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Pressure-Temperature Curves
for
Entergy Operations Inc. (EOI),
Using the K_{Ic} Methodology
River Bend

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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 February 1999 [1]. Several improvements were made to the P-T curve methodology; the improvements include, but are not limited to the following: 1) The incorporation of ASME Code Case N-640. 2) The use of the M_m calculation in the 1995 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} rather than K_{Ia} to determine T-RT_{NDT}. Descriptions of other improvements are included in the P-T curve methodology section.

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 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]. 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/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 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 and bottom head for the Pressure Test and Core Not Critical conditions. A common plot displaying curves A, B, and C on the same axes is also included.

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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 effective full power years (EFPY). The P-T curves are given in Section 5.0 and a tabulation of the curves is included in Appendix B.

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 February 1999 [1]. Several improvements were made to the P-T curve methodology; the improvements include, but are not limited to the following: 1) The incorporation of ASME Code Case N-640 [4]. 2) The use of the M_m calculation in the 1995 ASME Code paragraph G-2214.1 for a postulated defect normal to the direction of maximum stress [8]. ASME Code Case N-640 allows the use of K_{IC} rather than K_{Ia} to determine T-RT_{NDT}. Descriptions of other improvements are included in the P-T curve methodology section. 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.

The initial RT_{NDT} is the reference 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 were tabulated from the Certified Material Test Report (CMTR's). The data and methodology used to determine initial RT_{NDT} is documented in Section 4.1.

Adjusted Reference Temperature (ART) is the reference temperature including irradiation shift and a margin term. Regulatory Guide 1.99, Rev. 2 [6] provides the methods for calculating ART. The value of ART is a function of RPV ¼T fluence and beltline material chemistry. The ART calculation, methodology, and ART table for 32 EFPY are included in Section 4.2. The 32 EFPY ¼T plate fluence value of 5.75×10^{18} n/cm^2 used in this report was determined from 105% Power Uprate Evaluation Report for Entergy Operations Inc. River Bend Station [1]. A discussion of fluence is included in Section 4.2.1.2. The chemistry data is 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 to document which non-beltline discontinuity curves are used to protect the discontinuities.

Guidelines and requirements for operating and temperature monitoring are included in Appendix C. Finally, GE SIL 430, a GE service information letter regarding Reactor Pressure Vessel Temperature Monitoring is included in Appendix D.

2.0 Scope of the Analysis

This analysis was performed at a bounding reactor power of 3039 MWt (1.05 of 2894MWt). 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 February 1999 [1]. A detailed description of the P-T curve bases is included in Section 4.3. Several improvements were made to the P-T curve methodology; the improvements include, but are not limited to the following: 1) The incorporation of ASME Code Case N-640 [4]. 2) The use of the M_m calculation in the 1995 ASME Code paragraph G-2214.1 for a postulated defect normal to the direction of maximum stress [8]. ASME Code Case N-640 allows the use of K_{IC} rather than K_{Ia} to determine T-RT_{NDT}. Other improvements include, but are not limited to the following:

- 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 [5] 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 [6].

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 River Bend vessel components. The non-beltline limits are discussed in Section 4.3 and are also governed by requirements in [5].

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.

3.0 Analysis Assumptions

The following assumptions are made for this analysis:

For end-of-license (32 EFPY) fluence an 80% capacity factor is used to determine the EFPY for a 40-year plant life. The 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).

In those cases where the CMTR's for the forging material did not indicate the Charpy specimen orientation, the specimens were conservatively assumed to have a longitudinal orientation. Therefore, 30°F was added to the Charpy test temperature to convert from longitudinal to transverse for T_{50T}.

Where Charpy data was not available for heat numbers the purchase specifications was used. The purchase specification requires that weld materials have equal to or lower RT_{NDT}'s than the materials that are being welded. Thus the welds cannot be the limiting material. This occurred only for heat numbers in Table 4-2C and Table 4-2E.

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. 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 are 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.

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

To establish the initial RT_{NDT} temperatures for the River Bend 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, HAZ, forging, and weld material, and bolting material LST are summarized in the remainder of this section.

The first step in calculating RT_{NDT} is to establish the 50 ft-lb. transverse test temperature test specimen data (obtained from certified material test reports, CMTR's). For River Bend CMTR's, typically three energy values were listed at a given test temperature, corresponding to one set of Charpy tests. The Charpy plate materials are transversely oriented. Since the CMTR's for the forging material did not indicate the orientation of the Charpy specimens, the material was conservatively assumed to have a longitudinal orientation. Therefore, 30°F was added to the Charpy test temperature to convert from longitudinal to transverse for T_{50T}. River Bend's Charpy values were at or above 50 ft-lb and mils lat exp were at or above the required value. . The Charpy impact energy data were taken from the CMTR [16].

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. The Charpy impact energy data were taken from the CMTR [16]. River Bend's Charpy values and mils lat exp were at or above the required values.

Tables 4-1 thru 4-3 list the calculated initial RT_{NDT} values for the River Bend reactor vessel beltline and non-beltline materials whose Charpy test data were available. These tabulations include beltline, closure flange, nozzle, and bottom head materials that were considered in generating the P-T curves.

Table 4-1. Calculated Initial RT_{NDT} values for River Bend Vessel (Beltline Materials)

COMPONENT	Plant Specified Previous RTNDT (°F)	HEAT / FLUX / LOT	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{50T})	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
BELTLINE SHELL											
Low-Int. Plates	-20	C-3054-1	40	T	53	53	62	40	-40	-20	45
	+2	C-3054-2	70	T	51	64	62	70	-40	10	44
	+9	C-3138-2	60	T	66	50	51	60	-20	0	41
BELTLINE WELDS											
Longitudinal											
Welds within #2 Shell Ring											
E8018NM (3/16")	-50	492L4871 / / A421B27AF	10	n/a	56	58	61	10	-80	-50	37
E8018NM (5/32")	-60	492L4871 / / A421B27AE	0	n/a	50	51	57	0	-90	-60	36
Raco/NMM (Single Wire)	-60	5P6756 / Linde 124 / 0342	0	n/a	55	66	63	0	-60	-60	51
Raco/NMM (Tandem Wire)	-50	5P6756 / Linde 124 / 0342	10	n/a	64	72	77	10	-50	-50	35

Table 4-2-A Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline Plate Materials)

COMPONENT	HEAT	Plant Specified Previous RTNDT (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{50T}) (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
PLATES & FORGINGS:											
Bottom Head Plates											
Bottom Head Dollar	B-6552-1		60	T	51	60	50	60	0	0	36
Bottom Head Side Plates	A-1415-2		70	T	52	52	50	70	-30	10	41
	A-1417-2		50	T	70	50	60	50	-30	-10	40
Shell Courses											
Upper Shell Plates	A1417-1		10	T	71	53	68	10	-60	-50	45
	A1415-1		30	T	50	56	50	30	-30	-30	42
	A1494-2		20	T	55	63	50	20	-40	-40	46
Upper Int. Plates	C-2904-2		70	T	80	53	54	70	-30	10	46
	C-3001-2		20	T	50	58	62	20	-40	-40	45
	C-2929-2		10	T	58	70	53	10	-50	-50	38
Lower Shell Plates	C-2904-1		70	T	51	50	51	70	-20	10	40
	C-2879-1		70	T	52	51	50	70	0	10	40
Vessel Flange											
Shell Flange	51-2882		40	T	65	83	83	40	-40	-20	54
Top Head Flange											
Closure Head Flange	51-2882		20	T	99	98	78	20	-40	-40	61
Top Head Torus											
Closure Head Dollar	B-6669-1		70	T	52	50	51	70	-40	10	41
Closure Head Side Plates	B-6813-1		50	T	53	51	51	50	-40	-10	41
	B-6813-2		50	T	52	57	61	50	-40	-10	47

Table 4-2-B Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline Misc. Appurtenances & Nozzle Materials)

COMPONENT	HEAT	Plant Specified Previous RTNDT (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{50T}) (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
MISC APPURTENANCES:											
Dryer Hold Down Bracket	B6813-1		50	T	53	51	51	50	-40	-10	41
Skirt and Skirt Ext.	A-1966-3		30	T	52	50	55	30	-30	-30	43
	A-1966-4		60	T	53	56	50	60	-30	0	48
NOZZLES:											
N1 Recirc Outlet Nozzle	Q2Q69W		40	L	55	88	70	70	-20	10	46
N2 Recirc Inlet Nozzle	Q2QL3W		40	L	74	70	74	70	-20	10	54
N3 Steam Outlet Nozzle	Q2QL5W		40	L	100	104	126	70	-20	10	72
	Q2Q68W		40	L	92	102	111	70	-20	10	67
N4 Feedwater Nozzle	Q2QL3W		40	L	66	74	102	70	-20	10	50
N5 Core Spray Nozzle	Q2QL2W		40	L	91	108	96	70	-20	10	65
N6 RHR / LPCI Nozzle	Q2QL4W		40	L	51	64	50	70	-20	10	43
N7 Head Spray Nozzle	Q2QL4W		40	L	51	64	68	70	-20	10	40
N7 Blind Flange	C3687-2		40	T	61	53	61	40	-50	-20	44
N8 Spare Nozzle	Q2QL4W		40	L	66	81	58	70	-20	10	48
N8 Blind Flange	C3687-2		40	T	61	53	61	40	-50	-20	44
N9 Jet Pump	Q2Q68W		40	L	64	86	64	70	-20	10	57
N10 CRD Hyd Return Nozzle	Q2QL4W		40	L	71	53	57	70	-20	10	41
N15 Drain Nozzle	719282		30	L	180	209	239	60	-30	0	83
N16 Inst. Vib. Nozzle	Q2QL4W		40	L	70	77	82	70	-20	10	52
N16 Blind Flange	C3687-2		40	T	61	53	61	40	-50	-20	44

Table 4-2-C Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline Circumferential Weld Materials)

COMPONENT	HEAT or HEAT / FLUX / LOT	Plant Specified Previous RTNDT (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{NDT}) (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
WELDS:											
Circumferential:											
AA - Bottom Head to Shell 1											
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	55	68	0	-40	-40	50
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	57	55	0	-80	-60	40
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0342		10	n/a	53	54	55	10	-40	-40	51
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0342		10	n/a	57	59	58	10	-60	-50	47
Raco/NMM	3P4966 / Linde 124 / 0342										
AB - Shell 1 to Shell 2											
1/8	L83978 / / J414B27AD										
5/32	767916 / / D516B27AE										
3/16	03L048 / / B525B27AF		0	n/a	61	75	79	0	-80	-60	44
7/32	02R486 / / J404B27AG		-10	n/a	52	64	66	-10	-90	-70	39
Raco/NMM (Single Wire)	4P7465 / Linde 124 / 0751		0	n/a	63	57	68	0	-70	-60	45
Raco/NMM (Tandem Wire)	4P7465 / Linde 124 / 0751		0	n/a	79	83	74	0	-60	-60	54
Raco/NMM (Single Wire)	4P7216 / Linde 124 / 0751		10	n/a	60	60	64	10	-60	-50	41
Raco/NMM (Tandem Wire)	4P7216 / Linde 124 / 0751		-20	n/a	62	73	84	-20	-80	-80	40
AC - Shell 2 to Shell 3											
1/8	629865 / / A421A27AD										
5/32	640892 / / J424B27AE										
Raco/NMM	5P6771 / Linde 124 / 0342										
AD - Shell 3 to Shell 4											
Raco/NMM	5P7397 / Linde 124 / 0156										
AE - Shell 4 to Shell Flange											
Raco/NMM (Single Wire)	5P6756 / Linde 124 / 0342	-60	0	n/a	55	66	63	0	-60	-60	51
Raco/NMM (Tandem Wire)	5P6756 / Linde 124 / 0342	-50	10	n/a	64	72	77	10	-50	-50	35

* Where Charpy data was not available for heat numbers the purchase specifications was used. The purchase specification requires that weld materials have equal to or lower RT_{NDT}'s than the materials that are being welded. Thus the welds cannot be the limiting material.

Table 4-2-D Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline Longitudinal Weld Materials)

COMPONENT	HEAT or HEAT / FLUX / LOT	Plant Specified Previous RTNDT (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{50T}) (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
WELDS: (Cont.)											
Longitudinal Welds											
Welds within #1 Shell Ring											
BA & BB											
1/8	422K8511 / / G313A27AD		-20	n/a	65	74	127	-20	-80	-80	44
5/32	627260 / / B322A27AE		30	n/a	52	56	51	30	-40	-30	35
3/16	626677 / / G301A27AF		40	n/a	53	51	54	40	-40	-20	35
7/32	627069 / / C312A27AG		0	n/a	72	64	78	0	-60	-60	48
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	55	68	0	-40	-40	50
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0931		10	n/a	57	59	58	10	-60	-50	47
Welds within #3 Shell Ring											
BM											
1/8	422K8511 / / G313A27AD		-20	n/a	65	74	127	-20	-80	-80	44
3/16	626677 / / C301A27AF		40	n/a	53	51	54	40	-40	-20	35
5/32	627260 / / B322A27AE		30	n/a	52	56	51	30	-40	-30	35
5/32	492L4871 / / A421B27AE		0	n/a	50	51	57	0	-90	-60	36
7/32	627069 / / C312A27AG		0	n/a	72	64	78	0	-60	-60	48
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	55	68	0	-40	-40	50
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0931		10	n/a	57	59	58	10	-60	-50	47
BJ & BK											
1/8	422K8511 / / G313A27AD		-20	n/a	65	74	127	-20	-80	-80	44
3/16	626677 / / C301A27AF		40	n/a	53	51	54	40	-40	-20	35
7/32	627069 / / C312A27AG		0	n/a	72	64	78	0	-60	-60	48
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	55	68	0	-40	-40	50
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0931		10	n/a	57	59	58	10	-60	-50	47
Welds within #4 Shell Ring											
BP & BR & BS											
Raco/NMM (Single Wire)	5P5657 / Linde 124 / 0931		0	n/a	51	55	68	0	-40	-40	50
Raco/NMM (Tandem Wire)	5P5657 / Linde 124 / 0931		10	n/a	57	59	58	10	-60	-50	47

Table 4-2-E Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline N2 Nozzle Weld Materials)

