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Pressure-Temperature Curves

for

Dresden and Quad Cities Stations

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REVISION STATUS SHEET

Revision	Changes
2	Paragraph 3.1.1 changed to reflect electroslag weld chemistry value modification. Tables A-1 to A-4, B-1 to B-4, and C-1 to C-4 modified to include appropriate fluence values, electroslag chemistry values and number of vertical welds.

TABLE OF CONTENTS

TABLE OF APPENDICES

TABLE OF FIGURES

TABLE OF TABLES

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 22 effective full power years (EFPY); in addition, pressure test curves have been included for 18 and 20 EFPY. The methodology used to generate the P-T curves in this report is the same as the methodology used to generate the P-T curves in 1989 [1].

The pressure-temperature (P-T) curves are established to the requirements of 10CFR50, Appendix G [2] 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, Revision 2 [3], or Rev 2.

In addition to beltline considerations, there are non-beltline discontinuity limits such as nozzles, penetrations, and flanges which affect the P-T curves. The non-beltline limits are based on generic analyses which are adjusted to the maximum reference temperature of nil ductility transition (RT_{NDT}) for the applicable Dresden or Quad Cities vessel components. The non-beltline limits are also governed by requirements in [2].

Furthermore, curves are included to allow monitoring of the bottom head regions of the vessel separate from the beltline region and upper vessel. This refinement could minimize heating requirements prior to pressure testing. Temperature monitoring requirements and methods are available in GE Services Information Letter (SIL) 430 contained in Appendix L.

2.0 INITIAL REFERENCE TEMPERATURE

2.1 Background

In order to perform a complete analysis of the vessel P-T requirements, initial RT_{NDT} values are needed for all low alloy steel vessel components. The requirements for establishing the vessel component toughness prior to 1972 (including Dresden and Quad Cities) were per the ASME Code Section III, Subsection NB-2300 and are summarized as follows:

a. Test specimens shall be longitudinally oriented CVN specimens.

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

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

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

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

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

10CFR50 Appendix G [2] states that for vessels constructed to a version of the ASME Code prior to the Summer 1972 Addendum, fracture toughness data and data analyses must be supplemented in an approved manner. GE developed methods for analytically converting fracture toughness data for vessels constructed before 1972 to comply with current requirements. These methods were developed from data in WRC Bulletin 217 [4] and from data collected to respond to NRC questions on FSAR submittals in the late 1970s. In 1994, these methods of estimating RT_{NDT} were submitted for generic approval by the BWR Owners' Group [5], and approved by the NRC for generic use [6].

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

To establish the initial RT_{NDT} temperatures for the Dresden and Quad Cities vessels 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, and forging, and bolting material LST are summarized in the remainder of this section. The RT_{NDT} values for the vessel weld materials (except for the Quad Cities lower shell to lower intermediate shell weld, shown below) were not calculated; these values were obtained from other sources (see Section 3.0).

For vessel plate material, the first step in calculating RT_{NDT} is to establish the 50 ft-lb. transverse test temperature from longitudinal test specimen data (obtained from certified material test reports, CMTR's). For Dresden and Quad Cities CMTR's, typically six energy values were listed at a given test temperature, corresponding to two sets of Charpy tests. The lowest energy Charpy value is adjusted by adding 2°F per ft-lb. energy difference from 50 ft-lb. For example, for plate heat B3990-2 in the lower shell course of Dresden 2, the lowest Charpy energy and test temperature from the CMTR's is 34.0 ft-lb. at 10°F. The estimated 50 ft-lb. longitudinal test temperature is:

$$T_{50L} = 10°F + [(50 - 34.0) \text{ ft-lb.} * 2°F/\text{ft-lb.}] = 42°F$$

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

$$T_{50T} = 42°F + 30°F = 72°F$$

The initial RT_{NDT} is the greater of nil-ductility transition temperature (NDT) or (T_{50T} - 60°F). Dropweight testing to establish NDT for plate material was listed in the CMTR; the NDT for the case above was 10°F. Thus, the initial RT_{NDT} for plate heat B3990-2 was 12°F.

For the Quad Cities 2 lower shell to lower intermediate shell weld, the CVN results were used to calculate the RT_{NDT}. The 50 ft-lb. test temperature is applicable to the weld material, but the 30°F adjustment to convert longitudinal data to transverse data is not applicable to weld material. Heat # S3986 with flux lot 3870 has a lowest Charpy energy of 41 ft-lb. at 10°F as recorded in weld qualification records. Therefore,

$$T_{50T} = 10°F + [(50 - 41.0) \text{ ft-lb.} * 2°F/\text{ft-lb.}] = 28°F$$

For Quad Cities 2, dropweight testing to establish NDT was not recorded for the weld materials, but GE procedure requires that, when no NDT is available for the weld, the resulting RT_{NDT} should be -50°F or higher. The value of (T_{50T} - 60°F) in this example was -32°F; therefore, the initial RT_{NDT} was -32°F.

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

For vessel forging material, such as nozzles and closure flanges, the method for establishing RT_{NDT} is the same as for vessel plate material. For the feedwater nozzle at Dresden 2, the NDT was 40°F and the lowest CVN data was 29.5 ft-lb. at 40°F. The corresponding value of (T_{50T} – 60°F) was:

$$(T_{50T} - 60°F) = \{[40 + (50-29.5)\ ft\text{-}lb. * 2°F/ft\text{-}lb.] + 30°F\} - 60°F = 51°F.$$

Therefore, the initial RT_{NDT} was 51°F.

In the bottom head region of the vessel, the vessel plate method is applied for estimating RT_{NDT}. For the lower torus shell of Quad Cities 1 (Heat C1478-3), the NDT was 40°F and the lowest CVN data was 25 ft-lb. at 40°F. The corresponding value of (T_{50T} – 60°F) was:

$$(T_{50T} - 60°F) = \{[40 + (50-25)\ ft\text{-}lb. * 2°F/ft\text{-}lb.] + 30°F\} - 60°F = 60°F.$$

Therefore, the initial RT_{NDT} was 60°F.

For bolting material, the current ASME Code requirements define the lowest service temperature (LST) as the temperature at which transverse CVN energy of 45 ft-lb. and 25 mils lateral expansion (MLE) were achieved. If the required Charpy results are not met, or are not reported, but the CVN energy reported is above 30 ft-lb., the requirements of the ASME Code Section III, Subsection NB-2300 at construction are applied, namely that the 30 ft-lb. test temperature plus 60°F is the LST for the bolting materials. Charpy data for the Dresden and Quad Cities closure studs do not meet the 45 ft-lb., 25 MLE requirement at 10°F. Therefore, the LST for the bolting material was 70°F. However, the highest RT_{NDT} in the flange region is 23.1°F, for the vertical electroslag weld. Thus, the higher of the LST and the RT_{NDT} +60°F is 83.1°F, the boltup limit in the closure flange region.

The initial RT_{NDT} values for the Dresden and Quad Cities reactor vessel materials are listed in Tables 2-1 through 2-8. This tabulation includes beltline, closure flange and bottom head materials which were considered in generating the P-T curves.

COMPONENT		HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			(T_{50T}-60) (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
PLATES & FORGINGS:									
Top Head & Flange									
Dollar Plate MK201		B4065-2	40	52	60	60	10	40	40
Top Head Torus MK 202		B4056-1	10	88	56	78	-20	10	10
		B4056-2	10	35	30	38	20	10	20
		B4056-3	10	74	67	63	-20	10	10
Top Head Flange									
MK209	AJL#308	4P0426	10	75	98	74	-20	0	0
MK48	AHK#307	5P0453	10	72	101	114	-20	0	0
Shell Courses									
Upper Shell MK60		B4050-2	10	80	75	91	-20	10	10
		B4071-1	10	72	85	55	-20	10	10
		B4050-1	10	64	76	73	-20	10	10
Upper Int. Shell MK59		B3990-1	10	40	31	50	18	10	18
		B4017-1	10	26	37	30	28	10	28
		B4017-2	10	34	58	59	12	10	12
		B4030-1	10	45	38	37	6	-20	6
Low-Int. Shell MK58		B4030-2	10	47	41	49	-2	-10	-2
		B4030-1	10	45	38	37	6	-20	6
		B5764-1	10	54	58	37	6	10	10
		B4065-1	10	35	31	36	18	20	20
Lower Shell MK57		A9128-1	10	47	41	44	-2	30	30
		A9128-2	10	37	36	41	8	10	10
		B3990-2	10	37	34	42	12	10	12
Bottom Head									
Dollar Plate MK1		A9004-1	40	42	56	47	26	40	40
Upper Torus, Btm Head MK2		A9009-1	40	62	69	52	10	40	40
		A9009-2	40	43	57	69	24	40	40
		A9004-2	40	72	72	63	10	40	40
Lower Torus, Btm Head MK4		B3906-1	40	37	49	42	36	40	40
		B3906-2	10	38	47	52	4	40	40

Table 2-1: RT_{NDT} values for Dresden 2 Vessel Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			$(T_{50T}-60)$ (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
NOZZLES								
Recirc. Outlet Nozzle MK8	BT1958-1	40	36	36.5	34	42	-	42
Recirc Inlet Nozzle MK7	BT1958-2	40	34	42	31	48	40	48
Steam Outlet Nozzle	BT2001-1	40	52.5	49	36.5	37	40	40
MK14	ZT2036-3	40	41	61.5	54.5	28	-	28
Feedwater Nozzle	BT1746-1	40	37.5	29.5	44	51	40	51
MK10	BT2001-3	40	54	35.5	49	39	40	40
Core Spray Nozzle MK11	BT2001-2	40	44	44	39	32	40	40
6" Instrumentation, Vent & CRD HSR Nozzle MK206 & 204 & 13	ZT2043	40	102	130	117	10	-	10
Jet Pump Nozzle MK19	118077	40	79	89	71	10	40	40
Core Diff. Press & Liq. Con. Noz MK17	7-7553	40	32	31	30	50	40	50
Drain Nozzle MK22	212918	40	238	239	237	10	-	10
Isolation Cond. Nozzle MK15	BT2001-2	40	32.5	39.5	36.5	45	40	45
WELDS:								
Vertical Welds:								
ESW								23.1
SAW	1P0661							-5
SAW	1P0815							-5
Girth Welds:								
SAW	71249							10
STUDS:						**LST**		
Studs	67-80278	10	47	52	36	70	OK	
MK61	67-20372	10	53	35	58	70	OK	

Table 2-2: RT_{NDT} values for Dresden 2 Nozzle and Weld Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			(T_{50T}-60) (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
PLATES & FORGINGS:								
Top Head & Flange								
Dollar Plate MK201	C1177-4	40	73	72	74	10	40	40
Top Head Torus	A0458-2	10	54	60	73	-20	10	10
MK 202	C1173-4	10	70	51	74	-20	10	10
	C1177-3	10	54	69	70	-20	10	10
Top Head Flange								
MK209	5P1127	10	43	75.04	71.92	-6	10	10
MK48	5P1114	10	57	108	106	-20	-10	-10
Shell Courses								
Upper Shell	C1191-1	10	50	43	55	-6	10	10
MK60	C1191-2	10	40	49	52	0	10	10
	B5144-1	10	64	51	62	-20	10	10
Upper Int. Shell	B5144-2	10	65	66	40	0	10	10
MK59	C1516-1	10	39	43	49	2	10	10
	B5159-1	10	83	57	65	-20	10	10
Low-Int. Shell	C1290-2	10	45	60	62	-10	10	10
MK58	A0237-1	10	71	70	59	-20	10	10
	B5118-1	10	66	67	66	-20	10	10
Lower Shell	C1256-2	10	75	70	90	-20	-10	-10
MK57	C1182-2	10	70	61	64	-20	10	10
	B5159-2	10	55	50	65	-20	0	0
Bottom Head								
Dollar Plate MK1	A0284-2	40	54	65	60	10	40	40
Btm Head Torus, Btm Head	A0237-2	40	92	91	109	10	40	40
MK2	C1177-1	40	49	62	74	12	40	40
	C1177-2	40	66	64	83	10	40	40
	C1485-1*							40
Bottom Center, Btm Head	C1173-2	40	49	33	47	44	40	44
MK4	C1173-1	40	41	45	74	28	40	40
*CMTR not available-40F RTndt assumed per purchase specification 21A1109								

Table 2-3: RT_{NDT} values for Dresden 3 Vessel Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			$(T_{50T}-60)$ (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
NOZZLES								
Recirc. Outlet Nozzle MK8 (Transverse data)	ZT2405-1	40	65	74.5	74.5	-20	40	40
Recirc Inlet Nozzle	ZT2405-4	40	72.5	65	84	-20	40	40
MK7 (Transverse data)	ZT2405-3	40	78.5	64	60.5	-20	40	40
(Longitudinal)	ZT2869	40	31	37.5	39	48	30	48
Steam Outlet Nozzle MK14 (Transverse data)	ZT2405-2	40	52.5	42	49	4	40	40
Feedwater Nozzle	ZT2405-5	40	52.5	61.5	70.5	-20	40	40
MK10 (Transverse data)	ZT2885-6	40	32	34	36.5	34	30	34
Core Spray Nozzle	ZT2869-5	40	39	36	44.5	38	30	38
MK11	ZT2782	40	43	42	34	42	30	42
6" Instrumentation, Vent & CRD HSR Nozzle MK206 & 204 & 13	ZT3043	40	102	130	117	10	40	40
Jet Pump Nozzle MK19	EV8446	40	68.5	64	49	12	40	40
Core Diff. Press & Liq. Con. Noz MK17	ZT3043*							40
Drain Nozzle MK22	212918	40	238	239	237	10		10
Isolation Cond. Nozzle MK15 (Transverse data)	ZT2405-3	40	67	47.5	53.5	-12.5	40	40
WELDS:								
Vertical Welds	ESW							23.1
Girth Welds	299L44/ 8650							-5
STUDS:						**LST**		
Studs MK61	6720372	10	53	35	58	70	OK	

* Additional charpy data not available

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

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			$(T_{50T}-60)$ (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)
PLATES & FORGINGS:								
TOP HEAD and FLANGE								
Dollar Plate Mk 201	A0981-2	40	76	100	98	10	40	40
Torus MK 202	B5853-1	10	75	82	77	-20	10	10
	C2426-3	10	69	75	55	-20	10	10
	C1722-3	10	81	80	101	-20	10	10
	A0313-1	10	34	58	57	12	10	12
	C1501-3	10	48	94	94	-16	10	10
Flange Mk209	4P1201	10	77.6	57.3	87	-20	10	10
Mk48	4P1104	10	84.3	86.1	108.9	-20	10	10
SHELL COURSES								
Upper Shell Mk60	C1498-1	10	51	57	65	-20	10	10
	A0939-1	10	55	60	51	-20	10	10
	A0927-1	10	82	94	111	-20	10	10
Upper-Int. Shell Mk59	C1505-1	10	44	40	40	0	10	10
	C1501-1	10	46	60	55	-12	10	10
	B5918-1	10	65	52	54	-20	10	10
Lower-Int. Shell Mk58	C1505-2	10	48	43	48	-6	-20	-6
	C1498-2	10	75	68	100	-20	-30	-20
	A0931-1	10	75	81	72	-20	-30	-20
Lower Shell Mk57	B5524-1	10	40	53	55	0	-10	0
	A0610-1	10	84	55	62	-20	-20	-20
	C1485-2	10	54	45	53	-10	-30	-10
BOTTOM HEAD								
Dollar plate Mk1	B5861-1	40	46	38	48	34	40	40
Torus, lower Mk4	B5764-2	40	45	41	40	30	40	40
	C1478-3	40	25	42	45	60	40	60
Torus, upper Mk2	C1466-1	40	78	70	62	10	40	40
	C1466-2	40	62	65	38	34	40	40
	A0237-2	40	92	91	109	10	40	40
	C1177-1	40	66	64	83	10	40	40

Table 2-5: RT_{NDT} values for Quad Cities 1 Vessel Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			$(T_{50T}-60)$ (°F)	DROP WEIGHT NDT (°F)	RT_{NDT} (°F)
NOZZLES								
Recirc inlet	ZT2869-5	40	34	36.5	43	42	30	42
Mk7	ZT2869	40	42	42	69	26	30	30
(Transverse data)	ZT2405-4	40	42	61.5	76.5	4	40	40
(433H1	E25VW	40	98	107	108	10	40	40
Steam Outlet Mk14	ZT2869-2	40	31	38.5	32.5	48	30	48
Feedwater Mk10	ZT2885	40	31	35	36	48	30	48
Core Spray Mk11	ZT-2869-5	40	39	36	44.5	38	30	38
Closure Head, Vent, Jet Pump, CRD HSR & Core Diff. Press & Liq. Con. Noz Mk206 & 204 &.13 & 19 & 17	ZT3043	40	102	130	117	10	40	40
WELDS:								
Longitudinal Beltline Seams	ES							23.1
Low. Int. to Lower	72445/8688						-	-5
Girth Seam	406L44/8688						-	-5
STUDS:						LST		
Studs MK61	6720372	10	53	35	58	70	OK	

Table 2-6: RT_{NDT} values for Quad Cities 1 Nozzle and Weld Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			$(T_{50T}-60)$ (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
PLATES & FORGINGS:								
TOP HEAD and FLANGE								
Dollar Plate Mk 201	B5845-1	40	45	47	48	20	40	40
Torus	B5853-1	10	75	82	77	-20	10	10
MK 202	C2748-1	10	45	35	37	10	10	10
	C2748-3	10	45	39	60	2	10	10
	A0313-1	10	34	58	57	12	10	12
Flange								
Mk209	3P1131	10	92	168	115	-20	10	10
Mk48	3P1118	10	96	60	104	-20	10	10
SHELL COURSES								
Upper Shell	A0985-1	10	55	67	69	-20	10	10
Mk60	A0942-1	10	64	58	50	-20	10	10
	A0998-1	10	43	60	49	-6	10	10
Upper-Int. Shell	C1717-2	10	50	46	62	-12	10	10
Mk59	C1717-1	10	49	55	65	-18	10	10
	C1510-2	10	34	36	44	12	10	12
Lower-Int. Shell	C2753-2	10	68	64	50	-20	10	10
Mk58	C2868-1	10	72	51	44	-8	10	10
	C3307-2	10	60	87	77	-20	10	10
Lower Shell	C1516-2	10	40	39	37	6	-20	6
Mk57	C1501-2	10	66	54	60	-20	-10	-10
	C1722-2	10	41	47	35	10	-10	10
BOTTOM HEAD								
Dollar plate Mk1	C2393-1	40	50	53	34	42	40	42
Torus, lower	A1899-1	40	61	32	60	46	40	46
Mk4	A1907-1	40	47	64	91	16	40	40
Torus, upper	B6747-2	40	67	37	90	36	40	40
Mk2	C2702-1	40	63	75	61	10	40	40
	A1888-2	40	61	52	53	10	40	40
	C2588-1B	40	95	94	84	10	40	40

Table 2-7: RT_{NDT} values for Quad Cities 2 Vessel Materials.

COMPONENT	HEAT	TEST TEMP. (°F)	CHARPY ENERGY (FT-LB)			(T_{50T}-60) (°F)	DROP WEIGHT NDT	RT_{NDT} (°F)
NOZZLES								
Recirc Outlet Nozzle	ZT2885	40	36	39	39	38	30	38
Mk8	ZT2869-1	40	45.5	49	54	19	30	30
Recirc inlet Nozzle	ZT2872	40	45.5	37.5	36	38	30	38
Mk7	E25VW	40	68	89	66	10	30	30
Steam Outlet Nozzle Mk14	ZT3043-1	10	49	49	94	-18	30	30
Feedwater (Trans.)	ZT2405-5	40	52.5	61.5	70.5	10	40	40
Mk10	ZT2885	40	32	34	36.5	46	30	46
Core Spray Nozzle Mk11	E26VW	40	83	78	66	10	40	40
Closure Head, Vent CRD HSR & Core Diff. Press & Liq. Con Noz Mk206 & 204 & 13 & 17	ZT3043	40	102	130	117	10	40	40
Jet Pump Instr Mk19	BT2615	40	132	118	120	10	40	40
WELDS:								
Longitudinal Beltline Seams	ES						-	23.1
Low. Int. to Lower Girth Seam	S3986/3870	10	41	45	46	-32	-	-32
STUDS:						**LST**		
Studs MK61	6720372	10	53	35	58	70	OK	

Table 2-8: RT_{NDT} values for Quad Cities 2 Nozzle and Weld Materials.

3.0 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. 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 Appendices A, B and C for 18, 20, and 22 EFPY, respectively.

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

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

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

where,

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

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

$$f = 1/4\ T\ fluence / 10^{19}$$

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

3.1.1 Chemistry

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

Vessel Plate: Copper- plate manufacturer [7]; Nickel- highest value from CMTR.

Submerged arc welds: Copper and nickel from separate evaluation [8].

Electroslag welds: Copper and nickel from separate evaluations [9, 10]. Values are mean plus one standard deviation, per [3].

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 2.2), and provides a conservative adjustment to the 50 ft-lb. level, the value of σ_I is taken to be 0°F for the vessel plate materials and the Linde 124 weld. [1] The σ_I for the other welds varied: electroslag welds, 13°F[9, 10] and Linde 80 welds, 20°F [11], except for Heat #71249 where σ_I=0, since the initial RT_{NDT} is based on heat specific measurements.

3.1.2 Fluence

The 32 EFPY fluence at the 1/4T depth of vessel wall for the Dresden and Quad Cities vessels was obtained from surveillance capsule results [12-15]. The 32 EFPY fluence values used in this evaluation (along with its reference) were as follows:

Dresden 2: 3.6×10^{17} n/cm^2 [12]

Dresden 3: 5.1×10^{17} n/cm^2 [13]

Quad Cities 1: 3.5×10^{17} n/cm^2 [14]

Quad Cities 2: 4.9×10^{17} n/cm^2 [15]

3.2 Limiting Beltline Material

The limiting beltline material signifies the material which has been 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. Appendices A, B and C list values of beltline ART for 18, 20 and 22 EFPY, respectively, for the Dresden and Quad Cities plants. The tables show that the submerged arc weld for Dresden Unit 3 (Heat #299L44) is the most limiting vessel material up to 22 EFPY primarily due to its high copper content.

