ENCLOSURE 1

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NOS. 1 AND 2
DOCKET NOS. 50-325 AND 50-324/LICENSE NOS. DPR-71 AND DPR-62
REQUEST FOR LICENSE AMENDMENTS TO
REVISE TECHNICAL SPECIFICATION
PRESSURE-TEMPERATURE LIMIT CURVES

Basis For Change Request

In accordance with the Code of Federal Regulations, Title 10, Parts 50.90 and 2.101, Carolina Power & Light (CP&L) Company is requesting a revision to the Technical Specifications (TS) for the Brunswick Steam Electric Plant (BSEP), Unit Nos. 1 and 2. The proposed license amendments revise the reactor coolant system (RCS) pressure-temperature (P-T) limit curves for operation up to 32 effective full power years (EFPY).

In the BSEP TS, Figure 3.4.9-1 provides RCS P-T limits applicable to normal operation with the core not critical. Figure 3.4.9-2 provides RCS P-T limits applicable to normal operation with the core critical. Figure 3.4.9-3 provides RCS P-T limits applicable to hydrostatic and leak tests. Each existing TS figure is valid for use up to 19 EFPY.

Figure 3.4.9-1 is being revised to provide RCS P-T limits applicable to normal operation with the core not critical that are valid up to 32 EFPY. Figure 3.4.9-2 is being revised to provide RCS P-T limits applicable to normal operation with the core critical that are valid up to 32 EFPY. In order to provide future flexibility in performing hydrostatic and leak tests, three separate P-T limits curves applicable to hydrostatic and leak tests are being proposed. Figure 3.4.9-3 is being revised to provide P-T limits applicable to hydrostatic and leak tests that are valid up to 20 EFPY. New Figures 3.4.9-4 and 3.4.9-5 are being added to provide P-T limits applicable to hydrostatic and leak tests that are valid up to 24 EFPY and 32 EFPY, respectively. To support the addition of Figures 3.4.9-4 and 3.4.9-5, Surveillance Requirement 3.4.9.2.a is being revised to require completion of the following action within 30 minutes:

> [Verify] RCS pressure and temperature are within the applicable limits specified in Figures 3.4.9-3, 3.4.9-4, or 3.4.9-5, as applicable.

The revised P-T limits curves provide limitations valid until 32 EFPY. Each TS P-T limit figure contains two curves, a beltline curve and a bottom head curve. The beltline curve is based on the N16A/B nozzles; the N16A/B nozzles are the limiting reactor pressure vessel (RPV) material and are located in the beltline region. The bottom head curves define the P-T limits for the bottom head region of the RPV.

In accordance with 10 CFR 50, Appendix G, the BSEP TS limit changes in RCS temperature and pressure during heatup and cooldown to within the design assumptions and stress limits for cyclic operation. These limits are defined by the P-T limit curves for heatup, cooldown, and hydrostatic and leak testing. These curves are used during heatup and cooldown maneuvering, when P-T indications are monitored and compared to the applicable P-T limits curve to determine that operation is within allowable limits.

The P-T limits curves in the BSEP TS were established in accordance with 10 CFR 50, Appendix G, and the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Appendix G, to provide adequate margin to brittle failure during normal operation, anticipated operational occurrences, and system hydrostatic tests.

The revised P-T limits were developed using the stress intensity factor K_{IC} for the allowable material fracture toughness as permitted by ASME Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves for ASME Section XI, Division I," as an alternative method for determining the fracture toughness of RPV materials for use in determining P-T limits. An exemption to permit use of ASME Code Case N-640 for this application has been previously approved by the NRC in a letter dated October 3, 2001, from Mr. Donnie J. Ashley (NRC) to Mr. J. S. Keenan (CP&L) (i.e., ADAMS Accession Number ML012760157).

The adjusted reference temperature (ART) values for the limiting materials were developed using the methodology in NRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials." The detailed basis for development of the revised P-T limits curves is contained in CP&L Calculation 0B11-0005, Revision 1, "Development of RPV Pressure-Temperature Curves For BNP Units 1 & 2 For Up To 32 EFPY of Plant Operation." A copy of CP&L Calculation 0B11-0005 is provided Enclosure 2 of this letter.

CP&L Calculation Number 0B11-0012, Revision 0, evaluates the impact of neutron fluence on the beltline region of the BSEP, Unit 1 and Unit 2 reactor pressure vessels, including the impact of extended power uprate. Extended power uprate (i.e., operation up to 2923 megawatts thermal (MWt)) was authorized by NRC License Amendments 222 and 247 for BSEP, Units 1 and 2, respectively. The neutron fluence evaluation has been performed using the methodologies described in NRC Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," March 2001. A copy of CP&L Calculation Number 0B11-0012 is provided in Enclosure 3.

NRC Regulatory Issue Summary 2000-16, issued September 7, 2000, announced the availability of Revision 2 to the Reactor Vessel Integrity Database (RVID). The RVID, which was developed following NRC review of licensee responses to NRC Generic Letter 92-01, Revision 1, "Reactor Vessel Structural Integrity," consolidates data reflecting the status of reactor pressure vessel integrity for both pressurized water reactors and boiling water reactors. The RVID information for BSEP, Units 1 and 2, does not currently include data reflecting the effects of a power uprate to 2923 MWt (i.e., authorized by NRC License Amendments 222 and 247). Following NRC approval of the proposed P-T limit curves, CP&L plans to provide revised information to update information contained in the RVID based on the changes to neutron fluence associated with extended power uprate.

The revised P-T limit curves also include a correction factor for instrument uncertainty for both temperature and pressure. An evaluation of the impact of instrument uncertainty on the revised P-T limit curves is included in CP&L Calculation Number 0B21-1029, Revision 0, "Instrument Uncertainty for RCS Pressure/Temperature Limits Curve," a copy of which is provided in Enclosure 4.

ENCLOSURE 2

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NOS. 1 AND 2
DOCKET NOS. 50-325 AND 50-324/LICENSE NOS. DPR-71 AND DPR-62
REQUEST FOR LICENSE AMENDMENTS TO REVISE TECHNICAL SPECIFICATION
PRESSURE-TEMPERATURE LIMITS CURVES

CP&L Calculation 0B11-0005, Revision 1
"Development of RPV Pressure-Temperature Curves
For BNP Units 1 & 2
For Up To 32 EFPY of Plant Operation"

SYSTEM#: 1005

CALC. SUB-TYPE: RME

PRIORITY CODE: 4

QUALITY CLASS: A

CAROLINA POWER & LIGHT COMPANY

0B11-0005
(CALCULATION #)

Development of RPV Pressure-Temperature Curves For BNP Units 1 & 2 For Up To 32 EFPY of Plant Operation
(TITLE INCLUDING STRUCTURE/SYSTEM/COMPONENT)

BRUNSWICK NUCLEAR POWER PLANT

UNIT 0

APPROVAL

Revision: 1

Prepared By: Phillip Gore Date: 6-10-02

Reviewed By: Larry Yemma Date: 6-10-02

Design Supervisor: WB [illegible] Date: 6-10-02

(For Vendor Calculations)

Vendor Structural Integrity Associates Vendor Calculation Number CPL-54Q-303, Rev. 1 and Report SIR-00-132, Rev. 1

Owner's Review By Phillip Gore Date: 6-10-02

List of Vendor Pages (N/A if List of Effective Pages is added) N/A

List of Effective Pages

Page No.	Rev. No	Page No	Rev. No	ATTACHMENTS	
1	1			Number/Rev.	Number of Pages
2	1			1/1	31 (including cover sheet)
3	1			2/1	62 (including cover sheet)
4	1			3/1	11 (including cover sheet)
5	1			4/1	4 (including cover sheet)
6	1				
				AMENDMENTS	
				Letter/Rev	Number of Pages

Revision Summary

Rev. #	Date	Revision Summary
0	11/06/00	Original issue of calculation.
1	6/10/02	Revises pressure/temperature curves for extended power uprate (EPU) conditions.

Table of Contents

Attachments

No.	Description	Pages
1	SIA Report SIR-00-132, Rev. 1, " Brunswick Pressure-Temperature Curves"	31
2	SIA File No. W-CPL-54Q-303, Rev. 1, "Development of Updated P-T Curves For 32 EFPY"	62
3	Development of Pressure Test Curves for 20 and 24 Effective Full Power Years	11
4	Record of Lead Reviews	4

Purpose

This calculation incorporates the vendor documentation for revised pressure-temperature curves into the CP&L document system. New pressure-temperature curves for core not critical, core critical, and pressure test conditions have been developed to bound extended power uprate (EPU) conditions for up to 32 effective full power years (EFPY) of operation. This vendor documentation is included as Attachments 1 and 2 to this calculation. Additionally, utilizing the methodology set forth in Attachment 2, additional pressure test curves have been developed for 20 and 24 EFPY in order to minimize the pressure test temperature during scheduled pressure tests. Development of these curves is discussed in the body of this calculation.

References

References are included in Attachment 1 and Attachment 2.

Body of Calculation

Attachments 1 and 2 provide the vendor documentation for a full set of updated pressure-temperature curves (pressure test, core not critical and core critical) for BNP Units 1 and 2 for 32 EFPY of operation. The curves were developed in accordance with the 1989 ASME Code, Section XI, Appendix G and ASME Code Case N-640 which allows the use of K_{IC} for the allowable fracture toughness. ART_{NDT} estimates used in the development of the curves were determined in accordance with Regulatory Guide 1.99, Revision 2. The fluence estimates used in ART_{NDT} determination account for future planned power uprates up to 120% of original license thermal power at both Brunswick units. Values of 10° F and 15 psig have been included in the development of the curves to account for instrument uncertainty.

Additional pressure test curves were developed for 20 and 24 EFPY in order to minimize the test temperature during scheduled pressure tests. These curves were developed utilizing the methodology of the Attachment 1 and 2 reports. The computed fluence values for the N16 nozzles at 20 and 24 EFPY are contained on page 2 of Attachment 3. These values were interpolated from values contained in the Westinghouse fluence evaluation report (reference 5 of Attachment 1). The 20 and 24 EFPY fluence values were then used to compute ART_{NDT}, the results of which are shown in the table on page 3 of Attachment 3. The ART_{NDT} values were then input into the vendor's pressure-temperature curve calculation spreadsheet to produce the 20 and 24 EFPY pressure test curves. The results are contained in Attachment 3. These newly computed values are consistent with the results previously computed for 32 EFPY.

Conclusions

This calculation provides pressure-temperature curves for core critical, core not critical, and pressure test conditions for Unit 1 and Unit 2 for up to 32 effective full power years of operation.

Attachment 1

Structural Integrity Report SIR-00-132, Rev. 1

31 pages (including this sheet)

6595 S. Dayton Street
Suite 3000
Englewood, CO 80111-6128
Phone: 303-792-0077
Fax: 303-792-2158
www.structint.com
ckobilan@structint.com

May 7, 2002
CMK-02-003
SIR-00-132, Rev. 1

Mr. Blane Wilton
Brunswick Steam Electric Plant
Carolina Power & Light Company
P.O. Box 10429
Southport, NC 28461

Subject: Brunswick Pressure-Temperature Curves.

Dear Blane:

The Reference [1] calculation (attached) documents the revised set of pressure-temperature (P-T) curves developed for the Brunswick Steam Electric Plant, Units 1 and 2 (BSEP-1 and BSEP-2). This work was performed in accordance with the referenced contract, and includes a full set of updated P-T curves (i.e., pressure test, core not critical, and core critical conditions) for both BSEP units for 32 effective full power years (EFPY). The curves were developed in accordance with the 1989 ASME Code, Section XI, Appendix G [2] and ASME Code Case N-640 [3], which allows the use of K_{Ic} for the allowable material fracture toughness.

The inputs, methodology, and results for this effort are summarized in the sections that follow.

ART_{NDT} DETERMINATION

ART_{NDT} estimates were developed for the BSEP reactor pressure vessel (RPV) materials in accordance with Regulatory Guide 1.99, Revision 2 (RG 1.99) [4] for 32 EFPY, and are shown in Table 1 for both BSEP units. The inputs used for the calculations were based on the data documented in Reference [5]. The fluence estimates used in Table 1 have been scaled appropriately to account for future planned power uprates at both BSEP units.

P-T CURVE METHODOLOGY

The P-T curve methodology is based on the requirements of References [2], [3], [6], and [7]. The approach used for calculating the P-T curves is summarized below:

a. Assume a fluid temperature, T.

b. For the temperature, T, assumed in step (a), compute the temperature at the assumed flaw tip, $T_{1/4t}$ (i.e., 1/4t into the vessel wall). This is accomplished by adding a temperature drop term, $\Delta T_{1/4t}$, to T. The value of $\Delta T_{1/4t}$ is zero for the pressure test P-T curves (e.g., these tests are essentially isothermal), and is determined via heat transfer analysis for the other curves.

c. Calculate the allowable stress intensity factor, K_{IC} (as allowed per Reference [3]), based on $T_{1/4t}$ using the following relationship:

$$K_{IC} = 20.734\ e^{[0.02\ (T-ART)]} + 33.2$$

where:

where:	T	=	$T_{1/4t}$ (°F)
	ART	=	adjusted reference temperature for location under consideration and desired EFPY from Table 1 (°F)
	K_{IC}	=	allowable stress intensity factor (ksi√inch)

d. Calculate the allowable pressure stress intensity factor, K_{IP}, using the appropriate relationship for the P-T curve under consideration:

$K_{IP} = K_{IC}/1.5$ for Curve A (i.e., pressure-test curve)
$K_{IP} = (K_{IC}-K_{IT})/2.0$ for Curves B and C (i.e., core not critical and core critical curves)

where:	K_{IT}	=	thermal stress intensity factor (ksi√inch)
		=	$M_t \times \Delta T_w$ per Figure G-2214-2 of Reference [2] for the beltline and bottom head regions.
		=	5.4 ksi√inch for the N16A/B nozzles based on finite element analysis*
	ΔT_w	=	through-wall temperature drop, determined by heat transfer analysis (°F)
	M_t	=	factor from Figure G-2214-2 of Reference [2]
	K_{IP}	=	allowable pressure stress intensity factor (ksi√inch)

*NOTE: The value of K_{IT} was reviewed and still applies for EPU conditions.

e. Compute the pressure, P. The relationship for the pressure, P, to the allowable pressure stress intensity factor, K_{IP}, is as follows:

$$K_{IP} = M_m\, \sigma_m + M_b\, \sigma_b$$

where:	M_m	=	membrane stress correction factor from Figure G-2214-1 of Reference [2]
	σ_m	=	membrane stress due to pressure (ksi)
		=	PR/t for the beltline region.

	=	3.0PR/(2t) = 1.5PR/t for the spherical bottom head assuming a stress concentration factor of 3.0 for the bottom head penetrations. For the N16A/B nozzles, K_{IP} was determined directly based on finite element results, as shown below.
P	=	pressure (ksi)
R	=	maximum vessel radius (inches)
t	=	minimum vessel wall thickness (inches)
M_b	=	bending stress correction factor = $(2/3)M_m$
σ_b	=	bending stress due to pressure (ksi)
	=	0 for a thin-walled vessel

Thus, $P = K_{IP}t/(RM_m)$ for the beltline region
$P = K_{IP}t/(1.5RM_m)$ for the bottom head region
$P = 21.53\ K_{IP}$ for the N16A/B nozzles based on finite element analysis

f. Repeat steps (a) through (e) for other temperatures to generate a series of P-T points for each region.

g. Adjust for any applicable instrument errors for temperature and pressure from T and P, respectively. The resulting pressure and temperature series constitutes the P-T curve. The P-T curve relates the minimum required reactor fluid temperature to the reactor pressure for each region.

The following additional requirements were used to define the lower portion of the P-T curves. These limits are established by the discontinuity regions of the vessel (i.e., flanges), and are specified in Reference [6]:

For Pressure Test Conditions:

- Thermal stresses were assumed to be negligible during the pressure test condition and were therefore not considered.
- If P is greater than 20% of the pre-service hydro test pressure, the temperature must be greater than RT_{NDT} of the limiting flange material + 90°F. The pre-service hydro test pressure was 1,563 psig.
- If P is less than or equal to 20% of the pre-service hydro test pressure, the minimum temperature is typically greater than or equal to the RT_{NDT} of the limiting flange material + 60°F. The additional 60°F margin above that recommended in Reference [6] has been a standard recommendation by GE for the BWR industry. For the BSEP flange material, this minimum temperature would be 76°F (i.e., 16 + 60°F) for Unit 1, and 70°F (i.e., 10 + 60°F) for Unit 2. Since the 60°F margin is only a recommendation,

the minimum temperature for Unit 1 was set to 70°F to match Unit 2 and be consistent with past work.

For Core Not Critical Conditions:

- If P is greater than 20% of the pre-service hydro test pressure, the temperature must be greater than RT_{NDT} of the limiting flange material + 120°F.
- If P is less than or equal to 20% of the pre-service hydro test pressure, the minimum temperature is typically greater than or equal to the RT_{NDT} of the limiting flange material + 60°F. The additional 60°F margin above that recommended in Reference [6] has been a standard recommendation by GE for the BWR industry. For the BSEP flange material, this minimum temperature is 70°F for Unit 1 and 70°F for Unit 2, as identified above.

For Core Critical Conditions:

- Per the requirements of Table 1 of Reference [6], the core critical P-T limits must be 40°F above any Pressure Test or Core Not Critical curve limits. Core Not Critical conditions are more limiting than Pressure Test conditions, so Core Critical conditions are equal to Core Not Critical conditions plus 40°F.
- Another requirement of Table 1 of Reference [6] (or actually an allowance for the BWR), concerns minimum temperature for initial criticality in a startup. Given that water level is normal, BWRs are allowed initial criticality at the closure flange region temperature (RT_{NDT} + 60°F) if the pressure is below 20% of the pre-service hydro test pressure. This corresponds to 76°F for Unit 1 and 70°F for Unit 2, as identified above.
- Also per Table 1 of Reference [6], at pressures above 20% of the pre-service hydro test pressure, the Core Critical curve temperature must be at least that required for the pressure test (Pressure Test Curve at a conservative value of 1,100 psig). As a result of this requirement, the Core Critical curve must have a step at a pressure equal to 20% of the pre-service hydro pressure to the temperature required by the Pressure Test curve at 1,100 psig, or 40°F, whichever is greater.

HEAT TRANSFER ANALYSIS

Heat transfer analysis was undertaken to estimate the ΔT_w and $\Delta T_{1/4t}$ terms identified above. The P-T curves are developed considering a 100°F/hr heatup/cooldown. Therefore, a 100°F/hr cooldown from 550°F to 120°F was evaluated. Material properties were taken from the ASME Code [8] at an approximate average temperature of 350°F. The results at the end of the cooldown were conservatively selected so that maximum steady state temperature differences were achieved.

The heat transfer analysis results for all regions, including those for the N16A/B nozzles, are shown in Table 2. This analysis was reviewed and still applies for the EPU conditions

P-T CURVES

The resulting P-T curves and the detailed input and output are contained in Appendix A for BSEP-1, and Appendix B for BSEP-2. Only the limiting curves that represent both the N16A/B nozzles and beltline are plotted for all cases, as the N16A/B nozzles are limiting for the beltline region.

DEMONSTRATION OF BOUNDING ASSESSMENT FOR BOTTOM HEAD

Recent questions from the U. S. Nuclear Regulatory Commission (NRC) have indicated that updated P-T curves should bound any heatup/cooldown rate expected in the bottom head region during a transient event. The NRC bases their position on the definition of an "Anticipated Operational Occurrence" (AOO) in 10CFR50 Appendix A [9], which states: "Anticipated operational occurrences mean those conditions of normal operation which are expected to occur one or more times during the life of the nuclear power unit and include but are not limited to loss of power to all recirculation pumps, tripping of the turbine generator set, isolation of the main condenser, and loss of all offsite power."

Since Brunswick has experienced transient events in which the heatup\cooldown rate in the bottom head region exceeded 100°F/hr, these events may be considered by the NRC to be AOOs. Therefore, the bottom head P-T curves should be developed to account for the maximum heatup/cooldown rate expected. Therefore, an evaluation was performed to assess the adequacy of the 100°F/hr heatup/cooldown rate used in the development of the BSEP P-T curves with respect to AOOs in the bottom head region. The transient shown in Figure 1 was previously established as a bounding transient for the bottom head region for the BSEP reactors [10, 11], and was used as a basis for this evaluation.

In order to evaluate the alternate transient shown in Figure 1, two assessments were made: (1) an assessment for the bottom head region for pressure test conditions, and (2) assessment of transient conditions for the bottom head region for heatup/cooldown conditions.

Assessment of the BSEP-1 bottom head for pressure test conditions is shown in Figure 2, and for heatup/cooldown conditions is shown in Figure 3. In each figure, the existing Tech. Spec. P-T curve (labeled as "Tech Spec"), an independently derived version of the existing Tech. Spec. P-T curve (labeled as "Fixed-ID"), and a P-T curve developed using the alternate transient shown in Figure 1 (labeled as "Allow, ID") are included. Since these results are comparative in nature, the same conclusions are applicable for BSEP-2.

CONCLUSIONS

Based on the results shown in Figures 2 and 3, the following conclusions can be made:

- The P-T curves for a fixed rate of 100°F/hr are bounding compared to the alternate cooldown transient shown in Figure 1. These curves bound all expected operating conditions for the bottom head region, including the transient defined in Figure 1. The transient defined in Figure 1 was developed specifically to cover inadvertent cooldown events in the bottom head region, and to bound all actual operating conditions in the bottom head region.
- Referring to Figure 1, cooldown rates as high as 882°F/hr in the bottom head region have been accommodated. This rate is expected to cover all anticipated operating conditions. Step heatups of 317°F in one minute are also bounded by this assessment, as discussed in References [10] and [11]. Any events that exceed these rates, which is unlikely, are monitored via the Technical Specification pressure-temperature limit tracking procedures, coupled with ASME Code, Section XI, Appendix E evaluation procedures.
- These results are consistent with the conclusions in ASME Code, Section XI, Appendix G [2], where solutions are provided for heatup/cooldown rates of 100°F/hr or less. Appendix G states that "the results would be overly conservative if applied to rapid temperature changes."
- Revised P-T curves for both Brunswick units are contained in Appendices A and B. The bottom head curves for both Brunswick units bound all anticipated operating conditions.

This letter report completes all work associated with the Reference [12] contract. Please don't hesitate to call me if you have any questions.

Prepared By: ______________________
Chris M. Kobilan
Engineering Analyst

Reviewed By: ______________________
B. P. Templeton
Engineering Analyst

Approved By: ______________________
Gary L. Stevens, P. E.
Technical Director

cmk
Attachment
cc: CPL-54Q-106, -402

REFERENCES

1. Structural Integrity Associates Calculation, Revision 1, "Development of Updated P-T Curves For 32 EFPY," SI File No. CPL-54Q-303.

2. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Nonmandatory Appendix G, "Fracture Toughness Criteria for Protection Against Failure," 1989 Edition, No Addenda.

3. ASME Boiler and Pressure Vessel Code, Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, Approved February 26, 1999.

4. USNRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, (Task ME 305-4), May 1988.

5. CP&L Calculation No. 0B11-0012, Revision 0, [Westinghouse Electric Company LLC Report LTR-REA-02-7], "Neutron Exposure Evaluations for the Core Shroud and Pressure Vessel Brunswick Units 1 and 2", January 2002, SI File No. W-CPL-61Q-215.

6. U. S. Code of Federal Regulations, Title 10, Part 50, Appendix G, "Fracture Toughness Requirements," 1-1-98 Edition.

7. WRC Bulletin 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," PVRC Ad Hoc Group on Toughness Requirements, Welding Research Council, August 1972.

8. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Appendices, 1989 Edition, No Addenda.

9. U. S. Code of Federal Regulations, Title 10, Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," 1/1/98.

10. Structural Integrity Associates Calculation No. CPL-40Q-305, Revision 1, "Fracture Toughness Assessment of Bottom Head."

11. Structural Integrity Associates Report No. SIR-96-010, Revision 0, "Justification to Relax Requirements for Recirculation Pump Restart Following a Scram Event Brunswick Steam Electric Plant Units 1 and 2," SI File No. CPL-40Q-401.

12. SIP-01-136, CP&L Purchase Order No. 3744, Task Work Authorization Letter No. 01077B, 9/4/2001.

Table 1
RT_{NDT} Estimates for BSEP

Brunswick Unit 1 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry: Cu (wt %)	Chemistry: Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms: σ_Δ (°F)	Margin Terms: σ_I (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Shell Flange)	600	BV-3085	AFB176	16	0.09	0.88	N/A	N/A	N/A	0.0	32.0	16.0
BOTTOM HEAD	101	C4654	3	10	NR	0.55	N/A	N/A	N/A	0.0	32.0	10.0
NOTE:	The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.											
BELTLINE (Lower Int. Shell)	351	B8496	1	10	0.19	0.58	139.8	72.0	17.0	0.0	32.0	116.0
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-4A,4B	48	0.16	0.82	123.2	38.0	17.0	0.0	32.0	120.0

Fluence Information:

Location	Wall Thickness (inches): Full	Wall Thickness (inches): 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$
(Lower Int. Shell)	5.496	1.374	32.0	2.20E+18	0.719	1.58E+18	0.515
(N16A/B Nozzles)	5.496	1.374	32.0	7.65E+17	0.719	5.50E+17	0.308

Brunswick Unit 2 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry: Cu (wt %)	Chemistry: Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms: σ_Δ (°F)	Margin Terms: σ_I (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Top Head Flange)	706	1L-3335	AYT-173	10	0.11	0.80	N/A	N/A	N/A	0.0	32.0	10.0
BOTTOM HEAD	102	C4890	1A	40	NR	0.56	N/A	N/A	N/A	0.0	32.0	40.0
NOTE:	The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.											
BELTLINE (Lower Shell)	201	C4500	2	10	0.15	0.54	106.7	49.5	17.0	0.0	32.0	93.5
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-3A,3B	40	0.16	0.82	123.2	37.9	17.0	0.0	32.0	111.9

Fluence Information:

Location	Wall Thickness (inches): Full	Wall Thickness (inches): 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10\log f)}$
(Lower Shell)	5.466	1.367	32.0	1.74E+18	0.720	1.25E+18	0.464
(N16A/B Nozzles)	5.466	1.367	32.0	7.63E+17	0.720	5.50E+17	0.308

Table 2
Results of Heat Transfer Analysis

Variable	Beltline	Bottom Head	N16A/B Nozzles
ΔT_w (1)	Unit 1: 154.3 - 127.8 = 26.5°F Unit 2: 154.0 - 127.8 = 26.2°F	Unit 1: 153.2 - 127.7 = 25.5°F Unit 2: 153.5 - 127.7 = 25.8°F	Not required -- finite element solution used.
$\Delta T_{1/4t}$ (2)	Unit 1: 139.5 - 120.0 = 19.5°F Unit 2: 139.3 - 120.0 = 19.3°F	Unit 1: 138.9 - 120.0 = 18.9°F Unit 2: 139.1 - 120.0 = 19.1°F	Unit 1: 20.13°F Unit 2: 20.13°F
K_{IT}	Calc. per ASME Code, Section XI, App. G	Calc. per ASME Code, Section XI, App. G	Unit 1: 5.4 ksi√inch Unit 2: 5.4 ksi√inch

Notes:
1. ΔT_w is the temperature drop across the vessel wall, i.e., outside surface temperature - inside surface temperature.
2. $\Delta T_{1/4t}$ is the temperature difference between the fluid and the 1/4t location.

Figure 1: Alternate Cooldown Transient for BSEP Bottom Head Region

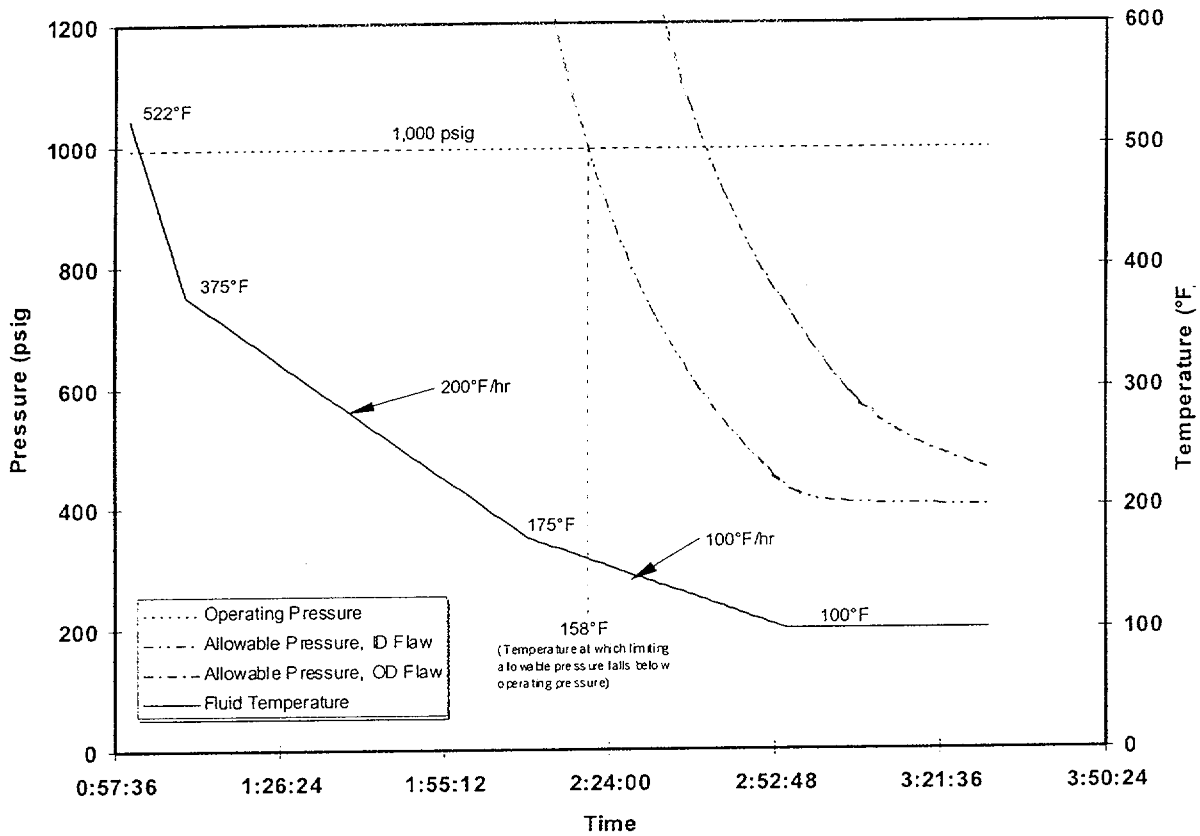


Figure 2: Pressure-Temperature Results for Pressure Test Conditions

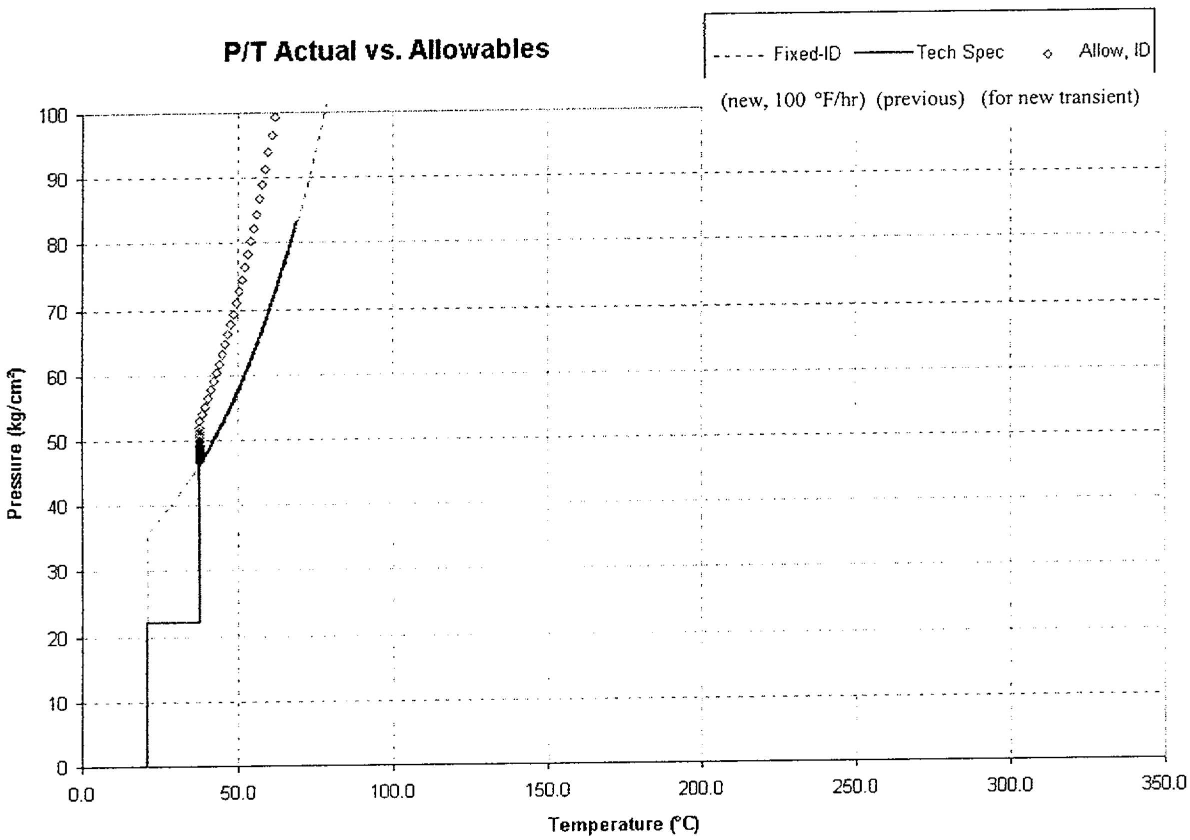
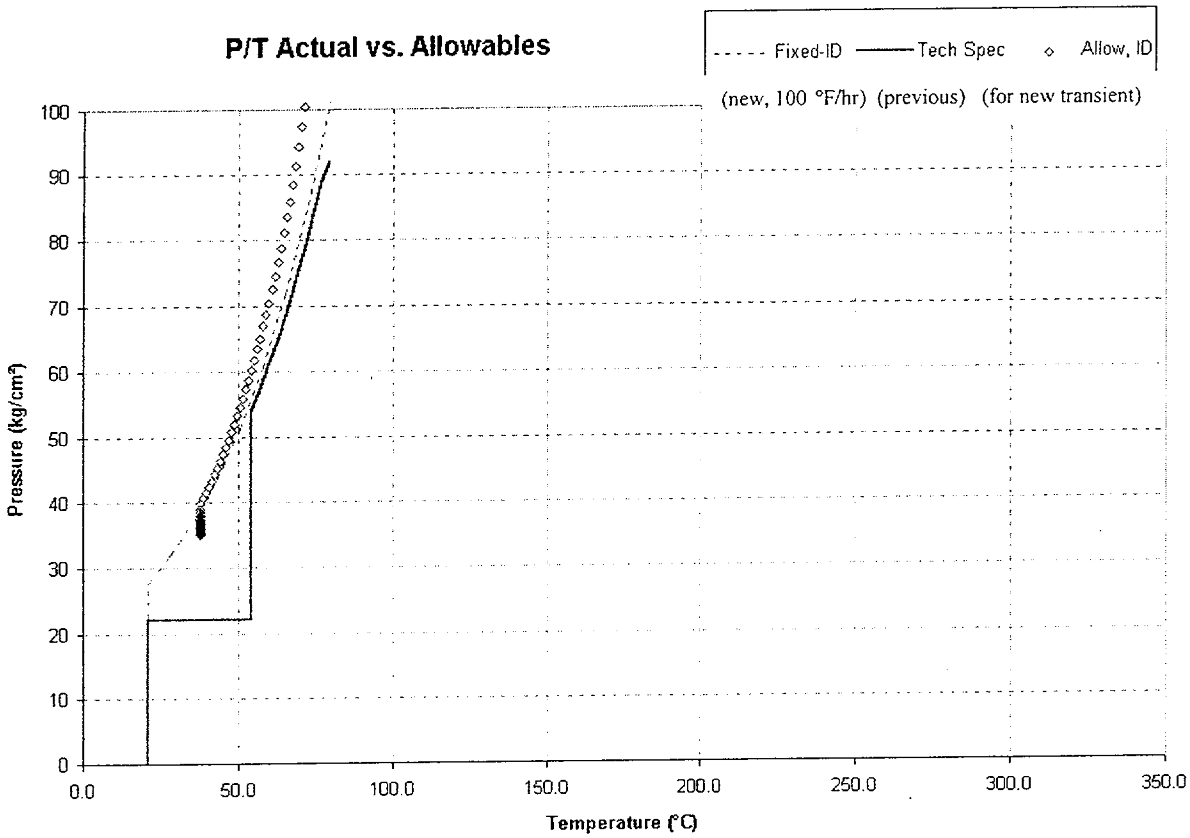


