APPENDIX "A"

TO RCS SYSTEM DESCRIPTION N3-68-4001

WATTS BAR UNIT 1

RCS PRESSURE AND TEMPERATURE LIMITS REPORT (PTLR)

REVISION 5

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RCS PRESSURE AND TEMPERATURE LIMITS REPORT FOR WATTS BAR UNIT 1

1.0 RCS Pressure and Temperature Limits Report (PTLR)

This PTLR for Watts Bar Unit 1 has been prepared in accordance with the requirements of Technical Specification 5.9.6. Revisions to the PTLR shall be provided to the NRC after issuance.

The Technical Specifications affected by this report are listed below:

LCO 3.4.3. RCS Pressure and Temperature (P/T) Limits
LCO 3.4.12 Cold Overpressure Mitigation System (COMS)

2.0 RCS Pressure and Temperature Limits

The limits for LCO 3.4.3 are presented in the subsection which follows. These limits have been developed (Ref. 1, 4) using the NRC-approved methodologies specified in Specification 5.9.6.

2.1 RCS Pressure and Temperature (P/T) Limits (LCO 3.4.3)

2.1.1 The RCS temperature rate-of-change limits are (Ref. 1):

a. A maximum heatup Rate 100 ^{o}F per hour.
b. A maximum cooldown Rate 100 ^{o}F per hour.
c. A maximum temperature change of 10 ^{o}F in any 1-hour period during inservice hydrostatic and leak testing operations above the heatup and cooldown limit curves.

2.1.2 The RCS P/T limits for heatup, cooldown, inservice hydrostatic and leak testing, and criticality are specified by Figures 2.1-1 and 2.1-2 (Ref. 1).

NOTE: The heat-up and cool-down curves are based on beltline conditions and do not compensate for pressure differences between the pressure transmitter and reactor midplane/beltline or for instrument inaccuracies. Refer to Table 2.1-3 for pressure differences (Ref. 2). Site Engineering Setpoint and Scaling documents SSD-1-P-68, -63, -64, -66, and -70 provide the adjusted curves for temperature and pressure limits which are compensated for pressure differential and instrument inaccuracy to be used for heatup and cooldown.

3.0 Cold Overpressure Mitigation System (LCO 3.4.12)

The lift setpoints for the pressurizer Power Operated Relief Valves (PORVs) are presented in the subsection which follows. These lift setpoints have been developed using the NRC-approved methodologies specified in Specification 5.9.6.

3.1 Pressurizer PORV Lift Setting Limits

The pressurizer PORV lift setpoints are depicted in Figures 3.1-1 through 3.1-4 and specified by Table 3.1-1 (Ref. 2). The limits for the COMS setpoints are contained in the 7 EFPY curves adjusted per ASME Code Case N-514 for Heatup (Figure 3.1-5 and Table 3.1-2) and Cooldown (Figure 3.1-6 and Table 3.1-3) (Ref. 1) which are based on beltline conditions and are not compensated for pressure differences between the pressure transmitter and the reactor midplane/beltline or for instrument inaccuracies. Refer to Table 2.1-3 for pressure differences (Ref. 2).

NOTE: These setpoints include allowance for pressure difference between the pressure transmitter and reactor midplane, and also includes 63 psig pressure channel uncertainty. Site Engineering Setpoint and Scaling documents for instrument loop numbers 1-T-68-1B and 1-T-68-43B contain the adjusted curves compensated for pressure differential and instrument inaccuracy which provides the PORV lift limits for the COMS.

4.0 Reactor Vessel Material Surveillance Program

The reactor vessel material irradiation surveillance specimens shall be removed and examined to determine changes in material properties. The removal schedule is provided in Table 4.0-1. The results of these examinations shall be used to update Figures 2.1-1, 2.1-2, and 3.1-1 through 3.1-4.

The pressure vessel steel surveillance program (Ref. 3) is in compliance with Appendix H to 10 CFR 50, entitled "Reactor Vessel Material Surveillance Program Requirements". The material test requirements and the acceptance standard utilize the reference nil-ductility temperature, RT_{NDT}, which is determined in accordance with ASTM E208. The empirical relationship between RT_{NDT} and the fracture toughness of the reactor vessel steel is developed in accordance with Appendix G, "Protection Against Non-Ductile Failure", to Section III of the ASME Boiler and Pressure Vessel Code. The surveillance capsule removal schedule meets the requirements of ASTM E185-82. The removal schedule is provided in Table 4.0-1.

5.0 Supplemental Data Tables

Table 5.1 contains a comparison of measured surveillance material 30 ft-lb transition temperature shifts and upper shelf energy decreases with Regulatory Guide 1.99, Revision 2, predictions. This table was intentionally left blank since no capsules were removed to date.

Table 5.2 shows calculations of the surveillance material chemistry factors using surveillance capsule data. This table was intentionally left blank since no capsules were removed to date.

Table 5.3 provides the required Watts Bar Unit 1 reactor vessel toughness data. The bolt-up temperature is also included in this table.

Table 5.4 provides a summary of the fluence values used in the generation of the heatup and cooldown limit curves.

Table 5.5 provides a summary of the adjusted reference temperature (ART) values of the Watts Bar Unit 1 reactor vessel beltline materials at the 1/4-T and 3/4-T locations for 7 EFPY.

Table 5.6 shows example calculations of the adjusted reference temperature (ART) values at 7 EFPY for the limiting Watts Bar Unit 1 reactor vessel material (Intermediate Shell Forging 05).

Table 5.7 provides a summary of the fluence values used in the Pressurized Thermal Shock (PTS) evaluation.

Table 5.8 provides RT_{PTS} values for Watts Bar Unit 1 for 32 EFPY.