COMPONENT	HEAT or HEAT / FLUX / LOT	Plant Specified Previous RTNDT (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			(T_{50T}) (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)	Min Lat Exp (mils)
WELDS: (Cont.)											
N2 Nozzle Welds											
60 & 120 & 240 & 300 Degrees											
1/8	629865 / / A421A27AD										
3/16	492L4871 / / A421B27AF		10	n/a	56	58	61	10	-80	-50	37
7/32	04T931 / / A423B27AG		0	n/a	65	69	72	0	-90	-60	48
1/4	05T776 / / L314A27AH		-10	n/a	69	72	81	-10	-70	-70	47
Raco/NMM (Single Wire)	5P6756 / Linde 124 / 0342	-60	0	n/a	55	66	63	0	-60	-60	51
Raco/NMM (Tandem Wire)	5P6756 / Linde 124 / 0342	-50	10	n/a	64	72	77	10	-50	-50	35
120 Degrees											
5/32	402P3162 / / H426B27AE										
3/16	401P2871 / / H430B27AF		10	n/a	75	76	107	10	-70	-50	60
7/32	07R458 / / S403B27AG		0	n/a	59	61	70	0	-60	-60	51
240 Degrees											
5/32	492L4871 / / A421B27AE	-60	0	n/a	50	51	57	0	-90	-60	36
300 Degrees											
5/32	402P3162 / / H426B27AE										
30 & 90 & 150 & 210 & 270 & 330 Degrees											
1/8	422K8511 / / G313A27AD		-20	n/a	65	74	127	-20	-80	-80	44
5/32	492L4871 / / A421B27AE	-60	0	n/a	50	51	57	0	-90	-60	36
3/16	492L4871 / / A421B27AF		10	n/a	56	58	61	10	-80	-50	37
1/4	05T776 / / L314A27AH		-10	n/a	69	72	81	-10	-70	-70	47
Raco/NMM (Single Wire)	5P6756 / Linde 124 / 0342	-60	0	n/a	55	66	63	0	-60	-60	51
Raco/NMM (Tandem Wire)	5P6756 / Linde 124 / 0342	-50	10	n/a	64	72	77	10	-50	-50	35
150 Degrees											
7/32	04T931 / / A423B27AG		0	n/a	65	69	72	0	-90	-60	48
3/16	401P2871 / / H430B27AF		10	n/a	75	76	107	10	-70	-50	60
7/32	07R458 / / S403B27AG		0	n/a	59	61	70	0	-60	-60	51
210 Degrees											
7/32	627069 / / C312A27AG		0	n/a	72	64	78	0	-60	-60	48
330 Degrees											
7/32	04T931 / / A423B27AG		0	n/a	65	69	72	0	-90	-60	48
1/8	629865 / / A421A27AD										

* Where Charpy data was not available for heat numbers the purchase specifications was used. The purchase specification requires that weld materials have equal to or lower RT_{NDT}'s than the materials that are being welded. Thus the welds cannot be the limiting material.

Table 4-3 Calculated Initial RT_{NDT} Values for River Bend Vessel (Non Beltline Bolt/Stud & Nut Materials)

COMPONENT	HEAT	Plant Specified Previous LST (°F)	TEST TEMP. (°F)	Trans or Long	CHARPY ENERGY (FT-LB)			LST (°F)	Min Lat Exp (mils)
STUDS:									
Closure	63182		10	n/a	50	51	51	10	26
	84299		10	n/a	49	50	49	10	25
N-7, N-8	11312		10	n/a	49	50	51	10	27
N-16	11312		10	n/a	49	50	51	10	27
NUTS:									
Closure	83706		10	n/a	50	51	54	10	28
N-7, N-8	11312		10	n/a	49	50	51	10	27
N-16	11312		10	n/a	49	50	51	10	27
Closure Washers	83706		10	n/a	50	51	54	10	28

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 were made and summarized in Table 4-3 for 32 EFPY.

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

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

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

where,

ΔRT_{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.

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.

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

4.2.1.1 Chemistry

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

- Vessel Plate: CMTR [16].
- Vertical Submerged arc welds: CMTR [16].

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. 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 $0.5^*\Delta RT_{NDT}$. 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.

4.2.1.2 Fluence

The Reactor Pressure Vessel fluences (f_{surf}) at 32 EFPY were determined from "105% Power Uprate Evaluation Report for Entergy Operations Inc. River Bend Station" [1].

The following 32 EFPY inside surface beltline plate and weld fluences were used:

Plate: $f_{surf} = 7.95 \times 10^{18}$ n/cm^2

Weld: $f_{surf} = 7.95 \times 10^{18}$ n/ cm^2

The 32 EFPY ¼T fluences are calculated using the following methodology from Rev. 2 [6]

$f_{1/4T} = f_{surf} * e^{-0.24*1.35}$

Where: 1.35 = ¼ of the minimum beltline shell thickness, 5.41 inches

The resulting ¼T fluences are:

Plate: $f_{1/4T} = 5.75 \times 10^{18}$ n/cm^2

Weld: $f_{1/4T} = 5.75 \times 10^{18}$ n/cm^2

Justification of Selected Fluence Value

The values used are the currently licensed values.

4.2.2 Limiting Beltline Material

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

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Table 4-4. River Bend Beltline ART Values (32 EFPY)

Shell #2

Thickness in inches =	5.41	32 EFPY Peak I.D. fluence =	7.95E+18 n/cm^2
		32 EFPY Peak 1/4 T fluence =	5.75E+18 n/cm^2
Ratio Peak/ Location =	1.00	32 EFPY Peak 1/4 T fluence =	5.75E+18 n/cm^2

COMPONENT - ID #	HEAT OR HEAT/FLUX/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:												
Low-Int. Plates												
22-1-1	C-3054-1	0.09	0.70	58	-20	5.7E+18	49.0	0	17	34.0	83.0	63.0
22-1-2	C-3054-2	0.09	0.70	58	10	5.7E+18	49.0	0	17	34.0	83.0	93.0
22-1-3	C-3138-2	0.08	0.63	51	0	5.7E+18	43.1	0	17	34.0	77.1	77.1
WELDS:												
Vertical Weld												
Welds: BE, BF, BG												
E8018NM (3/16")	492L4871 / A421B27AF	0.03	0.98	41	-50	5.7E+18	34.6	0	17	34.6	69.3	19.3
E8018NM (5/32")	492L4871 / A421B27AE	0.04	0.95	54	-60	5.7E+18	45.6	0	23	45.6	91.3	31.3
Raco/NMM (Single)	5P6756 / Linde 124 / 0342	0.084	0.938	113.6	-60	5.7E+18	96.0	0	28	56.0	152.0	92.0
Raco/NMM (Tandem)	5P6756 / Linde 124 / 0342	0.084	0.938	113.6	-50	5.7E+18	96.0	0	28	56.0	152.0	102.0
Girth												
(NONE)												

4.3 Pressure-Temperature Curve Methodology

4.3.1 Background

Nuclear Regulatory Commission (NRC) 10CFR50 Appendix G [5] specifies fracture toughness requirements to provide adequate margins of safety during the operating conditions that a pressure-retaining component may be subjected to over its service lifetime. The ASME Code (Appendix G of Section XI of the ASME Code [8]) forms the basis for the requirements of 10CFR50 Appendix G. The operating limits for pressure and temperature are required for three categories of operation: (a) hydrostatic pressure tests and leak tests, referred to as Curve A; (b) non-nuclear heatup/cooldown and low-level physics tests, referred to as Curve B; and (c) core critical operation, referred to as Curve C.

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

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

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

For the core not critical and the core critical 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]. 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 ¼T and ¾T locations. When combining pressure and thermal stresses, it is usually necessary to evaluate stresses at the ¼T location (inside surface flaw) and the ¾T 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 ¼T is assumed to be tensile for both heatup and cooldown. This results in the approach of applying the maximum tensile stress at the ¼T location. This approach is conservative because irradiation effects cause the allowable toughness, K_{Ir}, at ¼T to be less than that at ¾T 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 and 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 $\leq$ 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 $\leq$ 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 $\leq$ 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 [5] requirements. The non-beltline and beltline region operating limits are evaluated according to procedures in 10CFR50 Appendix G [5], ASME Code Appendix G [8], and Welding Research Council (WRC) Bulletin 175 [9]. The beltline region minimum temperature limits are adjusted to account for vessel irradiation.

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 to cause any significant shift of RT_{NDT}. Non-beltline components include nozzles, the closure flanges, some shell plates, the top and bottom head plates and the control rod drive (CRD) penetrations.

Detailed stress analyses of the non-beltline components were performed for the BWR/6 specifically for the purpose of fracture toughness analysis. The analyses took into account all mechanical loading and anticipated thermal transients. Transients considered include 100°F/hr start-up and shutdown, SCRAM, loss of feedwater heaters or flow, loss of recirculation pump flow, and all transients involving emergency core cooling injections. Primary membrane and bending stresses and secondary membrane and bending stresses due to the most severe of these transients were used according to the ASME Code [8] 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/6 Discontinuity Components for Use With FW (Upper Vessel) Curves A & B

Discontinuity Identification
FW Nozzle
RHR/LPCI Nozzle
CRD HYD System Return
Core Spray Nozzle
Recirculation Inlet Nozzle
Steam Outlet Nozzle
Support Skirt and Bottom Head
Jet Pump Instrumentation Nozzle
Water Level Instrumentation Nozzle
Shroud Support Attachment
Stabilizer Brackets*

*There are no stabilizer brackets at River Bend

Table 4-7. Applicable BWR/6 Discontinuity Components for Use with CRD (Bottom Head) Curves A&B

Discontinuity Identification
CRD and Bottom Head
Vibration Instrumentation Nozzle
Core ΔP and Liquid Control Nozzle
Top Head Nozzle
Recirculation Outlet Nozzle
Main Closure Flange
Steam Water Interface
Shell Discontinuities

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

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

In a finite element analysis [ ], the CRD penetration region was modeled to compute the local stresses for determination of the stress intensity factor, K_I. The evaluation was modified to consider the new requirement for M_m as discussed in ASME Code Section XI Appendix G [8] and shown below. The results of that computation were K_I = 143.6 ksi-in$^{1/2}$ for an applied pressure of 1593 psig (1563 psig preservice hydrotest pressure at the top of the vessel plus 30 psig hydrostatic pressure at the bottom of the vessel). The computed value of (T - RT_{NDT}) was 84°F.

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

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [8] was based on a thickness of 8.0 inches; hence, $t^{1/2} = 2.83$. The resulting value obtained was:

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

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

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

K_{Im} is calculated from the equation in Paragraph G-2214.1 [8] and K_{Ib} is calculated from the equation in Paragraph G-2214.2 [8]:

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

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

The total K_I is therefore:

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

This equation includes a safety factor of 1.5 on primary stress. The method to solve for $(T - RT_{NDT})$ for a specific K_I is based on the K_{IC} the equation of Paragraph A-4200 in ASME Appendix A [7]:

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

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

$$(T - RT_{NDT}) = 84°F$$

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

Pressure Test 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	144	84
1400	129	77
1200	111	66
1000	92	52
800	74	33
600	55	3
400	37	-88

The highest RT_{NDT} for the bottom head plates and welds is 10°F, as shown in Table 4-2.

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:

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

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:

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

The River Bend specific bottom head dimensions are R = 118.1875 inches and t= 6.689 inches minimum [17], resulting in:

$$\text{River Bend specific:} \quad R\,/\,(t)^{1/2} = 118.1875\,/\,(6.689)^{1/2} = 45.69 \text{ inch}^{1/2} \tag{4-3}$$

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

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

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

The calculated value of K_I for pressure test is multiplied by a safety factor (SF) of 1.5, per ASME Appendix G [8] for comparison with K_{IR}, the material fracture toughness. A safety factor of 2.0 is used for the core not critical. Therefore, the K_I value for the core not critical condition is $(143.6 / 1.5) \cdot 2.0 = 191.5$ ksi-in$^{1/2}$.

Therefore, the method to solve for (T - RT_{NDT}) for a specific K_I is based on the K_{IC} equation of Paragraph A-4200 in ASME Appendix A [7] 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

Figure 4-1. CRD Penetration Fracture Toughness Limiting Transients

The highest RT_{NDT} for the bottom head plates and welds is 10°F, as shown in Tables 4-2.

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 4-6, 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.

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 [9] together with the nozzle dimension for a generic 251-inch BWR/6 feedwater nozzle. The result of that computation was K_I = 200ksi-in$^{1/2}$ for an applied pressure of 1563 psig preservice hydrotest pressure.

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

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

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

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

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

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

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

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 [7] for the pressure test condition:

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

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

The highest RT_{NDT} for the nozzle materials is 10°F as described below. The generic pressure test P-T curve is applied to the River Bend feedwater nozzle curve by shifting the P vs. (T - RT_{NDT}) values above to reflect the RT_{NDT} value of 10°F.

Second, the P-T curve is dependent on the K_I value calculated. The River Bend specific vessel shell [17] and nozzle dimensions [18] applicable to the feedwater nozzle location and K_I are shown below:

Vessel Radius, R_v	110.1875 inches
Vessel Thickness, t_v	5.41 inches
Vessel Pressure, P_v	1563 psig

Pressure stress: σ = PR / t = 1563 psig · 110.1875 inches / (5.41 inches) = 31,834 psi. The Dead weight and thermal RFE stress of 2.967 ksi is conservatively added yielding σ = 34.8 ksi. The factor F (a/r_n) from Figure A5-1 of WRC-175 is 1.49 where :

a =	$\frac{1}{4}(t_n^{\ 2} + t_v^{\ 2})^{1/2}$	= 2.10 inches
t_n =	thickness of nozzle	= 6.44 inches
t_v =	thickness of vessel	= 5.41 inches
r_n =	apparent radius of nozzle	= r_i + 0.29 r_c=6.85 inches
r_i =	actual inner radius of nozzle	= 6.0 inches
r_c =	nozzle radius (nozzle corner radius)	= 2.94 inches

Thus, a/r_n = 2.10 / 6.85 = 0.306. The value F(a/r_n), taken from Figure A5-1 of WRC Bulletin 175 for an a/r_n of 0.306, is 1.47. Including the safety factor of 1.5, the stress intensity factor, K_I, is 1.5 σ $(\pi a)^{1/2} \cdot F(a/r_n)$:

Nominal $K_I = 1.5 \cdot 34.8 \cdot (\pi \cdot 2.10)^{1/2} \cdot 1.47 = 197.1$ ksi-in$^{1/2}$

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

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

Stresses were taken from a finite element analysis done specifically for the purpose of fracture toughness analysis [ ]. Analyses were performed for all feedwater nozzle transients that involved rapid temperature changes. The most severe of these was normal operation with cold 40°F feedwater injection, which is equivalent to hot standby, see Figure 4-2.

Figure 4-2. Feedwater Nozzle Fracture Toughness Limiting Transient

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 [9].

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:

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

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

Finite element analysis of a nozzle corner flaw was performed to determine appropriate values of $F(a/r_n)$ for Equation 4-4. These values are shown in Figure A5-1 of WRC Bulletin 175 [9].

