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INTEGRITY**
Associates, Inc.

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FILE No.: RBS-03Q-301

PROJECT No.: RBS-03Q

PROJECT NAME: Revised P-T Curves for River Bend

CLIENT: Entergy Operations, Inc. -- River Bend Station

CALCULATION TITLE: Pressure-Temperature Curve Calculation for 12 EFPY

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

The purpose of this calculation is to develop revised pressure-temperature (P-T) curves for River Bend Station for 12 effective full power years (EFPY) of operation.

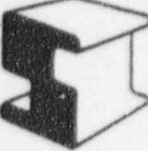
Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Dates
0	1 - 21, 1 disk	Original Issue	<i>Gary L. Stevens</i> Gary L. Stevens 10/16/96	Gary L. Stevens <i>Gary L. Stevens</i> 10/14/96 H. L. Gustin <i>H. L. Gustin</i> 10/15/96

1.0 INTRODUCTION

The purpose of this calculation is to develop revised pressure-temperature (P-T) curves for River Bend Station (RBS) valid for up to 12 effective full power years (EFPY) of operation. The current P-T curves [1] are valid for up to 8 EFPY of operation. The development of the current P-T curves, in accordance with Regulatory Guide 1.99, Revision 2 (RG 1.99) [2], is documented in Reference 3. The Reference 3 report includes the effects of the beltline, bottom head (CRD penetrations), and feedwater nozzle locations. The detailed specifics of precisely how the P-T curves were calculated are not included; however, all of the necessary inputs are included. Tabulated values for the current P-T curves are provided in Reference 4.

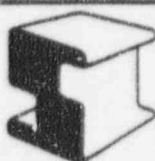
There are three objectives to this calculation, as identified in the scope of work for this contract:

1. **RT_{NDT} Determination:** The Reference 3 report provides RT_{NDT} estimates for all of the various RBS beltline materials. Since RT_{NDT} is an important and significant input parameter to the development of P-T curves, an EXCEL spreadsheet specific to RBS will be generated to validate the RT_{NDT} estimates contained in Reference 3. The spreadsheet will then be used to provide RT_{NDT} estimates for use in developing the P-T curves for RBS for 12 EFPY.
2. **Model Development:** A valid calculational model (EXCEL spreadsheet) will be established for computing P-T curves for RBS. The spreadsheet tool is convenient in that it possesses both computational and plotting capabilities, both of which are necessary for this effort. This tool provides further convenience in that it can be passed on to Entergy for future use in developing their own P-T curves, as well as to fulfill their requirement of providing the tabulated P-T points for the developed P-T curves. The tool will be "benchmarked" by first matching it to the current 8 EFPY curves. This step will ensure consistency with past work done for RBS in the Reference 3 report. Of particular interest are the thermal stress intensity factors previously calculated in Reference 3; since there can be significant variation in these factors depending upon the method of calculation used, benchmarking the model will eliminate any inconsistencies. Benchmarking against Reference 3 is considered reasonable, since it is apparent that significant effort has been placed on the RBS P-T curves in the past (i.e., Reference 2 has been revised).
3. **P-T Curve Development:** Once the spreadsheet model has been developed and benchmarked, P-T curves will be developed for 12 EFPY using the RT_{NDT} estimates established for RBS. The curves will be generated in the format shown in Reference 1 so that they are suitable for placement into the RBS Technical Specifications.

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2.0 RT_{NDT} DETERMINATION

Appendix A of Reference 3 provides RT_{NDT} estimates for the RBS beltline materials in accordance with RG 1.99 for various EFPY levels. An EXCEL spreadsheet was set up to perform the RT_{NDT} calculations, and is shown in Table 1. The inputs used for the calculations were obtained from Appendix A of Reference 3 unless otherwise noted. All details of the calculations are identified in the notes to the table. The results in Table 1 are seen to be identical to those of Appendix A of Reference 3 for 12 EFPY, thus confirming the previous RT_{NDT} estimates, as well as providing a "check" of the current results.



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Table 1: RBS RPV Beltline Adjusted Reference Temperature Estimates

(Data Source: Appendix A of SASR 89-20, Rev. 1, "Implementation of Regulatory Guide 1.99 Revision 2 for River Bend Station Unit 1," March 1990)

RPV thickness = 5.41 inches
 Reference Fluence = 6.600E+18 n/cm² at 32 EFPY (nominal peak value at RPV ID)
 Desired EFPY for RT_{NDT} Prediction = 12.0 EFPY
 Estimated Fluence ⁽¹⁾ = 2.475E+18 n/cm² (nominal peak value at RPV ID)
 Attenuated Fluence at 1/4T ⁽²⁾ = 1.789E+18 n/cm²
 Fluence Factor ⁽³⁾ = 0.5431

Part Name & Material	ID	Heat No.	Lot No.	Estimated Initial RT _{NDT} (°F)	Chemistry		Chemistry Factor ⁽⁴⁾ (°F)	Adjustments For 1/4 T			
					Cu (wt %)	Ni (wt %)		ΔRT _{NDT} ⁽⁵⁾ (°F)	Margin		ART ⁽⁷⁾ (°F)
									σ _A (°F) ⁽⁶⁾	σ _i (°F)	
Vessel Plate	22-1-3	C3138-2	---	9	0.08	0.63	51	27.7	13.8	0.0	64.4
Vessel Plate	22-1-1	C3054-1	---	-20	0.09	0.70	58	31.5	15.7	0.0	43.0
Vessel Plate	22-1-2	C3054-2	---	2	0.09	0.70	58	31.5	15.7	0.0	65.0
Vessel Weld	BE, BF, BG	492L4871	A421B27AE	-60	0.04	0.95	54	29.3	14.7	0.0	-1.3
Vessel Weld	BE, BF, BG	492L4871	A421B27AF	-50	0.03	0.98	41	22.3	11.1	0.0	-5.5
Vessel Weld	BE, BF, BG	5P6756	0342 (Tandem)	-50	0.09	0.92	122	66.3	28.0	0.0	72.3
Vessel Weld	BE, BF, BG	5P6756	0342 (Single)	-60	0.09	0.93	122	66.3	28.0	0.0	62.3
								Limiting Beltline ART = 72.3			

Notes:

- Estimated Fluence = (Reference Fluence) * (Desired EFPY)/(Reference EFPY).
- Attenuated Fluence = (Estimated Fluence) e^{-0.24x} where x = 1/4T distance per Section 1.1 of RG 1.99.
- Fluence factor = f^(10.28 - log η) where f = (Attenuated Fluence at 1/4T)/(1x10¹⁸) per Section 1.1 of RG 1.99.
- Obtained from RG 1.99, Table 1 (Welds) and Table 2 (Base Metal).
- ΔRT_{NDT} = (Chemistry Factor)*(Fluence Factor) per Section 1.1 of RG 1.99.
- σ_A = 17°F for base metal and 28°F for welds, except that σ_A need not exceed 0.50*ΔRT_{NDT} per Section 1.1 of RG 1.99.
- Adjusted Reference Temperature (ART) = Initial RT_{NDT} + ΔRT_{NDT} + 2*(σ_A² + σ_i²)^{1/2} per Section 1.1 of RG 1.99.

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3.0 P-T CURVE METHODOLOGY

In this section, the methodology for calculating P-T curves is detailed. This methodology will document the equations to be used by the EXCEL spreadsheet developed for this work. The methodology is based on the requirements of References 5 and 6.

The approach used for calculating the P-T curves is summarized below. Note that the following is based on developing a model that calculates P-T curves which match those previously developed by GE in Reference 3:

- a. Assume a coolant temperature, T_{coolant} .
- b. For the T_{coolant} 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 through-wall temperature drop term, ΔT_{wall} , to T_{coolant} . *The value of ΔT_{wall} will be varied such that the resulting P-T Curve A matches that previously determined by GE -- this eliminates any inconsistencies that may arise if ΔT_{wall} were determined by independent heat transfer analysis.*
- c. Calculate the allowable stress intensity factor, K_{IR} , based on $T_{1/4t}$ using the relationship from Reference 5:

$$K_{\text{IR}} = 1.223 e^{[0.0145(T - \text{ART} + 160)]} + 26.78$$

where: $T = T_{1/4t}$ ($^{\circ}\text{F}$)

ART = adjusted reference temperature for limiting beltline material ($^{\circ}\text{F}$)

K_{IR} = allowable stress intensity factor ($\text{ksi}\sqrt{\text{inch}}$)

Note that a maximum value of 200 $\text{ksi}\sqrt{\text{inch}}$ is allowed.