Table 5.9 provides RT_{PTS} values for Watts Bar Unit 1 for 48 EFPY.

REFERENCES

1. WCAP-13829 Revision 1, "Heatup and Cooldown Limit Curves for Normal Operation for Watts Bar Unit 1", February 1995.

2. Westinghouse Letter to TVA, WAT-D-9448, "Revised COMS PORV Setpoints," August 27, 1993.

3. WCAP-9298, Revision 1, "Watts Bar Unit 1 Reactor Vessel Radiation Surveillance Program", April 1993.

4. Westinghouse Letter to TVA, WAT-D-9526, "COMS".

5. WCAP-14040, Revision 1, "Methodology Used To Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves", December 1994.

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

INITIAL RT_{NDT} 47 °F

LIMITING ART AT 7 EFPY: 1/4-T, 181.1 °F

3/4-T, 147.7 °F

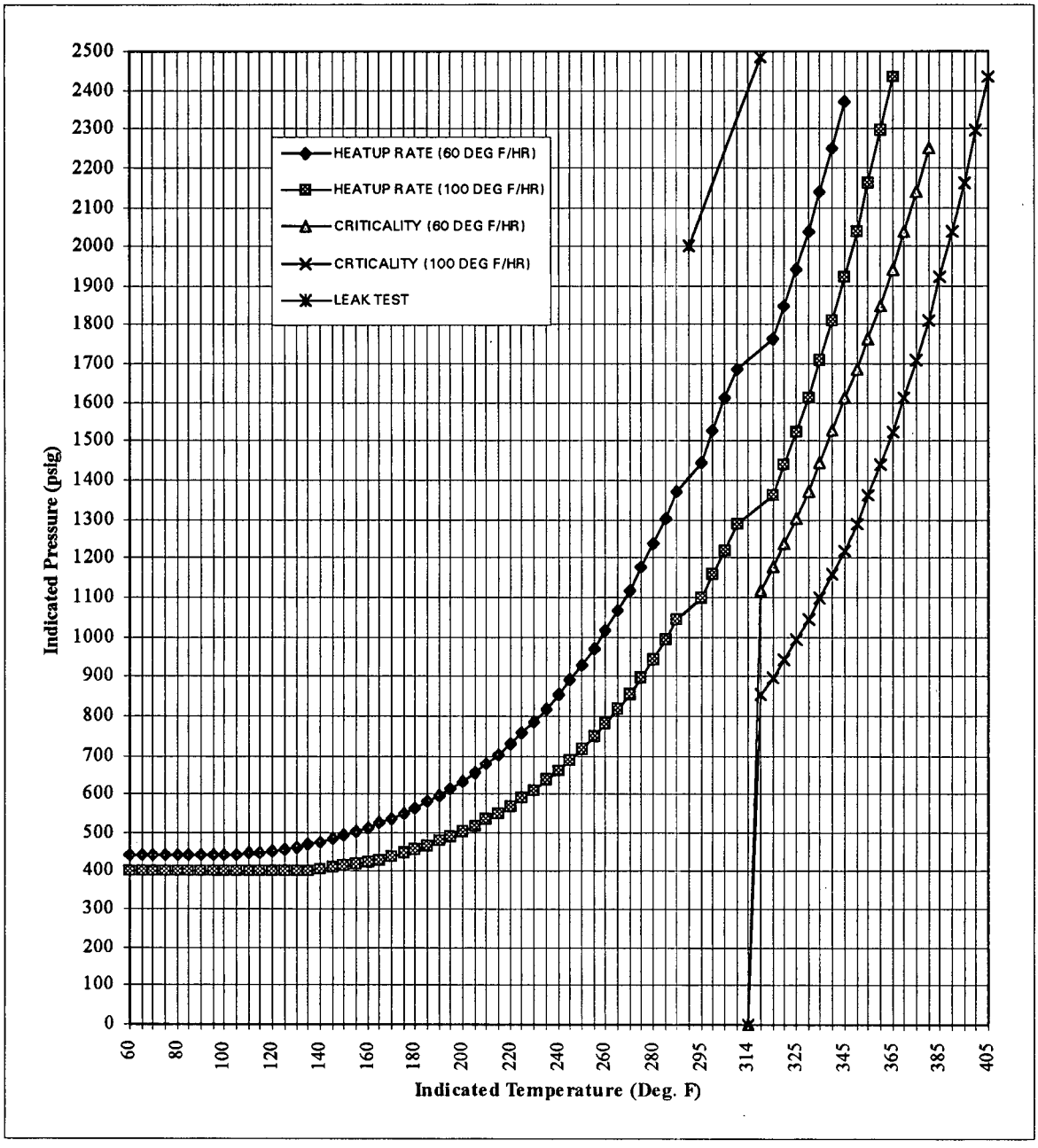

Figure 2.1-1

Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup rates of 60 and 100 °F/hr) Applicable for the First 7 EFPY (Without Margins for Instrumentation Errors)

(Plotted Data (Ref. 1) provided on Table 2.1-1)

Table 2.1-1
Watts Bar Unit 1 Heatup Limits
(Data points plotted in Figure 2.1-1)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
60	443.05	401.48			
65	443.05	401.48			
70	443.05	401.48			
75	443.05	401.48			
80	443.05	401.48			
85	443.05	401.48			
90	443.05	401.48			
95	443.05	401.48			
100	443.05	401.48			
105	444.11	401.48			
110	446.29	401.48			
115	449.34	401.48			
120	453.33	401.48			
125	458.10	401.48			
130	463.72	402.34			
135	470.07	404.05			
140	477.24	406.56			
145	485.17	409.93			
150	493.84	414.14			
155	503.41	419.16			
160	513.86	425.01			
165	525.20	431.68			
170	537.41	439.16			
175	550.72	447.59			
180	565.12	456.94			
185	580.63	467.24			
190	597.27	478.55			
195	615.30	490.90			