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 [8] methods for secondary portion, K_{Is}.

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

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 [9]. 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 [7]. The highest RT_{NDT} for the appropriate non-beltline components was then used to establish the P-T curves.

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

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 inch was used in the evaluation. However, a thickness of 7.5 inch is not conservative for the pressure stress evaluation. Therefore, the pressure stress (σ_{pm}) was adjusted for the actual vessel thickness of 6.1875 inch (i.e., σ_{pm} = 20.49 ksi was revised to 20.49 ksi *7.5 inch/6.1875 inch = 24.84 ksi). These stresses, and other inputs used in the generic calculations, are shown below:

σ_{pm} = 24.84 ksi $\quad$ σ_{sm} = 16.19 ksi $\quad$ σ_{ys} = 45.0 ksi $\quad$ t_v = 6.1875 inch

σ_{pb} = 0.22 ksi $\quad$ σ_{sb} = 19.04 ksi $\quad$ a = 2.36 inch $\quad$ r_n = 7.08 inch

t_n = 7.125 inch

In this case the total stress, 60.29 ksi, exceeds the yield stress, σ_{ys}, so the correction factor, R, is calculated to consider the nonlinear effects in the plastic region according to the following equation based on the assumptions and recommendation of WRC Bulletin 175 [9]. (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 $\quad$ σ_{sm} = 9.44 ksi

σ_{pb} = 0.13 ksi $\quad$ σ_{sb} = 11.10 ksi

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [8] was based on the 4a thickness ; hence, $t^{1/2}$ = 3.072. The resulting value obtained was:

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

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

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

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

$$F\ (a\ /\ r_n) = 1.4$$

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

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

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

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

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

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

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: 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 region component at River Bend is 10°F as shown in Tables 4-2. The generic curve is applied to the River Bend upper vessel by shifting the P vs. (T - RT_{NDT}) values above to reflect the RT_{NDT} value of 10°F.

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 [8], were based on a combination of pressure and thermal stresses for a ¼T 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 [8] 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 [8] 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 [7] 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 1070 psig at 32 EFPY. The following inputs were used in the beltline limit calculation:

Adjusted RT_{NDT} = Initial RT_{NDT} + Shift	A = -50 + 152 = 102°F (Based on ART values in Section 4.2)
Vessel Height	H = 832.5 inches
Bottom of Active Fuel Height	B = 208.56 inches
Vessel Radius (to inside of base material)	R = 110.1875 inches
Minimum Vessel Thickness (without clad)	t = 5.41 inches

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

$$\begin{aligned} P &= 1070 \text{ psi} + (H - B)\ 0.0361 \text{ psi/inch} = P \text{ psig} \\ &= 1070 + (832.5 - 208.56)\ 0.0361 = 1092.5 \text{ psig} \end{aligned} \tag{4-10}$$

Pressure stress:

$$\begin{aligned} \sigma &= PR/t \\ &= 1.092 \cdot 110.1875 / 5.41 = 22.2 \text{ ksi} \end{aligned} \tag{4-11}$$

The value of M_m for an inside axial postulated surface flaw from Paragraph G-2214.1 [8] was based on a thickness of 5.41 inches (the minimum thickness without cladding); hence, $t^{1/2} = 2.326$. The resulting value obtained was:

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

$$M_m = 0.926 \sqrt{t} \text{ for } 2 \leq \sqrt{t} \leq 3.464 = \mathbf{2.15}$$

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

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 [7], K_{Im} = 47.8, and K_{It} = 1.69 for a 20°F/hr coolant heatup/cooldown rate with a vessel thickness, t, that includes cladding:

$$(T - RT_{NDT}) = \ln[(1.5 \cdot K_{Im} + K_{It} - 33.2) / 20.734] / 0.02 \tag{4-12}$$
$$= \ln[(1.5 \cdot 47.8 + 1.69 - 33.2) / 20.734] / 0.02$$
$$= 33°F$$

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

$T = 33 + 102 = 135°F$ for $P = 1070$ psig

4.3.2.2.3 *Beltline Region - Core Not Critical Heatup/Cooldown*

The beltline curves for core not critical heatup/cooldown conditions are influenced by pressure stresses and thermal stresses, according to the relationship in ASME Section XI Appendix G [8]:

$$K_{IC} = 2.0 \cdot K_{Im} + K_{It} \tag{4-13}$$

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 [8] 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 [8]. The relationship used to compute the through-wall ΔT_w is based on one-dimensional heat conduction through an insulated flat plate:

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

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 [8]. Therefore, ΔT_w calculated from Equation 4-15 is used with the appropriate M_t of Figure G-2214-1 of ASME Appendix G [8] to compute K_{It} for heatup and cooldown.

The M_t relationships were derived in the Welding Research Council (WRC) Bulletin 175 [9] for infinitely long cracks of ¼T and $^1/_8$T. 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 1070 psi for 32 EFPY. The core not critical heatup/cooldown curve at 1070 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	=	0.466 ft (5.594 inches)
Thermal diffusivity at 550°F (most conservative value),	β	=	0.354 ft^2/ hr [16]

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:

$$\begin{aligned} \Delta T &= GC^2 / 2\beta \\ &= 100 \cdot (0.466)^2 / (2 \cdot 0.354) = 30.7°F \end{aligned} \tag{4-16}$$

The analyzed case for thermal stress is a ¼T flaw depth with wall thickness of C. The corresponding value of M_t (=0.275) can be interpolated from ASME Appendix G, Figure G-2214-1 [8]. Thus the thermal stress intensity factor, $K_{It} = M_t \cdot \Delta T = 8.44$, can be calculated. K_{Im} has the same value as that calculated in Section 4.3.2.2.2.

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

$$\begin{aligned} (T - RT_{NDT}) &= \ln[((2 \cdot K_{Im} + K_{It}) - 33.2) / 20.734] / 0.02 \\ &= \ln[(2 \cdot 47.8 + 8.44 - 33.2) / 20.734] / 0.02 \\ &= 62\ °F \end{aligned} \tag{4-17}$$

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

$T = 62 + 102 = 164$ °F for P = 1070 psig

4.3.2.3 Closure Flange Region

10CFR50 Appendix G [5] sets several minimum requirements for pressure and temperature in addition to those outlined in the ASME Code, based on the closure flange region RT_{NDT}. In some cases, the results of analysis for other regions exceed these requirements and closure flange limits do not affect the shape of the P-T curves. However, some closure flange requirements do impact the curves, as is true with River Bend at low pressures.

The approach used for River Bend for the bolt-up temperature was based on a conservative value of $(RT_{NDT} + 60)$, or the LST of the bolting materials, whichever is greater. The 60°F adder is included by GE for two reasons: 1) the pre-1971 requirements of the ASME Code Section III, Subsection A, Paragraph N-220 B included the 60°F adder, and 2) inclusion of the additional 60°F requirement above the RT_{NDT} provides the additional assurance that a flaw size between 0.1 and 0.24 inches is acceptable. As shown in Table 4-2, the limiting initial RT_{NDT} for the closure flange region is Closure Head Side Plates at -10°F, and the LST of the closure studs was 10°F; therefore, the bolt-up temperature value used is 50°F. This conservatism is appropriate because bolt-up is one of the more limiting operating conditions (high stress and low temperature) for brittle fracture. However, temperatures should not be permitted to be lower than 68°F, the Fuel shutdown margin, for the reason discussed below.

10CFR50 Appendix G, paragraph IV.A.2 [5] 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 [8] 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, the fuel shutdown margin, for the reason discussed below.

> *The shutdown margin, provided in the River Bend 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 50°F limit applies when the head is on and tensioned and the 68°F limit for the bottom head curve 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 [5] 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 [5], Table 1. Table 1 of [5] 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 [5] 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 10CFR50 Appendix G required minimum criticality temperature 50°F, based on an RT_{NDT} of -10°F; however, the minimum criticality temperature is limited to 68°F by the fuel shutdown margin, as noted in Section 4.3.2.3. In addition, above 312 psig for Curve C, 10CFR50 Appendix G requires that the temperature must be at least the greater of RT_{NDT} of the closure region + 160°F (-10°F+ 160°F=150°F) or the temperature required for the hydrostatic pressure test (135°F for Curve A at 1070 psig). The requirement of closure region RT_{NDT} + 160°F does cause 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 (Regions A & B)
- Upper vessel (Region 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 ¼T and ¾T locations because the maximum tensile stress for either heatup or cooldown is applied at the ¼T location. For beltline curves this approach has added conservatism because irradiation effects cause the allowable toughness, K_{Ir}, at ¼T to be less than that at ¾T for a given metal temperature.

The following P-T curves were generated for River Bend.

- Composite P-T curves were generated for each of the Pressure Test and Core Not Critical conditions at 32 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 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 32 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.
- A curve displaying the limiting P-T curve for each of the three categories of operation plotted on the same axis.

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 at 32 EFPY

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
	Upper Vessel Limits (FW Nozzle)	Figure 5-2	Table B-1
	Beltline Limits for 32 EFPY	Figure 5-3	Table B-1
Curve B			
	Bottom Head Limits (CRD Nozzle)	Figure 5-4	Table B-1
	Upper Vessel Limits (FW Nozzle)	Figure 5-5	Table B-1
	Beltline Limits for 32 EFPY	Figure 5-6	Table B-1
A, B, & C	**Composite Curves for 32 EFPY**		
	Bottom Head and Composite Curve A for 32 EFPY*	Figure 5-7	Table B-2 & Table B-3
	Bottom Head and Composite Curve B for 32 EFPY*	Figure 5-8	Table B-2 & Table B-3
	Composite Curve C for 32 EFPY**	Figure 5-9	Table B-3
	Curves A, B, and C	Figure 5-10	Table B-2
	Composite Curves A*,B*, and C** for 32 EFPY	Figure 5-11	Table B-3

* 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.

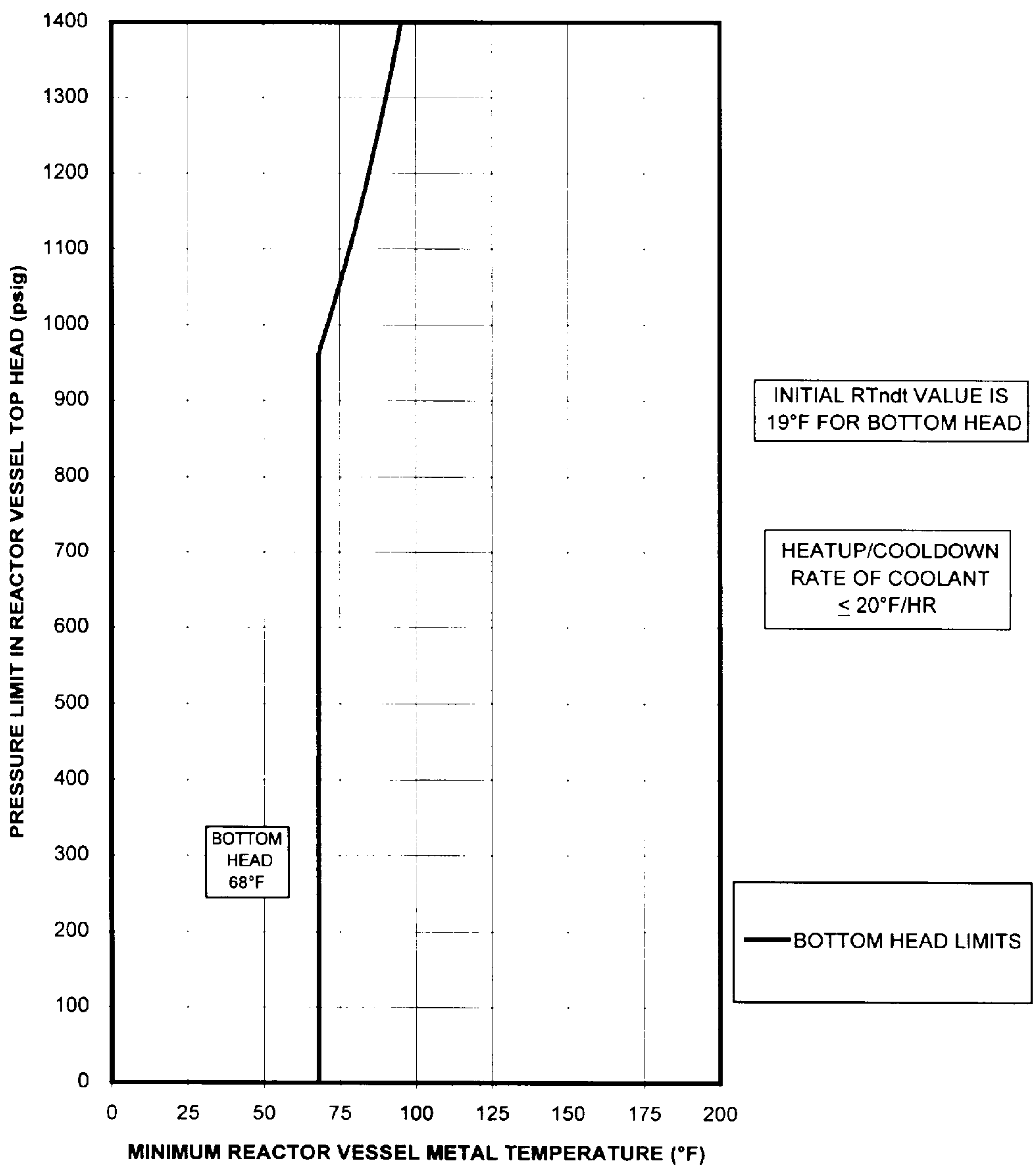

Figure 5-1. Bottom Head P-T Curve for Pressure Test [Curve A] [20°F/hr or less coolant heatup/cooldown]