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

$$K_{\text{IP}} = K_{\text{IR}}/1.5 \quad \text{for Curve A (i.e., pressure-test curve)}$$

$$K_{\text{IP}} = (K_{\text{IR}} - K_{\text{IT}})/2.0 \quad \text{for Curves B and C (i.e., core not critical and core critical curves)}$$

where: K_{IT} = thermal stress intensity factor ($\text{ksi}\sqrt{\text{inch}}$)

The value of K_{IT} will be varied such that the resulting P-T Curve B matches that previously determined by GE -- this eliminates any inconsistencies that may arise if K_{IT} were determined by independent thermal stress analysis.

K_{IP} = allowable pressure stress intensity factor ($\text{ksi}\sqrt{\text{inch}}$)



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- 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 5. *The upper line for M_m in Figure G-2214-1 (corresponding to $\sigma/\sigma_{ys} = 1.0$) will be conservatively used -- note that this conservatism will be compensated for in the adjustments of ΔT_{wall} and K_{IT} mentioned above.*

σ_m = membrane stress due to pressure (ksi)
 = PR/t for a thin-walled vessel
 P = pressure (ksi)
 R = vessel radius (inches)
 t = vessel minimum 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, $P = K_{IP}t/(RM_m)$

- f. Repeat steps (a) through (e) for other temperatures to generate a series of P-T points.
 g. Subtract any applicable instrument errors for temperature and pressure from $T_{coolant}$ and P, respectively. The resulting pressure and temperature series constitutes the P-T curve. *Instrument errors were assumed to be zero for RBS.* The P-T curve relates the minimum required reactor fluid temperature in the beltline region to the reactor pressure in the beltline region.

The following additional requirements were used by GE in the Reference 3 report to define the lower portion of the P-T curves. These limits are established by the discontinuity regions of the vessel (i.e., flanges, nozzles, etc.), and are retained throughout the current analysis (i.e., they are assumed correct and will not change since the discontinuity regions are not affected significantly by fluence):

For Curve A:

- 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 [6]. The pre-service hydro test pressure was assumed to be 1562.5 psig ($=312.5/0.20$), based on the fact that the current P-T curves establish this limit at 312.5 psig [4].

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- If P is less than 20% of the pre-service hydro test pressure, the temperature must be greater than 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 [3]. For the RBS flange material, this minimum temperature is 70°F [4].

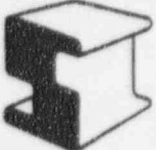
For Curve B:

- 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 [6].
- If P is less than 20% of the pre-service hydro test pressure, the temperature must be greater than 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 [3]. For the RBS flange material, this minimum temperature is 70°F [4].

For Curve C:

- Per the requirements of Paragraph IV.A.2 of Reference 6, the core critical (Curve C) P-T limits must be 40°F above any Curve A or B limits. Curve B is more limiting than Curve A, so Curve C is Curve B plus 40°F.
- Another requirement of Paragraph IV.A.2 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 70°F for RBS.
- Also per Paragraph IV.A.2 of Reference 6, at pressure above 20% of the pre-service hydro test pressure, the Curve C temperature must be at least that required for the pressure test (Curve A at 1,100 psig). As a result of this requirement, Curve C must have a step at a pressure equal to 20% of the pre-service hydro pressure to the temperature required by Curve A at 1,100 psig, or 40°F, whichever is greater. *(For the curves covered in this analysis through 12 EFPY, the 40°F step is limiting.)*

The vessel dimensions for the RBS plate material are documented in Reference 3. The limiting ART value used comes from Table 1 for 12 EFPY, and is 60.5°F for 8 EFPY per Appendix A of the Reference 3 report.

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4.0 P-T CURVE MODEL

An EXCEL spreadsheet was developed to perform the necessary calculations described in Section 3.0 and generate the P-T curves. A "benchmark" case was run in the spreadsheet for 8 EFPY, and the results are shown in Table 2 and Figure 1. Also contained within this table and figure are the current 8 EFPY Tech. Spec. curves [1,4]. Comparison of the two sets of curves demonstrates that the spreadsheet results are consistent and accurate.


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Table 2: RBS Pressure-Temperature Curve Calculation Results for 8 EPPY "Benchmark" Test Case

Lining Buttons Component = Vessel Head 6P6766 (Lot 8342, Random)
 EPPY = 12.8 inches
 Minimum Vessel Wall Thickness = 6.41 inches
 Maximum Vessel Inside Radius = 116.2 inches
 R_{1,adj} = 68.8 in
 Temperature Instrument Error = 0.8 °F
 Pressure Instrument Error = 0.8 psig
 Code Hydro Test Pressure = 1843.8 psig
 Boiling Temperature = 78 °F
 Fluid to 1041 Temp Adj = 0.83 °F
 Thermal Stress Intensity Factor, K_t = 10.8169
 (assumed value to match GE P-T Curve A results)
 (assumed value to match GE P-T Curve B and C only)

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Calculation Results:
 Membrane Correction Factor, M_m = 2.413