Figure 3: Pressure-Temperature Results for Heatup/Cooldown Conditions



Appendix A

Revised P-T Curves and Tabulated Values for BSEP-1

Table A-1. Tabulated Values for Bottom Head Curve A (BSEP-1, All EFPY)

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 1	
Component =	Bottom Head	
Vessel thickness, t =	5.400	inches (minimum)
M_t =	0.274	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	110.59375	inches (maximum)
RT_{NDT} =	10.0	°F ======> **All EFPYs**
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	1.50	(for spherical bottom head with penetrations)
Safety Factor =	1.50	(for pressure test)
M_m =	2.40	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	0.0	50.18	33.45	0	70	0
60	60.0	89.56	59.71	810	70	780
65	65.0	95.49	63.66	863	75	833
70	70.0	102.04	68.03	923	80	893
75	75.0	109.28	72.85	988	85	958
80	80.0	117.28	78.19	1060	90	1030
85	85.0	126.12	84.08	1140	95	1110
90	90.0	135.90	90.60	1229	100	1199
95	95.0	146.70	97.80	1326	105	1296
100	100.0	158.63	105.76	1434	110	1404

Table A-2. Tabulated Values for Beltline Curve A (BSEP-1, 32 EFPY)

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	**Brunswick 1**	
Component =	**N16 A/B**	(2" Instrument Nozzles)
Vessel thickness, t =	**N/A**	inches (minimum)
M_t =	**N/A**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**N/A**	inches (maximum)
RT_{NDT} =	**120.0**	°F ======> **32 EFPY**
ΔT_w =	**0.0**	°F (no thermal for pressure test)
K_{IT} =	**0.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**0.0**	°F (no thermal for pressure test)
Stress Multiplier, F =	**N/A**	
Safety Factor =	**1.50**	(for pressure test)
M_m =	**N/A**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**16.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	76.0	41.80	27.87	0	70	0
76	76.0	41.80	27.87	313	70	283
80	80.0	42.52	28.34	313	90	283
85	85.0	43.50	29.00	313	95	283
90	90.0	44.58	29.72	313	100	283
95	95.0	45.78	30.52	313	105	283
100	100.0	47.10	31.40	313	110	283
106	106.0	48.87	32.58	313	116	283
106	106.0	48.87	32.58	701	116	671
111	111.0	50.52	33.68	725	121	695
116	116.0	52.34	34.89	751	126	721
121	121.0	54.35	36.24	780	131	750
126	126.0	56.58	37.72	812	136	782
131	131.0	59.04	39.36	847	141	817
136	136.0	61.75	41.17	886	146	856
141	141.0	64.76	43.17	929	151	899
146	146.0	68.08	45.38	977	156	947
151	151.0	71.74	47.83	1030	161	1000
156	156.0	75.80	50.53	1088	166	1058
152	152.4	72.84	48.56	1045	162	1015
155	155.0	74.95	49.97	1076	165	1046
155	155.0	74.95	49.97	1076	165	1046
155	155.0	74.95	49.97	1076	165	1046
159.3	159.3	78.70	52.47	1130	169	1100
164	164.3	83.49	55.66	1198	174	1168
169	169.3	88.78	59.18	1274	179	1244
174	174.3	94.62	63.08	1358	184	1328

Figure A-1. Curve A (BSEP-1, 32 EFPY)

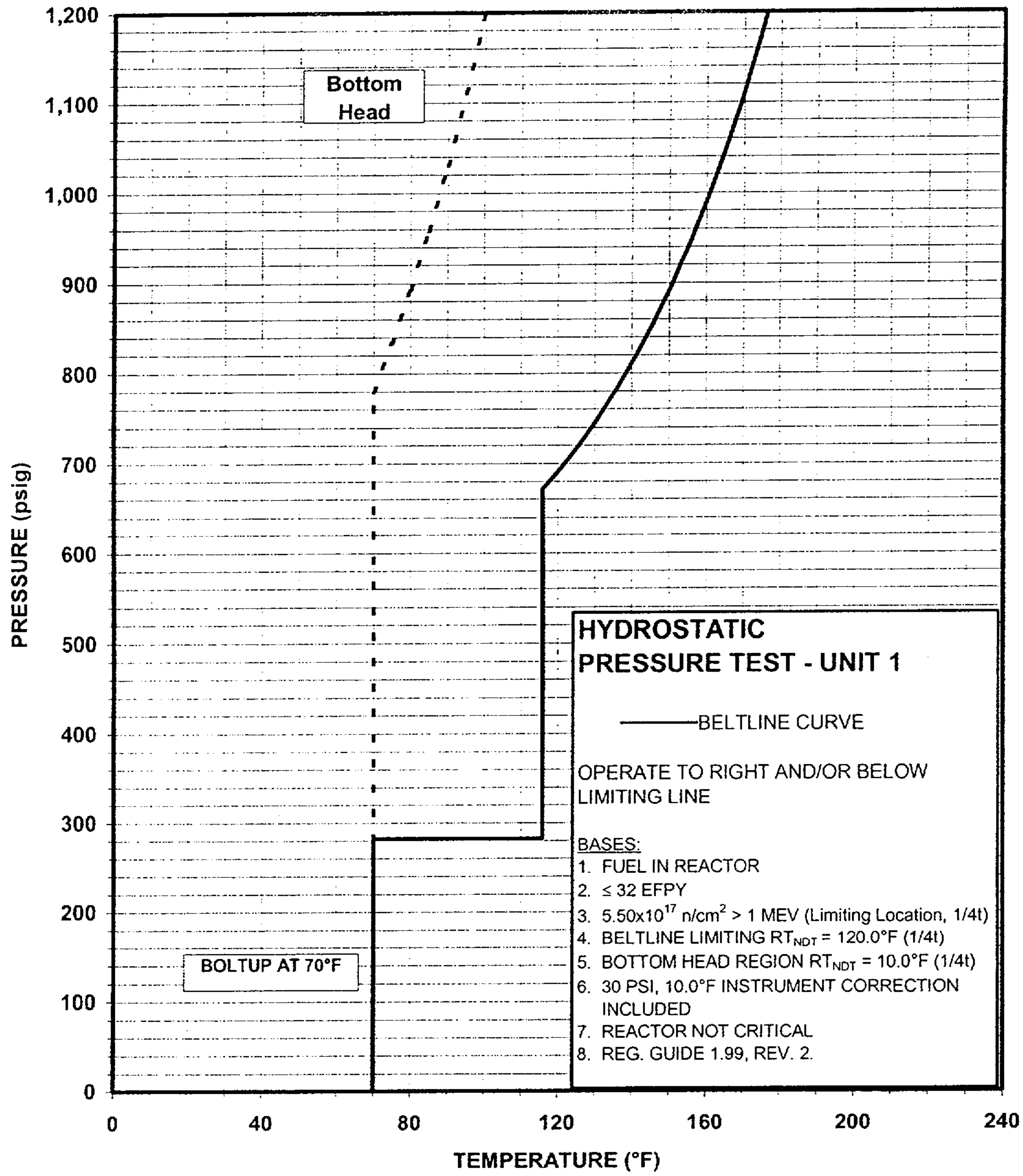


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Hydrostatic and Leak Tests ≤ 32 EFPY

Table A-3. Tabulated Values for Bottom Head Curve B (BSEP-1, All EFPY)

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	**Brunswick 1**	
Component =	**Bottom Head**	
Vessel thickness, t =	**5.400**	inches (minimum)
M_t =	**0.274**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**110.59375**	inches (maximum)
RT_{NDT} =	**10.0**	°F ======> **All EFPYs**
ΔT_w =	**25.5**	°F (temp. difference between inside and outside surfaces)
K_{IT} =	**7.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**18.9**	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	**1.50**	(for spherical bottom head with penetrations)
Safety Factor =	**2.00**	(for heatup/cooldown)
M_m =	**2.40**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**16.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	18.9	57.97	25.49	0	70	0
5	23.9	60.58	26.79	363	70	333
10	28.9	63.46	28.23	383	70	353
15	33.9	66.64	29.82	404	70	374
20	38.9	70.16	31.58	428	70	398
25	43.9	74.04	33.52	455	70	425
30	48.9	78.34	35.67	484	70	454
35	53.9	83.09	38.04	516	70	486
40	58.9	88.33	40.67	552	70	522
45	63.9	94.13	43.57	591	70	561
50	68.9	100.54	46.77	634	70	604
55	73.9	107.62	50.31	682	70	652
60	78.9	115.45	54.23	735	70	705
65	83.9	124.10	58.55	794	75	764
70	88.9	133.66	63.33	859	80	829
75	93.9	144.23	68.61	931	85	901
80	98.9	155.90	74.45	1010	90	980
85	103.9	168.81	80.91	1097	95	1067
90	108.9	183.07	88.04	1194	100	1164
95	113.9	198.83	95.92	1301	105	1271
100	118.9	200.00	96.50	1309	110	1279

Table A-4. Tabulated Values for Beltline Curve B (BSEP-1, 32 EFPY)

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	**Brunswick 1**	
Component =	**N16 A/B**	(2" Instrument Nozzles)
Vessel thickness, t =	**N/A**	inches (minimum)
M_t =	**N/A**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**N/A**	inches (maximum)
RT_{NDT} =	**120.0**	°F ======> **32 EFPY**
ΔT_w =	**N/A**	°F (temp. difference between inside and outside surfaces)
K_{IT} =	**5.4**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**20.1**	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	**N/A**	
Safety Factor =	**2.00**	(for heatup/cooldown)
M_m =	**N/A**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**16.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	96.1	46.06	20.33	0	70	0
76	96.1	46.06	20.33	313	70	283
80	100.1	47.13	20.87	313	90	283
85	105.1	48.60	21.60	313	95	283
90	110.1	50.22	22.41	313	100	283
95	115.1	52.01	23.30	313	105	283
100	120.1	53.99	24.29	313	110	283
136	156.1	75.91	35.25	313	146	283
136	156.1	75.91	35.25	759	146	729
141	161.1	80.40	37.50	807	151	777
146	166.1	85.36	39.98	861	156	831
151	171.1	90.85	42.72	920	161	890
156	176.1	96.91	45.76	985	166	955
161	181.1	103.61	49.11	1057	171	1027
166	186.1	111.02	52.81	1137	176	1107
171	191.1	119.20	56.90	1225	181	1195
176	196.1	128.25	61.42	1322	186	1292
181	201.1	138.24	66.42	1430	191	1400

Figure A-2. Curve B (BSEP-1, 32 EFPY)

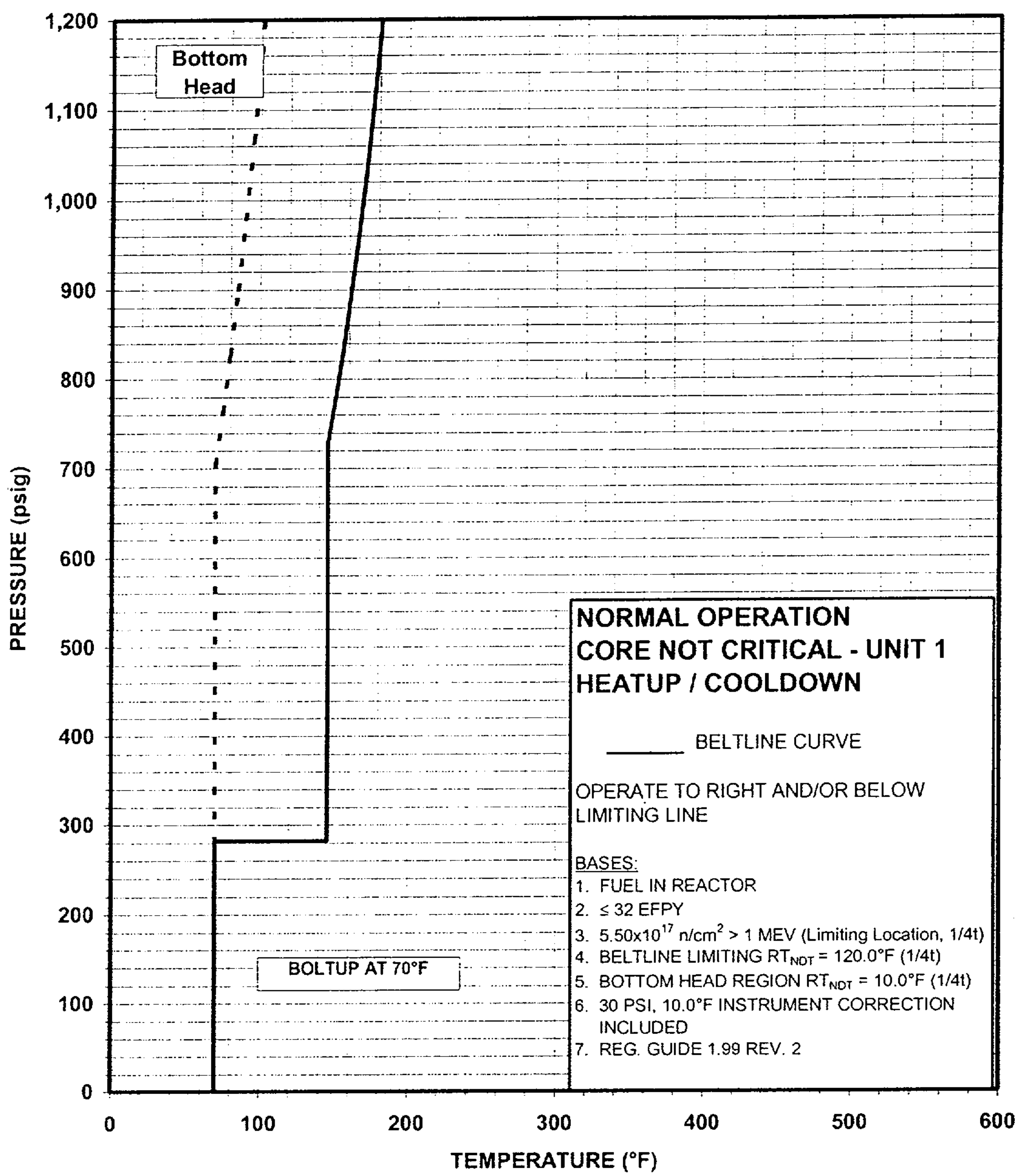


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Not Critical ≤ 32 EFPY

Table A-5. Tabulated Values for Curve C (BSEP-1, 32 EFPY)

Pressure-Temperature Curve Calculation

(Core Critical = Curve C)

Inputs:

Plant =	Brunswick 1	
EFPY =	32	
Curve A Leak Test Temperature =	159.3	°F (at 1,100 psig)
Hydro Test Pressure =	1,565	psig
Flange RT_{NDT} =	16.0	°F
Temperature Instrument Error =	10.0	°F

Adjusted Curve B Temperature N16 Nozzle (°F)	Adjusted Curve B Pressure for N16 Nozzle (psig)	Adjusted Curve B Temperature Bottom Head (°F)	Adjusted Curve B Pressure for Bottom Head (psig)	Curve C Temperature N16 Nozzle (°F)	Curve C Pressure N16 Nozzle (psig)	Curve C Temperature Bottom Head (°F)	Curve C Pressure Bottom Head (psig)
70	0	10	0	86.0	0	86.0	0
70	283	15	333	86.0	283	86.0	333
90	283	20	353	130.0	283	86.0	353
95	283	25	374	135.0	283	86.0	374
100	283	30	398	140.0	283	86.0	398
105	283	35	425	145.0	283	86.0	425
110	283	40	454	150.0	283	86.0	454
146	283	45	486	186.0	283	86.0	486
146	729	50	522	186.0	729	90.0	522
151	777	55	561	191.0	777	95.0	561
156	831	60	604	196.0	831	100.0	604
161	890	65	652	201.0	890	105.0	652
166	955	70	705	206.0	955	110.0	705
171	1027	75	764	211.0	1027	115.0	764
176	1107	80	829	216.0	1107	120.0	829
181	1195	85	901	221.0	1195	125.0	901
186	1292	90	980	226.0	1292	130.0	980
191	1400	95	1067	231.0	1400	135.0	1067
		100	1164			140.0	1164
		105	1271			145.0	1271
		110	1279			150.0	1279

Figure A-3. Curve C (BSEP-1, 32 EFPY)

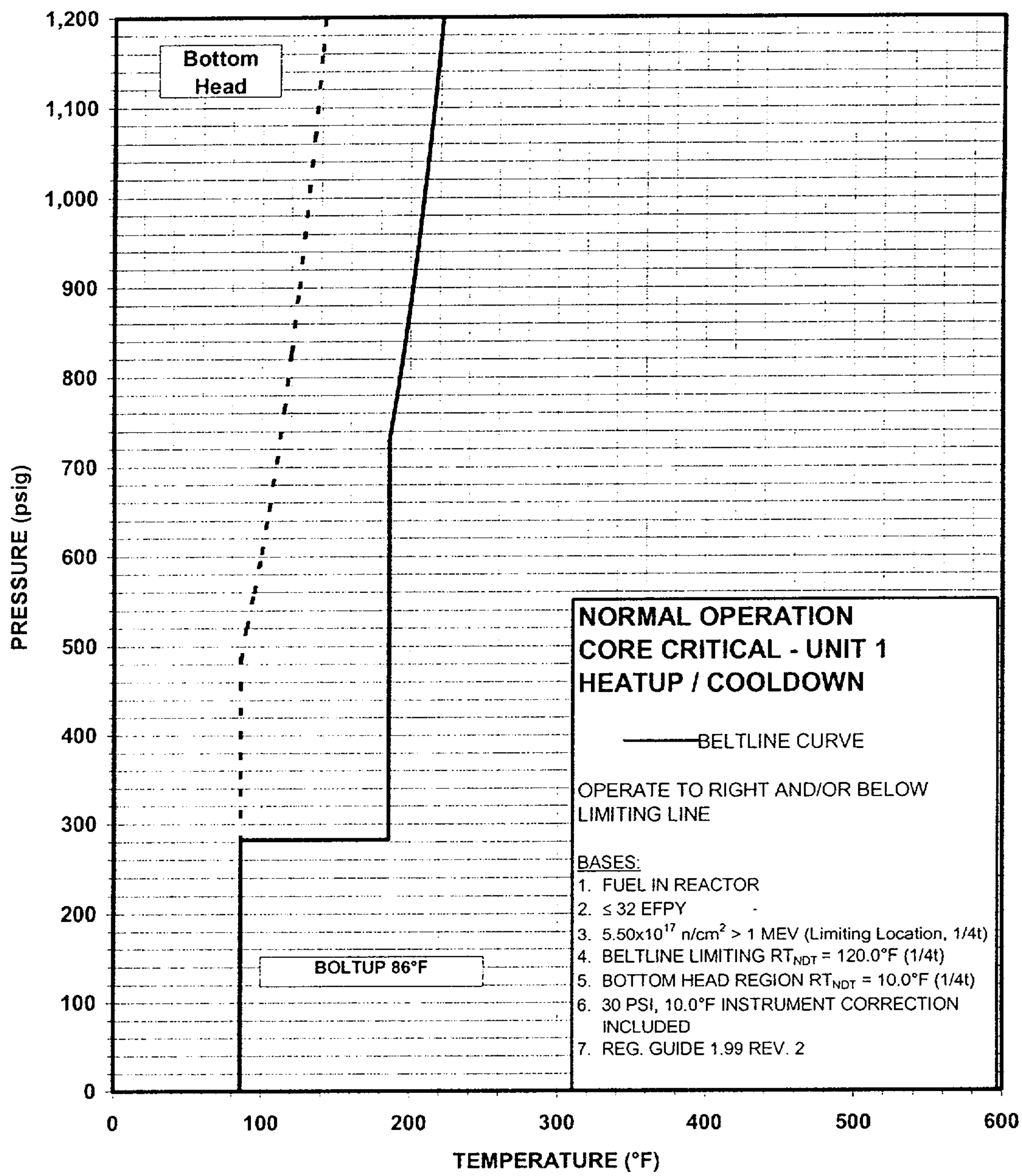


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Critical ≤ 32 EFPY

Appendix B

Revised P-T Curves and Tabulated Values for BSEP-2

Table B-1. Tabulated Values for Bottom Head Curve A (BSEP-2, All EFPY)

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant = **Brunswick 2**
Component = **Bottom Head**
Vessel thickness, t = **5.420** inches (minimum)
M_t = **0.274** (per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R = **110.3125** inches (maximum)
RT_{NDT} = **40.0** °F ======> **All EFPYs**
ΔT_w = **0.0** °F (no thermal for pressure test)
K_{IT} = **0.0** ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ = **0.0** °F (no thermal for pressure test)
Stress Multiplier, F = **1.50** (for spherical bottom head with penetrations)
Safety Factor = **1.50** (for pressure test)
M_m = **2.40** (per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error = **10.0** °F
Pressure Instrument Error = **30.0** psig
Hydro Test Pressure = **1563** psig
Flange RT_{NDT} = **10.0** °F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	0.0	42.52	28.34	0	70	0
60	60.0	64.13	42.75	584	70	554
65	65.0	67.38	44.92	613	75	583
70	70.0	70.98	47.32	646	80	616
75	75.0	74.95	49.97	682	85	652
80	80.0	79.34	52.90	722	90	692
85	85.0	84.20	56.13	766	95	736
90	90.0	89.56	59.71	815	100	785
95	95.0	95.49	63.66	869	105	839
100	100.0	102.04	68.03	928	110	898
105	105.0	109.28	72.85	994	115	964
110	110.0	117.28	78.19	1067	120	1037
115	115.0	126.12	84.08	1148	125	1118
120	120.0	135.90	90.60	1236	130	1206
125	125.0	146.70	97.80	1335	135	1305
130	130.0	158.63	105.76	1443	140	1413

Table B-2. Tabulated Values for Beltline Curve A (BSEP-2, 32 EFPY)

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 2	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	111.9	°F ======> **32 EFPY**
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	N/A	
Safety Factor =	1.50	(for pressure test)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	10.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	70.0	42.17	28.11	0	70	0
70	70.0	42.17	28.11	313	70	283
75	75.0	43.11	28.74	313	85	283
80	80.0	44.15	29.44	313	90	283
85	85.0	45.31	30.20	313	95	283
90	90.0	46.58	31.05	313	100	283
95	95.0	47.99	31.99	313	105	283
100	100.0	49.54	33.03	313	110	283
100	100.0	49.54	33.03	711	110	681
105	105.0	51.26	34.17	736	115	706
110	110.0	53.16	35.44	763	120	733
115	115.0	55.26	36.84	793	125	763
120	120.0	57.58	38.39	826	130	796
125	125.0	60.14	40.10	863	135	833
130	130.0	62.98	41.99	904	140	874
135	135.0	66.11	44.07	949	145	919
140	140.0	69.57	46.38	999	150	969
145	145.0	73.40	48.93	1053	155	1023
151.2	151.2	78.70	52.47	1130	161	1100
156	156.2	83.49	55.66	1198	166	1168
161	161.2	88.78	59.18	1274	171	1244
166	166.2	94.62	63.08	1358	176	1328
171	171.2	101.08	67.39	1451	181	1421

Figure B-1. Curve A (BSEP-2, 32 EFPY)

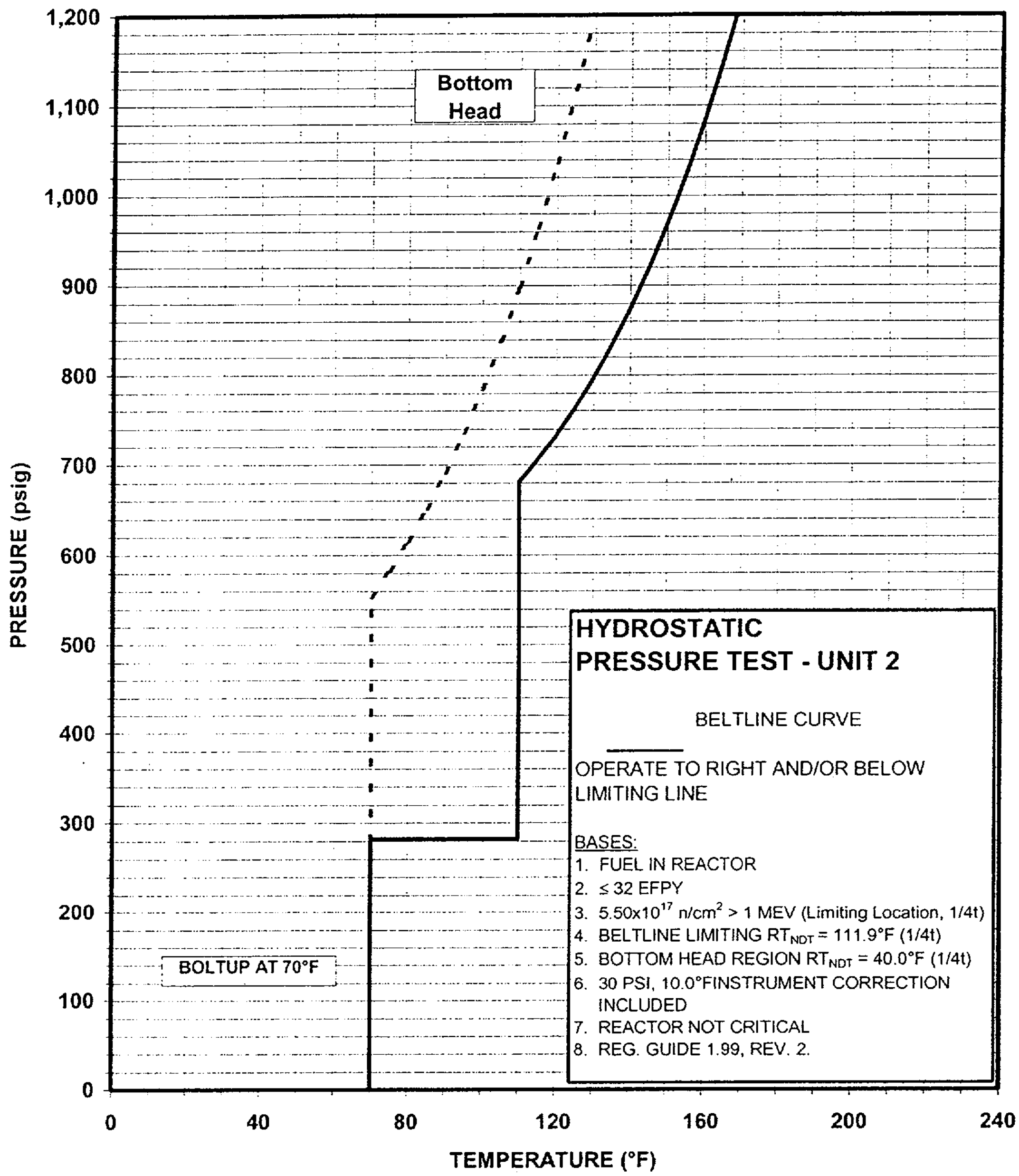


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Hydrostatic and Leak Tests ≤ 32 EFPY

Table B-3. Tabulated Values for Bottom Head Curve B (BSEP-2, All EFPY)

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	Brunswick 2	
Component =	Bottom Head	
Vessel thickness, t =	5.420	inches (minimum)
M_l =	0.274	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	110.3125	inches (maximum)
RT_{NDT} =	40.0	°F ======> **All EFPYs**
ΔT_w =	25.8	°F (temp. difference between inside and outside surfaces)
K_{IT} =	7.1	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	19.1	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	1.50	(for spherical bottom head with penetrations)
Safety Factor =	2.00	(for heatup/cooldown)
M_m =	2.40	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	10.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	19.1	46.85	19.89	0	70	0
5	24.1	48.29	20.60	281	70	251
10	29.1	49.87	21.40	292	70	262
15	34.1	51.63	22.27	304	70	274
20	39.1	53.56	23.24	317	70	287
25	44.1	55.71	24.31	332	70	302
30	49.1	58.07	25.50	348	70	318
35	54.1	60.69	26.80	366	70	336
40	59.1	63.58	28.25	386	70	356
45	64.1	66.77	29.85	407	70	377
50	69.1	70.31	31.61	431	70	401
55	74.1	74.21	33.56	458	70	428
60	79.1	78.52	35.72	488	70	458
65	84.1	83.29	38.10	520	75	490
70	89.1	88.56	40.74	556	80	526
75	94.1	94.38	43.65	596	85	566
80	99.1	100.81	46.87	640	90	610
85	104.1	107.92	50.42	688	95	658
90	109.1	115.78	54.35	742	100	712
95	114.1	124.47	58.69	801	105	771
100	119.1	134.06	63.49	867	110	837
105	124.1	144.67	68.80	939	115	909
110	129.1	156.40	74.66	1019	120	989
115	134.1	169.35	81.14	1107	125	1077
120	139.1	183.67	88.30	1205	130	1175
125	144.1	199.50	96.21	1313	135	1283
130	149.1	200.00	96.46	1316	140	1286

