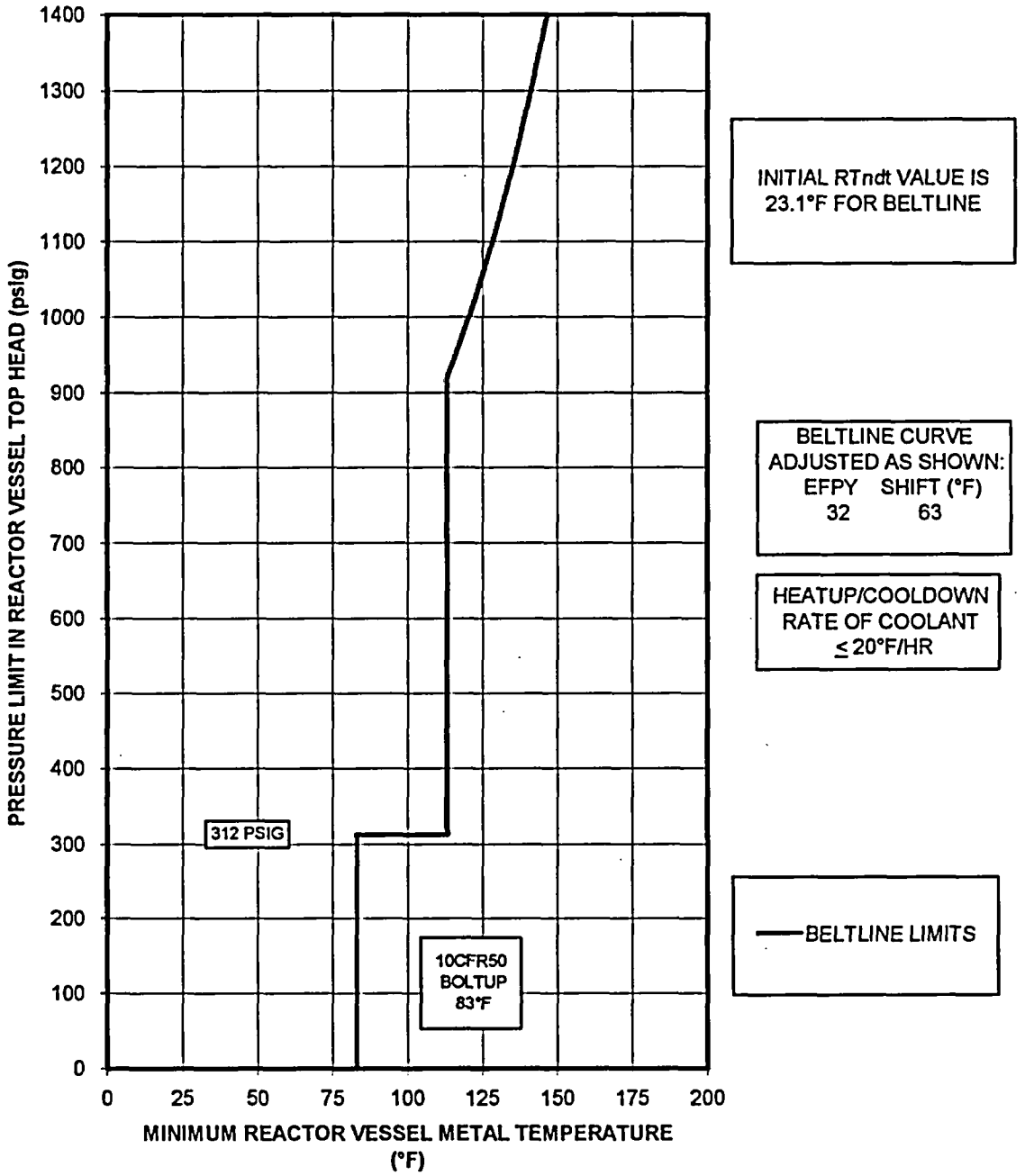

Figure G-3: Bounding Dresden 2&3 Beltline P-T Curve
for Pressure Test [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

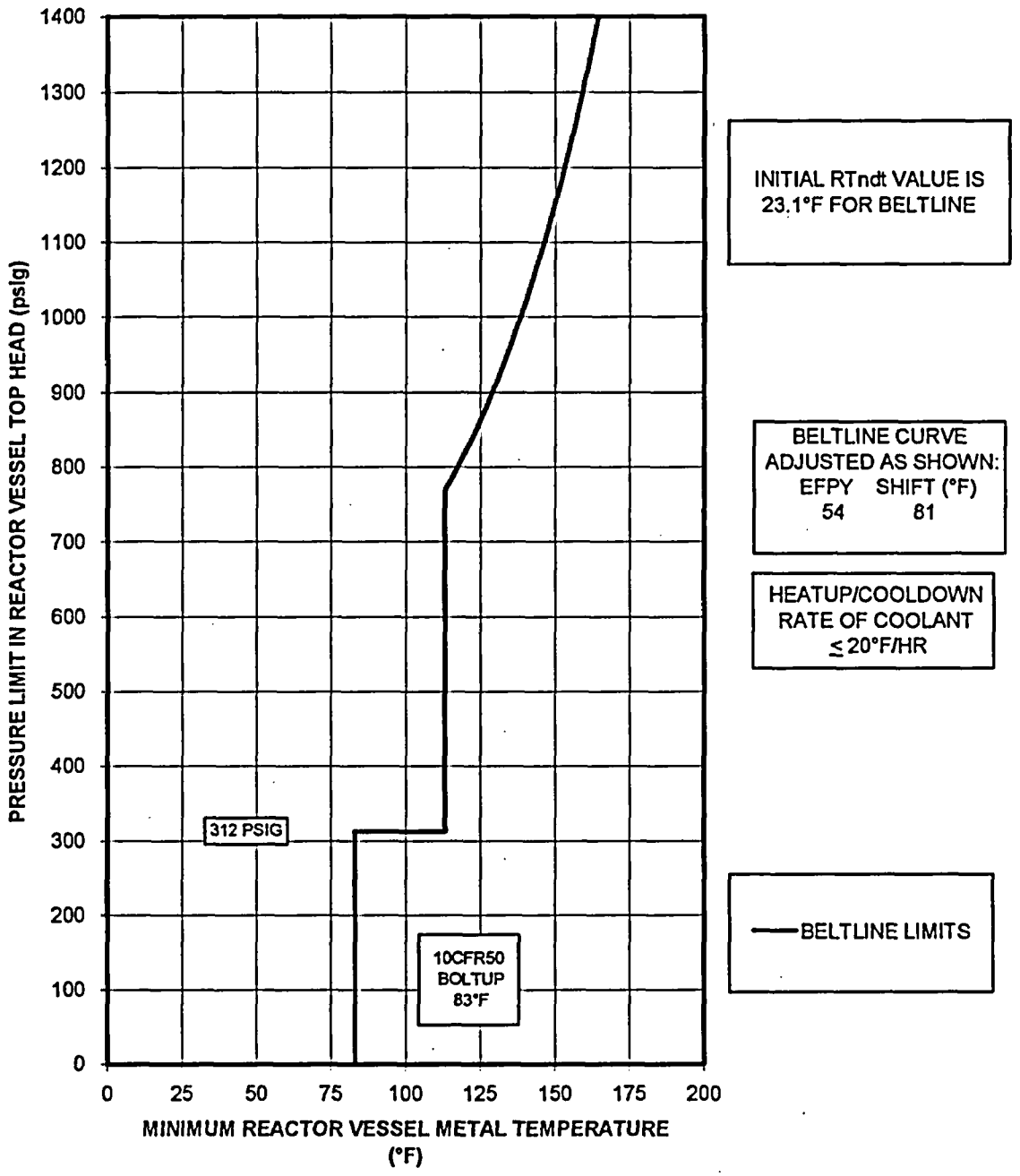

Figure G-4: Bounding Dresden 2&3 Beltline P-T Curve
for Pressure Test [Curve A] up to 54 EFPY [20°F/hr or less coolant heatup/cooldown]

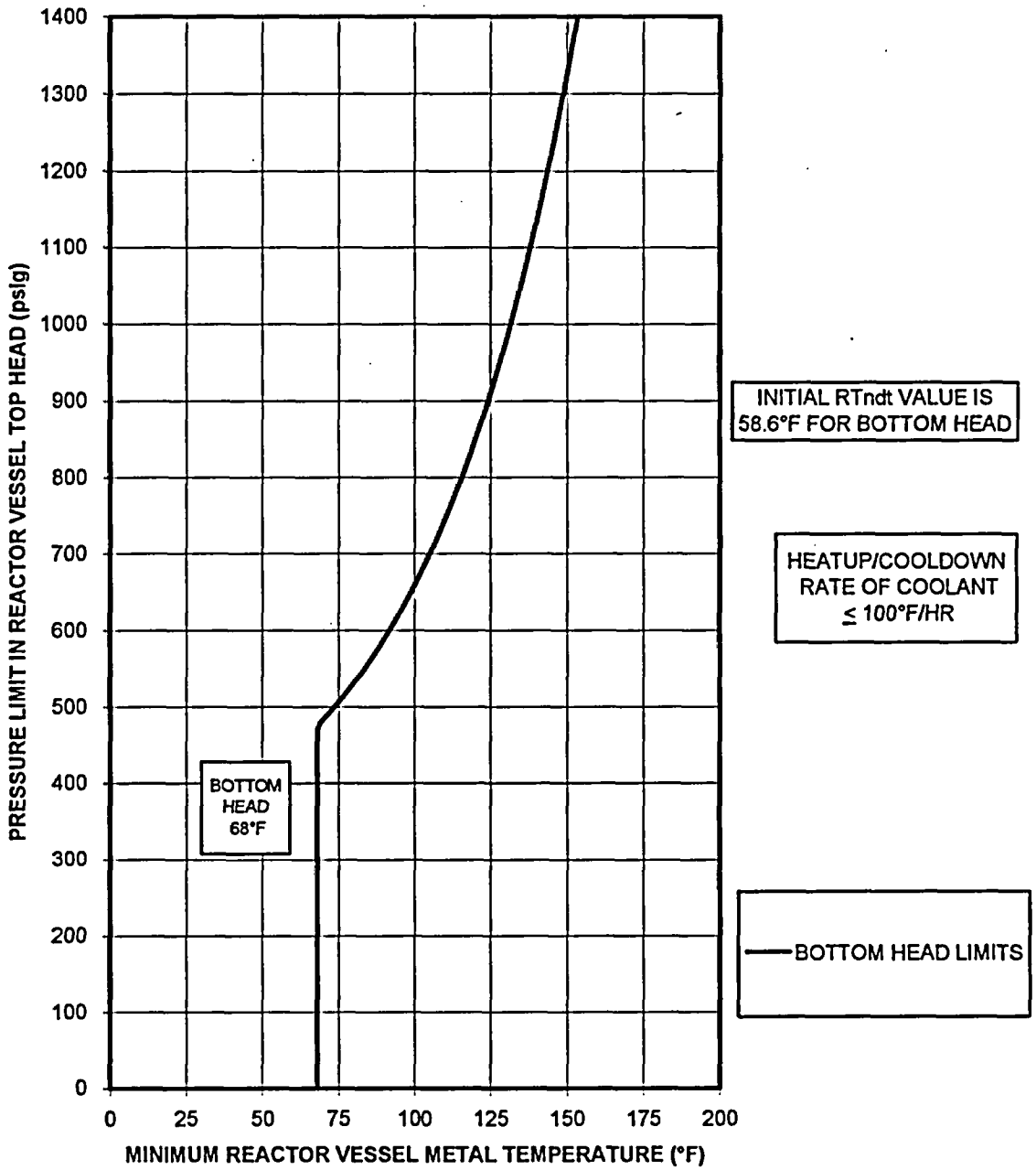

Figure G-5: Bounding Dresden 2&3 Bottom Head P-T Curve for Core Not Critical [Curve B]
[100°F/hr or less coolant heatup/cooldown]

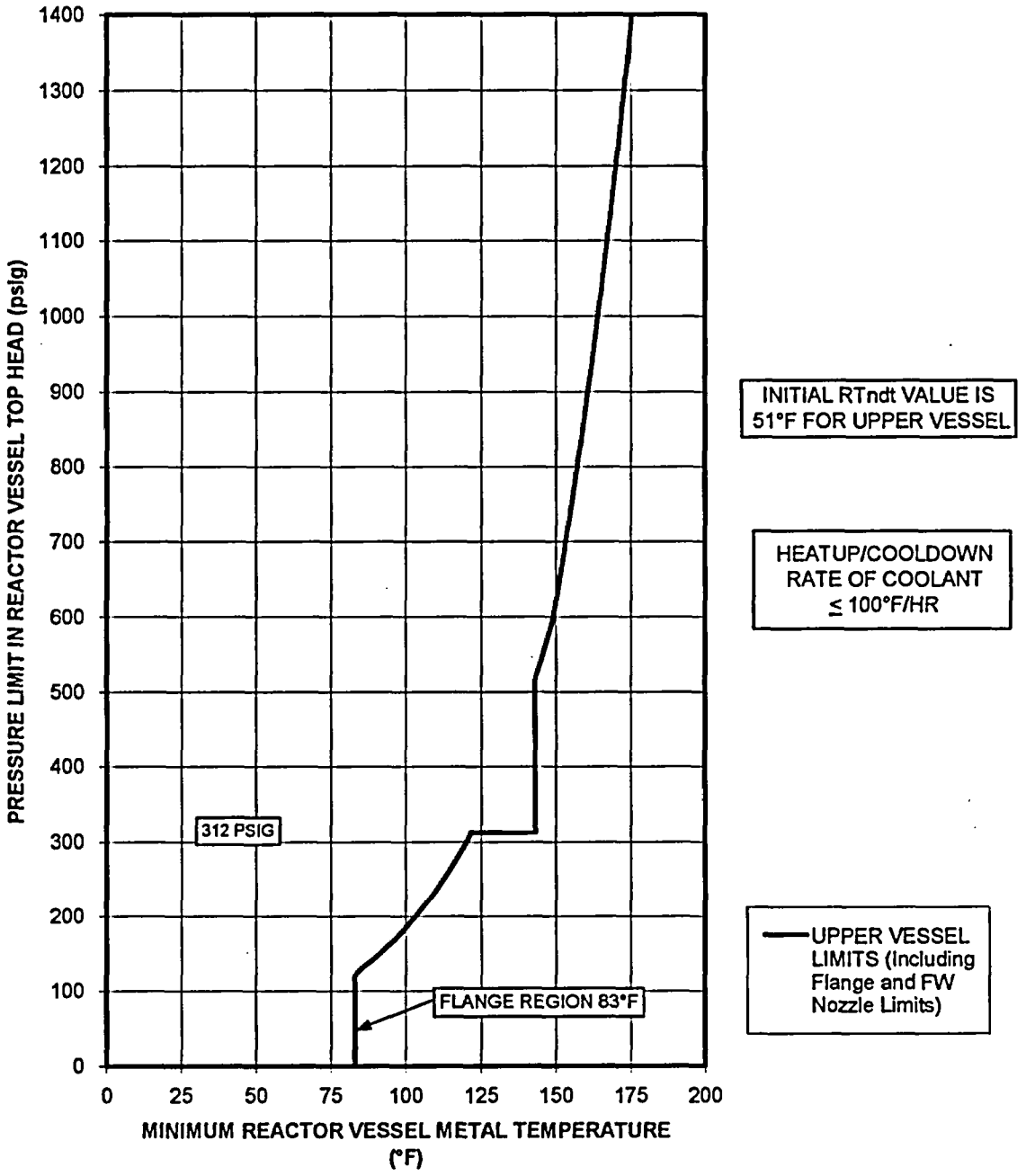

Figure G-6: Bounding Dresden 2&3 Upper Vessel P-T Curve for Core Not Critical [Curve B]
[100°F/hr or less coolant heatup/cooldown]