Table 2.1-1
Watts Bar Unit 1 Heatup Limits
(Data points plotted in Figure 2.1-1)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
200	634.60	504.29			
205	655.51	518.93			
210	678.00	534.82			
215	702.06	551.92			
220	727.92	570.53			
225	755.91	590.51			
230	785.79	612.21			
235	818.05	635.46			
240	852.61	660.68			
245	889.70	687.66			
250	929.52	716.88			
255	972.27	748.15			
260	1018.19	781.76			
265	1067.49	818.06			
270	1120.42	856.92			
275	1177.15	898.66			
280	1237.98	943.47			
285	1303.13	991.58			
290	1373.09	1043.20			
293			2000		
295	1447.99	1098.55			
300	1527.97	1157.76			
305	1612.31	1221.51			
310	1686.16	1289.68			
314			2485	0 to 1120.42	0 to 856.92
315	1765.15	1362.69		1177.15	898.66
320	1849.89	1440.81		1237.98	943.47

Table 2.1-1
Watts Bar Unit 1 Heatup Limits
(Data points plotted in Figure 2.1-1)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
325	1940.35	1524.60		1303.13	991.58
330	2037.07	1614.19		1373.09	1043.20
335	2140.54	1709.92		1447.99	1098.55
340	2250.90	1812.16		1527.97	1157.76
345	2368.62	1921.54		1612.31	1221.51
350		2038.25		1686.16	1289.68
355		2162.68		1765.15	1362.69
360		2295.42		1849.89	1440.81
365		2436.49		1940.35	1524.60
370				2037.07	1614.19
375				2140.54	1709.92
380				2250.90	1812.16
385				2368.62	1921.54
390					2038.25
395					2162.68
400					2295.42
405					2436.49

MATERIAL PROPERTY BASIS

LIMITING MATERIAL:	INTERMEDIATE SHELL FORGING 05
INITIAL RT_{NDT}	47 °F
LIMITING ART AT 7 EFPY:	1/4-T, 181.1 °F
	3/4-T, 147.7 °F

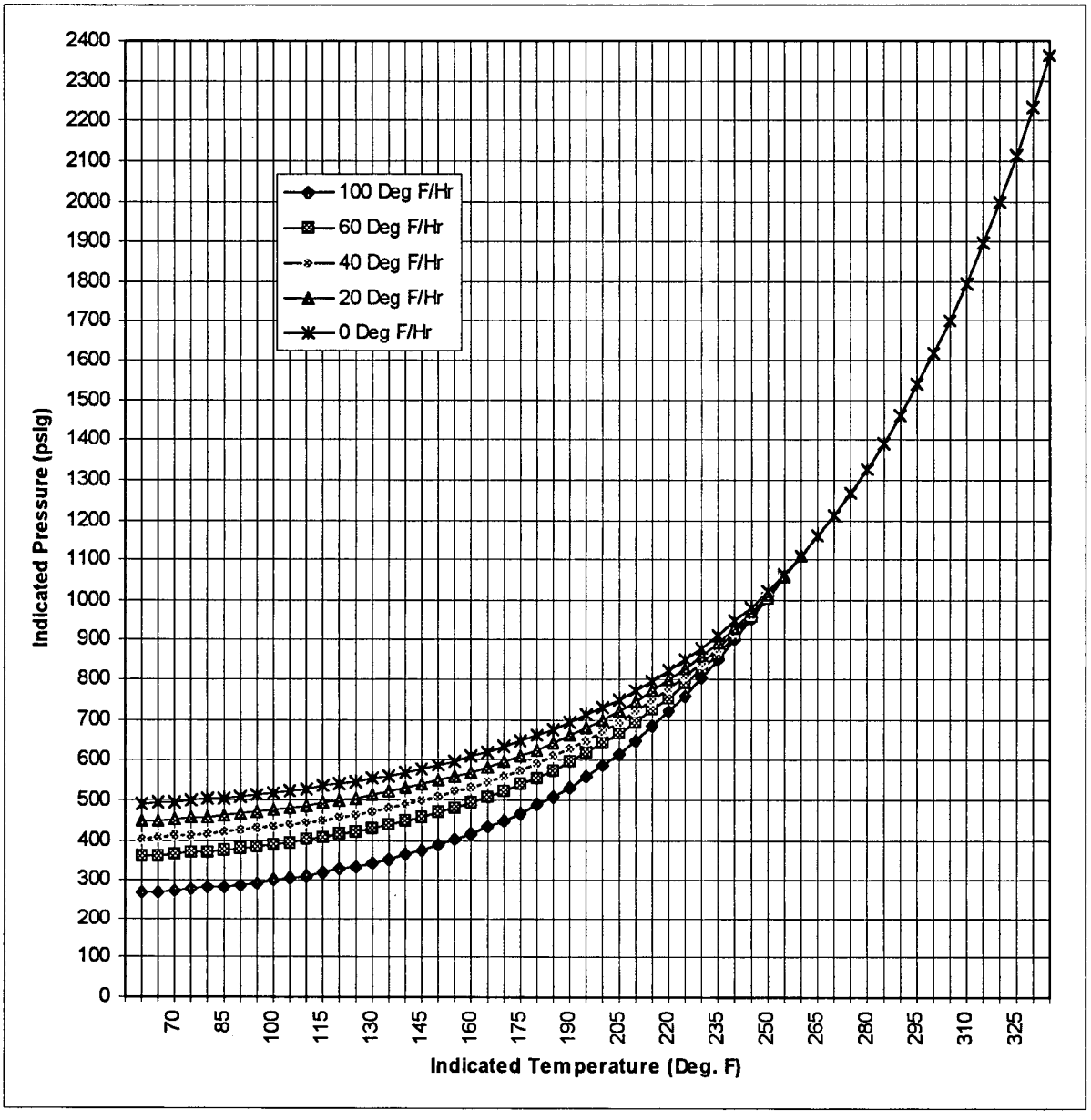

Figure 2.1-2

Watts Bar Unit 1 Reactor Coolant System Cooldown Limitations (Cooldown rates up to 100°F/hr) Applicable for the First 7 EFPY (Without Margins for Instrumentation Errors)