Table B-4. Tabulated Values for Beltline Curve B (BSEP-2, 32 EFPY)

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	Brunswick 2	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	111.9	°F ======> **32 EFPY**
ΔT_w =	N/A	°F (temp. difference between inside and outside surfaces)
K_{IT} =	5.4	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	20.1	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	N/A	
Safety Factor =	2.00	(for heatup/cooldown)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	10.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	90.1	46.62	20.61	0	70	0
70	90.1	46.62	20.61	313	70	283
75	95.1	48.03	21.31	313	85	283
80	100.1	49.59	22.09	313	90	283
85	105.1	51.31	22.95	313	95	283
90	110.1	53.21	23.91	313	100	283
95	115.1	55.32	24.96	313	105	283
100	120.1	57.64	26.12	313	110	283
105	125.1	60.21	27.41	313	115	283
110	130.1	63.06	28.83	313	120	283
115	135.1	66.20	30.40	313	125	283
120	140.1	69.67	32.13	313	130	283
125	145.1	73.50	34.05	313	135	283
130	150.1	77.74	36.17	313	140	283
130	150.1	77.74	36.17	779	140	749
135	155.1	82.42	38.51	829	145	799
140	160.1	87.60	41.10	885	150	855
145	165.1	93.32	43.96	946	155	916
150	170.1	99.65	47.12	1015	160	985
155	175.1	106.63	50.62	1090	165	1060
160	180.1	114.36	54.48	1173	170	1143
165	185.1	122.89	58.75	1265	175	1235
170	190.1	132.32	63.46	1366	180	1336

Figure B-2. Curve B (BSEP-2, 32 EFPY)

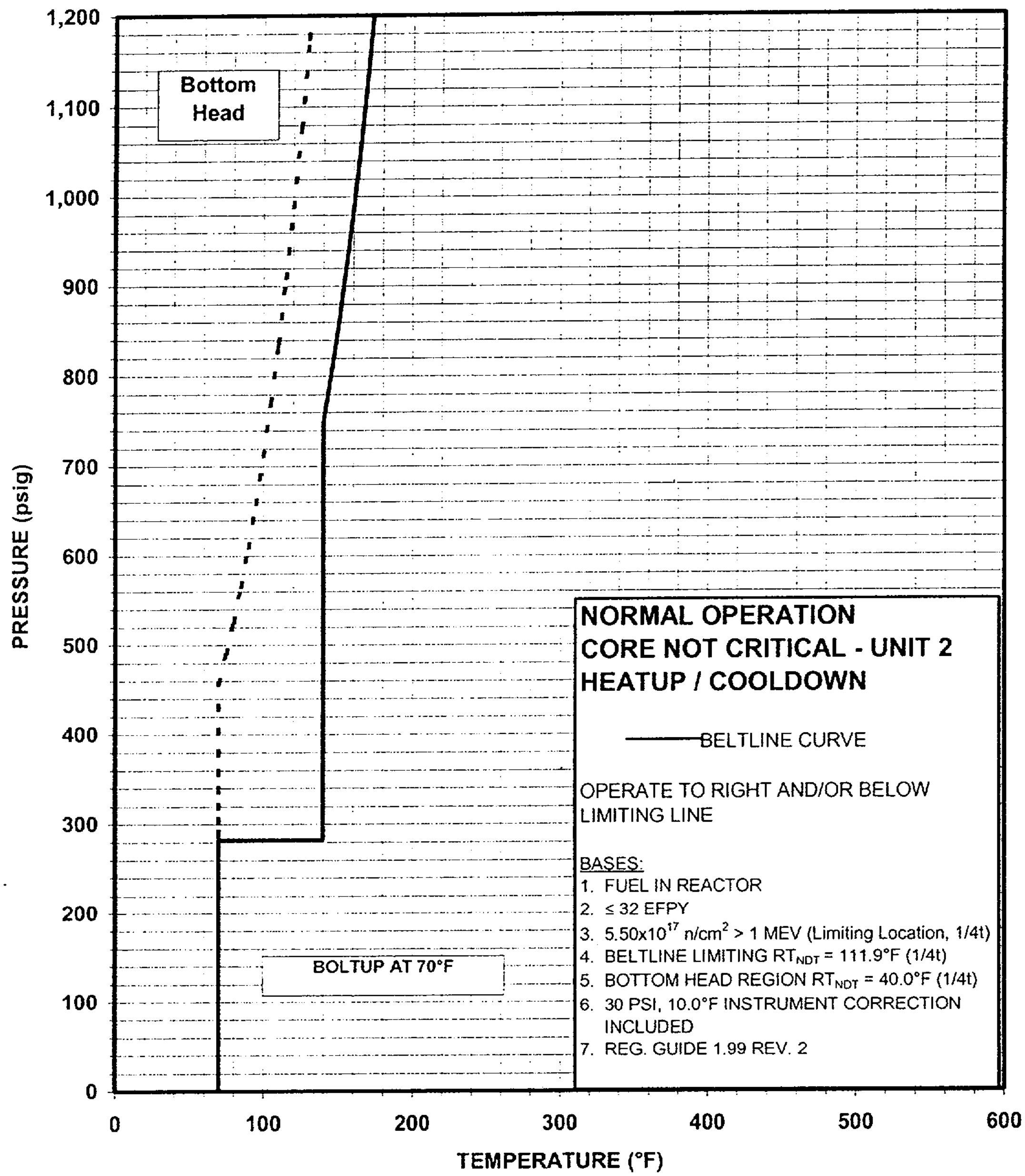


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Not Critical ≤ 32 EFPY

Table B-5. Tabulated Values for Curve C (BSEP-2, 32 EFPY)

Pressure-Temperature Curve Calculation

(Core Critical = Curve C)

Inputs:

Plant = **Brunswick 2**
EFPY = **32**
Curve A Leak Test Temperature = **151.2** °F (at 1,100 psig)
Hydro Test Pressure = **1,565** psig
Flange RT_{NDT} = **10.0** °F
Temperature Instrument Error = **10.0** °F

Adjusted Curve B Temperature N16 Nozzle (°F)	Adjusted Curve B Pressure for N16 Nozzle (psig)	Adjusted Curve B Temperature Bottom Head (°F)	Adjusted Curve B Pressure for Bottom Head (psig)	Curve C Temperature N16 Nozzle (°F)	Curve C Pressure N16 Nozzle (psig)	Curve C Temperature Bottom Head (°F)	Curve C Pressure Bottom Head (psig)
70	0	10	0	80.0	0	80.0	0
70	283	15	251	80.0	283	80.0	251
85	283	20	262	125.0	283	80.0	262
90	283	25	274	130.0	283	80.0	274
95	283	30	287	135.0	283	80.0	287
100	283	35	302	140.0	283	80.0	302
105	283	40	318	145.0	283	80.0	318
110	283	45	336	150.0	283	85.0	336
115	283	50	356	155.0	283	90.0	356
120	283	55	377	160.0	283	95.0	377
125	283	60	401	165.0	283	100.0	401
130	283	65	428	170.0	283	105.0	428
135	283	70	458	175.0	283	110.0	458
140	283	75	490	180.0	283	115.0	490
140	749	80	526	180.0	749	120.0	526
145	799	85	566	185.0	799	125.0	566
150	855	90	610	190.0	855	130.0	610
155	916	95	658	195.0	916	135.0	658
160.0	985	100	712	200.0	985	140.0	712
165.0	1060	105	771	205.0	1060	145.0	771
170.0	1143	110	837	210.0	1143	150.0	837
175.0	1235	115	909	215.0	1235	155.0	909
180.0	1336	120	989	220.0	1336	160.0	989
		125	1077			165.0	1077
		130	1175			170.0	1175
		135	1283			175.0	1283
		140	1286			180.0	1286

Figure B-3. Curve C (BSEP-2, 32 EFPY)

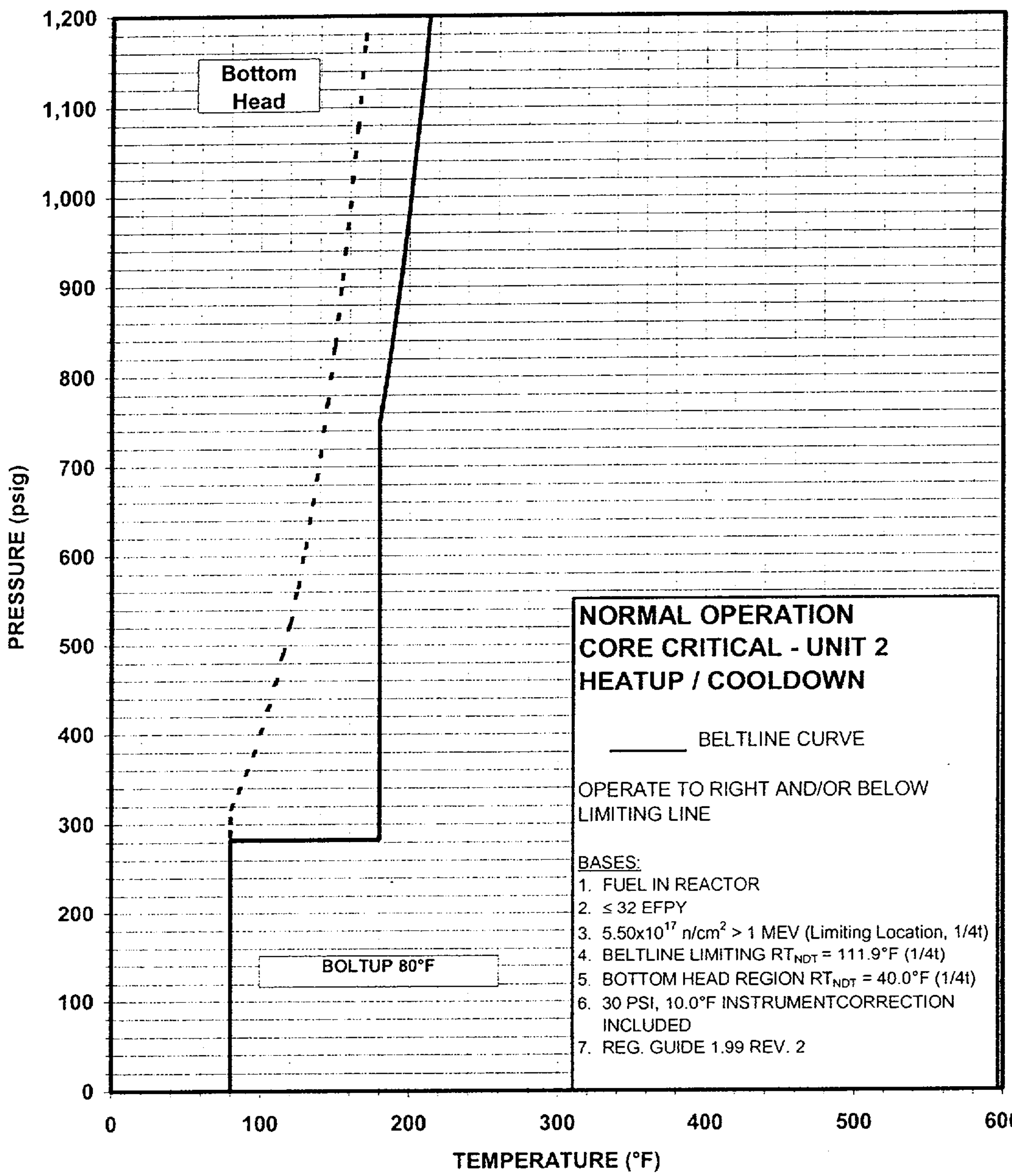


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Critical ≤ 32 EFPY

Attachment 2

Structural Integrity Calculation CPL-54Q-303, Rev. 1

62 pages (including this sheet)

RECORD COPY

STRUCTURAL INTEGRITY Associates, Inc.	CALCULATION PACKAGE	FILE No.: CPL-54Q-303 PROJECT No.: W-CPL-61Q

PROJECT NAME: Brunswick Extended Power Uprate Analyses

CLIENT: Carolina Power & Light Company (CP&L)

CALCULATION TITLE: Development of Updated P-T Curves For 32 EFPY

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-23 A-1 – A-13 B-1 – B-13 C-1 – C-13 Files on Project CD ROM	Original Issue	G. L. Stevens 10/19/00	G. L. Stevens 10/19/00 J. A. Hofmann 10/19/00
1	1-22 A-1-A-13 B-1 – B-13 C-1 – C-13 Files on Project CD ROM	Revise P-T Curves for updated fluence	G. L. Stevens Gary L. Stevens 5/13/02	C. M. ~~Kobilan~~ 5/6/02 B. P. Templeton B. P. T. BPT 5/6/02

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

The purpose of this calculation is to develop a full set of updated pressure-temperature (P-T) curves for both units of the Brunswick Steam Electric Plant (BSEP) for the beltline, bottom head, and N16 nozzle regions for 32 effective full power years (EFPY). This includes pressure test, core not critical, and core critical conditions, and incorporates updated RT_{NDT} estimates, as well as the results of all previous work performed on this subject. The P-T curves are developed to bound extended power uprate (EPU) condition for up to 120% of original license thermal power (OLTP).

2.0 RT_{NDT} DETERMINATION

Reference [15] provides updated RT_{NDT} estimates for the BSEP reactor pressure vessel (RPV) materials in accordance with Regulatory Guide 1.99, Revision 2 (RG 1.99) [2] for 32 EFPY including the effects of the various power up-rates implemented or planned for the BSEP units. The revised fluence values are found in Reference [15]. The results are summarized in this calculation in Table 1.

Table 1: RT_{NDT} Estimates for BSEP

Brunswick Unit 1 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms σ_u (°F)	Margin Terms σ_Δ (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Shell Flange)	600	BV-3085	AFB176	16	0.09	0.88	N/A	N/A	N/A	0.0	32.0	16.0
BOTTOM HEAD	101	C4654	3	10	NR	0.55	N/A	N/A	N/A	0.0	32.0	10.0
NOTE: The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.												
BELTLINE (Lower Int. Shell)	351	88496	1	10	0.19	0.58	139.8	72.0	17.0	0.0	32.0	116.0
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-4A,4B	48	0.16	0.82	123.2	38.0	17.0	0.0	32.0	120.0

Fluence Information:

Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{0.28-0.10\log f}$
(Lower Int. Shell)	5.496	1.374	32.0	2.20E+18	0.719	1.58E+18	0.515
(N16A/B Nozzles)	5.496	1.374	32.0	7.65E+17	0.719	5.50E+17	0.308

Brunswick Unit 2 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms σ_u (°F)	Margin Terms σ_Δ (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Top Head Flange)	706	1L-3335	AYT-173	10	0.11	0.80	N/A	N/A	N/A	0.0	32.0	10.0
BOTTOM HEAD	102	C4890	1A	40	NR	0.56	N/A	N/A	N/A	0.0	32.0	40.0
NOTE: The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.												
BELTLINE (Lower Shell)	201	C4500	2	10	0.15	0.54	106.7	49.5	17.0	0.0	32.0	93.5
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-3A,3B	40	0.16	0.82	123.2	37.9	17.0	0.0	32.0	111.9

Fluence Information:

Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{0.28-0.10\log f}$
(Lower Shell)	5.466	1.367	32.0	1.74E+18	0.720	1.25E+18	0.464
(N16A/B Nozzles)	5.466	1.367	32.0	7.63E+17	0.720	5.50E+17	0.308

3.0 P-T CURVE METHODOLOGY

In this section, the methodology for calculating P-T curves is detailed. This methodology documents the equations used by the EXCEL spreadsheet developed for this work. The methodology is based on the requirements of References [3] through [6].

It is assumed that the 1/4t (ID) flaw with a cooldown is controlling for P-T curve development, based on the following:

1. Due to attenuation effects, the fluence is significantly higher at the 1/4t location compared to the 3/4t location. Therefore, the ARTNDT is significantly higher at the 1/4t location.
2. The thermal tensile stress due to a 100 °F/hr Heatup (for a 3/4t flaw) is about the same as the thermal tensile stress due to a 100 °F/hr cooldown (for a 1/4t flaw).
3. The allowable material property (i.e., KIA or KIC) is lower at the end of a cooldown transient where thermal stresses are a maximum compared to the end of the Heatup transient.
4. For the RPV (i.e., a thin cylinder), the pressure stress is essentially constant through the wall, so the 1/4t and 3/4t pressure stresses are not significantly different.

The approach used for calculating the P-T curves is summarized below:

a. Assume a fluid temperature, T.

b. For the temperature, T, assumed in step (a), compute the temperature at the assumed flaw tip, $T_{1/4t}$ (i.e., 1/4t into the vessel wall). This is accomplished by adding a temperature drop term, $\Delta T_{1/4t}$, to T. The value of $\Delta T_{1/4t}$ is zero for the pressure test P-T curves (e.g., thermal is neglected), and is determined via heat transfer analysis for the other curves.

c. Calculate the allowable stress intensity factor, K_{IC} (as allowed per Reference [6]), based on $T_{1/4t}$ using the following relationship:

$$K_{IC} = 20.734\ e^{[0.02\ (T-ART)]} + 33.2$$

where: T = $T_{1/4t}$ (°F)

ART = adjusted reference temperature for location under consideration, as shown in Table 1 (°F)

K_{IC} = allowable stress intensity factor (ksi√inch)

d. Calculate the allowable pressure stress intensity factor, K_{IP}, using the appropriate relationship for the P-T curve under consideration:

$K_{IP} = K_{IC}/1.5$	for Curve A (i.e., pressure-test curve)
$K_{IP} = (K_{IC}-K_{IT})/2.0$	for Curves B and C (i.e., core not critical and core critical curves)

where:

K_{IT}	=	thermal stress intensity factor (ksi$\sqrt{}$inch)
	=	M_t x ΔT_w per Figure G-2214-2 of Reference [3] for the beltline and bottom head regions.
	=	5.4 ksi$\sqrt{}$inch for the N16A/B nozzles [7]*.
ΔT_w	=	through-wall temperature drop, determined by heat transfer analysis (°F).
M_t	=	factor from Figure G-2214-2 of Reference [3].
K_{IP}	=	allowable pressure stress intensity factor (ksi$\sqrt{}$inch).

*NOTE: The value of K_{IT} was reviewed in Reference [7] and still applies for EPU conditions.

e. Compute the pressure, P. The relationship for the pressure, P, to the allowable pressure stress intensity factor, K_{IP}, is as follows:

$$K_{IP} = M_m \sigma_m + M_b \sigma_b$$

where:

M_m	=	membrane stress correction factor from Figure G-2214-1 of Reference [3]. *The upper line for M_m in Figure G-2214-1 (corresponding to σ/σ_{ys} = 1.0) is conservatively used.*
σ_m	=	membrane stress due to pressure (ksi)
	=	PR/t for the beltline region.
	=	3.0PR/(2t) = 1.5PR/t for the spherical bottom head assuming a stress concentration factor of 3.0 for the bottom head penetrations. For the N16A/B nozzles, K_{IP} was determined directly based on finite element results, as shown below.
P	=	pressure (ksi)
R	=	maximum vessel radius (inches)
t	=	minimum vessel wall thickness (inches)
M_b	=	bending stress correction factor = $(2/3)M_m$
σ_b	=	bending stress due to pressure (ksi)
	=	0 for a thin-walled vessel

Thus, $P = K_{IP}t/(RM_m)$ for the beltline region
$P = K_{IP}t/(1.5RM_m)$ for the bottom head region
$P = 21.53\ K_{IP}$ for the N16A/B nozzles [7]

f. Repeat steps (a) through (e) for other temperatures to generate a series of P-T points for each region.

g. Adjust for any applicable instrument errors for temperature and pressure from T and P, respectively. The resulting pressure and temperature series constitutes the P-T curve. Instrument errors were calculated to be 10°F for temperature and 15 psig [16] (plus 15 psig for static water head*) for pressure consistent with past work and to account for the static head of water in a full vessel. The P-T curve relates the minimum required reactor fluid temperature to the reactor pressure for each region.

* NOTE: In previous P-T curve work, the 15 psig for static water head was not subtracted from the 20% hydrostatic pressure shelf, since this pressure value is a limit specified in 10 CFR 50 Appendix G. For the current analysis, the static head is conservatively subtracted from the 20% hydrostatic pressure shelf.

The following additional requirements were used to define the lower portion of the P-T curves. These limits are established by the discontinuity regions of the vessel (i.e., flanges), and are specified in Reference [4]:

For Pressure Test Conditions:

- Thermal stresses were assumed to be negligible during the pressure test condition and were therefore not considered.
- If P is greater than 20% of the pre-service hydro test pressure, the upper vessel temperature must be greater than RT_{NDT} of the limiting flange material + 90°F. The pre-service hydro test pressure was 1,563 psig.
- If P is less than or equal to 20% of the pre-service hydro test pressure, the minimum temperature is typically greater than or equal to the RT_{NDT} of the limiting flange material + 60°F. The additional 60°F margin above that recommended in Reference [4] has been a standard recommendation by GE for the BWR industry. For the BSEP flange material, this minimum temperature would be 76°F (i.e., 16 + 60°F) for Unit 1, and 70°F (i.e., 10 + 60°F) for Unit 2. Since the 60°F margin is only a recommendation, the minimum temperature for Unit 1 was set to 70°F to match Unit 2 and be consistent with past work.

For Core Not Critical Conditions:

- If P is greater than 20% of the pre-service hydro test pressure, the upper vessel temperature must be greater than RT_{NDT} of the limiting flange material + 120°F.
- If P is less than or equal to 20% of the pre-service hydro test pressure, the minimum temperature is typically greater than or equal to the RT_{NDT} of the limiting flange material + 60°F. The additional 60°F margin above that recommended in Reference [4] has been a standard recommendation by GE for the BWR industry. For the BSEP flange material, this minimum temperature is 70°F for Unit 1 and 70°F for Unit 2, as identified above.

For Core Critical Conditions:

- Per the requirements of Table 1 of Reference [4], the core critical P-T limits must be 40°F above any Pressure Test or Core Not Critical curve limits. Core Not Critical conditions are more limiting than Pressure Test conditions, so Core Critical conditions are equal to Core Not Critical conditions plus 40°F.
- Another requirement of Table 1 of Reference [4] (or actually an allowance for the BWR), concerns minimum temperature for initial criticality in a startup. Given that water level is normal, BWRs are allowed initial criticality at the closure flange region temperature (RT_{NDT} + 60°F) if the pressure is below 20% of the pre-service hydro test pressure. This corresponds to 76°F for Unit 1 and 70°F for Unit 2, as identified above. Accounting for an instrument uncertainty of 10°F, this corresponds to 86°F for Unit 1 and 80°F for Unit 2.
- Also per Table 1 of Reference [4], at pressures above 20% of the pre-service hydro test pressure, the Core Critical curve upper vessel temperature must be at least that required for the pressure test (Pressure Test Curve at 1,100 psig*). As a result of this requirement, the Core Critical curve for the beltline must have a step at a pressure equal to 20% of the pre-service hydro pressure to the temperature required by the Pressure Test curve at 1,100 psig, or 40°F, whichever is greater.

* NOTE: Per CP&L, the current pressure test requirement is 1,030 psig. For the purposes of P-T curve development, a pressure of 1,100 psig was conservatively used so that any potential future increases would be accommodated.

The vessel dimensions for the BSEP beltline, bottom head and N16A/B nozzle locations are documented in Reference [8].

4.0 HEAT TRANSFER ANALYSIS

Heat transfer analysis was undertaken to estimate the ΔT_w and $\Delta T_{1/4t}$ terms identified above. This was accomplished using the PIPE-TS2 computer code [9] for the beltline and bottom head regions. The analysis for the N16A/B nozzles was previously performed in Reference [10]. The analysis in Reference [10] was reviewed and still applies for the EPU conditions.

The P-T curves are developed considering a 100°F/hr heatup/cooldown. Therefore, a 100°F/hr cooldown from 550°F to 120°F was evaluated. The 550°F upper temperature was selected based on the approximate operating temperature (steam dome) for a BWR. The 120°F lower temperature was selected based upon the outside air temperature specified in Reference [10]. Material properties were taken from Reference [11] at an approximate average temperature of 350°F. Heat transfer coefficients and the outside air temperature were obtained from Reference [10]. Per Reference [8], the vessel material is SA-533 Gr. B Cl. 1. The results at the end of the cooldown, (T = 120°F, time = 3600*(550-120)/100 = 15,480 seconds) were conservatively selected so that maximum steady state temperature differences were achieved.

The PIPE-TS2 input files and the output file for t = 15,480 seconds are included in Appendix A for the beltline and bottom head regions for both BSEP units (4 cases total). The results for all regions, including those for the N16A/B nozzles from Reference [10], are shown in Table 2. These results are reflected in the P-T curve calculations contained in Appendices B and C.

Table 2: Results of Heat Transfer Analysis

Variable	Beltline [1]	Bottom Head [1]	N16A/B Nozzles [2]
ΔT_w [3]	Unit 1: 154.3 - 127.8 = 26.5°F Unit 2: 154.0 - 127.8 = 26.2°F	Unit 1: 153.2 - 127.7 = 25.5°F Unit 2: 153.5 - 127.7 = 25.8°F	Not required -- finite element solution used.
$\Delta T_{1/4t}$ [4]	Unit 1: 139.5 - 120.0 = 19.5°F Unit 2: 139.3 - 120.0 = 19.3°F	Unit 1: 138.9 - 120.0 = 18.9°F Unit 2: 139.1 - 120.0 = 19.1°F	Unit 1: 20.13°F Unit 2: 20.13°F
K_{IT}	Calc. per ASME Code, Section XI, App. G	Calc. per ASME Code, Section XI, App. G	Unit 1: 5.4 ksi√inch Unit 2: 5.4 ksi√inch

Notes:
1. Results are from PIPE-TS2 output contained in Appendix A.
2. Results are from References [7] and [10]. The Unit 2 nozzle results are assumed to be identical to those for Unit 1.
3. Per Reference [3], ΔT_w is the temperature drop across the vessel wall, i.e., outside surface temperature - inside surface temperature.
4. Since the P-T curves are being generated as a function of fluid temperature, $\Delta T_{1/4t}$ is the temperature difference between the fluid and the 1/4t location.

5.0 P-T CURVES

The resulting P-T curves and the detailed input and output are contained in Appendix B for BSEP-1, and Appendix C for BSEP-2. For the beltline region, only the limiting curves that represent the bounding results for the beltline region are plotted for all cases. The comparisons shown in the tables and graphs of Appendices B and C between the N16A/B nozzles and the beltline plate material for 32 EFPY demonstrate that the N16A/B nozzles are limiting for the beltline region. (Note: This comparison is very clear for BSEP-2 from the figures on pages C5 and C10, and there is essentially no difference between the N16A/B nozzles and the beltline for BSEP-1 from the figures on pages B5 and B10, so the N16A/B nozzles are considered to govern.)

6.0 DEMONSTRATION OF BOUNDING ASSESSMENT FOR BOTTOM HEAD

Recent questions from the NRC have indicated that updated P-T curves should bound any heatup/cooldown rate expected in the bottom head region during a transient event. The NRC bases their position on the definition of an "Anticipated Operational Occurrence" (AOO) in 10CFR50 Appendix A [12], which states: "Anticipated operational occurrences mean those conditions of normal operation which are expected to occur one or more times during the life of the nuclear power unit and include but are not limited to loss of power to all recirculation pumps, tripping of the turbine generator set, isolation of the main condenser, and loss of all offsite power."

Since Brunswick has had several transient events in which the heatup\cooldown rate in the bottom head region exceeded 100°F/hr, these events may be considered by the NRC to be AOOs. Therefore, the bottom head P-T curves should be developed to account for the maximum heatup/cooldown rate expected.

In this section, an evaluation is performed to assess the adequacy of the 100°F/hr heatup/cooldown rate used in the development of the BSEP P-T curves with respect to AOOs in the bottom head region.

6.1 METHODOLOGY

The SPHERE spreadsheet methodology used for the Reference [13] assessment will again be used for this work. A three-step process will be applied to investigate this problem: (1) reproduce the Reference [13] results to verify the proper functioning of the SPHERE spreadsheet for this project, (2) perform an assessment for the bottom head region for pressure test conditions using the SPHERE spreadsheet, and (3) perform an assessment of transient conditions for the bottom head region for heatup/cooldown conditions using the SPHERE spreadsheet. Each of these steps is described in detail in the subsections that follow.

6.2 STEP 1: REPRODUCE PREVIOUS RESULTS

Pages 25-28 of the Reference [13] calculation contain the alternate transient evaluation for Brunswick. The alternate transient, as defined in Figure 7-1 of Reference [14], is shown again here in Figure 1. The transient shown in Figure 1 was previously established as a bounding transient for the bottom head region for the Brunswick reactors.

The inputs to SPHERE, as identified in Figures 8, 9, and 18 of Reference [13], were again input to the spreadsheet, as shown in Figures 2 through 4, and a solution was obtained. The resulting pressure/temperature results are shown in Figure 5. Comparing these results to those from Figure 19 of Reference [13], it can be seen that identical results were achieved. Therefore, the SPHERE spreadsheet is considered to be verified and functioning correctly for the purposes of this assessment.