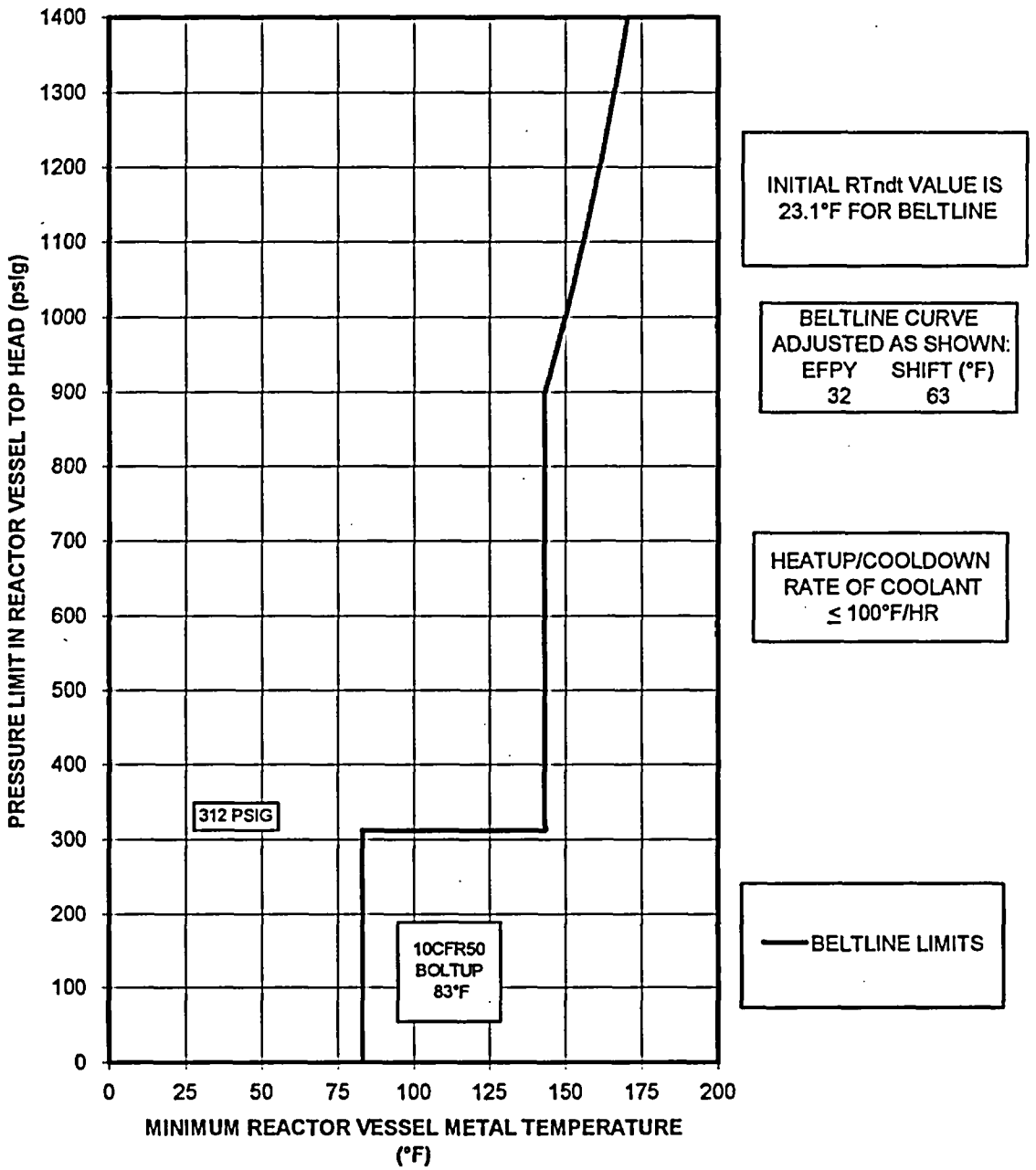

Figure G-7: Bounding Dresden 2&3 Beltline P-T Curve
for Core Not Critical [Curve B] up to 32 EFPY
[100°F/hr or less coolant heatup/cooldown]

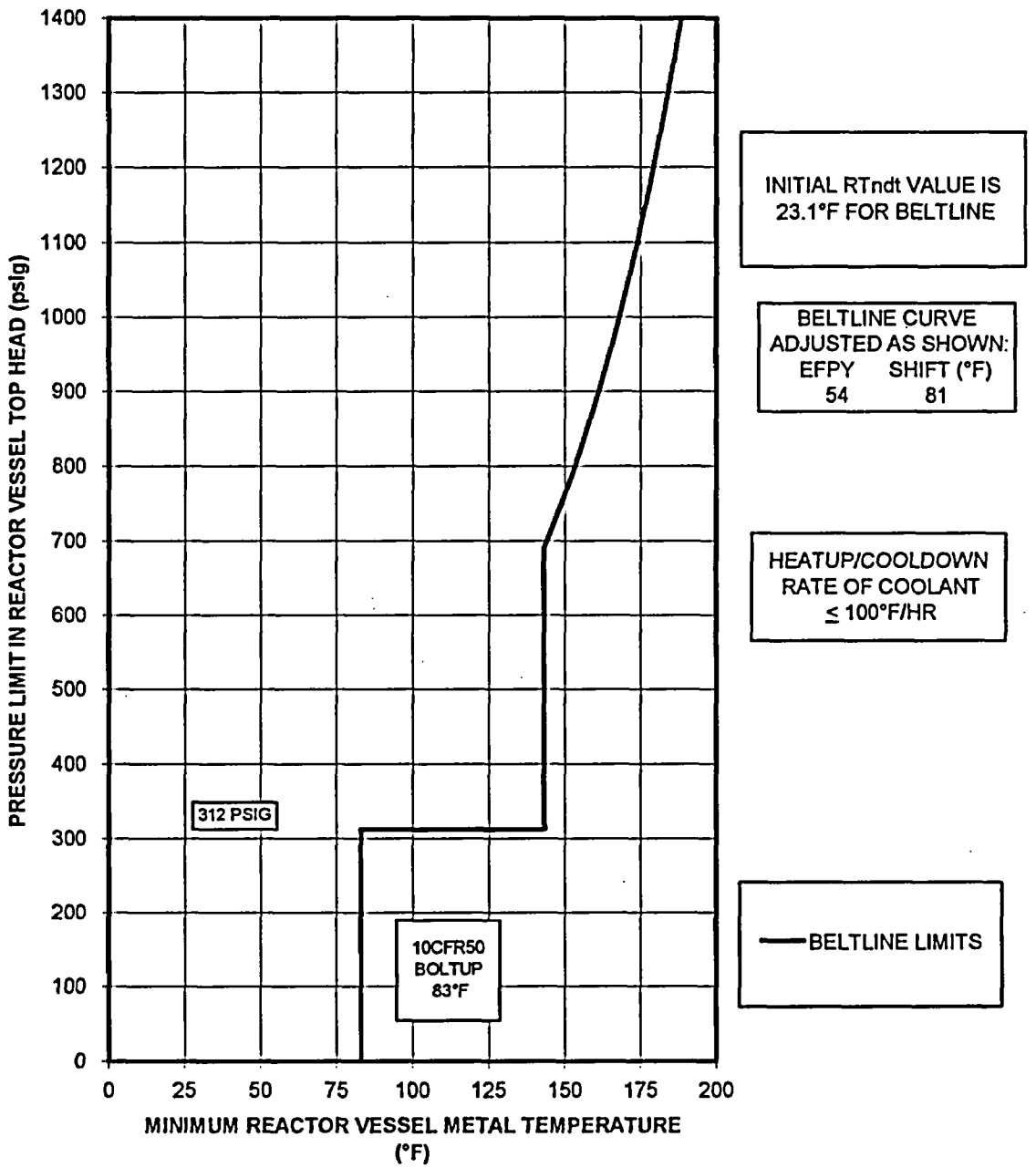

Figure G-8: Bounding Dresden 2&3 Beltline P-T Curve
for Core Not Critical [Curve B] up to 54 EFPY
[100°F/hr or less coolant heatup/cooldown]

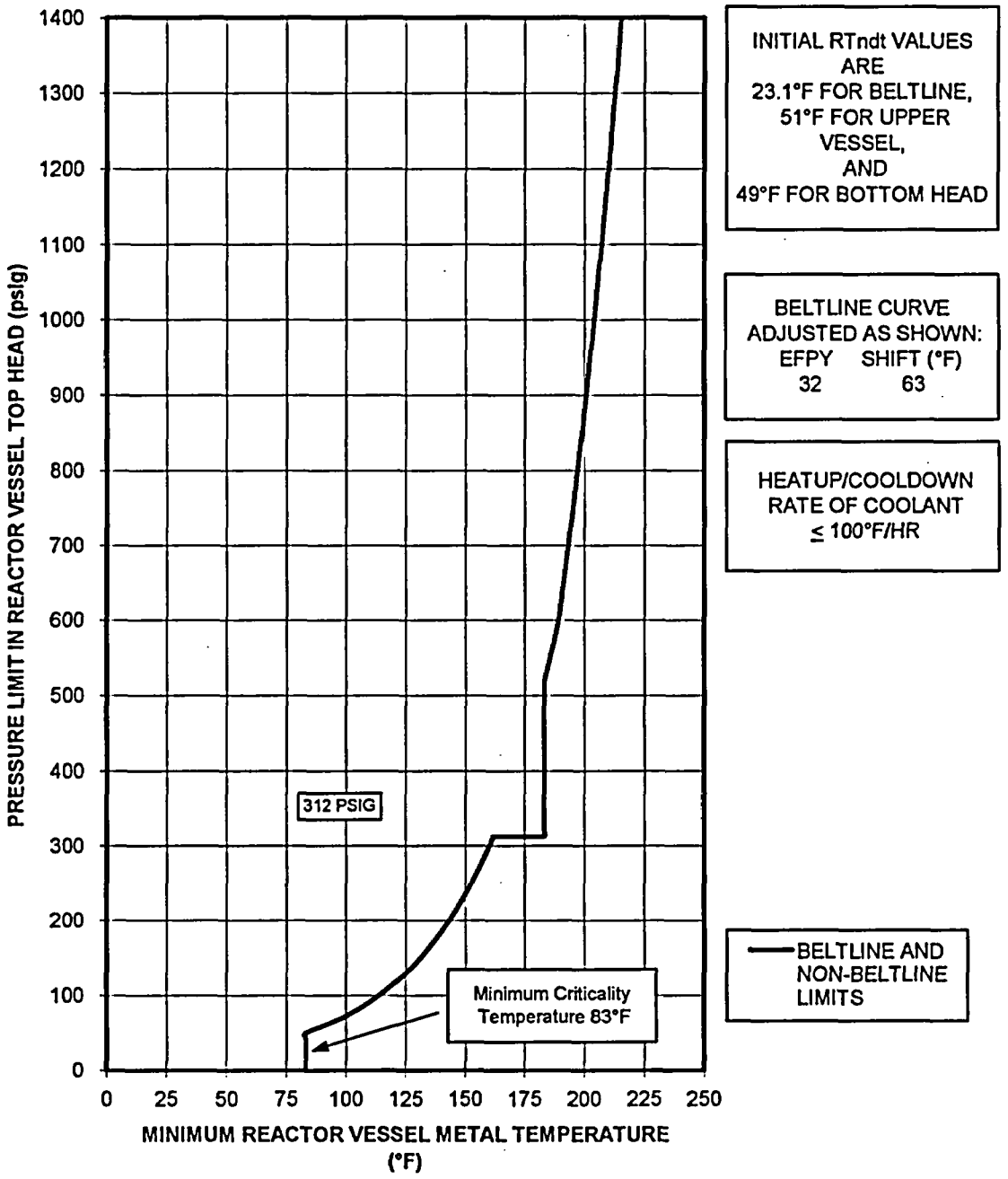

Figure G-9: Bounding Dresden 2&3 Core Critical P-T Curves [Curve C] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

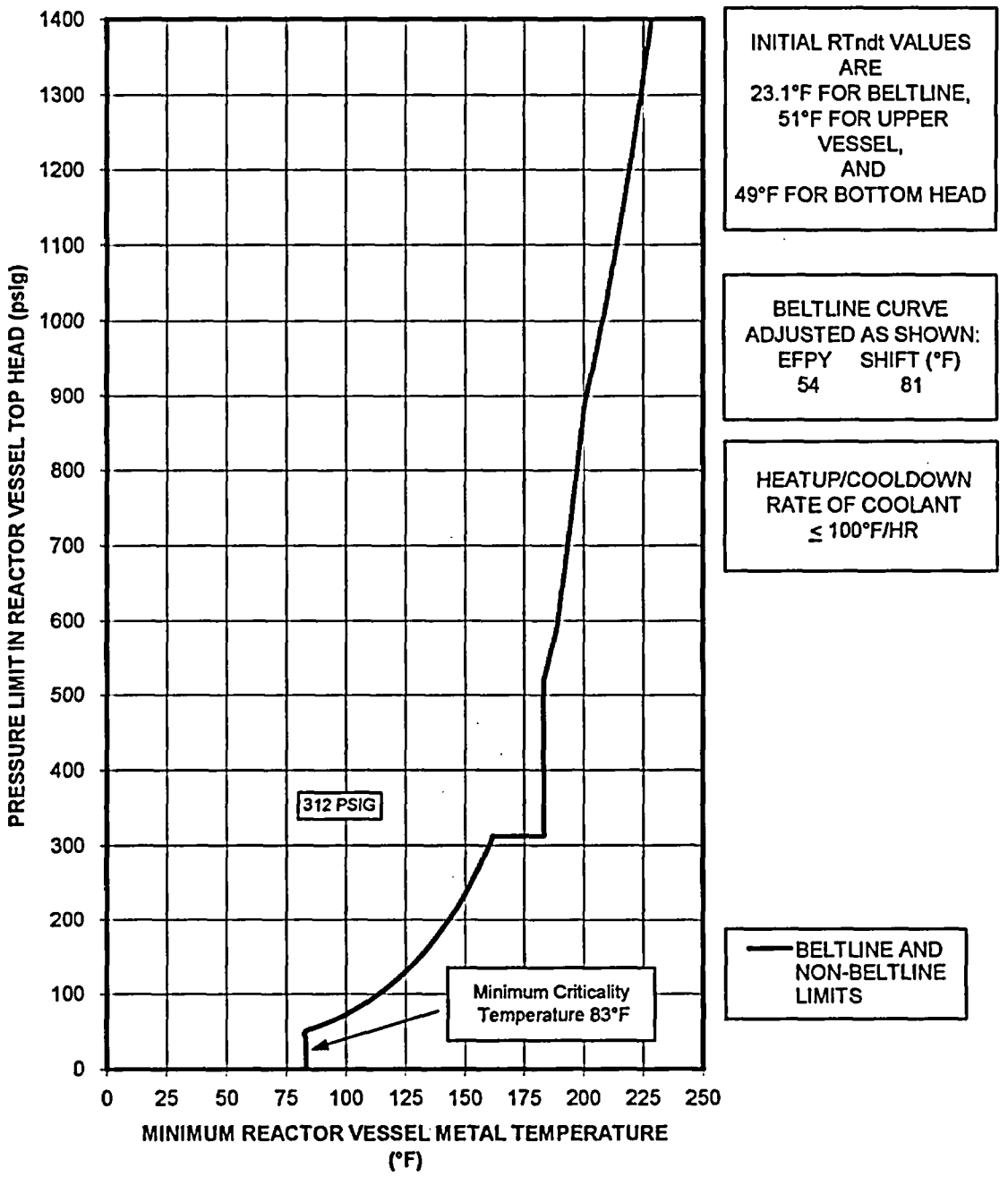

Figure G-10: Bounding Dresden 2&3 Core Critical P-T Curves [Curve C] up to 54 EFPY [100°F/hr or less coolant heatup/cooldown]