(Plotted Data (Ref. 1) provided on Table 2.1-2)

Table 2.1-2
Watts Bar Unit 1 Cooldown Limits
(Data plotted on Figure 2.1-2)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	100 °F/HR	60 °F/HR	40 °F/HR	20 °F/HR	0 °F/HR
60	266.59	359.39	404.02	447.48	490.13
65	269.45	362.11	406.70	450.24	492.77
70	272.56	365.11	409.67	453.18	495.72
75	276.04	368.41	412.91	456.38	498.88
80	279.82	371.97	416.40	459.81	502.28
85	283.98	375.89	420.21	463.54	505.94
90	288.53	380.12	424.32	467.55	509.87
95	293.54	384.74	428.79	471.89	514.09
100	298.99	389.73	433.61	476.55	518.64
105	304.97	395.18	438.77	481.60	523.52
110	311.45	401.06	444.40	487.03	528.77
115	318.55	407.40	450.52	492.81	534.42
120	326.20	414.30	457.10	499.12	540.39
125	334.59	421.80	464.24	505.93	546.91
130	343.66	429.89	471.92	513.26	553.93
135	353.56	438.60	480.25	521.17	561.47
140	364.21	448.06	489.20	529.67	569.58
145	375.84	458.32	498.80	538.75	578.31
150	388.41	469.38	509.23	548.62	587.56
155	402.06	481.35	520.50	559.26	597.63
160	416.74	494.17	532.63	570.71	608.47
165	432.73	508.12	545.63	582.92	620.12
170	449.91	523.16	559.73	596.19	632.50
175	468.61	539.30	574.96	610.49	645.97
180	488.79	556.81	591.21	625.85	660.44
185	510.54	575.72	608.89	642.29	675.98
190	534.09	595.96	627.89	660.09	692.57
195	559.46	617.94	648.27	679.12	710.56
200	586.80	641.47	670.32	699.74	729.70
205	616.49	667.02	693.97	721.92	750.49
210	648.35	694.35	719.52	745.65	772.78

Table 2.1-2
Watts Bar Unit 1 Cooldown Limits
(Data plotted on Figure 2.1-2)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	100 °F/HR	60 °F/HR	40 °F/HR	20 °F/HR	0 °F/HR
215	682.74	723.96	746.96	771.30	796.64
220	719.95	755.76	776.41	798.79	822.23
225	760.01	789.97	808.37	828.31	849.99
230	803.10	826.78	842.54	860.26	879.55
235	849.59	866.62	879.31	894.47	911.51
240	899.62	909.35	918.85	931.19	945.77
245	953.53	955.36	961.60	970.69	982.53
250	1011.36	1004.81	1007.39	1013.15	1022.00
255		1057.86	1056.69	1058.81	1064.40
260			1109.45	1107.90	1109.98
265					1158.95
270					1211.57
275					1268.05
280					1328.61
285					1393.44
290					1463.21
295					1537.95
300					1618.11
305					1703.92
310					1795.88
315					1894.39
320					1999.72
325					2112.46
330					2232.88
335					2361.41