Figure 1: Alternate Cooldown Transient for Brunswick Bottom Head Region

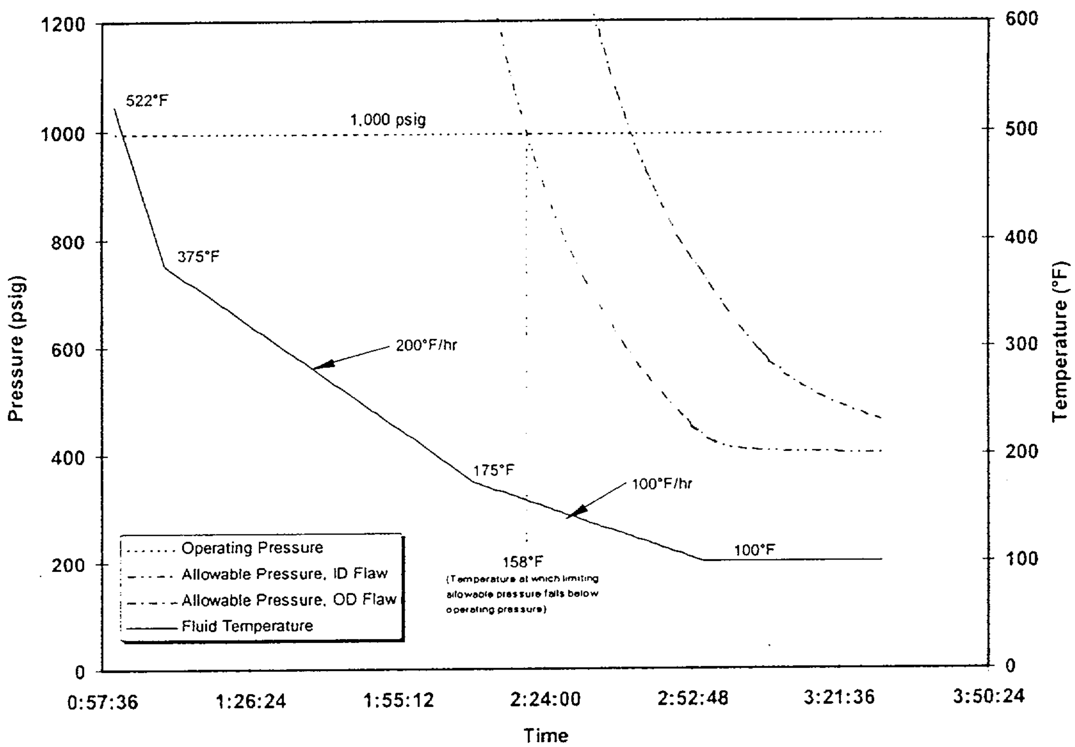


Figure 2: RPV Input Data for SPHERE

(Compares to Figure 18 of Reference [13])

RPV Input Data

Close RPVIMS

Input Finished

Erase Input

Date	Time	Press (kg/cm²)	Temp (°C)	Temp (°F)
12/15/1995	1:00:00	70.30704	272.2222	522
12/15/1995	1:10:00	70.30704	190.5556	375
12/15/1995	2:10:00	70.30704	79.44444	175
12/15/1995	2:55:00	70.30704	37.77778	100
12/15/1995	3:30:00	70.30704	37.77778	100

Figure 3: User Variables Input Data for SPHERE

(Compares to Figure 8 of Reference [13])

User Variables

evnt_typ	C	Type of event: C=core critical, N=core not crit, P=pressure test
eval_typ	3	Kic evaluation: 1=JEAC 4206, 2=hybrid, 3=Section XI

ys	47500	Material Yield Stress [psi]

	1/4 T	3/4 T	
ART	4.4	4.4	Adjusted Reference Temperature 40°F

	1/4 T	3/4 T	
a	42.8625	128.5875	calculated crack depth [mm]

Figure 4: Location-Specific Input Data for SPHERE

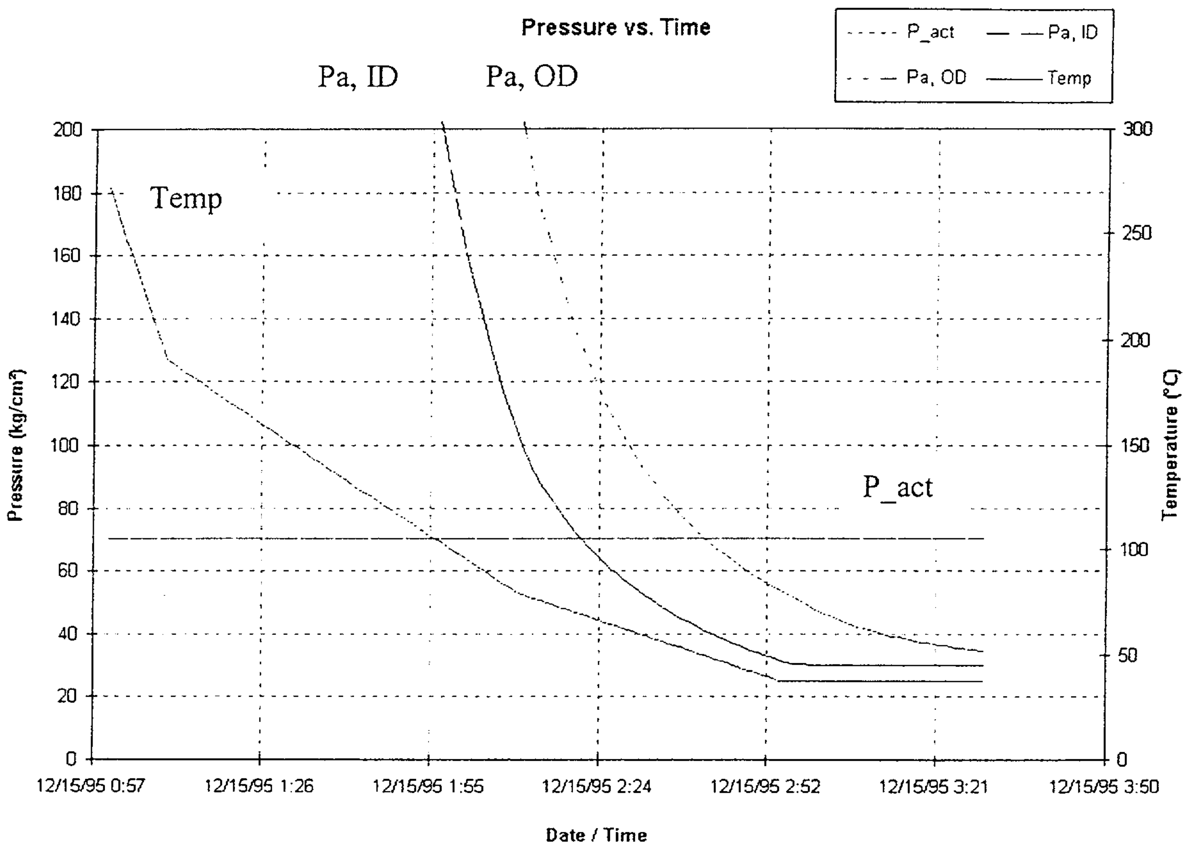
(Compares to Figure 9 of Reference [13])

Location-Specific Data

title:	RPV Bottom Head	
outside radius:	116.9375	[in]
wall thickness:	6.75	[in]
inside radius:	110.1875	[in]
ID heat xfer coeff:	356.5	[BTU/hr-ft²-°F]
Material Properties:		
conductivity:	23.8	[BTU/hr-ft-°F]
coeff. of thermal exp.:	7.50E-06	[in/in-°F]
specific heat:	0.1232384	[BTU/lb·°F]
mass density:	0.2801	[lb/in³]
Young's modulus:	2.77E+07	[psi]
Poisson's ratio:	0.3	
Yield Strength	47500	[psi]

Note: The dimensions shown in this figure are based on nominal dimensions, and are different than the limiting (i.e., maximum or minimum) dimensions used in the P-T curves developed in the Appendices of this calculation. Use of nominal dimensions is appropriate for this "comparative" study, whereas limiting dimensions are appropriate for the P-T curve limits.

Figure 5: Pressure/Temperature Results for Alternate Cooldown Transient (Compares to Figure 19 of Reference [13])



6.3 STEP 2: ASSESS TRANSIENT FOR PRESSURE TEST CONDITIONS

The P-T curves in this calculation were developed for a 100°F/hr cooldown rate. Because of the use of K_{IC}, the bottom head curves are primarily controlled by the 10 CFR 50 Appendix G temperature limits. Therefore, for the purposes of this evaluation, a more rigorous assessment can be provided by evaluating the P-T curves developed using K_{IA}.

The inputs for the Brunswick Unit 1 bottom head region were obtained from the Reference [13] calculation and input to SPHERE for pressure test conditions. A calculation was performed for pressure test conditions (i.e., no thermal), as well as the alternate transient shown in Figure 1. The inputs are shown in Figures 6 through 9, and the resulting P-T curves are shown in Figure 10.

The results shown in Figure 10 indicate that previous results obtained using K_{IA} were reproduced. Thus, a second level of verification is provided for the SPHERE spreadsheet, in that it was able to independently reproduce the previous P-T curve results.

Figure 6: RPV Input Data for SPHERE for Pressure Test Conditions

RPV Input Data

Close RPVIMS

Input Finished

Erase Input

Date	Time	Press (kg/cm²)	Temp (°C)	Temp (°F)
12/15/1995	1:00:00	70.30704	272.2222	522
12/15/1995	1:10:00	70.30704	190.5556	375
12/15/1995	2:10:00	70.30704	79.44444	175
12/15/1995	2:55:00	70.30704	37.77778	100
12/15/1995	3:30:00	70.30704	37.77778	100

Figure 7: User Variables Input Data for SPHERE for Pressure Test Conditions

User Variables

evnt_typ	P	Type of event: C=core critical, N=core not crit, P=pressure test
eval_typ	3	Kic evaluation: 1=JEAC 4206, 2=hybrid, 3=Section XI

ys	47500	Material Yield Stress [psi]

	1/4 T	3/4 T	
ART	-12.2	-12.2	Adjusted Reference Temperature 10°F

	1/4 T	3/4 T	
a	34.29	102.87	calculated crack depth [mm]

Figure 8: Location-Specific Input Data for SPHERE for Pressure Test Conditions

Location-Specific Data

title:	RPV Bottom Head	
outside radius:	115.99375	[in]
wall thickness:	5.4	[in]
inside radius:	110.59375	[in]
ID heat xfer coeff:	356.5	[BTU/hr-ft²-°F]
Material Properties:		
conductivity:	23.8	[BTU/hr-ft-°F]
coeff. of thermal exp.:	7.50E-06	[in/in-°F]
specific heat:	0.1232384	[BTU/lb·°F]
mass density:	0.2801	[lb/in³]
Young's modulus:	2.77E+07	[psi]
Poisson's ratio:	0.3	
Yield Strength	47500	[psi]

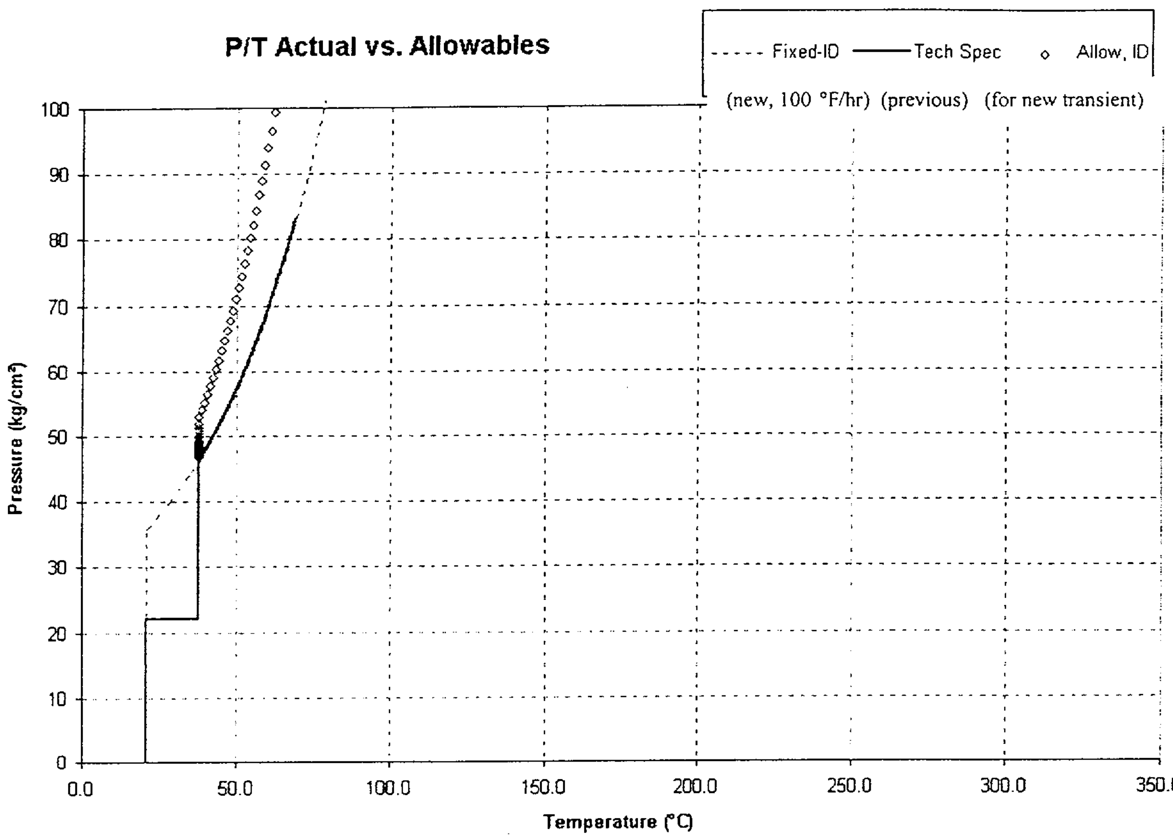
Note: The dimensions shown in this figure are based on nominal dimensions, and are different than the limiting (i.e., maximum or minimum) dimensions used in the P-T curves developed in the Appendices of this calculation. Use of nominal dimensions is appropriate for this "comparative" study, whereas limiting dimensions are appropriate for the P-T curve limits.

Figure 9: Fixed P/T Curves Input Data for SPHERE for Pressure Test Conditions

Fixed P/T Curves:

Temp.	Allowable Pressures (psi)
T (°F)	Pres.Test
70.0	0.0
70.0	313.0
75.0	313.0
80.0	313.0
85.0	313.0
90.0	313.0
95.0	313.0
100.0	313.0
100.0	657.0
105.0	688.0
110.0	722.0
115.0	758.0
120.0	797.0
125.0	838.0
130.0	883.0
135.0	931.0
140.0	983.0
151.0	1115.0
156.0	1181.0

Figure 10: Pressure-Temperature Results for Pressure Test Conditions



6.4 STEP 3: ASSESS TRANSIENT FOR HEATUP/COOLDOWN CONDITIONS

The inputs for the Brunswick Unit 1 bottom head region were obtained from the Reference [13] calculation and input to SPHERE for heatup/cooldown conditions. A calculation was performed for heatup/cooldown conditions for a fixed cooldown rate of 100°F/hr, as well as the alternate transient shown in Figure 1. The inputs are shown in Figures 11 through 14, and the resulting P-T curves are shown in Figure 15.

The results shown in Figure 15 indicate that previous results obtained using K_{IA} were again essentially reproduced. The small differences in the curves are attributed to small differences in the thermal stress solution employed in SPHERE vs. the previous evaluation. Thus, a third level of verification is provided for the SPHERE spreadsheet, in that it was able to independently reproduce the previous P-T curve results.

Figure 11: RPV Input Data for SPHERE for Heatup/Cooldown Conditions

RPV Input Data

Close RPVIMS

Input Finished

Erase Input

Date	Time	Press (kg/cm²)	Temp (°C)	Temp (°F)
12/15/1995	1:00:00	70.30704	272.2222	522
12/15/1995	1:10:00	70.30704	190.5556	375
12/15/1995	2:10:00	70.30704	79.44444	175
12/15/1995	2:55:00	70.30704	37.77778	100
12/15/1995	3:30:00	70.30704	37.77778	100

Figure 12: User Variables Input Data for SPHERE for Heatup/Cooldown Conditions

User Variables

evnt_typ	N	Type of event: C=core critical, N=core not crit, P=pressure test
eval_typ	3	Kic evaluation: 1=JEAC 4206, 2=hybrid, 3=Section XI

ys	47500	Material Yield Stress [psi]

	1/4 T	3/4 T	
ART	-12.2	-12.2	Adjusted Reference Temperature 10°F

	1/4 T	3/4 T	
a	34.29	102.87	calculated crack depth [mm]

Figure 13: Location-Specific Input Data for SPHERE for Heatup/Cooldown Conditions

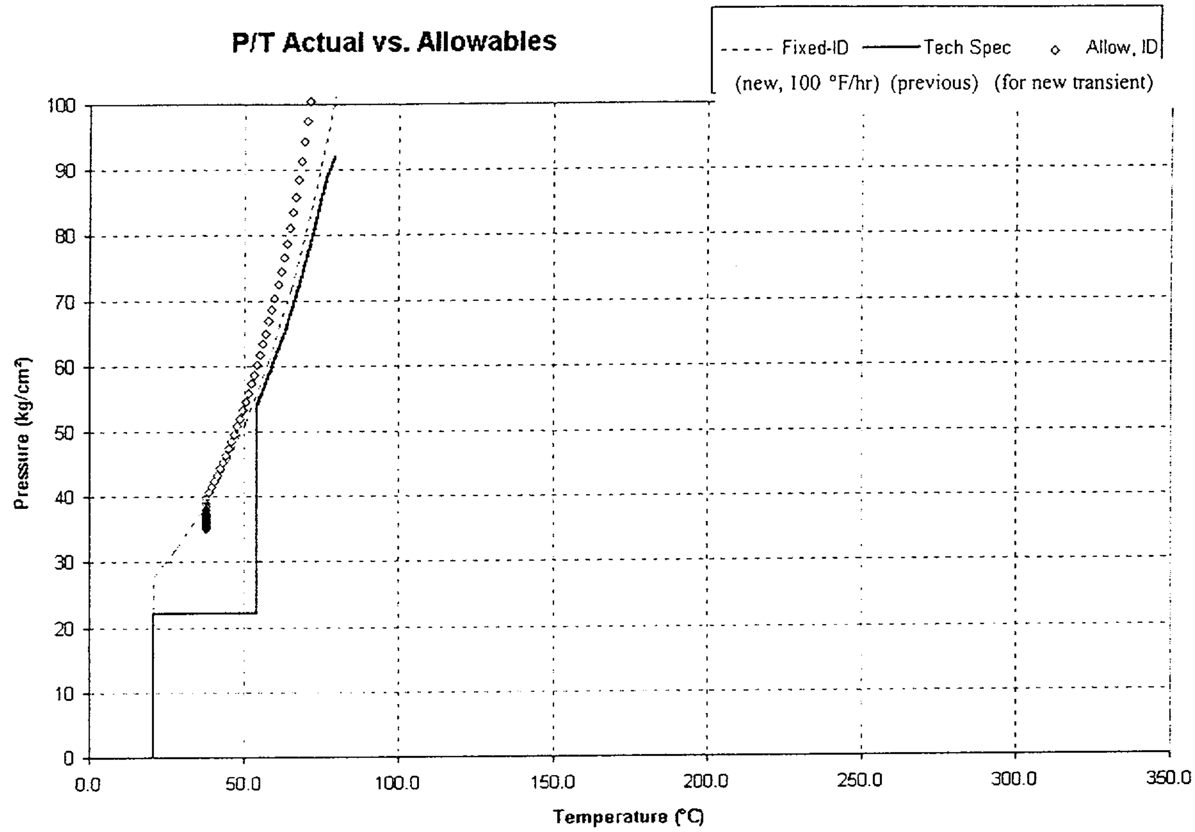
Location-Specific Data

title:	RPV Bottom Head	
outside radius:	115.99375	[in]
wall thickness:	5.4	[in]
inside radius:	110.59375	[in]
ID heat xfer coeff:	356.5	[BTU/hr-ft²-°F]
Material Properties:		
conductivity:	23.8	[BTU/hr-ft-°F]
coeff. of thermal exp.:	7.50E-06	[in/in-°F]
specific heat:	0.1232384	[BTU/lb-°F]
mass density:	0.2801	[lb/in³]
Young's modulus:	2.77E+07	[psi]
Poisson's ratio:	0.3	
Yield Strength	47500	[psi]

Figure 14: Fixed P/T Curves Input Data for SPHERE for Heatup/Cooldown Conditions

Fixed P/T Curves:	
Temp.	Allowable Pressures (psi)
T (°F)	Pres.Test
70.0	0.0
70.0	313.0
70.0	313.0
75.0	313.0
80.0	313.0
85.0	313.0
90.0	313.0
95.0	313.0
130.0	313.0
130.0	767.0
135.0	814.0
140.0	865.0
145.0	920.0
150.0	979.0
155.0	1043.0
160.0	1111.0
165.0	1185.0
170.0	1264.0
175.0	1309.0

Figure 15: Pressure-Temperature Results for Heatup/Cooldown Conditions



7.0 CONCLUSIONS

Based on the results shown in Figures 10 and 15, the following conclusions can be made:

- The P-T curves developed in this calculation for a fixed rate of 100°F/hr are bounding compared to the alternate cooldown transient shown in Figure 1. The alternate cooldown transient was developed specifically to bound all actual operating conditions in the bottom head region. Therefore, the P-T curves bound all expected operating conditions for the bottom head region, including the transient defined in Figure 1. The transient defined in Figure 1 was developed specifically to cover inadvertent cooldown events in the bottom head region, and to bound all actual operating conditions in the bottom head region.

- These results are consistent with the methodology in ASME Code, Section XI, Appendix G [3], where solutions are provided for heatup/cooldown rates of 100°F/hr or less. Appendix G states that "the results would be overly conservative if applied to rapid temperature changes."

- The conclusions shown here for Unit 1 also apply to Unit 2, since the same comparative results would be obtained for a different set of geometry/material inputs.

It is therefore concluded that the P-T curves included in Appendices B and C of this calculation for the bottom head region for both Brunswick units bound all anticipated operating conditions.

8.0 REFERENCES

1. Not Used.

2. USNRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, (Task ME 305-4), May 1988.

3. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Nonmandatory Appendix G, "Fracture Toughness Criteria for Protection Against Failure," 1989 Edition, No Addenda.

4. U. S. Code of Federal Regulations, Title 10, Part 50, Appendix G, "Fracture Toughness Requirements," 1-1-98 Edition.

5. WRC Bulletin 175, "PVRC Recommendations on Toughness Requirements for Ferritic Materials," PVRC Ad Hoc Group on Toughness Requirements, Welding Research Council, August 1972.

6. ASME Boiler and Pressure Vessel Code, Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves," Section XI, Division 1, Approved February 26, 1999.

7. Structural Integrity Associates Calculation No. CPL-36Q-306, Revision 0, "Evaluation of BSEP Unit 1 P-T Curves for Heat-up and Cooldown," 5/16/95.

8. Structural Integrity Associates Calculation No. CPL-42Q-302, Revision 1, "Brunswick Units 1 and 2 Hydro Test P-T Curve Development," 8/22/96.

9. PIPE-TS2, "Program to Compute the Transient Thermal and Stress Response of an Axisymmetric Two-Material Cylinder," Version 1.01, Structural Integrity Associates.

10. Structural Integrity Associates Calculation No. CPL-36Q-305, Revision 0, "Cool-down Temperature/Stress Analysis of the N16 Nozzle at Brunswick Unit 1," 5/17/95.

11. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Appendices, 1989 Edition, No Addenda.

12. U. S. Code of Federal Regulations, Title 10, Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," 1/1/98.

13. Structural Integrity Associates Calculation No. CPL-40Q-305, Revision 1, "Fracture Toughness Assessment of Bottom Head."

14. Structural Integrity Associates Report No. SIR-96-010, Revision 0, "Justification to Relax Requirements for Recirculation Pump Restart Following a Scram Event Brunswick Steam Electric Plant Units 1 and 2," SI File No. CPL-40Q-401.

15. CP&L Calculation No. 0B11-0012, Revision 0, [Westinghouse Electric Company LLC Report LTR-REA-02-7], "Neutron Exposure Evaluations for the Core Shroud and Pressure Vessel Brunswick Units 1 and 2", January 2002, SI File No. W-CPL-61Q-215.

16. E-mail from P. Gore (CP&L) to G. Stevens (SI), "FW: P/T Calc", 4/3/02, 10:49 am, SI File No. W-CPL-61Q-218.

17. CPL Calculation 0B21-1029, Revision 0, "Instrument Uncertainty for RCS Pressure/Temperature Limits Curve", SI File No.W-CPL-61Q-218.

END

Appendix A

PIPE-TS2 Input/Output Files for Heat Transfer Analysis of Beltline and Bottom Head Regions

File = "U1-BELT.IN"	[2 pages]
File = "15480.STP" (for Unit 1 beltline)	[1 page]
File = "U1-BOTHD.IN"	[2 pages]
File = "15480.STP" (for Unit 1 bottom head)	[1 page]
File = "U2-BELT.IN"	[2 pages]
File = "15480.STP" (for Unit 2 beltline)	[1 page]
File = "U2-BOTHD.IN"	[2 pages]
File = "15480.STP" (for Unit 2 bottom head)	[1 page]
Total =	[12 pages]

```
File = "U1-BELT.IN"

******  PIPE-TS2 INPUT FILE  =>  100f.in (TOP OF FILE)  ******
" Note that a blank line must preceed each line with ==> at start"

"==> Next 3 lines are CASE DESCRIPTIONS (or blanks) in parentheses"
"Cooldown Transient for Brunswick Unit 1"
"100F/hr, 550F to 120F"
"Vessel Shell Location"

"==> Next information is the pipe geometry"
"   First line is number of pipe nodes - 40 max"
"   Next line is inside radius (in.) and outside radius(in.)"
"   Next line is interface rad. (in.) / nodes in first material"
               40
               110.59375   116.08975
               110.73115   1

"==> Next line is initial pipe wall temperature"
               550

"==> Next series of lines is Inside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               3
               0            550
               15480        120
               16000        120

"==> Next series of lines is Inside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0            356.5
               16000        356.5

"==> Next series of lines is Outside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               2
               0            120
               16000        120

"==> Next series of lines is Outside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0            0.2
               16000        0.2
```

```
"==> Following are inner material properties (LAS, Clad is neglected) @350F ('89
Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
              23.8
"    Density * Specific Heat (Btu/Ft3)"
              59.649
"    Modulus of Elasticity (ksi)"
              27.7e3
"    Coefficient of Thermal Expansion (per F)"
              7.50e-6
"    Poissons Ratio"
              .3

"==> Following are outer material properties (LAS) @350F ('89 Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
              23.8
"    Density * Specific Heat (Btu/Ft3)"
              59.649
"    Modulus of Elasticity (ksi)"
              27.7e3
"    Coefficient of Thermal Expansion (per F)"
              7.50e-6
"    Poissons Ratio"
              .3

"==> Value of uniform temperature which is stress free in cylinder"
"    Stress-free temperature (F) may be any value"
              70

"==> Timestep and time control information (seconds)"
"     Timestep Max <= 0.5*{[(Ro-Ri)/nodes]^2/[k/RhoCp]}*3600"
"     Next line is number of time control intervals "
              1
"   end of interval - time step - print interval"
              16000         10.0            360
********************* END OF FILE  *******************
   CREATED   DATE:  12-18-1998       TIME:  09:30:00
```

File = "15480.STP" (for Unit 1 beltline)

1	110.5938	+5.29	+5.29	-0.00	+3.92	+3.94	127.8	132.3
2	110.7311	+4.89	+4.90	+0.01	+3.72	+3.74	129.1	133.0
3	110.8685	+4.50	+4.51	+0.01	+3.53	+3.55	130.4	133.7
4	111.0059	+4.13	+4.14	+0.02	+3.33	+3.35	131.7	134.3
5	111.1433	+3.76	+3.78	+0.02	+3.13	+3.16	132.9	135.0
6	111.2807	+3.40	+3.43	+0.03	+2.94	+2.96	134.1	135.6
7	111.4181	+3.06	+3.09	+0.03	+2.74	+2.77	135.2	136.3
8	111.5555	+2.72	+2.76	+0.03	+2.55	+2.57	136.3	136.9
9	111.6929	+2.40	+2.44	+0.04	+2.35	+2.38	137.4	137.6
10	111.8303	+2.08	+2.12	+0.04	+2.16	+2.18	138.5	138.3
11	111.9677	+1.78	+1.82	+0.04	+1.96	+1.99	139.5	138.9
12	112.1051	+1.49	+1.53	+0.04	+1.76	+1.79	140.4	139.6
13	112.2425	+1.21	+1.25	+0.05	+1.57	+1.60	141.4	140.2
14	112.3799	+0.93	+0.98	+0.05	+1.37	+1.40	142.3	140.9
15	112.5173	+0.67	+0.72	+0.05	+1.18	+1.20	143.2	141.6
16	112.6547	+0.42	+0.47	+0.05	+0.98	+1.01	144.0	142.2
17	112.7921	+0.18	+0.23	+0.05	+0.78	+0.81	144.8	142.9
18	112.9295	-0.05	-0.00	+0.05	+0.59	+0.62	145.6	143.5
19	113.0669	-0.27	-0.22	+0.05	+0.39	+0.42	146.4	144.2
20	113.2043	-0.48	-0.43	+0.05	+0.20	+0.23	147.1	144.8
21	113.3417	-0.68	-0.63	+0.05	+0.00	+0.03	147.7	145.5
22	113.4791	-0.87	-0.82	+0.05	-0.19	-0.16	148.4	146.2
23	113.6165	-1.05	-1.00	+0.05	-0.39	-0.36	149.0	146.8
24	113.7539	-1.22	-1.17	+0.04	-0.59	-0.55	149.6	147.5
25	113.8913	-1.38	-1.33	+0.04	-0.78	-0.75	150.1	148.1
26	114.0287	-1.53	-1.49	+0.04	-0.98	-0.94	150.6	148.8
27	114.1661	-1.66	-1.63	+0.04	-1.17	-1.14	151.1	149.5
28	114.3035	-1.79	-1.76	+0.04	-1.37	-1.33	151.5	150.1
29	114.4409	-1.91	-1.88	+0.03	-1.57	-1.53	151.9	150.8
30	114.5783	-2.02	-1.99	+0.03	-1.76	-1.73	152.3	151.4
31	114.7157	-2.12	-2.09	+0.03	-1.96	-1.92	152.7	152.1
32	114.8531	-2.21	-2.18	+0.03	-2.15	-2.12	153.0	152.8
33	114.9905	-2.29	-2.27	+0.02	-2.35	-2.31	153.2	153.4
34	115.1279	-2.36	-2.34	+0.02	-2.54	-2.51	153.5	154.1
35	115.2653	-2.42	-2.40	+0.02	-2.74	-2.70	153.7	154.7
36	115.4027	-2.47	-2.45	+0.02	-2.94	-2.90	153.9	155.4
37	115.5401	-2.51	-2.50	+0.01	-3.13	-3.09	154.0	156.0
38	115.6775	-2.54	-2.53	+0.01	-3.33	-3.29	154.1	156.7
39	115.8149	-2.56	-2.55	+0.01	-3.52	-3.48	154.2	157.4
40	115.9523	-2.57	-2.57	+0.00	-3.72	-3.68	154.3	158.0
41	116.0897	-2.57	-2.57	+0.00	-3.92	-3.87	154.3	158.7

15480

```
File = "U1-BOTHD.IN"

******  PIPE-TS2 INPUT FILE  =>  100f.in (TOP OF FILE)  ******
" Note that a blank line must preceed each line with ==> at start"

"==> Next 3 lines are CASE DESCRIPTIONS (or blanks) in parentheses"
"Cooldown Transient for Brunswick Unit 1"
"100F/hr, 550F to 120F"
"Bottom Head Location"

"==> Next information is the pipe geometry"
"   First line is number of pipe nodes - 40 max"
"   Next line is inside radius (in.) and outside radius(in.)"
"   Next line is interface rad. (in.) / nodes in first material"
               40
               110.59375   115.99375
               110.72875   1

"==> Next line is initial pipe wall temperature"
               550

"==> Next series of lines is Inside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               3
               0             550
               15480         120
               16000         120

"==> Next series of lines is Inside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0            356.5
               16000        356.5

"==> Next series of lines is Outside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               2
               0             120
               16000         120

"==> Next series of lines is Outside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0            0.2
               16000        0.2
```

```
"==> Following are inner material properties (LAS, Clad is neglected) @350F ('89
Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
              23.8
"    Density * Specific Heat (Btu/Ft3)"
              59.649
"    Modulus of Elasticity (ksi)"
              27.7e3
"    Coefficient of Thermal Expansion (per F)"
              7.50e-6
"    Poissons Ratio"
              .3

"==> Following are outer material properties (LAS) @350F ('89 Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
              23.8
"    Density * Specific Heat (Btu/Ft3)"
              59.649
"    Modulus of Elasticity (ksi)"
              27.7e3
"    Coefficient of Thermal Expansion (per F)"
              7.50e-6
"    Poissons Ratio"
              .3

"==> Value of uniform temperature which is stress free in cylinder"
"    Stress-free temperature (F) may be any value"
              70

"==> Timestep and time control information (seconds)"
"     Timestep Max <= 0.5*{[(Ro-Ri)/nodes]^2/[k/RhoCp]}*3600"
"     Next line is number of time control intervals "
              1
"   end of interval - time step - print interval"
              16000         10.0           360
********************* END OF FILE  *******************
   CREATED   DATE:  12-18-1998       TIME:  09:30:00
```

File = "15480.STP" (for Unit 1 bottom head)

1	110.5938	+5.10	+5.10	-0.00	+3.78	+3.80	127.7	132.0
2	110.7288	+4.72	+4.73	+0.01	+3.59	+3.62	128.9	132.7
3	110.8638	+4.35	+4.36	+0.01	+3.40	+3.43	130.2	133.3
4	110.9988	+3.98	+4.00	+0.02	+3.21	+3.24	131.4	133.9
5	111.1338	+3.63	+3.65	+0.02	+3.02	+3.05	132.6	134.6
6	111.2688	+3.28	+3.31	+0.03	+2.83	+2.86	133.7	135.2
7	111.4038	+2.95	+2.98	+0.03	+2.65	+2.67	134.8	135.9
8	111.5388	+2.63	+2.66	+0.03	+2.46	+2.48	135.9	136.5
9	111.6738	+2.32	+2.35	+0.04	+2.27	+2.29	136.9	137.1
10	111.8088	+2.01	+2.05	+0.04	+2.08	+2.11	137.9	137.8
11	111.9438	+1.72	+1.76	+0.04	+1.89	+1.92	138.9	138.4
12	112.0788	+1.44	+1.48	+0.04	+1.70	+1.73	139.9	139.0
13	112.2138	+1.17	+1.21	+0.04	+1.51	+1.54	140.8	139.7
14	112.3488	+0.90	+0.95	+0.04	+1.32	+1.35	141.7	140.3
15	112.4838	+0.65	+0.70	+0.05	+1.13	+1.16	142.5	140.9
16	112.6188	+0.41	+0.45	+0.05	+0.95	+0.97	143.3	141.6
17	112.7538	+0.18	+0.22	+0.05	+0.76	+0.79	144.1	142.2
18	112.8888	-0.05	-0.00	+0.05	+0.57	+0.60	144.9	142.8
19	113.0238	-0.26	-0.21	+0.05	+0.38	+0.41	145.6	143.5
20	113.1588	-0.46	-0.42	+0.05	+0.19	+0.22	146.3	144.1
21	113.2938	-0.66	-0.61	+0.05	+0.00	+0.03	146.9	144.7
22	113.4288	-0.84	-0.79	+0.04	-0.19	-0.16	147.5	145.4
23	113.5638	-1.01	-0.97	+0.04	-0.38	-0.35	148.1	146.0
24	113.6988	-1.17	-1.13	+0.04	-0.57	-0.53	148.7	146.7
25	113.8338	-1.33	-1.29	+0.04	-0.75	-0.72	149.2	147.3
26	113.9688	-1.47	-1.43	+0.04	-0.94	-0.91	149.7	147.9
27	114.1038	-1.61	-1.57	+0.04	-1.13	-1.10	150.1	148.6
28	114.2388	-1.73	-1.70	+0.03	-1.32	-1.29	150.6	149.2
29	114.3738	-1.85	-1.81	+0.03	-1.51	-1.48	151.0	149.8
30	114.5088	-1.95	-1.92	+0.03	-1.70	-1.67	151.3	150.5
31	114.6438	-2.05	-2.02	+0.03	-1.89	-1.86	151.7	151.1
32	114.7788	-2.13	-2.11	+0.03	-2.08	-2.04	152.0	151.7
33	114.9138	-2.21	-2.19	+0.02	-2.27	-2.23	152.2	152.4
34	115.0488	-2.28	-2.26	+0.02	-2.45	-2.42	152.5	153.0
35	115.1838	-2.33	-2.32	+0.02	-2.64	-2.61	152.7	153.6
36	115.3188	-2.38	-2.37	+0.01	-2.83	-2.80	152.8	154.3
37	115.4538	-2.42	-2.41	+0.01	-3.02	-2.99	153.0	154.9
38	115.5888	-2.45	-2.44	+0.01	-3.21	-3.18	153.1	155.6
39	115.7238	-2.47	-2.46	+0.01	-3.40	-3.36	153.2	156.2
40	115.8588	-2.48	-2.48	+0.00	-3.59	-3.55	153.2	156.8
41	115.9938	-2.48	-2.48	-0.00	-3.78	-3.74	153.2	157.5