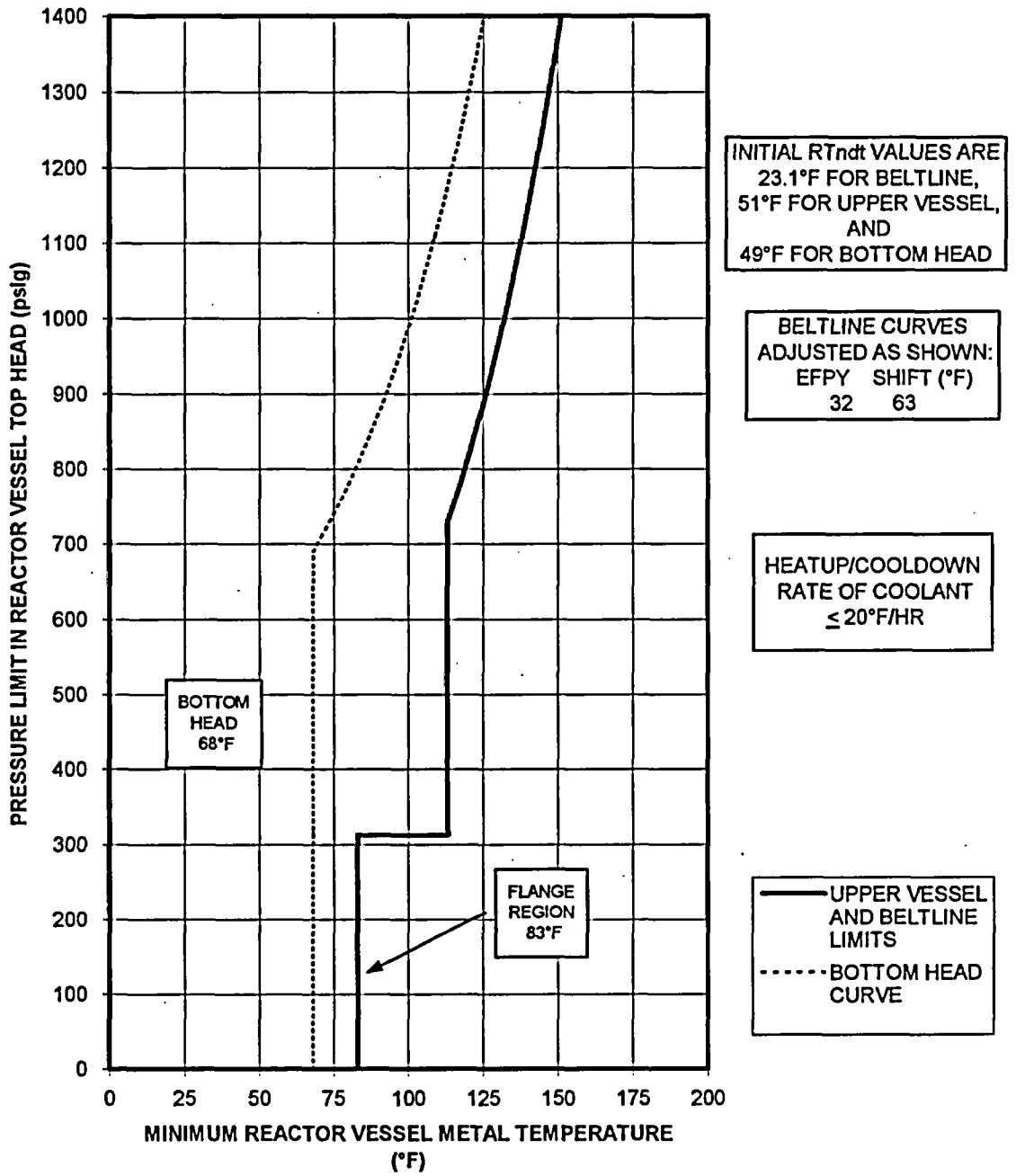

Figure G-11: Bounding Dresden 2&3 Composite Pressure Test P-T Curves [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

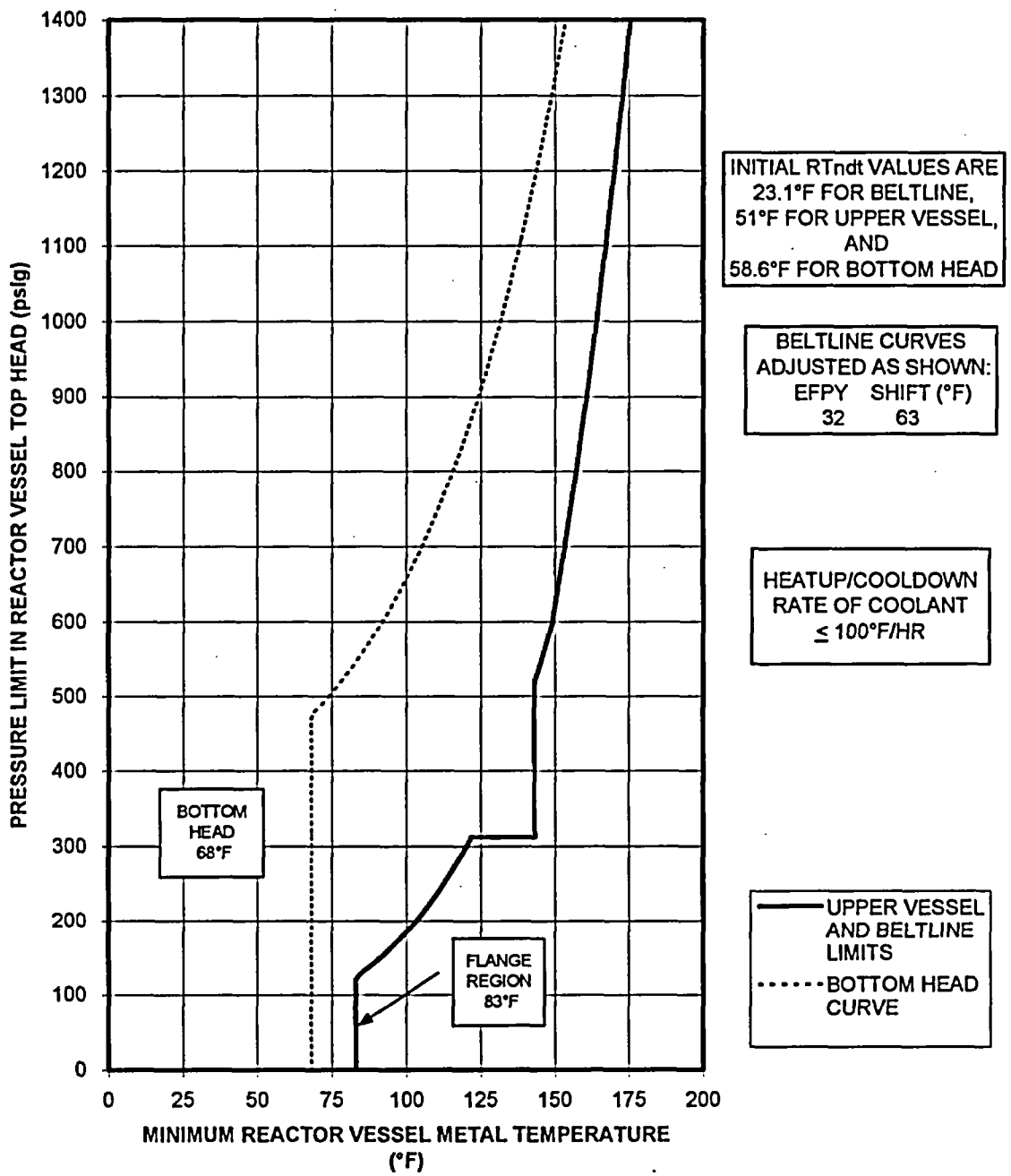

Figure G-12: Bounding Dresden 2&3 Composite Core Not Critical P-T Curves [Curve B] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

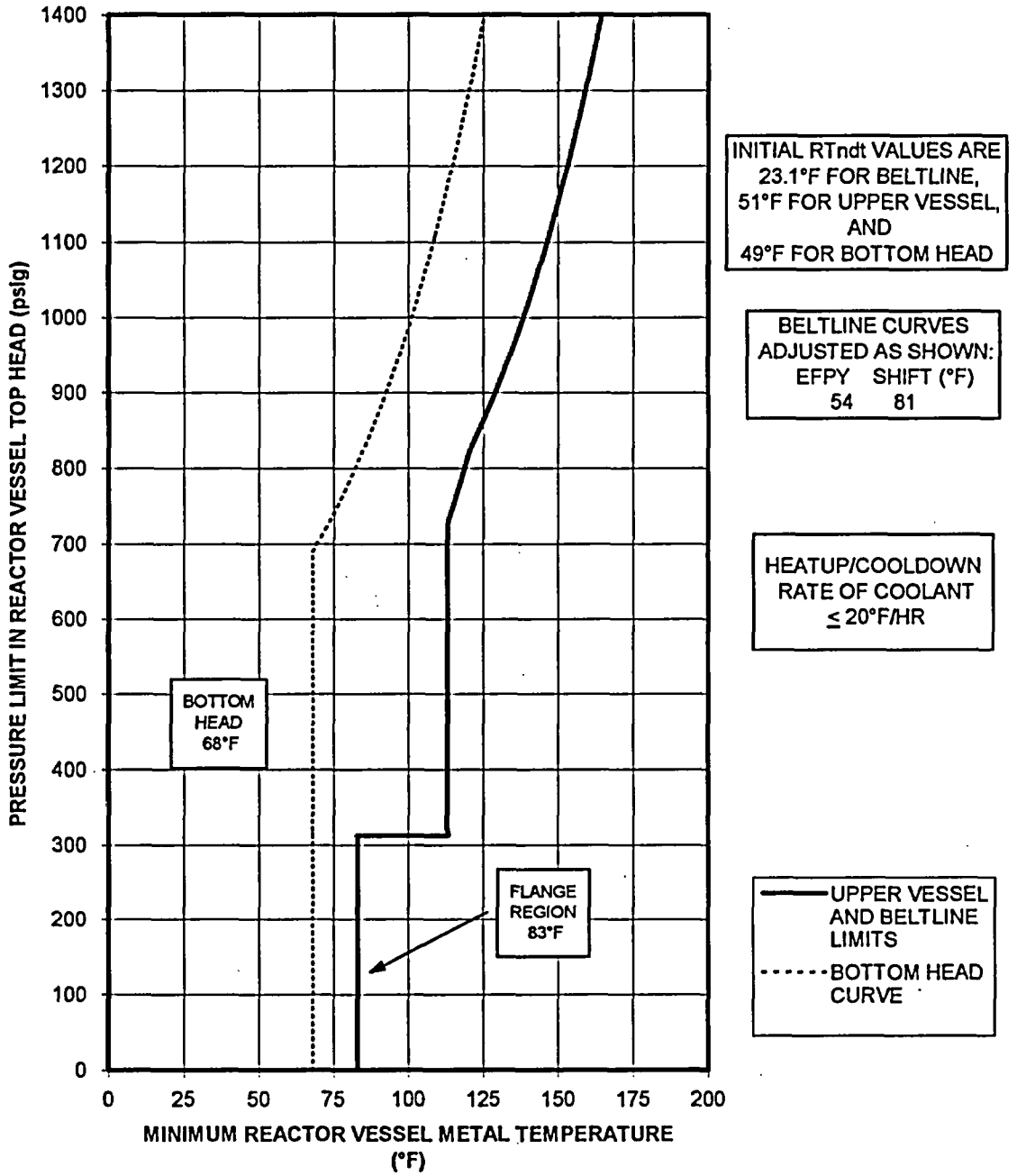

Figure G-13: Bounding Dresden 2&3 Composite Pressure Test P-T Curves [Curve A] up to 54 EFPY [20°F/hr or less coolant heatup/cooldown]

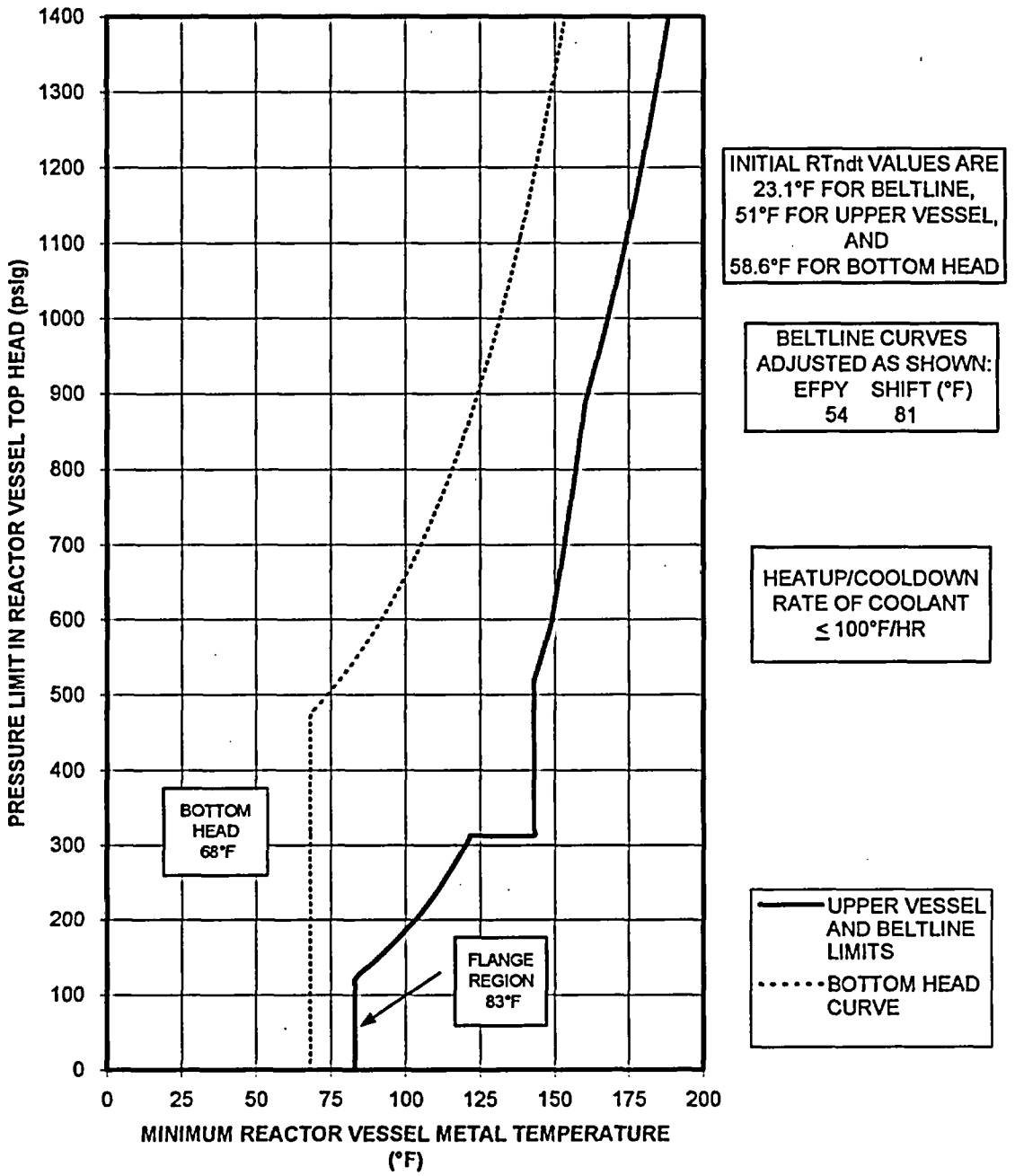

Figure G-14: Bounding Dresden 2&3 Composite Core Not Critical P-T Curves [Curve B] for up to 54 EFPY [100°F/hr or less coolant heatup/cooldown]

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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	83.1	83.1	68.0	83.1	83.1
10	68.0	83.1	83.1	68.0	83.1	83.1
20	68.0	83.1	83.1	68.0	83.1	83.1
30	68.0	83.1	83.1	68.0	83.1	83.1
40	68.0	83.1	83.1	68.0	83.1	83.1
50	68.0	83.1	83.1	68.0	83.1	83.1
60	68.0	83.1	83.1	68.0	83.1	83.1
70	68.0	83.1	83.1	68.0	83.1	83.1
80	68.0	83.1	83.1	68.0	83.1	83.1
90	68.0	83.1	83.1	68.0	83.1	83.1
100	68.0	83.1	83.1	68.0	83.1	83.1
110	68.0	83.1	83.1	68.0	83.1	83.1
120	68.0	83.1	83.1	68.0	83.1	83.1
130	68.0	83.1	83.1	68.0	85.2	83.1
140	68.0	83.1	83.1	68.0	88.4	83.1
150	68.0	83.1	83.1	68.0	91.2	83.1
160	68.0	83.1	83.1	68.0	93.9	83.1
170	68.0	83.1	83.1	68.0	96.5	83.1
180	68.0	83.1	83.1	68.0	98.9	83.1
190	68.0	83.1	83.1	68.0	101.2	83.1
200	68.0	83.1	83.1	68.0	103.3	83.1
210	68.0	83.1	83.1	68.0	105.3	83.1
220	68.0	83.1	83.1	68.0	107.3	83.1
230	68.0	83.1	83.1	68.0	109.1	83.1
240	68.0	83.1	83.1	68.0	110.9	83.1