4.0 PRESSURE-TEMPERATURE CURVES

4.1 Background

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 three vessel regions that affect the operating limits: the closure flange region, the core beltline region, and the remainder of the vessel, or non-beltline regions. The closure flange region limits are controlling at lower pressures primarily because of 10CFR50 Appendix G [2] requirements. The non-beltline and beltline region operating limits are evaluated according to procedures in 10CFR50 Appendix G [2], ASME Code Appendix G [16], and Welding Research Council (WRC) Bulletin 175 [17], with the beltline region minimum temperature limits adjusted to account for vessel irradiation. Although not required, bottom head curves were also provided; the limits for the bottom head curves are evaluated the same as the other non-beltline regions.

Figure 4-1 is Curve A for 22 EFPY; the bottom head limits are shown separately. This curve is valid for heatup/cooldown rates less than or equal to 20°F/hr. Similar curves with data tabulation for 18 and 20 EFPY are presented in Appendices D (18 EFPY) and E (20 EFPY). The data tabulation for Figure 4-1 is presented in Appendix F.

Curve B (100°F/hr heatup/cooldown) is shown in Figure 4-2; again the bottom head temperature limits are presented separately from the remainder of the vessel. The data tabulation is also presented in Appendix F. Curve C (100°F/hr heatup/cooldown) is shown in Figure 4-3. A separate bottom head curve is not shown, since the bottom head does not have a significant temperature variation from the remainder of the vessel during core critical operation. Again, the data tabulation is presented in Appendix F.

If the heatup/cooldown rate is increased to 200°F/hr, then Figure 4-4 is the result for Curve B at 22 EFPY. The data tabulation for this curve is presented in Appendix G of this report. Similarly, Curve C at 22 EFPY and a 200°F/hr heatup/cooldown rate is presented in Figure 4-5. The data tabulation is shown in Appendix G of this report. (Appendix G of this report also contains Curve A data at 22 EFPY for comparison, although it is unaffected by the heatup/cooldown rate)

The underlying curves used to prepare Figure 4-1 are shown in Appendix H of this report for illustration purposes. These curves present the curve for each component (e.g., feedwater nozzle, beltline, etc.) considered for P-T curve evaluation. The requirements for each vessel region influencing the P-T curves are discussed below.

Appendix I contains separate P-T limit curves (and data) for the beltline and non-beltline regions for a heatup/cooldown rate of 100°F/hour. Curve A'; Curve B' and Curve C' in Appendix I are valid to 22 EFPY of operation. Similarly, for a heatup/cooldown rate of 200°F/hour, the separate P-T limit curves (and data) for the beltline and non-beltline regions are shown in Appendix J; Curves A', B' and C' are valid through 22 EFPY of operation.

4.2 Non-Beltline Regions

Non-beltline regions are those locations that receive too little fluence to cause any RT_{NDT} shift. Non-beltline components include the 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 thermal transients anticipated. Transients considered included 100°F/hr and 200°F/hr startup 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 [16] to develop plots of allowable pressure (P) versus temperature relative to the reference temperature (T - RT_{NDT}). Plots were developed for the two most limiting BWR/6 components; the feedwater nozzle and the CRD penetration. All other components in the non-beltline regions are categorized under one of these two components.

The BWR/6 results have been applied to earlier BWR non-beltline vessel components based on the facts that earlier vessel component geometries are not significantly different from BWR/6 configurations, and mechanical and thermal loading are comparable. The BWR/6 non-beltline region results were applied to Dresden and Quad Cities by adding the highest RT_{NDT} values for the non-beltline discontinuities to the appropriate P versus (T - RT_{NDT}) curves for the BWR/6 CRD penetration or feedwater nozzle. The initial RT_{NDT} values for non-beltline components are listed in Tables 2-1 through 2-8. The test temperature of 40°F, from the vessel purchase spec, was conservatively used as the value of initial RT_{NDT} to account for nozzle forgings, other than the feedwater nozzle, that were not tested. However, the basis for the feedwater nozzle limits was an initial RT_{NDT} of 51°F for the Dresden 2 feedwater nozzle. The bottom head torus of Quad Cities 1 with an initial RT_{NDT} of 60°F was used as a basis for the CRD penetration limits.

Under certain conditions, the minimum bottom head temperature can be significantly cooler than the beltline or closure flange region. These conditions can occur when the recirculation pumps are operating at low speed (or off), and during water injection through the control rod drives. To account for these circumstances, individual temperature limits for the bottom head were established.

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 [16]. The limiting flange region RT_{NDT} is 23.1°F, from the electroslag weld in the upper shell. At low pressure, ASME Code Appendix G allows the beltline and bottom head regions to experience even lower metal temperatures than the flange region RT_{NDT}. However, these temperatures should not be reached for another reason.

The shutdown margin for the Dresden and Quad Cities plants 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, extensive further calculations would be required to justify a lower temperature. Because the water temperature is currently limited to a minimum of 68°F, the metal temperature should not fall below this limit while fuel is in the vessel. The 68°F limit applies when the head is on and tensioned, and also when the head is off. (When fuel has been removed from the vessel, the head is tensioned, and the pressure is below 40 psi, the limiting vessel temperature is equal to the limiting RT_{NDT} of the vessel materials. This limiting RT_{NDT} is 51°F.) When the head is not tensioned and fuel is not in the vessel, the requirements of 10CFR50 Appendix G do not apply, and there are no limits on the vessel temperatures.

4.3 Core Beltline Region

The pressure-temperature (P-T) limits for the beltline region are determined according to the methods in ASME Code Appendix G [16]. As the beltline fluence increases during operation, these curves shift by an amount as discussed in Section 3.1. For the Dresden and Quad Cities vessels, the beltline curves were more limiting through 22 EFPY at typical operating pressures.

The stress intensity factors (K_I), calculated for the beltline region according to ASME Code Appendix G procedures, were based on a combination of pressure and thermal stresses for a 1/4 T 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 both 100°F/hr and 200°F/hr thermal gradient. The shift values of the most limiting materials from Appendices A-C were used to adjust the RT_{NDT} values for the P-T limits.

4.4 Closure Flange Region

10CFR50 Appendix G [2] 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 they do not affect the shape of the P-T curves. However, some closure flange requirements do impact the curves.

The ASME Code [16] requirement for boltup was at qualification temperature (T_{30L}) plus 60°F. Current ASME Code requirements state, in Paragraph G-2222(c), that for application of full bolt preload and reactor pressure up to 20% of hydrostatic test pressure, the RPV metal temperature must be at RT_{NDT} or greater. The approach used for Dresden and Quad Cities for the boltup temperature was based on a more conservative value of (RT_{NDT} + 60), or the LST of the bolting materials, whichever is greater. The limiting initial RT_{NDT} for the closure flange region was the electroslag weld in the upper shell at 23.1°F and the LST of the closure studs was 70°F; therefore the boltup temperature value used was 83.1°F. This conservatism is appropriate because boltup is one of the more limiting operating conditions (high stress and low temperature) for brittle fracture.

10CFR50 Appendix G, paragraph IV.A.2 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). The Curve A requirement causes a 30°F shift at 20% hydrotest pressure (312 psig) as shown in Figure 4-1. The Curve B (Figures 4-2 and 4-4) requirement has essentially no impact on the figure because the analytical results per Appendix 5 of [17] for the non-beltline regions exceed the temperature of (RT_{NDT} + 120°F) at 312 psig.

4.5 Core Critical Operation Requirements of 10CFR50, Appendix G

Curve C, the core critical operation curve shown in Figure 4-3 and 4-5, is generated from the requirements of 10CFR50 Appendix G [2], Table 1. Essentially Table 1 requires that core critical P-T limits be 40°F above any Curve A or B limits when pressure exceeds 20% of the preservice system hydrotest pressure. Curve B is more limiting than Curve A, so limiting Curve C values must be at least Curve B plus 40°F above 312 psig.

Table 1 of [2] indicates that for BWR's with water level within normal range for power operation, the allowed initial criticality at the closure flange region is (RT_{NDT} + 60°F) at pressures below 312 psig. This requirement makes the minimum criticality temperature 83.1°F, based on a RT_{NDT} of 23.1°F. In addition, above 312 psig, the Curve C temperature must be at least that required for the hydrostatic pressure test (Curve A at 1120 psig).

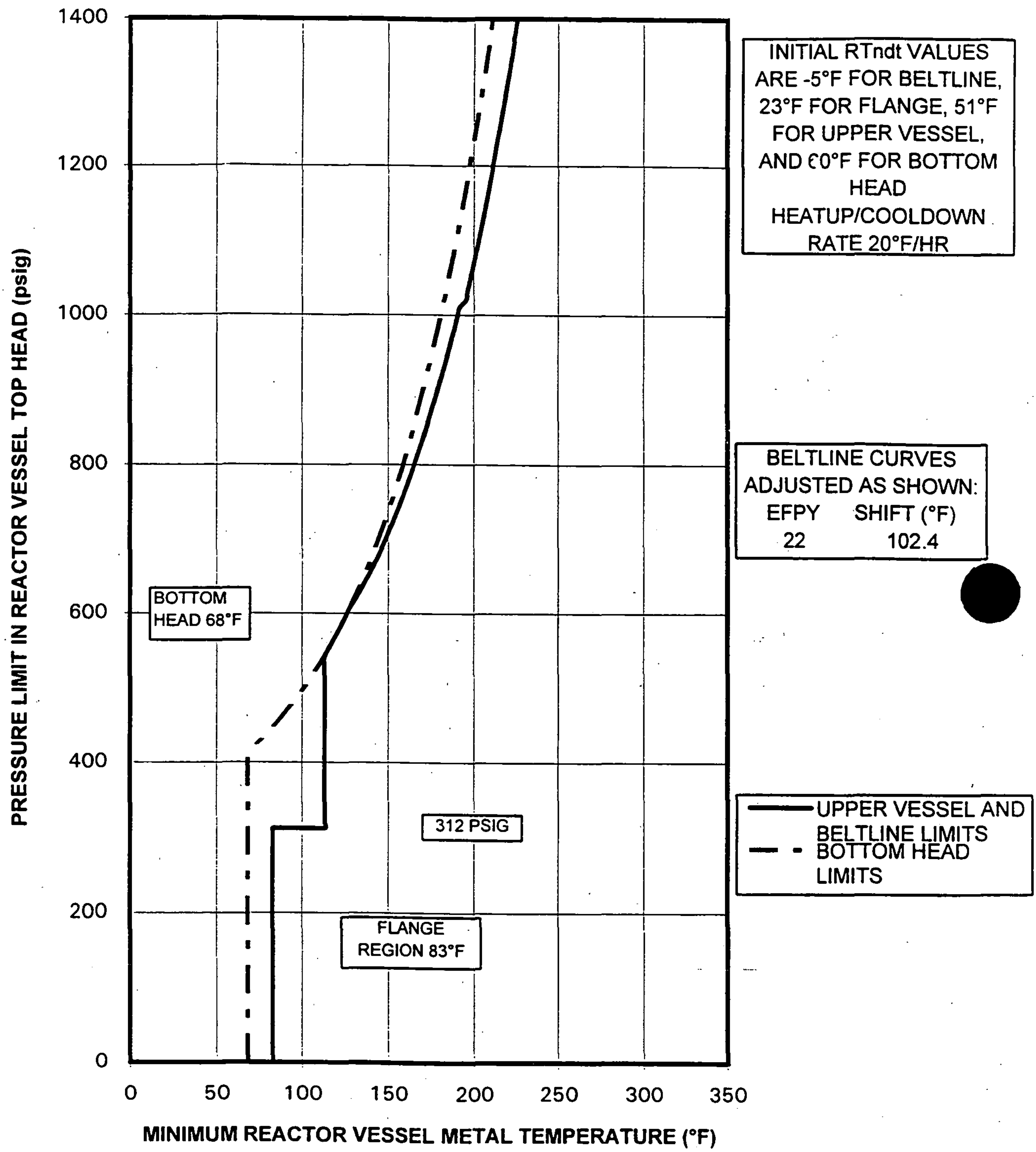

Figure 4-1: P-T Curves for Pressure Test [Curve A]

[20°F/hr heatup/cooldown]

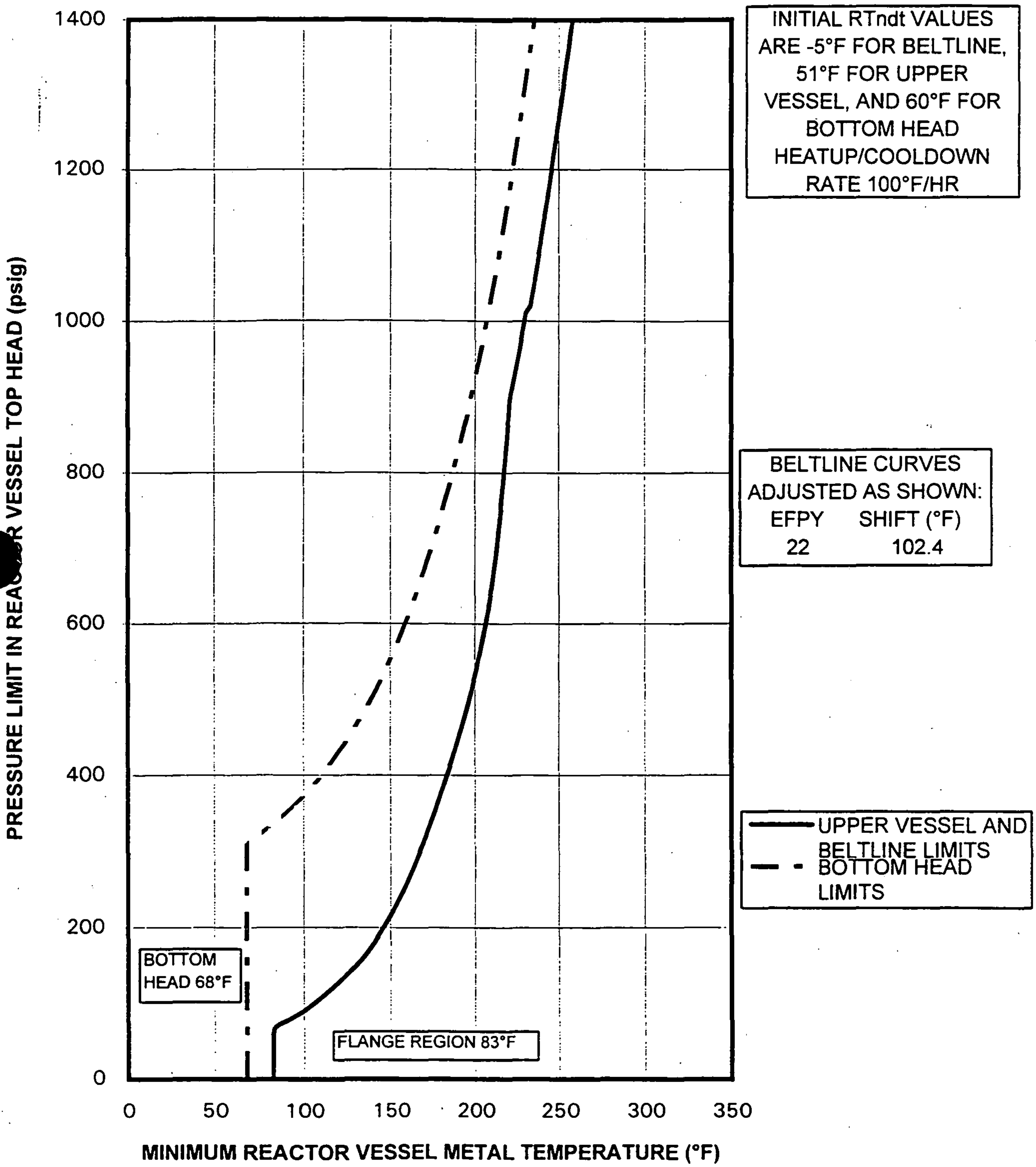

Figure 4-2: Non-Nuclear Heatup/Cooldown P-T curves (100°F/hr.) [Curve B]

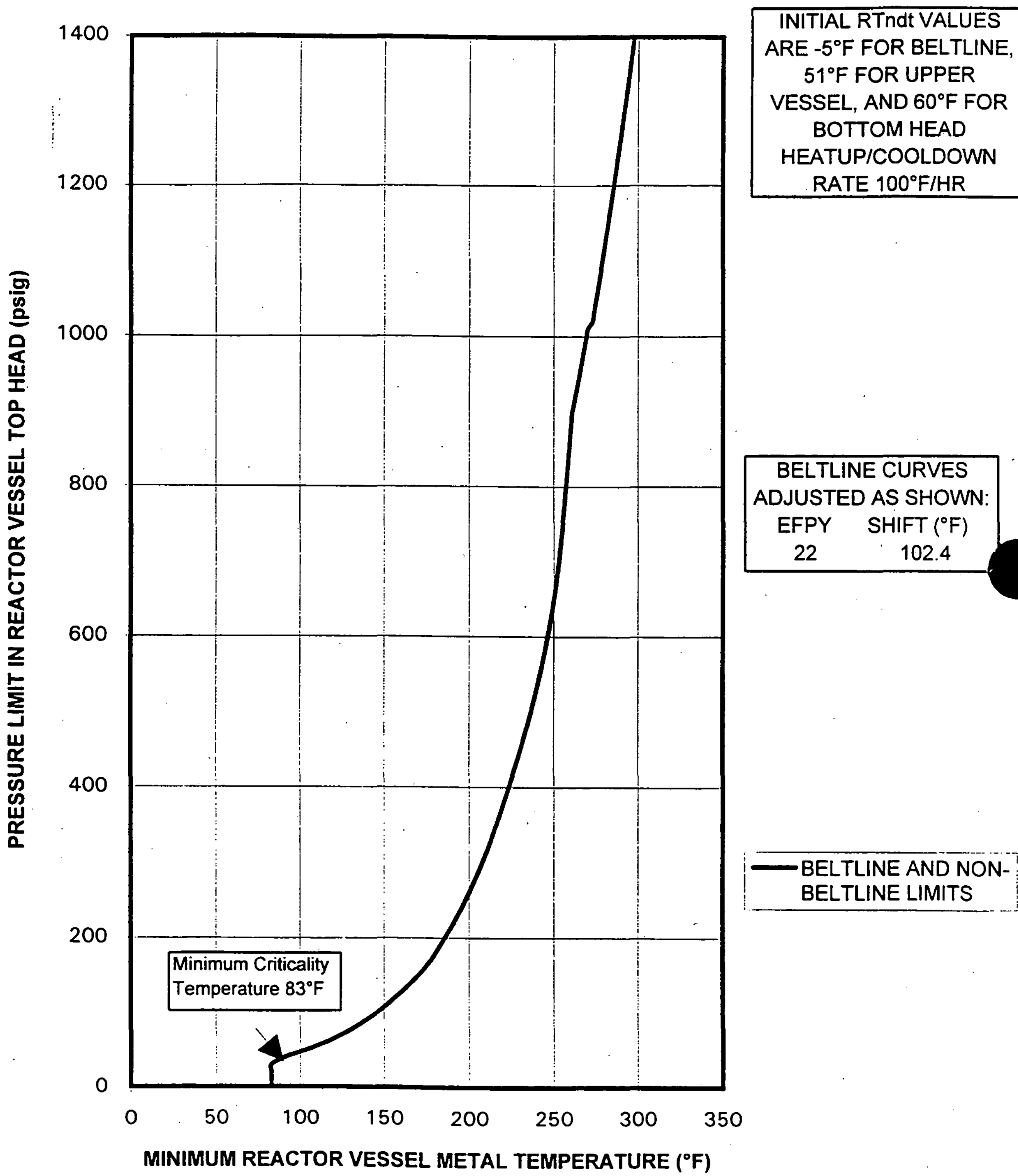

Figure 4-3: Core Critical P-T Curves(100°F/hr.) [Curve C]

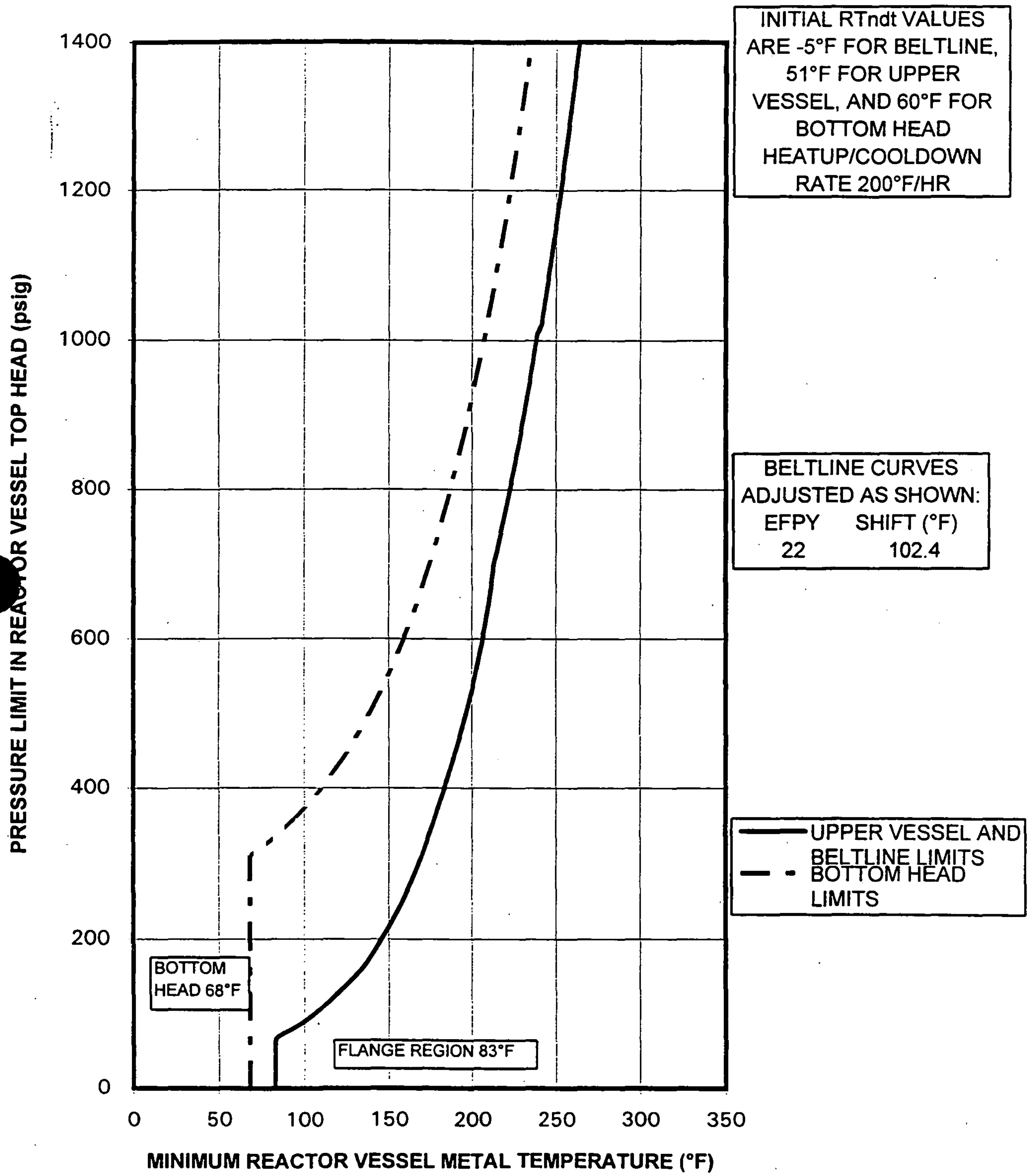

Figure 4-4: Non-Nuclear Heatup/Cooldown P-T curves (200°F/hr.) [Curve B]