15480

```
File = "U2-BELT.IN"

******  PIPE-TS2 INPUT FILE  =>  100f.in (TOP OF FILE)  ******
" Note that a blank line must preceed each line with ==> at start"

"==> Next 3 lines are CASE DESCRIPTIONS (or blanks) in parentheses"
"Cooldown Transient for Brunswick Unit 2"
"100F/hr, 550F to 120F"
"Vessel Shell Location"

"==> Next information is the pipe geometry"
"   First line is number of pipe nodes - 40 max"
"   Next line is inside radius (in.) and outside radius(in.)"
"   Next line is interface rad. (in.) / nodes in first material"
               40
               110.3125   115.7785
               110.44915   1

"==> Next line is initial pipe wall temperature"
               550

"==> Next series of lines is Inside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               3
               0             550
               15480         120
               16000         120

"==> Next series of lines is Inside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0            356.5
               16000        356.5

"==> Next series of lines is Outside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
               2
               0             120
               16000         120

"==> Next series of lines is Outside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
               2
               0             0.2
               16000         0.2
```

```
"==> Following are inner material properties (LAS, Clad is neglected) @350F ('89
Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
            23.8
"    Density * Specific Heat (Btu/Ft3)"
            59.649
"    Modulus of Elasticity (ksi)"
            27.7e3
"    Coefficient of Thermal Expansion (per F)"
            7.50e-6
"    Poissons Ratio"
            .3

"==> Following are outer material properties (LAS) @350F ('89 Code)"
"    Thermal conductivity (Btu/Hr-Ft-F)"
            23.8
"    Density * Specific Heat (Btu/Ft3)"
            59.649
"    Modulus of Elasticity (ksi)"
            27.7e3
"    Coefficient of Thermal Expansion (per F)"
            7.50e-6
"    Poissons Ratio"
            .3

"==> Value of uniform temperature which is stress free in cylinder"
"    Stress-free temperature (F) may be any value"
            70

"==> Timestep and time control information (seconds)"
"     Timestep Max <= 0.5*{[(Ro-Ri)/nodes]^2/[k/RhoCp]}*3600"
"     Next line is number of time control intervals "
            1
"   end of interval - time step - print interval"
            16000        10.0           360
********************** END OF FILE ********************
   CREATED   DATE:  12-18-1998       TIME:  09:30:00
```

File = "15480.STP" (for Unit 2 beltline)

1	110.3125	+5.23	+5.23	+0.00	+3.88	+3.90	127.8	132.3
2	110.4492	+4.84	+4.85	+0.01	+3.68	+3.71	129.1	132.9
3	110.5858	+4.46	+4.47	+0.01	+3.49	+3.51	130.3	133.6
4	110.7225	+4.08	+4.10	+0.02	+3.29	+3.32	131.6	134.2
5	110.8591	+3.72	+3.74	+0.02	+3.10	+3.13	132.8	134.9
6	110.9958	+3.37	+3.39	+0.03	+2.91	+2.93	134.0	135.5
7	111.1324	+3.03	+3.06	+0.03	+2.71	+2.74	135.1	136.2
8	111.2691	+2.69	+2.73	+0.03	+2.52	+2.55	136.2	136.8
9	111.4057	+2.37	+2.41	+0.04	+2.33	+2.35	137.3	137.5
10	111.5424	+2.06	+2.10	+0.04	+2.13	+2.16	138.3	138.1
11	111.6790	+1.76	+1.80	+0.04	+1.94	+1.97	139.3	138.8
12	111.8157	+1.47	+1.52	+0.04	+1.74	+1.77	140.3	139.4
13	111.9523	+1.19	+1.24	+0.05	+1.55	+1.58	141.2	140.1
14	112.0890	+0.93	+0.97	+0.05	+1.36	+1.39	142.1	140.7
15	112.2256	+0.67	+0.71	+0.05	+1.16	+1.19	143.0	141.4
16	112.3623	+0.42	+0.47	+0.05	+0.97	+1.00	143.8	142.0
17	112.4989	+0.18	+0.23	+0.05	+0.78	+0.81	144.6	142.7
18	112.6356	-0.05	-0.00	+0.05	+0.58	+0.61	145.4	143.3
19	112.7722	-0.27	-0.22	+0.05	+0.39	+0.42	146.1	144.0
20	112.9089	-0.47	-0.43	+0.05	+0.19	+0.23	146.8	144.6
21	113.0455	-0.67	-0.63	+0.05	+0.00	+0.03	147.5	145.3
22	113.1822	-0.86	-0.81	+0.05	-0.19	-0.16	148.1	145.9
23	113.3188	-1.04	-0.99	+0.04	-0.39	-0.35	148.7	146.6
24	113.4555	-1.20	-1.16	+0.04	-0.58	-0.55	149.3	147.2
25	113.5921	-1.36	-1.32	+0.04	-0.77	-0.74	149.8	147.9
26	113.7288	-1.51	-1.47	+0.04	-0.97	-0.93	150.3	148.5
27	113.8654	-1.65	-1.61	+0.04	-1.16	-1.13	150.8	149.2
28	114.0021	-1.78	-1.74	+0.04	-1.35	-1.32	151.3	149.8
29	114.1387	-1.89	-1.86	+0.03	-1.55	-1.51	151.7	150.5
30	114.2754	-2.00	-1.97	+0.03	-1.74	-1.71	152.0	151.1
31	114.4120	-2.10	-2.07	+0.03	-1.94	-1.90	152.4	151.8
32	114.5487	-2.19	-2.16	+0.03	-2.13	-2.10	152.7	152.5
33	114.6853	-2.27	-2.24	+0.02	-2.32	-2.29	152.9	153.1
34	114.8220	-2.33	-2.31	+0.02	-2.52	-2.48	153.2	153.8
35	114.9586	-2.39	-2.38	+0.02	-2.71	-2.68	153.4	154.4
36	115.0953	-2.44	-2.43	+0.01	-2.90	-2.87	153.6	155.1
37	115.2319	-2.48	-2.47	+0.01	-3.10	-3.06	153.7	155.7
38	115.3686	-2.51	-2.50	+0.01	-3.29	-3.26	153.8	156.4
39	115.5052	-2.53	-2.53	+0.01	-3.49	-3.45	153.9	157.0
40	115.6419	-2.54	-2.54	+0.00	-3.68	-3.64	153.9	157.7
41	115.7785	-2.54	-2.54	+0.00	-3.87	-3.84	154.0	158.3

15480

```
File = "U2-BOTHD.IN"

****** PIPE-TS2 INPUT FILE => 100f.in (TOP OF FILE) ******
" Note that a blank line must preceed each line with ==> at start"

"==> Next 3 lines are CASE DESCRIPTIONS (or blanks) in parentheses"
"Cooldown Transient for Brunswick Unit 2"
"100F/hr, 550F to 120F"
"Bottom Head Location"

"==> Next information is the pipe geometry"
"   First line is number of pipe nodes - 40 max"
"   Next line is inside radius (in.) and outside radius(in.)"
"   Next line is interface rad. (in.) / nodes in first material"
              40
              110.3125    115.7325
              110.4480    1

"==> Next line is initial pipe wall temperature"
              550

"==> Next series of lines is Inside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
              3
              0             550
              15480         120
              16000         120

"==> Next series of lines is Inside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
              2
              0            356.5
              16000        356.5

"==> Next series of lines is Outside Temperature history"
"    First entry is number of input data pairs - 40 Max"
"    Data pairs follow as   Time(sec)   Temperature(F)"
              2
              0             120
              16000         120

"==> Next series of lines is Outside Ht. Tx. Coefficient history"
"    First entry is number of input data pairs - 40 max"
"    Data pairs:  Time(sec)   Ht. Tx. Coefficient(Btu/hr-ft2-F)"
              2
              0             0.2
              16000         0.2
```

```
"==> Following are inner material properties (LAS, Clad is neglected) @350F ('89
Code)"
"     Thermal conductivity (Btu/Hr-Ft-F)"
                23.8
"     Density * Specific Heat (Btu/Ft3)"
                59.649
"     Modulus of Elasticity (ksi)"
                27.7e3
"     Coefficient of Thermal Expansion (per F)"
                7.50e-6
"     Poissons Ratio"
                .3

"==> Following are outer material properties (LAS) @350F ('89 Code)"
"     Thermal conductivity (Btu/Hr-Ft-F)"
                23.8
"     Density * Specific Heat (Btu/Ft3)"
                59.649
"     Modulus of Elasticity (ksi)"
                27.7e3
"     Coefficient of Thermal Expansion (per F)"
                7.50e-6
"     Poissons Ratio"
                .3

"==> Value of uniform temperature which is stress free in cylinder"
"     Stress-free temperature (F) may be any value"
                70

"==> Timestep and time control information (seconds)"
"      Timestep Max <= 0.5*{[(Ro-Ri)/nodes]^2/[k/RhoCp]}*3600"
"      Next line is number of time control intervals "
                1
"    end of interval - time step - print interval"
                16000         10.0          360
********************** END OF FILE  ********************
   CREATED   DATE:  12-18-1998       TIME:  09:30:00
```

File = "15480.STP" (for Unit 2 bottom head)

1	110.3125	+5.15	+5.15	+0.00	+3.82	+3.84	127.7	132.1
2	110.4480	+4.76	+4.77	+0.01	+3.63	+3.65	129.0	132.8
3	110.5835	+4.38	+4.40	+0.01	+3.43	+3.46	130.2	133.4
4	110.7190	+4.02	+4.03	+0.02	+3.24	+3.27	131.5	134.0
5	110.8545	+3.66	+3.68	+0.02	+3.05	+3.08	132.6	134.7
6	110.9900	+3.31	+3.34	+0.03	+2.86	+2.89	133.8	135.3
7	111.1255	+2.98	+3.01	+0.03	+2.67	+2.70	134.9	136.0
8	111.2610	+2.65	+2.68	+0.03	+2.48	+2.51	136.0	136.6
9	111.3965	+2.34	+2.37	+0.04	+2.29	+2.32	137.1	137.2
10	111.5320	+2.03	+2.07	+0.04	+2.10	+2.13	138.1	137.9
11	111.6675	+1.74	+1.78	+0.04	+1.91	+1.93	139.1	138.5
12	111.8030	+1.45	+1.49	+0.04	+1.72	+1.74	140.0	139.2
13	111.9385	+1.18	+1.22	+0.04	+1.53	+1.55	140.9	139.8
14	112.0740	+0.91	+0.96	+0.05	+1.34	+1.36	141.8	140.5
15	112.2095	+0.66	+0.70	+0.05	+1.15	+1.17	142.7	141.1
16	112.3450	+0.41	+0.46	+0.05	+0.95	+0.98	143.5	141.7
17	112.4805	+0.18	+0.22	+0.05	+0.76	+0.79	144.3	142.4
18	112.6160	-0.05	-0.00	+0.05	+0.57	+0.60	145.0	143.0
19	112.7515	-0.26	-0.22	+0.05	+0.38	+0.41	145.8	143.7
20	112.8870	-0.47	-0.42	+0.05	+0.19	+0.22	146.5	144.3
21	113.0225	-0.66	-0.62	+0.05	+0.00	+0.03	147.1	144.9
22	113.1580	-0.85	-0.80	+0.04	-0.19	-0.16	147.7	145.6
23	113.2935	-1.02	-0.98	+0.04	-0.38	-0.35	148.3	146.2
24	113.4290	-1.19	-1.14	+0.04	-0.57	-0.54	148.9	146.9
25	113.5645	-1.34	-1.30	+0.04	-0.76	-0.73	149.4	147.5
26	113.7000	-1.49	-1.45	+0.04	-0.95	-0.92	149.9	148.2
27	113.8354	-1.62	-1.58	+0.04	-1.14	-1.11	150.4	148.8
28	113.9709	-1.75	-1.71	+0.03	-1.33	-1.30	150.8	149.4
29	114.1064	-1.86	-1.83	+0.03	-1.52	-1.49	151.2	150.1
30	114.2419	-1.97	-1.94	+0.03	-1.72	-1.68	151.6	150.7
31	114.3774	-2.07	-2.04	+0.03	-1.91	-1.87	151.9	151.4
32	114.5129	-2.15	-2.13	+0.03	-2.10	-2.06	152.2	152.0
33	114.6484	-2.23	-2.21	+0.02	-2.29	-2.25	152.5	152.6
34	114.7839	-2.30	-2.28	+0.02	-2.48	-2.44	152.7	153.3
35	114.9194	-2.36	-2.34	+0.02	-2.67	-2.63	152.9	153.9
36	115.0549	-2.40	-2.39	+0.01	-2.86	-2.82	153.1	154.6
37	115.1904	-2.44	-2.43	+0.01	-3.05	-3.01	153.2	155.2
38	115.3259	-2.47	-2.46	+0.01	-3.24	-3.20	153.3	155.8
39	115.4614	-2.49	-2.49	+0.01	-3.43	-3.39	153.4	156.5
40	115.5969	-2.50	-2.50	+0.00	-3.62	-3.58	153.5	157.1
41	115.7324	-2.50	-2.50	+0.00	-3.81	-3.77	153.5	157.8

15480

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

APPENDIX B

(P-T CURVES FOR BSEP-1)

File = "REV_U1-PTEST.XLS" (Pressure Test Curves):	
Sheet = "Beltline (32)" (for beltline @ 32 EFPY)	[1 page]
Sheet = "Bottom Head" (for bottom head)	[1 page]
Sheet = "N16 Nozzle (32)" (for N16 Nozzle @ 32 EFPY)	[1 page]
Plot = "Beltline vs. Nozzle" (shows nozzle is limiting)	[1 page]
Plot = "32 EFPY Curve" (P-T curve for 32 EFPY)	[1 page]
File = "REV_U1-CNC.XLS" (Core Not Critical Curves):	
Sheet = "Beltline (32)" (for beltline @ 32 EFPY)	[1 page]
Sheet = "Bottom Head" (for bottom head)	[1 page]
Sheet = "N16 Nozzle (32)" (for N16 Nozzle @ 32 EFPY)	[1 page]
Plot = "Beltline vs. Nozzle" (shows nozzle is limiting)	[1 page]
Plot = "32 EFPY CNC Curve" (P-T curve for 32 EFPY)	[1 page]
File = "REV_U1-CC.XLS" (Core Critical Curves):	
Sheet = "Curve C (32)" (for N16 Nozzle & Bottom Head @ 32 EFPY)	[1 page]
Plot = "32 EFPY CC Curve" (P-T curve for 32 EFPY)	[1 page]
Total =	[12 pages]

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	**Brunswick 1**	
Component =	**Beltline**	
Vessel thickness, t =	**5.496**	inches (minimum)
M_t =	**0.274**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**110.59375**	inches (maximum)
RT_{NDT} =	**116.0**	°F ======> **32 EFPY**
ΔT_w =	**0.0**	°F (no thermal for pressure test)
K_{IT} =	**0.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**0.0**	°F (no thermal for pressure test)
Stress Multiplier, F =	**1.00**	
Safety Factor =	**1.50**	(for pressure test)
M_m =	**2.40**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**16.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	76.0	42.52	28.34	0	70	0
76	76.0	42.52	28.34	313	70	283
80	80.0	43.29	28.86	313	90	283
85	85.0	44.35	29.57	313	95	283
90	90.0	45.53	30.35	313	100	283
95	95.0	46.82	31.22	313	105	283
100	100.0	48.26	32.17	313	110	283
106	106.0	50.18	33.45	313	116	283
106	106.0	50.18	33.45	693	116	663
111	111.0	51.96	34.64	717	121	687
116	116.0	53.93	35.96	745	126	715
121	121.0	56.11	37.41	775	131	745
126	126.0	58.52	39.02	808	136	778
131	131.0	61.19	40.79	845	141	815
136	136.0	64.13	42.75	885	146	855
141	141.0	67.38	44.92	930	151	900
146	146.0	70.98	47.32	980	156	950
151	151.0	74.95	49.97	1035	161	1005
156	156.0	79.34	52.90	1095	166	1065
158.6	158.6	81.81	54.54	1129	169	1099
164	163.6	86.92	57.95	1200	174	1170
169	168.6	92.57	61.71	1278	179	1248
174	173.6	98.81	65.88	1364	184	1334

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant = **Brunswick 1**
Component = **Bottom Head**
Vessel thickness, t = **5.400** inches (minimum)
M_t = **0.274** (per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R = **110.59375** inches (maximum)
RT_{NDT} = **10.0** °F ======> **All EFPYs**
ΔT_w = **0.0** °F (no thermal for pressure test)
K_{IT} = **0.0** ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ = **0.0** °F (no thermal for pressure test)
Stress Multiplier, F = **1.50** (for spherical bottom head with penetrations)
Safety Factor = **1.50** (for pressure test)
M_m = **2.40** (per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error = **10.0** °F
Pressure Instrument Error = **30.0** psig
Hydro Test Pressure = **1563** psig
Flange RT_{NDT} = **16.0** °F

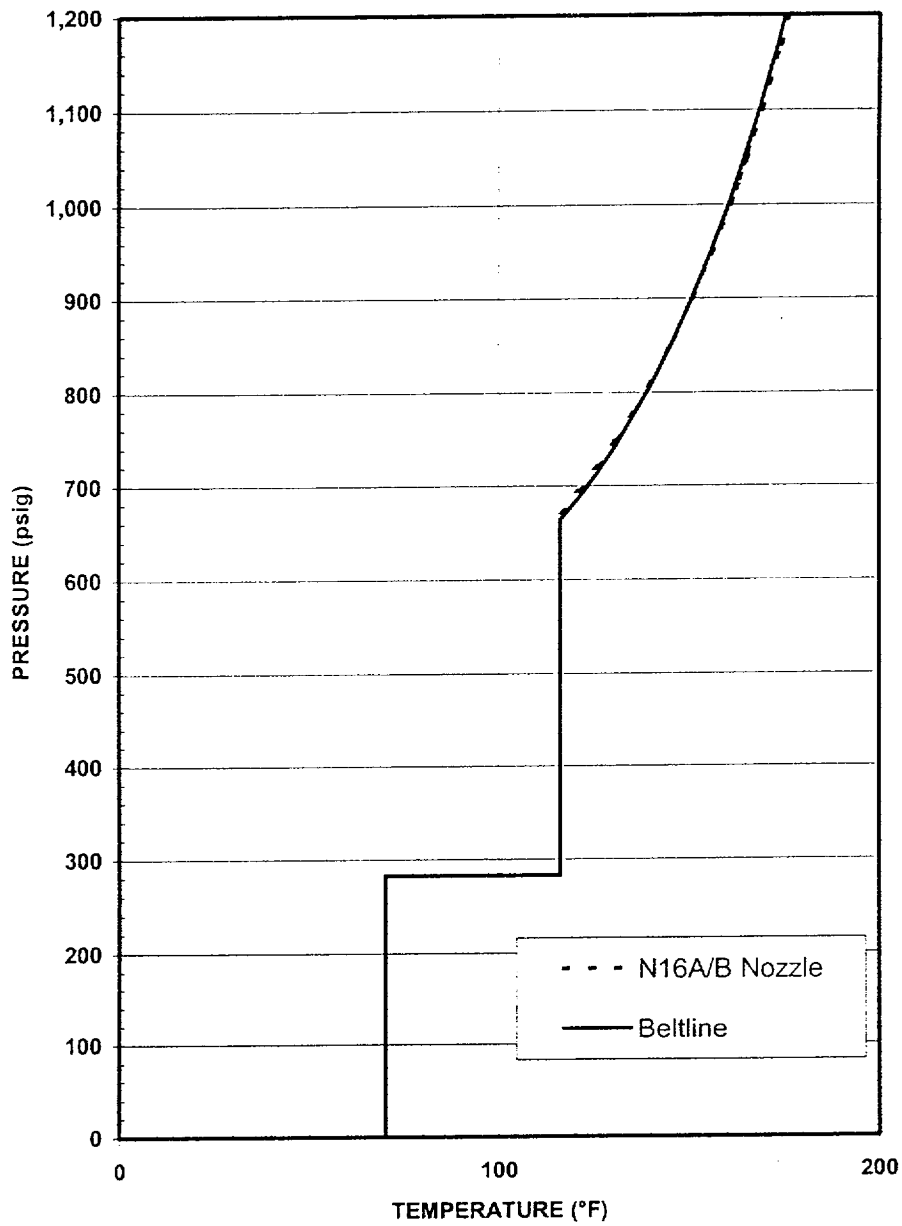
Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	0.0	50.18	33.45	0	70	0
60	60.0	89.56	59.71	810	70	780
65	65.0	95.49	63.66	863	75	833
70	70.0	102.04	68.03	923	80	893
75	75.0	109.28	72.85	988	85	958
80	80.0	117.28	78.19	1060	90	1030
85	85.0	126.12	84.08	1140	95	1110
90	90.0	135.90	90.60	1229	100	1199
95	95.0	146.70	97.80	1326	105	1296
100	100.0	158.63	105.76	1434	110	1404

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 1	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	120.0	°F ======> 32 EFPY
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	N/A	
Safety Factor =	1.50	(for pressure test)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	76.0	41.80	27.87	0	70	0
76	76.0	41.80	27.87	313	70	283
80	80.0	42.52	28.34	313	90	283
85	85.0	43.50	29.00	313	95	283
90	90.0	44.58	29.72	313	100	283
95	95.0	45.78	30.52	313	105	283
100	100.0	47.10	31.40	313	110	283
106	106.0	48.87	32.58	313	116	283
106	106.0	48.87	32.58	701	116	671
111	111.0	50.52	33.68	725	121	695
116	116.0	52.34	34.89	751	126	721
121	121.0	54.35	36.24	780	131	750
126	126.0	56.58	37.72	812	136	782
131	131.0	59.04	39.36	847	141	817
136	136.0	61.75	41.17	886	146	856
141	141.0	64.76	43.17	929	151	899
146	146.0	68.08	45.38	977	156	947
151	151.0	71.74	47.83	1030	161	1000
156	156.0	75.80	50.53	1088	166	1058
152	152.4	72.84	48.56	1045	162	1015
155	155.0	74.95	49.97	1076	165	1046
155	155.0	74.95	49.97	1076	165	1046
155	155.0	74.95	49.97	1076	165	1046
159.3	159.3	78.70	52.47	1130	169	1100
164	164.3	83.49	55.66	1198	174	1168
169	169.3	88.78	59.18	1274	179	1244
174	174.3	94.62	63.08	1358	184	1328



BELTLINE VS. N16A/B NOZZLE @ 32 EFPY
PRESSURE TEST CONDITIONS
(NOZZLE IS MORE LIMITING)

	Revision	0	1		
	Preparer/Date	GLS 10/19/00	CMK 05/06/02		
	Checker/Date	JAH 10/19/00	BPT 05/06/02		
	File No. **CPL-54Q-303**			**Page** B5 **of** B13	

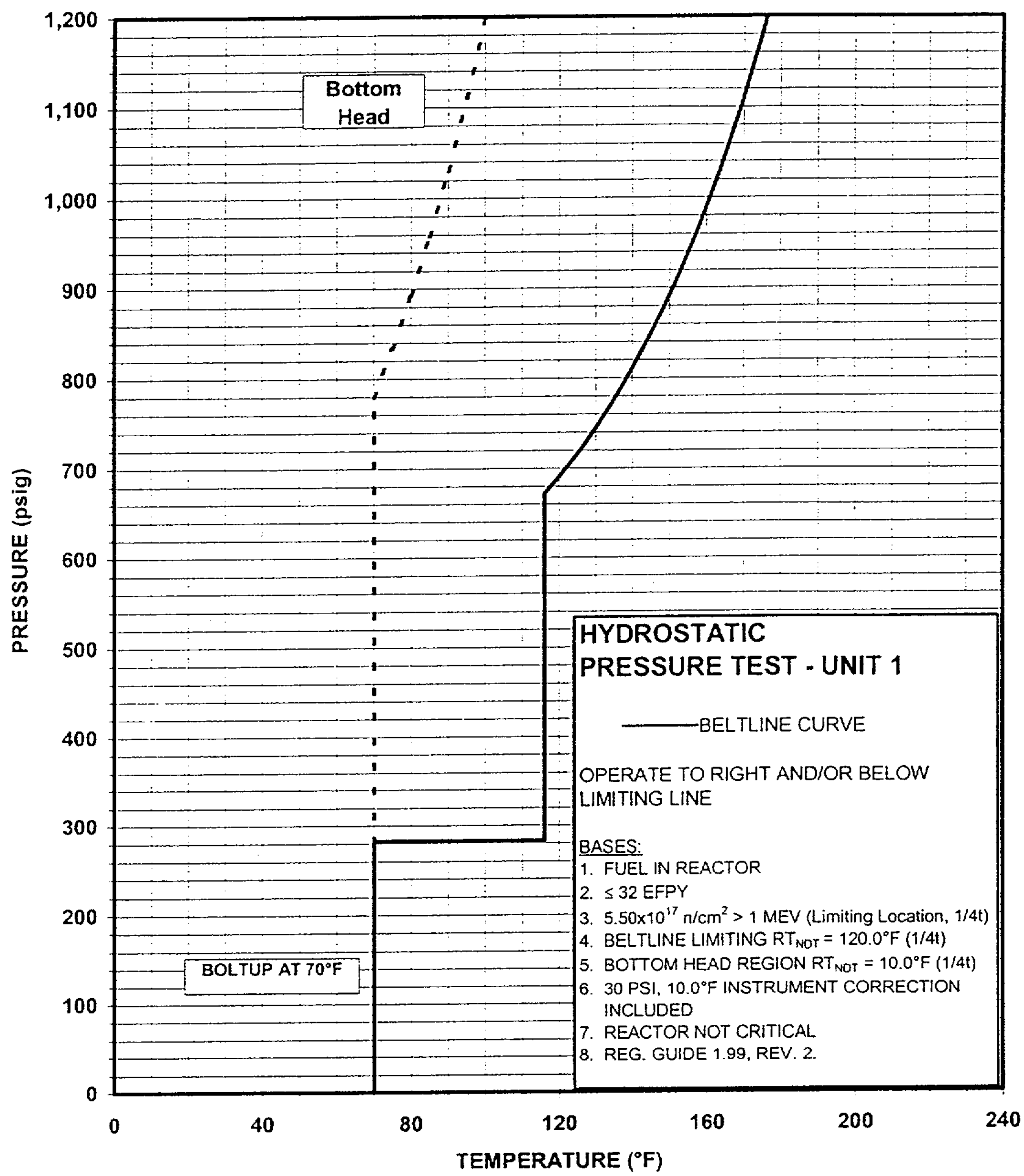


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Hydrostatic and Leak Tests ≤ 32 EFPY

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

File No. CPL-54Q-303

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	**Brunswick 1**	
Component =	**Beltline**	
Vessel thickness, t =	**5.496**	inches (minimum)
M_t =	**0.274**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**110.59375**	inches (maximum)
RT_{NDT} =	**116.0**	°F ======> 32 EFPY
ΔT_w =	**26.5**	°F (temp. difference between inside and outside surfaces)
K_{IT} =	**7.3**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**19.5**	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	**1.00**	
Safety Factor =	**2.00**	(for heatup/cooldown)
M_m =	**2.40**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**16.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	95.5	46.96	19.84	0	70	0
76	95.5	46.96	19.84	313	70	283
80	99.5	48.11	20.42	313	90	283
85	104.5	49.67	21.20	313	95	283
90	109.5	51.41	22.07	313	100	283
95	114.5	53.32	23.02	313	105	283
100	119.5	55.44	24.08	313	110	283
136	155.5	78.89	35.81	313	146	283
136	155.5	78.89	35.81	741	146	711
141	160.5	83.69	38.21	791	151	761
146	165.5	89.00	40.86	846	156	816
151	170.5	94.87	43.80	907	161	877
156	175.5	101.35	47.04	974	166	944
161	180.5	108.52	50.62	1048	171	1018
166	185.5	116.44	54.59	1130	176	1100
171	190.5	125.20	58.96	1221	181	1191
176	195.5	134.87	63.80	1321	186	1291
181	200.5	145.57	69.15	1432	191	1402

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	Brunswick 1	
Component =	Bottom Head	
Vessel thickness, t =	5.400	inches (minimum)
M_t =	0.274	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	110.59375	inches (maximum)
RT_{NDT} =	10.0	°F ======> **All EFPYs**
ΔT_w =	25.5	°F (temp. difference between inside and outside surfaces)
K_{IT} =	7.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	18.9	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	1.50	(for spherical bottom head with penetrations)
Safety Factor =	2.00	(for heatup/cooldown)
M_m =	2.40	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

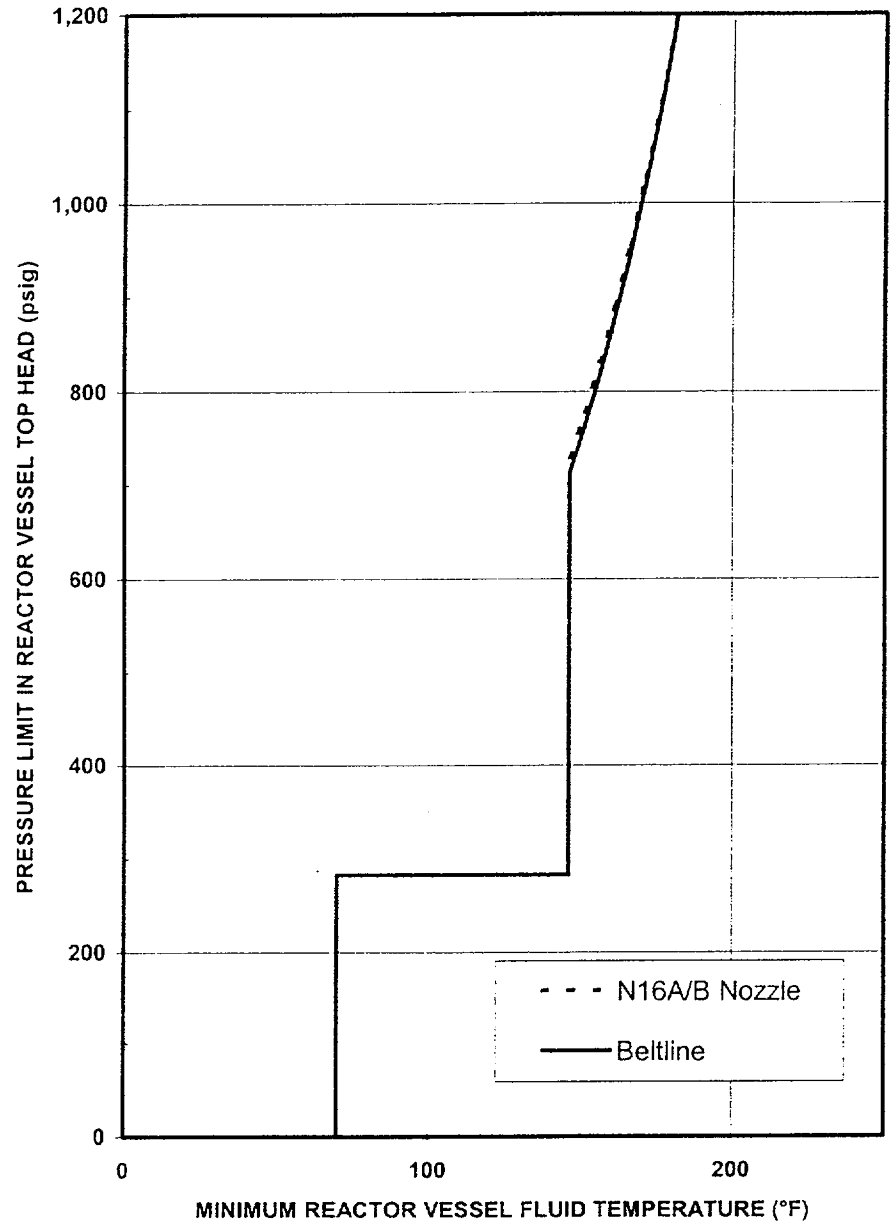
Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	18.9	57.97	25.49	0	70	0
5	23.9	60.58	26.79	363	70	333
10	28.9	63.46	28.23	383	70	353
15	33.9	66.64	29.82	404	70	374
20	38.9	70.16	31.58	428	70	398
25	43.9	74.04	33.52	455	70	425
30	48.9	78.34	35.67	484	70	454
35	53.9	83.09	38.04	516	70	486
40	58.9	88.33	40.67	552	70	522
45	63.9	94.13	43.57	591	70	561
50	68.9	100.54	46.77	634	70	604
55	73.9	107.62	50.31	682	70	652
60	78.9	115.45	54.23	735	70	705
65	83.9	124.10	58.55	794	75	764
70	88.9	133.66	63.33	859	80	829
75	93.9	144.23	68.61	931	85	901
80	98.9	155.90	74.45	1010	90	980
85	103.9	168.81	80.91	1097	95	1067
90	108.9	183.07	88.04	1194	100	1164
95	113.9	198.83	95.92	1301	105	1271
100	118.9	200.00	96.50	1309	110	1279