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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)
250	68.0	83.1	83.1	68.0	112.6	83.1
260	68.0	83.1	83.1	68.0	114.2	83.1
270	68.0	83.1	83.1	68.0	115.8	83.1
280	68.0	83.1	83.1	68.0	117.3	83.1
290	68.0	83.1	83.1	68.0	118.8	83.1
300	68.0	83.1	83.1	68.0	120.2	83.1
310	68.0	83.1	83.1	68.0	121.5	83.1
312.5	68.0	83.1	83.1	68.0	121.9	83.1
312.5	68.0	113.1	113.1	68.0	143.1	143.1
320	68.0	113.1	113.1	68.0	143.1	143.1
330	68.0	113.1	113.1	68.0	143.1	143.1
340	68.0	113.1	113.1	68.0	143.1	143.1
350	68.0	113.1	113.1	68.0	143.1	143.1
360	68.0	113.1	113.1	68.0	143.1	143.1
370	68.0	113.1	113.1	68.0	143.1	143.1
380	68.0	113.1	113.1	68.0	143.1	143.1
390	68.0	113.1	113.1	68.0	143.1	143.1
400	68.0	113.1	113.1	68.0	143.1	143.1
410	68.0	113.1	113.1	68.0	143.1	143.1
420	68.0	113.1	113.1	68.0	143.1	143.1
430	68.0	113.1	113.1	68.0	143.1	143.1
440	68.0	113.1	113.1	68.0	143.1	143.1
450	68.0	113.1	113.1	68.0	143.1	143.1
460	68.0	113.1	113.1	68.0	143.1	143.1
470	68.0	113.1	113.1	68.0	143.1	143.1
480	68.0	113.1	113.1	69.1	143.1	143.1
490	68.0	113.1	113.1	71.4	143.1	143.1

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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)
500	68.0	113.1	113.1	73.6	143.1	143.1
510	68.0	113.1	113.1	75.8	143.1	143.1
520	68.0	113.1	113.1	77.8	143.2	143.1
530	68.0	113.1	113.1	79.8	144.0	143.1
540	68.0	113.1	113.1	81.7	144.8	143.1
550	68.0	113.1	113.1	83.5	145.6	143.1
560	68.0	113.1	113.1	85.3	146.4	143.1
570	68.0	113.1	113.1	87.0	147.1	143.1
580	68.0	113.1	113.1	88.6	147.9	143.1
590	68.0	113.1	113.1	90.2	148.6	143.1
600	68.0	113.1	113.1	91.8	149.1	143.1
610	68.0	113.1	113.1	93.3	149.6	143.1
620	68.0	113.1	113.1	94.7	150.0	143.1
630	68.0	113.1	113.1	96.1	150.4	143.1
640	68.0	113.1	113.1	97.5	150.8	143.1
650	68.0	113.1	113.1	98.8	151.2	143.1
660	68.0	113.1	113.1	100.1	151.7	143.1
670	68.0	113.1	113.1	101.4	152.1	143.1
680	68.0	113.1	113.1	102.7	152.5	143.1
690	68.0	113.1	113.1	103.9	152.9	143.1
700	69.2	113.1	113.1	105.0	153.3	143.1
710	70.7	113.1	113.1	106.2	153.7	143.1
720	72.1	113.1	113.1	107.3	154.1	143.1
730	73.5	113.3	113.1	108.4	154.5	143.1
740	74.8	114.1	113.1	109.5	154.9	143.1
750	76.1	115.0	113.1	110.6	155.2	143.1
760	77.4	115.8	113.1	111.6	155.6	143.1

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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)
770	78.6	116.6	113.1	112.6	156.0	143.1
780	79.8	117.3	113.1	113.6	156.4	143.1
790	81.0	118.1	113.1	114.6	156.8	143.1
800	82.2	118.9	113.1	115.5	157.1	143.1
810	83.3	119.6	113.1	116.5	157.5	143.1
820	84.4	120.4	113.1	117.4	157.9	143.1
830	85.5	121.1	113.1	118.3	158.2	143.1
840	86.5	121.8	113.1	119.2	158.6	143.1
850	87.6	122.5	113.1	120.0	158.9	143.1
860	88.6	123.2	113.1	120.9	159.3	143.1
870	89.6	123.9	113.1	121.7	159.6	143.1
880	90.5	124.6	113.1	122.6	160.0	143.1
890	91.5	125.3	113.1	123.4	160.3	143.1
900	92.4	125.9	113.1	124.2	160.7	143.2
910	93.4	126.6	113.1	125.0	161.0	143.9
920	94.3	127.2	113.1	125.7	161.4	144.6
930	95.1	127.9	114.0	126.5	161.7	145.3
940	96.0	128.5	115.0	127.3	162.0	146.0
950	96.9	129.1	115.9	128.0	162.4	146.7
960	97.7	129.7	116.8	128.7	162.7	147.3
970	98.6	130.3	117.8	129.5	163.0	148.0
980	99.4	130.9	118.7	130.2	163.4	148.6
990	100.2	131.5	119.5	130.9	163.7	149.3
1000	101.0	132.1	120.4	131.6	164.0	149.9
1010	101.7	132.7	121.2	132.2	164.3	150.6
1020	102.5	133.2	122.1	132.9	164.6	151.2
1030	103.3	133.8	122.9	133.6	165.0	151.8

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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)
1040	104.0	134.4	123.7	134.2	165.3	152.4
1050	104.7	134.9	124.5	134.9	165.6	153.0
1060	105.4	135.5	125.3	135.5	165.9	153.6
1070	106.2	136.0	126.1	136.1	166.2	154.2
1080	106.9	136.5	126.8	136.8	166.5	154.8
1090	107.6	137.1	127.6	137.4	166.8	155.3
1100	108.2	137.6	128.3	138.0	167.1	155.9
1105	108.6	137.8	128.7	138.3	167.3	156.2
1110	108.9	138.1	129.0	138.6	167.4	156.4
1120	109.6	138.6	129.7	139.2	167.7	157.0
1130	110.2	139.1	130.5	139.8	168.0	157.5
1140	110.9	139.6	131.2	140.3	168.3	158.1
1150	111.5	140.1	131.8	140.9	168.6	158.6
1160	112.1	140.6	132.5	141.5	168.9	159.1
1170	112.8	141.1	133.2	142.0	169.2	159.7
1180	113.4	141.6	133.8	142.6	169.5	160.2
1190	114.0	142.1	134.5	143.1	169.7	160.7
1200	114.6	142.5	135.1	143.7	170.0	161.2
1210	115.2	143.0	135.8	144.2	170.3	161.7
1220	115.8	143.5	136.4	144.8	170.6	162.2
1230	116.3	143.9	137.0	145.3	170.9	162.7
1240	116.9	144.4	137.6	145.8	171.2	163.2
1250	117.5	144.8	138.2	146.3	171.4	163.7
1260	118.0	145.3	138.8	146.8	171.7	164.2
1270	118.6	145.7	139.4	147.3	172.0	164.6
1280	119.1	146.2	140.0	147.8	172.2	165.1
1290	119.7	146.6	140.6	148.3	172.5	165.6

TABLE G-2. Bounding Dresden 2&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 G-1, G-2, G-3, G-5, G-6 and G-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)
1300	120.2	147.0	141.1	148.8	172.8	166.0
1310	120.7	147.5	141.7	149.3	173.1	166.5
1320	121.3	147.9	142.3	149.8	173.3	166.9
1330	121.8	148.3	142.8	150.2	173.6	167.4
1340	122.3	148.7	143.4	150.7	173.8	167.8
1350	122.8	149.1	143.9	151.2	174.1	168.3
1360	123.3	149.6	144.4	151.6	174.4	168.7
1370	123.8	150.0	145.0	152.1	174.6	169.1
1380	124.3	150.4	145.5	152.5	174.9	169.6
1390	124.8	150.8	146.0	153.0	175.1	170.0
1400	125.3	151.2	146.5	153.4	175.4	170.4

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
0	68.0	83.1	68.0	83.1	83.1
10	68.0	83.1	68.0	83.1	83.1
20	68.0	83.1	68.0	83.1	83.1
30	68.0	83.1	68.0	83.1	83.1
40	68.0	83.1	68.0	83.1	83.1
50	68.0	83.1	68.0	83.1	83.1
60	68.0	83.1	68.0	83.1	91.0
70	68.0	83.1	68.0	83.1	98.2
80	68.0	83.1	68.0	83.1	104.2
90	68.0	83.1	68.0	83.1	109.3
100	68.0	83.1	68.0	83.1	113.8
110	68.0	83.1	68.0	83.1	117.9
120	68.0	83.1	68.0	83.1	121.7
130	68.0	83.1	68.0	85.2	125.2
140	68.0	83.1	68.0	88.4	128.4
150	68.0	83.1	68.0	91.2	131.2
160	68.0	83.1	68.0	93.9	133.9
170	68.0	83.1	68.0	96.5	136.5
180	68.0	83.1	68.0	98.9	138.9
190	68.0	83.1	68.0	101.2	141.2
200	68.0	83.1	68.0	103.3	143.3
210	68.0	83.1	68.0	105.3	145.3

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
220	68.0	83.1	68.0	107.3	147.3
230	68.0	83.1	68.0	109.1	149.1
240	68.0	83.1	68.0	110.9	150.9
250	68.0	83.1	68.0	112.6	152.6
260	68.0	83.1	68.0	114.2	154.2
270	68.0	83.1	68.0	115.8	155.8
280	68.0	83.1	68.0	117.3	157.3
290	68.0	83.1	68.0	118.8	158.8
300	68.0	83.1	68.0	120.2	160.2
310	68.0	83.1	68.0	121.5	161.5
312.5	68.0	83.1	68.0	121.9	161.9
312.5	68.0	113.1	68.0	143.1	183.1
320	68.0	113.1	68.0	143.1	183.1
330	68.0	113.1	68.0	143.1	183.1
340	68.0	113.1	68.0	143.1	183.1
350	68.0	113.1	68.0	143.1	183.1
360	68.0	113.1	68.0	143.1	183.1
370	68.0	113.1	68.0	143.1	183.1
380	68.0	113.1	68.0	143.1	183.1
390	68.0	113.1	68.0	143.1	183.1
400	68.0	113.1	68.0	143.1	183.1
410	68.0	113.1	68.0	143.1	183.1
420	68.0	113.1	68.0	143.1	183.1

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
430	68.0	113.1	68.0	143.1	183.1
440	68.0	113.1	68.0	143.1	183.1
450	68.0	113.1	68.0	143.1	183.1
460	68.0	113.1	68.0	143.1	183.1
470	68.0	113.1	68.0	143.1	183.1
480	68.0	113.1	69.1	143.1	183.1
490	68.0	113.1	71.4	143.1	183.1
500	68.0	113.1	73.6	143.1	183.1
510	68.0	113.1	75.8	143.1	183.1
520	68.0	113.1	77.8	143.2	183.2
530	68.0	113.1	79.8	144.0	184.0
540	68.0	113.1	81.7	144.8	184.8
550	68.0	113.1	83.5	145.6	185.6
560	68.0	113.1	85.3	146.4	186.4
570	68.0	113.1	87.0	147.1	187.1
580	68.0	113.1	88.6	147.9	187.9
590	68.0	113.1	90.2	148.6	188.6
600	68.0	113.1	91.8	149.1	189.1
610	68.0	113.1	93.3	149.6	189.6
620	68.0	113.1	94.7	150.0	190.0
630	68.0	113.1	96.1	150.4	190.4
640	68.0	113.1	97.5	150.8	190.8
650	68.0	113.1	98.8	151.2	191.2

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
660	68.0	113.1	100.1	151.7	191.7
670	68.0	113.1	101.4	152.1	192.1
680	68.0	113.1	102.7	152.5	192.5
690	68.0	113.1	103.9	152.9	192.9
700	69.2	113.1	105.0	153.3	193.3
710	70.7	113.1	106.2	153.7	193.7
720	72.1	113.1	107.3	154.1	194.1
730	73.5	113.3	108.4	154.5	194.5
740	74.8	114.1	109.5	154.9	194.9
750	76.1	115.0	110.6	155.2	195.2
760	77.4	115.8	111.6	155.6	195.6
770	78.6	116.6	112.6	156.0	196.0
780	79.8	117.3	113.6	156.4	196.4
790	81.0	118.1	114.6	156.8	196.8
800	82.2	118.9	115.5	157.1	197.1
810	83.3	119.6	116.5	157.5	197.5
820	84.4	120.4	117.4	157.9	197.9
830	85.5	121.1	118.3	158.2	198.2
840	86.5	121.8	119.2	158.6	198.6
850	87.6	122.5	120.0	158.9	198.9
860	88.6	123.2	120.9	159.3	199.3
870	89.6	123.9	121.7	159.6	199.6
880	90.5	124.6	122.6	160.0	200.0

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
890	91.5	125.3	123.4	160.3	200.3
900	92.4	125.9	124.2	160.7	200.7
910	93.4	126.6	125.0	161.0	201.0
920	94.3	127.2	125.7	161.4	201.4
930	95.1	127.9	126.5	161.7	201.7
940	96.0	128.5	127.3	162.0	202.0
950	96.9	129.1	128.0	162.4	202.4
960	97.7	129.7	128.7	162.7	202.7
970	98.6	130.3	129.5	163.0	203.0
980	99.4	130.9	130.2	163.4	203.4
990	100.2	131.5	130.9	163.7	203.7
1000	101.0	132.1	131.6	164.0	204.0
1010	101.7	132.7	132.2	164.3	204.3
1020	102.5	133.2	132.9	164.6	204.6
1030	103.3	133.8	133.6	165.0	205.0
1040	104.0	134.4	134.2	165.3	205.3
1050	104.7	134.9	134.9	165.6	205.6
1060	105.4	135.5	135.5	165.9	205.9
1070	106.2	136.0	136.1	166.2	206.2
1080	106.9	136.5	136.8	166.5	206.5
1090	107.6	137.1	137.4	166.8	206.8
1100	108.2	137.6	138.0	167.1	207.1
1105	108.6	137.8	138.3	167.3	207.3

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
1110	108.9	138.1	138.6	167.4	207.4
1120	109.6	138.6	139.2	167.7	207.7
1130	110.2	139.1	139.8	168.0	208.0
1140	110.9	139.6	140.3	168.3	208.3
1150	111.5	140.1	140.9	168.6	208.6
1160	112.1	140.6	141.5	168.9	208.9
1170	112.8	141.1	142.0	169.2	209.2
1180	113.4	141.6	142.6	169.5	209.5
1190	114.0	142.1	143.1	169.7	209.7
1200	114.6	142.5	143.7	170.0	210.0
1210	115.2	143.0	144.2	170.3	210.3
1220	115.8	143.5	144.8	170.6	210.6
1230	116.3	143.9	145.3	170.9	210.9
1240	116.9	144.4	145.8	171.2	211.2
1250	117.5	144.8	146.3	171.4	211.4
1260	118.0	145.3	146.8	171.7	211.7
1270	118.6	145.7	147.3	172.0	212.0
1280	119.1	146.2	147.8	172.2	212.2
1290	119.7	146.6	148.3	172.5	212.5
1300	120.2	147.0	148.8	172.8	212.8
1310	120.7	147.5	149.3	173.1	213.1
1320	121.3	147.9	149.8	173.3	213.3
1330	121.8	148.3	150.2	173.6	213.6

TABLE G-3. Bounding Dresden 2&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 G-9, G-11 and G-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)	UPPER RPV & BELTLINE AT 32 EFPY CURVE C (°F)
1340	122.3	148.7	150.7	173.8	213.8
1350	122.8	149.1	151.2	174.1	214.1
1360	123.3	149.6	151.6	174.4	214.4
1370	123.8	150.0	152.1	174.6	214.6
1380	124.3	150.4	152.5	174.9	214.9
1390	124.8	150.8	153.0	175.1	215.1
1400	125.3	151.2	153.4	175.4	215.4