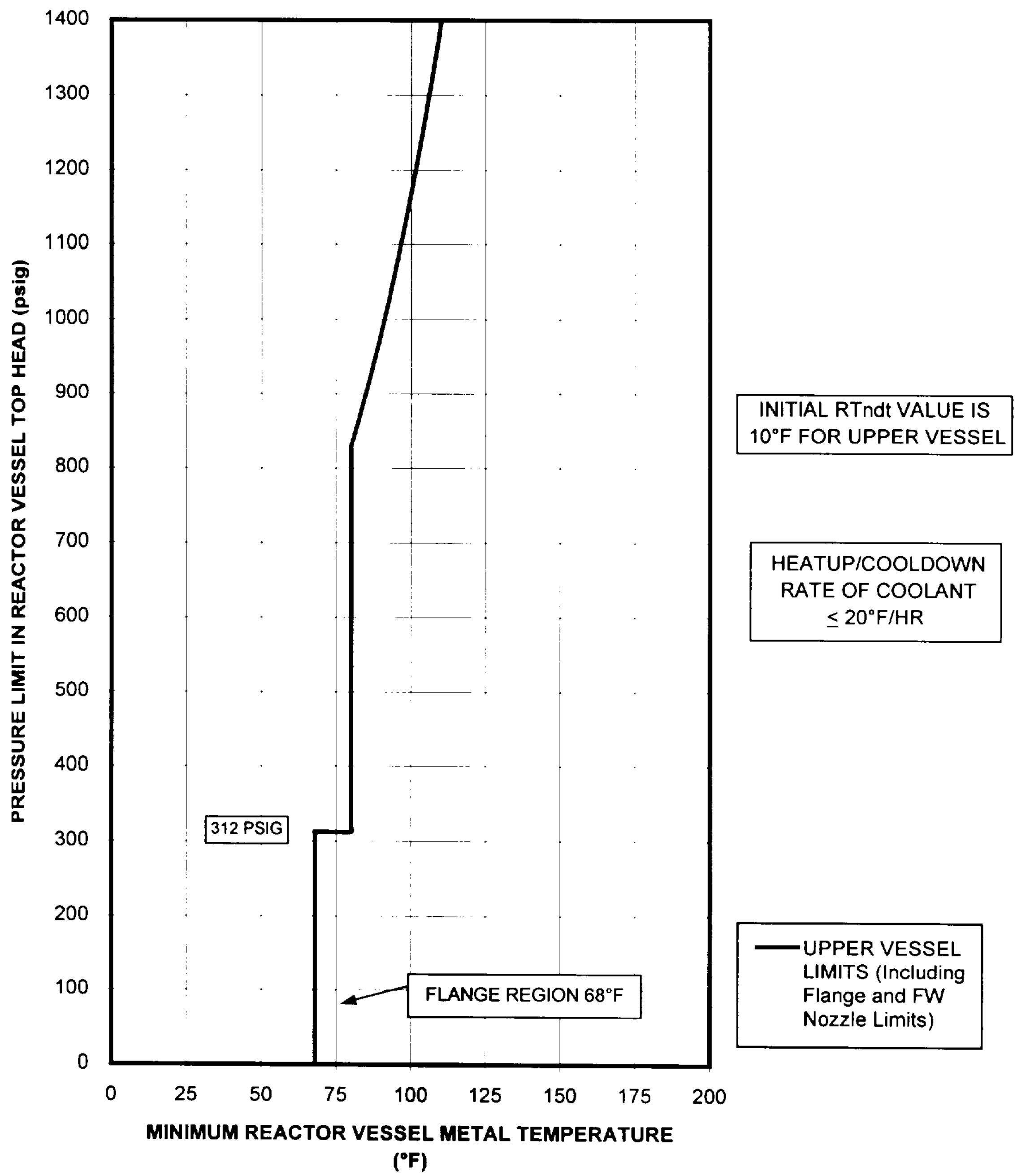

Figure 5-2. Upper Vessel P-T Curve for Pressure Test [Curve A] [20°F/hr or less coolant heatup/cooldown]

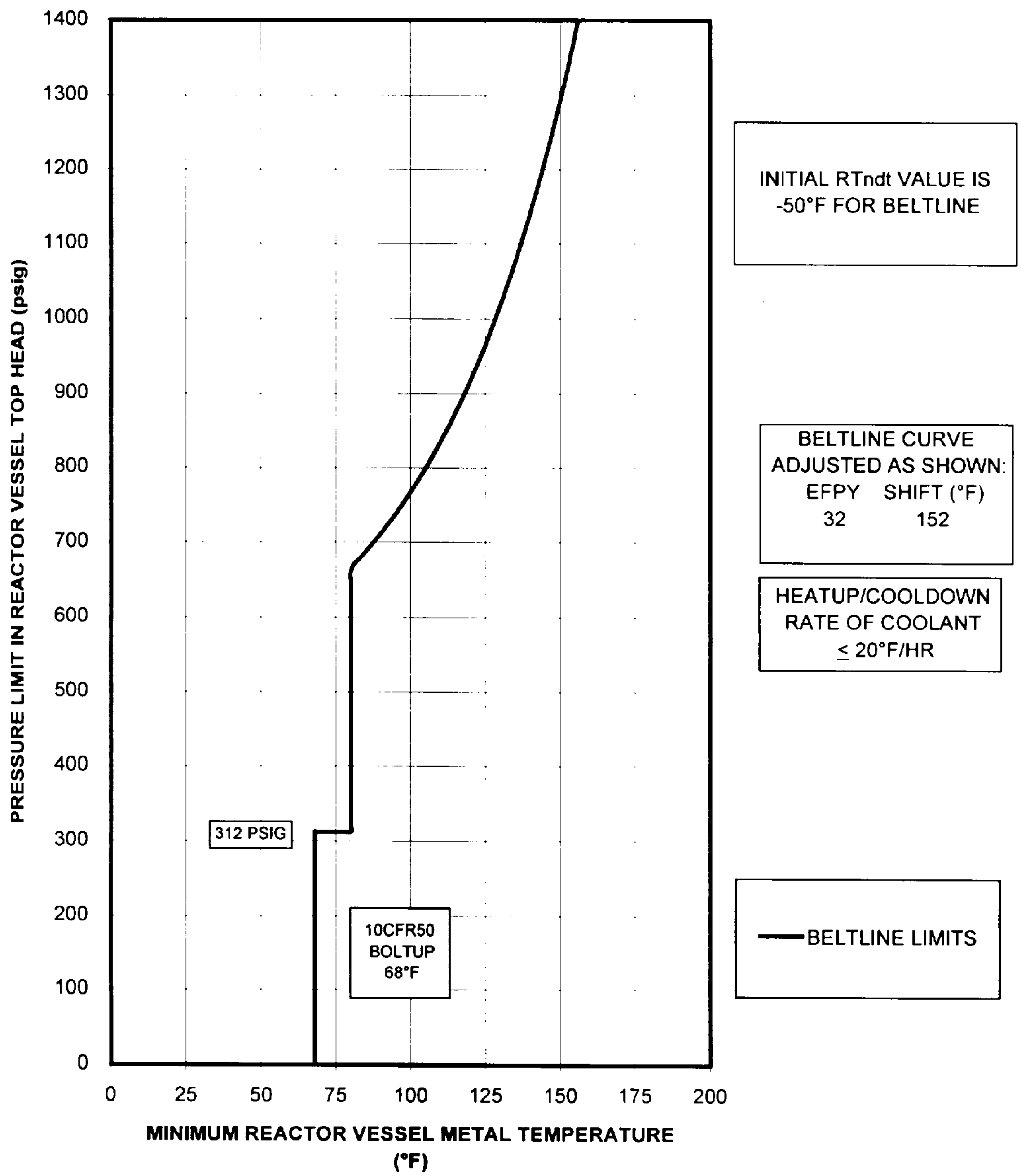

Figure 5-3. Beltline P-T Curve for Pressure Test [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

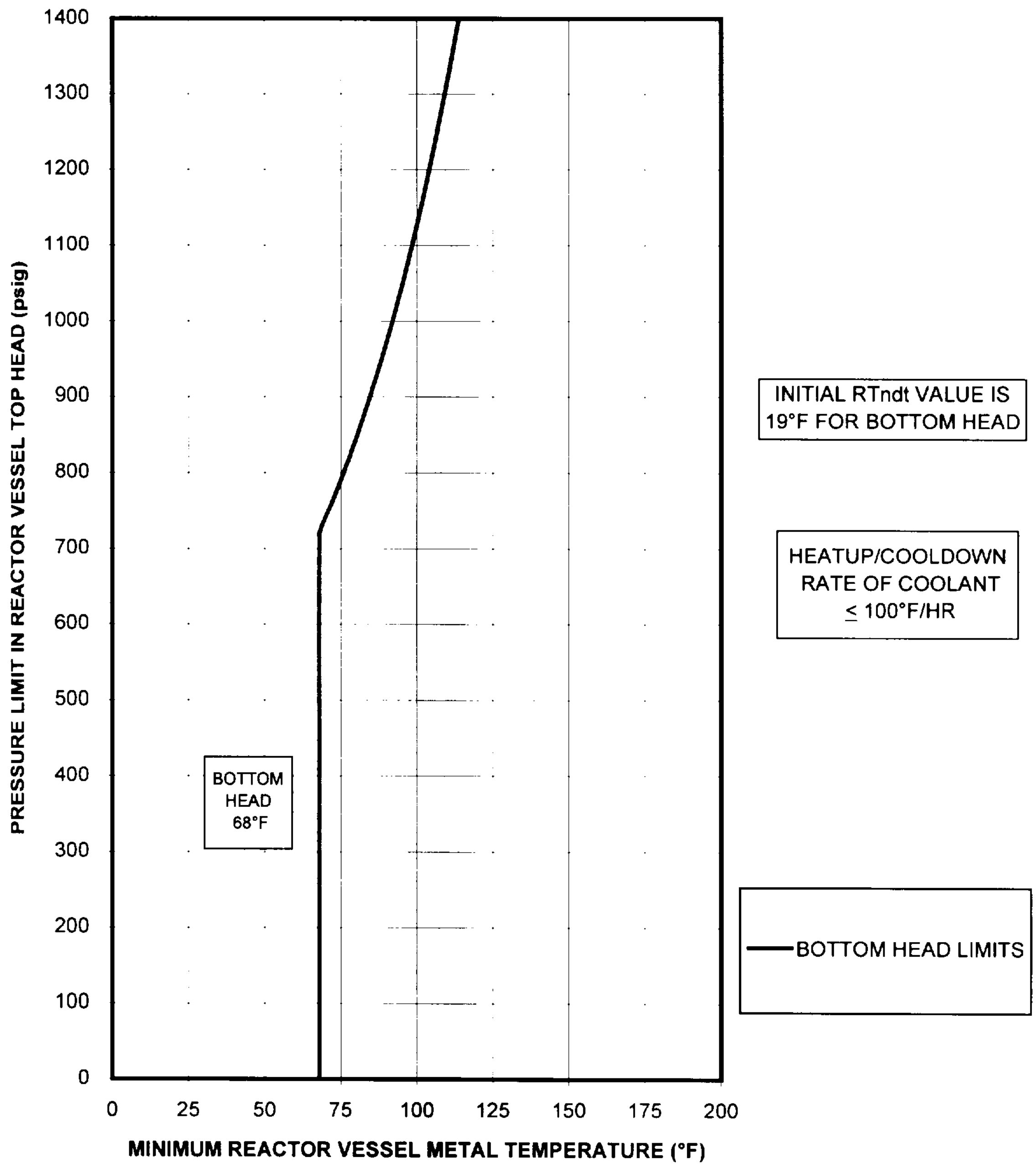

Figure 5-4. Bottom Head P-T Curve for Core Not Critical [Curve B] [100°F/hr or less coolant heatup/cooldown]