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	Brunswick 1	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	120.0	°F ======> **32 EFPY**
ΔT_w =	N/A	°F (temp. difference between inside and outside surfaces)
K_{IT} =	5.4	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	20.1	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	N/A	
Safety Factor =	2.00	(for heatup/cooldown)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	96.1	46.06	20.33	0	70	0
76	96.1	46.06	20.33	313	70	283
80	100.1	47.13	20.87	313	90	283
85	105.1	48.60	21.60	313	95	283
90	110.1	50.22	22.41	313	100	283
95	115.1	52.01	23.30	313	105	283
100	120.1	53.99	24.29	313	110	283
136	156.1	75.91	35.25	313	146	283
136	156.1	75.91	35.25	759	146	729
141	161.1	80.40	37.50	807	151	777
146	166.1	85.36	39.98	861	156	831
151	171.1	90.85	42.72	920	161	890
156	176.1	96.91	45.76	985	166	955
161	181.1	103.61	49.11	1057	171	1027
166	186.1	111.02	52.81	1137	176	1107
171	191.1	119.20	56.90	1225	181	1195
176	196.1	128.25	61.42	1322	186	1292
181	201.1	138.24	66.42	1430	191	1400



BELTLINE VS. N16A/B NOZZLE @ 32 EFPY
CORE NOT CRITICAL CONDITIONS
(NOZZLE IS MORE LIMITING)

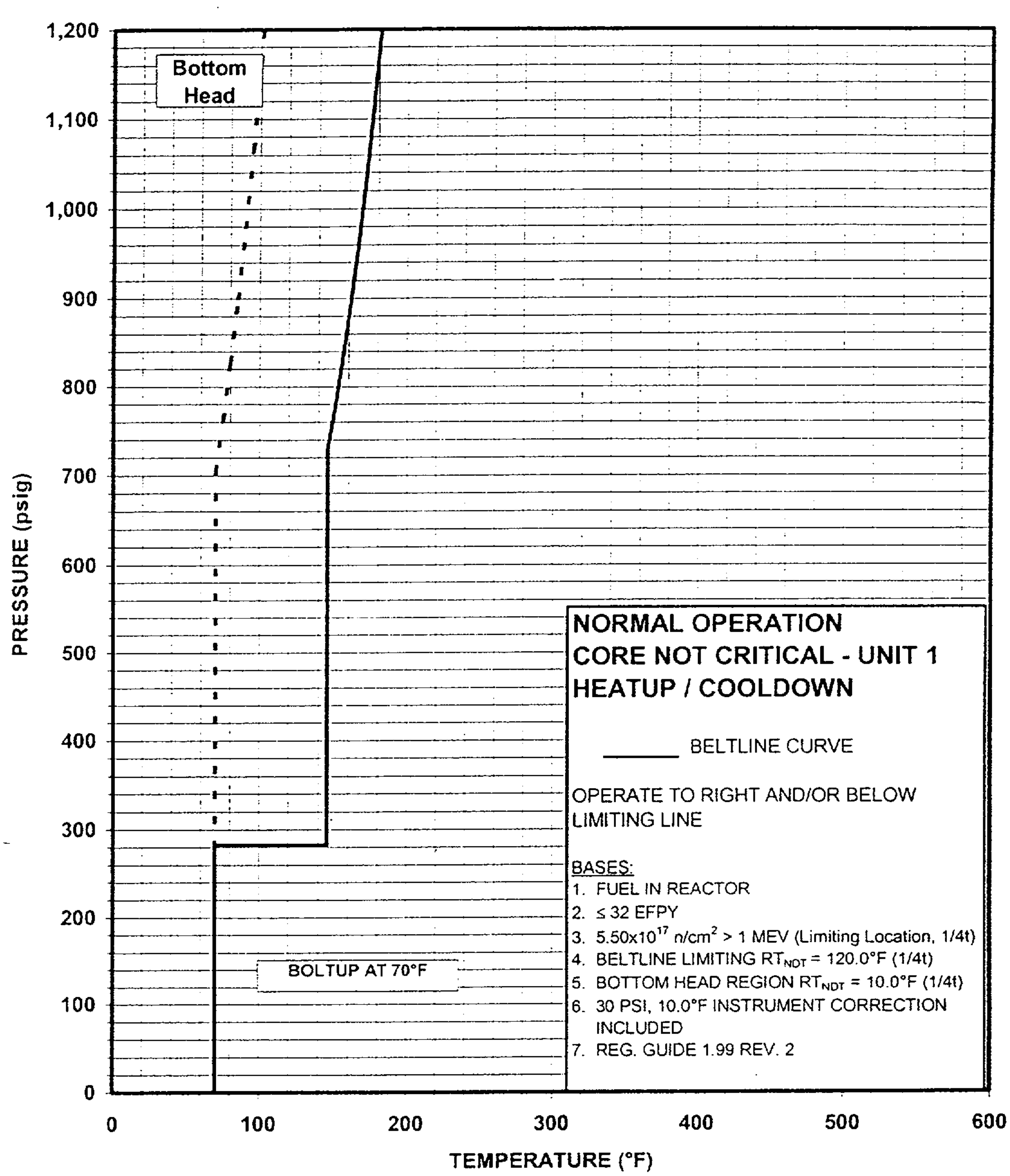


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Not Critical ≤ 32 EFPY

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

Pressure-Temperature Curve Calculation

(Core Critical = Curve C)

Inputs:

Plant = **Brunswick 1**
EFPY = **32**
Curve A Leak Test Temperature = **159.3** °F (at 1,100 psig)
Hydro Test Pressure = **1,565** psig
Flange RT_{NDT} = **16.0** °F
Temperature Instrument Error = **10.0** °F

Adjusted Curve B Temperature N16 Nozzle (°F)	Adjusted Curve B Pressure for N16 Nozzle (psig)	Adjusted Curve B Temperature Bottom Head (°F)	Adjusted Curve B Pressure for Bottom Head (psig)	Curve C Temperature N16 Nozzle (°F)	Curve C Pressure N16 Nozzle (psig)	Curve C Temperature Bottom Head (°F)	Curve C Pressure Bottom Head (psig)
70	0	10	0	86.0	0	86.0	0
70	283	15	333	86.0	283	86.0	333
90	283	20	353	130.0	283	86.0	353
95	283	25	374	135.0	283	86.0	374
100	283	30	398	140.0	283	86.0	398
105	283	35	425	145.0	283	86.0	425
110	283	40	454	150.0	283	86.0	454
146	283	45	486	186.0	283	86.0	486
146	729	50	522	186.0	729	90.0	522
151	777	55	561	191.0	777	95.0	561
156	831	60	604	196.0	831	100.0	604
161	890	65	652	201.0	890	105.0	652
166	955	70	705	206.0	955	110.0	705
171	1027	75	764	211.0	1027	115.0	764
176	1107	80	829	216.0	1107	120.0	829
181	1195	85	901	221.0	1195	125.0	901
186	1292	90	980	226.0	1292	130.0	980
191	1400	95	1067	231.0	1400	135.0	1067
		100	1164			140.0	1164
		105	1271			145.0	1271
		110	1279			150.0	1279

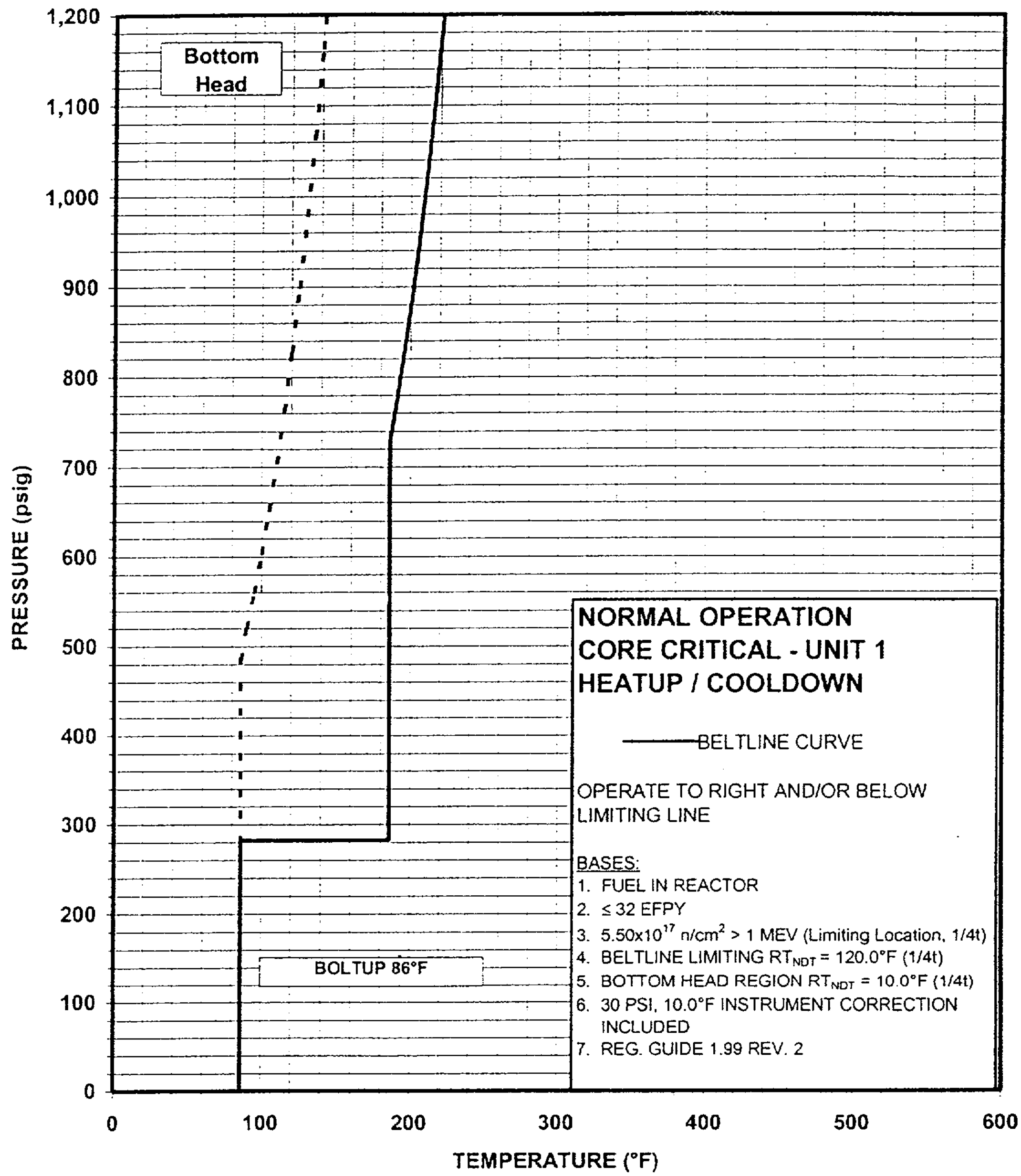


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Critical ≤ 32 EFPY

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

APPENDIX C

(P-T CURVES FOR BSEP-2)

File = "REV_U2-PTEST.XLS" (Pressure Test Curves):	
Sheet = "Beltline (32)" (for beltline @ 32 EFPY)	[1 page]
Sheet = "Bottom Head" (for bottom head)	[1 page]
Sheet = "N16 Nozzle (32)" (for N16 Nozzle @ 32 EFPY)	[1 page]
Plot = "Beltline vs. Nozzle" (shows nozzle is limiting)	[1 page]
Plot = "32 EFPY Curve" (P-T curve for 32 EFPY)	[1 page]
File = "REV_U2-CNC.XLS" (Core Not Critical Curves):	
Sheet = "Beltline (32)" (for beltline @ 32 EFPY)	[1 page]
Sheet = "Bottom Head" (for bottom head)	[1 page]
Sheet = "N16 Nozzle (32)" (for N16 Nozzle @ 32 EFPY)	[1 page]
Plot = "Beltline vs. Nozzle" (shows nozzle is limiting)	[1 page]
Plot = "32 EFPY CNC Curve" (P-T curve for 32 EFPY)	[1 page]
File = "REV_U2-CC.XLS" (Core Critical Curves):	
Sheet = "Curve C (32)" (for N16 Nozzle & Bottom Head @ 32 EFPY)	[1 page]
Plot = "32 EFPY CC Curve" (P-T curve for 32 EFPY)	[1 page]
Total =	[12 pages]

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	**Brunswick 2**	
Component =	**Beltline**	
Vessel thickness, t =	**5.466**	inches (minimum)
M_l =	**0.274**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**110.3125**	inches (maximum)
RT_{NDT} =	**93.5**	°F ======> **32 EFPY**
ΔT_w =	**0.0**	°F (no thermal for pressure test)
K_{IT} =	**0.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**0.0**	°F (no thermal for pressure test)
Stress Multiplier, F =	**1.00**	
Safety Factor =	**1.50**	(for pressure test)
M_m =	**2.40**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**10.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	70.0	46.16	30.77	0	70	0
70	70.0	46.16	30.77	313	70	283
75	75.0	47.52	31.68	313	85	283
80	80.0	49.03	32.69	313	90	283
85	85.0	50.69	33.80	313	95	283
90	90.0	52.53	35.02	313	100	283
95	95.0	54.57	36.38	313	105	283
100	100.0	56.81	37.87	313	110	283
100	100.0	56.81	37.87	782	110	752
105	105.0	59.30	39.53	816	115	786
110	110.0	62.04	41.36	854	120	824
115	115.0	65.07	43.38	896	125	866
120	120.0	68.43	45.62	942	130	912
125	125.0	72.13	48.09	993	135	963
136.4	136.4	82.10	54.73	1130	146	1100
141	141.4	87.24	58.16	1201	151	1171
146	146.4	92.93	61.95	1279	156	1249
151	151.4	99.21	66.14	1365	161	1335
156	156.4	106.15	70.77	1461	166	1431

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant = **Brunswick 2**
Component = **Bottom Head**
Vessel thickness, t = **5.420** inches (minimum)
M_t = **0.274** (per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R = **110.3125** inches (maximum)
RT_{NDT} = **40.0** °F ======> **All EFPYs**
ΔT_w = **0.0** °F (no thermal for pressure test)
K_{IT} = **0.0** ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ = **0.0** °F (no thermal for pressure test)
Stress Multiplier, F = **1.50** (for spherical bottom head with penetrations)
Safety Factor = **1.50** (for pressure test)
M_m = **2.40** (per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error = **10.0** °F
Pressure Instrument Error = **30.0** psig
Hydro Test Pressure = **1563** psig
Flange RT_{NDT} = **10.0** °F

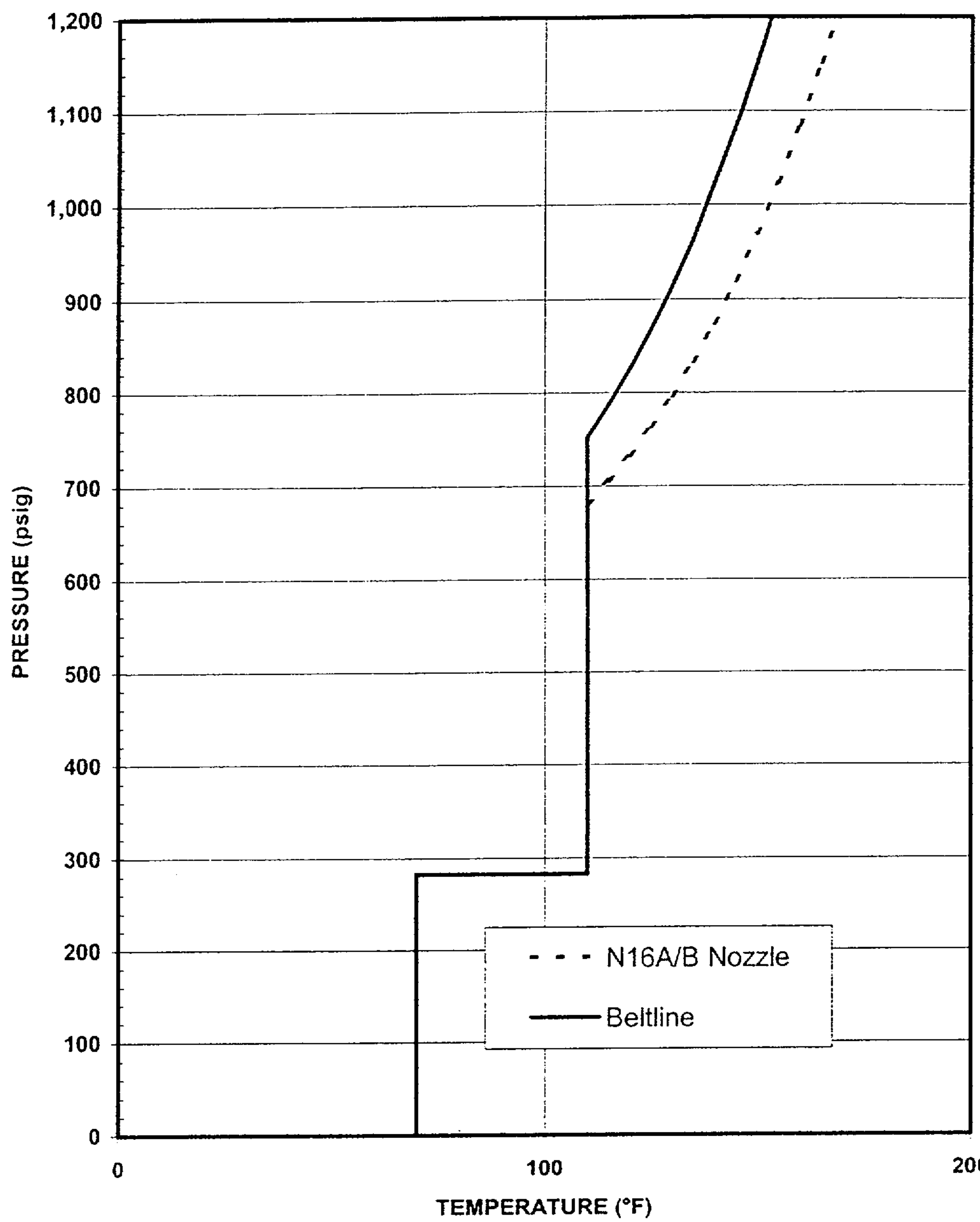
Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	0.0	42.52	28.34	0	70	0
60	60.0	64.13	42.75	584	70	554
65	65.0	67.38	44.92	613	75	583
70	70.0	70.98	47.32	646	80	616
75	75.0	74.95	49.97	682	85	652
80	80.0	79.34	52.90	722	90	692
85	85.0	84.20	56.13	766	95	736
90	90.0	89.56	59.71	815	100	785
95	95.0	95.49	63.66	869	105	839
100	100.0	102.04	68.03	928	110	898
105	105.0	109.28	72.85	994	115	964
110	110.0	117.28	78.19	1067	120	1037
115	115.0	126.12	84.08	1148	125	1118
120	120.0	135.90	90.60	1236	130	1206
125	125.0	146.70	97.80	1335	135	1305
130	130.0	158.63	105.76	1443	140	1413

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	**Brunswick 2**	
Component =	**N16 A/B**	(2" Instrument Nozzles)
Vessel thickness, t =	**N/A**	inches (minimum)
M_t =	**N/A**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**N/A**	inches (maximum)
RT_{NDT} =	**111.9**	°F ======> **32 EFPY**
ΔT_w =	**0.0**	°F (no thermal for pressure test)
K_{IT} =	**0.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**0.0**	°F (no thermal for pressure test)
Stress Multiplier, F =	**N/A**	
Safety Factor =	**1.50**	(for pressure test)
M_m =	**N/A**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**10.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	70.0	42.17	28.11	0	70	0
70	70.0	42.17	28.11	313	70	283
75	75.0	43.11	28.74	313	85	283
80	80.0	44.15	29.44	313	90	283
85	85.0	45.31	30.20	313	95	283
90	90.0	46.58	31.05	313	100	283
95	95.0	47.99	31.99	313	105	283
100	100.0	49.54	33.03	313	110	283
100	100.0	49.54	33.03	711	110	681
105	105.0	51.26	34.17	736	115	706
110	110.0	53.16	35.44	763	120	733
115	115.0	55.26	36.84	793	125	763
120	120.0	57.58	38.39	826	130	796
125	125.0	60.14	40.10	863	135	833
130	130.0	62.98	41.99	904	140	874
135	135.0	66.11	44.07	949	145	919
140	140.0	69.57	46.38	999	150	969
145	145.0	73.40	48.93	1053	155	1023
151.2	151.2	78.70	52.47	1130	161	1100
156	156.2	83.49	55.66	1198	166	1168
161	161.2	88.78	59.18	1274	171	1244
166	166.2	94.62	63.08	1358	176	1328
171	171.2	101.08	67.39	1451	181	1421



BELTLINE VS. N16A/B NOZZLE @ 32 EFPY
PRESSURE TEST CONDITIONS
(NOZZLE IS MORE LIMITING)

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

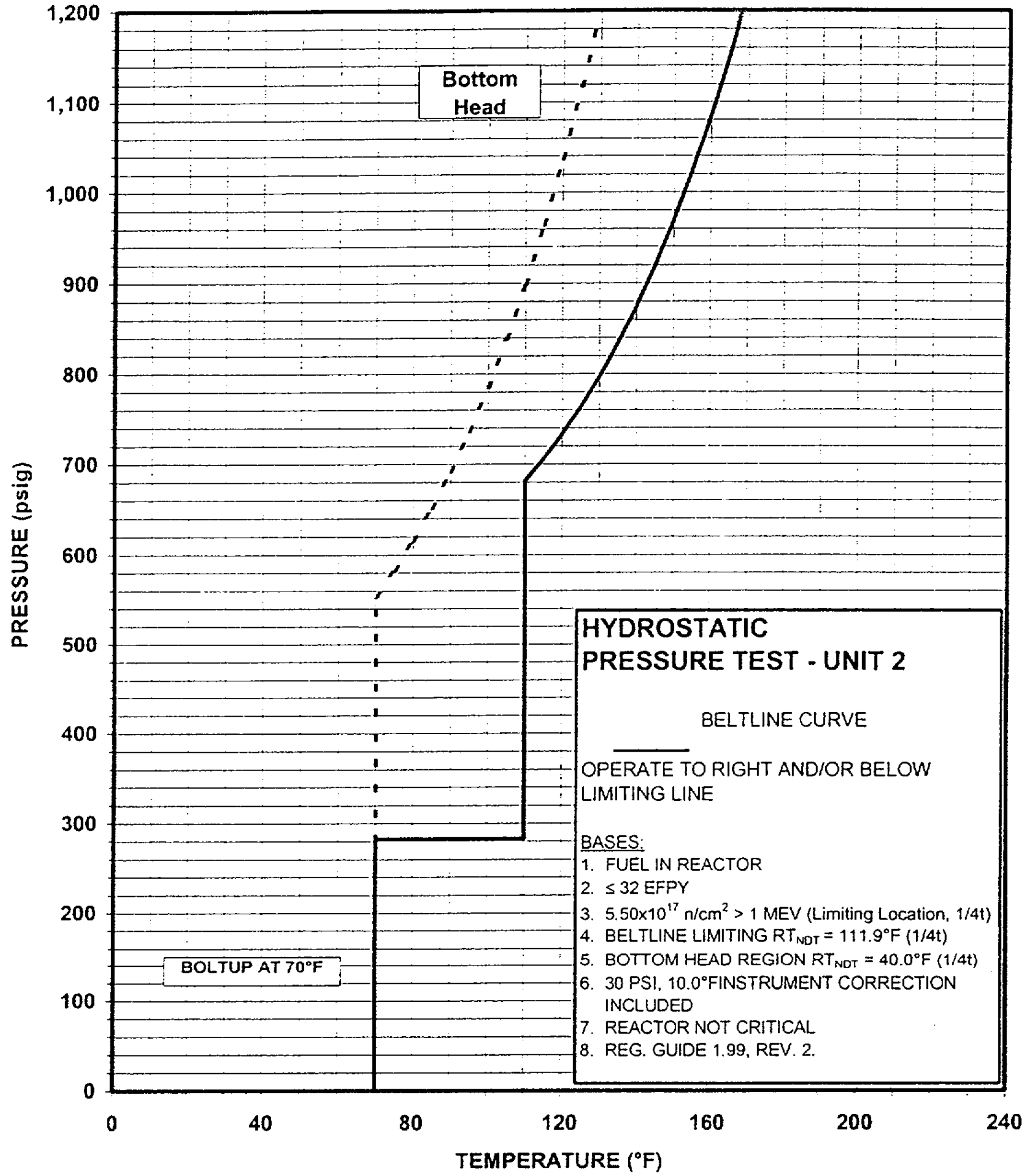


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Hydrostatic and Leak Tests ≤ 32 EFPY

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	**Brunswick 2**	
Component =	**Beltline**	
Vessel thickness, t =	**5.466**	inches (minimum)
M_t =	**0.274**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**110.3125**	inches (maximum)
RT_{NDT} =	**93.5**	°F ======> 32 EFPY
ΔT_w =	**26.2**	°F (temp. difference between inside and outside surfaces)
K_{IT} =	**7.2**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**19.3**	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	**1.00**	
Safety Factor =	**2.00**	(for heatup/cooldown)
M_m =	**2.40**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**10.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	89.3	52.26	22.54	0	70	0
70	89.3	52.26	22.54	313	70	283
75	94.3	54.27	23.54	313	85	283
80	99.3	56.48	24.65	313	90	283
85	104.3	58.93	25.87	313	95	283
90	109.3	61.64	27.22	313	100	283
95	114.3	64.63	28.72	313	105	283
100	119.3	67.94	30.37	313	110	283
105	124.3	71.59	32.20	313	115	283
110	129.3	75.63	34.22	313	120	283
115	134.3	80.09	36.45	313	125	283
120	139.3	85.02	38.91	313	130	283
125	144.3	90.47	41.64	313	135	283
130	149.3	96.49	44.65	313	140	283
130	149.3	96.49	44.65	922	140	892
135	154.3	103.15	47.98	991	145	961
140	159.3	110.51	51.66	1067	150	1037
145	164.3	118.64	55.72	1150	155	1120
150	169.3	127.62	60.22	1243	160	1213
155	174.3	137.55	65.18	1346	165	1316
160	179.3	148.53	70.67	1459	170	1429

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant = **Brunswick 2**
Component = **Bottom Head**
Vessel thickness, t = **5.420** inches (minimum)
M_t = **0.274** (per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R = **110.3125** inches (maximum)
RT_{NDT} = **40.0** °F ======> **All EFPYs**
ΔT_w = **25.8** °F (temp. difference between inside and outside surfaces)
K_{IT} = **7.1** ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ = **19.1** °F (temperature difference between fluid and crack tip)
Stress Multiplier, F = **1.50** (for spherical bottom head with penetrations)
Safety Factor = **2.00** (for heatup/cooldown)
M_m = **2.40** (per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error = **10.0** °F
Pressure Instrument Error = **30.0** psig
Hydro Test Pressure = **1563** psig
Flange RT_{NDT} = **10.0** °F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
0	19.1	46.85	19.89	0	70	0
5	24.1	48.29	20.60	281	70	251
10	29.1	49.87	21.40	292	70	262
15	34.1	51.63	22.27	304	70	274
20	39.1	53.56	23.24	317	70	287
25	44.1	55.71	24.31	332	70	302
30	49.1	58.07	25.50	348	70	318
35	54.1	60.69	26.80	366	70	336
40	59.1	63.58	28.25	386	70	356
45	64.1	66.77	29.85	407	70	377
50	69.1	70.31	31.61	431	70	401
55	74.1	74.21	33.56	458	70	428
60	79.1	78.52	35.72	488	70	458
65	84.1	83.29	38.10	520	75	490
70	89.1	88.56	40.74	556	80	526
75	94.1	94.38	43.65	596	85	566
80	99.1	100.81	46.87	640	90	610
85	104.1	107.92	50.42	688	95	658
90	109.1	115.78	54.35	742	100	712
95	114.1	124.47	58.69	801	105	771
100	119.1	134.06	63.49	867	110	837
105	124.1	144.67	68.80	939	115	909
110	129.1	156.40	74.66	1019	120	989
115	134.1	169.35	81.14	1107	125	1077
120	139.1	183.67	88.30	1205	130	1175
125	144.1	199.50	96.21	1313	135	1283
130	149.1	200.00	96.46	1316	140	1286

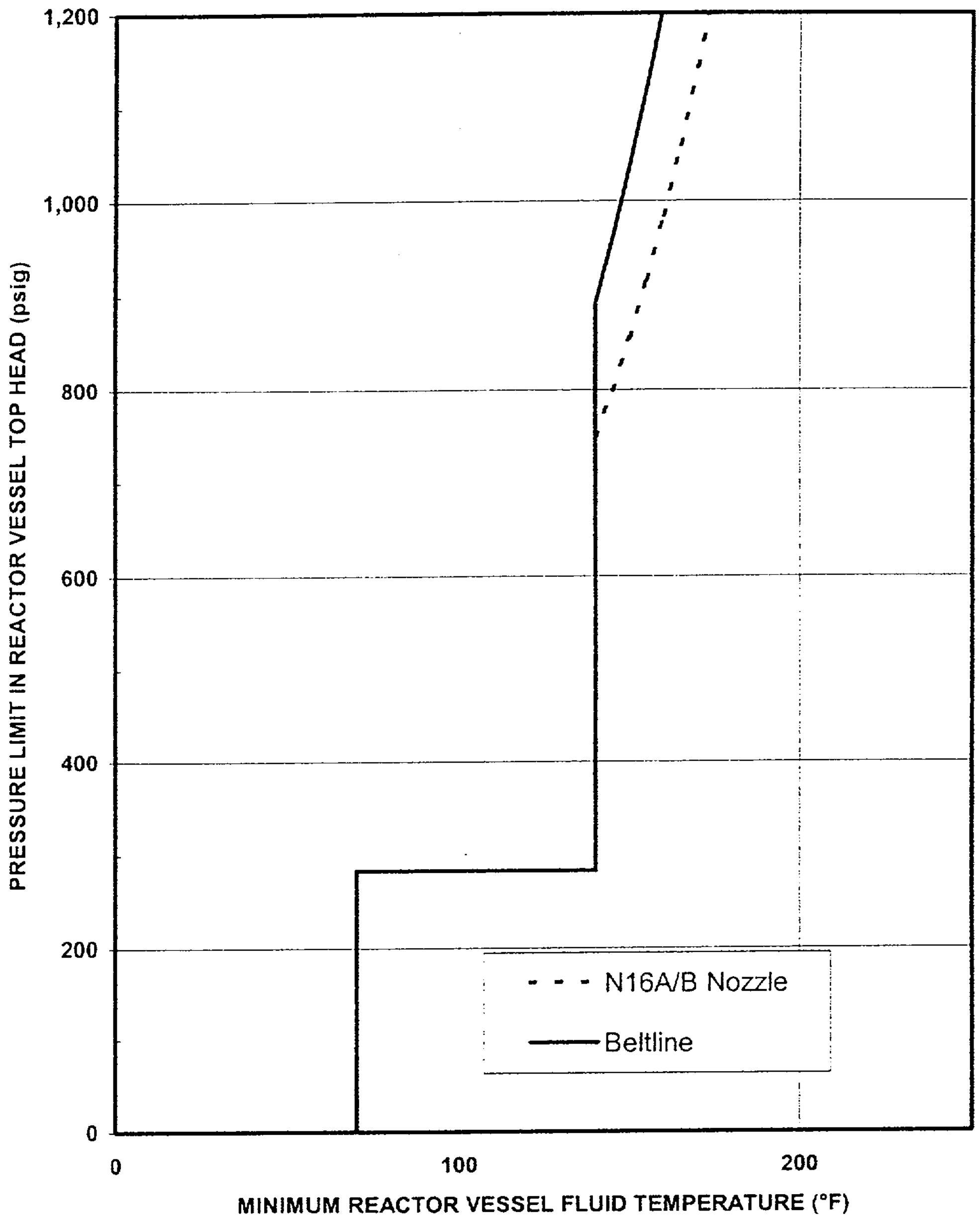
Pressure-Temperature Curve Calculation

(Core Not Critical)