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
0	68.0	83.1	83.1	68.0	83.1	83.1
10	68.0	83.1	83.1	68.0	83.1	83.1
20	68.0	83.1	83.1	68.0	83.1	83.1
30	68.0	83.1	83.1	68.0	83.1	83.1
40	68.0	83.1	83.1	68.0	83.1	83.1
50	68.0	83.1	83.1	68.0	83.1	83.1
60	68.0	83.1	83.1	68.0	83.1	83.1
70	68.0	83.1	83.1	68.0	83.1	83.1
80	68.0	83.1	83.1	68.0	83.1	83.1
90	68.0	83.1	83.1	68.0	83.1	83.1
100	68.0	83.1	83.1	68.0	83.1	83.1
110	68.0	83.1	83.1	68.0	83.1	83.1
120	68.0	83.1	83.1	68.0	83.1	83.1
130	68.0	83.1	83.1	68.0	85.2	83.1
140	68.0	83.1	83.1	68.0	88.4	83.1
150	68.0	83.1	83.1	68.0	91.2	83.1
160	68.0	83.1	83.1	68.0	93.9	83.1
170	68.0	83.1	83.1	68.0	96.5	83.1
180	68.0	83.1	83.1	68.0	98.9	83.1
190	68.0	83.1	83.1	68.0	101.2	83.1
200	68.0	83.1	83.1	68.0	103.3	83.1
210	68.0	83.1	83.1	68.0	105.3	83.1
220	68.0	83.1	83.1	68.0	107.3	83.1
230	68.0	83.1	83.1	68.0	109.1	83.1
240	68.0	83.1	83.1	68.0	110.9	83.1

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
250	68.0	83.1	83.1	68.0	112.6	83.1
260	68.0	83.1	83.1	68.0	114.2	83.1
270	68.0	83.1	83.1	68.0	115.8	83.1
280	68.0	83.1	83.1	68.0	117.3	83.1
290	68.0	83.1	83.1	68.0	118.8	83.1
300	68.0	83.1	83.1	68.0	120.2	83.1
310	68.0	83.1	83.1	68.0	121.5	83.1
312.5	68.0	83.1	83.1	68.0	121.9	83.1
312.5	68.0	113.1	113.1	68.0	143.1	143.1
320	68.0	113.1	113.1	68.0	143.1	143.1
330	68.0	113.1	113.1	68.0	143.1	143.1
340	68.0	113.1	113.1	68.0	143.1	143.1
350	68.0	113.1	113.1	68.0	143.1	143.1
360	68.0	113.1	113.1	68.0	143.1	143.1
370	68.0	113.1	113.1	68.0	143.1	143.1
380	68.0	113.1	113.1	68.0	143.1	143.1
390	68.0	113.1	113.1	68.0	143.1	143.1
400	68.0	113.1	113.1	68.0	143.1	143.1
410	68.0	113.1	113.1	68.0	143.1	143.1
420	68.0	113.1	113.1	68.0	143.1	143.1
430	68.0	113.1	113.1	68.0	143.1	143.1
440	68.0	113.1	113.1	68.0	143.1	143.1
450	68.0	113.1	113.1	68.0	143.1	143.1
460	68.0	113.1	113.1	68.0	143.1	143.1
470	68.0	113.1	113.1	68.0	143.1	143.1
480	68.0	113.1	113.1	69.1	143.1	143.1
490	68.0	113.1	113.1	71.4	143.1	143.1

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
500	68.0	113.1	113.1	73.6	143.1	143.1
510	68.0	113.1	113.1	75.8	143.1	143.1
520	68.0	113.1	113.1	77.8	143.2	143.1
530	68.0	113.1	113.1	79.8	144.0	143.1
540	68.0	113.1	113.1	81.7	144.8	143.1
550	68.0	113.1	113.1	83.5	145.6	143.1
560	68.0	113.1	113.1	85.3	146.4	143.1
570	68.0	113.1	113.1	87.0	147.1	143.1
580	68.0	113.1	113.1	88.6	147.9	143.1
590	68.0	113.1	113.1	90.2	148.6	143.1
600	68.0	113.1	113.1	91.8	149.1	143.1
610	68.0	113.1	113.1	93.3	149.6	143.1
620	68.0	113.1	113.1	94.7	150.0	143.1
630	68.0	113.1	113.1	96.1	150.4	143.1
640	68.0	113.1	113.1	97.5	150.8	143.1
650	68.0	113.1	113.1	98.8	151.2	143.1
660	68.0	113.1	113.1	100.1	151.7	143.1
670	68.0	113.1	113.1	101.4	152.1	143.1
680	68.0	113.1	113.1	102.7	152.5	143.1
690	68.0	113.1	113.1	103.9	152.9	143.1
700	69.2	113.1	113.1	105.0	153.3	144.0
710	70.7	113.1	113.1	106.2	153.7	145.1
720	72.1	113.1	113.1	107.3	154.1	146.0
730	73.5	113.3	113.1	108.4	154.5	147.0
740	74.8	114.1	113.1	109.5	154.9	148.0
750	76.1	115.0	113.1	110.6	155.2	148.9
760	77.4	115.8	113.1	111.6	155.6	149.8

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
770	78.6	116.6	113.3	112.6	156.0	150.7
780	79.8	117.3	114.7	113.6	156.4	151.6
790	81.0	118.1	116.1	114.6	156.8	152.5
800	82.2	118.9	117.4	115.5	157.1	153.3
810	83.3	119.6	118.7	116.5	157.5	154.2
820	84.4	120.4	120.0	117.4	157.9	155.0
830	85.5	121.1	121.2	118.3	158.2	155.8
840	86.5	121.8	122.4	119.2	158.6	156.6
850	87.6	122.5	123.5	120.0	158.9	157.4
860	88.6	123.2	124.7	120.9	159.3	158.2
870	89.6	123.9	125.8	121.7	159.6	158.9
880	90.5	124.6	126.9	122.6	160.0	159.7
890	91.5	125.3	128.0	123.4	160.3	160.4
900	92.4	125.9	129.0	124.2	160.7	161.2
910	93.4	126.6	130.0	125.0	161.0	161.9
920	94.3	127.2	131.0	125.7	161.4	162.6
930	95.1	127.9	132.0	126.5	161.7	163.3
940	96.0	128.5	133.0	127.3	162.0	164.0
950	96.9	129.1	133.9	128.0	162.4	164.7
960	97.7	129.7	134.8	128.7	162.7	165.3
970	98.6	130.3	135.8	129.5	163.0	166.0
980	99.4	130.9	136.7	130.2	163.4	166.6
990	100.2	131.5	137.5	130.9	163.7	167.3
1000	101.0	132.1	138.4	131.6	164.0	167.9
1010	101.7	132.7	139.2	132.2	164.3	168.6
1020	102.5	133.2	140.1	132.9	164.6	169.2
1030	103.3	133.8	140.9	133.6	165.0	169.8

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
1040	104.0	134.4	141.7	134.2	165.3	170.4
1050	104.7	134.9	142.5	134.9	165.6	171.0
1060	105.4	135.5	143.3	135.5	165.9	171.6
1070	106.2	136.0	144.1	136.1	166.2	172.2
1080	106.9	136.5	144.8	136.8	166.5	172.8
1090	107.6	137.1	145.6	137.4	166.8	173.3
1100	108.2	137.6	146.3	138.0	167.1	173.9
1105	108.6	137.8	146.7	138.3	167.3	174.2
1110	108.9	138.1	147.0	138.6	167.4	174.4
1120	109.6	138.6	147.7	139.2	167.7	175.0
1130	110.2	139.1	148.5	139.8	168.0	175.5
1140	110.9	139.6	149.2	140.3	168.3	176.1
1150	111.5	140.1	149.8	140.9	168.6	176.6
1160	112.1	140.6	150.5	141.5	168.9	177.1
1170	112.8	141.1	151.2	142.0	169.2	177.7
1180	113.4	141.6	151.8	142.6	169.5	178.2
1190	114.0	142.1	152.5	143.1	169.7	178.7
1200	114.6	142.5	153.1	143.7	170.0	179.2
1210	115.2	143.0	153.8	144.2	170.3	179.7
1220	115.8	143.5	154.4	144.8	170.6	180.2
1230	116.3	143.9	155.0	145.3	170.9	180.7
1240	116.9	144.4	155.6	145.8	171.2	181.2
1250	117.5	144.8	156.2	146.3	171.4	181.7
1260	118.0	145.3	156.8	146.8	171.7	182.2
1270	118.6	145.7	157.4	147.3	172.0	182.6
1280	119.1	146.2	158.0	147.8	172.2	183.1
1290	119.7	146.6	158.6	148.3	172.5	183.6

TABLE G-4. Bounding Dresden 2&3 P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-1, G-2, G-4, G-5, G-6 and G-8

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER VESSEL CURVE A (°F)	54 EFPY BELTLINE CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER VESSEL CURVE B (°F)	54 EFPY BELTLINE CURVE B (°F)
1300	120.2	147.0	159.1	148.8	172.8	184.0
1310	120.7	147.5	159.7	149.3	173.1	184.5
1320	121.3	147.9	160.3	149.8	173.3	184.9
1330	121.8	148.3	160.8	150.2	173.6	185.4
1340	122.3	148.7	161.4	150.7	173.8	185.8
1350	122.8	149.1	161.9	151.2	174.1	186.3
1360	123.3	149.6	162.4	151.6	174.4	186.7
1370	123.8	150.0	163.0	152.1	174.6	187.1
1380	124.3	150.4	163.5	152.5	174.9	187.6
1390	124.8	150.8	164.0	153.0	175.1	188.0
1400	125.3	151.2	164.5	153.4	175.4	188.4

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
0	68.0	83.1	68.0	83.1	83.1
10	68.0	83.1	68.0	83.1	83.1
20	68.0	83.1	68.0	83.1	83.1
30	68.0	83.1	68.0	83.1	83.1
40	68.0	83.1	68.0	83.1	83.1
50	68.0	83.1	68.0	83.1	83.1
60	68.0	83.1	68.0	83.1	91.0
70	68.0	83.1	68.0	83.1	98.2
80	68.0	83.1	68.0	83.1	104.2
90	68.0	83.1	68.0	83.1	109.3
100	68.0	83.1	68.0	83.1	113.8
110	68.0	83.1	68.0	83.1	117.9
120	68.0	83.1	68.0	83.1	121.7
130	68.0	83.1	68.0	85.2	125.2
140	68.0	83.1	68.0	88.4	128.4
150	68.0	83.1	68.0	91.2	131.2
160	68.0	83.1	68.0	93.9	133.9
170	68.0	83.1	68.0	96.5	136.5
180	68.0	83.1	68.0	98.9	138.9
190	68.0	83.1	68.0	101.2	141.2
200	68.0	83.1	68.0	103.3	143.3
210	68.0	83.1	68.0	105.3	145.3

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
220	68.0	83.1	68.0	107.3	147.3
230	68.0	83.1	68.0	109.1	149.1
240	68.0	83.1	68.0	110.9	150.9
250	68.0	83.1	68.0	112.6	152.6
260	68.0	83.1	68.0	114.2	154.2
270	68.0	83.1	68.0	115.8	155.8
280	68.0	83.1	68.0	117.3	157.3
290	68.0	83.1	68.0	118.8	158.8
300	68.0	83.1	68.0	120.2	160.2
310	68.0	83.1	68.0	121.5	161.5
312.5	68.0	83.1	68.0	121.9	161.9
312.5	68.0	113.1	68.0	143.1	183.1
320	68.0	113.1	68.0	143.1	183.1
330	68.0	113.1	68.0	143.1	183.1
340	68.0	113.1	68.0	143.1	183.1
350	68.0	113.1	68.0	143.1	183.1
360	68.0	113.1	68.0	143.1	183.1
370	68.0	113.1	68.0	143.1	183.1
380	68.0	113.1	68.0	143.1	183.1
390	68.0	113.1	68.0	143.1	183.1
400	68.0	113.1	68.0	143.1	183.1
410	68.0	113.1	68.0	143.1	183.1
420	68.0	113.1	68.0	143.1	183.1

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
430	68.0	113.1	68.0	143.1	183.1
440	68.0	113.1	68.0	143.1	183.1
450	68.0	113.1	68.0	143.1	183.1
460	68.0	113.1	68.0	143.1	183.1
470	68.0	113.1	68.0	143.1	183.1
480	68.0	113.1	69.1	143.1	183.1
490	68.0	113.1	71.4	143.1	183.1
500	68.0	113.1	73.6	143.1	183.1
510	68.0	113.1	75.8	143.1	183.1
520	68.0	113.1	77.8	143.2	183.2
530	68.0	113.1	79.8	144.0	184.0
540	68.0	113.1	81.7	144.8	184.8
550	68.0	113.1	83.5	145.6	185.6
560	68.0	113.1	85.3	146.4	186.4
570	68.0	113.1	87.0	147.1	187.1
580	68.0	113.1	88.6	147.9	187.9
590	68.0	113.1	90.2	148.6	188.6
600	68.0	113.1	91.8	149.1	189.1
610	68.0	113.1	93.3	149.6	189.6
620	68.0	113.1	94.7	150.0	190.0
630	68.0	113.1	96.1	150.4	190.4
640	68.0	113.1	97.5	150.8	190.8
650	68.0	113.1	98.8	151.2	191.2

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
660	68.0	113.1	100.1	151.7	191.7
670	68.0	113.1	101.4	152.1	192.1
680	68.0	113.1	102.7	152.5	192.5
690	68.0	113.1	103.9	152.9	192.9
700	69.2	113.1	105.0	153.3	193.3
710	70.7	113.1	106.2	153.7	193.7
720	72.1	113.1	107.3	154.1	194.1
730	73.5	113.3	108.4	154.5	194.5
740	74.8	114.1	109.5	154.9	194.9
750	76.1	115.0	110.6	155.2	195.2
760	77.4	115.8	111.6	155.6	195.6
770	78.6	116.6	112.6	156.0	196.0
780	79.8	117.3	113.6	156.4	196.4
790	81.0	118.1	114.6	156.8	196.8
800	82.2	118.9	115.5	157.1	197.1
810	83.3	119.6	116.5	157.5	197.5
820	84.4	120.4	117.4	157.9	197.9
830	85.5	121.2	118.3	158.2	198.2
840	86.5	122.4	119.2	158.6	198.6
850	87.6	123.5	120.0	158.9	198.9
860	88.6	124.7	120.9	159.3	199.3
870	89.6	125.8	121.7	159.6	199.6
880	90.5	126.9	122.6	160.0	200.0

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
890	91.5	128.0	123.4	160.4	200.4
900	92.4	129.0	124.2	161.2	201.2
910	93.4	130.0	125.0	161.9	201.9
920	94.3	131.0	125.7	162.6	202.6
930	95.1	132.0	126.5	163.3	203.3
940	96.0	133.0	127.3	164.0	204.0
950	96.9	133.9	128.0	164.7	204.7
960	97.7	134.8	128.7	165.3	205.3
970	98.6	135.8	129.5	166.0	206.0
980	99.4	136.7	130.2	166.6	206.6
990	100.2	137.5	130.9	167.3	207.3
1000	101.0	138.4	131.6	167.9	207.9
1010	101.7	139.2	132.2	168.6	208.6
1020	102.5	140.1	132.9	169.2	209.2
1030	103.3	140.9	133.6	169.8	209.8
1040	104.0	141.7	134.2	170.4	210.4
1050	104.7	142.5	134.9	171.0	211.0
1060	105.4	143.3	135.5	171.6	211.6
1070	106.2	144.1	136.1	172.2	212.2
1080	106.9	144.8	136.8	172.8	212.8
1090	107.6	145.6	137.4	173.3	213.3
1100	108.2	146.3	138.0	173.9	213.9
1105	108.6	146.7	138.3	174.2	214.2