Reactor Coolant Temperature T _{co} (°F)	Adjusted Temperature at 1041 (°F)	Adjusted Temperature for P-T Curve (°F)	CURVE A' CALCULATIONS			CURVE A CALCULATIONS			CURVE B' CALCULATIONS			CURVE B CALCULATIONS			CURVE C' CALCULATIONS			CURVE C CALCULATIONS		
			R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)	R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)	R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)	R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)	R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)	R _{co} (inches)	P (psig)	Adjusted Pressure for P-T Curve (psig)
118.0	124.0	118.0	54.04	787.4	787.4	38.70	787.4	787.4	38.70	787.4	787.4	38.70	787.4	787.4	38.70	787.4	787.4	38.70	787.4	787.4
119.0	125.0	119.0	54.50	793.6	793.6	39.00	793.6	793.6	39.00	793.6	793.6	39.00	793.6	793.6	39.00	793.6	793.6	39.00	793.6	793.6
120.0	126.0	120.0	54.98	799.9	799.9	39.31	799.9	799.9	39.31	799.9	799.9	39.31	799.9	799.9	39.31	799.9	799.9	39.31	799.9	799.9
121.0	127.0	121.0	55.43	806.3	806.3	39.62	806.3	806.3	39.62	806.3	806.3	39.62	806.3	806.3	39.62	806.3	806.3	39.62	806.3	806.3
122.0	128.0	122.0	55.91	812.7	812.7	39.94	812.7	812.7	39.94	812.7	812.7	39.94	812.7	812.7	39.94	812.7	812.7	39.94	812.7	812.7
123.0	129.0	123.0	56.40	819.3	819.3	40.26	819.3	819.3	40.26	819.3	819.3	40.26	819.3	819.3	40.26	819.3	819.3	40.26	819.3	819.3
124.0	130.0	124.0	56.89	826.0	826.0	40.59	826.0	826.0	40.59	826.0	826.0	40.59	826.0	826.0	40.59	826.0	826.0	40.59	826.0	826.0
125.0	131.0	125.0	57.38	832.7	832.7	40.92	832.7	832.7	40.92	832.7	832.7	40.92	832.7	832.7	40.92	832.7	832.7	40.92	832.7	832.7
126.0	132.0	126.0	57.89	839.6	839.6	41.26	839.6	839.6	41.26	839.6	839.6	41.26	839.6	839.6	41.26	839.6	839.6	41.26	839.6	839.6
127.0	133.0	127.0	58.40	846.5	846.5	41.60	846.5	846.5	41.60	846.5	846.5	41.60	846.5	846.5	41.60	846.5	846.5	41.60	846.5	846.5
128.0	134.0	128.0	58.92	853.6	853.6	41.95	853.6	853.6	41.95	853.6	853.6	41.95	853.6	853.6	41.95	853.6	853.6	41.95	853.6	853.6
129.0	135.0	129.0	59.45	860.7	860.7	42.30	860.7	860.7	42.30	860.7	860.7	42.30	860.7	860.7	42.30	860.7	860.7	42.30	860.7	860.7
130.0	136.0	130.0	59.99	868.0	868.0	42.66	868.0	868.0	42.66	868.0	868.0	42.66	868.0	868.0	42.66	868.0	868.0	42.66	868.0	868.0
131.0	137.0	131.0	60.53	875.4	875.4	43.02	875.4	875.4	43.02	875.4	875.4	43.02	875.4	875.4	43.02	875.4	875.4	43.02	875.4	875.4
132.0	138.0	132.0	61.08	882.9	882.9	43.39	882.9	882.9	43.39	882.9	882.9	43.39	882.9	882.9	43.39	882.9	882.9	43.39	882.9	882.9
133.0	139.0	133.0	61.64	890.4	890.4	43.76	890.4	890.4	43.76	890.4	890.4	43.76	890.4	890.4	43.76	890.4	890.4	43.76	890.4	890.4
134.0	140.0	134.0	62.21	898.1	898.1	44.14	898.1	898.1	44.14	898.1	898.1	44.14	898.1	898.1	44.14	898.1	898.1	44.14	898.1	898.1
135.0	141.0	135.0	62.78	905.0	905.0	44.52	905.0	905.0	44.52	905.0	905.0	44.52	905.0	905.0	44.52	905.0	905.0	44.52	905.0	905.0
136.0	142.0	136.0	63.37	911.9	911.9	44.91	911.9	911.9	44.91	911.9	911.9	44.91	911.9	911.9	44.91	911.9	911.9	44.91	911.9	911.9
137.0	143.0	137.0	63.96	919.0	919.0	45.31	919.0	919.0	45.31	919.0	919.0	45.31	919.0	919.0	45.31	919.0	919.0	45.31	919.0	919.0
138.0	144.0	138.0	64.56	926.1	926.1	45.71	926.1	926.1	45.71	926.1	926.1	45.71	926.1	926.1	45.71	926.1	926.1	45.71	926.1	926.1
139.0	145.0	139.0	65.17	933.4	933.4	46.12	933.4	933.4	46.12	933.4	933.4	46.12	933.4	933.4	46.12	933.4	933.4	46.12	933.4	933.4
140.0	146.0	140.0	65.79	940.8	940.8	46.53	940.8	940.8	46.53	940.8	940.8	46.53	940.8	940.8	46.53	940.8	940.8	46.53	940.8	940.8
141.0	147.0	141.0	66.42	948.3	948.3	46.95	948.3	948.3	46.95	948.3	948.3	46.95	948.3	948.3	46.95	948.3	948.3	46.95	948.3	948.3
142.0	148.0	142.0	67.06	955.9	955.9	47.37	955.9	955.9	47.37	955.9	955.9	47.37	955.9	955.9	47.37	955.9	955.9	47.37	955.9	955.9
143.0	149.0	143.0	67.70	963.9	963.9	47.80	963.9	963.9	47.80	963.9	963.9	47.80	963.9	963.9	47.80	963.9	963.9	47.80	963.9	963.9
144.0	150.0	144.0	68.36	971.7	971.7	48.24	971.7	971.7	48.24	971.7	971.7	48.24	971.7	971.7	48.24	971.7	971.7	48.24	971.7	971.7
145.0	151.0	145.0	69.03	979.8	979.8	48.68	979.8	979.8	48.68	979.8	979.8	48.68	979.8	979.8	48.68	979.8	979.8	48.68	979.8	979.8
146.0	152.0	146.0	69.70	988.0	988.0	49.13	988.0	988.0	49.13	988.0	988.0	49.13	988.0	988.0	49.13	988.0	988.0	49.13	988.0	988.0
147.0	153.0	147.0	70.39	996.5	996.5	49.59	996.5	996.5	49.59	996.5	996.5	49.59	996.5	996.5	49.59	996.5	996.5	49.59	996.5	996.5
148.0	154.0	148.0	71.08	1005.1	1005.1	50.06	1005.1	1005.1	50.06	1005.1	1005.1	50.06	1005.1	1005.1	50.06	1005.1	1005.1	50.06	1005.1	1005.1
149.0	155.0	149.0	71.79	1013.8	1013.8	50.53	1013.8	1013.8	50.53	1013.8	1013.8	50.53	1013.8	1013.8	50.53	1013.8	1013.8	50.53	1013.8	1013.8
150.0	156.0	150.0	72.50	1022.8	1022.8	51.00	1022.8	1022.8	51.00	1022.8	1022.8	51.00	1022.8	1022.8	51.00	1022.8	1022.8	51.00	1022.8	1022.8
151.0	157.0	151.0	73.23	1031.7	1031.7	51.46	1031.7	1031.7	51.46	1031.7	1031.7	51.46	1031.7	1031.7	51.46	1031.7	1031.7	51.46	1031.7	1031.7
152.0	158.0	152.0	73.97	1040.7	1040.7	51.98	1040.7	1040.7	51.98	1040.7	1040.7	51.98	1040.7	1040.7	51.98	1040.7	1040.7	51.98	1040.7	1040.7
153.0	159.0	153.0	74.71	1049.7	1049.7	52.48	1049.7	1049.7	52.48	1049.7	1049.7	52.48	1049.7	1049.7	52.48	1049.7	1049.7	52.48	1049.7	1049.7
154.0	160.0	154.0	75.47	1058.8	1058.8	52.98	1058.8	1058.8	52.98	1058.8	1058.8	52.98	1058.8	1058.8	52.98	1058.8	1058.8	52.98	1058.8	1058.8
155.0	161.0	155.0	76.24	1068.0	1068.0	53.50	1068.0	1068.0	53.50	1068.0	1068.0	53.50	1068.0	1068.0	53.50	1068.0	1068.0	53.50	1068.0	1068.0
156.0	162.0	156.0	77.00	1077.3	1077.3	54.02	1077.3	1077.3	54.02	1077.3	1077.3	54.02	1077.3	1077.3	54.02	1077.3	1077.3	54.02	1077.3	1077.3
157.0	163.0	157.0	77.77	1086.8	1086.8	54.54	1086.8	1086.8	54.54	1086.8	1086.8	54.54	1086.8	1086.8	54.54	1086.8	1086.8	54.54	1086.8	1086.8
158.0	164.0	158.0	78.55	1096.5	1096.5	55.08	1096.5	1096.5	55.08	1096.5	1096.5	55.08	1096.5	1096.5	55.08	1096.5	1096.5	55.08	1096.5	1096.5
159.0	165.0	159.0	79.34	1106.3	1106.3	55.62	1106.3	1106.3	55.62	1106.3	1106.3	55.62	1106.3	1106.3	55.62	1106.3	1106.3	55.62	1106.3	1106.3
160.0	166.0	160.0	80.14	1116.3	1116.3	56.16	1116.3	1116.3	56.16	1116.3	1116.3	56.16	1116.3	1116.3	56.16	1116.3	1116.3	56.16	1116.3	1116.3

Table 2: RBS Pressure-Temperature Curve Calculation Results for 8 EPPY "Benchmark" Test Case

Inputs:

Limiting Bedline Component = Vessel Weld SP9786 (Lat 8342, Tondens)
 EPPY = 12.8
 Maximum Vessel Vial Thickness = 8.41 inches
 Maximum Vessel Inside Radius = 118.3 inches
 Maximum Vessel Inside Radius = 60.8 inches
 RT₅₀₀ = 8.8 inches
 Temperature Instrument Error = 8.8 inches
 Pressure Instrument Error = 8.8 inches
 Code Hydro Test Pressure = 1583.8 psig
 Backup Temperature = 78 inches
 Fluid to 10AT Temp Act = 6.83 inches
 Thermal Stress Intensity Factor, K_{ts} = 18.819

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(assumed value to match GE P-T Curve A results)

(assumed value to match GE P-T curve results, used for Curves B and C only)

Calculation Results:

Membrane Correction Factor, M_m = 2.413

Reactor Component Temperature T _m	Adjusted Temperature at 10AT for P-T Curve	Adjusted Temperature for P-T Curve	CURVE A CALCULATIONS			CURVE B CALCULATIONS			CURVE C CALCULATIONS			SEPPY Tech. Spec. Curve A Temperature (°F)	SEPPY Tech. Spec. Curve B Temperature (°F)	SEPPY Tech. Spec. Curve C Temperature (°F)	SEPPY Tech. Spec. Curve C Pressure (psig)
			K _{ts} (inches)	P _{max} (psig)	P _{min} (psig)	K _{ts} (inches)	P _{max} (psig)	P _{min} (psig)	K _{ts} (inches)	P _{max} (psig)	P _{min} (psig)				
181.0	181.0	181.0	83.10	1154.8	1154.8	58.74	1154.8	1154.8	37.10	754.8	754.8	181.6	181.6	201.6	770
182.0	182.0	182.0	83.95	1160.0	1160.0	57.30	1160.0	1160.0	37.52	763.5	763.5	182.8	182.8	202.8	780
183.0	183.0	183.0	84.82	1167.7	1167.7	56.46	1167.7	1167.7	37.95	772.3	772.3	183.9	183.9	203.9	790
184.0	184.0	184.0	85.70	1177.7	1177.7	55.46	1177.7	1177.7	38.38	781.2	781.2	185.0	185.0	205.0	800
185.0	185.0	185.0	86.58	1189.6	1189.6	54.08	1189.6	1189.6	38.84	790.3	790.3	186.1	186.1	206.1	810
186.0	186.0	186.0	87.49	1201.7	1201.7	52.66	1201.7	1201.7	39.29	799.5	799.5	187.2	187.2	207.2	820
187.0	187.0	187.0	88.40	1213.9	1213.9	51.08	1213.9	1213.9	39.75	808.8	808.8	188.3	188.3	208.3	830
188.0	188.0	188.0	89.33	1226.4	1226.4	49.48	1226.4	1226.4	40.21	818.2	818.2	189.3	189.3	209.3	840
189.0	189.0	189.0	90.28	1239.0	1239.0	47.86	1239.0	1239.0	40.68	827.8	827.8	190.4	190.4	210.4	850
190.0	190.0	190.0	91.23	1251.8	1251.8	46.24	1251.8	1251.8	41.16	837.6	837.6	191.4	191.4	211.4	860
191.0	191.0	191.0	92.20	1264.7	1264.7	44.61	1264.7	1264.7	41.65	847.4	847.4	192.4	192.4	212.4	870
192.0	192.0	192.0	93.19	1277.9	1277.9	43.06	1277.9	1277.9	42.14	857.4	857.4	193.4	193.4	213.4	880
193.0	193.0	193.0	94.20	1291.3	1291.3	41.52	1291.3	1291.3	42.64	867.6	867.6	194.4	194.4	214.4	890
194.0	194.0	194.0	95.19	1304.8	1304.8	40.00	1304.8	1304.8	43.15	877.9	877.9	195.3	195.3	215.3	900
195.0	195.0	195.0	96.20	1318.6	1318.6	38.49	1318.6	1318.6	43.66	888.4	888.4	196.2	196.2	216.2	910
196.0	196.0	196.0	97.23	1332.5	1332.5	36.98	1332.5	1332.5	44.18	899.0	899.0	197.2	197.2	217.2	920
197.0	197.0	197.0	98.27	1346.7	1346.7	35.48	1346.7	1346.7	44.71	909.8	909.8	198.1	198.1	218.1	930
198.0	198.0	198.0	99.33	1361.0	1361.0	34.00	1361.0	1361.0	45.25	920.7	920.7	199.0	199.0	219.0	940
199.0	199.0	199.0	100.41	1375.6	1375.6	32.53	1375.6	1375.6	45.78	931.8	931.8	200.0	200.0	220.0	950
200.0	200.0	200.0	101.50	1390.4	1390.4	31.08	1390.4	1390.4	46.35	943.1	943.1	201.0	201.0	221.0	960
201.0	201.0	201.0	102.60	1405.4	1405.4	29.64	1405.4	1405.4	46.91	954.5	954.5	202.0	202.0	222.0	970
202.0	202.0	202.0	103.72	1420.6	1420.6	28.24	1420.6	1420.6	47.48	966.1	966.1	203.0	203.0	223.0	980
203.0	203.0	203.0	104.85	1436.1	1436.1	26.86	1436.1	1436.1	48.05	977.8	977.8	204.0	204.0	224.0	990
204.0	204.0	204.0	106.00	1451.7	1451.7	25.50	1451.7	1451.7	48.64	989.7	989.7	205.0	205.0	225.0	1000
205.0	205.0	205.0	107.16	1467.6	1467.6	24.16	1467.6	1467.6	49.23	1001.8	1001.8	206.0	206.0	226.0	1010
206.0	206.0	206.0	108.33	1483.8	1483.8	22.84	1483.8	1483.8	49.84	1014.1	1014.1	207.0	207.0	227.0	1020
207.0	207.0	207.0	109.50	1500.1	1500.1	21.54	1500.1	1500.1	50.45	1026.6	1026.6	208.0	208.0	228.0	1030
208.0	208.0	208.0	110.68	1516.7	1516.7	20.26	1516.7	1516.7	51.07	1039.2	1039.2	209.0	209.0	229.0	1040
209.0	209.0	209.0	111.81	1533.6	1533.6	19.00	1533.6	1533.6	51.70	1052.0	1052.0	210.0	210.0	230.0	1050
210.0	210.0	210.0	113.05	1550.7	1550.7	17.75	1550.7	1550.7	52.34	1065.0	1065.0	211.0	211.0	231.0	1060
211.0	211.0	211.0	114.31	1568.0	1568.0	16.52	1568.0	1568.0	52.98	1078.2	1078.2	212.0	212.0	232.0	1070
212.0	212.0	212.0	115.59	1585.6	1585.6	15.33	1585.6	1585.6	53.65	1091.6	1091.6	213.0	213.0	233.0	1080
213.0	213.0	213.0	116.89	1603.5	1603.5	14.16	1603.5	1603.5	54.31	1105.2	1105.2	214.0	214.0	234.0	1090
214.0	214.0	214.0	118.20	1621.6	1621.6	13.00	1621.6	1621.6	54.99	1119.0	1119.0	215.0	215.0	235.0	1100
215.0	215.0	215.0	119.54	1640.0	1640.0	11.86	1640.0	1640.0	55.68	1133.0	1133.0	216.0	216.0	236.0	1110
216.0	216.0	216.0	120.89	1658.7	1658.7	10.75	1658.7	1658.7	56.38	1147.1	1147.1	217.0	217.0	237.0	1120
217.0	217.0	217.0	122.27	1677.7	1677.7	9.66	1677.7	1677.7	57.08	1161.5	1161.5	218.0	218.0	238.0	1130
218.0	218.0	218.0	123.66	1697.0	1697.0	8.59	1697.0	1697.0	57.80	1176.1	1176.1	219.0	219.0	239.0	1140
219.0	219.0	219.0	125.08	1716.5	1716.5	7.54	1716.5	1716.5	58.53	1191.0	1191.0	220.0	220.0	240.0	1150
220.0	220.0	220.0	126.51	1736.1	1736.1	6.50	1736.1	1736.1	59.27	1206.0	1206.0	221.0	221.0	241.0	1160
221.0	221.0	221.0	127.97	1756.0	1756.0	5.48	1756.0	1756.0	60.02	1221.3	1221.3	222.0	222.0	242.0	1170
222.0	222.0	222.0	129.45	1776.1	1776.1	4.48	1776.1	1776.1	60.78	1236.7	1236.7	223.0	223.0	243.0	1180
223.0	223.0	223.0	130.95	1796.4	1796.4	3.49	1796.4	1796.4	61.55	1252.4	1252.4	224.0	224.0	244.0	1190
224.0	224.0	224.0	132.47	1816.9	1816.9	2.52	1816.9	1816.9	62.33	1268.4	1268.4	225.0	225.0	245.0	1200

Table 2: RBS Pressure-Temperature Curve Calculation Results for 8 EFY "Benchmark" Test Case

Inputs:

Limiting Bellows Component = Vessel Weld 6P6766 (Lot 8342, Tandem)
 EFY = 12.8
 Minimum Vessel Wall Thickness = 6.41 inches
 Maximum Vessel Inside Radius = 116.2 inches
 RT_{min} = 66.5 °F
 Temperature Instrument Error = 0.0 °F
 Pressure Instrument Error = 0.0 psig
 Code Hydro Test Pressure = 1862.6 psig
 Bolting Temperature = 70 °F
 Fluid to HAT Temp. Adj. = 0.83 °F (assumed value to match GE P-T Curve A results)
 Thermal Stress Intensity Factor, K_{ts} = 10.916 bar-inch (assumed value to match GE P-T curve results, used for Curves B and C only)