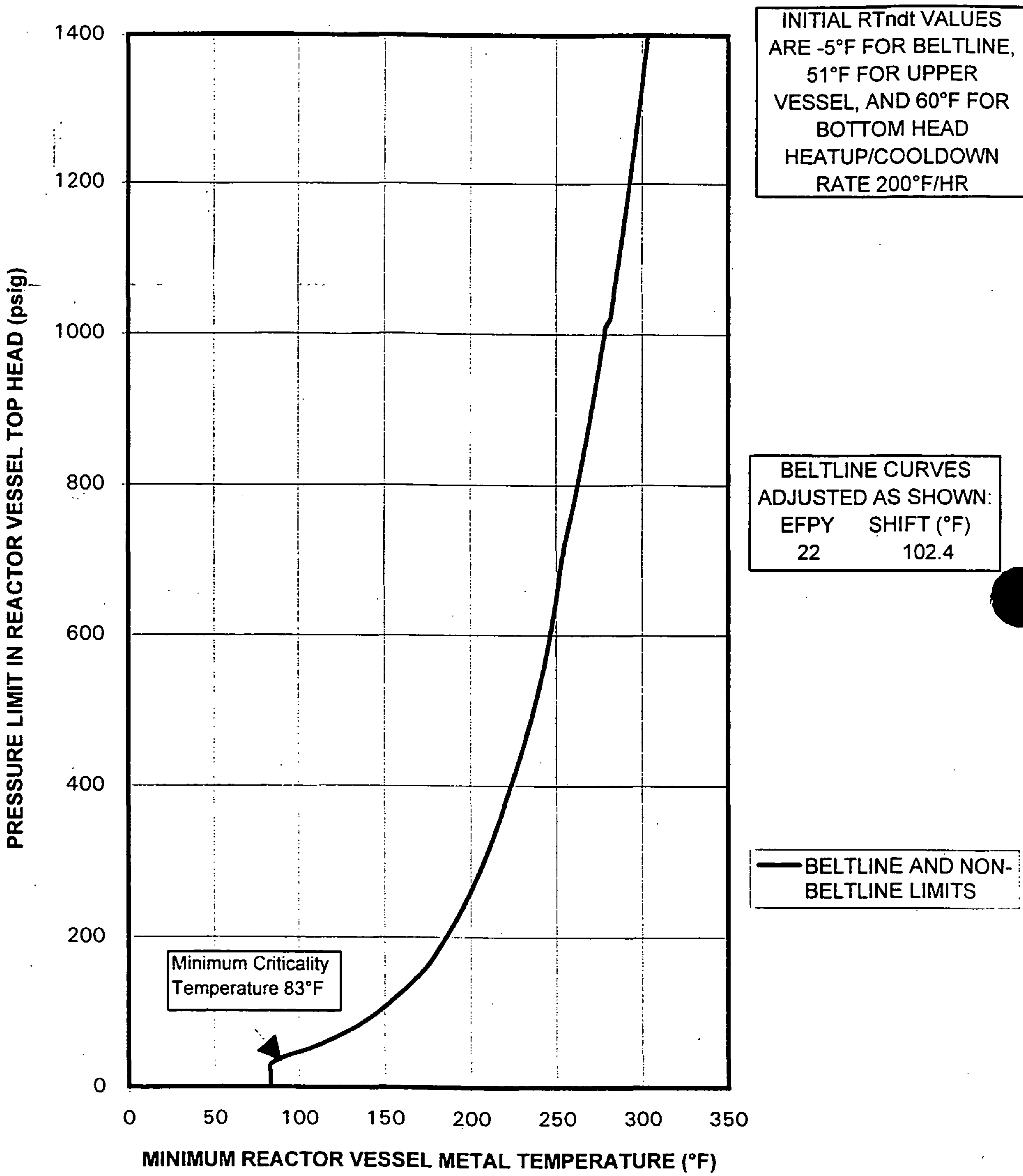

Figure 4-5: Core Critical P-T Curves(200°F/hr.) [Curve C]

5.0 REFERENCES

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

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

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

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8. L.B. Gross, "Chemical Composition of B&W Fabricated Reactor Vessel Beltline Welds," BAW-2121P, April 1991.

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

10. "Evaluation of RT_{NDT}, USE, and Chemical Composition of Core Region Electroslag Welds for Quad Cities Units 1 and 2," BAW-2259, January 1996.

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

12. "Dresden Nuclear Power Station Unit 2 Reactor Vessel Irradiation Surveillance Program Analysis of Capsule No. 8," SwRI No. 06-6901-002, March 1983.

13. "Dresden Nuclear Power Station Unit 3 Reactor Vessel Irradiation Surveillance Program Analysis of Capsule No. 18," SwRI No. 06-7484-003, February 1984.

14. "Quad Cities Nuclear Power Station Unit 1 Reactor Vessel Irradiation Surveillance Program Analysis of Capsule No. 8," SwRI No. 06-7857, August 1984.

15. "Quad Cities Nuclear Power Station Unit 2 Reactor Vessel Irradiation Surveillance Program Analysis of Capsule No. 18," SwRI No. 06-7484-002, March 1984.

16. "Fracture Toughness Criteria for Protection Against Failure," Appendix G to Section III of the ASME Boiler & Pressure Vessel Code, 1989 Edition.

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

APPENDIX A

ADJUSTED REFERENCE TEMPERATURE VALUES

18 EFPY

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 3.60E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.49E+17 n/cm^2
18 EFPY Peak I.D. fluence = 2.03E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.40E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 3.60E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.49E+17 n/cm^2
18 EFPY Peak I.D. fluence = 2.03E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.40E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	18 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	18 EFPY Shift °F	18 EFPY ART °F
PLATES:													
Lower													
6-198-2			A-9128-2	0.2	0.55	143	10.0	19.6	0.0	9.8	19.6	39.3	49.3
6-198-3			B-3990-2	0.18	0.51	125	12.0	17.2	0.0	8.6	17.2	34.3	46.3
6-198-1			A-9128-1	0.2	0.55	143	30.0	19.6	0.0	9.8	19.6	39.3	69.3
Lower-Intmed													
6-198-12			B4065-1	0.23	0.55	160	20.0	22.0	0.0	11.0	22.0	43.9	63.9
6-198-13			B5764-1	0.1	0.5	65	10.0	8.9	0.0	4.5	8.9	17.8	27.8
6-198-11			B4030-1	0.2	0.59	147	6.0	20.2	0.0	10.1	20.2	40.4	46.4
6-198-9			B4030-2	0.2	0.58	145	-2.0	19.9	0.0	10.0	19.9	39.8	37.8
VERTICAL WELDS:													
Lower-Intmed	ES	2	*	0.24	0.36	139	23.1	19.1	13.0	9.5	32.3	51.3	74.4
	SAW	2	1P0661/8304**	0.19	0.63	162	-5.0	22.2	20.0	11.1	45.8	68.0	63.0
			1P0815/8350**	0.17	0.52	138	-5.0	18.9	20.0	9.5	44.3	63.2	58.2
Lower Shell	ES	3	*	0.24	0.36	139	23.1	19.1	13.0	9.5	32.3	51.3	74.4
	SAW	1	1P0815/8304**	0.17	0.52	138	-5.0	18.9	20.0	9.5	44.3	63.2	58.2
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		71249/8504***	0.26	0.61	182	10	25.0	0.0	12.5	25.0	50.0	60.0

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld-RTndtand σ_I values from BAW-1803-1, dated May 1991.
*** RTndt and σ_I values from EPRI NP-373, dated 1977.
*** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.

Table A-1: Dresden 2 Beltline ART Values (18 EFPY)

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 5.10E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.53E+17 n/cm^2
18 EFPY Peak I.D. fluence = 2.87E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.99E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 5.10E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.53E+17 n/cm^2
18 EFPY Peak I.D. fluence = 2.87E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.99E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	18 EFPY Δ RTndt °F	σ_I °F	σ_Δ °F	Margin °F	18 EFPY Shift °F	18 EFPY ART °F
PLATES:													
Lower													
6-111-2			C1256-2	0.11	0.5	73	-10.0	12.5	0.0	6.3	12.5	25.0	15.0
6-111-6			B5159-2	0.24	0.47	153	0.0	26.2	0.0	13.1	26.2	52.4	52.4
6-111-7			C1182-2	0.22	0.5	148	10.0	25.4	0.0	12.7	25.4	50.7	60.7
Lower-Intmed													
6-111-3			A0237-1	0.23	0.49	151	10.0	25.9	0.0	12.9	25.9	51.7	61.7
6-111-10			B5118-1	0.22	0.49	146	10.0	25.0	0.0	12.5	25.0	50.0	60.0
6-111-11			C1290-2	0.15	0.49	104	10.0	17.8	0.0	8.9	17.8	35.6	45.6
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	23.8	13.0	11.9	35.3	59.1	82.2
Lower Shell	ES	3	*	0.24	0.36	139	23.1	23.8	13.0	11.9	35.3	59.1	82.2
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		299L44/8650**	0.35	0.68	224	-5	38.4	20.0	19.2	55.4	93.8	88.8

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table A-2: Dresden 3 Beltline ART Values (18 EFPY)

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
18 EFPY Peak I.D. fluence = 1.97E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.36E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
18 EFPY Peak I.D. fluence = 1.97E+17 n/cm^2
18 EFPY Peak 1/4 T fluence = 1.36E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	18 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	18 EFPY Shift °F	18 EFPY ART °F
PLATES:													
Lower													
6-122-1			B5524-1	0.27	0.57	180	0.0	24.3	0.0	12.1	24.3	48.5	48.5
6-122-2			A0610-1	0.21	0.51	143	-20.0	19.3	0.0	9.6	19.3	38.5	18.5
6-122-11			C1485-2	0.23	0.5	153	-10.0	20.6	0.0	10.3	20.6	41.2	31.2
Lower-Intmed													
6-122-4			C1505-2	0.18	0.52	126	-6.0	17.0	0.0	8.5	17.0	34.0	28.0
6-122-6			C1498-2	0.17	0.5	119	-20.0	16.0	0.0	8.0	16.0	32.1	12.1
6-122-13			A0931-1	0.14	0.51	96	-20.0	12.9	0.0	6.5	12.9	25.9	5.9
VERTICAL WELDS:													
Lower-Intmed	ES	4	*	0.24	0.36	139	23.1	18.7	13.0	9.4	32.0	50.8	73.9
Lower Shell	ES	4	*	0.24	0.36	139	23.1	18.7	13.0	9.4	32.0	50.8	73.9
GIRTH WELD:													
Lower shell to	SAW		72445/8688**	0.21	0.59	162	-5.0	21.8	20.0	10.9	45.6	67.4	62.4
Lower-Intmed	SAW		406L44/8688**	0.31	0.59	197	-5.0	26.6	20.0	13.3	48.0	74.6	69.6

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table A-3: Quad Cities 1 Beltline ART Values (18 EFPY)

Plate

Thickness = 6.13 inches

Plate

32 EFPY Peak I.D. fluence =	4.90E+17 n/cm^2
32 EFPY Peak 1/4 T fluence =	3.39E+17 n/cm^2
18 EFPY Peak I.D. fluence =	2.76E+17 n/cm^2
18 EFPY Peak 1/4 T fluence =	1.91E+17 n/cm^2

Weld

Thickness = 6.13 inches

Weld

32 EFPY Peak I.D. fluence =	4.90E+17 n/cm^2
32 EFPY Peak 1/4 T fluence =	3.39E+17 n/cm^2
18 EFPY Peak I.D. fluence =	2.76E+17 n/cm^2
18 EFPY Peak 1/4 T fluence =	1.91E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	18 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	18 EFPY Shift °F	18 EFPY ART °F
PLATES:													
Lower													
6-122-8			C1516-2	0.16	0.46	108	6.0	18.0	0.0	9.0	18.0	36.1	42.1
6-122-10			C1501-2	0.18	0.49	124	-10.0	20.7	0.0	10.4	20.7	41.4	31.4
6-122-14			C1722-2	0.14	0.54	97	10.0	16.2	0.0	8.1	16.2	32.4	42.4
Lower-Intmed													
6-139-16			C2753-2	0.08	0.5	51	10.0	8.5	0.0	4.3	8.5	17.0	27.0
6-139-22			C2868-1	0.08	0.48	51	10.0	8.5	0.0	4.3	8.5	17.0	27.0
6-139-25			C3307-2	0.12	0.55	82	10.0	13.7	0.0	6.9	13.7	27.4	37.4
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	23.2	13.0	11.6	34.9	58.1	81.2
Lower Shell	ES	3	*	0.24	0.36	139	23.1	23.2	13.0	11.6	34.9	58.1	81.2
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		S3986/3870 Linde 124	0.05	0.96	68	-32.0	11.4	0.0	5.7	11.4	22.7	-9.3

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.

Table A-4: Quad Cities 2 Beltline ART Values (18 EFPY)

APPENDIX B

ADJUSTED REFERENCE TEMPERATURE VALUES

20 EFPY

Plate			
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence = 3.60E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence = 2.49E+17 n/cm^2
			20 EFPY Peak I.D. fluence = 2.25E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence = 1.56E+17 n/cm^2

Weld			
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence = 3.60E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence = 2.49E+17 n/cm^2
			20 EFPY Peak I.D. fluence = 2.25E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence = 1.56E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	20 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	20 EFPY Shift °F	20 EFPY ART °F
PLATES:													
Lower													
6-198-2			A-9128-2	0.2	0.55	143	10.0	21.0	0.0	10.5	21.0	42.0	52.0
6-198-3			B-3990-2	0.18	0.51	125	12.0	18.4	0.0	9.2	18.4	36.7	48.7
6-198-1			A-9128-1	0.2	0.55	143	30.0	21.0	0.0	10.5	21.0	42.0	72.0
Lower-Intmed													
6-198-12			B4065-1	0.23	0.55	160	20.0	23.5	0.0	11.8	23.5	47.0	67.0
6-198-13			B5764-1	0.1	0.5	65	10.0	9.6	0.0	4.8	9.6	19.1	29.1
6-198-11			B4030-1	0.2	0.59	147	6.0	21.6	0.0	10.8	21.6	43.2	49.2
6-198-9			B4030-2	0.2	0.58	145	-2.0	21.3	0.0	10.7	21.3	42.6	40.6
VERTICAL WELDS:													
Lower-Intmed	ES	2	*	0.24	0.36	139	23.1	20.4	13.0	10.2	33.1	53.5	76.6
	SAW	2	1P0661/8304**	0.19	0.63	162	-5.0	23.8	20.0	11.9	46.5	70.4	65.4
			1P0815/8350**	0.17	0.52	138	-5.0	20.3	20.0	10.1	44.8	65.1	60.1
Lower Shell	ES	3	*	0.24	0.36	139	23.1	20.4	13.0	10.2	33.1	53.5	76.6
	SAW	1	1P0815/8304**	0.17	0.52	138	-5.0	20.3	20.0	10.1	44.8	65.1	60.1
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		71249/8504***	0.26	0.61	182	10	26.7	0.0	13.4	26.7	53.5	63.5

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld-RTndtand σ_I values from BAW-1803-1, dated May 1991.
*** RTndt and σ_I values from EPRI NP-373, dated 1977.
*** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.

Table B-1: Dresden 2 Beltline ART Values (20 EFPY)

Plate			**Plate**	
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence =	5.10E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence =	3.53E+17 n/cm^2
			20 EFPY Peak I.D. fluence =	3.19E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence =	2.21E+17 n/cm^2
Weld			**Weld**	
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence =	5.10E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence =	3.53E+17 n/cm^2
			20 EFPY Peak I.D. fluence =	3.19E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence =	2.21E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	20 EFPY Δ RTndt °F	σ_I °F	σ_Δ °F	Margin °F	20 EFPY Shift °F	20 EFPY ART °F
PLATES:													
Lower													
6-111-2			C1256-2	0.11	0.5	73	-10.0	13.3	0.0	6.7	13.3	26.7	16.7
6-111-6			B5159-2	0.24	0.47	153	0.0	28.0	0.0	14.0	28.0	55.9	55.9
6-111-7			C1182-2	0.22	0.5	148	10.0	27.1	0.0	13.5	27.1	54.1	64.1
Lower-Intmed													
6-111-3			A0237-1	0.23	0.49	151	10.0	27.6	0.0	13.8	27.6	55.2	65.2
6-111-10			B5118-1	0.22	0.49	146	10.0	26.7	0.0	13.3	26.7	53.4	63.4
6-111-11			C1290-2	0.15	0.49	104	10.0	19.0	0.0	9.5	19.0	38.0	48.0
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	25.4	13.0	12.7	36.4	61.8	84.9
Lower Shell	ES	3	*	0.24	0.36	139	23.1	25.4	13.0	12.7	36.4	61.8	84.9
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		299L44/8650**	0.35	0.68	224	-5.0	40.9	20.0	20.5	57.2	98.2	93.2

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table B-2: Dresden 3 Beltline ART Values (20 EFPY)

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
20 EFPY Peak I.D. fluence = 2.19E+17 n/cm^2
20 EFPY Peak 1/4 T fluence = 1.51E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
20 EFPY Peak I.D. fluence = 2.19E+17 n/cm^2
20 EFPY Peak 1/4 T fluence = 1.51E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	20 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	20 EFPY Shift °F	20 EFPY ART °F
PLATES:													
Lower													
6-122-1			B5524-1	0.27	0.57	180	0.0	26.0	0.0	13.0	26.0	52.0	52.0
6-122-2			A0610-1	0.21	0.51	143	-20.0	20.6	0.0	10.3	20.6	41.3	21.3
6-122-11			C1485-2	0.23	0.5	153	-10.0	22.1	0.0	11.0	22.1	44.2	34.2
Lower-Intmed													
6-122-4			C1505-2	0.18	0.52	126	-6.0	18.2	0.0	9.1	18.2	36.4	30.4
6-122-6			C1498-2	0.17	0.5	119	-20.0	17.2	0.0	8.6	17.2	34.3	14.3
6-122-13			A0931-1	0.14	0.51	96	-20.0	13.9	0.0	6.9	13.9	27.7	7.7
VERTICAL WELDS:													
Lower-Intmed	ES	4	*	0.24	0.36	139	23.1	20.1	13.0	10.0	32.8	52.9	76.0
Lower Shell	ES	4	*	0.24	0.36	139	23.1	20.1	13.0	10.0	32.8	52.9	76.0
GIRTH WELD:													
Lower shell to	SAW		72445/8688**	0.21	0.59	162	-5.0	23.4	20.0	11.7	46.3	69.7	64.7
Lower-Intmed	SAW		406L44/8688**	0.31	0.59	197	-5.0	28.4	20.0	14.2	49.1	77.5	72.5

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table B-3: Quad Cities 1 Beltline ART Values (20 EFPY)

Plate			**Plate**	
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence =	4.90E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence =	3.39E+17 n/cm^2
			20 EFPY Peak I.D. fluence =	3.06E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence =	2.12E+17 n/cm^2
Weld			**Weld**	
Thickness =	6.13	inches	32 EFPY Peak I.D. fluence =	4.90E+17 n/cm^2
			32 EFPY Peak 1/4 T fluence =	3.39E+17 n/cm^2
			20 EFPY Peak I.D. fluence =	3.06E+17 n/cm^2
			20 EFPY Peak 1/4 T fluence =	2.12E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	20 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	20 EFPY Shift °F	20 EFPY ART °F
PLATES:													
Lower													
6-122-8			C1516-2	0.16	0.46	108	6.0	19.3	0.0	9.6	19.3	38.5	44.5
6-122-10			C1501-2	0.18	0.49	124	-10.0	22.1	0.0	11.1	22.1	44.2	34.2
6-122-14			C1722-2	0.14	0.54	97	10.0	17.3	0.0	8.6	17.3	34.6	44.6
Lower-Intmed													
6-139-16			C2753-2	0.08	0.5	51	10.0	9.1	0.0	4.5	9.1	18.2	28.2
6-139-22			C2868-1	0.08	0.48	51	10.0	9.1	0.0	4.5	9.1	18.2	28.2
6-139-25			C3307-2	0.12	0.55	82	10.0	14.6	0.0	7.3	14.6	29.2	39.2
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	24.8	13.0	12.4	35.9	60.7	83.8
Lower Shell	ES	3	*	0.24	0.36	139	23.1	24.8	13.0	12.4	35.9	60.7	83.8
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		S3986/3870 Linde 124	0.05	0.96	68	-32.0	12.1	0.0	6.1	12.1	24.3	-7.7

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.