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
1110	108.9	147.0	138.6	174.4	214.4
1120	109.6	147.7	139.2	175.0	215.0
1130	110.2	148.5	139.8	175.5	215.5
1140	110.9	149.2	140.3	176.1	216.1
1150	111.5	149.8	140.9	176.6	216.6
1160	112.1	150.5	141.5	177.1	217.1
1170	112.8	151.2	142.0	177.7	217.7
1180	113.4	151.8	142.6	178.2	218.2
1190	114.0	152.5	143.1	178.7	218.7
1200	114.6	153.1	143.7	179.2	219.2
1210	115.2	153.8	144.2	179.7	219.7
1220	115.8	154.4	144.8	180.2	220.2
1230	116.3	155.0	145.3	180.7	220.7
1240	116.9	155.6	145.8	181.2	221.2
1250	117.5	156.2	146.3	181.7	221.7
1260	118.0	156.8	146.8	182.2	222.2
1270	118.6	157.4	147.3	182.6	222.6
1280	119.1	158.0	147.8	183.1	223.1
1290	119.7	158.6	148.3	183.6	223.6
1300	120.2	159.1	148.8	184.0	224.0
1310	120.7	159.7	149.3	184.5	224.5
1320	121.3	160.3	149.8	184.9	224.9
1330	121.8	160.8	150.2	185.4	225.4

TABLE G-5. Bounding Dresden 2&3
Composite P-T Curve Values for 54 EFPY

Required Coolant Temperatures at 100 °F/hr for Curves B & C and 20 °F/hr for Curve A for Figures G-10, G-13 and G-14

PRESSURE (PSIG)	BOTTOM HEAD CURVE A (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE A (°F)	BOTTOM HEAD CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE B (°F)	UPPER RPV & BELTLINE AT 54 EFPY CURVE C (°F)
1340	122.3	161.4	150.7	185.8	225.8
1350	122.8	161.9	151.2	186.3	226.3
1360	123.3	162.4	151.6	186.7	226.7
1370	123.8	163.0	152.1	187.1	227.1
1380	124.3	163.5	152.5	187.6	227.6
1390	124.8	164.0	153.0	188.0	228.0
1400	125.3	164.5	153.4	188.4	228.4

APPENDIX B
Pressure-Temperature Curves,
Amendment Request to Support Operation to 54 Effective Full Power Years
Quad Cities Nuclear Power Station

Attachment 1

Description of Proposed Changes, Technical Analysis, and Regulatory Analysis

Subject: Request for Changes Related to Technical Specifications Section 3.4.9, "Reactor Coolant System Pressure and Temperature (P/T) Limits"

Attachment 1

Description of Proposed Changes, Technical Analysis, and Regulatory Analysis

1. DESCRIPTION

In accordance with 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company, LLC (EGC) requests a change to Facility Operating License Nos. DPR-29 and DPR-30, and to Technical Specifications (TS), Section 3.4.9, "Reactor Coolant System Pressure and Temperature (P/T) Limits," for Quad Cities Nuclear Power Station (QCNPS), Units 1 and 2. This amendment request revises the P/T limits curves for 54 effective full power years (EFPY), and resolves a non-conservative condition for TS Section 3.4.9, Figure 3.4.9-2, "Non-Nuclear Heatup/Cooldown Curve," for QCNPS. In accordance with NRC Administrative Letter 98-10, "Dispositioning of Technical Specifications That Are Insufficient to Assure Plant Safety," administrative controls have been put in place at QCNPS until the license amendment request is approved.

EGC requests approval of the proposed changes no later than November 7, 2005.

2. PROPOSED CHANGE

The proposed changes are as follows.

- Replace the current TS Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3 with revised TS Figures 3.4.9-1 through 3.4.9-3. The revised P/T curves are applicable to 54 effective full power years (EFPY) as determined for a 40-year license with a 20 year renewed period.

EGC has reviewed the proposed changes and verified that there is no impact on previous submittals awaiting NRC approval.

3. BACKGROUND

In Reference 1, General Electric Company (GE) submitted Licensing Topical Report (LTR) NEDC-32983P, "General Electric Methodology for Reactor Vessel Fast Neutron Flux Evaluations," dated October 1, 2000, to the NRC. The LTR, which is in compliance with Regulatory Guide (RG) 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," dated March 2001, described a proposed methodology for calculating reactor pressure vessel (RPV) fast neutron fluence. This methodology received NRC approval in Reference 2. This approved methodology was used to develop the P/T limits curves for the proposed changes in this request. Attachments 4 and 5 contain reports that describe the GE methodology used in calculating the RPV fluence and provide results used for determining P/T curves for QCNPS, Units 1 and 2.

In Reference 3, the NRC approved Amendments Nos. 202 and 198 to the Facility Operating Licenses for QCNPS, Units 1 and 2, respectively, permitting extended power uprate (EPU) operations. The amendments allowed an increase in the maximum authorized operating power level from 2511 megawatts thermal (MWt) to 2957 MWt, an increase of approximately 17.8%. The NRC approved the EPU license amendment request on December 21, 2001. QCNPS Unit 2 began EPU operations on March 5, 2002, and Unit 1 began EPU operations on November 26, 2002. Operation at EPU power levels affects the RPV fluence and the determination of the P/T limits for the proposed change addresses this issue.

In addition, these amendments approved the use of the current P/T limits curves in TS Section 3.4.9 through 32 EFPY based, in part, on the use of Code Cases N-588 and N-640 of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. Code Cases N-588 and N-640 were reviewed and approved for use by the NRC. Code Case N-588 permits the postulation of a circumferentially oriented flaw (in lieu of an axially-oriented flaw) for the evaluation of the circumferential welds in RPV P/T limits curves. Code Case N-640 permits the use of an alternate reference fracture toughness for reactor vessel materials in determining the P/T limits.

In Reference 4, EGC requested a renewal of the operating licenses for QCNPS, Units 1 and 2, to extend operation of these facilities to 60 years. The proposed changes in this request support the continued operation of these facilities to 54 EFPY, corresponding to a 60-year plant life. In Reference 5, Southern Nuclear Operating Company, Inc., submitted a similar request for Edwin I. Hatch Nuclear Plant, Units 1 and 2. The NRC approved this request in Reference 6.

4. TECHNICAL ANALYSIS

The P/T limits curves are prescribed during normal operation to avoid encountering pressure, temperature, and temperature rate-of-change conditions that might cause undetected flaws to propagate and cause nonductile failure of the reactor coolant pressure boundary, a condition that is unanalyzed. The operating limits for pressure and temperature are required for three categories of operation: (a) hydrostatic pressure tests and leak tests, (b) non-nuclear heatup/cooldown and low-level physics tests, and (c) core critical operation.

Methodology

Attachments 4 and 5 describe the methodology used by GE to develop P/T curves. This methodology is similar to that used to generate P/T curves submitted to the NRC in Reference 7, in which EGC requested a change to the P/T limits curves in TS Figures 3.4.9-1, 3.4.9-2, and 3.4.9-3 for Dresden Nuclear Power Station (DNPS), Units 2 and 3. During the NRC's review of Reference 7, the NRC requested additional information regarding a comparison of stresses listed in Reference 8, including those stresses associated with two transient conditions considered in the analysis. As a result of the NRC's questions, the stress report was further reviewed and the K_I values for the limiting normal and upset transients were determined.

An evaluation was performed using plant specific inputs to scale the stresses for the limiting normal and upset thermal transients, which determined that the bottom head region of the non-nuclear heatup/cooldown curve was non-conservative for QCNPS. Specifically, the current P/T curve for the reactor pressure vessel bottom head region of Figure 3.4.9-2, "Non-nuclear Heatup/Cooldown Curve," was determined to be non-conservative by 14.6 degrees Fahrenheit (°F) for QCNPS Unit 1 and 11.6°F for Unit 2 during a bounding anticipated operational occurrence for the improper start of an idle recirculation pump, which is more severe than the normal upset condition (i.e., loss of feedwater transient). Since the P/T limits are established considering the safety factors of ASME Section XI, Appendix G, this non-conservativism in the region of the bottom head curve implies that a safety factor of two may not be maintained if the plant is conducting operations with the RPV bottom head pressure and temperature near the existing curve in TS Figure 3.4.9-2.

Attachment 1

Description of Proposed Changes, Technical Analysis, and Regulatory Analysis

In accordance with NRC Administrative Letter 98-10, administrative controls have been put in place at QCNPS until the license amendment request is approved. QCNPS procedure QCOS 0201-02, "Primary System Boundary Thermal Limitations," was revised to incorporate a shift of 14.6°F in the P/T curve for TS Figure 3.4.9-2, which bounds the non-conservativism for both units. QCNPS performed a review of the interim compensatory action involving this procedure change in accordance with 10 CFR 50.59, "Changes, tests, and experiments."

In addition, the P/T curves for DNPS were revised and resubmitted during the review. Reference 9 contains additional details associated with the review of the GE methodology and EGC's responses to NRC questions associated with this review. The NRC approved the Reference 7 request for DNPS in Reference 10.

The P/T curve methodology includes the following.

1) Incorporation of ASME Code Case N-640, "Alternative Fracture Toughness for Development of P-T Limit Curves for ASME Section XI, Division 1."

2) Use of the M_m calculation in the ASME Code, paragraph G-2214.1, for a postulated defect normal to the direction of maximum stress.

ASME Code Case N-588 allows the use of an alternative procedure for calculating the applied stress intensity factors for axial and circumferential welds. ASME Code Case N-640 allows the use of K_{IC} in Figure A-4200-1of ASME Code, Section XI, Appendix A, in lieu of K_{Ia} of Figure G-2210-1 of Appendix G, to determine T-RT_{NDT}. Use of NRC-approved ASME Code Cases (i.e., N-588, and N-640) in conjunction with earlier versions of the ASME Code endorsed in 10 CFR 50.55a, "Codes and standards," may also be used for the development of P/T limit curves without the need for an exemption. These alternatives to the Appendix G methodology have been proposed and accepted as appropriate alternatives and are documented in Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1." Use of the M_m calculation is discussed in the BWR/6 generic evaluation in ASME Code, Section XI, Appendix G.

The proposed P/T curves, and the methodology used to develop them, comply with ASME Code, Section III, Appendix G, and ASTM E 185, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels," requirements for monitoring fracture toughness, minimum temperature, and performing material surveillances in accordance with 10 CFR 50, Appendix G, "Fracture Toughness Requirements," and 10 CFR 50, Appendix H, "Reactor Vessel Material Surveillance Program Requirements."

Analysis Assumptions

The analysis used the following assumptions.

(1) For end-of-license (54 EFPY) fluence, a mixed capacity factor was used to determine the EFPY for a 60-year plant life. An 80% capacity factor is assumed up to 21.1 EFPY for Unit 1 (21 EFPY for Unit 2). To consider recent improvements in plant operation, a 97.5% capacity factor is used beginning at 21.1 EFPY for Unit 1 (21 EFPY for Unit 2). Hence, 54 EFPY is assumed to represent 60 years of operation.

(2) The hydrostatic test will be conducted at or below 1105.5 psig.

(3) The shutdown margin, provided in the TS for QCNPS, Units 1 and 2, is calculated for a water temperature of 68°F.

(4) Considerations for EPU were included in the analysis. The P/T limits were calculated using a pre-EPU and a post-EPU RPV neutron fluence, both calculated in accordance with RG 1.190. The pre-EPU fluence corresponds to 21.1 EFPY for Unit 1 (21 EFPY for Unit 2) and the post-EPU fluence corresponds to 32.9 EFPY (33 EFPY for Unit 3) for 54 EFPY calculations.

Protection Against Brittle Fracture

The P/T curves are composites created by superimposing limits derived from stress analyses of those portions of the reactor vessel and head that are the most restrictive, thereby representing the bounding results for the combined Unit 1 and Unit 2 curves. The curves present steam dome pressure versus minimum vessel temperature, including appropriate non-beltline limits and irradiation embrittlement effects in the beltline. These curves have been combined to make it easier for Operations personnel to choose the correct curves during plant operations. The table below identifies curves in TS Section 3.4.9 in Attachment 3, and the corresponding figures in Attachments 4 and 5 for QCNPS, Units 1 and 2. The composite curves in the GE reports are identical for both QCNPS units.

TS Figure	TS Page	Title	GE Report Figure	GE Report Page
3.4.9-1	3.4.9-6	"Non-Nuclear Inservice Leak and Hydrostatic Testing Curve"	G-13, Curve A	G-16
3.4.9-2	3.4.9-7	"Non-Nuclear Heatup/Cooldown Curve"	G-14, Curve B	G-17
3.4.9-3	3.4.9-8	"Critical Operations Curve"	G-10, Curve C	G-13

Each P/T curve defines an acceptable region for normal operation and provides guidance for heatup or cooldown maneuvering. Adherence to the limits specified by the P/T curves assures that the RPV and piping of the reactor coolant pressure boundary have sufficient margin to brittle failure during normal operation, anticipated operational occurrences, and system hydrostatic tests. Operation within the limits of the P/T curves protects the RPV and the reactor boundary from brittle failure.

The curves presented in the proposed TS figures are composite curves for QCNPS, Units 1 and 2. These curves were developed by choosing the most limiting pressure from the analysis results of the two units for each metal temperature.

5. REGULATORY ANALYSIS

5.1 No Significant Hazards Consideration

According to 10 CFR 50.92, "Issuance of amendment," paragraph (c), a proposed amendment to an operating license involves no significant hazards consideration if operation of the facility in accordance with the proposed amendment would not:

(1) Involve a significant increase in the probability or consequences of an accident previously evaluated; or

(2) Create the possibility of a new or different kind of accident from any accident previously evaluated; or

(3) Involve a significant reduction in a margin of safety.

In support of this determination, an evaluation of each of the three criteria set forth in 10 CFR 50.92 is provided below regarding the proposed license amendment.

Does the change involve a significant increase in the probability or consequences of an accident previously evaluated?

The P/T limits are prescribed during all operational conditions to avoid encountering pressure, temperature, and temperature rate-of-change conditions that might cause undetected flaws to propagate, resulting in non-ductile failure of the reactor coolant pressure boundary, which is an unanalyzed condition. The methodology used to determine the P/T limits has been approved by the NRC and thus is an acceptable method for determining these limits. Therefore, the proposed changes do not affect the probability of an accident previously evaluated.

There is no specific accident that postulates a non-ductile failure of the reactor coolant pressure boundary. The loss of coolant accident analyzed for the plant assumes a 4.281 square feet complete break of the Recirculation pump suction line. The revision to the P/T limits does not change this assumption. Thus, the radiological consequences of any accident previously evaluated are not increased.

Therefore, the proposed changes do not involve a significant increase in the probability or consequences of an accident previously evaluated.

Does the change create the possibility of a new or different kind of accident from any accident previously evaluated?

The proposed changes do not change the response of plant equipment to transient conditions. The proposed changes do not introduce any new equipment, modes of system operation, or failure mechanisms.

Non-ductile failure of the reactor coolant pressure boundary is not an analyzed accident, as previously discussed in Reference 11. The proposed changes to the P/T limits were developed using an NRC-approved methodology, and thus the revised limits will

continue to provide protection against non-ductile failure of the reactor coolant pressure boundary.

Therefore, the proposed changes do not create the possibility of a new or different kind of accident from any previously evaluated.

Does the change involve a significant reduction in a margin of safety?

The margin of safety related to the proposed changes is the margin between the proposed P/T limits and the pressures and temperatures that would produce non-ductile failure of the reactor coolant pressure boundary. NRC requirements to protect the integrity of the reactor coolant pressure boundary in nuclear power plants is established in 10 CFR 50, Appendix G, "Fracture Toughness Requirements," which requires that the P/T limits for an operating plant be at least as conservative as those that would be generated if the methods of American Society of Mechanical Engineers (ASME) Section XI, Appendix G, were applied. The use of an NRC-approved methodology, together with conservatively chosen plant-specific input parameters, provides an acceptable margin of safety. Therefore, the proposed changes do not involve a significant reduction in a margin of safety.

Conclusion

Based upon the above responses, EGC concludes that the proposed amendment presents no significant hazards consideration under the standards set forth in 10 CFR 50.92 and, accordingly, a finding of no significant hazards consideration is justified.