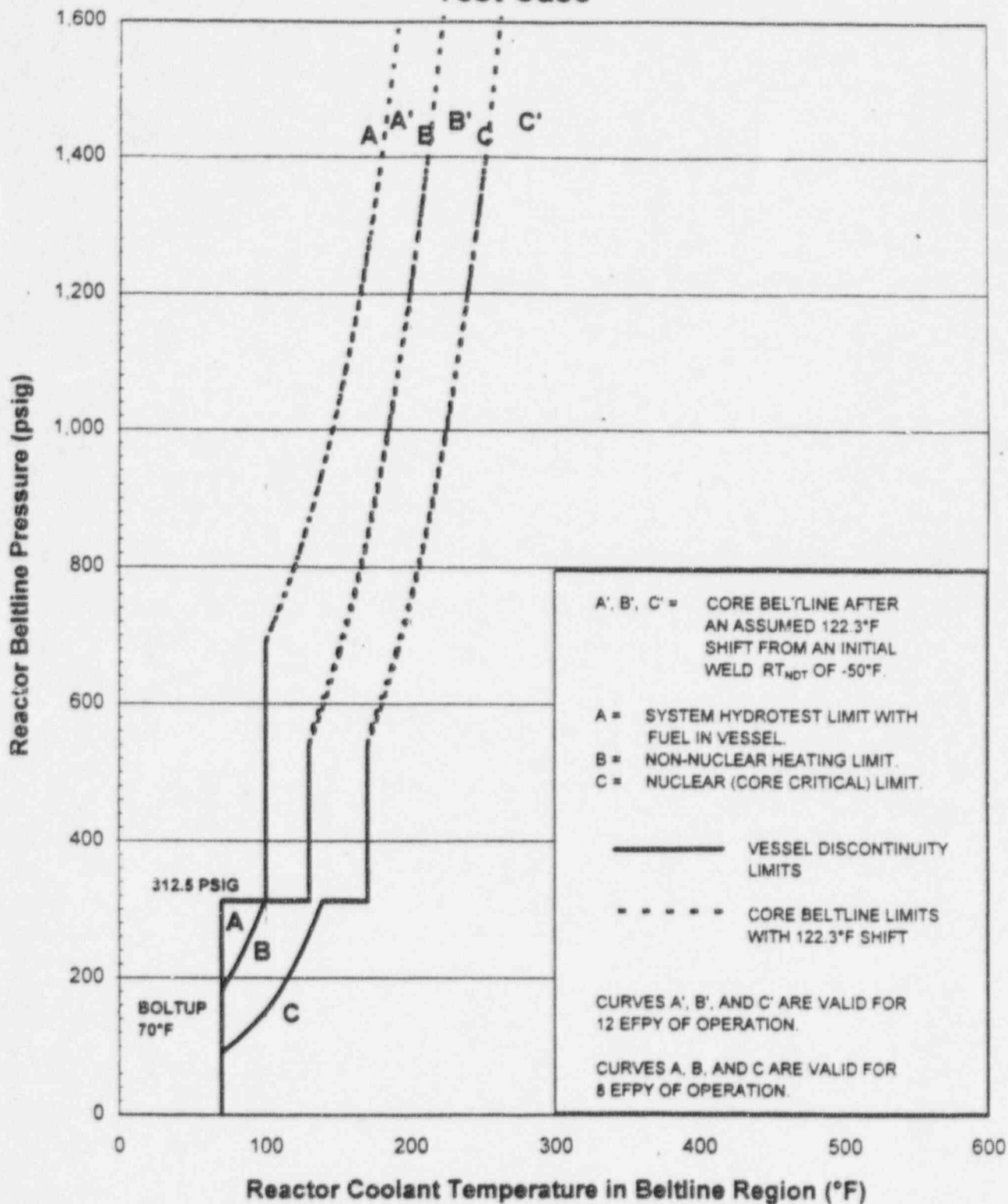
Calculation Results:

Membrane Correction Factor, M_m = 2.413

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Reactor Coolant Temperature T _{ref} (°F)	Adjusted Temperature at HAT (°F)	Adjusted Temperature for P-T Curve (°F)	K _{ts} (bar-inch)	CURVE A CALCULATIONS		EFY Tech. Spec. Curve A Temperature (°F)	EFY Tech. Spec. Curve A Pressure (psig)	CURVE B CALCULATIONS		EFY Tech. Spec. Curve B Temperature (°F)	EFY Tech. Spec. Curve B Pressure (psig)	CURVE C CALCULATIONS		EFY Tech. Spec. Curve C Temperature (°F)	EFY Tech. Spec. Curve C Pressure (psig)
				Calculated Pressure P (psig)	Adjusted Pressure for P-T Curve (psig)			Calculated Pressure P (psig)	Adjusted Pressure for P-T Curve (psig)			Calculated Pressure P (psig)	Adjusted Pressure for P-T Curve (psig)		
205.0	211.0	205.0	137.17			166.1	1210	63.13	1284.5	1284.5	200.0	1210	245.0	240.0	1210
206.0	212.0	206.0	138.78			166.5	1220	63.93	1300.9	1300.9	200.6	1220	245.0	240.6	1220
207.0	213.0	207.0	140.42			167.7	1230	64.75	1317.6	1317.6	201.3	1230	247.0	241.3	1230
208.0	214.0	208.0	142.07			168.5	1240	65.58	1334.5	1334.5	201.9	1240	248.0	241.9	1240
209.0	215.0	209.0	143.76			169.3	1250	66.42	1351.6	1351.6	202.6	1250	249.0	242.6	1250
210.0	216.0	210.0	145.47			170.0	1260	67.28	1369.0	1369.0	203.2	1260	250.0	243.2	1260
211.0	217.0	211.0	147.20			170.6	1270	68.15	1386.6	1386.6	203.9	1270	251.0	243.9	1270
212.0	218.0	212.0	148.96			171.6	1280	69.02	1404.5	1404.5	204.5	1280	252.0	244.5	1280
213.0	219.0	213.0	150.74			172.3	1290	69.82	1422.7	1422.7	205.1	1290	253.0	245.1	1290
214.0	220.0	214.0	152.55			173.1	1300	70.62	1441.1	1441.1	205.7	1300	254.0	245.7	1300
215.0	221.0	215.0	154.39			173.8	1310	71.74	1459.8	1459.8	206.3	1310	255.0	246.3	1310
216.0	222.0	216.0	156.26			174.5	1320	72.67	1478.8	1478.8	207.0	1320	256.0	247.0	1320
217.0	223.0	217.0	158.15			175.3	1330	73.62	1498.0	1498.0	207.6	1330	257.0	247.6	1330
218.0	224.0	218.0	160.07			176.0	1340	74.58	1517.5	1517.5	208.2	1340	258.0	248.2	1340
219.0	225.0	219.0	162.01			176.7	1350	75.55	1537.3	1537.3	208.7	1350	259.0	248.7	1350
220.0	226.0	220.0	163.99			177.4	1360	76.54	1557.4	1557.4	209.3	1360	260.0	249.3	1360
221.0	227.0	221.0	165.99			178.1	1370	77.54	1577.8	1577.8	209.9	1370	261.0	249.9	1370
222.0	228.0	222.0	168.02			178.8	1380	78.56	1598.5	1598.5	210.5	1380	262.0	250.5	1380
223.0	229.0	223.0	170.09			179.4	1390	79.59	1619.5	1619.5	211.1	1390	263.0	251.1	1390
224.0	230.0	224.0	172.18			180.1	1400	80.64	1640.8	1640.8	211.6	1400	264.0	251.6	1400
225.0	231.0	225.0	174.30												
226.0	232.0	226.0	176.46												
227.0	233.0	227.0	178.64												
228.0	234.0	228.0	180.86												
229.0	235.0	229.0	183.11												
230.0	236.0	230.0	185.40												
231.0	237.0	231.0	187.71												
232.0	238.0	232.0	190.06												
233.0	239.0	233.0	192.45												
234.0	240.0	234.0	194.87												
235.0	241.0	235.0	197.32												
236.0	242.0	236.0	199.81												
237.0	243.0	237.0	200.00												
238.0	244.0	238.0	200.00												
239.0	245.0	239.0	200.00												

**Figure 1: RBS P-T Curves for 8 EFPY "Benchmark"
Test Case**



5.0 P-T CURVES FOR 12 EFPY

The limiting ART value of 72.3°F for 12 EFPY from Table 1 was entered into the spreadsheet developed in Section 4.0 to generate the 12 EFPY P-T curves. The results are shown in Table 3 and Figure 2. Also contained within this table and figure are the current 8 EFPY Tech. Spec. curves [1.4] for comparative purposes.