Table B-4: Quad Cities 2 Beltline ART Values (20 EFPY)

APPENDIX C

ADJUSTED REFERENCE TEMPERATURE VALUES

22 EFPY

Plate Thickness =	6.13	inches	
Plate	32 EFPY Peak I.D. fluence =	3.60E+17 n/cm^2	
	32 EFPY Peak 1/4 T fluence =	2.49E+17 n/cm^2	
	22 EFPY Peak I.D. fluence =	2.48E+17 n/cm^2	
	22 EFPY Peak 1/4 T fluence =	1.71E+17 n/cm^2	
Weld Thickness =	6.13	inches	
Weld	32 EFPY Peak I.D. fluence =	3.60E+17 n/cm^2	
	32 EFPY Peak 1/4 T fluence =	2.49E+17 n/cm^2	
	22 EFPY Peak I.D. fluence =	2.48E+17 n/cm^2	
	22 EFPY Peak 1/4 T fluence =	1.71E+17 n/cm^2	

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	22 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	22 EFPY Shift °F	22 EFPY ART °F
PLATES:													
Lower													
6-198-2			A-9128-2	0.2	0.55	143	10.0	22.3	0.0	11.2	22.3	44.7	54.7
6-198-3			B-3990-2	0.18	0.51	125	12.0	19.5	0.0	9.8	19.5	39.0	51.0
6-198-1			A-9128-1	0.2	0.55	143	30.0	22.3	0.0	11.2	22.3	44.7	74.7
Lower-Intmed													
6-198-12			B4065-1	0.23	0.55	160	20.0	25.0	0.0	12.5	25.0	50.0	70.0
6-198-13			B5764-1	0.1	0.5	65	10.0	10.1	0.0	5.1	10.1	20.3	30.3
6-198-11			B4030-1	0.2	0.59	147	6.0	23.0	0.0	11.5	23.0	45.9	51.9
6-198-9			B4030-2	0.2	0.58	145	-2.0	22.6	0.0	11.3	22.6	45.3	43.3
VERTICAL WELDS:													
Lower-Intmed	ES	2	*	0.24	0.36	139	23.1	21.7	13.0	10.9	33.9	55.6	78.7
	SAW	2	1P0661/8304**	0.19	0.63	162	-5.0	25.3	20.0	12.6	47.3	72.6	67.6
			1P0815/8350**	0.17	0.52	138	-5.0	21.5	20.0	10.8	45.4	67.0	62.0
Lower Shell	ES	3	*	0.24	0.36	136	23.1	21.2	13.0	10.6	33.6	54.8	77.9
	SAW	1	1P0815/8304**	0.17	0.52	138	-5.0	21.5	20.0	10.8	45.4	67.0	62.0
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		71249/8504***	0.26	0.61	182	10	28.4	0.0	14.2	28.4	56.8	66.8

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld-RTndtand σ_I values from BAW-1803-1, dated May 1991.
*** RTndt and σ_I values from EPRI NP-373, dated 1977.
*** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.

Table C-1: Dresden 2 Beltline ART Values (22 EFPY)

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 5.10E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.53E+17 n/cm^2
22 EFPY Peak I.D. fluence = 3.51E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 2.43E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 5.10E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.53E+17 n/cm^2
22 EFPY Peak I.D. fluence = 3.51E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 2.43E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	22 EFPY Δ RTndt °F	σ_I °F	σ_Δ °F	Margin °F	22 EFPY Shift °F	22 EFPY ART °F
PLATES:													
Lower													
6-111-2			C1256-2	0.11	0.5	73	-10.0	14.1	0.0	7.1	14.1	28.3	18.3
6-111-6			B5159-2	0.24	0.47	153	0.0	29.6	0.0	14.8	29.6	59.3	59.3
6-111-7			C1182-2	0.22	0.5	148	10.0	28.7	0.0	14.3	28.7	57.3	67.3
Lower-Intmed													
6-111-3			A0237-1	0.23	0.49	151	10.0	29.2	0.0	14.6	29.2	58.5	68.5
6-111-10			B5118-1	0.22	0.49	146	10.0	28.3	0.0	14.1	28.3	56.5	66.5
6-111-11			C1290-2	0.15	0.49	104	10.0	20.1	0.0	10.1	20.1	40.3	50.3
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	26.9	13.0	13.5	37.4	64.3	87.4
Lower Shell	ES	3	*	0.24	0.36	139	23.1	26.9	13.0	13.5	37.4	64.3	87.4
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		299L44/8650**	0.35	0.68	224	-5.0	43.4	20.0	21.7	59.0	102.4	97.4

*Values obtained from BAW-2258, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table C-2: Dresden 3 Beltline ART Values (22 EFPY)

Plate
Thickness = 6.13 inches

Weld
Thickness = 6.13 inches

Plate

32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
22 EFPY Peak I.D. fluence = 2.41E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 1.67E+17 n/cm^2

Weld

32 EFPY Peak I.D. fluence = 3.50E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 2.42E+17 n/cm^2
22 EFPY Peak I.D. fluence = 2.41E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 1.67E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	22 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	22 EFPY Shift °F	22 EFPY ART °F
PLATES:													
Lower													
6-122-1			B5524-1	0.27	0.57	180	0.0	27.6	0.0	13.8	27.6	55.2	55.2
6-122-2			A0610-1	0.21	0.51	143	-20.0	21.9	0.0	11.0	21.9	43.9	23.9
6-122-11			C1485-2	0.23	0.5	153	-10.0	23.5	0.0	11.7	23.5	46.9	36.9
Lower-Intmed													
6-122-4			C1505-2	0.18	0.52	126	-6.0	19.3	0.0	9.7	19.3	38.7	32.7
6-122-6			C1498-2	0.17	0.5	119	-20.0	18.3	0.0	9.1	18.3	36.5	16.5
6-122-13			A0931-1	0.14	0.51	96	-20.0	14.7	0.0	7.4	14.7	29.4	9.4
VERTICAL WELDS:													
Lower-Intmed	ES	4	*	0.24	0.36	139	23.1	21.3	13.0	10.7	33.6	54.9	78.0
Lower Shell	ES	4	*	0.24	0.36	139	23.1	21.3	13.0	10.7	33.6	54.9	78.0
GIRTH WELD:													
Lower shell to	SAW		72445/8688**	0.21	0.59	162	-5.0	24.8	20.0	12.4	47.1	71.9	66.9
Lower-Intmed	SAW		406L44/8688**	0.31	0.59	197	-5.0	30.2	20.0	15.1	50.1	80.3	75.3

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.
** Linde 80 weld- Chemistry values from BAW-2121P, dated April 1991.
** Linde 80 weld- RTndt and σ_I values from BAW-1803-1, dated May 1991.

Table C-3: Quad Cities 1 Beltline ART Values (22 EFPY)

Plate
Thickness = 6.13 inches

Plate
32 EFPY Peak I.D. fluence = 4.90E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.39E+17 n/cm^2
22 EFPY Peak I.D. fluence = 3.37E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 2.33E+17 n/cm^2

Weld
Thickness = 6.13 inches

Weld
32 EFPY Peak I.D. fluence = 4.90E+17 n/cm^2
32 EFPY Peak 1/4 T fluence = 3.39E+17 n/cm^2
22 EFPY Peak I.D. fluence = 3.37E+17 n/cm^2
22 EFPY Peak 1/4 T fluence = 2.33E+17 n/cm^2

COMPONENT	Weld Type	# of Vertical Weld Seams	HEAT OR HEAT/LOT	%Cu	%Ni	CF	Initial RTndt °F	22 EFPY Δ RTndt °F	σ_I	σ_Δ	Margin °F	22 EFPY Shift °F	22 EFPY ART °F
PLATES:													
Lower													
6-122-8			C1516-2	0.16	0.46	108	6.0	20.4	0.0	10.2	20.4	40.8	46.8
6-122-10			C1501-2	0.18	0.49	124	-10.0	23.4	0.0	11.7	23.4	46.9	36.9
6-122-14			C1722-2	0.14	0.54	97	10.0	18.3	0.0	9.2	18.3	36.7	46.7
Lower-Intmed													
6-139-16			C2753-2	0.08	0.5	51	10.0	9.6	0.0	4.8	9.6	19.3	29.3
6-139-22			C2868-1	0.08	0.48	51	10.0	9.6	0.0	4.8	9.6	19.3	29.3
6-139-25			C3307-2	0.12	0.55	82	10.0	15.5	0.0	7.8	15.5	31.0	41.0
VERTICAL WELDS:													
Lower-Intmed	ES	3	*	0.24	0.36	139	23.1	26.3	13.0	13.1	37.0	63.2	86.3
Lower Shell	ES	3	*	0.24	0.36	139	23.1	26.3	13.0	13.1	37.0	63.2	86.3
GIRTH WELD:													
Lower shell to Lower-Intermed	SAW		S3986/3870 Linde 124	0.05	0.96	68	-32.0	12.9	0.0	6.4	12.9	25.7	-6.3

*Values obtained from BAW-2259, dated January 1996. Values include one standard deviation.

Table C-4: Quad Cities 2 Beltline ART Values (22 EFPY)

APPENDIX D

PRESSURE TEST CURVE (CURVE A) AND DATA TABULATION

[20°F/HR Heatup/Cooldown]

18 EFPY

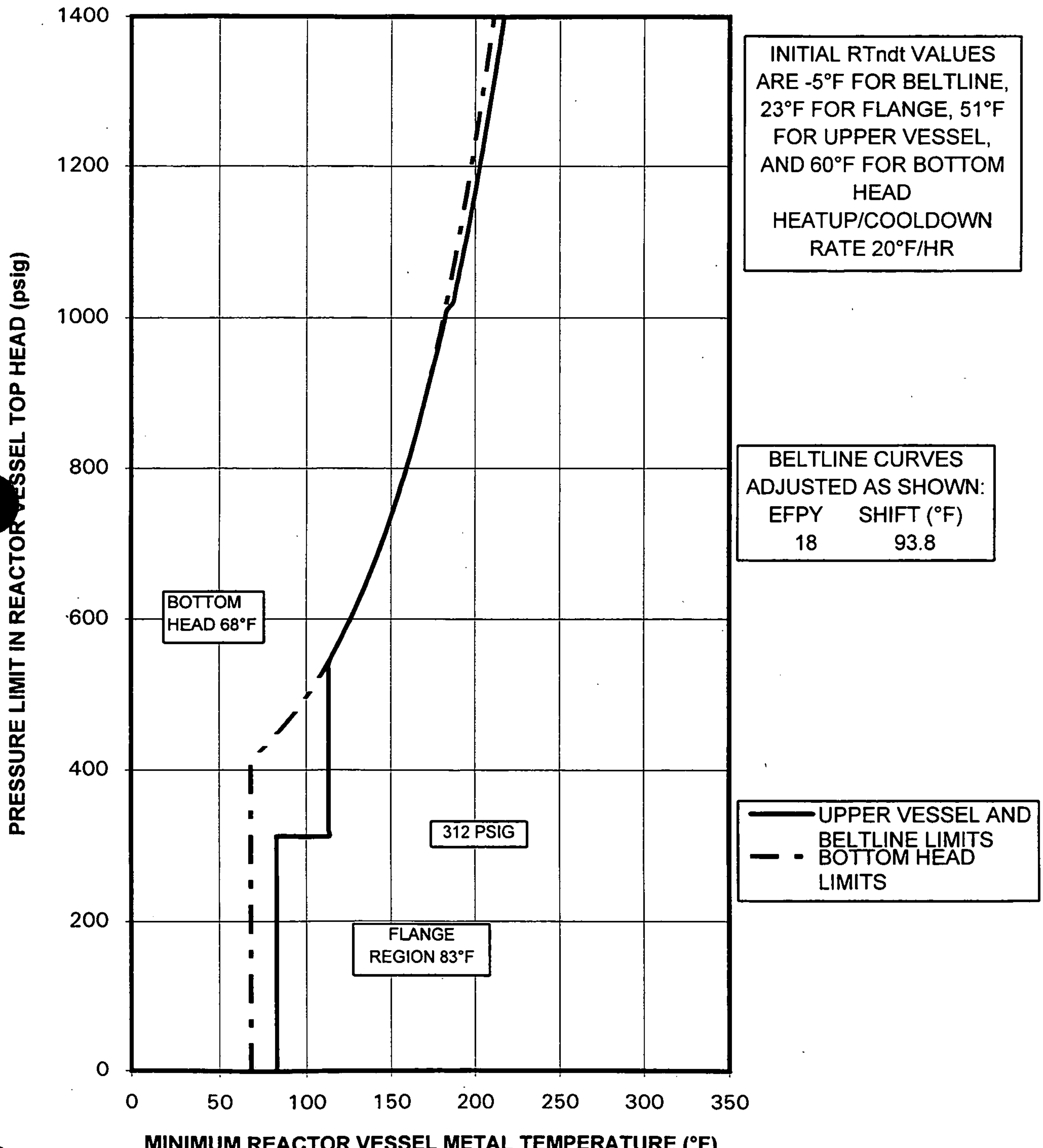

Figure D-1: Pressure Test Curve (Curve A)

TABLE D-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES
FOR FIGURE D-1

PRESSURE	BOTTOM HEAD	UPP VESS & 18 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
0	68.0	83.0
10	68.0	83.0
20	68.0	83.0
30	68.0	83.0
40	68.0	83.0
50	68.0	83.0
60	68.0	83.0
70	68.0	83.0
80	68.0	83.0
90	68.0	83.0
100	68.0	83.0
110	68.0	83.0
120	68.0	83.0
130	68.0	83.0
140	68.0	83.0
150	68.0	83.0
160	68.0	83.0
170	68.0	83.0
180	68.0	83.0
190	68.0	83.0
200	68.0	83.0
210	68.0	83.0
220	68.0	83.0
230	68.0	83.0
240	68.0	83.0
250	68.0	83.0
260	68.0	83.0
270	68.0	83.0
280	68.0	83.0
290	68.0	83.0

TABLE D-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES
FOR FIGURE D-1

PRESSURE	BOTTOM HEAD	UPP VESS & 18 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
300	68.0	83.0
310	68.0	83.0
312.5	68.0	83.0
312.5	68.0	113.0
320	68.0	113.0
330	68.0	113.0
340	68.0	113.0
350	68.0	113.0
360	68.0	113.0
370	68.0	113.0
380	68.0	113.0
390	68.0	113.0
400	68.0	113.0
410	68.0	113.0
420	71.4	113.0
430	75.9	113.0
440	80.1	113.0
450	84.1	113.0
460	87.8	113.0
470	91.4	113.0
480	94.8	113.0
490	98.0	113.0
500	101.1	113.0
510	104.0	113.0
520	106.9	113.0
530	109.6	113.0
540	112.2	113.0
550	114.7	114.7
560	117.2	117.2
570	119.5	119.5

TABLE D-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES
FOR FIGURE D-1

PRESSURE	BOTTOM HEAD	UPP VESS & 18 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
580	121.8	121.8
590	124.0	124.0
600	126.1	126.1
610	128.2	128.2
620	130.2	130.2
630	132.1	132.1
640	134.0	134.0
650	135.9	135.9
660	137.7	137.7
670	139.4	139.4
680	141.1	141.1
690	142.8	142.8
700	144.4	144.4
710	146.0	146.0
720	147.6	147.6
730	149.1	149.1
740	150.6	150.6
750	152.0	152.0
760	153.5	153.5
770	154.8	154.8
780	156.2	156.2
790	157.6	157.6
800	158.9	158.9
810	160.2	160.2
820	161.4	161.4
830	162.7	162.7
840	163.9	163.9
850	165.1	165.1
860	166.3	166.3
870	167.5	167.5

TABLE D-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES
FOR FIGURE D-1

PRESSURE	BOTTOM HEAD	UPP VESS & 18 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
880	168.6	168.6
890	169.7	169.7
900	170.8	170.8
910	171.9	171.9
920	173.0	173.1
930	174.0	174.3
940	175.1	175.5
950	176.1	176.6
960	177.1	177.7
970	178.1	178.8
980	179.1	179.9
990	180.0	181.0
1000	181.0	182.1
1010	181.9	183.1
1020	182.9	186.7
1030	183.8	187.7
1040	184.7	188.7
1050	185.6	189.7
1060	186.5	190.7
1070	187.3	191.6
1080	188.2	192.5
1090	189.0	193.4
1100	189.9	194.4
1110	190.7	195.3
1120	191.5	196.1
1130	192.3	197.0
1140	193.1	197.9
1150	193.9	198.7
1160	194.7	199.6
1170	195.5	200.4

TABLE D-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES
FOR FIGURE D-1

PRESSURE	BOTTOM HEAD	UPP VESS & 18 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
1180	196.2	201.2
1190	197.0	202.0
1200	197.7	202.8
1210	198.5	203.6
1220	199.2	204.4
1230	199.9	205.2
1240	200.6	205.9
1250	201.3	206.7
1260	202.0	207.4
1270	202.7	208.2
1280	203.4	208.9
1290	204.1	209.6
1300	204.8	210.4
1310	205.4	211.1
1320	206.1	211.8
1330	206.8	212.5
1340	207.4	213.2
1350	208.1	213.8
1360	208.7	214.5
1370	209.3	215.2
1380	209.9	215.9
1390	210.6	216.5
1400	211.2	217.2

APPENDIX E

PRESSURE TEST CURVE (CURVE A) AND DATA TABULATION

[20°F/HR Heatup/Cooldown]

20 EFPY

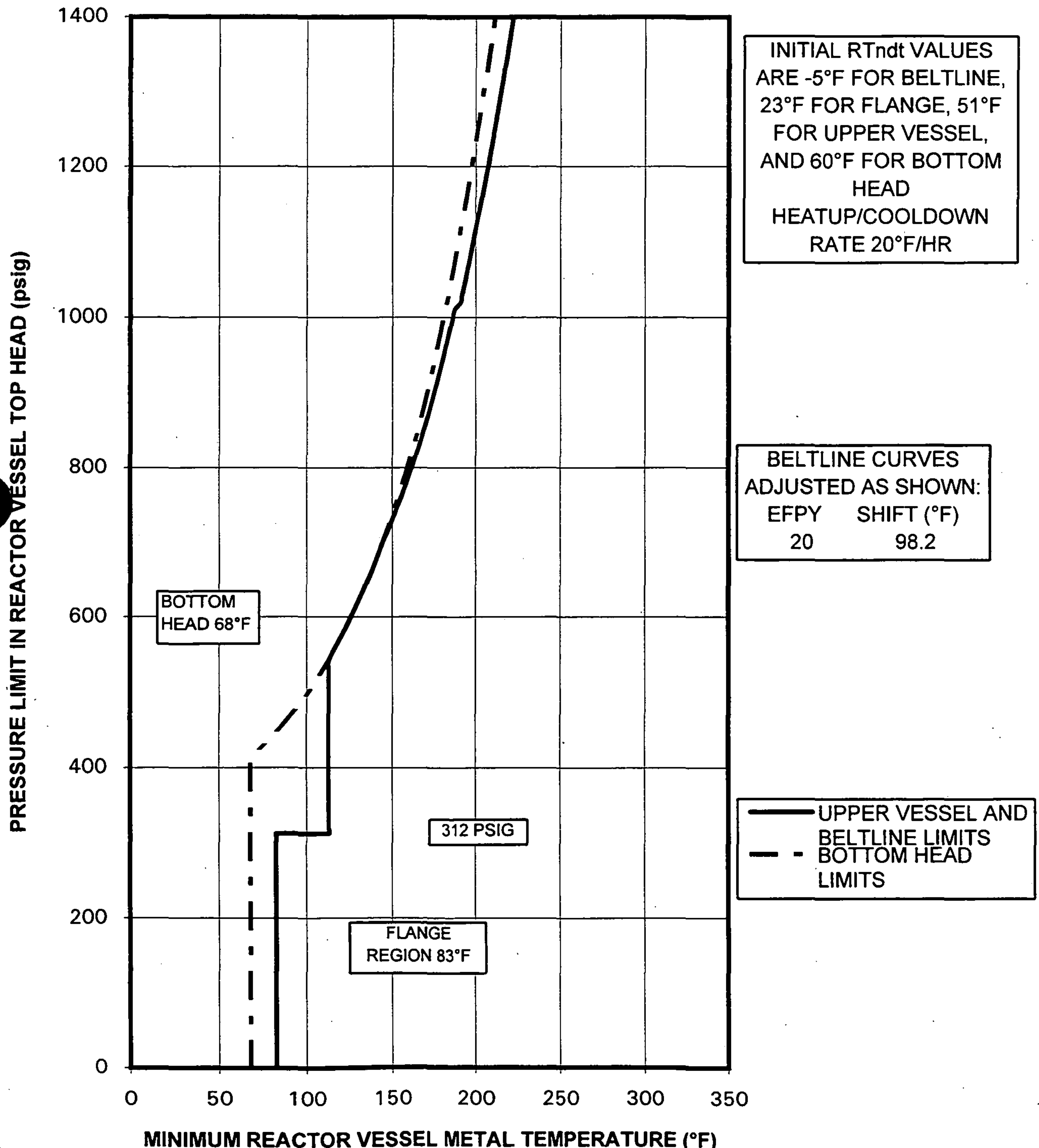

Figure E-1: Pressure Test Curve (Curve A)

TABLE E-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE E-1

PRESSURE	BOTTOM HEAD	UPP VESS & 20 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
0	68.0	83.0
10	68.0	83.0
20	68.0	83.0
30	68.0	83.0
40	68.0	83.0
50	68.0	83.0
60	68.0	83.0
70	68.0	83.0
80	68.0	83.0
90	68.0	83.0
100	68.0	83.0
110	68.0	83.0
120	68.0	83.0
130	68.0	83.0
140	68.0	83.0
150	68.0	83.0
160	68.0	83.0
170	68.0	83.0
180	68.0	83.0
190	68.0	83.0
200	68.0	83.0
210	68.0	83.0
220	68.0	83.0
230	68.0	83.0
240	68.0	83.0
250	68.0	83.0
260	68.0	83.0
270	68.0	83.0
280	68.0	83.0
290	68.0	83.0

TABLE E-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE E-1

PRESSURE	BOTTOM HEAD	UPP VESS & 20 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
300	68.0	83.0
310	68.0	83.0
312.5	68.0	83.0
312.5	68.0	113.0
320	68.0	113.0
330	68.0	113.0
340	68.0	113.0
350	68.0	113.0
360	68.0	113.0
370	68.0	113.0
380	68.0	113.0
390	68.0	113.0
400	68.0	113.0
410	68.0	113.0
420	71.4	113.0
430	75.9	113.0
440	80.1	113.0
450	84.1	113.0
460	87.8	113.0
470	91.4	113.0
480	94.8	113.0
490	98.0	113.0
500	101.1	113.0
510	104.0	113.0
520	106.9	113.0
530	109.6	113.0
540	112.2	113.0
550	114.7	114.7
560	117.2	117.2
570	119.5	119.5