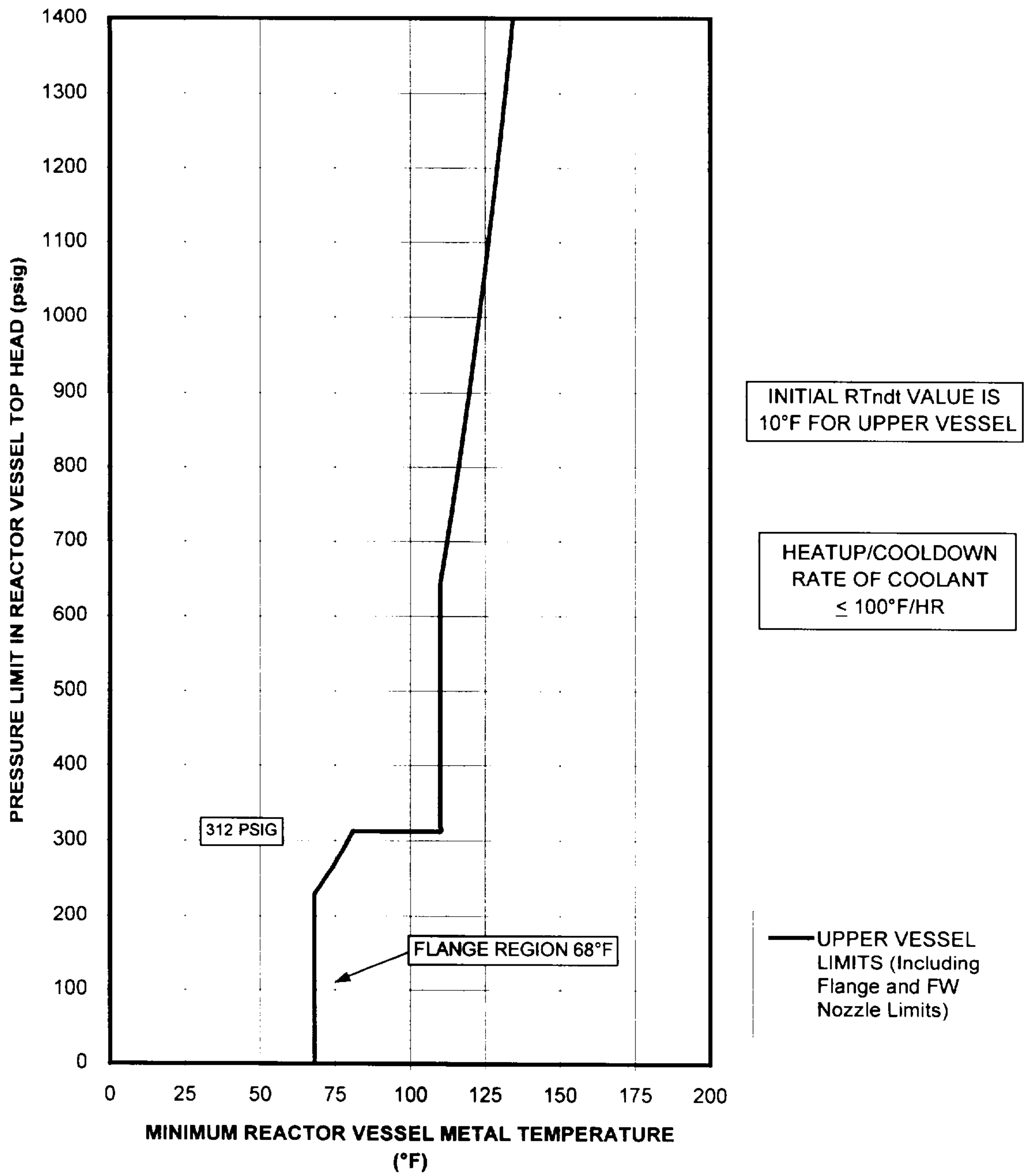

**Figure 5-5. Upper Vessel P-T Curve for Core Not Critical [Curve B]
[100°F/hr or less coolant heatup/cooldown]**

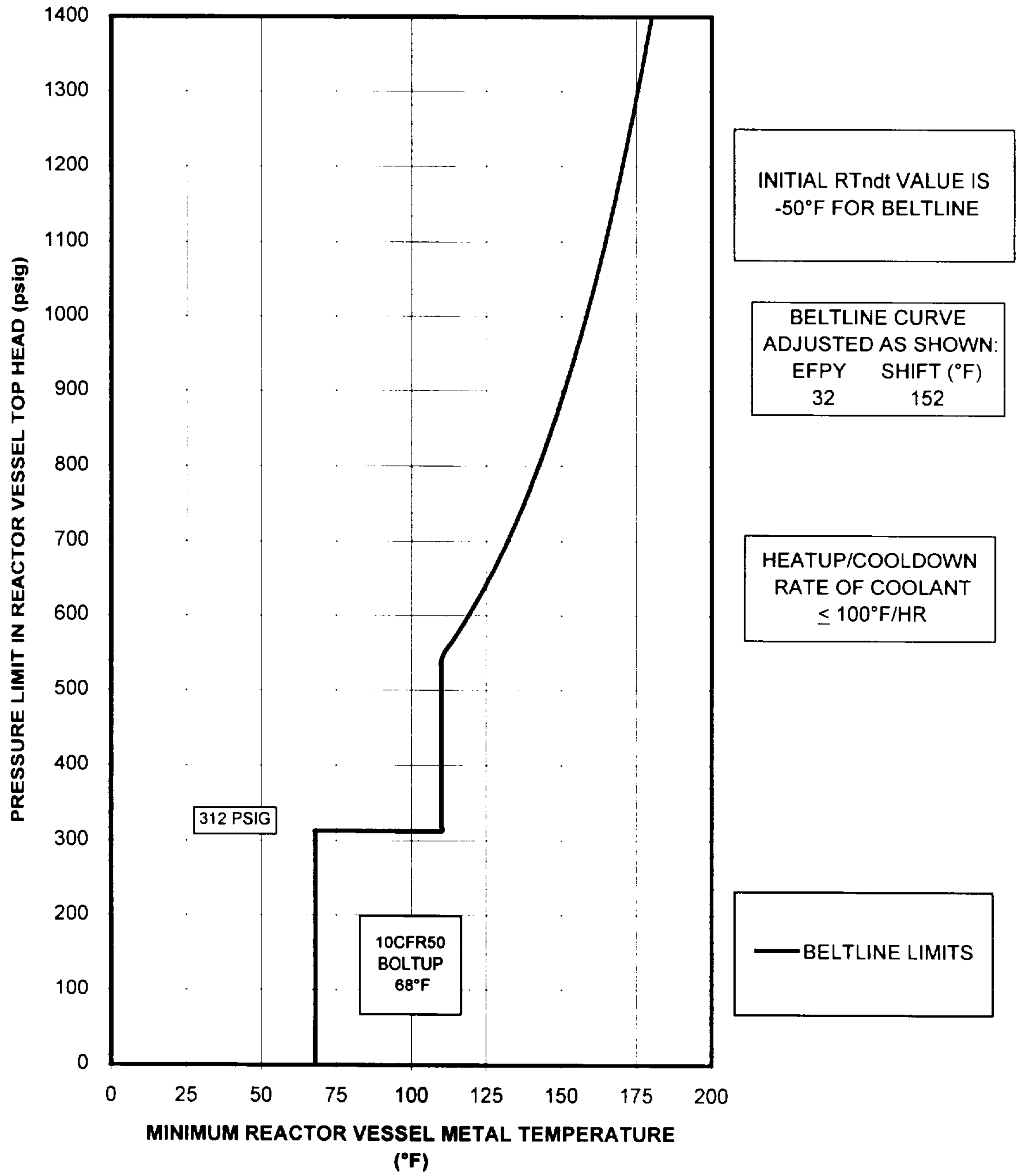

Figure 5-6. Beltline P-T Curve for Core Not Critical [Curve B] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

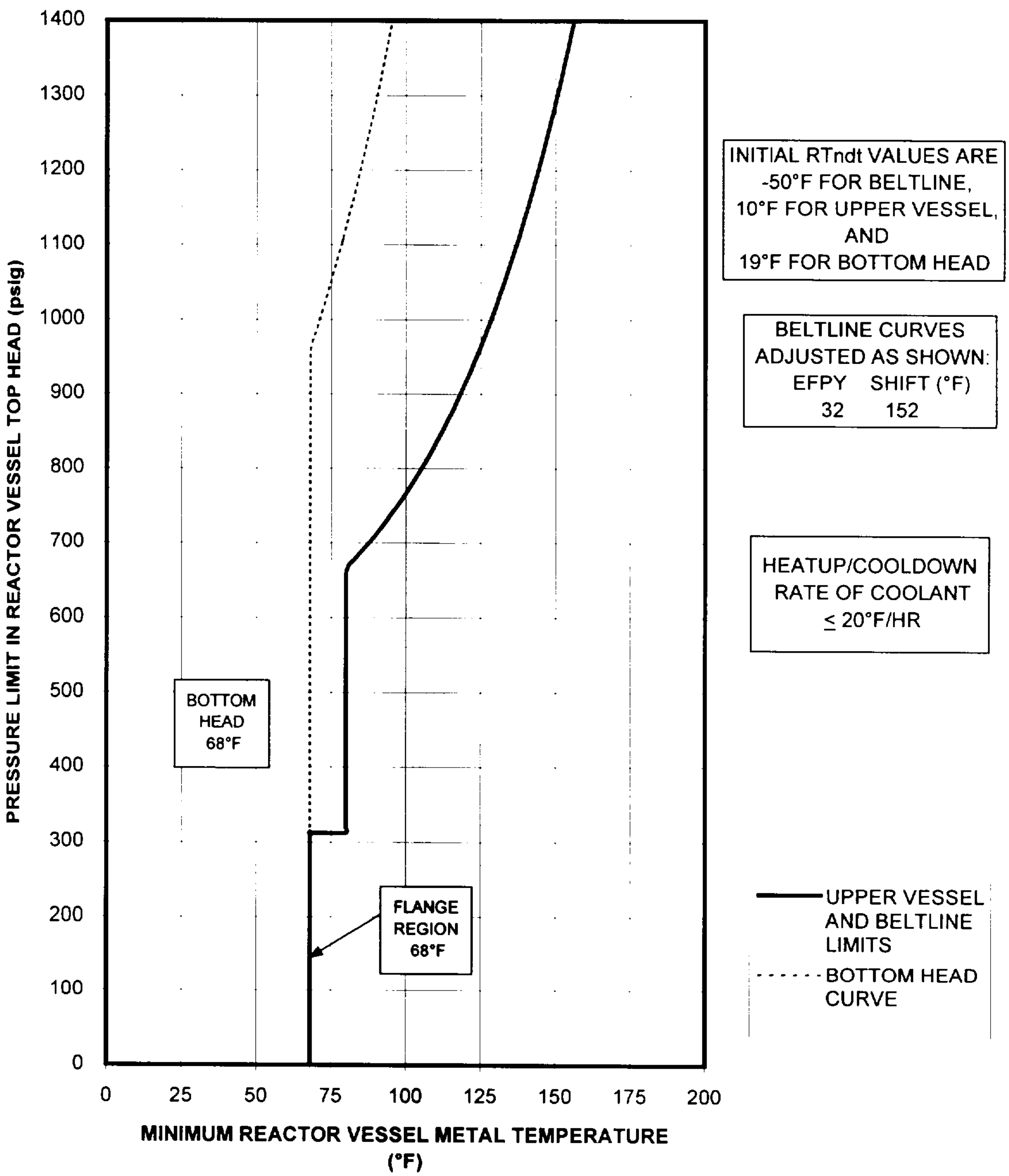

Figure 5-7. Pressure Test P-T Curves [Curve A] up to 32 EFPY [20°F/hr or less coolant heatup/cooldown]

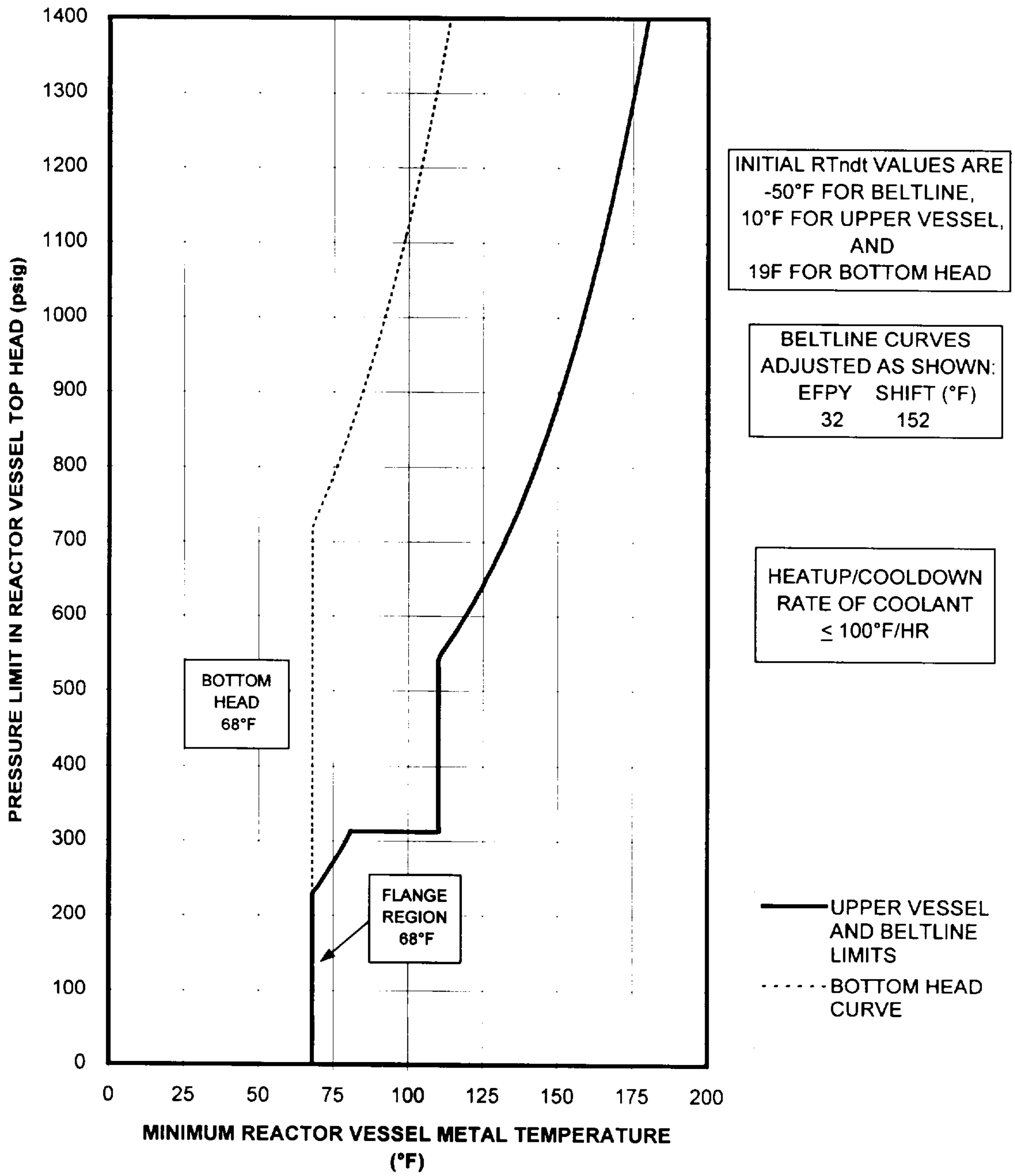

Figure 5-8. Core Not Critical P-T Curves [Curve B] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

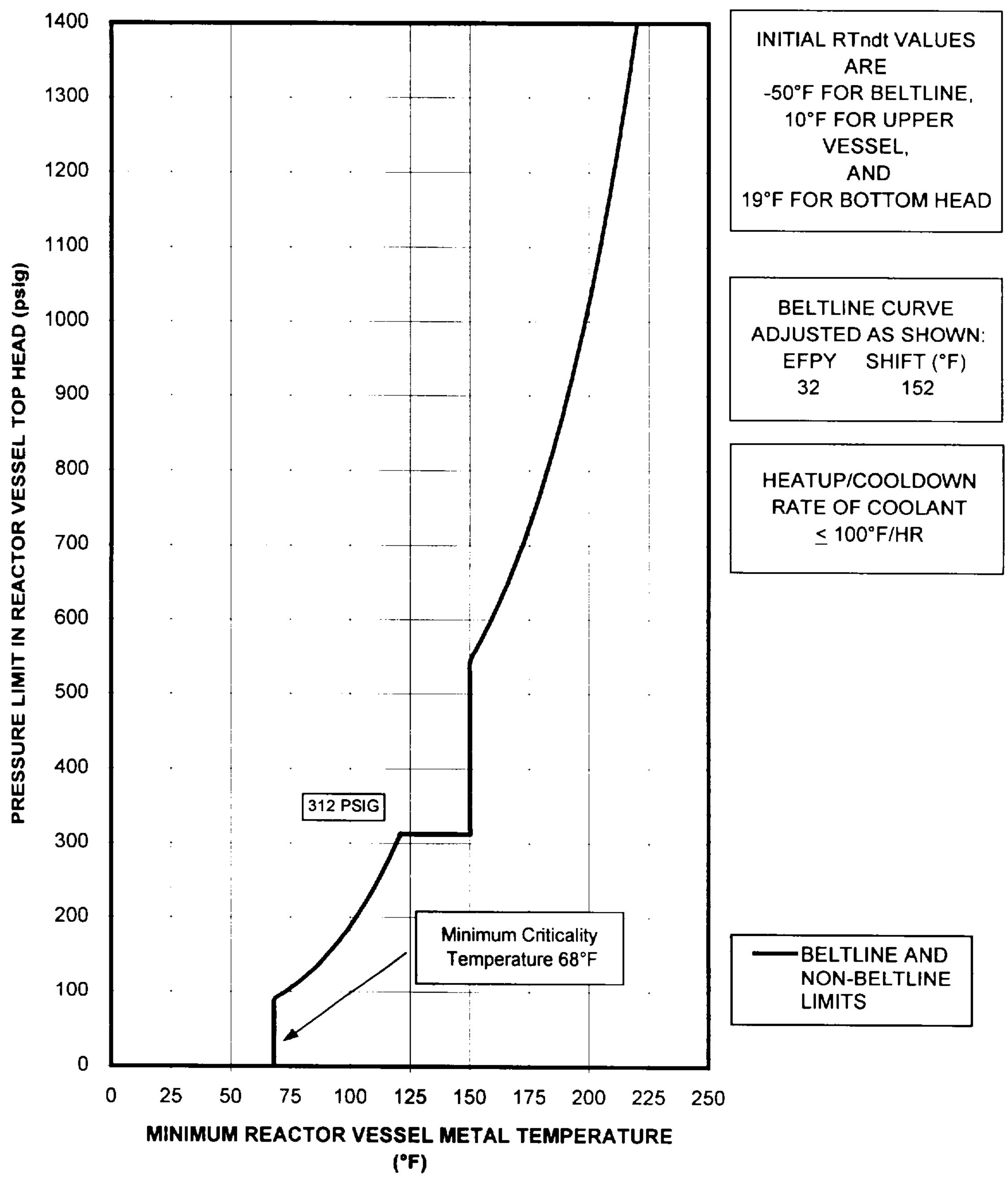

Figure 5-9. Core Critical P-T Curves [Curve C] up to 32 EFPY [100°F/hr or less coolant heatup/cooldown]