5.2 Applicable Regulatory Requirements/Criteria

The P/T limits are not derived from Design Basis Accident (DBA) analyses. They are prescribed during normal operation to avoid encountering pressure, temperature, and temperature rate-of-change conditions that might cause undetected flaws to propagate and cause nonductile failure of the reactor coolant pressure boundary, a condition that is unanalyzed. Therefore, the P/T curves must be included in the TS for QCNPS, Units 1 and 2, in accordance with Criterion 2 of 10 CFR 50.36, "Limiting conditions for operation," paragraph (c)(2)(ii).

6. ENVIRONMENTAL CONSIDERATION

In accordance with 10 CFR 50.90, "Application for amendment of license or construction permit," Exelon Generation Company, LLC (EGC) requests a change to Facility Operating License Nos. DPR-29 and DPR-30, and the Technical Specifications (TS) for Quad Cities Nuclear Power Station (QNPS), Units 1 and 2. The proposed change is to TS Section 3.4.9, "Reactor Coolant System Pressure and Temperature (P/T) Limits," to revise the P/T limits curves.

EGC evaluated the proposed change against the criteria in 10 CFR 51.21, "Criteria for and identification of licensing and regulatory actions requiring environmental assessments." EGC determined that the proposed change meets the criteria for a categorical exclusion as set forth

in 10 CFR 51.22, "Criterion for categorical exclusion; identification of licensing and regulatory actions eligible for categorical exclusion or otherwise not requiring environmental review," paragraph (c)(9). EGC determined that no irreversible consequences exist, in accordance with 10 CFR 50.92, "Issuance of amendment," paragraph (b). This change is proposed as an amendment to a license issued pursuant to 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities," which changes a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, "Standards for Protection Against Radiation," or that changes an inspection or a surveillance requirement, and the amendment meets the following criteria:

(i) The amendment involves no significant hazards consideration.

As demonstrated in Section 5.1, this proposed change does not involve any significant hazards consideration.

(ii) There is no significant change in the types or significant increase in the amounts of any effluent that may be released.

The proposed change revises the P/T limits curves of TS Section 3.4.9. It does not allow for an increase in the unit power level and does not increase the production, nor alter the flow path or method of disposal, of radioactive waste or byproducts. Therefore, the proposed change does not affect the actual unit effluents.

(ii) There is no significant increase in individual or cumulative occupational radiation exposure.

The proposed change will not result in changes in the configuration of the facility. There will be no change in the level of controls or methodology used for processing of radioactive effluents or handling of solid radioactive waste, nor will the proposal result in any change to the normal radiation levels within the plant. Therefore, there will be no increase in individual or cumulative occupational radiation exposure resulting from this change.

7. REFERENCES

1. Letter from J. F. Klapproth (General Electric Company) to U. S. NRC, "Submittal of GE Proprietary Document NEDC-32983P, 'General Electric Methodology for Reactor Vessel Fast Neutron Flux Evaluations,'" dated September 1, 2000

2. Letter from U. S. NRC to J. F. Klapproth (General Electric Company), "Safety Evaluation for NEDC-32983P, 'General Electric Methodology for Reactor Pressure Vessel Fast Neutron Flux Evaluation,'" dated September 14, 2001

3. Letter from U. S. NRC to O. D. Kingsley (Exelon Generation Company, LLC), "Quad Cities Nuclear Power Station, Unit Nos. 1 and 2 - Issuance of Amendments for Extended Power Uprate," dated December 21, 2001

4. Letter from J. A. Benjamin (Exelon Generation Company, LLC) to U. S. NRC, "Application for Renewed Operating Licenses," dated January 3, 2003

5. Letter from H. L. Sumner, Jr., (Southern Nuclear Operating Company, Inc.) to U. S. NRC, "Edwin I. Hatch Nuclear Plant, Request to Revise Technical Specifications: Pressure and Temperature Limits," dated June 1, 2000

6. Letter from U. S. NRC to H. L. Sumner, Jr., (Southern Nuclear Operating Company, Inc.), "Edwin I. Hatch Nuclear Plant, Units 1 and 2, Issuance of Amendments," dated August 29, 2000

7. Letter from P. R. Simpson, (Exelon Generation Company, LLC) to U. S. NRC, "Request for Changes Related to Technical Specifications Section 3.4.9, 'Reactor Coolant System Pressure and Temperature Limits,'" dated February 27, 2003

8. General Electric Reports, GE-NE-0000-0002-9629 and GE-NE-0000-0002-9600, "Pressure-Temperature Curves for Exelon Dresden Unit 2," and "Pressure-Temperature Curves for Exelon Dresden Unit 3," respectively, dated February 2003

9. Letter from P. R. Simpson, (Exelon Generation Company, LLC) to U. S. NRC, "Additional Information Regarding Request for License Amendment for Pressure – Temperature Limits," dated September 11, 2003

10. Letter from U. S. NRC to J. L. Skolds (Exelon Generation Company, LLC), "Dresden Nuclear Power Station, Units 2 and 3 – Issuance of Amendments Regarding Pressure and Temperature Limits," dated November 26, 2004

11. Letter from P. R. Simpson, (Exelon Generation Company, LLC) to U. S. NRC, "Additional Information Regarding Request for License Amendment for Pressure - Temperature Limits," dated July 17, 2003

Attachment 2

Markup of Technical Specification Pages for Proposed Changes

TS PAGES

3.4.9-6
3.4.9-7
3.4.9-8

TS BASES PAGES

B 3.4.9-1
B 3.4.9-9

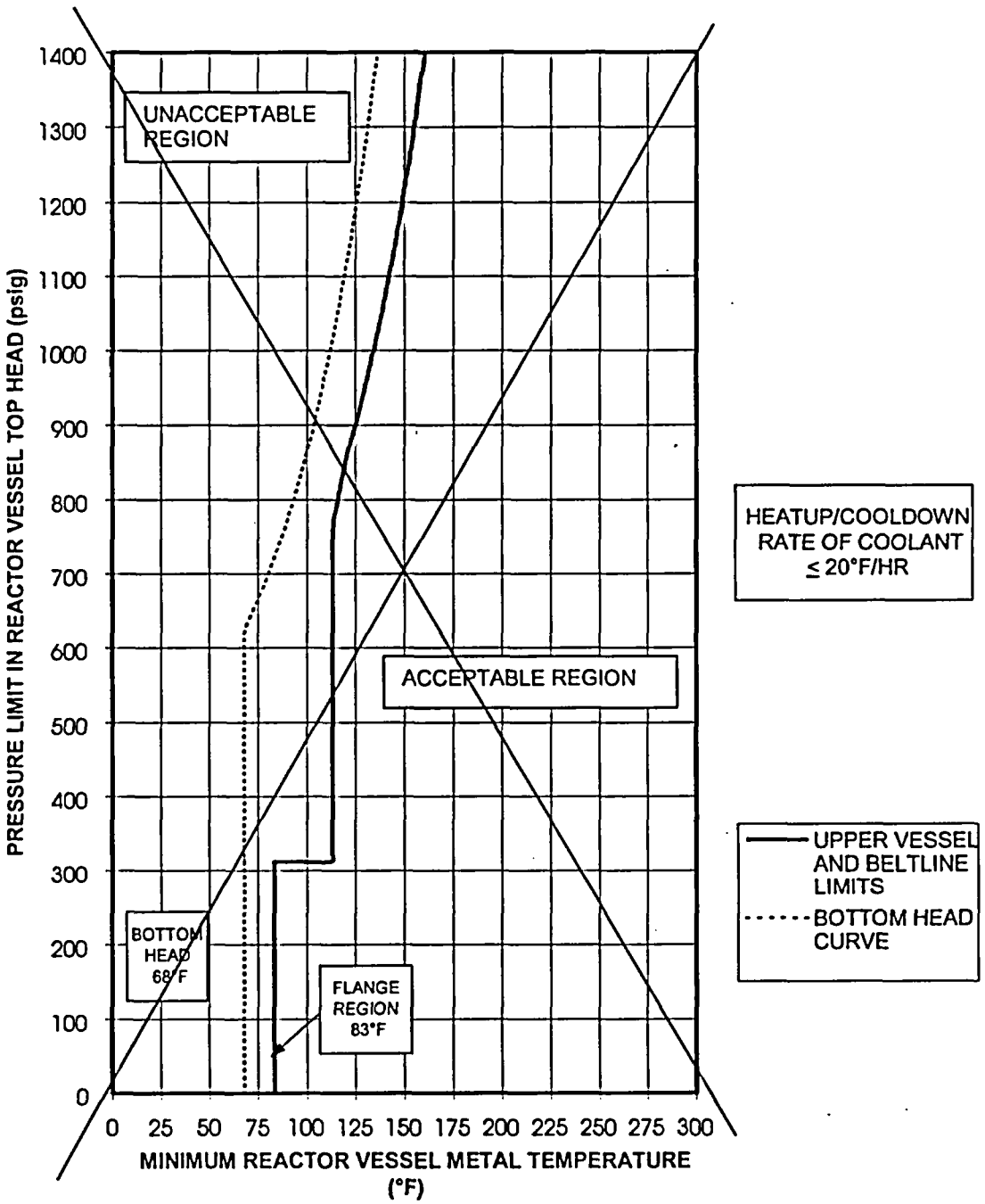

Figure 3.4.9-1 (Page 1 of 1)
Non-Nuclear Inservice Leak and Hydrostatic Testing Curve
(Valid to ~~32~~ 54 EFPY)

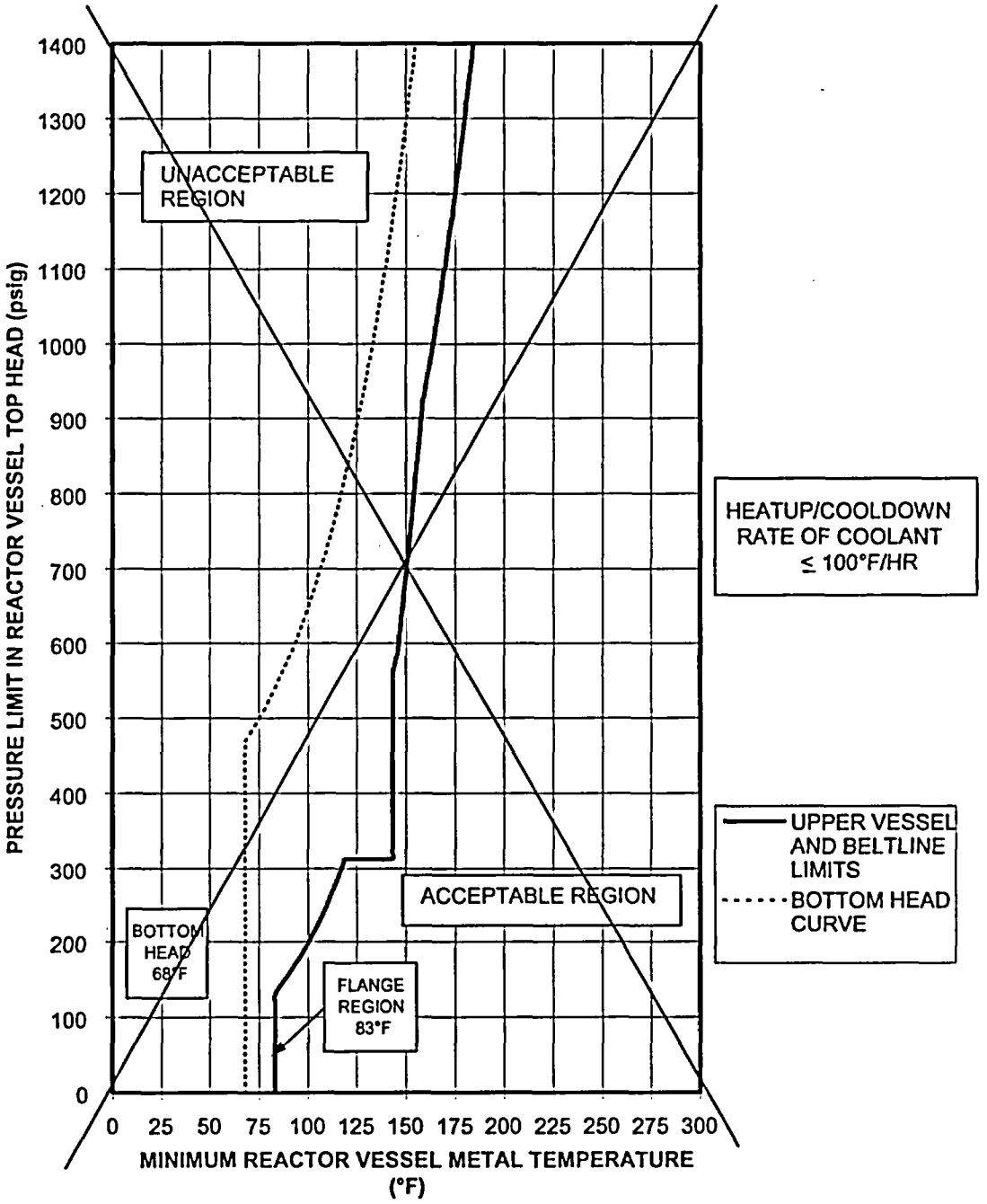

Figure 3.4.9-2 (Page 1 of 1)
Non Nuclear Heatup/Cooldown Curve
(Valid to ~~32~~ 54 EFPY)

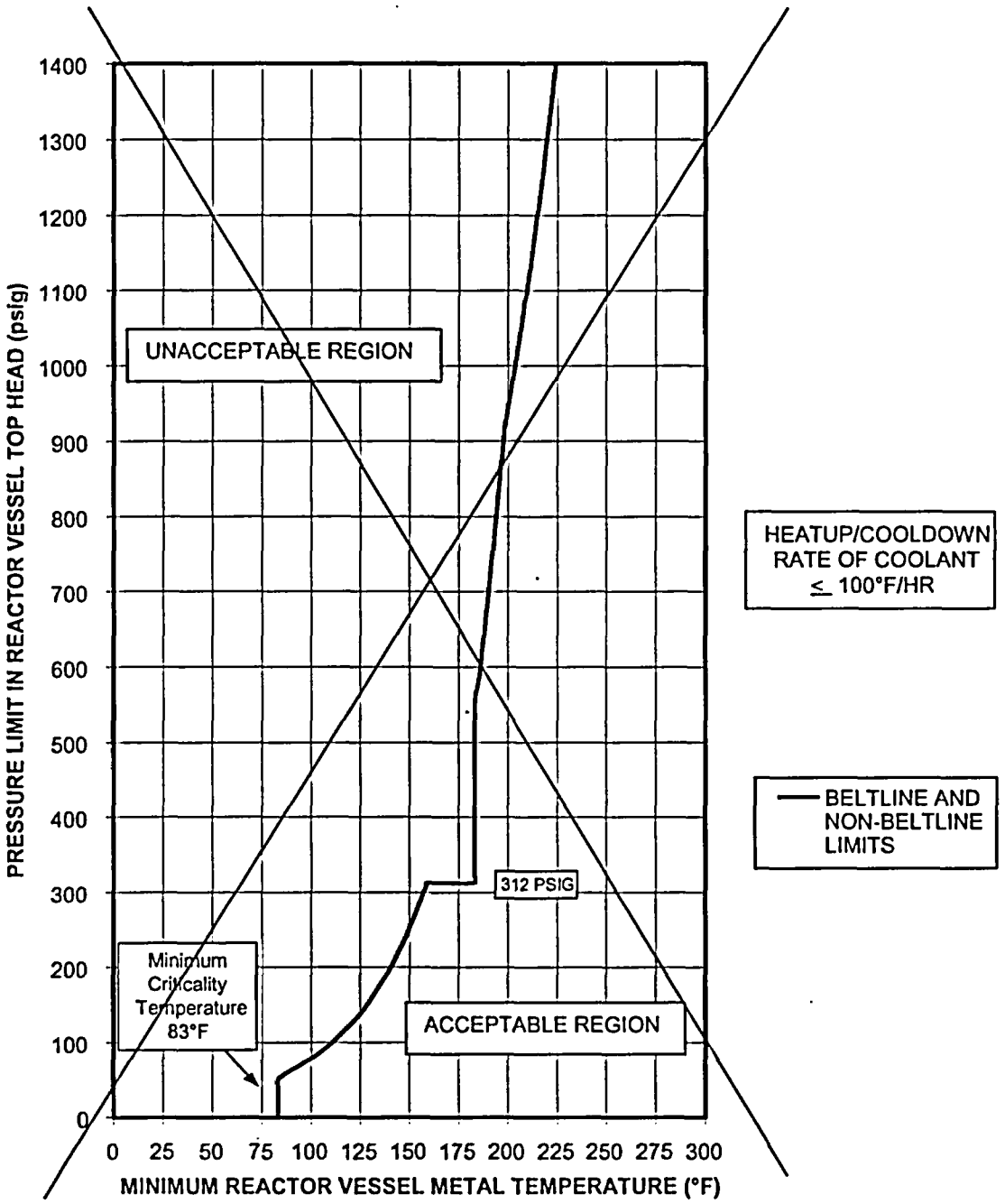

Figure 3.4.9-3 (Page 1 of 1)
Critical Operations Curve
(Valid to ~~32~~ 54 EFPY)

B 3.4 REACTOR COOLANT SYSTEM (RCS)

B 3.4.9 RCS Pressure and Temperature (P/T) Limits

BASES

BACKGROUND

All components of the RCS are designed to withstand effects of cyclic loads due to system pressure and temperature changes. These loads are introduced by startup (heatup) and shutdown (cooldown) operations, power transients, and reactor trips. This LCO limits the pressure and temperature changes during RCS heatup and cooldown, within the design assumptions and the stress limits for cyclic operation.