Table 2.1-3

Pressure Differentials

Number of Pumps	Delta P (psi)
0	5.2
1	31.0
2	38.0
3	52.0
4	74.0

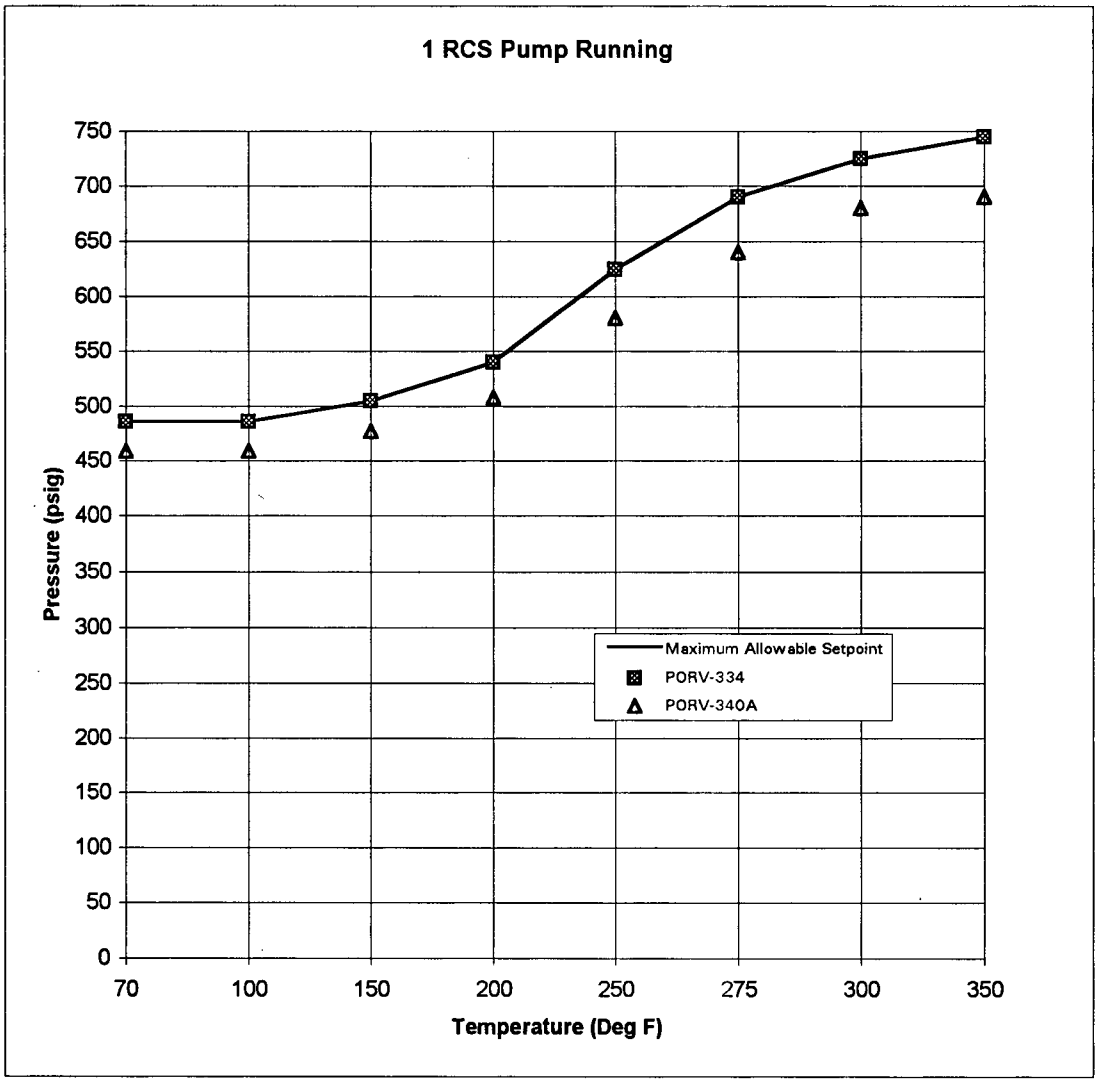

Figure 3.1-1

PORV Setpoint vs RCS Temperature
(Plotted data (Ref. 3) provided on Table 3.1-1)

NOTE: Westinghouse PORV Numbers 456 and 455A
Correspond to TVA PORV Numbers 334 and 340A

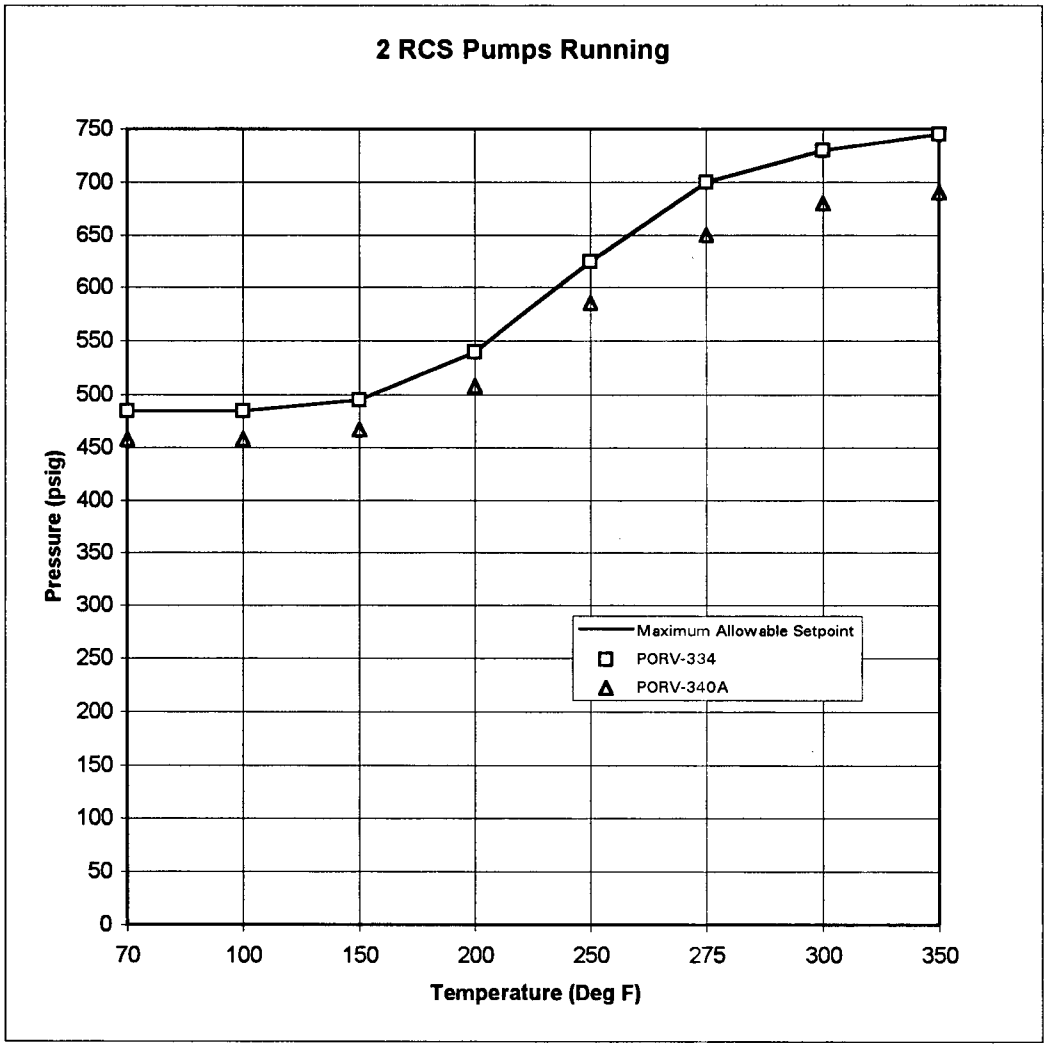

Figure 3.1-2

PORV Setpoint vs RCS Temperature
(Plotted data (Ref. 3) provided on Table 3.1-1)