Plant =	**Brunswick 2**	
Component =	**N16 A/B**	(2" Instrument Nozzles)
Vessel thickness, t =	**N/A**	inches (minimum)
M_t =	**N/A**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**N/A**	inches (maximum)
RT_{NDT} =	**111.9**	°F ======> **32 EFPY**
ΔT_w =	**N/A**	°F (temp. difference between inside and outside surfaces)
K_{IT} =	**5.4**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**20.1**	°F (temperature difference between fluid and crack tip)
Stress Multiplier, F =	**N/A**	
Safety Factor =	**2.00**	(for heatup/cooldown)
M_m =	**N/A**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**10.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	90.1	46.62	20.61	0	70	0
70	90.1	46.62	20.61	313	70	283
75	95.1	48.03	21.31	313	85	283
80	100.1	49.59	22.09	313	90	283
85	105.1	51.31	22.95	313	95	283
90	110.1	53.21	23.91	313	100	283
95	115.1	55.32	24.96	313	105	283
100	120.1	57.64	26.12	313	110	283
105	125.1	60.21	27.41	313	115	283
110	130.1	63.06	28.83	313	120	283
115	135.1	66.20	30.40	313	125	283
120	140.1	69.67	32.13	313	130	283
125	145.1	73.50	34.05	313	135	283
130	150.1	77.74	36.17	313	140	283
130	150.1	77.74	36.17	779	140	749
135	155.1	82.42	38.51	829	145	799
140	160.1	87.60	41.10	885	150	855
145	165.1	93.32	43.96	946	155	916
150	170.1	99.65	47.12	1015	160	985
155	175.1	106.63	50.62	1090	165	1060
160	180.1	114.36	54.48	1173	170	1143
165	185.1	122.89	58.75	1265	175	1235
170	190.1	132.32	63.46	1366	180	1336

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		



BELTLINE VS. N16A/B NOZZLE @ 32 EFPY
CORE NOT CRITICAL CONDITIONS
(NOZZLE IS MORE LIMITING)

	Revision	0	1		
	Preparer/Date	GLS 10/19/00	CMK 05/06/02		
	Checker/Date	JAH 10/19/00	BPT 05/06/02		
	File No. **CPL-54Q-303**			**Page** C10 **of** C13	

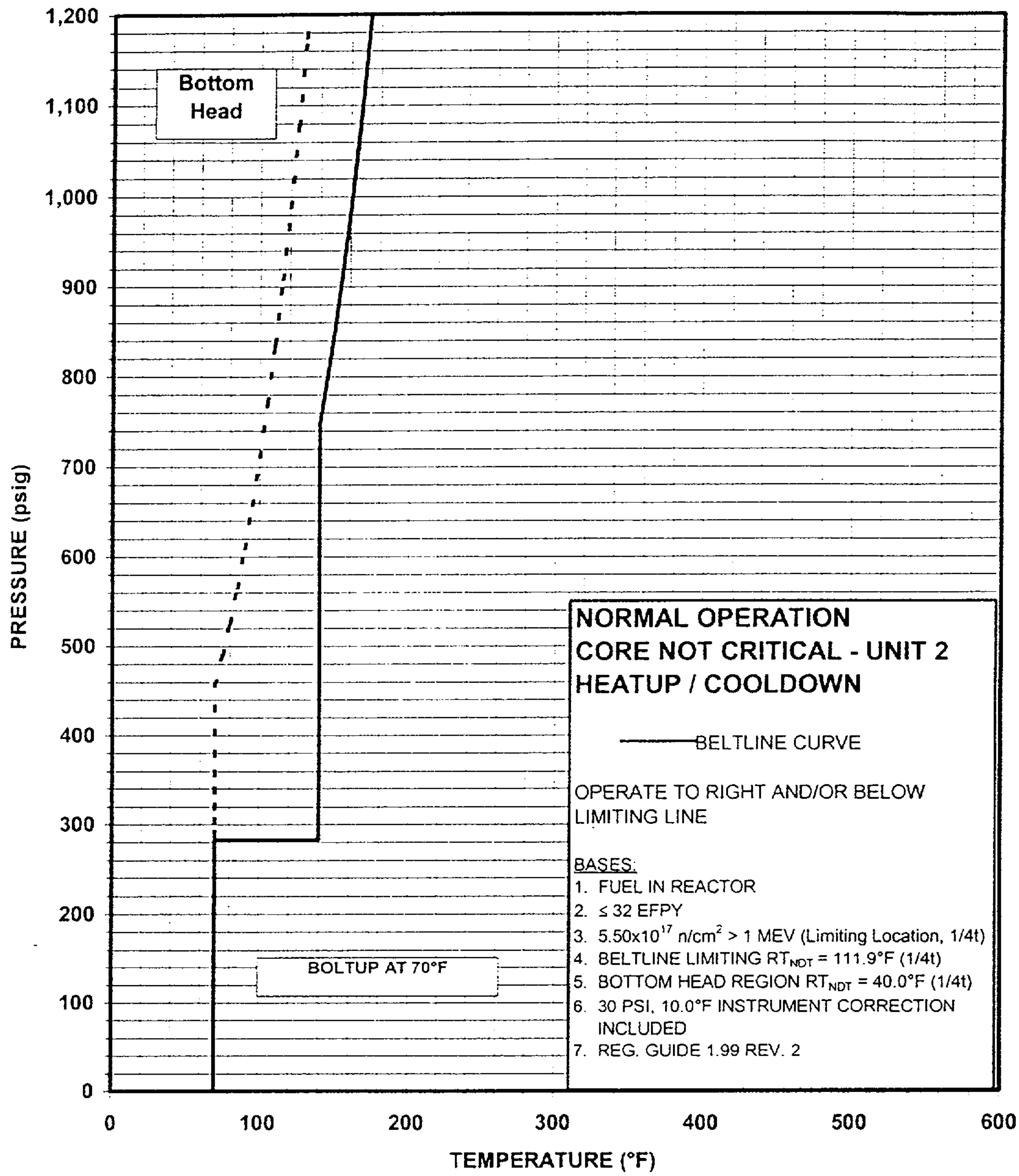


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Not Critical ≤ 32 EFPY

	Revision	0	1		
	Preparer/Date	GLS 10/19/00	CMK 05/06/02		
	Checker/Date	JAH 10/19/00	BPT 05/06/02		
	File No. **CPL-54Q-303**			**Page** C11 **of** C13	

Pressure-Temperature Curve Calculation

(Core Critical = Curve C)

Inputs:

Plant =	**Brunswick 2**	
EFPY =	**32**	
Curve A Leak Test Temperature =	**151.2**	°F (at 1,100 psig)
Hydro Test Pressure =	**1,565**	psig
Flange RT_{NDT} =	**10.0**	°F
Temperature Instrument Error =	**10.0**	°F

Adjusted Curve B Temperature N16 Nozzle (°F)	Adjusted Curve B Pressure for N16 Nozzle (psig)	Adjusted Curve B Temperature Bottom Head (°F)	Adjusted Curve B Pressure for Bottom Head (psig)	Curve C Temperature N16 Nozzle (°F)	Curve C Pressure N16 Nozzle (psig)	Curve C Temperature Bottom Head (°F)	Curve C Pressure Bottom Head (psig)
70	0	10	0	80.0	0	80.0	0
70	283	15	251	80.0	283	80.0	251
85	283	20	262	125.0	283	80.0	262
90	283	25	274	130.0	283	80.0	274
95	283	30	287	135.0	283	80.0	287
100	283	35	302	140.0	283	80.0	302
105	283	40	318	145.0	283	80.0	318
110	283	45	336	150.0	283	85.0	336
115	283	50	356	155.0	283	90.0	356
120	283	55	377	160.0	283	95.0	377
125	283	60	401	165.0	283	100.0	401
130	283	65	428	170.0	283	105.0	428
135	283	70	458	175.0	283	110.0	458
140	283	75	490	180.0	283	115.0	490
140	749	80	526	180.0	749	120.0	526
145	799	85	566	185.0	799	125.0	566
150	855	90	610	190.0	855	130.0	610
155	916	95	658	195.0	916	135.0	658
160.0	985	100	712	200.0	985	140.0	712
165.0	1060	105	771	205.0	1060	145.0	771
170.0	1143	110	837	210.0	1143	150.0	837
175.0	1235	115	909	215.0	1235	155.0	909
180.0	1336	120	989	220.0	1336	160.0	989
		125	1077			165.0	1077
		130	1175			170.0	1175
		135	1283			175.0	1283
		140	1286			180.0	1286

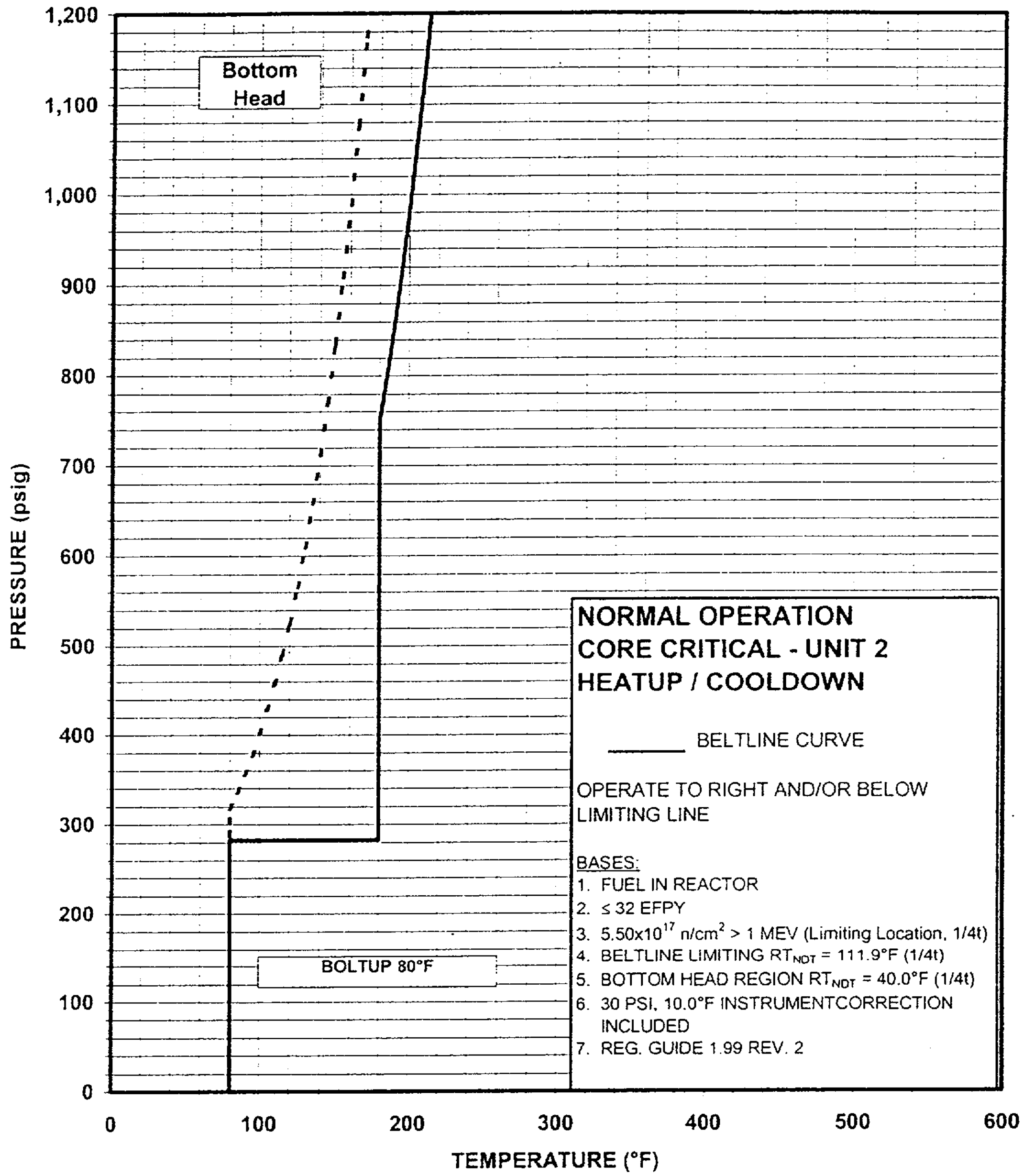


Figure x.x.x-x (page 1 of 1)
RCS Pressure and Temperature Limits
Normal Operation With Core Critical ≤ 32 EFPY

Revision	0	1		
Preparer/Date	GLS 10/19/00	CMK 05/06/02		
Checker/Date	JAH 10/19/00	BPT 05/06/02		

File No. CPL-54Q-303

Attachment 3
Development of Pressure Test Curves for 20 and 24 Effective Full Power Years

11 pages (including this sheet)

Fast Neutron Fluence Data For BNP Units 1 and 2			
Unit 1		Unit 2	
EFPY	Fluence (n/cm^2, E>1.0 Mev)	EFPY	Fluence (n/cm^2, E>1.0 Mev)
17.87	*3.71E+17*	*13.77*	*2.91E+17*
19.71	*4.23E+17*	*15.46*	*3.20E+17*
20.00	**4.31E+17**	*17.33*	*3.56E+17*
21.60	*4.75E+17*	*19.21*	*4.06E+17*
23.50	*5.28E+17*	**20.00**	**4.28E+17**
24.00	**5.42E+17**	*21.04*	*4.57E+17*
25.40	*5.81E+17*	*22.91*	*5.10E+17*
27.30	*6.34E+17*	**24.00**	**5.40E+17**
29.20	*6.87E+17*	*24.81*	*5.62E+17*
31.10	*7.40E+17*	*26.71*	*6.15E+17*
36.00	*8.77E+17*	*36.00*	*8.75E+17*
54.00	*1.38E+18*	*54.00*	*1.38E+18*

Notes:

1. The above values in italicized text were taken from Westinghouse Report LTR-REA-02-7 (CP&L Calculation 0B11-0012, Rev. 0).
2. The above values in bold text are interpolated values.

Brunswick Unit 1 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_I (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Shell Flange)	600	BV-3085	AFB176	16	0.09	0.88	N/A	N/A	N/A	0.0	32.0	16.0
BOTTOM HEAD	101	C4654	3	10	NR	0.55	N/A	N/A	N/A	0.0	32.0	10.0
NOTE: The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.												
BELTLINE (Lower Int. Shell)	351	B8496	1	10	0.19	0.58	139.8	72.0	17.0	0.0	32.0	116.0
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-4A,4B	48	0.16	0.82	123.2	38.0	17.0	0.0	32.0	120.0
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-4A,4B	48	0.16	0.82	123.2	27.6	13.8	0.0	20.0	103.2
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-4A,4B	48	0.16	0.82	123.2	31.4	15.7	0.0	24.0	110.9

Fluence Information:

Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10 \log f)}$
(Lower Int. Shell)	5.496	1.374	32.0	2.20E+18	0.719	1.58E+18	0.515
(N16A/B Nozzles)	5.496	1.374	32.0	7.65E+17	0.719	5.50E+17	0.308
(N16A/B Nozzles)	5.496	1.374	20.0	4.31E+17	0.719	3.10E+17	0.224
(N16A/B Nozzles)	5.496	1.374	24.0	5.42E+17	0.719	3.90E+17	0.255

Brunswick Unit 2 Limiting RPV Material Summary

Part Name & Material	MK No.	Heat No.	Slab or Lot No.	Estimated Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t: ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_I (°F)	EFPY	ART_{NDT} (°F)
FLANGE REGION (Top Head Flange)	706	1L-3335	AYT-173	10	0.11	0.80	N/A	N/A	N/A	0.0	32.0	10.0
BOTTOM HEAD	102	C4890	1A	40	NR	0.56	N/A	N/A	N/A	0.0	32.0	40.0
NOTE: The adjusted reference temperature values are the same for all EFPYs for the above locations since there are no significant irradiation effects.												
BELTLINE (Lower Shell)	201	C4500	2	10	0.15	0.54	106.7	49.5	17.0	0.0	32.0	93.5
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-3A,3B	40	0.16	0.82	123.2	37.9	17.0	0.0	32.0	111.9
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-3A,3B	40	0.16	0.82	123.2	27.5	13.7	0.0	20.0	95.0
BELTLINE (N16A/B Nozzles)	302	Q2Q1VW	247P-3A,3B	40	0.16	0.82	123.2	31.4	15.7	0.0	24.0	102.8

Fluence Information:

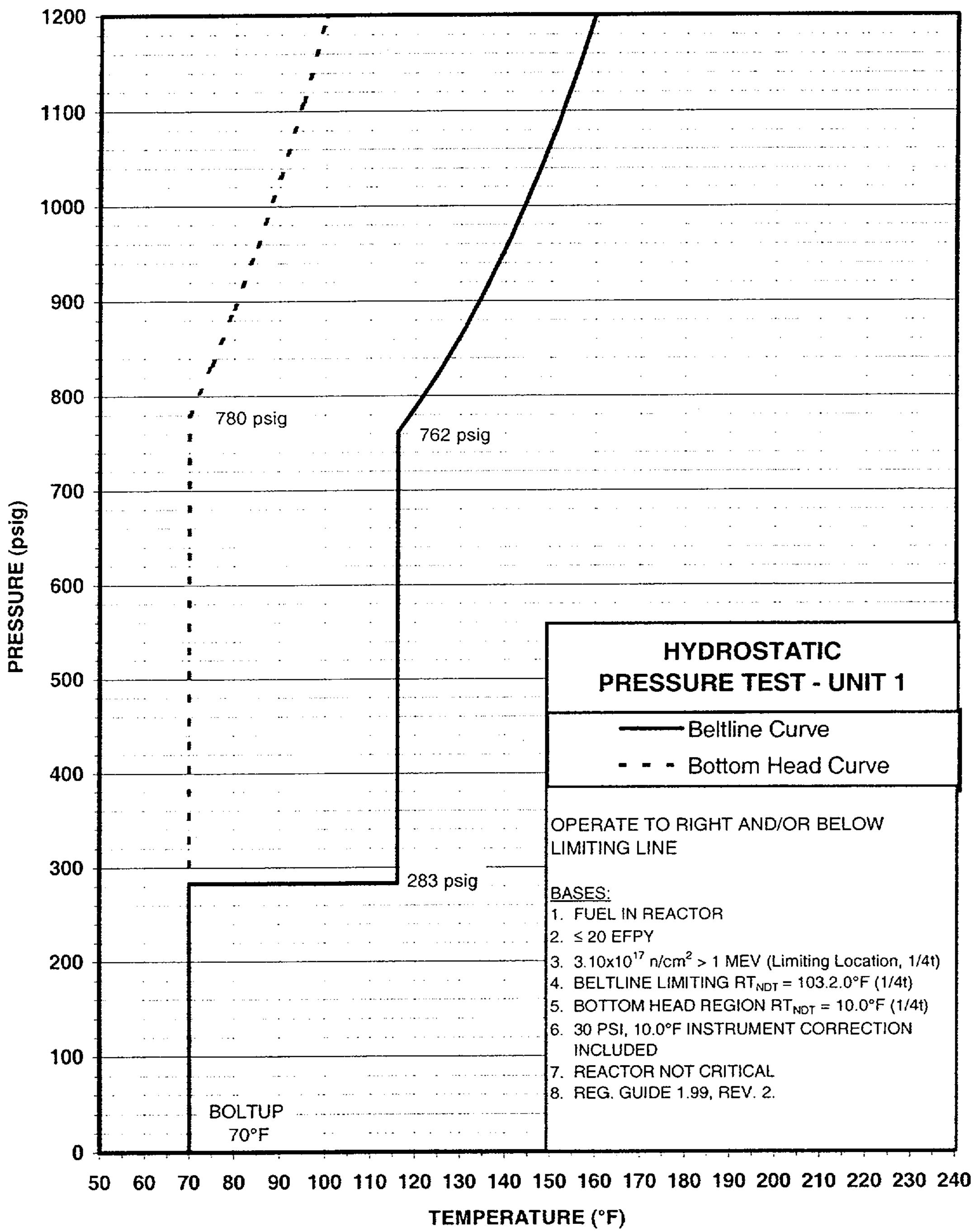
Location	Wall Thickness (inches) Full	Wall Thickness (inches) 1/4t	EFPY	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence @ 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28-0.10 \log f)}$
(Lower Shell)	5.466	1.367	32.0	1.74E+18	0.720	1.25E+18	0.464
(N16A/B Nozzles)	5.466	1.367	32.0	7.63E+17	0.720	5.50E+17	0.308
(N16A/B Nozzles)	5.466	1.367	20.0	4.28E+17	0.720	3.08E+17	0.223
(N16A/B Nozzles)	5.466	1.367	24.0	5.40E+17	0.720	3.89E+17	0.255

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 1	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	103.2	°F ======> **20 EFPY**
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	N/A	
Safety Factor =	1.50	(for pressure test)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	76.0	45.24	30.16	0	70	0
76	76.0	45.24	30.16	313	70	283
80	80.0	46.25	30.83	313	90	283
85	85.0	47.62	31.75	313	95	283
90	90.0	49.14	32.76	313	100	283
95	95.0	50.81	33.87	313	105	283
100	100.0	52.66	35.11	313	110	283
106	106.0	55.15	36.76	313	116	283
106	106.0	55.15	36.76	792	116	762
111	111.0	57.45	38.30	825	121	795
116	116.0	60.00	40.00	861	126	831
121	121.0	62.82	41.88	902	131	872
126	126.0	65.94	43.96	946	136	916
131	131.0	69.38	46.25	996	141	966
136	136.0	73.19	48.79	1050	146	1020
136.80	136.8	73.83	49.22	1060	147	1030
141	141.0	77.39	51.60	1111	151	1081
146	146.0	82.04	54.69	1178	156	1148
151	151.0	87.18	58.12	1251	161	1221
156	156.0	92.85	61.90	1333	166	1303
152	152.4	88.71	59.14	1273	162	1243
155	155.0	91.67	61.12	1316	165	1286
155	155.0	91.67	61.12	1316	165	1286
155	155.0	91.67	61.12	1316	165	1286
159.3	159.3	96.92	64.62	1391	169	1361
164	164.3	103.63	69.08	1487	174	1457
169	169.3	111.03	74.02	1594	179	1564
174	174.3	119.22	79.48	1711	184	1681



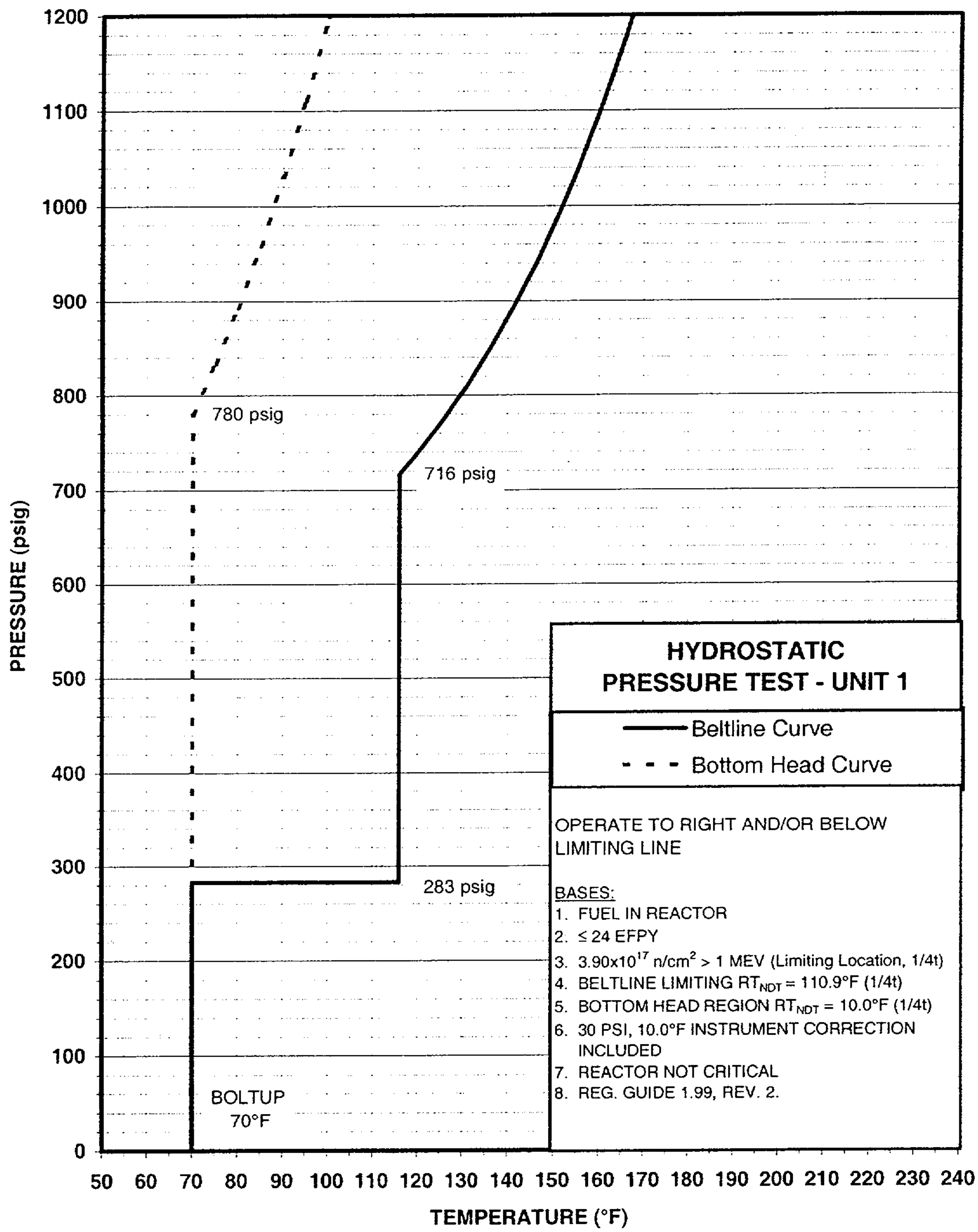
PRESSURE (psig)
TEMPERATURE (°F)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
780 psig
762 psig
283 psig
BOLTUP
70°F
HYDROSTATIC
PRESSURE TEST - UNIT 1
Beltline Curve
Bottom Head Curve
OPERATE TO RIGHT AND/OR BELOW LIMITING LINE
BASES:
1. FUEL IN REACTOR
2. ≤ 20 EFPY
3. 3.10x10^17 n/cm^2 > 1 MEV (Limiting Location, 1/4t)
4. BELTLINE LIMITING RTNDT = 103.2.0°F (1/4t)
5. BOTTOM HEAD REGION RTNDT = 10.0°F (1/4t)
6. 30 PSI, 10.0°F INSTRUMENT CORRECTION INCLUDED
7. REACTOR NOT CRITICAL
8. REG. GUIDE 1.99, REV. 2.

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 1	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	110.9	°F ======> 24 EFPY
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	N/A	
Safety Factor =	1.50	(for pressure test)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	16.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
76	76.0	43.52	29.01	0	70	0
76	76.0	43.52	29.01	313	70	283
80	80.0	44.38	29.58	313	90	283
85	85.0	45.55	30.37	313	95	283
90	90.0	46.85	31.23	313	100	283
95	95.0	48.29	32.19	313	105	283
100	100.0	49.87	33.25	313	110	283
106	106.0	52.00	34.67	313	116	283
106	106.0	52.00	34.67	746	116	716
111	111.0	53.98	35.98	775	121	745
116	116.0	56.16	37.44	806	126	776
121	121.0	58.58	39.05	841	131	811
126	126.0	61.24	40.83	879	136	849
131	131.0	64.19	42.80	921	141	891
136	136.0	67.45	44.97	968	146	938
141	141.0	71.06	47.37	1020	151	990
144.60	144.6	73.88	49.25	1060	155	1030
146	146.0	75.04	50.02	1077	156	1047
151	151.0	79.44	52.96	1140	161	1110
156	156.0	84.30	56.20	1210	166	1180
152	152.4	80.75	53.83	1159	162	1129
155	155.0	83.29	55.53	1195	165	1165
155	155.0	83.29	55.53	1195	165	1165
155	155.0	83.29	55.53	1195	165	1165
159.3	159.3	87.79	58.52	1260	169	1230
164	164.3	93.53	62.35	1342	174	1312
169	169.3	99.87	66.58	1433	179	1403
174	174.3	106.88	71.26	1534	184	1504



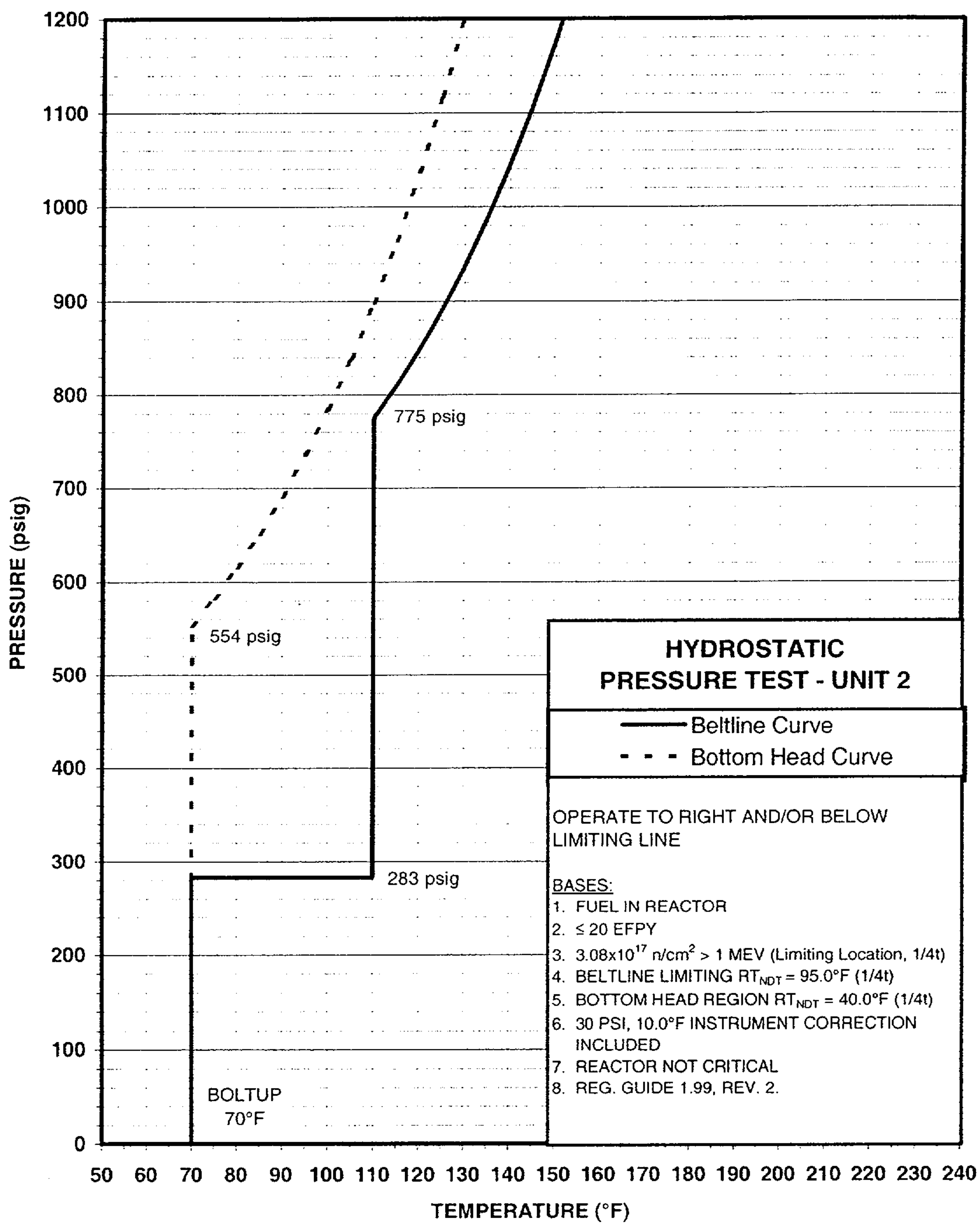
PRESSURE (psig)
TEMPERATURE (°F)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
780 psig
716 psig
283 psig
BOLTUP
70°F
HYDROSTATIC
PRESSURE TEST - UNIT 1
Beltline Curve
Bottom Head Curve
OPERATE TO RIGHT AND/OR BELOW
LIMITING LINE
BASES:
1. FUEL IN REACTOR
2. ≤ 24 EFPY
3. 3.90x10^17 n/cm^2 > 1 MEV (Limiting Location, 1/4t)
4. BELTLINE LIMITING RTNDT = 110.9°F (1/4t)
5. BOTTOM HEAD REGION RTNDT = 10.0°F (1/4t)
6. 30 PSI, 10.0°F INSTRUMENT CORRECTION INCLUDED
7. REACTOR NOT CRITICAL
8. REG. GUIDE 1.99, REV. 2.