TABLE E-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE E-1

PRESSURE	BOTTOM HEAD	UPP VESS & 20 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
580	121.8	121.8
590	124.0	124.0
600	126.1	126.1
610	128.2	128.2
620	130.2	130.2
630	132.1	132.1
640	134.0	134.0
650	135.9	135.9
660	137.7	137.7
670	139.4	139.4
680	141.1	141.1
690	142.8	142.8
700	144.4	144.4
710	146.0	146.3
720	147.6	148.1
730	149.1	149.9
740	150.6	151.7
750	152.0	153.4
760	153.5	155.1
770	154.8	156.7
780	156.2	158.3
790	157.6	159.9
800	158.9	161.4
810	160.2	162.9
820	161.4	164.4
830	162.7	165.8
840	163.9	167.2
850	165.1	168.6
860	166.3	169.9
870	167.5	171.3

TABLE E-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE E-1

PRESSURE	BOTTOM HEAD	UPP VESS & 20 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
880	168.6	172.5
890	169.7	173.8
900	170.8	175.1
910	171.9	176.3
920	173.0	177.5
930	174.0	178.7
940	175.1	179.9
950	176.1	181.0
960	177.1	182.1
970	178.1	183.2
980	179.1	184.3
990	180.0	185.4
1000	181.0	186.5
1010	181.9	187.5
1020	182.9	191.1
1030	183.8	192.1
1040	184.7	193.1
1050	185.6	194.1
1060	186.5	195.1
1070	187.3	196.0
1080	188.2	196.9
1090	189.0	197.8
1100	189.9	198.8
1110	190.7	199.7
1120	191.5	200.5
1130	192.3	201.4
1140	193.1	202.3
1150	193.9	203.1
1160	194.7	204.0
1170	195.5	204.8

TABLE E-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE E-1

PRESSURE	BOTTOM HEAD	UPP VESS & 20 EFPY
	CURVE A	BELT A
(PSIG)	(°F)	(°F)
1180	196.2	205.6
1190	197.0	206.4
1200	197.7	207.2
1210	198.5	208.0
1220	199.2	208.8
1230	199.9	209.6
1240	200.6	210.3
1250	201.3	211.1
1260	202.0	211.8
1270	202.7	212.6
1280	203.4	213.3
1290	204.1	214.0
1300	204.8	214.8
1310	205.4	215.5
1320	206.1	216.2
1330	206.8	216.9
1340	207.4	217.6
1350	208.1	218.2
1360	208.7	218.9
1370	209.3	219.6
1380	209.9	220.3
1390	210.6	220.9
1400	211.2	221.6

APPENDIX F

PRESSURE TEST CURVE (CURVE A)

[20°F/HR Heatup/Cooldown]

NON-NUCLEAR HEATUP/COOLDOWN (CURVE B)

[100°F/HR Heatup/Cooldown]

CORE CRITICAL OPERATION (CURVE C)

[100°F/HR Heatup/Cooldown]

AND DATA TABULATION

22 EFPY

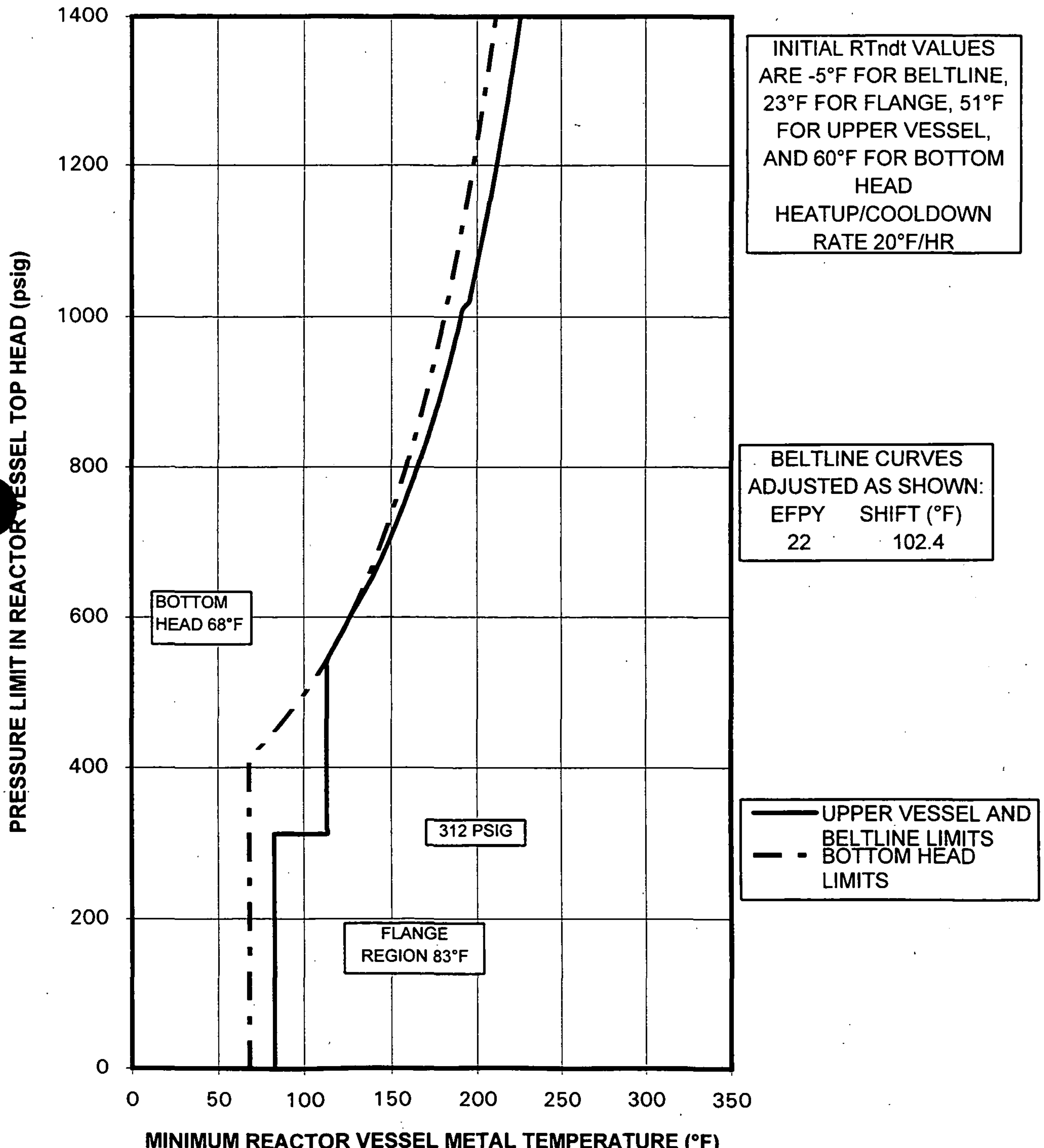

Figure F-1: Pressure Test Curve (Curve A)

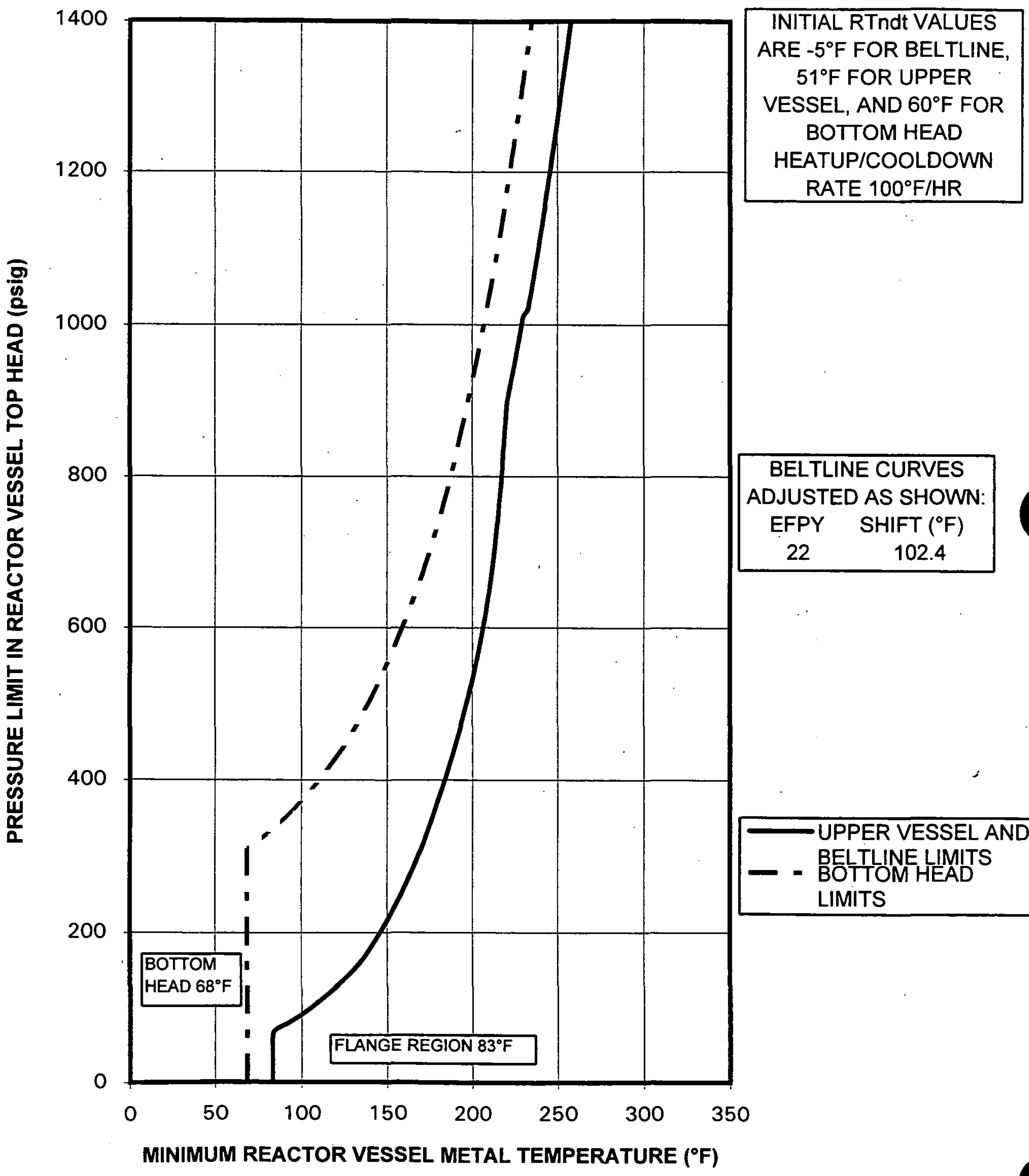

Figure F-2: Non-Nuclear Heatup/Cooldown (Curve B)

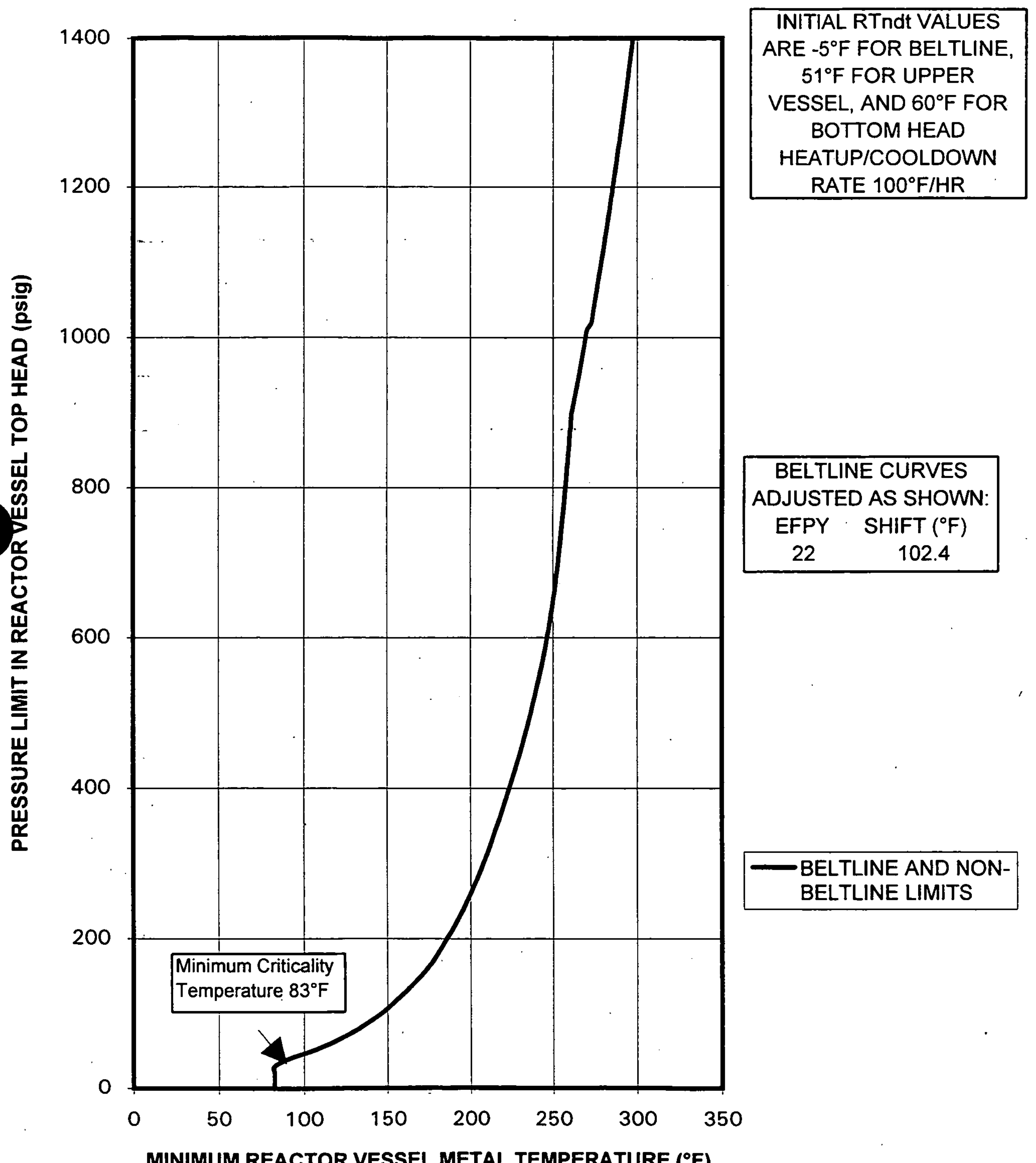

Figure F-3: Core Critical Operation (Curve C)

TABLE F-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURES F-1 THROUGH F-3

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
0	68.0	83.0	68.0	83.0	83.0
10	68.0	83.0	68.0	83.0	83.0
20	68.0	83.0	68.0	83.0	83.0
30	68.0	83.0	68.0	83.0	83.0
40	68.0	83.0	68.0	83.0	91.0
50	68.0	83.0	68.0	83.0	104.0
60	68.0	83.0	68.0	83.0	115.0
70	68.0	83.0	68.0	84.5	124.5
80	68.0	83.0	68.0	92.7	132.7
90	68.0	83.0	68.0	99.7	139.7
100	68.0	83.0	68.0	105.8	145.8
110	68.0	83.0	68.0	111.4	151.4
120	68.0	83.0	68.0	116.3	156.3
130	68.0	83.0	68.0	121.1	161.1
140	68.0	83.0	68.0	125.7	165.7
150	68.0	83.0	68.0	130.0	170.0
160	68.0	83.0	68.0	133.9	173.9
170	68.0	83.0	68.0	137.3	177.3
180	68.0	83.0	68.0	140.3	180.3
190	68.0	83.0	68.0	143.1	183.1
200	68.0	83.0	68.0	145.8	185.8
210	68.0	83.0	68.0	148.5	188.5
220	68.0	83.0	68.0	151.1	191.1
230	68.0	83.0	68.0	153.4	193.4
240	68.0	83.0	68.0	155.7	195.7
250	68.0	83.0	68.0	157.9	197.9
260	68.0	83.0	68.0	160.0	200.0
270	68.0	83.0	68.0	162.0	202.0
280	68.0	83.0	68.0	164.0	204.0
290	68.0	83.0	68.0	165.9	205.9

TABLE F-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURES F-1 THROUGH F-3

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
300	68.0	83.0	68.0	167.7	207.7
310	68.0	83.0	68.2	169.5	209.5
312.5	68.0	83.0	69.8	169.9	209.9
312.5	68.0	113.0	69.8	169.9	209.9
320	68.0	113.0	74.4	171.2	211.2
330	68.0	113.0	80.1	172.8	212.8
340	68.0	113.0	85.3	174.4	214.4
350	68.0	113.0	90.2	176.0	216.0
360	68.0	113.0	94.8	177.5	217.5
370	68.0	113.0	99.0	179.0	219.0
380	68.0	113.0	103.0	180.5	220.5
390	68.0	113.0	106.8	182.0	222.0
400	68.0	113.0	110.4	183.5	223.5
410	68.0	113.0	113.9	185.0	225.0
420	71.4	113.0	117.1	186.4	226.4
430	75.9	113.0	120.2	187.8	227.8
440	80.1	113.0	123.2	189.2	229.2
450	84.1	113.0	126.1	190.5	230.5
460	87.8	113.0	128.8	191.8	231.8
470	91.4	113.0	131.5	193.1	233.1
480	94.8	113.0	134.0	194.3	234.3
490	98.0	113.0	136.5	195.5	235.5
500	101.1	113.0	138.8	196.7	236.7
510	104.0	113.0	141.1	197.8	237.8
520	106.9	113.0	143.3	198.9	238.9
530	109.6	113.0	145.5	200.0	240.0
540	112.2	113.0	147.5	201.0	241.0
550	114.7	114.7	149.6	202.0	242.0
560	117.2	117.2	151.5	203.0	243.0
570	119.5	119.5	153.4	203.9	243.9

TABLE F-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURES F-1 THROUGH F-3

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
580	121.8	121.8	155.3	204.8	244.8
590	124.0	124.0	157.1	205.7	245.7
600	126.1	126.1	158.9	206.5	246.5
610	128.2	128.5	160.6	207.3	247.3
620	130.2	131.0	162.3	208.1	248.1
630	132.1	133.5	163.9	208.8	248.8
640	134.0	135.9	165.5	209.5	249.5
650	135.9	138.1	167.0	210.2	250.2
660	137.7	140.4	168.6	210.8	250.8
670	139.4	142.5	170.1	211.4	251.4
680	141.1	144.6	171.5	212.0	252.0
690	142.8	146.6	173.0	212.5	252.5
700	144.4	148.6	174.4	213.0	253.0
710	146.0	150.5	175.7	213.5	253.5
720	147.6	152.3	177.1	214.0	254.0
730	149.1	154.1	178.4	214.4	254.4
740	150.6	155.9	179.7	214.9	254.9
750	152.0	157.6	181.0	215.3	255.3
760	153.5	159.3	182.2	215.7	255.7
770	154.8	160.9	183.5	216.2	256.2
780	156.2	162.5	184.7	216.6	256.6
790	157.6	164.1	185.9	217.0	257.0
800	158.9	165.6	187.0	217.4	257.4
810	160.2	167.1	188.2	217.8	257.8
820	161.4	168.6	189.3	218.2	258.2
830	162.7	170.0	190.4	218.5	258.5
840	163.9	171.4	191.5	218.9	258.9
850	165.1	172.8	192.6	219.2	259.2
860	166.3	174.1	193.6	219.6	259.6
870	167.5	175.5	194.7	219.9	259.9

TABLE F-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURES F-1 THROUGH F-3

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
880	168.6	176.7	195.7	220.3	260.3
890	169.7	178.0	196.7	220.6	260.6
900	170.8	179.3	197.7	221.0	261.0
910	171.9	180.5	198.7	221.9	261.9
920	173.0	181.7	199.7	222.8	262.8
930	174.0	182.9	200.6	223.7	263.7
940	175.1	184.1	201.6	224.5	264.5
950	176.1	185.2	202.5	225.4	265.4
960	177.1	186.3	203.4	226.2	266.2
970	178.1	187.4	204.3	227.0	267.0
980	179.1	188.5	205.2	227.9	267.9
990	180.0	189.6	206.1	228.7	268.7
1000	181.0	190.7	207.0	229.5	269.5
1010	181.9	191.7	207.8	230.3	270.3
1020	182.9	195.3	208.7	233.1	273.1
1030	183.8	196.3	209.5	233.8	273.8
1040	184.7	197.3	210.3	234.6	274.6
1050	185.6	198.3	211.2	235.4	275.4
1060	186.5	199.3	212.0	236.1	276.1
1070	187.3	200.2	212.8	236.8	276.8
1080	188.2	201.1	213.6	237.6	277.6
1090	189.0	202.0	214.3	238.3	278.3
1100	189.9	203.0	215.1	239.0	279.0
1110	190.7	203.9	215.9	239.7	279.7
1120	191.5	204.7	216.6	240.4	280.4
1130	192.3	205.6	217.4	241.1	281.1
1140	193.1	206.5	218.1	241.8	281.8
1150	193.9	207.3	218.9	242.5	282.5
1160	194.7	208.2	219.6	243.2	283.2
1170	195.5	209.0	220.3	243.8	283.8

TABLE F-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURES F-1 THROUGH F-3

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
1180	196.2	209.8	221.0	244.5	284.5
1190	197.0	210.6	221.7	245.1	285.1
1200	197.7	211.4	222.4	245.8	285.8
1210	198.5	212.2	223.1	246.4	286.4
1220	199.2	213.0	223.8	247.1	287.1
1230	199.9	213.8	224.5	247.7	287.7
1240	200.6	214.5	225.1	248.3	288.3
1250	201.3	215.3	225.8	248.9	288.9
1260	202.0	216.0	226.4	249.6	289.6
1270	202.7	216.8	227.1	250.2	290.2
1280	203.4	217.5	227.7	250.8	290.8
1290	204.1	218.2	228.4	251.4	291.4
1300	204.8	219.0	229.0	252.0	292.0
1310	205.4	219.7	229.6	252.5	292.5
1320	206.1	220.4	230.3	253.1	293.1
1330	206.8	221.1	230.9	253.7	293.7
1340	207.4	221.8	231.5	254.3	294.3
1350	208.1	222.4	232.1	254.8	294.8
1360	208.7	223.1	232.7	255.4	295.4
1370	209.3	223.8	233.3	256.0	296.0
1380	209.9	224.5	233.9	256.5	296.5
1390	210.6	225.1	234.4	257.1	297.1
1400	211.2	225.8	235.0	257.6	297.6