NOTE: Westinghouse PORV Numbers 456 and 455A
Correspond to TVA PORV Numbers 334 and 340A

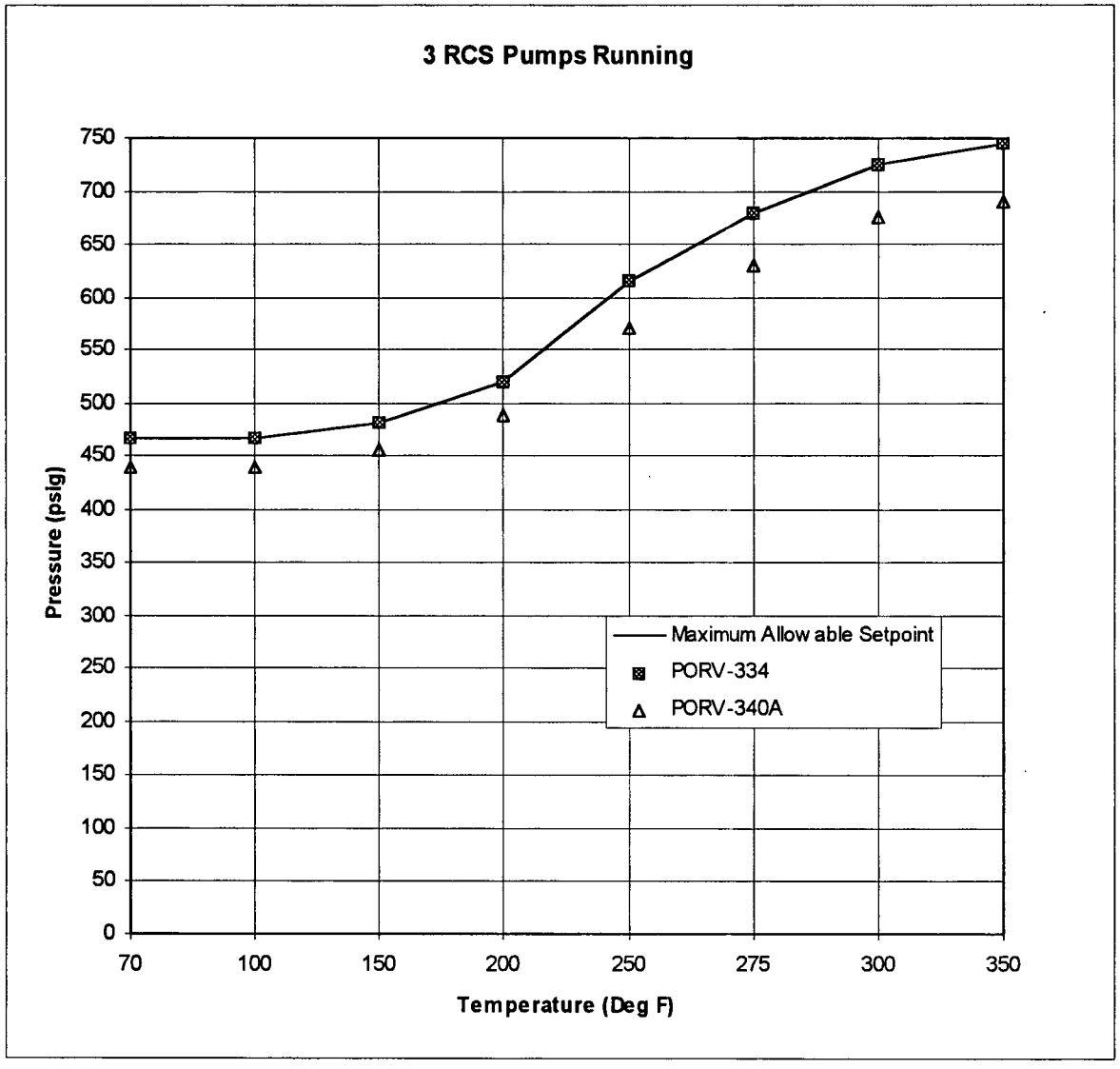

Figure 3.1-3

PORV Setpoint vs RCS Temperature
(Plotted data (Ref. 3) provided on Table 3.1-1)

NOTE: Westinghouse PORV Numbers 456 and 455A
Correspond to TVA PORV Numbers 334 and 340A