The Specification contains P/T limit curves for heatup, cooldown, and inservice leak and hydrostatic testing, and criticality, and also limits the maximum rate of change of reactor coolant temperature. The P/T limit curves are applicable for 32 effective full power years. 54

Each P/T limit curve defines an acceptable region for normal operation. The usual use of the curves is operational guidance during heatup or cooldown maneuvering, when pressure and temperature indications are monitored and compared to the applicable curve to determine that operation is within the allowable region.

The LCO establishes operating limits that provide a margin to brittle failure of the reactor vessel and piping of the reactor coolant pressure boundary (RCPB). The vessel is the component most subject to brittle failure. Therefore, the LCO limits apply mainly to the vessel.

10 CFR 50, Appendix G (Ref. 1), requires the establishment of P/T limits for material fracture toughness requirements of the RCPB materials. Reference 1 requires an adequate margin to brittle failure during normal operation, anticipated operational occurrences, and system hydrostatic tests. It mandates the use of the ASME Code, Section III, Appendix G (Ref. 2).

The actual shift in the RT_{NDT} of the vessel material will be established periodically by removing and evaluating the irradiated reactor vessel material specimens, in accordance with ASTM E 185 (Ref. 3) and Appendix H of 10 CFR 50 (Ref. 4). The operating P/T limit curves will be adjusted,

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.4.9.5, SR 3.4.9.6, and SR 3.4.9.7 (continued)

because of the reduced margin to the limits. When in MODE 4 with RCS temperature ≤ 113°F, monitoring of the flange temperature is required every 12 hours to ensure the temperature is within the specified limits.

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

SR 3.4.9.5 is modified by a Note that requires the Surveillance to be performed only when tensioning the reactor vessel head bolting studs. SR 3.4.9.6 is modified by a Note that requires the Surveillance to be initiated 30 minutes after RCS temperature ≤ 93°F in MODE 4. SR 3.4.9.7 is modified by a Note that requires the Surveillance to be initiated 12 hours after RCS temperature ≤ 113°F in MODE 4. The Notes contained in these SRs are necessary to specify when the reactor vessel flange and head flange temperatures are required to be verified to be within the specified limits.

REFERENCES

1. 10 CFR 50, Appendix G.

2. ASME, Boiler and Pressure Vessel Code, Section III, Appendix G.

3. ASTM E 185-82, July 1982.

4. 10 CFR 50, Appendix H.

5. Regulatory Guide 1.99, Revision 2, May 1988.

6. ASME, Boiler and Pressure Vessel Code, Section XI, Appendix E.

7. ~~Letter from S.N. Bailey (NRC) to ComEd, "Quad Cities - Issuance of Amendments - Revised Pressure Temperature Limits," dated February 4, 2000.~~

[Letter from (NRC) addressing the current amendment request for revising the P/T limits curves]

8. UFSAR, Section 15.4.4.3.

Attachment 3

Retyped Technical Specification Pages for Proposed Changes

REVISED TS PAGE

3.4.9-6
3.4.9-7
3.4.9-8

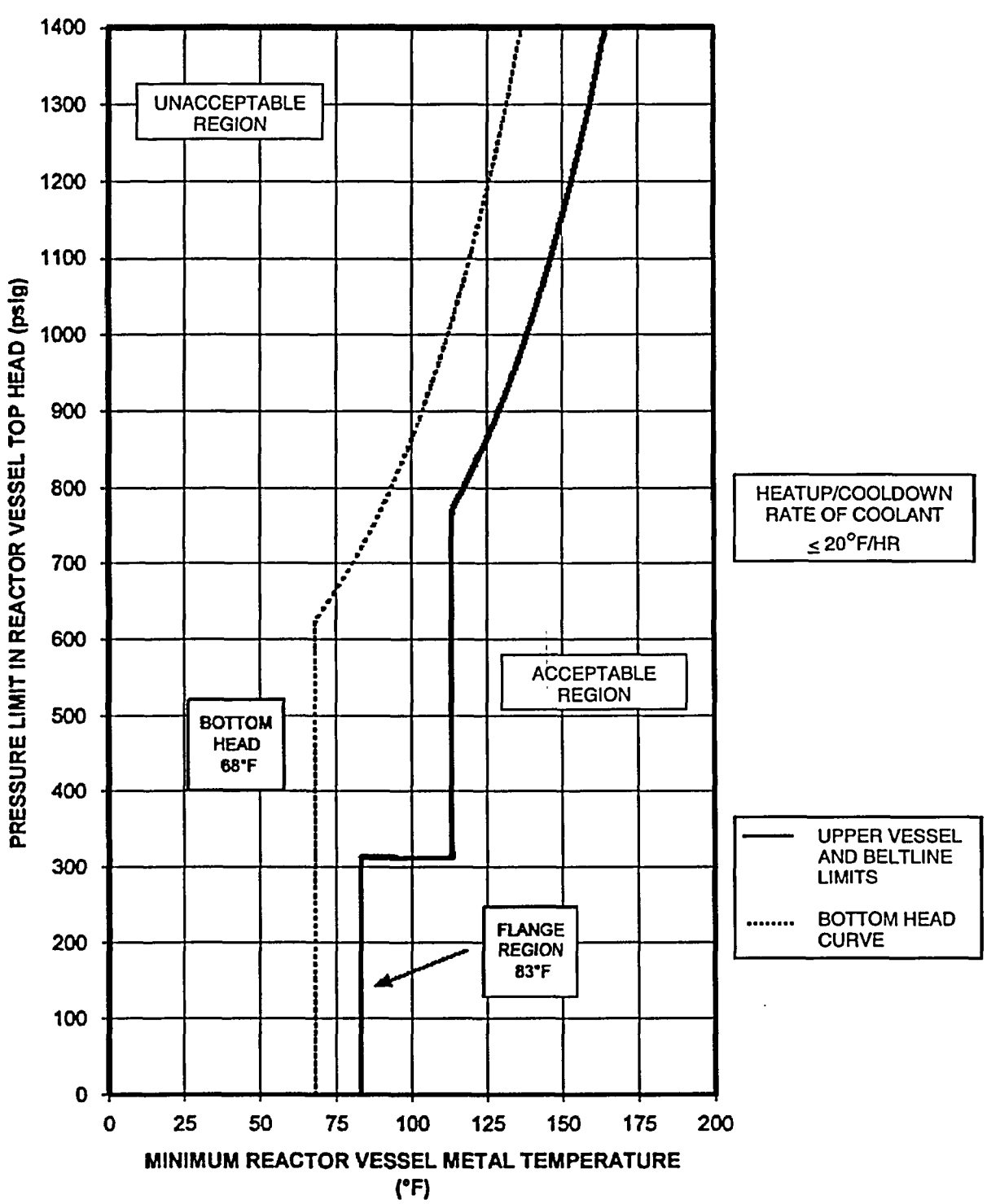

Figure 3.4.9-1 (Page 1 of 1)
Non-Nuclear Inservice Leak and Hydrostatic Testing Curve
(Valid to 54 EFPY)

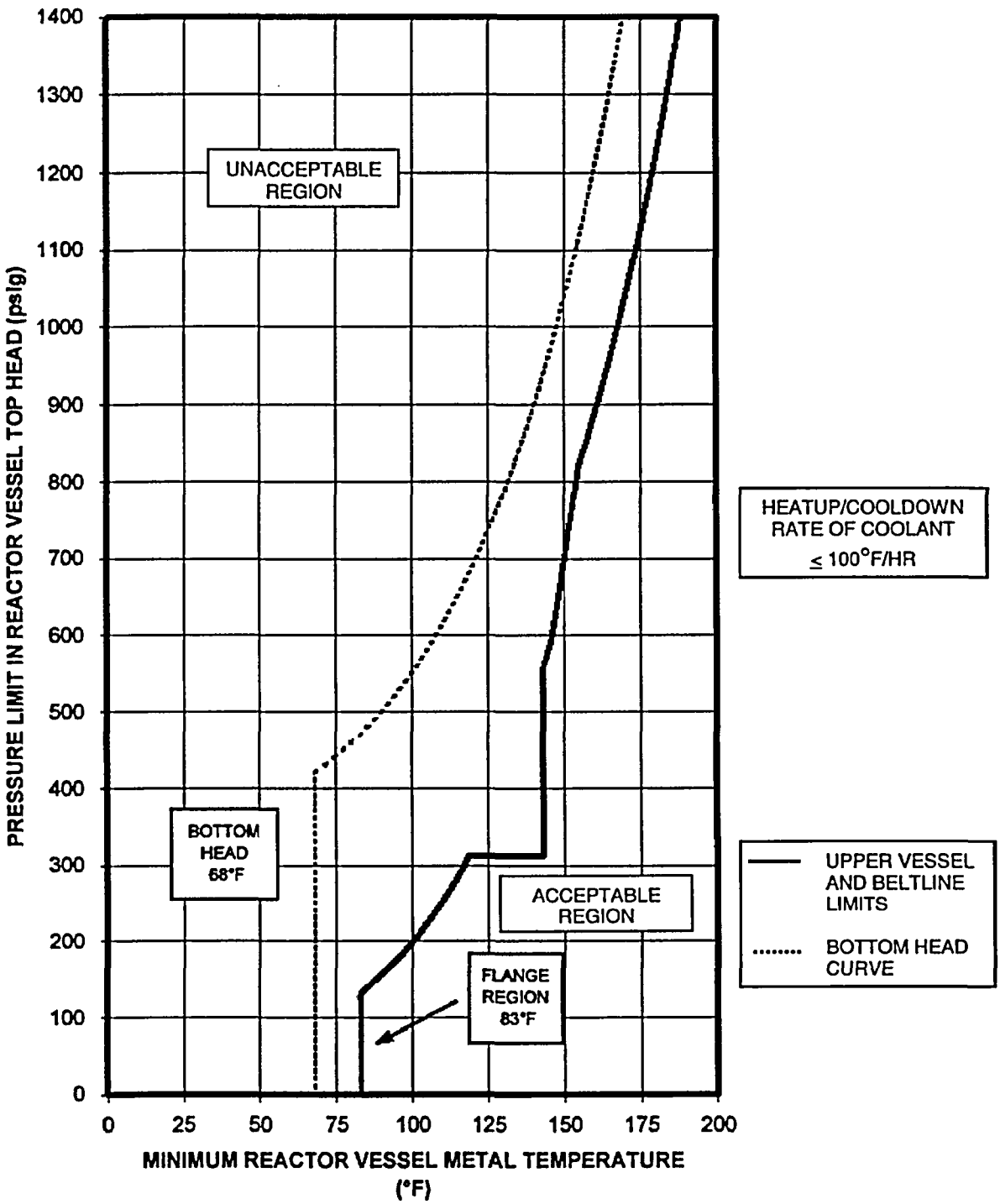

Figure 3.4.9-2 (Page 1 of 1)
Non-Nuclear Heatup/Cooldown Curve
(Valid to 54 EFPY)

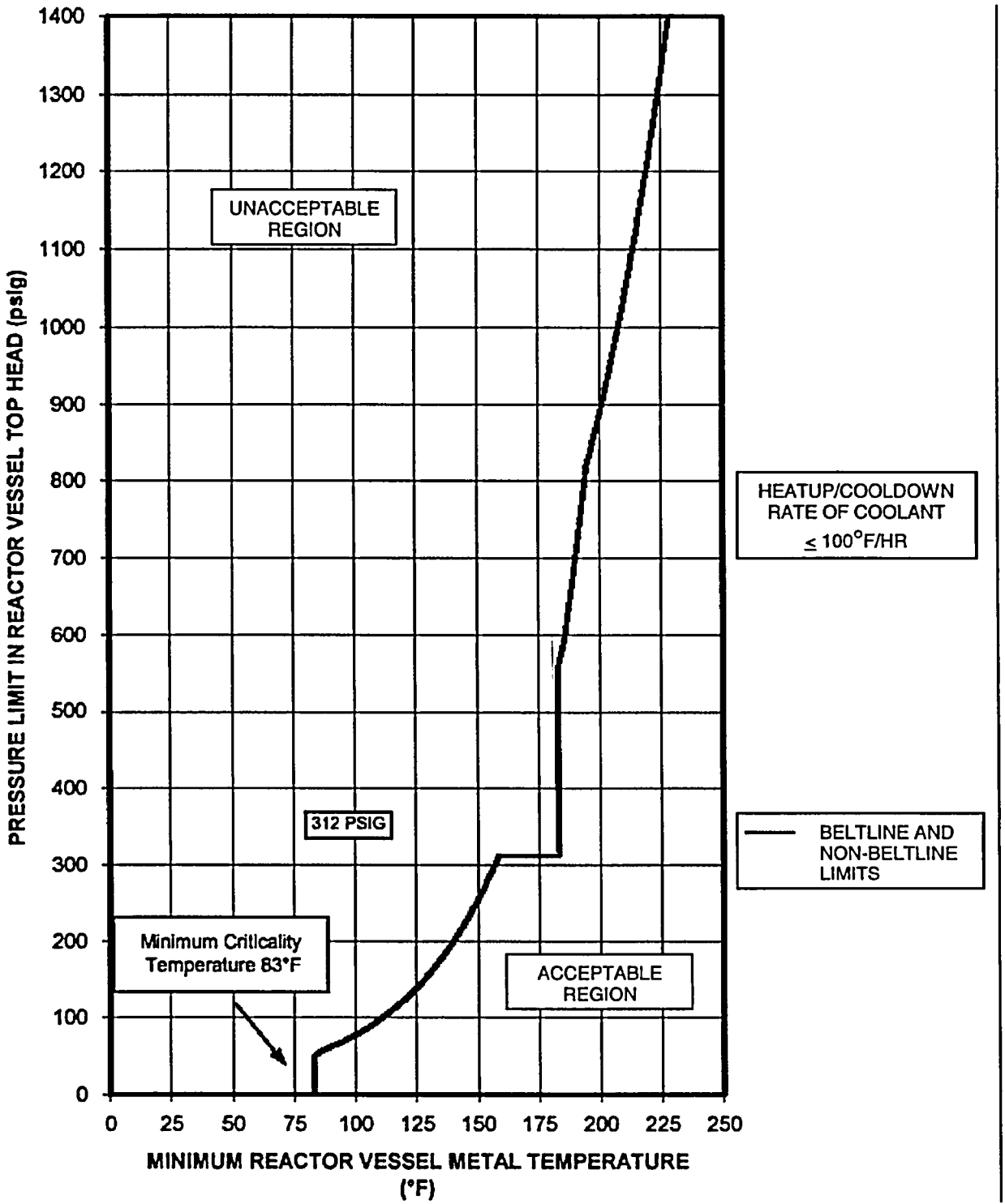

Figure 3.4.9-3 (Page 1 of 1)
Critical Operations Curve
(Valid to 54 EFPY)