APPENDIX G

PRESSURE TEST CURVE (CURVE A)

[20°F/HR Heatup/Cooldown]

NON-NUCLEAR HEATUP/COOLDOWN (CURVE B)

[200°F/HR Heatup/Cooldown]

CORE CRITICAL OPERATION (CURVE C)

[200°F/HR Heatup/Cooldown]

AND DATA TABULATION

22 EFPY

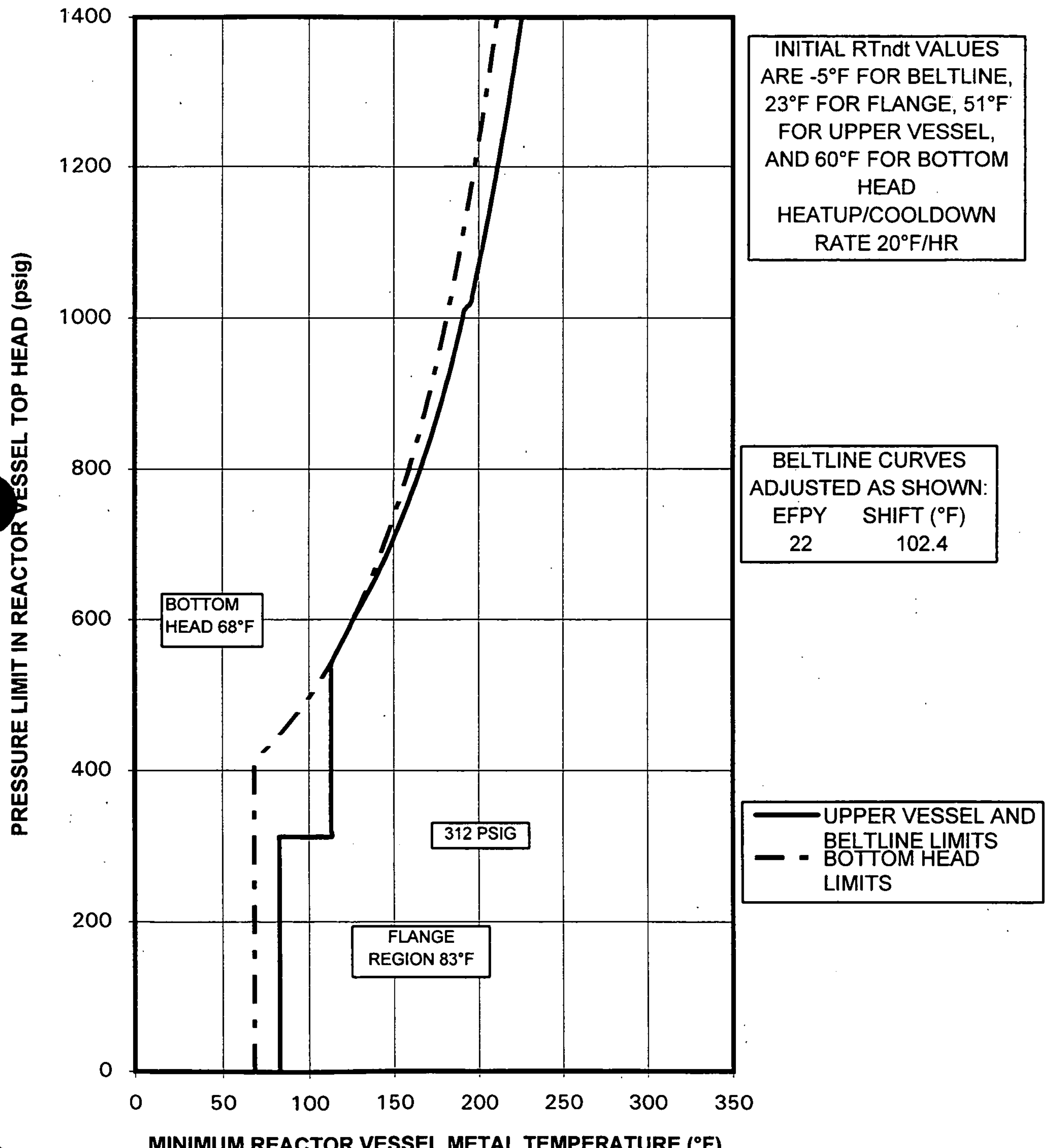

Figure G-1: Pressure Test Curve (Curve A)

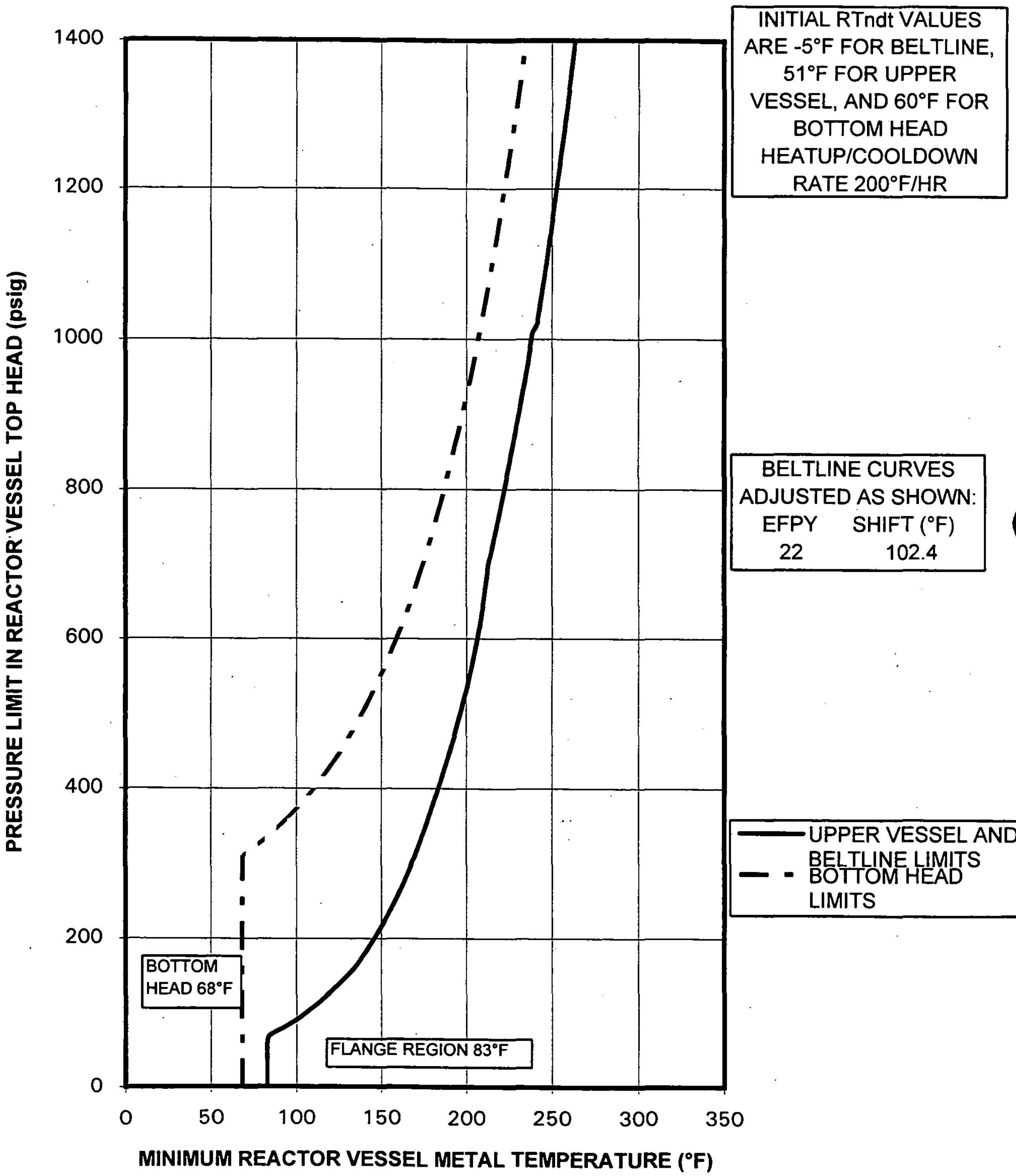

Figure G-2: Non-Nuclear Heatup/Cooldown (Curve B)

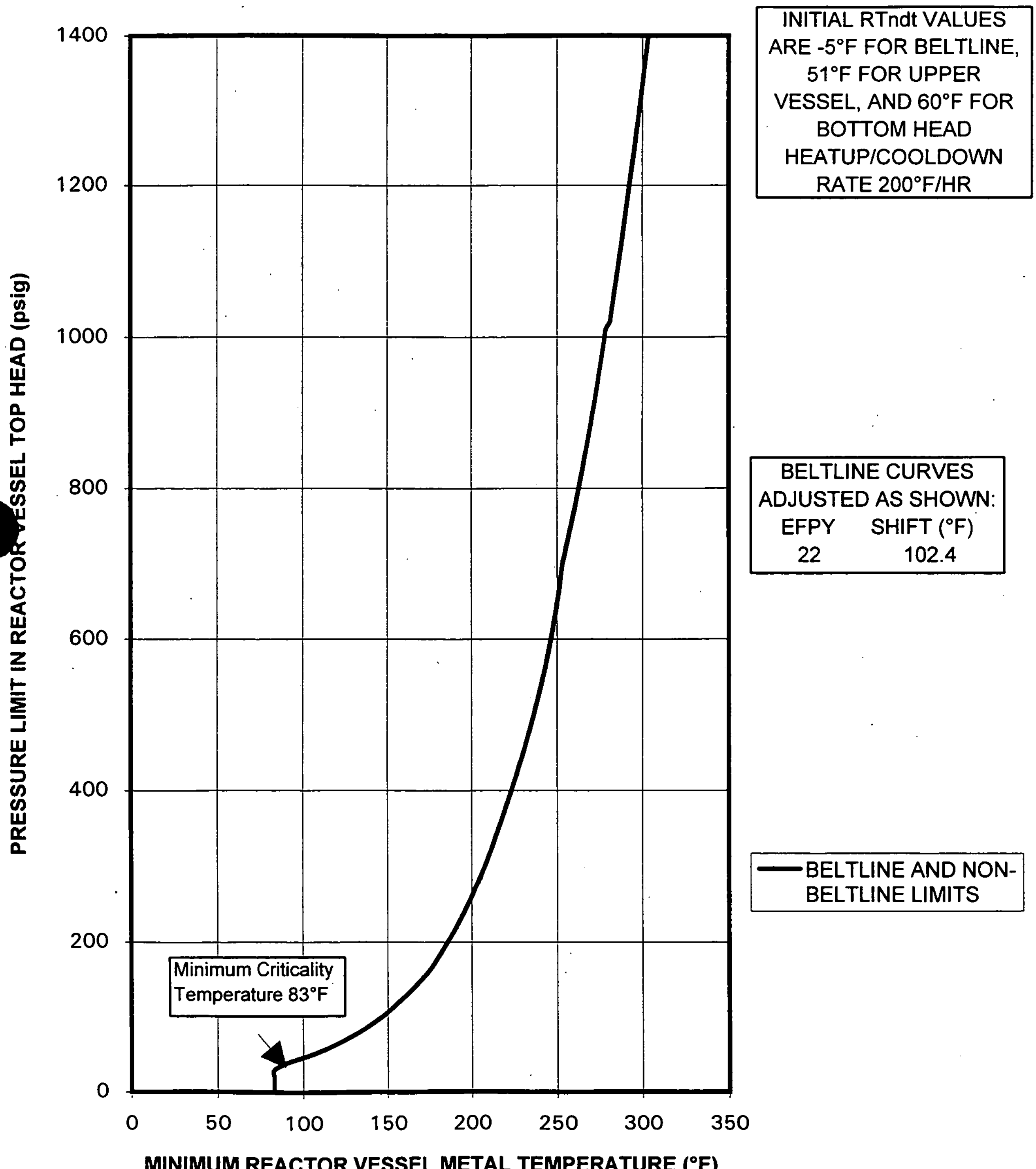

Figure G-3: Core Critical Operation (Curve C)

TABLE G-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE G-1

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
0	68.0	83.0	68.0	83.0	83.0
10	68.0	83.0	68.0	83.0	83.0
20	68.0	83.0	68.0	83.0	83.0
30	68.0	83.0	68.0	83.0	83.0
40	68.0	83.0	68.0	83.0	91.0
50	68.0	83.0	68.0	83.0	104.0
60	68.0	83.0	68.0	83.0	115.0
70	68.0	83.0	68.0	84.5	124.5
80	68.0	83.0	68.0	92.7	132.7
90	68.0	83.0	68.0	99.7	139.7
100	68.0	83.0	68.0	105.8	145.8
110	68.0	83.0	68.0	111.4	151.4
120	68.0	83.0	68.0	116.3	156.3
130	68.0	83.0	68.0	121.1	161.1
140	68.0	83.0	68.0	125.7	165.7
150	68.0	83.0	68.0	130.0	170.0
160	68.0	83.0	68.0	133.9	173.9
170	68.0	83.0	68.0	137.3	177.3
180	68.0	83.0	68.0	140.3	180.3
190	68.0	83.0	68.0	143.1	183.1
200	68.0	83.0	68.0	145.8	185.8
210	68.0	83.0	68.0	148.5	188.5
220	68.0	83.0	68.0	151.1	191.1
230	68.0	83.0	68.0	153.4	193.4
240	68.0	83.0	68.0	155.7	195.7
250	68.0	83.0	68.0	157.9	197.9
260	68.0	83.0	68.0	160.0	200.0
270	68.0	83.0	68.0	162.0	202.0
280	68.0	83.0	68.0	164.0	204.0
290	68.0	83.0	68.0	165.9	205.9

TABLE G-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE G-1

PRESSURE	BOTTOM HEAD CURVE A	UPP VESS & 22 EFPY BELT A	BOTTOM HEAD CURVE B	UPP VESS & 22 EFPY BELT B	RPV 22 EFPY CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
300	68.0	83.0	68.0	167.7	207.7
310	68.0	83.0	68.2	169.5	209.5
312.5	68.0	83.0	69.8	169.9	209.9
312.5	68.0	113.0	69.8	169.9	209.9
320	68.0	113.0	74.4	171.2	211.2
330	68.0	113.0	80.1	172.8	212.8
340	68.0	113.0	85.3	174.4	214.4
350	68.0	113.0	90.2	176.0	216.0
360	68.0	113.0	94.8	177.5	217.5
370	68.0	113.0	99.0	179.0	219.0
380	68.0	113.0	103.0	180.5	220.5
390	68.0	113.0	106.8	182.0	222.0
400	68.0	113.0	110.4	183.5	223.5
410	68.0	113.0	113.9	185.0	225.0
420	71.4	113.0	117.1	186.4	226.4
430	75.9	113.0	120.2	187.8	227.8
440	80.1	113.0	123.2	189.2	229.2
450	84.1	113.0	126.1	190.5	230.5
460	87.8	113.0	128.8	191.8	231.8
470	91.4	113.0	131.5	193.1	233.1
480	94.8	113.0	134.0	194.3	234.3
490	98.0	113.0	136.5	195.5	235.5
500	101.1	113.0	138.8	196.7	236.7
510	104.0	113.0	141.1	197.8	237.8
520	106.9	113.0	143.3	198.9	238.9
530	109.6	113.0	145.5	200.0	240.0
540	112.2	113.0	147.5	201.0	241.0
550	114.7	114.7	149.6	202.0	242.0
560	117.2	117.2	151.5	203.0	243.0
570	119.5	119.5	153.4	203.9	243.9

TABLE G-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE G-1

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
580	121.8	121.8	155.3	204.8	244.8
590	124.0	124.0	157.1	205.7	245.7
600	126.1	126.1	158.9	206.5	246.5
610	128.2	128.5	160.6	207.3	247.3
620	130.2	131.0	162.3	208.1	248.1
630	132.1	133.5	163.9	208.8	248.8
640	134.0	135.9	165.5	209.5	249.5
650	135.9	138.1	167.0	210.2	250.2
660	137.7	140.4	168.6	210.8	250.8
670	139.4	142.5	170.1	211.4	251.4
680	141.1	144.6	171.5	212.0	252.0
690	142.8	146.6	173.0	212.5	252.5
700	144.4	148.6	174.4	213.0	253.0
710	146.0	150.5	175.7	214.0	254.0
720	147.6	152.3	177.1	215.0	255.0
730	149.1	154.1	178.4	216.0	256.0
740	150.6	155.9	179.7	217.0	257.0
750	152.0	157.6	181.0	217.9	257.9
760	153.5	159.3	182.2	218.9	258.9
770	154.8	160.9	183.5	219.8	259.8
780	156.2	162.5	184.7	220.7	260.7
790	157.6	164.1	185.9	221.6	261.6
800	158.9	165.6	187.0	222.5	262.5
810	160.2	167.1	188.2	223.4	263.4
820	161.4	168.6	189.3	224.2	264.2
830	162.7	170.0	190.4	225.1	265.1
840	163.9	171.4	191.5	225.9	265.9
850	165.1	172.8	192.6	226.8	266.8
860	166.3	174.1	193.6	227.6	267.6
870	167.5	175.5	194.7	228.4	268.4

TABLE G-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE G-1

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
880	168.6	176.7	195.7	229.2	269.2
890	169.7	178.0	196.7	230.0	270.0
900	170.8	179.3	197.7	230.8	270.8
910	171.9	180.5	198.7	231.6	271.6
920	173.0	181.7	199.7	232.3	272.3
930	174.0	182.9	200.6	233.1	273.1
940	175.1	184.1	201.6	233.9	273.9
950	176.1	185.2	202.5	234.6	274.6
960	177.1	186.3	203.4	235.3	275.3
970	178.1	187.4	204.3	236.1	276.1
980	179.1	188.5	205.2	236.8	276.8
990	180.0	189.6	206.1	237.5	277.5
1000	181.0	190.7	207.0	238.2	278.2
1010	181.9	191.7	207.8	238.9	278.9
1020	182.9	195.3	208.7	241.4	281.4
1030	183.8	196.3	209.5	242.1	282.1
1040	184.7	197.3	210.3	242.7	282.7
1050	185.6	198.3	211.2	243.4	283.4
1060	186.5	199.3	212.0	244.1	284.1
1070	187.3	200.2	212.8	244.7	284.7
1080	188.2	201.1	213.6	245.4	285.4
1090	189.0	202.0	214.3	246.0	286.0
1100	189.9	203.0	215.1	246.7	286.7
1110	190.7	203.9	215.9	247.3	287.3
1120	191.5	204.7	216.6	247.9	287.9
1130	192.3	205.6	217.4	248.6	288.6
1140	193.1	206.5	218.1	249.2	289.2
1150	193.9	207.3	218.9	249.8	289.8
1160	194.7	208.2	219.6	250.4	290.4
1170	195.5	209.0	220.3	251.0	291.0

TABLE G-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE G-1

PRESSURE	BOTTOM HEAD	UPP VESS & 22 EFPY	BOTTOM HEAD	UPP VESS & 22 EFPY	RPV 22 EFPY
	CURVE A	BELT A	CURVE B	BELT B	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)
1180	196.2	209.8	221.0	251.6	291.6
1190	197.0	210.6	221.7	252.2	292.2
1200	197.7	211.4	222.4	252.8	292.8
1210	198.5	212.2	223.1	253.3	293.3
1220	199.2	213.0	223.8	253.9	293.9
1230	199.9	213.8	224.5	254.5	294.5
1240	200.6	214.5	225.1	255.1	295.1
1250	201.3	215.3	225.8	255.6	295.6
1260	202.0	216.0	226.4	256.2	296.2
1270	202.7	216.8	227.1	256.7	296.7
1280	203.4	217.5	227.7	257.3	297.3
1290	204.1	218.2	228.4	257.8	297.8
1300	204.8	219.0	229.0	258.4	298.4
1310	205.4	219.7	229.6	258.9	298.9
1320	206.1	220.4	230.3	259.4	299.4
1330	206.8	221.1	230.9	260.0	300.0
1340	207.4	221.8	231.5	260.5	300.5
1350	208.1	222.4	232.1	261.0	301.0
1360	208.7	223.1	232.7	261.5	301.5
1370	209.3	223.8	233.3	262.0	302.0
1380	209.9	224.5	233.9	262.5	302.5
1390	210.6	225.1	234.4	263.0	303.0
1400	211.2	225.8	235.0	263.5	303.5