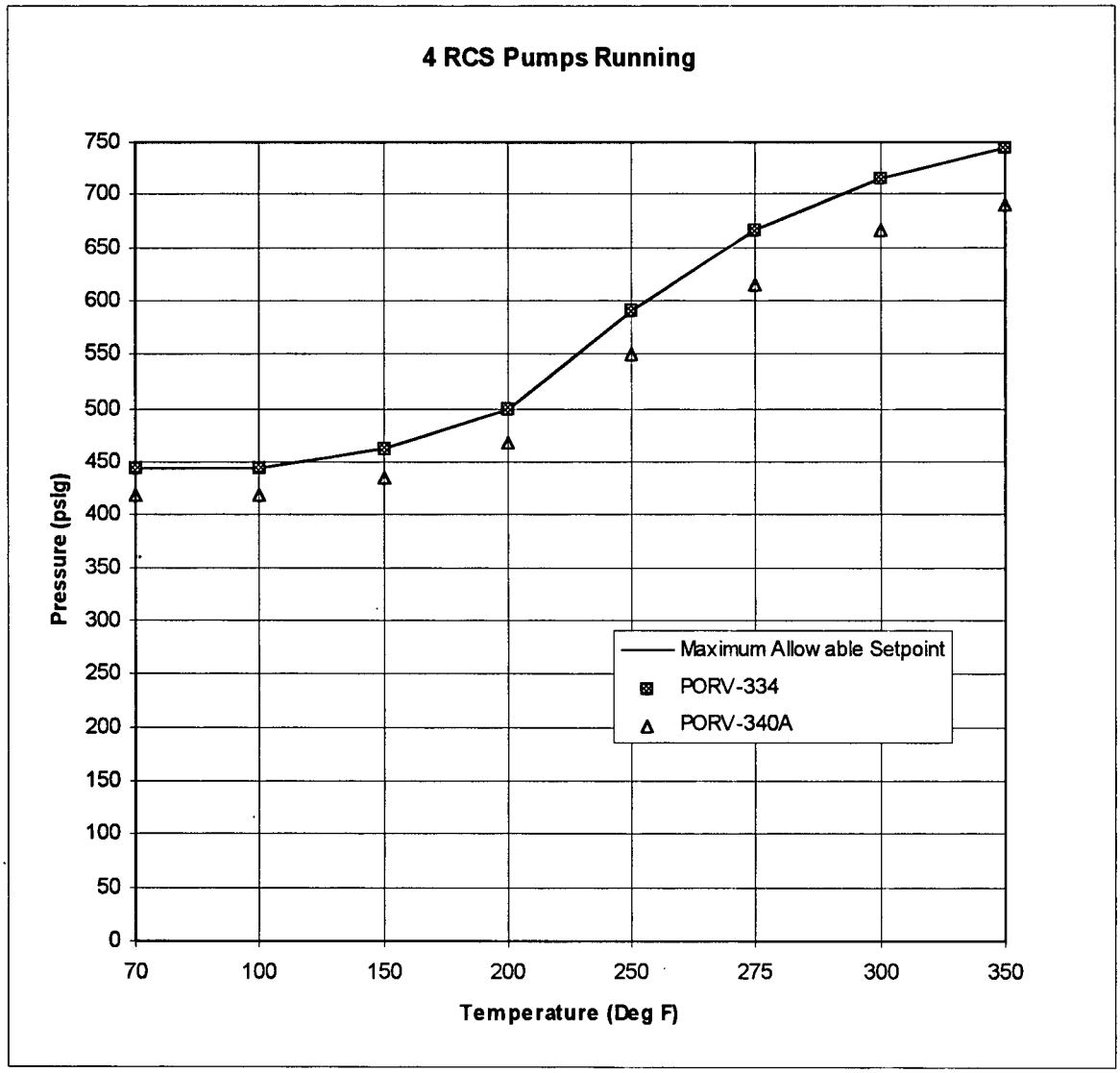

Figure 3.1-4

PORV Setpoint vs RCS Temperature
(Plotted data (Ref. 3) provided on Table 3.1-1)

NOTE: Westinghouse PORV Numbers 456 and 455A
Correspond to TVA PORV Numbers 334 and 340A

Table 3.1-1
Watts Bar Unit 1 PORV Setpoints vs Temperature
(Data (Ref. 3) plotted on Figures 3.1-1 through 3.1-4)

TEMP (F)	SETPOINTS (PSIG)							
	1 RCS PUMP OPERATING		2 RCS PUMPS OPERATING		3 RCS PUMPS OPERATING		4 RCS PUMPS OPERATING	
	PORV-334	PORV-340A	PORV-334	PORV-340A	PORV-334	PORV-340A	PORV-334	PORV-340A
70	486	459	485	458*	467	440*	445*	418*
100	486	459	485	458*	467	440*	445*	418*
150	505	477	495	467	482	455*	462	435*
200	540	508	540	508	520	488	500	468
250	625	580	625	585	615	570	590	550
275	690	640	700	650	680	630	665	615
300	730	680	730	680	725	675	715	665
350	745	690	745	690	745	690	745	690
450	2350	2350	2350	2350	2350	2350	2350	2350

- Setpoint violates pump seal limit. The pump seal limit includes a 63 psig adjustment for pressure channel uncertainty.