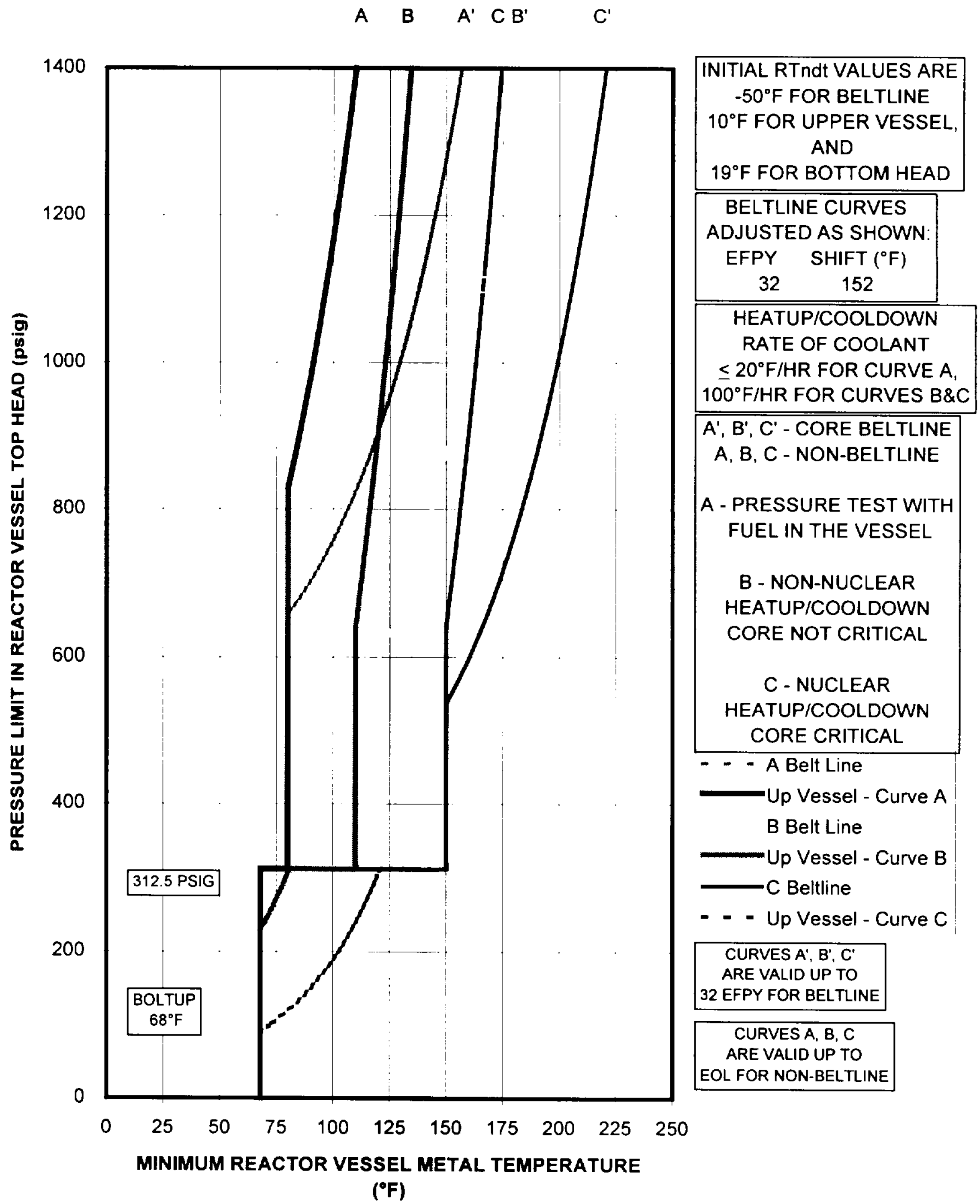

Figure 5-10. P-T Curves A, B, and C up to 32 EFPY

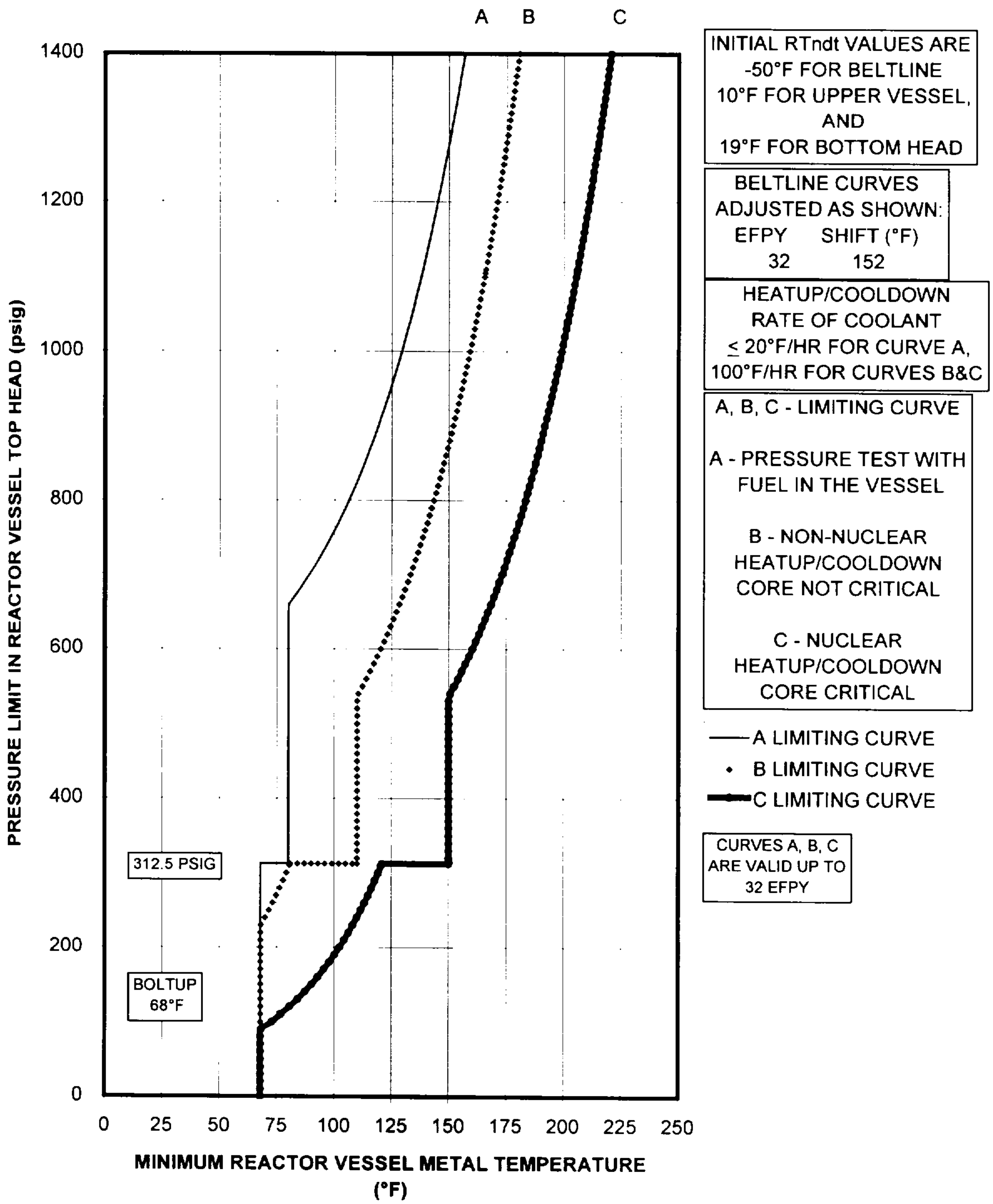

Figure 5-11. P-T Curves A, B, and C up to 32 EFPY

References

1. R.G. Carey & B.J. Branlund, "105% Power Uprate Evaluation Report for Entergy Operations Inc. River Bend Station" GE-NE, San Jose, CA, February 1999, (GE-NE-A22-00081-12, Rev 0 (SDDF # 7222.250-000-008A) (GE Proprietary)(Customer Supplied Data)

2. GE Drawing Number 762E458, Revision 7, "Reactor Cycles – Reactor Vessel," GE-NED, San Jose, CA. River Bend RPV Thermal Cycle Diagram. (GE Proprietary)

3. GE Drawing Number 166B7307, Revision 6, "Reactor Vessel - Nozzle Thermal Cycles," GE-BWRs, San Jose, CA. River Bend Nozzle Thermal Cycle Diagram. (GE Proprietary)

4. ASME Code Cases

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

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

7. "Analysis of Flaws," Appendix A to Section XI of the ASME Boiler & Pressure Vessel Code, 1992 Edition.

8. "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.

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

10. Not Used

11. Not Used

12. Not Used

13.

14.

15.

16. CMTRs

16.1 Reactor Pressure Vessel Material Certs for River Bend, (GE PO # 205-H8968, MPL# B13-D003)

16.2 "Weld Certs for River Bend 1"

16.3 Roger Pepper – CBIN Design., "Surveillance Test Specimen Documentation For GE PO #205-H8968", January 1980, VPF#3614-651-1 (Customer Supplied Data)

16.4 Steven E. Glenn – CB&I, Letter "Re: Requested River Bend 1 Heat & Lot Numbers", December 14, 1983, In DRF A00-01935 (Vol 1 of 1) / (App.G)

16.5 BJ Branlund & LJ Tilly – GENE - (VIP-78) "Integrated Surveillance Program" GE DRF# B13-02023-00 (Index G. Page 985)

16.6 T.J Griesbach – ATI Consulting.,"CB&I Fabrication Records for the River Bend Reactor Vessel", September 1998 (Customer Supplied Data)

17. CB & I Nuclear Company, Drawing # 1 Revision 8
"Vessel Outline"
Chicago, Illinois (GE-NE VPF# 3614-450-9)

18. CB & I Nuclear Company, Drawing # 218-FN4-0
"N4 Feedwater Nozzle Forging"
Chicago, Illinois (GE-NE VPF# 3613-562-3)

Appendix A

Description of Discontinuities

Table A-1. Geometric Discontinuities for River Bend - BWR/6 - 218" Vessel

Table A-1. Cont. - Geometric Discontinuities for River Bend - BWR/6 - 218" Vessel

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

Nozzle or Appurtenance Identification	Nozzle or Appurtenance	Material	Reference	Remarks
N11	N11 - Core Differential Press & Liquid Control - Bottom Head - Elev. 8 1/16 " actual	SB 166 -Alloy 600	2, 5, 10, 40, 46, 58	Nozzles or appurtenances < 2.5" or made from Alloy 600 require no fracture toughness evaluation.
N12	N12 - Instrumentation - Penetrations in Shell Ring 2- Elev. 358" theoretical	SA 336 CL F8 - Austenitic Steel	1, 5, 10, 46, 58	In Belt Line Region - Nozzles or appurtenances < 2.5" or made from stainless steel require no fracture toughness evaluation.
N13	N13 - Instrumentation - Penetrations in Shell Ring 3-Elev. 509" theoretical	SA 336 CL F8 - Austenitic Steel	1, 5, 10, 46, 58	Nozzles or appurtenances < 2.5" or made from stainless steel require no fracture toughness evaluation.
N14	N14 - Instrumentation - Penetrations in Shell Ring 4-Elev. 586 1/4 " theoretical	SA 336 CL F8 - Austenitic Steel	1, 5, 10, 46, 58	Nozzles or appurtenances < 2.5" or made from stainless steel require no fracture toughness evaluation.
N17 / MK STD-25-0	N17 - Seal Leak Detector Elev. Shell Flangethickness <2.5"* - Flange	MS 600 - SB 166 - Alloy 600	5, 10, 46, 56	Nozzles or appurtenances < 2.5" or made from Alloy 600 require no fracture toughness evaluation.
N18	N18 - Core Differential Pressure - Bottom Head- Elev. 7 7/8 " actual	Material - SA 336 CL F8 Austenitic Steel	2, 5, 10, 41, 46, 58	Nozzles or appurtenances < 2.5" or made from stainless steel require no fracture toughness evaluation.
(17-1) to (12-A)	Shroud Support Stub to Bottom Head	MS 61.0 - SB 168 - Alloy 600	13, 18	Nozzles or appurtenances made from Alloy 600 require no fracture toughness evaluation.
(20-A) to (21-A)	Shroud Support Ring Material - to Shell 1	MS 61.0 -SB 168 - Alloy 600	3, 7, 19, 20, 21, 44, 48	Nozzles or appurtenances < 2.5" or made from Alloy 600 require no fracture toughness evaluation.

* These nozzles are the closure flange leak detection nozzles.