APPENDIX H

CURVE A BREAKDOWN

22 EFPY

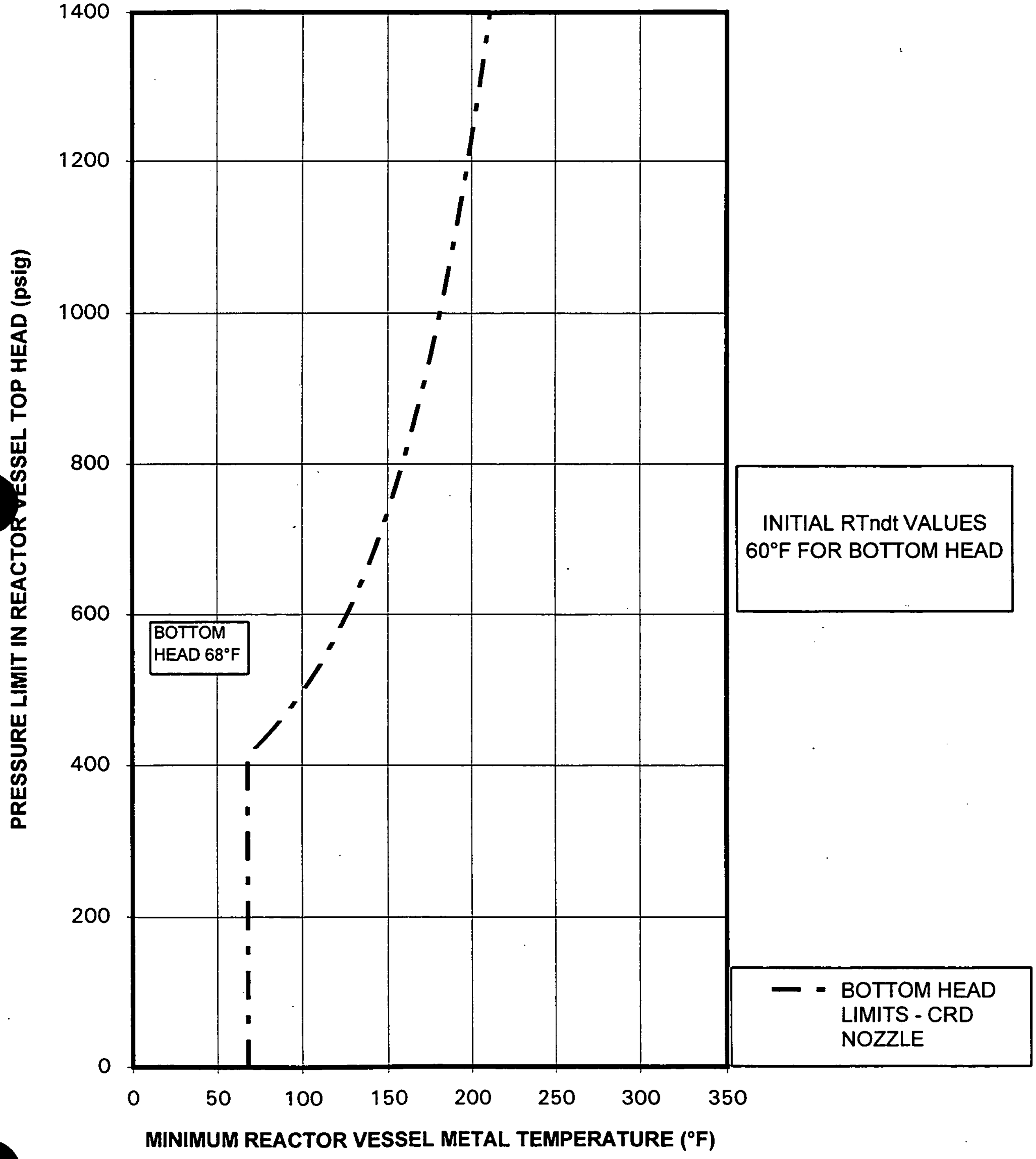

Figure H-1: Bottom Head Limits [CRD Nozzle]

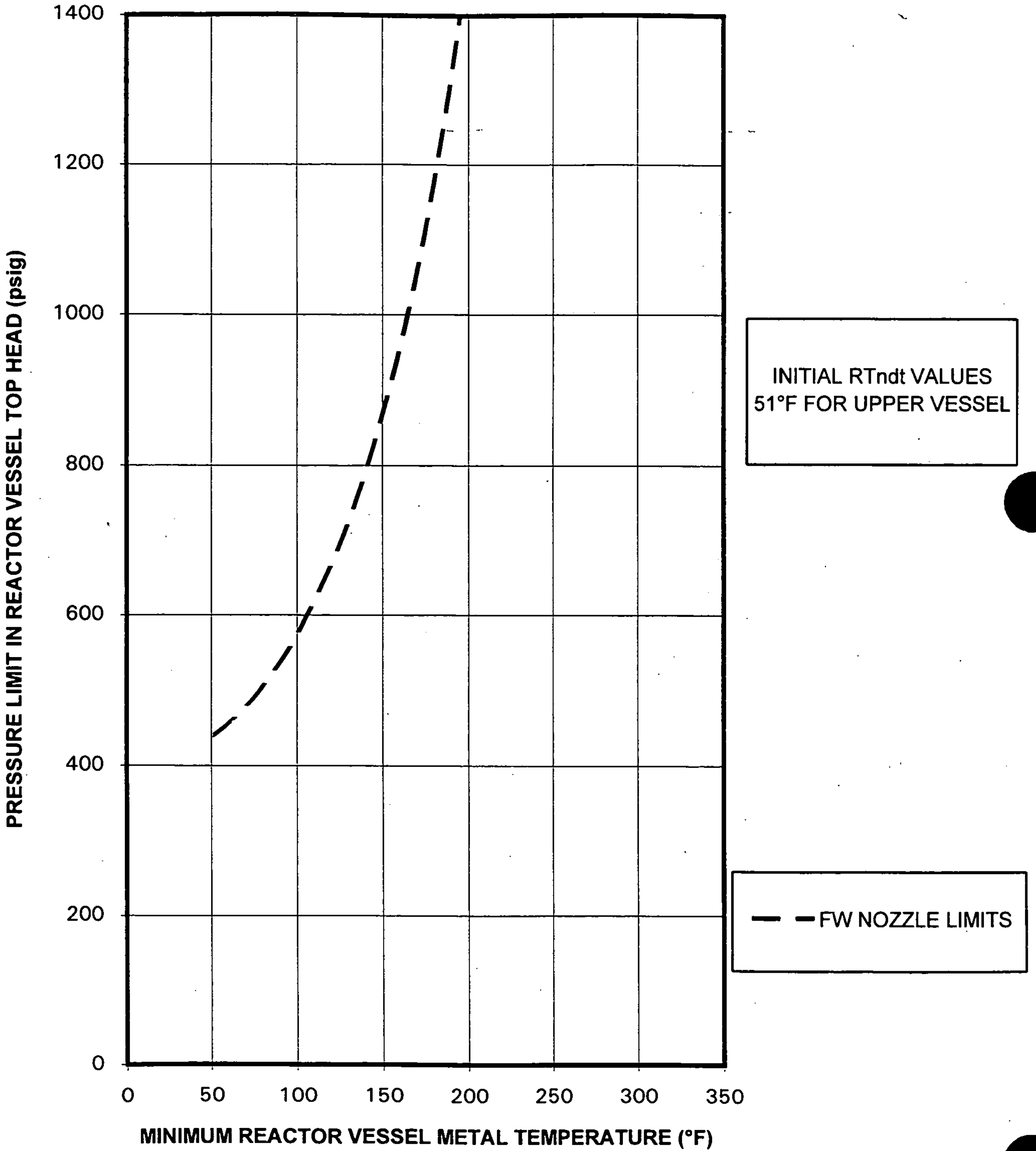

Figure H-2: FW Nozzle Limits

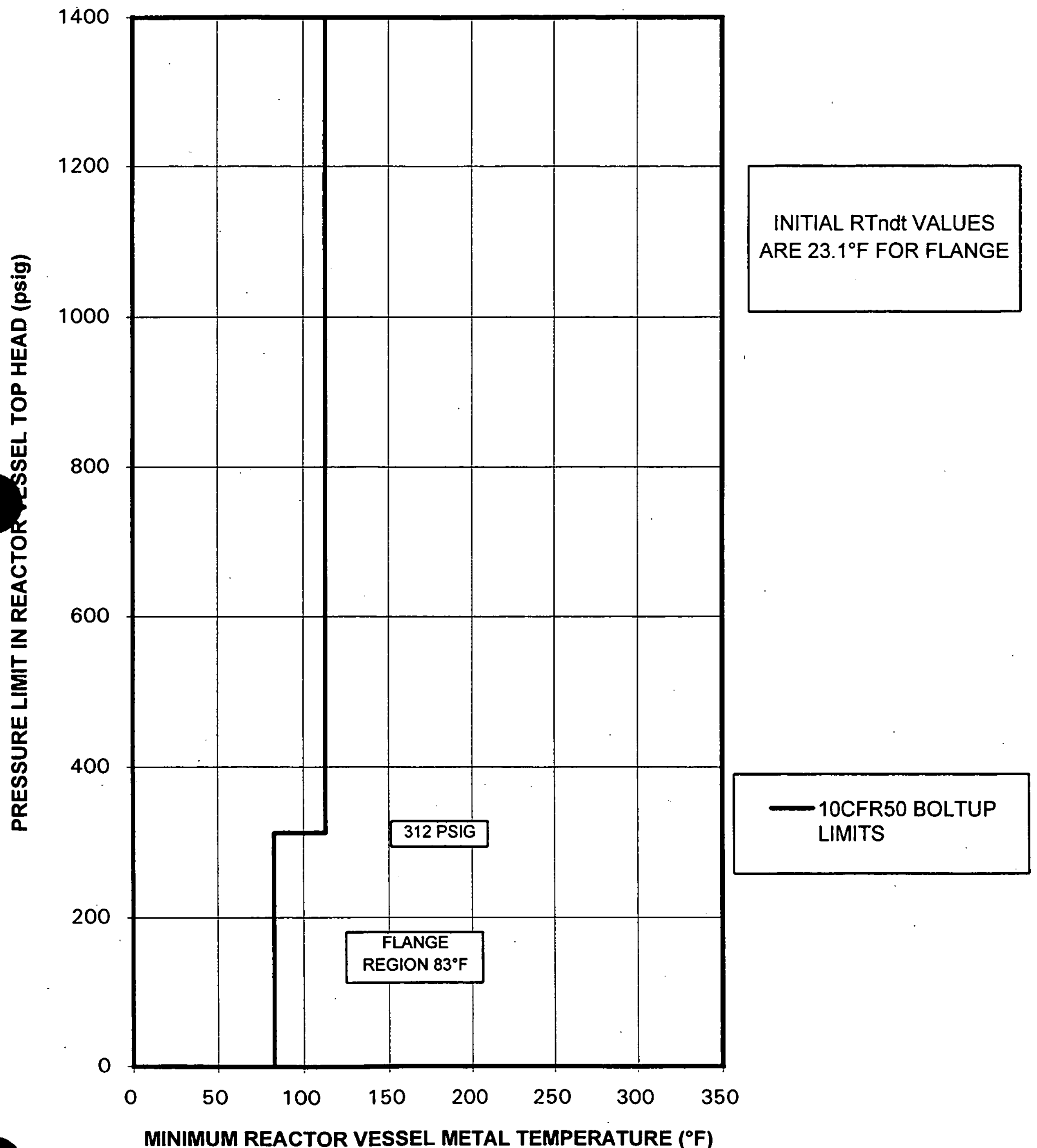

Figure H-3: 10CFR50 Boltup Limits

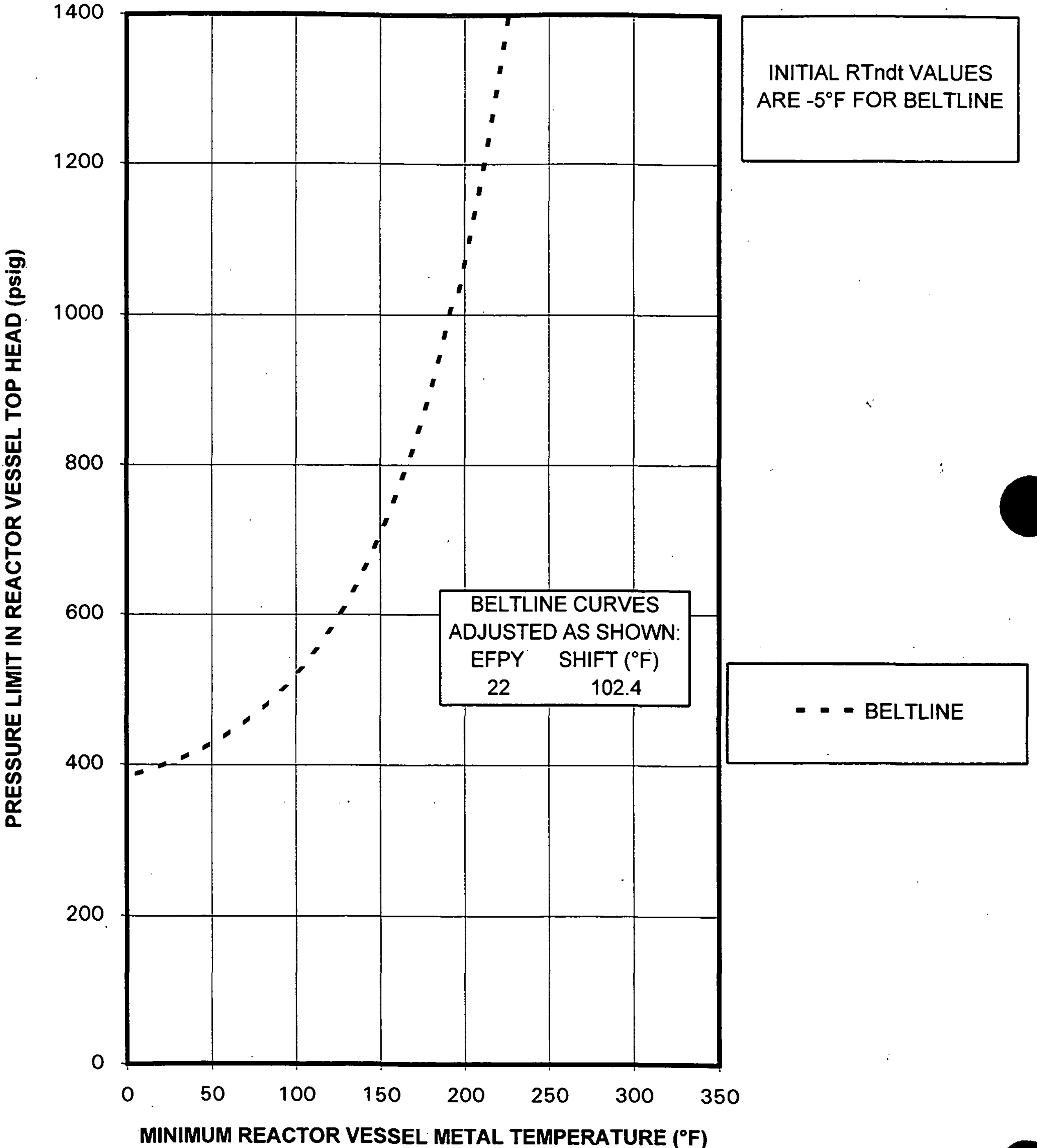

Figure H-4: Beltline Curve A

APPENDIX I

P-T LIMIT CURVES AND DATA TABULATION

CURVE A-20°F/HR Heatup/Cooldown

CURVES B AND C -100°F/HR Heatup/Cooldown

22 EFPY

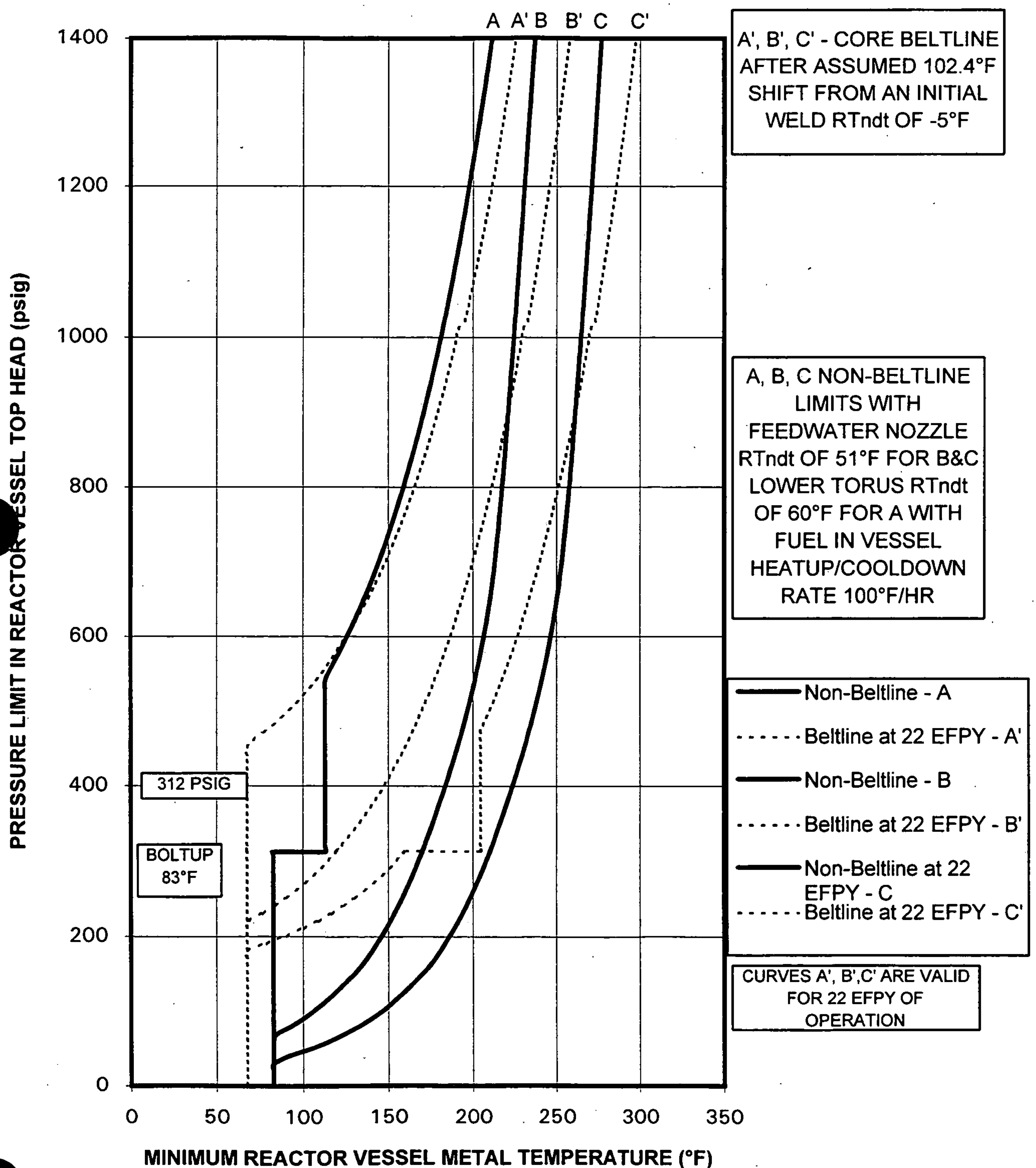

Figure I-1: P-T Limit Curve for 100°F Heatup/Cooldown

TABLE I-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE I-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
0	83.0	68.0	68.0	83.0	68.0	83.0
10	83.0	68.0	68.0	83.0	68.0	83.0
20	83.0	68.0	68.0	83.0	68.0	83.0
30	83.0	68.0	68.0	83.0	68.0	83.0
40	83.0	68.0	68.0	83.0	68.0	91.0
50	83.0	68.0	68.0	83.0	68.0	104.0
60	83.0	68.0	68.0	83.0	68.0	115.0
70	83.0	68.0	68.0	84.5	68.0	124.5
80	83.0	68.0	68.0	92.7	68.0	132.7
90	83.0	68.0	68.0	99.7	68.0	139.7
100	83.0	68.0	68.0	105.8	68.0	145.8
110	83.0	68.0	68.0	111.4	68.0	151.4
120	83.0	68.0	68.0	116.3	68.0	156.3
130	83.0	68.0	68.0	121.1	68.0	161.1
140	83.0	68.0	68.0	125.7	68.0	165.7
150	83.0	68.0	68.0	130.0	68.0	170.0
160	83.0	68.0	68.0	133.9	68.0	173.9
170	83.0	68.0	68.0	137.3	68.0	177.3
180	83.0	68.0	68.0	140.3	68.0	180.3
190	83.0	68.0	68.0	143.1	78.8	183.1
200	83.0	68.0	68.0	145.8	90.4	185.8
210	83.0	68.0	68.0	148.5	100.4	188.5
220	83.0	68.0	69.1	151.1	109.1	191.1
230	83.0	68.0	76.8	153.4	116.8	193.4
240	83.0	68.0	83.7	155.7	123.7	195.7
250	83.0	68.0	90.0	157.9	130.0	197.9
260	83.0	68.0	95.8	160.0	135.8	200.0
270	83.0	68.0	101.1	162.0	141.1	202.0
280	83.0	68.0	106.1	164.0	146.1	204.0
290	83.0	68.0	110.7	165.9	150.7	205.9

TABLE I-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE I-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
300	83.0	68.0	115.0	167.7	155.0	207.7
310	83.0	68.0	119.1	169.5	159.1	209.5
312.5	83.0	68.0	120.1	169.9	160.1	209.9
312.5	113.0	68.0	120.1	169.9	204.7	209.9
320	113.0	68.0	123.0	171.2	204.7	211.2
330	113.0	68.0	126.6	172.8	204.7	212.8
340	113.0	68.0	130.1	174.4	204.7	214.4
350	113.0	68.0	133.3	176.0	204.7	216.0
360	113.0	68.0	136.5	177.5	204.7	217.5
370	113.0	68.0	139.5	179.0	204.7	219.0
380	113.0	68.0	142.4	180.5	204.7	220.5
390	113.0	68.0	145.1	182.0	204.7	222.0
400	113.0	68.0	147.8	183.5	204.7	223.5
410	113.0	68.0	150.4	185.0	204.7	225.0
420	113.0	68.0	152.8	186.4	204.7	226.4
430	113.0	68.0	155.2	187.8	204.7	227.8
440	113.0	68.0	157.5	189.2	204.7	229.2
450	113.0	68.0	159.7	190.5	204.7	230.5
460	113.0	71.4	161.9	191.8	204.7	231.8
470	113.0	77.1	164.0	193.1	204.7	233.1
480	113.0	82.4	166.0	194.3	206.0	234.3
490	113.0	87.2	168.0	195.5	208.0	235.5
500	113.0	91.8	169.9	196.7	209.9	236.7
510	113.0	96.1	171.8	197.8	211.8	237.8
520	113.0	100.1	173.6	198.9	213.6	238.9
530	113.0	103.9	175.4	200.0	215.4	240.0
540	113.0	107.5	177.1	201.0	217.1	241.0
550	114.7	110.9	178.8	202.0	218.8	242.0
560	117.2	114.2	180.4	203.0	220.4	243.0
570	119.5	117.3	182.0	203.9	222.0	243.9