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Checked By: *11* 10/15/96

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Table 3: RBS Pressure-Temperature Curve Calculation Results for 12 EPFV

(Leaking Badness Component = Vessel Head 889786 (Lot 8342, Tandem))
 EPFV = 12.8
 Minimum Vessel Wall Thickness = 8.41 inches
 Maximum Vessel Inside Radius = 118.2 inches
 R1, R2 = 72.3 inches
 Temperature Instrument Error = 0.0 °F
 Pressure Instrument Error = 0.0 psig
 Code Hydro Test Pressure = 1882.6 psig
 Fluid to 1041 Temp. Adj = 78 °F
 Thermal Stress Intensity Factor K_{ts} = 18.814
 (assumed value to match GE P-T Curve A results)
 (assumed value to match GE P-T Curve results, used for Curves B and C only)

Calculation Results:
 Membrane Correction Factor, M_m = 2.413

Reactor Coolant Temperature T_{mc}	Adjusted Temperature at 1041 T_{mc}	Adjusted Temperature for P-T Curve T_{mc}	CURVE A CALCULATIONS				CURVE B CALCULATIONS				CURVE C CALCULATIONS				CURVE D CALCULATIONS			
			R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)	R_{ts} (ksi)
118.0	124.0	118.0	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13	53.13
119.0	125.0	119.0	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51	53.51
120.0	126.0	120.0	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90	53.90
121.0	127.0	121.0	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30	54.30
122.0	128.0	122.0	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70	54.70
123.0	129.0	123.0	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11
124.0	130.0	124.0	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52	55.52
125.0	131.0	125.0	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94	55.94
126.0	132.0	126.0	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37	56.37
127.0	133.0	127.0	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80	56.80
128.0	134.0	128.0	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24	57.24
129.0	135.0	129.0	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68	57.68
130.0	136.0	130.0	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14	58.14
131.0	137.0	131.0	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59	58.59
132.0	138.0	132.0	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08	59.08
133.0	139.0	133.0	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53	59.53
134.0	140.0	134.0	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01	60.01
135.0	141.0	135.0	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48	60.48
136.0	142.0	136.0	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97	60.97
137.0	143.0	137.0	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49	61.49
138.0	144.0	138.0	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99	61.99
139.0	145.0	139.0	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51	62.51
140.0	146.0	140.0	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03	63.03
141.0	147.0	141.0	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58	63.58
142.0	148.0	142.0	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08	64.08
143.0	149.0	143.0	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64	64.64
144.0	150.0	144.0	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19	65.19
145.0	151.0	145.0	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75	65.75
146.0	152.0	146.0	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32	66.32
147.0	153.0	147.0	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90	66.90
148.0	154.0	148.0	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48	67.48
149.0	155.0	149.0	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08	68.08
150.0	156.0	150.0	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68	68.68
151.0	157.0	151.0	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30
152.0	158.0	152.0	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92	69.92
153.0	159.0	153.0	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55	70.55
154.0	160.0	154.0	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19	71.19
155.0	161.0	155.0	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84	71.84
156.0	162.0	156.0	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49	72.49
157.0	163.0	157.0	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16	73.16
158.0	164.0	158.0	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84	73.84
159.0	165.0	159.0	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53	74.53
160.0	166.0	160.0	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22	75.22

Table 3: RBS Pressure-Temperature Curve Calculation Results for 12 EPPY

Inputs:

Entering Bellows Components = Vessel Weld 692746 (Lst 9342, Tension)

EPPY = 12.0 inches

Minimum Vessel Wall Thickness = 6.41 inches

Maximum Vessel Inside Radius = 110.2 inches

RT_{min} = 72.3 °F

Temperature Instrument Error = 6.0 °F

Pressure Instrument Error = 8.0 psig

Code Hydro Test Pressure = 1882.8 psig

Boilup Temperature = 78 °F

Fixed to 141 Temp Aq = 6.83 °F

Thermal Stress Intensity Factor K_t = 18.911

Checked by: *AD* 10/14/96

10/15/96

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(assumed value to match GE P-T Curve A results)

(assumed value to match GE P-T Curve results, used for Curves B and C only)

Calculation Results:

Membrane Correction Factor M_m = 2.413

Reactor Coolant Temperature T _{in} (°F)	CURVE A CALCULATIONS				CURVE B CALCULATIONS				CURVE C CALCULATIONS				SEPPY Tech. Spec. Curve A				SEPPY Tech. Spec. Curve B				SEPPY Tech. Spec. Curve C							
	Adjusted Temperature at 146T for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)	Adjusted Temperature for P-T Curve	Adjusted Temperature for P-T Curve	K _t (psi-inch)	P (psi)
181.0	187.0	181.0	75.93	50.82	1030.0	1030.0	32.51	681.5	681.5	681.5	32.51	681.5	181.8	181.8	770	770	181.8	181.8	770	770	201.0	201.0	201.0	201.0	201.8	201.8	770	770
182.0	188.0	182.0	76.65	51.10	1036.8	1036.8	32.47	684.8	684.8	684.8	32.47	684.8	182.8	182.8	780	780	182.8	182.8	780	780	202.0	202.0	202.0	202.0	202.8	202.8	780	780
183.0	189.0	183.0	77.38	51.58	1043.6	1043.6	32.33	678.2	678.2	678.2	32.33	678.2	183.9	183.9	790	790	183.9	183.9	790	790	203.0	203.0	203.0	203.0	203.9	203.9	790	790
184.0	190.0	184.0	78.12	52.08	1050.7	1050.7	33.80	683.8	683.8	683.8	33.80	683.8	185.0	185.0	800	800	185.0	185.0	800	800	204.0	204.0	204.0	204.0	205.0	205.0	800	800
185.0	191.0	185.0	78.87	52.58	1057.8	1057.8	33.96	691.4	691.4	691.4	33.96	691.4	186.1	186.1	810	810	186.1	186.1	810	810	205.0	205.0	205.0	205.0	206.1	206.1	810	810
186.0	192.0	186.0	79.63	53.08	1065.2	1065.2	34.36	699.1	699.1	699.1	34.36	699.1	187.2	187.2	820	820	187.2	187.2	820	820	206.0	206.0	206.0	206.0	207.2	207.2	820	820
187.0	193.0	187.0	80.40	53.60	1072.8	1072.8	34.74	707.0	707.0	707.0	34.74	707.0	188.3	188.3	830	830	188.3	188.3	830	830	207.0	207.0	207.0	207.0	208.3	208.3	830	830
188.0	194.0	188.0	81.18	54.12	1101.3	1101.3	35.14	714.9	714.9	714.9	35.14	714.9	189.3	189.3	840	840	189.3	189.3	840	840	208.0	208.0	208.0	208.0	209.3	209.3	840	840
189.0	195.0	189.0	81.96	54.65	1112.0	1112.0	35.53	723.0	723.0	723.0	35.53	723.0	190.4	190.4	850	850	190.4	190.4	850	850	209.0	209.0	209.0	209.0	210.4	210.4	850	850
190.0	196.0	190.0	82.76	55.19	1123.0	1123.0	35.94	731.2	731.2	731.2	35.94	731.2	191.4	191.4	860	860	191.4	191.4	860	860	210.0	210.0	210.0	210.0	211.4	211.4	860	860
191.0	197.0	191.0	83.60	55.73	1134.1	1134.1	36.35	739.6	739.6	739.6	36.35	739.6	192.4	192.4	870	870	192.4	192.4	870	870	211.0	211.0	211.0	211.0	212.4	212.4	870	870
192.0	198.0	192.0	84.43	56.28	1145.3	1145.3	36.76	748.0	748.0	748.0	36.76	748.0	193.4	193.4	880	880	193.4	193.4	880	880	212.0	212.0	212.0	212.0	213.4	213.4	880	880
193.0	199.0	193.0	85.27	56.85	1156.7	1156.7	37.18	756.6	756.6	756.6	37.18	756.6	194.4	194.4	890	890	194.4	194.4	890	890	213.0	213.0	213.0	213.0	214.4	214.4	890	890
194.0	200.0	194.0	86.13	57.42	1168.3	1168.3	37.61	765.3	765.3	765.3	37.61	765.3	195.3	195.3	900	900	195.3	195.3	900	900	214.0	214.0	214.0	214.0	215.3	215.3	900	900
195.0	201.0	195.0	86.99	58.00	1180.1	1180.1	38.04	774.1	774.1	774.1	38.04	774.1	196.3	196.3	910	910	196.3	196.3	910	910	215.0	215.0	215.0	215.0	216.3	216.3	910	910
196.0	202.0	196.0	87.87	58.56	1192.0	1192.0	38.48	783.0	783.0	783.0	38.48	783.0	197.2	197.2	920	920	197.2	197.2	920	920	216.0	216.0	216.0	216.0	217.2	217.2	920	920
197.0	203.0	197.0	88.76	59.18	1204.1	1204.1	38.93	792.1	792.1	792.1	38.93	792.1	198.1	198.1	930	930	198.1	198.1	930	930	217.0	217.0	217.0	217.0	218.1	218.1	930	930
198.0	204.0	198.0	89.67	59.78	1216.4	1216.4	39.38	801.3	801.3	801.3	39.38	801.3	199.0	199.0	940	940	199.0	199.0	940	940	218.0	218.0	218.0	218.0	219.0	219.0	940	940
199.0	205.0	199.0	90.59	60.30	1228.9	1228.9	39.84	810.7	810.7	810.7	39.84	810.7	200.0	200.0	950	950	200.0	200.0	950	950	219.0	219.0	219.0	219.0	220.8	220.8	950	950
200.0	206.0	200.0	91.52	61.01	1241.5	1241.5	40.31	820.1	820.1	820.1	40.31	820.1	201.0	201.0	960	960	201.0	201.0	960	960	220.0	220.0	220.0	220.0	221.7	221.7	960	960
201.0	207.0	201.0	92.47	61.64	1254.3	1254.3	40.78	829.8	829.8	829.8	40.78	829.8	202.0	202.0	970	970	202.0	202.0	970	970	221.0	221.0	221.0	221.0	222.6	222.6	970	970
202.0	208.0	202.0	93.43	62.28	1267.4	1267.4	41.26	839.5	839.5	839.5	41.26	839.5	203.0	203.0	980	980	203.0	203.0	980	980	222.0	222.0	222.0	222.0	223.4	223.4	980	980
203.0	209.0	203.0	94.40	62.93	1280.6	1280.6	41.74	849.4	849.4	849.4	41.74	849.4	204.0	204.0	990	990	204.0	204.0	990	990	223.0	223.0	223.0	223.0	224.3	224.3	990	990
204.0	210.0	204.0	95.36	63.59	1294.0	1294.0	42.24	859.5	859.5	859.5	42.24	859.5	205.0	205.0	1000	1000	205.0	205.0	1000	1000	224.0	224.0	224.0	224.0	225.1	225.1	1000	1000
205.0	211.0	205.0	96.39	64.28	1307.6	1307.6	42.74	869.7	869.7	869.7	42.74	869.7	206.0	206.0	1010	1010	206.0	206.0	1010	1010	225.0	225.0	225.0	225.0	225.9	225.9	1010	1010
206.0	212.0	206.0	97.41	64.94	1321.3	1321.3	43.25	880.0	880.0	880.0	43.25	880.0	207.0	207.0	1020	1020	207.0	207.0	1020	1020	226.0	226.0	226.0	226.0	226.7	226.7	1020	1020
207.0	213.0	207.0	98.44	65.62	1335.3	1335.3	43.76	890.5	890.5	890.5	43.76	890.5	208.0	208.0	1030	1030	208.0	208.0	1030	1030	227.0	227.0	227.0	227.0	227.5	227.5	1030	1030
208.0	214.0	208.0	99.46	66.32	1349.5	1349.5	44.26	901.2	901.2	901.2	44.26	901.2	209.0	209.0	1040	1040	209.0	209.0	1040	1040	228.0	228.0	228.0	228.0	228.3	228.3	1040	1040
209.0	215.0	209.0	100.55	67.03	1363.9	1363.9	44.72	912.0	912.0	912.0	44.72	912.0	210.0	210.0	1050	1050	210.0	210.0	1050	1050	229.0	229.0	229.0	229.0	229.1	229.1	1050	1050
210.0	216.0	210.0	101.62	67.75	1378.6	1378.6	45.18	922.9	922.9	922.9	45.18	922.9	211.0	211.0	1060	1060	211.0	211.0	1060	1060	230.0	230.0	230.0	230.0	229.9	229.9	1060	1060
211.0	217.0	211.0	102.72	68.48	1393.4	1393.4	45.60	934.0	934.0	934.0	45.60	934.0	212.0	212.0	1070	1070	212.0	212.0	1070	1070	231.0	231.0	231.0	231.0	230.7	230.7	1070	1070
212.0	218.0	212.0	103.83	69.22	1408.4	1408.4	46.00	945.3	945.3	945.3	46.00	945.3	213.0	213.0	1080	1080	213.0	213.0	1080	1080	232.0	232.0	232.0	232.0	231.4	231.4	1080	1080
213.0	219.0	213.0	104.95	70.00			46.40	956.8	956.8	956.8	46.40	956.8	214.0	214.0	1090	1090	214.0	214.0	1090	1090	233.0	233.0	233.0	233.0	232.2	232.2	1090	1090
214.0	220.0	214.0	106.09	70.80			46.82	968.4	968.4	968.4	46.82	968.4	215.0	215.0	1100	1100	215.0	215.0	1100	1100	234.0	234.0	234.0	234.0	232.9	232.9	1100	1100
215.0	221.0	215.0	107.25	71.63			47.25	980.2	980.2	980.2	47.25	980.2	216.0	216.0	1110	1110	216.0	216.0	1110	1110	235.0	235.0	235.0	235.0	233.7	233.7	1110	1110
216.0	222.0	216.0	108.43	72.48			47.68	992.1	992.1	992.1	47.68	992.1	217.0	217.0	1120	1120	217.0	217.0	1120	1120	236.0	236.0	236.0	236.0	234.4	234.4	1120	1120
217.0	223.0	217.0	109.62	73.33			48.10	1004.3	1004.3	1004.3	48.10	1004.3	218.0	218.0	1130	1130	218.0	218.0	1130	1130	237.0	237.0	237.0	237.0	235.1	235.1	1130	1130
218.0	224.0	218.0	110.83	74.18			48.52	1016.6	1016.6	1016.6	48.52	1016.6	219.0	219.0	1140	1140	219.0	219.0	1140	1140	238.0	238.0	238.0					

Table 3: RBS Pressure-Temperature Curve Calculation Results for 12 EFPP

Inputs: Lending Estimate Components = Vessel Head SP4764 (Lot 8342, Taisidem)

EFPP = 12.8 inches
 Minimum Vessel Wall Thickness = 8.41 inches
 Maximum Vessel Inside Radius = 118.2 inches
 RT_{min} = 72.3 °F
 Temperature Instrument Error = 0.8 °F
 Pressure Instrument Error = 0.8 psi
 Code Hydro Test Pressure = 1663.6 psi
 Hydro Test Temperature = 78 °F
 Fluid to 1413 Temp Adj = 8.00 °F
 Thermal Stress Intensity Factor K_t = 10.000

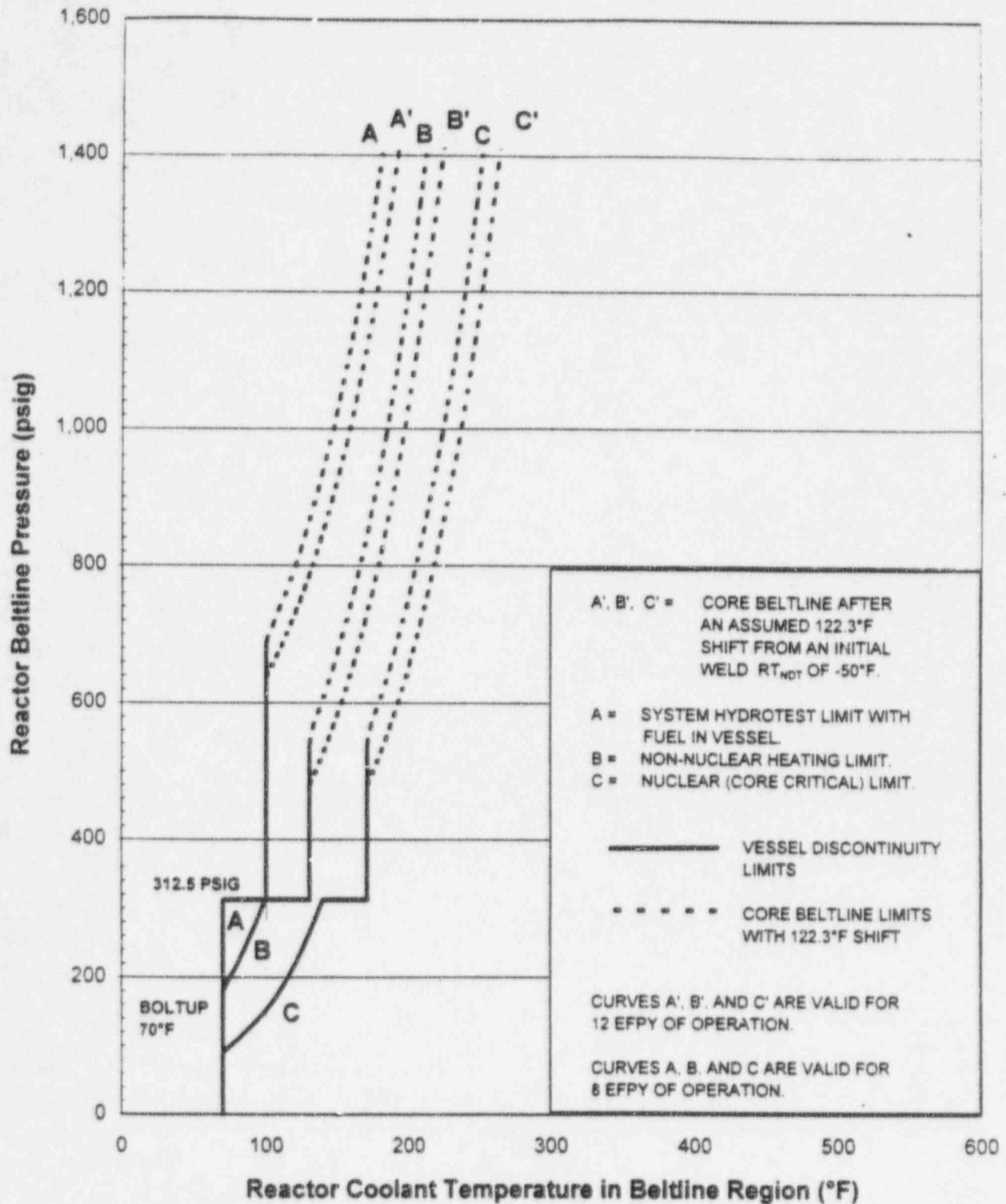
(assumed value to match GE P-T Curve A results)
 (assumed value to match GE P-T curve results used for Curves B and C only)