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

Nozzle or Appurtenance Identification	Nozzle or Appurtenance	Material	Reference	Remarks
MK STD-20-0	Feedwater Sparger Bracket	SA 182 TP F304 L Austenitic Steel	35, 54	Nozzles or appurtenances made from stainless steel require no fracture toughness evaluation.
MK STD-22-0	Core Spray Bracket -	SA 182 TP F304 L Austenitic Steel	37, 55	Nozzles or appurtenances made from stainless steel require no fracture toughness evaluation.
MK STD-18-0	Steam Dryer Support Bracket	SA 182 TP F304 Austenitic Steel	33, 53	Nozzles or appurtenances made from stainless steel require no fracture toughness evaluation.
MK STD-17-0	Guide Rod Bracket Attachment	SA 182 TP F304 Austenitic Steel	32, 52	Nozzles or appurtenances made from stainless steel require no fracture toughness evaluation.
MK 29-1	Refueling Bellows Bar - 1 ¼" Bar	SA516 GR 70	27	Nozzles or appurtenances < 2.5" require no fracture toughness evaluation.
	Incore Penetrations		14, 17	Nozzles or appurtenances < 2.5" require no fracture toughness evaluation.
MK 14-**-**	Control Rod Drive Penetrations - Bottom Head	MS-55.0 - SB-167 - Alloy 600	14, 15, 16, 17	Nozzles or appurtenances made from Alloy 600 require no fracture toughness evaluation.
MK 64-1	Top Head Lifting Lugs	SA 533 GRB CL I	39	Not a pressure boundary component and loads only occur on this component when the reactor is shutdown during an outage. Therefore, no fracture toughness evaluation is required.
MK 55-1	Name Plate Pad for Shell	SA516 GR70	31	Not a pressure boundary component
MK 55-2	Name Plate Pad for Top Head	SA516 GR70	31	Not a pressure boundary component

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

Nozzle or Appurtenance Identification	Nozzle or Appurtenance	Material	Reference	Remarks
.	Surveillance Bracket PadsDimension -max pads size 1 29/32" by 1 5/16" & 1 3/8" by 2 31/32"	Weld Buildup is stainless steel thus conclude bracket is stainless steel	23, 36, 49	Belt Line Region - Not a pressure boundary component & appurtenances < 2.5" or made of stainless steel require no fracture toughness evaluation.
.	Jet Pump Pads	Weld Buildup is stainless steel and TR-108728 states BWR 6's pads are stainless steel	23, 38, 50, 51 ,62	Belt Line Region - Not a pressure boundary component & appurtenances made from stainless steel require no fracture toughness evaluation.

Appendix A References

1 CB & I Nuclear Company, Drawing # R1 Revision 6
" Weld Seam & Mat'l Identification for Shell Ring & Flange Assemblies"
Chicago, Illinois (GE-NE VPF# 3614-657-2)

2 CB & I Nuclear Company, Drawing # R2 Revision 3
"Top Head & Bottom Head Weld Seam & Plate Identification"
Chicago, Illinois (GE-NE VPF# 3614-658)

3 CB & I Nuclear Company, Drawing # R5 Revision 2
"Shroud Support Assembly Weld Seams & Material Ident"
Chicago, Illinois (GE-NE VPF# 3614-661)

4 CB & I Nuclear Company, Drawing # R6 Revision 3
"Nozzle, Safe End & Thermal Sleeve Weld Seam Identification"
Chicago, Illinois (GE-NE VPF# 3614-662)

5 CB & I Nuclear Company, Drawing # R7 Revision 5
"Nozzles, Safe Ends, & Thermal Sleeves Weld Seam Identification"
Chicago, Illinois (GE-NE VPF# 3614-663)

6 CB & I Nuclear Company, Drawing # 1 Revision 8
"Vessel Outline"
Chicago, Illinois (GE-NE VPF# 3614-450-9)

7 CB & I Nuclear Company, Drawing # 2 Revision 5
"Vessel Assembly (With Summary of Shipping Pieces)"
Chicago, Illinois (GE-NE VPF# 3614-451-6)

8 CB & I Nuclear Company, Drawing # 5 Revision 1
"Seam Details (Shell)"
Chicago, Illinois (GE-NE VPF# 3614-454-2)

9 CB & I Nuclear Company, Drawing # 6 Revision 2
"Seam Details (Heads)"
Chicago, Illinois (GE-NE VPF# 3614-455-3)

10 CB & I Nuclear Company, Drawing # 7 Revision 4
"Seam Details for Nozzles"
Chicago, Illinois (GE-NE VPF# 3614-456-5)

12	CB & I Nuclear Company, "Bottom Head Plate Details" Chicago, Illinois (GE-NE VPF#	Drawing #	11 3614-460-6)	Revision	5
13	CB & I Nuclear Company, "Bottom Head Assembly" Chicago, Illinois (GE-NE VPF#	Drawing #	12 3614-461-6)	Revision	5
14	CB & I Nuclear Company, "Plan of Bottom Head Penetrations" Chicago, Illinois (GE-NE VPF#	Drawing #	13 3614-462-3)	Revision	2
15	CB & I Nuclear Company, "Control Rod Drive Detail" Chicago, Illinois (GE-NE VPF#	Drawing #	14 3614-463-2)	Revision	1
16	CB & I Nuclear Company, "Control Rod Drive Penetration Details" Chicago, Illinois (GE-NE VPF#	Drawing #	15 3614-464-5)	Revision	4
17	CB & I Nuclear Company, "Incore Penetration Details" Chicago, Illinois (GE-NE VPF#	Drawing #	16 3614-465-5)	Revision	4
18	CB & I Nuclear Company, "Shroud Support Stubs & Location" Chicago, Illinois (GE-NE VPF#	Drawing #	17 3614-466-3)	Revision	2
19	CB & I Nuclear Company, "Shroud Support Fabrication Details" Chicago, Illinois (GE-NE VPF#	Drawing #	18 3614-467-1)	Revision	1
20	CB & I Nuclear Company, "Shroud Support Assembly Details" Chicago, Illinois (GE-NE VPF#	Drawing #	19 3614-468-2)	Revision	2
21	CB & I Nuclear Company, "Shroud Support Assembly" Chicago, Illinois (GE-NE VPF#	Drawing #	20 3614-469-1)	Revision	1
22	CB & I Nuclear Company, "#1 Shell Ring Assy" Chicago, Illinois (GE-NE VPF#	Drawing #	21 3614-470-4)	Revision	3
23	CB & I Nuclear Company, "#2 Shell Ring Assy" Chicago, Illinois (GE-NE VPF#	Drawing #	22 3614-471-6)	Revision	5
24	CB & I Nuclear Company, "#3 Shell Ring Assembly"	Drawing #	23	Revision	3

	Chicago, Illinois	(GE-NE VPF#	3614-472-4)		
25	CB & I Nuclear Company, "#4 Shell Ring Assembly" Chicago, Illinois	Drawing # (GE-NE VPF#	24 3614-473 –5)	Revision	4
26	CB & I Nuclear Company, "Shell Flange Details" Chicago, Illinois	Drawing # (GE-NE VPF#	28 3614-477-3)	Revision	2
27	CB & I Nuclear Company, "Shell Flange Assembly" Chicago, Illinois	Drawing # (GE-NE VPF#	29 3614-478-3)	Revision	2
28	CB & I Nuclear Company, "Top Head Flange Assembly" Chicago, Illinois	Drawing # (GE-NE VPF#	34 3614-483-4)	Revision	3
29	CB & I Nuclear Company, "Top Head Details" Chicago, Illinois	Drawing # (GE-NE VPF#	35 3614-484-3)	Revision	2
30	CB & I Nuclear Company, "Top Head Assembly" Chicago, Illinois	Drawing # (GE-NE VPF#	36 3614-485-3)	Revision	2
31	CB & I Nuclear Company, "Name Plate Pads for Shell & Top Head Flange" Chicago, Illinois	Drawing # (GE-NE VPF#	55 3614-504-3)	Revision	2
32	CB & I Nuclear Company, "Guide Rod Bracket Attachment" Chicago, Illinois	Drawing # (GE-NE VPF#	57 3614-506-3)	Revision	2
33	CB & I Nuclear Company, "Steam Dryer Support Bracket Attachment" Chicago, Illinois	Drawing # (GE-NE VPF#	58 3614-507-3)	Revision	2
34	CB & I Nuclear Company, "Steam Dryer Hold Down Bracket Attachment" Chicago, Illinois	Drawing # (GE-NE VPF#	59 3614-508-2)	Revision	1
35	CB & I Nuclear Company, "Feedwater Sparger Bracket Attachment" Chicago, Illinois	Drawing # (GE-NE VPF#	60 3614-509-4)	Revision	3
36	CB & I Nuclear Company, "Surveillance Bracket Pads" Chicago, Illinois	Drawing # (GE-NE VPF#	61 3614-649-3)	Revision	5

37 CB & I Nuclear Company, Drawing # 62 Revision 2
"Core Spray Bracket Attachment"
Chicago, Illinois (GE-NE VPF# 3614-511-3)

38 CB & I Nuclear Company, Drawing # 63 Revision 2
"Jet Pump Riser Support Pads"
Chicago, Illinois (GE-NE VPF# 3614-512-3)

39 CB & I Nuclear Company, Drawing # 64 Revision 1
"Top Head Lifting Lugs"
Chicago, Illinois (GE-NE VPF# 3614-513-2)

40 CB & I Nuclear Company, Drawing # 76 Revision 5
"N11 Sleeve Attachment (Core Differential Pressure & Liquid Control)"
Chicago, Illinois (GE-NE VPF# 3614-594-7)

41 CB & I Nuclear Company, Drawing # 77 Revision 2
"N18 Sleeve Attachment (Core Differential Pressure)"
Chicago, Illinois (GE-NE VPF# 3614-631-4)

42 CB & I Nuclear Company, Drawing # 81 Revision 2
"As-Built Vessel Seam Locations"
Chicago, Illinois (GE-NE VPF# 3614-668-2)

43 CB & I Nuclear Company, Drawing # 82 Revision 2
"Top & Bottom Head As-Built Seam Locations"
Chicago, Illinois (GE-NE VPF# 3614-669)

44 CB & I Nuclear Company, Drawing # 83 Revision 3
"As-Built Vessel Shell Dimensions"
Chicago, Illinois (GE-NE VPF# 3614-703)

45 CB & I Nuclear Company, Drawing # 86 Revision 2
"As-Built Nozzle Locations (Shell)"
Chicago, Illinois (GE-NE VPF# 3614-706)

46 CB & I Nuclear Company, Drawing # 87 Revision 2
"As-Built Nozzle Locations (Shell)"
Chicago, Illinois (GE-NE VPF# 3614-707)

47 CB & I Nuclear Company, Drawing # 88 Revision 3
"As-Built Top Head Attach Locations"
Chicago, Illinois (GE-NE VPF# 3614-708)

48 CB & I Nuclear Company, Drawing # 89 Revision 2
"As-Built Shroud Support Dimensions"
Chicago, Illinois (GE-NE VPF# 3614-709)

49 CB & I Nuclear Company, Drawing # 94 Revision 3
"As-Built Shroud Support Dimensions"

Chicago, Illinois (GE-NE VPF# 3614-714)

50 CB & I Nuclear Company, Drawing # 95 Revision 2
"As-Built Shroud Support Dimensions"
Chicago, Illinois (GE-NE VPF# 3614-730)

51 CB & I Nuclear Company, Drawing # 96 Revision 2
"As-Built Shroud Support Dimensions"
Chicago, Illinois (GE-NE VPF# 3614-715)

52 CB & I Nuclear Company, Drawing # STD-17-0
"Guide Rod Bracket Forging"
Chicago, Illinois (GE-NE VPF# 3613-616-3)

53 CB & I Nuclear Company, Drawing # STD-18-0
"Steam Dryer Support Bracket"
Chicago, Illinois (GE-NE VPF# 3613-617-1)

54 CB & I Nuclear Company, Drawing # STD-20-0
"Feedwater Sparger Bracket Forging"
Chicago, Illinois (GE-NE VPF# 3613-619-2)

55 CB & I Nuclear Company, Drawing # STD-22-0
"Core Spray Bracket Forging"
Chicago, Illinois (GE-NE VPF# 3613-621-2)

56 CB & I Nuclear Company, Drawing # STD-25-0
"N17 Nozzle Forging (Seal Leak Detector)"
Chicago, Illinois (GE-NE VPF# 3613-624-1)

57 CB & I Nuclear Company, Drawing # 218-BDH-0
"Steam Dryer Hold Down Bracket"
Chicago, Illinois (GE-NE VPF# 3613-801-2)

58 (ASME) American Society of Mechanical Engineers
Boiler and Pressure Vessel Code - Section II - 1971
"Material Specifications (Part A - Ferrous)"

59 CMTRs
(GE PO # 205-H8968, MPL# B13-D003)

60 River Bend Station Updated Safety Analysis Report
Figure 5.3-6 (Beltline Weld Seam and Plate Locations for River Bend 1)

61 Design Verification Record / Design Input Request
(Input Data for GE Task DIR for P-T Curve Calculations)
Page 6, Item 9.

62 BWR Vessel and Internals Project – TR-108728
(BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41))

Appendix B

Pressure Temperature Curve Data Tabulation

Table B-1. River Bend 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, 5-4, 5-5, 5-6, and 5-10

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)	UPPER VESSEL CURVE C (°F)	32 EFPY BELTLINE CURVE C (°F)
0	68	68	68	68	68	68	68	68
10	68	68	68	68	68	68	68	68
20	68	68	68	68	68	68	68	68
30	68	68	68	68	68	68	68	68
40	68	68	68	68	68	68	68	68
50	68	68	68	68	68	68	68	68
60	68	68	68	68	68	68	68	68
70	68	68	68	68	68	68	68	68
80	68	68	68	68	68	68	68	68
90	68	68	68	68	68	68	68	68
100	68	68	68	68	68	68	73	68
110	68	68	68	68	68	68	77	68
120	68	68	68	68	68	68	81	68
130	68	68	68	68	68	68	84	68
140	68	68	68	68	68	68	87	68
150	68	68	68	68	68	68	90	68
160	68	68	68	68	68	68	93	68
170	68	68	68	68	68	68	96	68
180	68	68	68	68	68	68	98	68
190	68	68	68	68	68	68	100	68
200	68	68	68	68	68	68	102	68
210	68	68	68	68	68	68	104	68
220	68	68	68	68	68	68	106	68
230	68	68	68	68	68	68	108	68
240	68	68	68	68	70	68	110	68
250	68	68	68	68	72	68	112	68
260	68	68	68	68	73	68	113	68
270	68	68	68	68	75	68	115	68
280	68	68	68	68	76	68	116	68
290	68	68	68	68	78	68	118	68
300	68	68	68	68	79	68	119	68
310	68	68	68	68	81	68	121	68
313	68	68	68	68	81	68	121	68
313	68	80	80	68	110	110	150	150
320	68	80	80	68	110	110	150	150
330	68	80	80	68	110	110	150	150
340	68	80	80	68	110	110	150	150
350	68	80	80	68	110	110	150	150
360	68	80	80	68	110	110	150	150
370	68	80	80	68	110	110	150	150
380	68	80	80	68	110	110	150	150
390	68	80	80	68	110	110	150	150
400	68	80	80	68	110	110	150	150

Table B-1. Cont. - River Bend 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, 5-4, 5-5, 5-6, and 5-10