TABLE I-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE I-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
580	121.8	120.3	183.6	204.8	223.6	244.8
590	124.0	123.1	185.1	205.7	225.1	245.7
600	126.1	125.9	186.6	206.5	226.6	246.5
610	128.2	128.5	188.1	207.3	228.1	247.3
620	130.2	131.0	189.5	208.1	229.5	248.1
630	132.1	133.5	191.0	208.8	231.0	248.8
640	134.0	135.9	192.3	209.5	232.3	249.5
650	135.9	138.1	193.7	210.2	233.7	250.2
660	137.7	140.4	195.0	210.8	235.0	250.8
670	139.4	142.5	196.3	211.4	236.3	251.4
680	141.1	144.6	197.6	212.0	237.6	252.0
690	142.8	146.6	198.9	212.5	238.9	252.5
700	144.4	148.6	200.1	213.0	240.1	253.0
710	146.0	150.5	201.3	213.5	241.3	253.5
720	147.6	152.3	202.5	214.0	242.5	254.0
730	149.1	154.1	203.7	214.4	243.7	254.4
740	150.6	155.9	204.8	214.9	244.8	254.9
750	152.0	157.6	205.9	215.3	245.9	255.3
760	153.5	159.3	207.1	215.7	247.1	255.7
770	154.8	160.9	208.1	216.2	248.1	256.2
780	156.2	162.5	209.2	216.6	249.2	256.6
790	157.6	164.1	210.3	217.0	250.3	257.0
800	158.9	165.6	211.3	217.4	251.3	257.4
810	160.2	167.1	212.4	217.8	252.4	257.8
820	161.4	168.6	213.4	218.2	253.4	258.2
830	162.7	170.0	214.4	218.5	254.4	258.5
840	163.9	171.4	215.4	218.9	255.4	258.9
850	165.1	172.8	216.3	219.2	256.3	259.2
860	166.3	174.1	217.3	219.6	257.3	259.6
870	167.5	175.5	218.2	219.9	258.2	259.9

TABLE I-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE I-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
880	168.6	176.7	219.2	220.3	259.2	260.3
890	169.7	178.0	220.1	220.6	260.1	260.6
900	170.8	179.3	221.0	220.9	261.0	260.9
910	171.9	180.5	221.9	221.3	261.9	261.3
920	173.0	181.7	222.8	221.6	262.8	261.6
930	174.0	182.9	223.7	222.0	263.7	262.0
940	175.1	184.1	224.5	222.3	264.5	262.3
950	176.1	185.2	225.4	222.6	265.4	262.6
960	177.1	186.3	226.2	223.0	266.2	263.0
970	178.1	187.4	227.0	223.3	267.0	263.3
980	179.1	188.5	227.9	223.7	267.9	263.7
990	180.0	189.6	228.7	224.0	268.7	264.0
1000	181.0	190.7	229.5	224.3	269.5	264.3
1010	181.9	191.7	230.3	224.7	270.3	264.7
1020	182.9	195.3	233.1	225.0	273.1	265.0
1030	183.8	196.3	233.8	225.4	273.8	265.4
1040	184.7	197.3	234.6	225.7	274.6	265.7
1050	185.6	198.3	235.4	226.0	275.4	266.0
1060	186.5	199.3	236.1	226.3	276.1	266.3
1070	187.3	200.2	236.8	226.7	276.8	266.7
1080	188.2	201.1	237.6	227.0	277.6	267.0
1090	189.0	202.0	238.3	227.3	278.3	267.3
1100	189.9	203.0	239.0	227.6	279.0	267.6
1110	190.7	203.9	239.7	228.0	279.7	268.0
1120	191.5	204.7	240.4	228.3	280.4	268.3
1130	192.3	205.6	241.1	228.6	281.1	268.6
1140	193.1	206.5	241.8	229.0	281.8	269.0
1150	193.9	207.3	242.5	229.3	282.5	269.3
1160	194.7	208.2	243.2	229.6	283.2	269.6
1170	195.5	209.0	243.8	229.9	283.8	269.9

TABLE I-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 100°F/HR
FOR FIGURE I-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
1180	196.2	209.8	244.5	230.3	284.5	270.3
1190	197.0	210.6	245.1	230.6	285.1	270.6
1200	197.7	211.4	245.8	230.9	285.8	270.9
1210	198.5	212.2	246.4	231.2	286.4	271.2
1220	199.2	213.0	247.1	231.5	287.1	271.5
1230	199.9	213.8	247.7	231.8	287.7	271.8
1240	200.6	214.5	248.3	232.1	288.3	272.1
1250	201.3	215.3	248.9	232.5	288.9	272.5
1260	202.0	216.0	249.6	232.8	289.6	272.8
1270	202.7	216.8	250.2	233.1	290.2	273.1
1280	203.4	217.5	250.8	233.4	290.8	273.4
1290	204.1	218.2	251.4	233.7	291.4	273.7
1300	204.8	219.0	252.0	234.0	292.0	274.0
1310	205.4	219.7	252.5	234.3	292.5	274.3
1320	206.1	220.4	253.1	234.6	293.1	274.6
1330	206.8	221.1	253.7	234.9	293.7	274.9
1340	207.4	221.8	254.3	235.2	294.3	275.2
1350	208.1	222.4	254.8	235.5	294.8	275.5
1360	208.7	223.1	255.4	235.8	295.4	275.8
1370	209.3	223.8	256.0	236.1	296.0	276.1
1380	209.9	224.5	256.5	236.4	296.5	276.4
1390	210.6	225.1	257.1	236.7	297.1	276.7
1400	211.2	225.8	257.6	237.0	297.6	277.0

APPENDIX J

P-T LIMIT CURVES AND DATA TABULATION

CURVE A-20°F/HR Heatup/Cooldown

CURVES B AND C-200°F/HR Heatup/Cooldown

22 EFPY

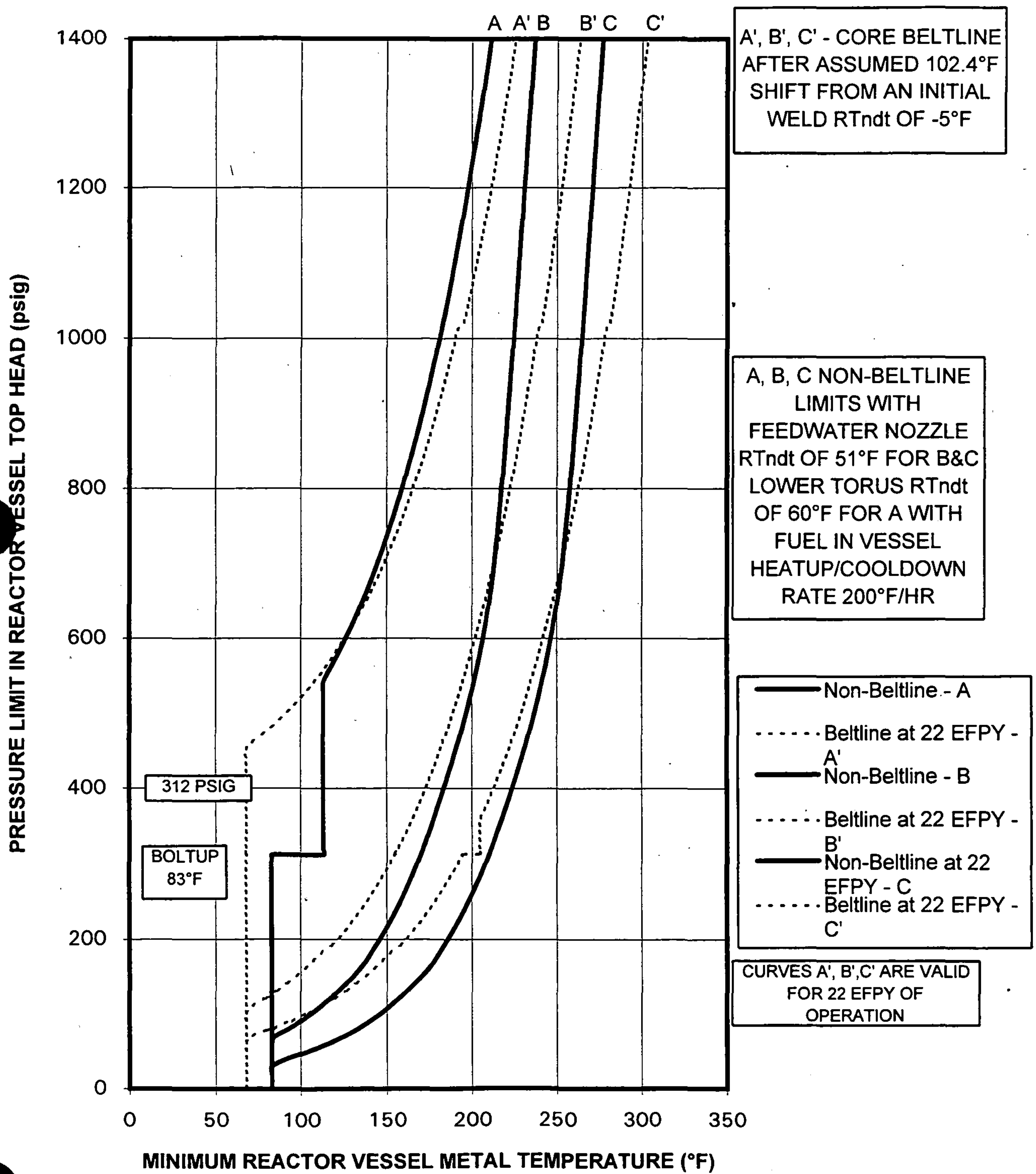

Figure J-1: P-T Limit Curves for 200°F Heatup/Cooldown

TABLE J-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE J-1

PRESSURE (PSIG)	NON-BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	22 EFPY BELTLINE CURVE C (°F)	NON-BELTLINE CURVE C (°F)
0	83.0	68.0	68.0	83.0	68.0	83.0
10	83.0	68.0	68.0	83.0	68.0	83.0
20	83.0	68.0	68.0	83.0	68.0	83.0
30	83.0	68.0	68.0	83.0	68.0	83.0
40	83.0	68.0	68.0	83.0	68.0	91.0
50	83.0	68.0	68.0	83.0	68.0	104.0
60	83.0	68.0	68.0	83.0	68.0	115.0
70	83.0	68.0	68.0	84.5	71.4	124.5
80	83.0	68.0	68.0	92.7	84.0	132.7
90	83.0	68.0	68.0	99.7	94.6	139.7
100	83.0	68.0	68.0	105.8	103.8	145.8
110	83.0	68.0	71.9	111.4	111.9	151.4
120	83.0	68.0	79.2	116.3	119.2	156.3
130	83.0	68.0	85.7	121.1	125.7	161.1
140	83.0	68.0	91.7	125.7	131.7	165.7
150	83.0	68.0	97.3	130.0	137.3	170.0
160	83.0	68.0	102.4	133.9	142.4	173.9
170	83.0	68.0	107.1	137.3	147.1	177.3
180	83.0	68.0	111.6	140.3	151.6	180.3
190	83.0	68.0	117.7	143.1	157.7	183.1
200	83.0	68.0	121.7	145.8	161.7	185.8
210	83.0	68.0	125.4	148.5	165.4	188.5
220	83.0	68.0	128.9	151.1	168.9	191.1
230	83.0	68.0	132.2	153.4	172.2	193.4
240	83.0	68.0	135.4	155.7	175.4	195.7
250	83.0	68.0	138.5	157.9	178.5	197.9
260	83.0	68.0	141.4	160.0	181.4	200.0
270	83.0	68.0	144.2	162.0	184.2	202.0
280	83.0	68.0	146.9	164.0	186.9	204.0
290	83.0	68.0	149.5	165.9	189.5	205.9

TABLE J-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE J-1

PRESSURE	NON-BELTLINE	22 EFPY BELTLINE	22 EFPY BELTLINE	UPPER VESSEL	22 EFPY BELTLINE	NON-BELTLINE
	CURVE A	CURVE A	CURVE B	CURVE B	CURVE C	CURVE C
(PSIG)	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)
300	83.0	68.0	152.0	167.7	192.0	207.7
310	83.0	68.0	154.4	169.5	194.4	209.5
312.5	83.0	68.0	155.0	169.9	195.0	209.9
312.5	113.0	68.0	155.0	169.9	204.7	209.9
320	113.0	68.0	156.7	171.2	204.7	211.2
330	113.0	68.0	159.0	172.8	204.7	212.8
340	113.0	68.0	161.2	174.4	204.7	214.4
350	113.0	68.0	163.3	176.0	204.7	216.0
360	113.0	68.0	165.3	177.5	205.3	217.5
370	113.0	68.0	167.3	179.0	207.3	219.0
380	113.0	68.0	169.3	180.5	209.3	220.5
390	113.0	68.0	171.2	182.0	211.2	222.0
400	113.0	68.0	173.0	183.5	213.0	223.5
410	113.0	68.0	174.8	185.0	214.8	225.0
420	113.0	68.0	176.5	186.4	216.5	226.4
430	113.0	68.0	178.2	187.8	218.2	227.8
440	113.0	68.0	179.9	189.2	219.9	229.2
450	113.0	68.0	181.5	190.5	221.5	230.5
460	113.0	71.4	183.1	191.8	223.1	231.8
470	113.0	77.1	184.6	193.1	224.6	233.1
480	113.0	82.4	186.1	194.3	226.1	234.3
490	113.0	87.2	187.6	195.5	227.6	235.5
500	113.0	91.8	189.1	196.7	229.1	236.7
510	113.0	96.1	190.5	197.8	230.5	237.8
520	113.0	100.1	191.9	198.9	231.9	238.9
530	113.0	103.9	193.2	200.0	233.2	240.0
540	113.0	107.5	194.6	201.0	234.6	241.0
550	114.7	110.9	195.9	202.0	235.9	242.0
560	117.2	114.2	197.2	203.0	237.2	243.0
570	119.5	117.3	198.4	203.9	238.4	243.9

TABLE J-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE J-1

PRESSURE (PSIG)	NON-BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	22 EFPY BELTLINE CURVE C (°F)	NON-BELTLINE CURVE C (°F)
580	121.8	120.3	199.7	204.8	239.7	244.8
590	124.0	123.1	200.9	205.7	240.9	245.7
600	126.1	125.9	202.1	206.5	242.1	246.5
610	128.2	128.5	203.3	207.3	243.3	247.3
620	130.2	131.0	204.4	208.1	244.4	248.1
630	132.1	133.5	205.6	208.8	245.6	248.8
640	134.0	135.9	206.7	209.5	246.7	249.5
650	135.9	138.1	207.8	210.2	247.8	250.2
660	137.7	140.4	208.9	210.8	248.9	250.8
670	139.4	142.5	209.9	211.4	249.9	251.4
680	141.1	144.6	211.0	212.0	251.0	252.0
690	142.8	146.6	212.0	212.5	252.0	252.5
700	144.4	148.6	213.0	213.0	253.0	253.0
710	146.0	150.5	214.0	213.5	254.0	253.5
720	147.6	152.3	215.0	214.0	255.0	254.0
730	149.1	154.1	216.0	214.4	256.0	254.4
740	150.6	155.9	217.0	214.9	257.0	254.9
750	152.0	157.6	217.9	215.3	257.9	255.3
760	153.5	159.3	218.9	215.7	258.9	255.7
770	154.8	160.9	219.8	216.2	259.8	256.2
780	156.2	162.5	220.7	216.6	260.7	256.6
790	157.6	164.1	221.6	217.0	261.6	257.0
800	158.9	165.6	222.5	217.4	262.5	257.4
810	160.2	167.1	223.4	217.8	263.4	257.8
820	161.4	168.6	224.2	218.2	264.2	258.2
830	162.7	170.0	225.1	218.5	265.1	258.5
840	163.9	171.4	225.9	218.9	265.9	258.9
850	165.1	172.8	226.8	219.2	266.8	259.2
860	166.3	174.1	227.6	219.6	267.6	259.6
870	167.5	175.5	228.4	219.9	268.4	259.9

TABLE J-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE J-1

PRESSURE (PSIG)	NON-BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	22 EFPY BELTLINE CURVE C (°F)	NON-BELTLINE CURVE C (°F)
880	168.6	176.7	229.2	220.3	269.2	260.3
890	169.7	178.0	230.0	220.6	270.0	260.6
900	170.8	179.3	230.8	220.9	270.8	260.9
910	171.9	180.5	231.6	221.3	271.6	261.3
920	173.0	181.7	232.3	221.6	272.3	261.6
930	174.0	182.9	233.1	222.0	273.1	262.0
940	175.1	184.1	233.9	222.3	273.9	262.3
950	176.1	185.2	234.6	222.6	274.6	262.6
960	177.1	186.3	235.3	223.0	275.3	263.0
970	178.1	187.4	236.1	223.3	276.1	263.3
980	179.1	188.5	236.8	223.7	276.8	263.7
990	180.0	189.6	237.5	224.0	277.5	264.0
1000	181.0	190.7	238.2	224.3	278.2	264.3
1010	181.9	191.7	238.9	224.7	278.9	264.7
1020	182.9	195.3	241.4	225.0	281.4	265.0
1030	183.8	196.3	242.1	225.4	282.1	265.4
1040	184.7	197.3	242.7	225.7	282.7	265.7
1050	185.6	198.3	243.4	226.0	283.4	266.0
1060	186.5	199.3	244.1	226.3	284.1	266.3
1070	187.3	200.2	244.7	226.7	284.7	266.7
1080	188.2	201.1	245.4	227.0	285.4	267.0
1090	189.0	202.0	246.0	227.3	286.0	267.3
1100	189.9	203.0	246.7	227.6	286.7	267.6
1110	190.7	203.9	247.3	228.0	287.3	268.0
1120	191.5	204.7	247.9	228.3	287.9	268.3
1130	192.3	205.6	248.6	228.6	288.6	268.6
1140	193.1	206.5	249.2	229.0	289.2	269.0
1150	193.9	207.3	249.8	229.3	289.8	269.3
1160	194.7	208.2	250.4	229.6	290.4	269.6
1170	195.5	209.0	251.0	229.9	291.0	269.9

TABLE J-1. Dresden 2 & 3 and Quad Cities 1 & 2 P-T Curve Values

REQUIRED TEMPERATURES AT 200°F/HR
FOR FIGURE J-1

PRESSURE (PSIG)	NON-BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE A (°F)	22 EFPY BELTLINE CURVE B (°F)	UPPER VESSEL CURVE B (°F)	22 EFPY BELTLINE CURVE C (°F)	NON-BELTLINE CURVE C (°F)
1180	196.2	209.8	251.6	230.3	291.6	270.3
1190	197.0	210.6	252.2	230.6	292.2	270.6
1200	197.7	211.4	252.8	230.9	292.8	270.9
1210	198.5	212.2	253.3	231.2	293.3	271.2
1220	199.2	213.0	253.9	231.5	293.9	271.5
1230	199.9	213.8	254.5	231.8	294.5	271.8
1240	200.6	214.5	255.1	232.1	295.1	272.1
1250	201.3	215.3	255.6	232.5	295.6	272.5
1260	202.0	216.0	256.2	232.8	296.2	272.8
1270	202.7	216.8	256.7	233.1	296.7	273.1
1280	203.4	217.5	257.3	233.4	297.3	273.4
1290	204.1	218.2	257.8	233.7	297.8	273.7
1300	204.8	219.0	258.4	234.0	298.4	274.0
1310	205.4	219.7	258.9	234.3	298.9	274.3
1320	206.1	220.4	259.4	234.6	299.4	274.6
1330	206.8	221.1	260.0	234.9	300.0	274.9
1340	207.4	221.8	260.5	235.2	300.5	275.2
1350	208.1	222.4	261.0	235.5	301.0	275.5
1360	208.7	223.1	261.5	235.8	301.5	275.8
1370	209.3	223.8	262.0	236.1	302.0	276.1
1380	209.9	224.5	262.5	236.4	302.5	276.4
1390	210.6	225.1	263.0	236.7	303.0	276.7
1400	211.2	225.8	263.5	237.0	303.5	277.0

APPENDIX K

OPERATING AND TEMPERATURE MONITORING REQUIREMENTS

K.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.

Monitoring the bottom head separately from the beltline region may reduce the required pressure test temperature in these regions. 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 which showed that thermocouples on the vessel near the feedwater nozzles, or temperature measurements of water in the recirculation loops provide good estimates of the beltline temperature during pressure testing. Thermocouples on the RPV flange to shell junction outside surface should be used to monitor compliance with upper vessel curve. Thermocouples on the bottom head outside surface should be used to monitor compliance with bottom head curves. A description of these measurements is given in GE SIL 430, attached in Appendix L. First, however, it should be determined whether there are significant temperature differences between the beltline region and the bottom head region.

K.2 DETERMINING WHICH CURVE TO FOLLOW

The following subsections outline the criteria needed for determining which curve is governing during different situations.

K.2.1 Curve A: Pressure Test

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

K.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 vessel is heating up or cooling down faster than 20°F per hour during a hydrotest and when the core is not critical.

K.2.3 Curve C: Core Critical Operation

The operator must obey this curve whenever the core is critical. An exception to this principle is for low-level physics tests; Curve B must be obeyed during these situations. For the purposes of the P-T curves, the core can be considered critical when more than one control rod is withdrawn.

K.3 REACTOR OPERATION VERSUS OPERATING LIMITS

For most reactor operating conditions, 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 (100°F or 200°F in one hour period heat-up)
- Shutdown (100°F or 200°F in one hour period cooldown)
- Recirculation pump trip, bottom head stratification (Curve B compliance)

APPENDIX L

GE SIL 430

NUCLEAR SERVICES | INFORMATION LETTER
NUCLEAR SYSTEMS & SERVICES OPERATIONS • SAN JOSE, CALIFORNIA

September 27,1985
File Tab B

SIL No. 430
Category 4

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 temeprature 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.

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Service Information and Analysis

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Customer Service Information

Product Reference:
B21-Nuclear Boiler

GENERAL ELECTRIC

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 100F°/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 100F°/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 10-15F° lower than steam dome saturation temperature) caused primarily by FW flow variations.
	Alternate measurement for RPV drain line temperature (can use to comply with ΔT limit between steam dome saturation temperature and bottom head drain line temperature).	
RHR heat exchanger inlet coolant temperature	Alternate measurement for Tech Spec 100F°/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 ΔT limit between steam dome saturated temperature and drain line coolant temperature.	Must have drain line flow. Otherwise, lower than actual temperature and higher ΔT's will be indicated. ΔT limit is 100F° for BWR6s and 145F° 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).

Measurement	Use	Limitations
	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.
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.
Bottom head outside surface T/Cs	One of two 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 ΔT limits for vessel heatup and cooldown should be checked during initial plant startup tests when initial RPV vessel heatup and cooldown tests are run.