Calculation Results: Membrane Correction Factor M_m = 2.413

Prepared by: AD 10/14/96
 Checked by: HA 10/15/96
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Reaction Control Temperature T _{ref}	CURVE A CALCULATIONS				CURVE B CALCULATIONS				CURVE C CALCULATIONS			
	Adjusted Temperature at 1413 °F	Adjusted Temperature for P-T Curve °F	Adjusted Pressure for P-T Curve [psig]	K _t [psi-inch] [psi-inch]	Calculated Pressure P [psig]	Adjusted Pressure for P-T Curve [psig]	Tech. Spec. Curve A Temperature °F	SEFPY Tech. Spec. Curve A Pressure [psig]	Calculated Pressure P [psig]	Adjusted Pressure for P-T Curve [psig]	Tech. Spec. Curve B Temperature °F	SEFPY Tech. Spec. Curve B Pressure [psig]
205.0	211.0	205.0	118.81	54.45	1107.6	1107.6	166.1	1210	1107.6	1107.6	200.0	1210
206.0	212.0	206.0	121.17	55.13	1121.7	1121.7	168.9	1220	1121.7	1121.7	200.6	1220
207.0	213.0	207.0	123.54	55.82	1135.8	1135.8	167.7	1230	1135.8	1135.8	201.3	1230
208.0	214.0	208.0	125.94	56.52	1150.0	1150.0	166.5	1240	1150.0	1150.0	201.8	1240
209.0	215.0	209.0	128.36	57.23	1164.4	1164.4	169.3	1250	1164.4	1164.4	202.8	1250
210.0	216.0	210.0	130.80	57.95	1179.1	1179.1	170.0	1260	1179.1	1179.1	203.2	1260
211.0	217.0	211.0	133.26	58.68	1194.0	1194.0	170.8	1270	1194.0	1194.0	203.9	1270
212.0	218.0	212.0	135.75	59.42	1209.0	1209.0	171.6	1280	1209.0	1209.0	204.5	1280
213.0	219.0	213.0	138.25	60.17	1224.3	1224.3	172.3	1290	1224.3	1224.3	205.1	1290
214.0	220.0	214.0	140.77	60.93	1239.9	1239.9	173.1	1300	1239.9	1239.9	205.7	1300
215.0	221.0	215.0	143.32	61.71	1255.6	1255.6	173.8	1310	1255.6	1255.6	206.3	1310
216.0	222.0	216.0	145.89	62.49	1271.6	1271.6	174.5	1320	1271.6	1271.6	207.0	1320
217.0	223.0	217.0	148.48	63.28	1287.8	1287.8	175.3	1330	1287.8	1287.8	207.6	1330
218.0	224.0	218.0	151.09	64.10	1304.3	1304.3	176.0	1340	1304.3	1304.3	208.2	1340
219.0	225.0	219.0	153.75	64.92	1320.9	1320.9	176.7	1350	1320.9	1320.9	208.7	1350
220.0	226.0	220.0	156.41	65.75	1337.9	1337.9	177.4	1360	1337.9	1337.9	209.3	1360
221.0	227.0	221.0	159.10	66.58	1355.1	1355.1	178.1	1370	1355.1	1355.1	209.9	1370
222.0	228.0	222.0	161.81	67.45	1372.5	1372.5	178.8	1380	1372.5	1372.5	210.5	1380
223.0	229.0	223.0	164.55	68.32	1390.2	1390.2	179.4	1390	1390.2	1390.2	211.1	1390
224.0	230.0	224.0	167.31	69.20	1408.1	1408.1	180.1	1400	1408.1	1408.1	211.6	1400
225.0	231.0	225.0	170.09									
226.0	232.0	226.0	172.92									
227.0	233.0	227.0	175.76									
228.0	234.0	228.0	178.63									
229.0	235.0	229.0	181.53									
230.0	236.0	230.0	184.45									
231.0	237.0	231.0	187.40									
232.0	238.0	232.0	190.40									
233.0	239.0	233.0	193.43									
234.0	240.0	234.0	196.43									
235.0	241.0	235.0	199.50									
236.0	242.0	236.0	202.60									
237.0	243.0	237.0	205.73									
238.0	244.0	238.0	208.89									
239.0	245.0	239.0	212.09									

Figure 2: RBS P-T Curves for 12 EFYPY



6.0 SUMMARY AND CONCLUSIONS


The analysis documented in this calculation develops RT_{NDT} estimates and P-T curves for the RBS reactor pressure vessel. EXCEL spreadsheets were developed for each of these items.

Table 1 provides the results of the RT_{NDT} estimations. Those results are identical to estimates previously developed in Appendix A of the Reference 3 report, thus confirming the past results and the spreadsheet used for the current analysis.

Table 2 and Figure 1 provide the results of the P-T curve spreadsheet developed for RBS. Comparison of the calculated results for 8 EFPY to those contained in the current Tech. Spec. P-T curves for 8 EFPY demonstrate the validity of the spreadsheet, as the two sets of results are seen to be identical.

Finally, Table 3 and Figure 2 provide the results of the P-T curve spreadsheet for 12 EFPY. The results are seen to be reasonable based on the "shift" in results from those at 8 EFPY. This, coupled with the results of the "benchmark" test case, conclude the Figure 2 P-T limits to be appropriate for RBS for 12 EFPY of operation.

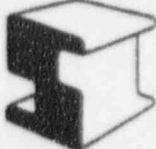
NOTE: *Although the spreadsheet tool for generating P-T curves has been validated, each future use of this spreadsheet should be validated on a case-by-case basis. All possible temperature limitation requirements were not placed into the spreadsheet for "automatic" implementation. For example, the minimum temperature described above for Curve C that requires the minimum Curve C temperature to be equal to the temperature of Curve A at 1,100 psig was not necessary for this analysis (i.e., Curve A @ 1,100 psig \approx 168°F whereas Curve A + 40°F at pressures just above 312.5 psig = 170°F = more limiting). At some point in the near future (i.e., beyond 12 EFPY), this requirement will be necessary (it was implemented in the 32 EFPY curves in Reference 3). Therefore, modifications of the spreadsheet to account for this and other requirements may have to be made as a part of future use of the spreadsheets. Therefore, each use of the spreadsheet should be "sanity checked" for reasonableness.*

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	Checked By:	HLD 10/15/96			
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7.0 REFERENCES

1. RBS Technical Specifications, Amendment No. 81, Figure 3.4.11-1, "Minimum Temperature Required vs. RCS Pressure." SI File No. RBS-03Q-202.
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. GE Report No. SASR 89-20, Revision 1, "Implementation of Regulatory Guide 1.99 Revision 2 for River Bend Station Unit 1." March 1990, SI File No. RBS-03Q-203.
4. Letter No. G-LD-2-085 from W. D. Arndt (GE) to Mr. J. C. Deddens (GSU), "Tabulated Values from 8 EFPY Curves River Bend Station," May 26, 1992. (EOI File #3221.110-000-004A), SI File No. RBS-03Q-201.
5. 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.
6. U. S. Code of Federal Regulations, Chapter 10, Part 50, Appendix G, "Fracture Toughness Requirements," 1-1-96 Edition.

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