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)	UPPER VESSEL CURVE C (°F)	32 EFPY BELTLINE CURVE C (°F)
410	68	80	80	68	110	110	150	150
420	68	80	80	68	110	110	150	150
430	68	80	80	68	110	110	150	150
440	68	80	80	68	110	110	150	150
450	68	80	80	68	110	110	150	150
460	68	80	80	68	110	110	150	150
470	68	80	80	68	110	110	150	150
480	68	80	80	68	110	110	150	150
490	68	80	80	68	110	110	150	150
500	68	80	80	68	110	110	150	150
510	68	80	80	68	110	110	150	150
520	68	80	80	68	110	110	150	150
530	68	80	80	68	110	110	150	150
540	68	80	80	68	110	111	150	151
550	68	80	80	68	110	112	150	152
560	68	80	80	68	110	114	150	154
570	68	80	80	68	110	116	150	156
580	68	80	80	68	110	117	150	157
590	68	80	80	68	110	119	150	159
600	68	80	80	68	110	120	150	160
610	68	80	80	68	110	122	150	162
620	68	80	80	68	110	123	150	163
630	68	80	80	68	110	124	150	164
640	68	80	80	68	110	126	150	166
650	68	80	80	68	110	127	150	167
660	68	80	80	68	111	128	151	168
670	68	80	83	68	111	130	151	170
680	68	80	85	68	111	131	151	171
690	68	80	87	68	112	132	152	172
700	68	80	89	68	112	133	152	173
710	68	80	91	68	113	134	153	174
720	68	80	93	68	113	135	153	175
730	68	80	95	69	113	136	153	176
740	68	80	97	70	114	137	154	177
750	68	80	98	71	114	139	154	179
760	68	80	100	72	115	140	155	180
770	68	80	102	73	115	141	155	181
780	68	80	103	74	115	141	155	181
790	68	80	105	75	116	142	156	182
800	68	80	106	76	116	143	156	183
810	68	80	108	77	116	144	156	184
820	68	80	109	78	117	145	157	185
830	68	80	111	79	117	146	157	186

Table B-1. Cont. - River Bend 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, 5-4, 5-5, 5-6, and 5-10

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)	UPPER VESSEL CURVE C (°F)	32 EFPY BELTLINE CURVE C (°F)
840	68	81	112	80	118	147	158	187
850	68	82	113	80	118	148	158	188
860	68	82	114	81	118	149	158	189
870	68	83	116	82	119	149	159	189
880	68	84	117	83	119	150	159	190
890	68	84	118	84	119	151	159	191
900	68	85	119	85	120	152	160	192
910	68	86	120	85	120	153	160	193
920	68	86	121	86	120	153	160	193
930	68	87	122	87	121	154	161	194
940	68	87	123	88	121	155	161	195
950	68	88	124	88	121	156	161	196
960	68	89	125	89	122	156	162	196
970	69	89	126	90	122	157	162	197
980	69	90	127	91	122	158	162	198
990	70	91	128	91	123	158	163	198
1000	71	91	129	92	123	159	163	199
1010	72	92	130	93	123	160	163	200
1020	72	92	131	93	124	160	164	200
1030	73	93	132	94	124	161	164	201
1040	74	93	133	95	124	162	164	202
1050	75	94	134	95	125	162	165	202
1060	75	94	135	96	125	163	165	203
1070	76	95	135	97	125	164	165	204
1080	77	96	136	97	126	164	166	204
1090	78	96	137	98	126	165	166	205
1100	78	97	138	98	126	165	166	205
1105	79	97	138	99	126	166	166	206
1110	79	97	138	99	126	166	166	206
1120	80	98	139	100	127	167	167	207
1130	80	98	140	100	127	167	167	207
1140	81	99	141	101	127	168	167	208
1150	82	99	141	101	128	168	168	208
1160	82	100	142	102	128	169	168	209
1170	83	100	143	102	128	169	168	209
1180	83	101	144	103	128	170	168	210
1190	84	101	144	104	129	171	169	211
1200	85	102	145	104	129	171	169	211
1210	85	102	146	105	129	172	169	212
1220	86	102	146	105	130	172	170	212
1230	86	103	147	106	130	173	170	213
1240	87	103	148	106	130	173	170	213
1250	87	104	148	107	130	174	170	214

Table B-1. Cont. - River Bend 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, 5-4, 5-5, 5-6, and 5-10

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)	UPPER VESSEL CURVE C (°F)	32 EFPY BELTLINE CURVE C (°F)
1260	88	104	149	107	131	174	171	214
1270	89	105	149	108	131	175	171	215
1280	89	105	150	108	131	175	171	215
1290	90	106	151	109	132	176	172	216
1300	90	106	151	109	132	176	172	216
1310	91	106	152	110	132	177	172	217
1320	91	107	152	110	132	177	172	217
1330	92	107	153	111	133	178	173	218
1340	92	108	154	111	133	178	173	218
1350	93	108	154	112	133	178	173	218
1360	93	109	155	112	133	179	173	219
1370	94	109	155	112	134	179	174	219
1380	94	109	156	113	134	180	174	220
1390	95	110	156	113	134	180	174	220
1400	95	110	157	114	134	181	174	221

Table B2. River Bend 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 5-7 and 5-8

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)
0	68	68	68	68
10	68	68	68	68
20	68	68	68	68
30	68	68	68	68
40	68	68	68	68
50	68	68	68	68
60	68	68	68	68
70	68	68	68	68
80	68	68	68	68
90	68	68	68	68
100	68	68	68	68
110	68	68	68	68
120	68	68	68	68
130	68	68	68	68
140	68	68	68	68
150	68	68	68	68
160	68	68	68	68
170	68	68	68	68
180	68	68	68	68
190	68	68	68	68
200	68	68	68	68
210	68	68	68	68
220	68	68	68	68
230	68	68	68	68
240	68	68	68	70
250	68	68	68	72
260	68	68	68	73
270	68	68	68	75
280	68	68	68	76
290	68	68	68	78
300	68	68	68	79
310	68	68	68	81
313	68	68	68	81
313	68	80	68	110
320	68	80	68	110
330	68	80	68	110
340	68	80	68	110
350	68	80	68	110

Table B2. Cont. - River Bend 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 5-7 and 5-8

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)
360	68	80	68	110
370	68	80	68	110
380	68	80	68	110
390	68	80	68	110
400	68	80	68	110
410	68	80	68	110
420	68	80	68	110
430	68	80	68	110
440	68	80	68	110
450	68	80	68	110
460	68	80	68	110
470	68	80	68	110
480	68	80	68	110
490	68	80	68	110
500	68	80	68	110
510	68	80	68	110
520	68	80	68	110
530	68	80	68	110
540	68	80	68	111
550	68	80	68	112
560	68	80	68	114
570	68	80	68	116
580	68	80	68	117
590	68	80	68	119
600	68	80	68	120
610	68	80	68	122
620	68	80	68	123
630	68	80	68	124
640	68	80	68	126
650	68	80	68	127
660	68	80	68	128
670	68	83	68	130
680	68	85	68	131
690	68	87	68	132
700	68	89	68	133
710	68	91	68	134
720	68	93	68	135
730	68	95	69	136

Table B2. Cont. - River Bend 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 5-7 and 5-8

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)
740	68	97	70	137
750	68	98	71	139
760	68	100	72	140
770	68	102	73	141
780	68	103	74	141
790	68	105	75	142
800	68	106	76	143
810	68	108	77	144
820	68	109	78	145
830	68	111	79	146
840	68	112	80	147
850	68	113	80	148
860	68	114	81	149
870	68	116	82	149
880	68	117	83	150
890	68	118	84	151
900	68	119	85	152
910	68	120	85	153
920	68	121	86	153
930	68	122	87	154
940	68	123	88	155
950	68	124	88	156
960	68	125	89	156
970	69	126	90	157
980	69	127	91	158
990	70	128	91	158
1000	71	129	92	159
1010	72	130	93	160
1020	72	131	93	160
1030	73	132	94	161
1040	74	133	95	162
1050	75	134	95	162
1060	75	135	96	163
1070	76	135	97	164
1080	77	136	97	164
1090	78	137	98	165
1100	78	138	98	165
1105	79	138	99	166

Table B2. Cont. - River Bend 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 5-7 and 5-8

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)
1110	79	138	99	166
1120	80	139	100	167
1130	80	140	100	167
1140	81	141	101	168
1150	82	141	101	168
1160	82	142	102	169
1170	83	143	102	169
1180	83	144	103	170
1190	84	144	104	171
1200	85	145	104	171
1210	85	146	105	172
1220	86	146	105	172
1230	86	147	106	173
1240	87	148	106	173
1250	87	148	107	174
1260	88	149	107	174
1270	89	149	108	175
1280	89	150	108	175
1290	90	151	109	176
1300	90	151	109	176
1310	91	152	110	177
1320	91	152	110	177
1330	92	153	111	178
1340	92	154	111	178
1350	93	154	112	178
1360	93	155	112	179
1370	94	155	112	179
1380	94	156	113	180
1390	95	156	113	180
1400	95	157	114	181

TABLE B-3. River Bend Unit 1 Limiting 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 and 5-11

PRESSURE (PSIG)	A LIMITING (°F)	B LIMITING (°F)	C LIMITING (°F)
0	68	68	68
10	68	68	68
20	68	68	68
30	68	68	68
40	68	68	68
50	68	68	68
60	68	68	68
70	68	68	68
80	68	68	68
90	68	68	68
100	68	68	73
110	68	68	77
120	68	68	81
130	68	68	84
140	68	68	87
150	68	68	90
160	68	68	93
170	68	68	96
180	68	68	98
190	68	68	100
200	68	68	102
210	68	68	104
220	68	68	106
230	68	68	108
240	68	70	110
250	68	72	112
260	68	73	113
270	68	75	115
280	68	76	116
290	68	78	118
300	68	79	119
310	68	81	121
313	68	81	121
313	80	110	150
320	80	110	150
330	80	110	150
340	80	110	150
350	80	110	150

TABLE B-3. River Bend Unit 1 Limiting 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 and 5-11

PRESSURE (PSIG)	A LIMITING (°F)	B LIMITING (°F)	C LIMITING (°F)
360	80	110	150
370	80	110	150
380	80	110	150
390	80	110	150
400	80	110	150
410	80	110	150
420	80	110	150
430	80	110	150
440	80	110	150
450	80	110	150
460	80	110	150
470	80	110	150
480	80	110	150
490	80	110	150
500	80	110	150
510	80	110	150
520	80	110	150
530	80	110	150
540	80	111	151
550	80	112	152
560	80	114	154
570	80	116	156
580	80	117	157
590	80	119	159
600	80	120	160
610	80	122	162
620	80	123	163
630	80	124	164
640	80	126	166
650	80	127	167
660	80	128	168
670	83	130	170
680	85	131	171
690	87	132	172
700	89	133	173
710	91	134	174
720	93	135	175
730	95	136	176

TABLE B-3. River Bend Unit 1 Limiting 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 and 5-11

PRESSURE (PSIG)	A LIMITING (°F)	B LIMITING (°F)	C LIMITING (°F)
740	97	137	177
750	98	139	179
760	100	140	180
770	102	141	181
780	103	141	181
790	105	142	182
800	106	143	183
810	108	144	184
820	109	145	185
830	111	146	186
840	112	147	187
850	113	148	188
860	114	149	189
870	116	149	189
880	117	150	190
890	118	151	191
900	119	152	192
910	120	153	193
920	121	153	193
930	122	154	194
940	123	155	195
950	124	156	196
960	125	156	196
970	126	157	197
980	127	158	198
990	128	158	198
1000	129	159	199
1010	130	160	200
1020	131	160	200
1030	132	161	201
1040	133	162	202
1050	134	162	202
1060	135	163	203
1070	135	164	204
1080	136	164	204
1090	137	165	205
1100	138	165	205
1105	138	166	206

TABLE B-3. River Bend Unit 1 Limiting 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 and 5-11

PRESSURE (PSIG)	A LIMITING (°F)	B LIMITING (°F)	C LIMITING (°F)
1110	138	166	206
1120	139	167	207
1130	140	167	207
1140	141	168	208
1150	141	168	208
1160	142	169	209
1170	143	169	209
1180	144	170	210
1190	144	171	211
1200	145	171	211
1210	146	172	212
1220	146	172	212
1230	147	173	213
1240	148	173	213
1250	148	174	214
1260	149	174	214
1270	149	175	215
1280	150	175	215
1290	151	176	216
1300	151	176	216
1310	152	177	217
1320	152	177	217
1330	153	178	218
1340	154	178	218
1350	154	178	218
1360	155	179	219
1370	155	179	219
1380	156	180	220
1390	156	180	220
1400	157	181	221

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 curves. 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 Appendix D.

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 which 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 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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ATTACHMENT 4

TO

LETTER NO. RBF1-01-0010

(GE Proprietary Information)

GE-NE-B13-02094-00-01

"Pressure Temperature Curves
for
Entergy Operations, Inc. (EOI)
Using the K_{Ic} Methodology"

LICENSE NO. NPF-47

ENTERGY OPERATIONS, INC.

Docket No. 50-45

General Electric Company

AFFIDAVIT

I, George B. Stramback, being duly sworn, depose and state as follows:

(1) I am Project Manager, Regulatory Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in the GE proprietary report GE-NE-B13-02094-00-01, *Pressure-Temperature Curves for Entergy Operations Inc. (EOI) Using the K_{Ic} Methodology RiverBend,* Revision 0, Class III (GE Proprietary Information), dated January 2001. The proprietary information is delineated by bars marked in the margin adjacent to the specific material.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), 2.790(a)(4), and 2.790(d)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals cost or price information, production capacities, budget levels, or commercial strategies of General Electric, its customers, or its suppliers;

d. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, of potential commercial value to General Electric;

e. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in both paragraphs (4)a. and (4)b., above.

(5) The information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains detailed methods and processes, which GE has developed and applied to pressure-temperature curves for the BWR over a number of years.

The development of the BWR pressure-temperature curves was achieved at a significant cost, on the order of ¾ million dollars, to GE. The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends development of the expertise to determine and apply the appropriate evaluation process. In beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

STATE OF CALIFORNIA)
) ss:
COUNTY OF SANTA CLARA)

George B. Stramback, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of his knowledge, information, and belief.

Executed at San Jose, California, this 17th day of January 2001.

George B. Stramback
George B. Stramback
General Electric Company

Subscribed and sworn before me this 17th day of January 2001.

VICKY D. SCHROER
Commission # 1224251
Notary Public - California
Santa Clara County
My Comm. Expires Jun 12, 2003

Vicky D Schroer
Notary Public, State of California