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	Brunswick 2	
Component =	N16 A/B	(2" Instrument Nozzles)
Vessel thickness, t =	N/A	inches (minimum)
M_t =	N/A	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	N/A	inches (maximum)
RT_{NDT} =	95.0	°F ======> **20 EFPY**
ΔT_w =	0.0	°F (no thermal for pressure test)
K_{IT} =	0.0	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	0.0	°F (no thermal for pressure test)
Stress Multiplier, F =	N/A	
Safety Factor =	1.50	(for pressure test)
M_m =	N/A	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	10.0	°F
Pressure Instrument Error =	30.0	psig
Hydro Test Pressure =	1563	psig
Flange RT_{NDT} =	10.0	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	70.0	45.78	30.52	0	70	0
70	70.0	45.78	30.52	313	70	283
75	75.0	47.10	31.40	313	85	283
80	80.0	48.56	32.37	313	90	283
85	85.0	50.18	33.45	313	95	283
90	90.0	51.96	34.64	313	100	283
95	95.0	53.93	35.96	313	105	283
100	100.0	56.11	37.41	313	110	283
100	100.0	56.11	37.41	805	110	775
105	105.0	58.52	39.02	840	115	810
110	110.0	61.19	40.79	878	120	848
115	115.0	64.13	42.75	920	125	890
120	120.0	67.38	44.92	967	130	937
125	125.0	70.98	47.32	1019	135	989
128.6	128.6	73.80	49.20	1059	139	1029
130	130.0	74.95	49.97	1076	140	1046
135	135.0	79.34	52.90	1139	145	1109
140	140.0	84.20	56.13	1209	150	1179
145	145.0	89.56	59.71	1285	155	1255
151.2	151.2	97.00	64.67	1392	161	1362
156	156.2	103.71	69.14	1489	166	1459
161	161.2	111.13	74.08	1595	171	1565
166	166.2	119.32	79.55	1713	176	1683
171	171.2	128.38	85.59	1843	181	1813



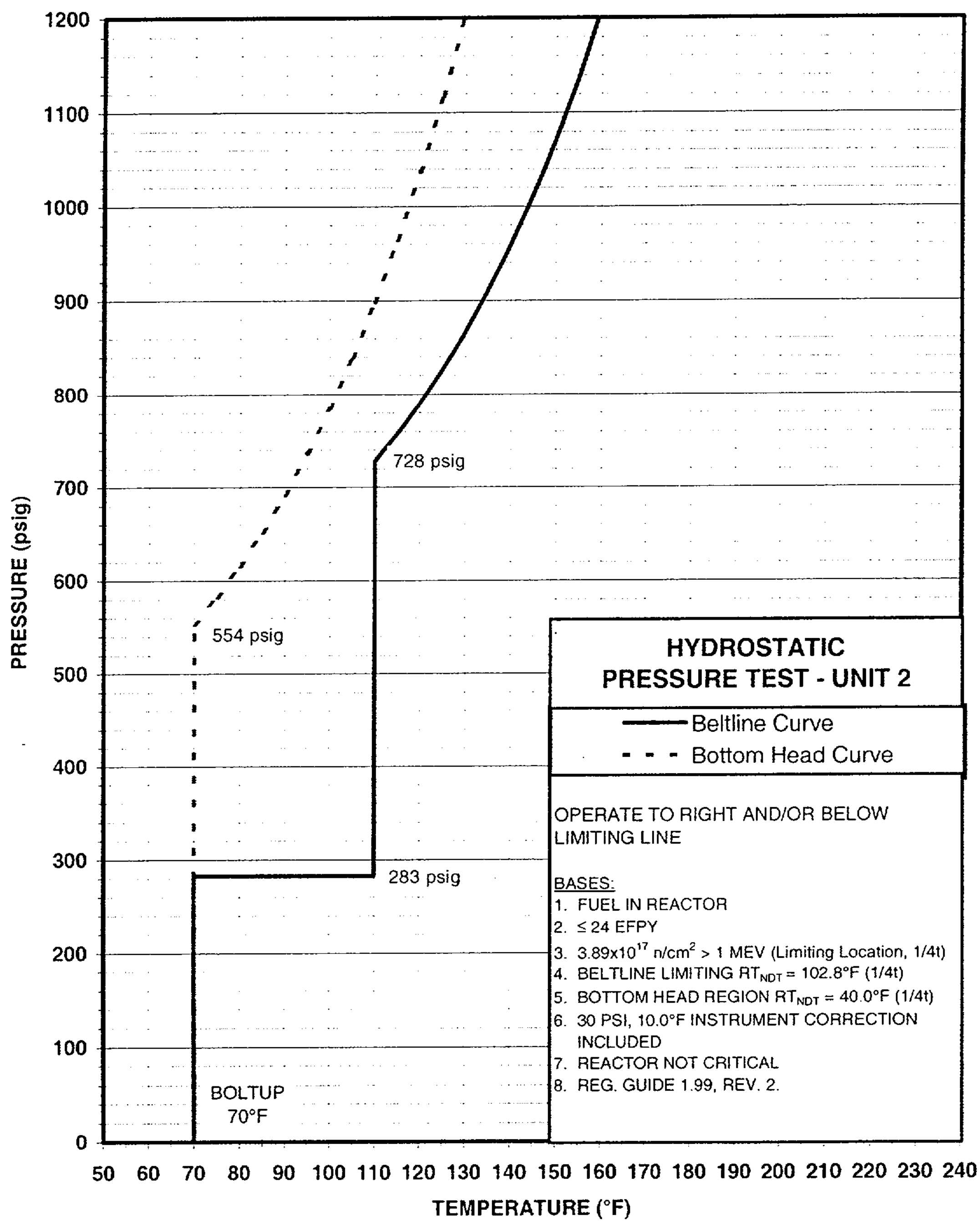
HYDROSTATIC PRESSURE TEST - UNIT 2
Beltline Curve
Bottom Head Curve
OPERATE TO RIGHT AND/OR BELOW LIMITING LINE
BASES:
1. FUEL IN REACTOR
2. ≤ 20 EFPY
3. 3.08x10^17 n/cm^2 > 1 MEV (Limiting Location, 1/4t)
4. BELTLINE LIMITING RT_NDT = 95.0°F (1/4t)
5. BOTTOM HEAD REGION RT_NDT = 40.0°F (1/4t)
6. 30 PSI, 10.0°F INSTRUMENT CORRECTION INCLUDED
7. REACTOR NOT CRITICAL
8. REG. GUIDE 1.99, REV. 2.
775 psig
554 psig
283 psig
BOLTUP
70°F
PRESSURE (psig)
TEMPERATURE (°F)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240

Pressure-Temperature Curve Calculation

(Pressure Test)

Plant =	**Brunswick 2**	
Component =	**N16 A/B**	(2" Instrument Nozzles)
Vessel thickness, t =	**N/A**	inches (minimum)
M_t =	**N/A**	(per Figure G-2214-2 of App. G, mod. for E, α)
Vessel Radius, R =	**N/A**	inches (maximum)
RT_{NDT} =	**102.8**	°F ======> **24 EFPY**
ΔT_w =	**0.0**	°F (no thermal for pressure test)
K_{IT} =	**0.0**	ksi*inch$^{1/2}$
$\Delta T_{1/4t}$ =	**0.0**	°F (no thermal for pressure test)
Stress Multiplier, F =	**N/A**	
Safety Factor =	**1.50**	(for pressure test)
M_m =	**N/A**	(per Figure G-2214-1 of App. G, assuming σ/σ_{ys} = 1.0)
Temperature Instrument Error =	**10.0**	°F
Pressure Instrument Error =	**30.0**	psig
Hydro Test Pressure =	**1563**	psig
Flange RT_{NDT} =	**10.0**	°F

Fluid Temperature T (°F)	1/4t Temperature (°F)	K_{Ic} (ksi*inch$^{1/2}$)	K_{IP} (ksi*inch$^{1/2}$)	Calculated Pressure P (psig)	Adjusted Temperature for P-T Curve (°F)	Adjusted Pressure for P-T Curve (psig)
70	70.0	43.96	29.31	0	70	0
70	70.0	43.96	29.31	313	70	283
75	75.0	45.09	30.06	313	85	283
80	80.0	46.34	30.89	313	90	283
85	85.0	47.72	31.82	313	95	283
90	90.0	49.25	32.83	313	100	283
95	95.0	50.94	33.96	313	105	283
100	100.0	52.80	35.20	313	110	283
100	100.0	52.80	35.20	758	110	728
105	105.0	54.87	36.58	788	115	758
110	110.0	57.15	38.10	820	120	790
115	115.0	59.66	39.78	856	125	826
120	120.0	62.45	41.63	896	130	866
125	125.0	65.52	43.68	940	135	910
130	130.0	68.92	45.95	989	140	959
135	135.0	72.68	48.45	1043	145	1013
137	136.5	73.88	49.25	1060	147	1030
140	140.0	76.83	51.22	1103	150	1073
145	145.0	81.42	54.28	1169	155	1139
151.2	151.2	87.79	58.52	1260	161	1230
156	156.2	93.53	62.35	1342	166	1312
161	161.2	99.87	66.58	1433	171	1403
166	166.2	106.88	71.26	1534	176	1504
171	171.2	114.63	76.42	1645	181	1615



HYDROSTATIC
PRESSURE TEST - UNIT 2
Beltline Curve
Bottom Head Curve
OPERATE TO RIGHT AND/OR BELOW LIMITING LINE
BASES:
1. FUEL IN REACTOR
2. ≤ 24 EFPY
3. 3.89x10^17 n/cm^2 > 1 MEV (Limiting Location, 1/4t)
4. BELTLINE LIMITING RTNDT = 102.8°F (1/4t)
5. BOTTOM HEAD REGION RTNDT = 40.0°F (1/4t)
6. 30 PSI, 10.0°F INSTRUMENT CORRECTION INCLUDED
7. REACTOR NOT CRITICAL
8. REG. GUIDE 1.99, REV. 2.
728 psig
554 psig
283 psig
BOLTUP
70°F
PRESSURE (psig)
TEMPERATURE (°F)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240

Attachment 4
Record of Lead Review Forms
4 pages (including this sheet)

ATTACHMENT 2
Sheet 1 of 1
Record of Lead Review

Design SIA Report SIR-00-132, Rev. 1 **Revision** 1

The signature below of the Lead Reviewer records that:
- the review indicated below has been performed by the Lead Reviewer;
- appropriate reviews were performed and errors/deficiencies (for all reviews performed) have been resolved and these records are included in the design package;
- the review was performed in accordance with EGR-NGGC-0003.

☐ **Design Verification Review** ☐ **Engineering Review** ☒ **Owner's Review**
- ☐ Design Review
- ☐ Alternate Calculation
- ☐ Qualification Testing

☐ **Special Engineering Review** ______

☐ YES ☐ N/A **Other Records are attached.**

Phillip Gore / Phillip Gore MECHANICAL 6-10-02

Lead Reviewer **(print/sign)** **Discipline** **Date**

Item No.	Deficiency	Resolution
	None.	

FORM EGR-NGGC-0003-2-5
This form is a QA Record when completed and included with a completed design package. Owner's Reviews may be processed as stand alone QA records when Owner's Review is completed.

ATTACHMENT 2
Sheet 1 of 1
Record of Lead Review

Design CPL-54Q-303, Rev. 1 **Revision** 1

The signature below of the Lead Reviewer records that:
- the review indicated below has been performed by the Lead Reviewer;
- appropriate reviews were performed and errors/deficiencies (for all reviews performed) have been resolved and these records are included in the design package;
- the review was performed in accordance with EGR-NGGC-0003.

☐ **Design Verification Review** ☐ **Engineering Review** ☒ **Owner's Review**
- ☐ Design Review
- ☐ Alternate Calculation
- ☐ Qualification Testing

☐ **Special Engineering Review** ______

☐ YES ☐ N/A **Other Records are attached.**

Phillip Gore / Phillip Gore — MECHANICAL — 6-10-02

Lead Reviewer **(print/sign)** — **Discipline** — **Date**

Item No.	Deficiency	Resolution
	None	

FORM EGR-NGGC-0003-2-5
This form is a QA Record when completed and included with a completed design package. Owner's Reviews may be processed as stand alone QA records when Owner's Review is completed.

ATTACHMENT 2
Sheet 1 of 1
Record of Lead Review

Design 0B11-0005 **Revision** 1

The signature below of the Lead Reviewer records that:

- the review indicated below has been performed by the Lead Reviewer;
- appropriate reviews were performed and errors/deficiencies (for all reviews performed) have been resolved and these records are included in the design package;
- the review was performed in accordance with EGR-NGGC-0003.

☒ **Design Verification Review** ☐ **Engineering Review** ☐ **Owner's Review**

☒ Design Review
☐ Alternate Calculation
☐ Qualification Testing

☐ **Special Engineering Review** ______

☐ YES ☐ N/A **Other Records are attached.**

Larry Yemma / Larry Yemma — MECHANICAL — 6/10/02
Lead Reviewer (print/sign) — **Discipline** — **Date**

Item No.	Deficiency	Resolution
	None	

FORM EGR-NGGC-0003-2-5
This form is a QA Record when completed and included with a completed design package. Owner's Reviews may be processed as stand alone QA records when Owner's Review is completed.

ENCLOSURE 3

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NOS. 1 AND 2
DOCKET NOS. 50-325 AND 50-324/LICENSE NOS. DPR-71 AND DPR-62
REQUEST FOR LICENSE AMENDMENTS TO REVISE TECHNICAL SPECIFICATION
PRESSURE-TEMPERATURE LIMITS CURVES

CP&L Calculation 0B11-0012, Revision 0
"Neutron Exposure Evaluations for the Core Shroud
and Pressure Vessel, Brunswick Units 1 and 2"

SYSTEM#: 1005

CALC. SUB-TYPE: RME

PRIORITY CODE: 4

QUALITY CLASS: A

CAROLINA POWER & LIGHT COMPANY

0B11-0012
(CALCULATION #)

Neutron Exposure Evaluations for the Core Shroud and Pressure Vessel Brunswick Units 1 and 2
(TITLE INCLUDING STRUCTURE/SYSTEM/COMPONENT)

BRUNSWICK NUCLEAR POWER PLANT

UNITS 1 & 2

APPROVAL

Revision: 0

Prepared By: N/A Date: ______

Reviewed By: N/A Date: ______

Design Supervisor: N/A Date: ______

(For Vendor Calculations)

Vendor Westinghouse Electric Company LLC

Owner's Review By Phillip Gore/ Phillip Gore Date: 2-14-02

List of Effective Pages

Page No.	Rev. No	Page No	Rev. No	ATTACHMENTS	
1	0			Number/Rev.	Number of Pages
2	0			1/0	77 (including Cover Sheet)
				AMENDMENTS	
				Letter/Rev	Number of Pages

ATTACHMENT 1

Westinghouse Electric Company LLC
Report No. LTR-REA-02-7, Rev. 0
78 Pages

(Including Cover Sheet)

LTR-REA-02-7

Neutron Exposure Evaluations for the Core Shroud and Pressure Vessel Brunswick Units 1 and 2

Richard K. Disney
Radiation Engineering and Analysis

January 2002

Verified By: S. L. Anderson
Radiation Engineering and Analysis

WESTINGHOUSE ELECTRIC COMPANY LLC
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

1.0 Background

In the assessment of the state of embrittlement of light water reactor (LWR) pressure vessels, an accurate evaluation of the neutron exposure of each of the materials comprising the beltline region of the vessel is required. In Appendix G to 10 CFR 50[1] , the beltline region is defined as *"the region of the reactor vessel shell material (including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the reactor core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage"*. In Appendix H to 10 CFR 50[1], the threshold fast neutron fluence (E > 1.0 Mev) to be used to determine if a specific material is to be included in the beltline region is further defined as 1.0E+17 n/cm^2. Therefore, in order to encompass all areas of the reactor vessel anticipated to accrue a fast neutron exposure greater than 1.0E+17 n/cm^2, plant specific exposure assessments must include evaluations not only at locations of maximum exposure at the inner diameter of the vessel, but, also as a function of axial, azimuthal, and radial location throughout the vessel wall. Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence"[2] describes state-of-the-art calculation and measurement procedures that are acceptable to the NRC staff for determining pressure vessel fluence applicable to these beltline locations.

This report describes neutron fluence assessments performed for the Brunswick Unit 1 and Unit 2 pressure vessel beltline regions based on the guidance specified in Regulatory Guide 1.190. In these assessments, fast neutron exposures expressed in terms of fast neutron fluence (E > 1.0 Mev) were established for materials comprising the beltline region of the respective pressure vessels.

Exposures of the materials were determined on a plant and fuel cycle specific basis for the first 16 operating cycles at Brunswick Unit 1 and the first 18 operating cycles at Brunswick Unit 2. At the conclusion of fuel cycle 16, Brunswick Unit 1 is anticipated to have accrued approximately 21.6 effective full power years (efpy) of operation. Likewise at the conclusion of fuel cycle 18, Brunswick Unit 2 is expected to have accrued approximately 22.9 efpy.

Following completion of the plant specific exposure assessments encompassing the fuel cycles designed to date, projections of the future neutron exposure of the pressure vessel beltline materials extending to 54 efpy of operation were performed for both units. In performing the fluence projections for future operation, several scenarios were assumed in order to provide a matrix of material exposures based on a series of fuel management and power uprate options.

The fuel management strategies employed during the operating lifetime of both Brunswick Units 1 and 2 are categorized as the introduction of new fuel bundle types as summarized in the following tabulation.

Brunswick Fuel Management Strategies					
	UNIT 1			UNIT 2	
CYCLE	Fuel Type	# Loaded	Cycle	Fuel Type	# Loaded
1-5	GE4-GE6	N/A	1-6	GE3-GE6	N/A
6	GE7	176	7	GE7	148
7	GE8	184	8	GE8	184
8	GE10	160	9	GE9	168
9	GE10	124	10	GE10	148
10	GE10	156	11	GE10	152
11	GE13	200	12	GE13	200
12	GE13	196	13	GE13	184
13	GE13	220	14	GE13	200
14	GE14	248	15	GE14	220
EQUIL	GE14	N/A	EQUIL	GE14	N/A

Fuel types loaded in the cycles are as follows:

GE7 has an active fuel length of 150" with no part length rods.

GE8 has an active fuel length of 150" with no part length rods.

GE9 has an active fuel length of 150" with 60 fuel pins from 0 to 144" and 49 pins from 144" to 150".

GE10 has an active fuel length of 150" with 60 fuel pins from 0" to 144" and 50 from 144" to 150".

GE13 has an active fuel length of 146" with 74 fuel pins from 0" to 108", 66 pins from 108" to 138" and 54 pins from 138" to 146".

GE14 has an active fuel length of 150" with 92 pins from 0-84", 78 pins 84-144" and 62 pins from 144-150"

Fuel Types GE3 to GE6 all have fuel up to 150" with no part length fuel pins.

The transition to an equilibrium cycle assumes 256 bundles of GE14 per reload.

An uprate from the initial operating core power of 2436 MWt to a core power of 2558 was implemented in cycle 11 for Unit 1 and in cycle 13 for Unit 2. A future uprate in Unit 1 power to 2728 MWt is planned for cycle 14 and with a further uprate to 2923 MWt planned in cycle 15 and equilibrium cycles. A future uprate in Unit 2 power to 2801 MWt is planned for cycle 16 with a further uprate to 2923 MWt planned in cycle 17 and equilibrium cycles. The following fluence projections scenarios are based on the various fuel management scenarios and power uprate options:

Based on the above fuel management scenarios for Unit 1 and Unit 2, neutron exposure projections applicable to the core shroud structure and the pressure vessel were developed for Brunswick Units 1 and 2. Results of these plant specific calculations are provided in Section 2.0 of this report.

2.0 Neutron Transport Calculations

Method of Analysis

In performing the fast neutron exposure evaluations for the Brunswick Units 1 and 2 reactors, plant specific forward transport calculations were carried out using the three-dimensional flux synthesis technique described in Section 1.3.4 of Regulatory Guide 1.190. For all fuel cycles, the following single channel synthesis equation was employed:

$$\varphi(r,\theta,z) = \varphi(r,\theta) * \frac{\varphi(r,z)}{\varphi(r)}$$

Where $\phi(r,\theta,z)$ is the synthesized three-dimensional neutron flux distribution, $\phi(r,\theta)$ is the transport solution in r,θ geometry, $\phi(r,z)$ is the two-dimensional solution for a cylindrical reactor model using the actual axial core power distribution, and $\phi(r)$ is the one-dimensional solution for a cylindrical reactor model using the same source per unit height as that used in the r,θ two-dimensional calculation.

For the Brunswick Units 1 and 2 analyses, all of the transport calculations were carried out using the DORT two-dimensional discrete ordinates code Version 3.1[3] and the BUGLE-96 cross–section library[4]. The BUGLE-96 library provides a 67 group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor application. In these analyses, anisotropic scattering was treated with a P_3 legendre expansion and the angular discretization was modeled with an S_8 order of angular quadrature.

A plan view of the r,θ model of the Brunswick Units 1 and 2 reactor geometry at the core midplane is shown in Figure 2.1-1. Since the reactor exhibits octant symmetry only a 0° to 45° sector is depicted. In addition to the active core, core shroud, pressure vessel, and primary biological shield, the model also included explicit representations of the risers and jet pump tubes and surveillance capsule, and the insulation located external to the pressure vessel. The modeling is representative of the core midplane elevation. The surveillance capsule model was retained from earlier analyses of capsules internal to the reactor vessel wall.

From a neutronic standpoint, the inclusion of the surveillance capsule and associated support structure in the analytical model is significant. Since the presence of the capsules and structure has a marked impact on the magnitude of the neutron flux as well as on the relative neutron and gamma ray spectra at dosimetry locations within the capsules, a meaningful evaluation of the radiation environment internal to the capsules can be made only when these perturbation effects are properly accounted for in the analysis.

In developing the r,θ analytical model of the reactor geometry shown in Figure 2.1-1, nominal design dimensions were employed for the various structural components with the core shroud dimension based on design information provided by Reference 8. The remainder of the model was derived from earlier design data provided in Reference 5. Water temperatures and, hence, coolant density in the reactor core, in the water region internal to the core shroud, and the downcomer region of the reactor were taken to be representative of full power operating conditions. The reactor core itself was treated as a homogeneous mixture of fuel, cladding, water, and miscellaneous core structures. The r,θ geometric mesh definition for the reactor model shown in Figure 2.1-1 consisted of 114 radial by 99 azimuthal intervals. Mesh interval size was chosen to assure convergence of the pointwise flux solution in the DORT transport calculations. Pointwise inner iteration flux convergence criterion utilized in the r,θ calculations was set at a value of 0.001.

A section view of the r,z model of the Brunswick Units 1 and 2 reactors is shown in Figure 2.1-2. The model extended radially from the centerline of the reactor core out to a location interior to the primary biological shield. The axial span of the model is from an elevation approximately 25 inches below the active fuel zone to approximately 21 inches above the active fuel. The axial extent of the model was chosen to permit the determination of the maximum exposure of vessel materials expected to experience a fast neutron fluence greater than 1.0e+17 n/cm^2 (E > 1.0 Mev) over the service life of the respective units.

As in the case of the r,θ model, nominal design dimensions and full power coolant densities were employed in the calculations. In this case, the homogenous core region was treated as an equivalent cylinder with axial zoning appropriate to modeling the change in void fraction in the coolant and fuel and cladding density in the fuel bundles. The active core was modeled as seven axial zones and the coolant void fraction in each zone was used to adjust the water density in the zone to match the average value over the zone height. The modeling of the fuel types loaded into the active core in each cycle were modeled as homogeneous materials with reduced fuel and cladding densities in the appropriate elevations in the active core region. The water density in the zones with reduced fuel/cladding density was adjusted to model the increased volume fraction of the water/steam coolant. The total volume of the cylindrical region model of the active core has a volume equal to that of the active core zone. The stainless steel riser and jet pump tubes located between the core shroud and the pressure vessel were modeled as shown in Figure 2.1-1. The riser wall and jet tube wall areas and thickness are preserved in the r,θ representation of the cylindrical cross-section. The r,z geometric mesh description of the reactor model shown in Figure 2.1-2 consisted of 114 radial by 85 axial intervals. Mesh sizes were defined to assure that proper pointwise flux convergence is achieved during the inner iterations of the DORT solution. The pointwise inner iteration flux convergence criterion utilized in the r,z calculations was set at a value of 0.001.

The one-dimensional radial model used in the synthesis procedure consisted of the same 114 radial mesh intervals included in the r,z model. Thus, radial synthesis factors could be determined on a mesh-by-mesh basis throughout the entire geometry.

The core power distributions used in the plant specific transport analysis for the Brunswick Units 1 and 2 reactors were taken from the appropriate fuel cycle design information provided in References 5 through 13 for Unit 1 and Unit 2. The data extracted from the design reports included fuel bundle exposures for beginning of cycle

(BOC) and end of cycle (EOC) conditions. Core average axial distributions were also extracted from the reference documents and data transmittals.

In constructing the core source distributions from the fuel bundle exposure data, the energy distribution of the fission neutron source was based on an appropriate fission split for uranium and plutonium isotopes. From that assumed fission split, composite values of energy release per fission, neutron yield per fission, and fission spectrum were determined.

The fuel cycle information provided for the Brunswick Unit 1 and Unit 2 plant is summarized in Table 2.1-1. The cycle times and operating thermal power used in the prediction of the neutron flux distributions in the various models required for the synthesis methodology are list in Table 2.1-1. Also shown are the total accumulated cycle times by cycle including actual cycle operations and projected values for future cycles. Listed in Table 2.1-1 is the last two cycles used to provide projected fluence values to 36 and 54 effective full power years.

Table 2.1-1

Brunswick Unit 1
Fuel Management and Operating Cycle Parameters

Cycle	Fuel Type	Operating Power, Mwd	Cycle Time, EFPD	Cycle Time, EFPY	Operating Time, EFPY
1	GE4	2436	463.7	1.270	1.270
2	GE5	2436	265.1	0.726	1.997
3	GE6	2436	407.6	1.117	3.113
4	GE6	2436	404.9	1.109	4.223
5	GE7	2436	403.0	1.104	5.327
6	GE7	2436	430.2	1.179	6.506
7	GE8	2436	460.3	1.261	7.767
8	GE10	2436	339.1	0.929	8.696
9	GE10	2436	406.3	1.113	9.809
10	GE10	2436	462.4	1.267	11.076
11	GE13	2558	499.8	1.369	12.445
12	GE13	2558	611.6	1.676	14.121
13	GE13	2558	700.0	1.918	16.038
14	GE14	2728	668.0	1.830	17.868
15	GE14	2923	674.0	1.847	19.715
16	GE14	2923	689.0	1.888	21.603
17	GE14	2923	693.0	1.899	23.501
18	GE14	2923	693.0	1.899	25.400
19	GE14	2923	693.0	1.899	27.299
20	GE14	2923	693.0	1.899	29.197
21	GE14	2923	693.0	1.899	31.096
EQ/36Y	GE14	2923	4562.0	12.499	36.000
EQ/54Y	GE14	2923	6570.0	18.000	54.000

Table 2.1-2

Brunswick Unit 2

Fuel Management and Operating Cycle Parameters

Cycle	Fuel Type	Operating Power, Mwd	Cycle Time, EFPD	Cycle Time, EFPY	Operating Time, EFPY
1	GE3	2436	350.5	0.960	0.960
2	GE4	2436	301.6	0.826	1.786
3	GE5	2436	187.2	0.513	2.299
4	GE6	2436	310.0	0.849	3.149
5	GE6	2436	298.7	0.818	3.967
6	GE7	2436	289.0	0.792	4.759
7	GE7	2436	475.4	1.303	6.062
8	GE8	2436	440.7	1.207	7.269
9	GE9	2436	424.9	1.164	8.433
10	GE10	2436	372.5	1.021	9.454
11	GE10	2436	541.9	1.485	10.938
12	GE13	2436	511.8	1.402	12.340
13	GE13	2558	520.9	1.427	13.767
14	GE13	2558	616.5	1.689	15.456
15	GE14	2558	682.3	1.869	17.326
16	GE14	2801	689.0	1.888	19.213
17	GE14	2923	667.0	1.827	21.041
18	GE14	2923	682.0	1.868	22.909
19	GE14	2923	693.0	1.899	24.808
20	GE14	2923	693.0	1.899	26.707
EQ/36Y	GE14	2923	4085.1	11.192	36.000
EQ/54Y	GE14	2923	6570.0	18.000	54.000

Figure 2.1-1

Brunswick Units 1 and 2 r,θ Reactor Geometry

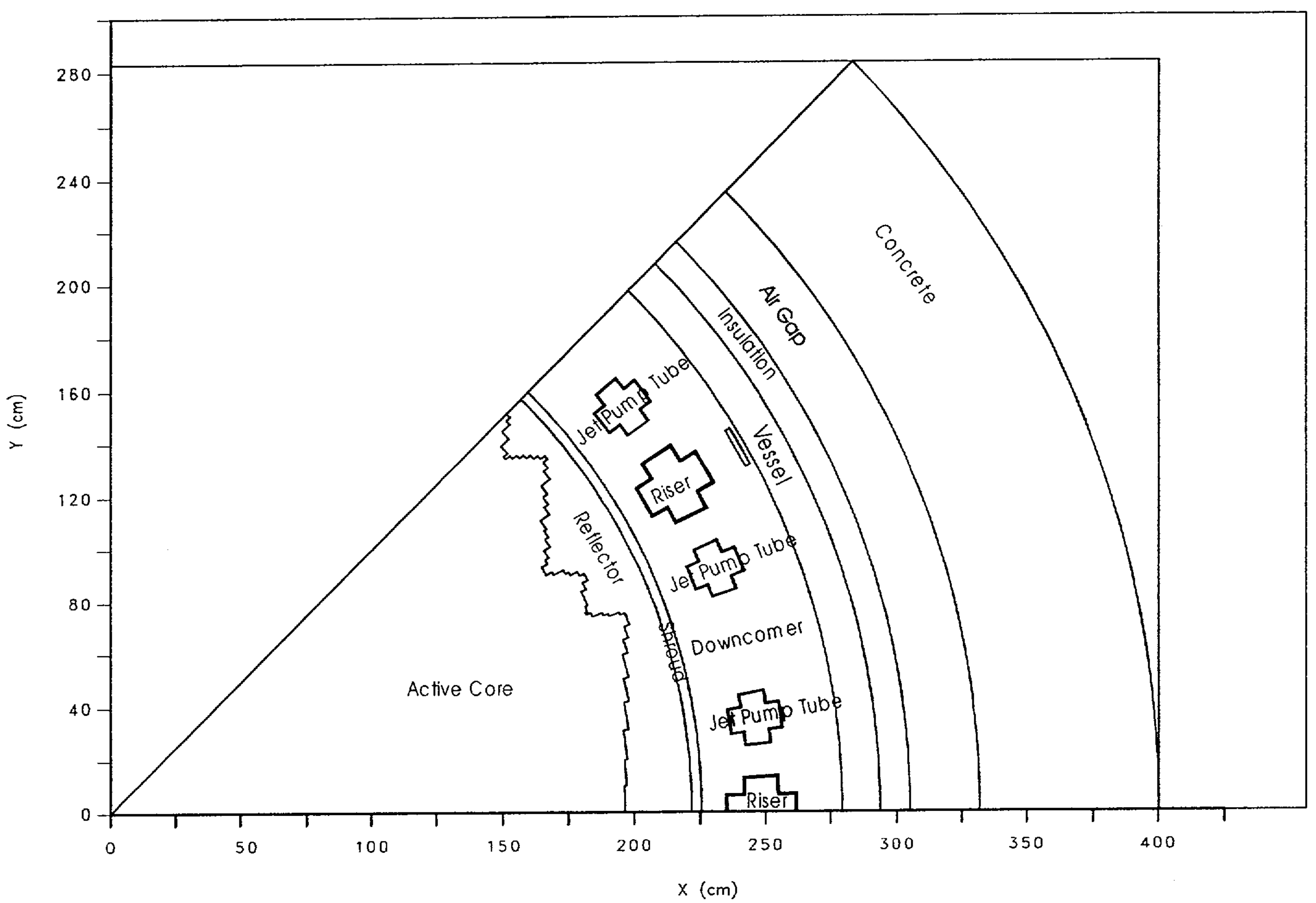


Figure 2.1-2

Brunswick Units 1 and 2 r,z Reactor Geometry