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

INITIAL RT_{NDT} 47 °F

LIMITING ART AT 7 EFPY: 1/4-T, 181.1 °F

3/4-T, 147.7 °F

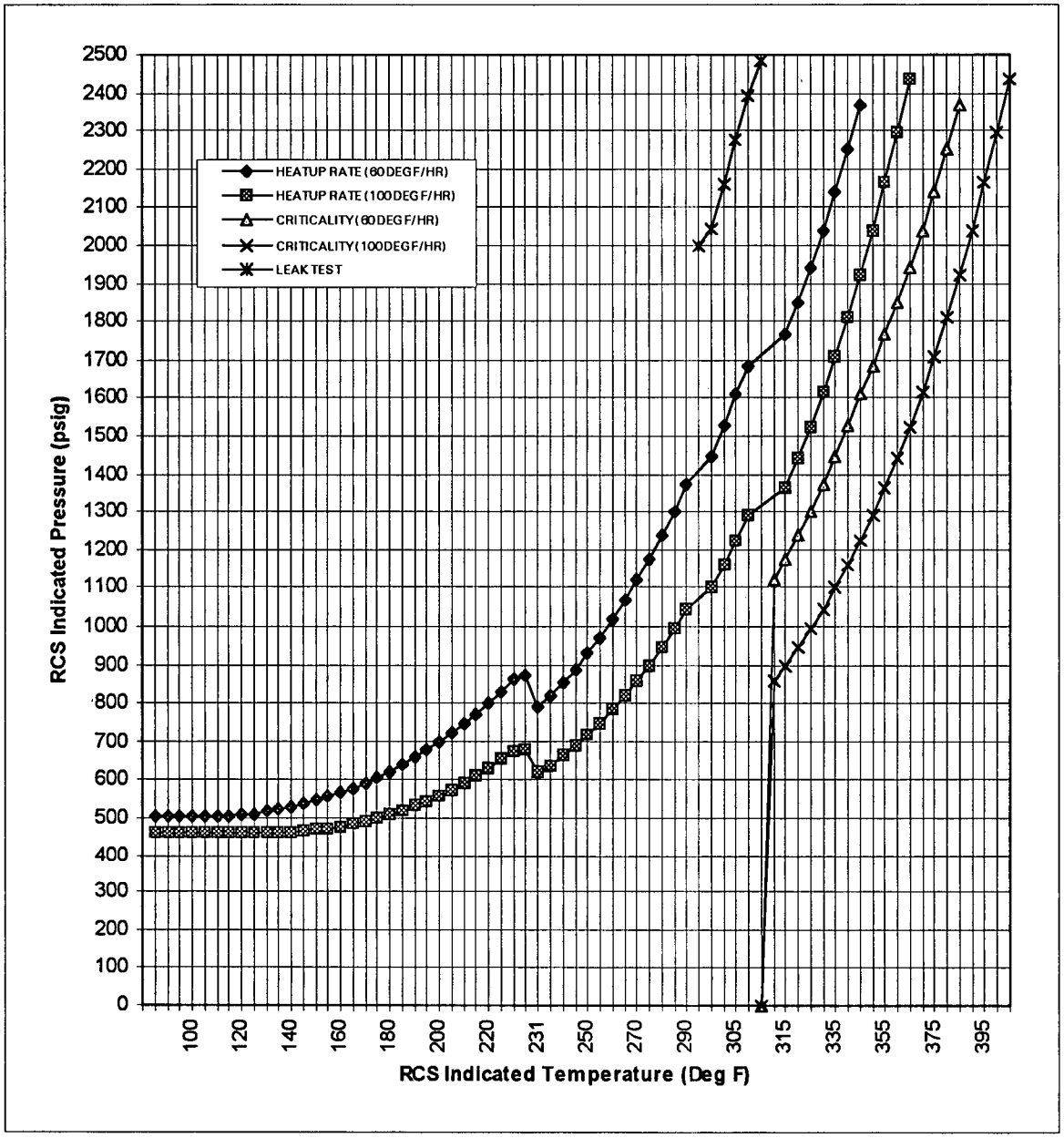

Figure 3.1-5

Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup rates of 60 and 100°F/hr) Applicable for the First 7 EFPY (Without Margins for Instrumentation Errors) Including 10% Relaxation in Pressure for Temperature < 231°F per ASME Code Case N-514

(Plotted Data (Ref. 1) provided on Table 3.1-2)

Table 3.1-2
Watts Bar Unit 1 Heatup Limits
(Data (Ref. 1) plotted on Figure 3.1-5)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
85	506	462			
90	506	462			
95	506	462			
100	506	462			
105	506	462			
110	506	462			
115	506	462			
120	509	462			
125	512	462			
130	517	462			
135	523	462			
140	530	463			
145	538	465			
150	547	469			
155	557	473			
160	568	478			
165	580	484			
170	593	492			
175	607	500			
180	623	510			
185	640	521			
190	658	532			
195	678	545			
200	699	560			
205	722	575			

Table 3.1-2
Watts Bar Unit 1 Heatup Limits
(Data (Ref. 1) plotted on Figure 3.1-5)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
210	746	592			
215	773	611			
220	801	631			
225	832	653			
230	865	676			
231	872	682			
231	792	620			
235	818	638			
240	853	663			
245	890	690			
250	930	719			
255	972	750			
260	1018	784			
265	1068	820			
270	1121	858			
275	1177	900			
280	1238	945			
285	1303	993			
290	1373	1044			
293			2000		
295	1448	1100	2046		
300	1528	1159	2162		
305	1612	1223	2277		
310	1686	1291	2393		
314			2485	0.0 to 1121	0.0 to 858

Table 3.1-2
Watts Bar Unit 1 Heatup Limits
(Data (Ref. 1) plotted on Figure 3.1-5)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	HEATUP RATE (60 °F/HR)	HEATUP RATE (100 °F/HR)	LEAK TEST LIMITS	CRITICALITY LIMITS (60 °F/HR)	CRITICALITY LIMITS (100 °F/HR)
315	1765	1364		1177	900
320	1850	1442		1238	945
325	1940	1525		1303	993
330	2037	1615		1373	1044
335	2141	1711		1448	1100
340	2251	1813		1528	1159
345	2369	1922		1612	1223
350		2039		1686	1291
355		2163		1765	1364
360		2296		1850	1442
365		2437		1940	1525
370				2037	1615
375				2141	1711
380				2251	1813
385				2369	1922
390					2039
395					2163
400					2296
405					2437

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

INITIAL RT_{NDT} 47 °F

LIMITING ART AT 7 EFPY: 1/4-T, 181.1 °F

3/4-T, 147.7 °F

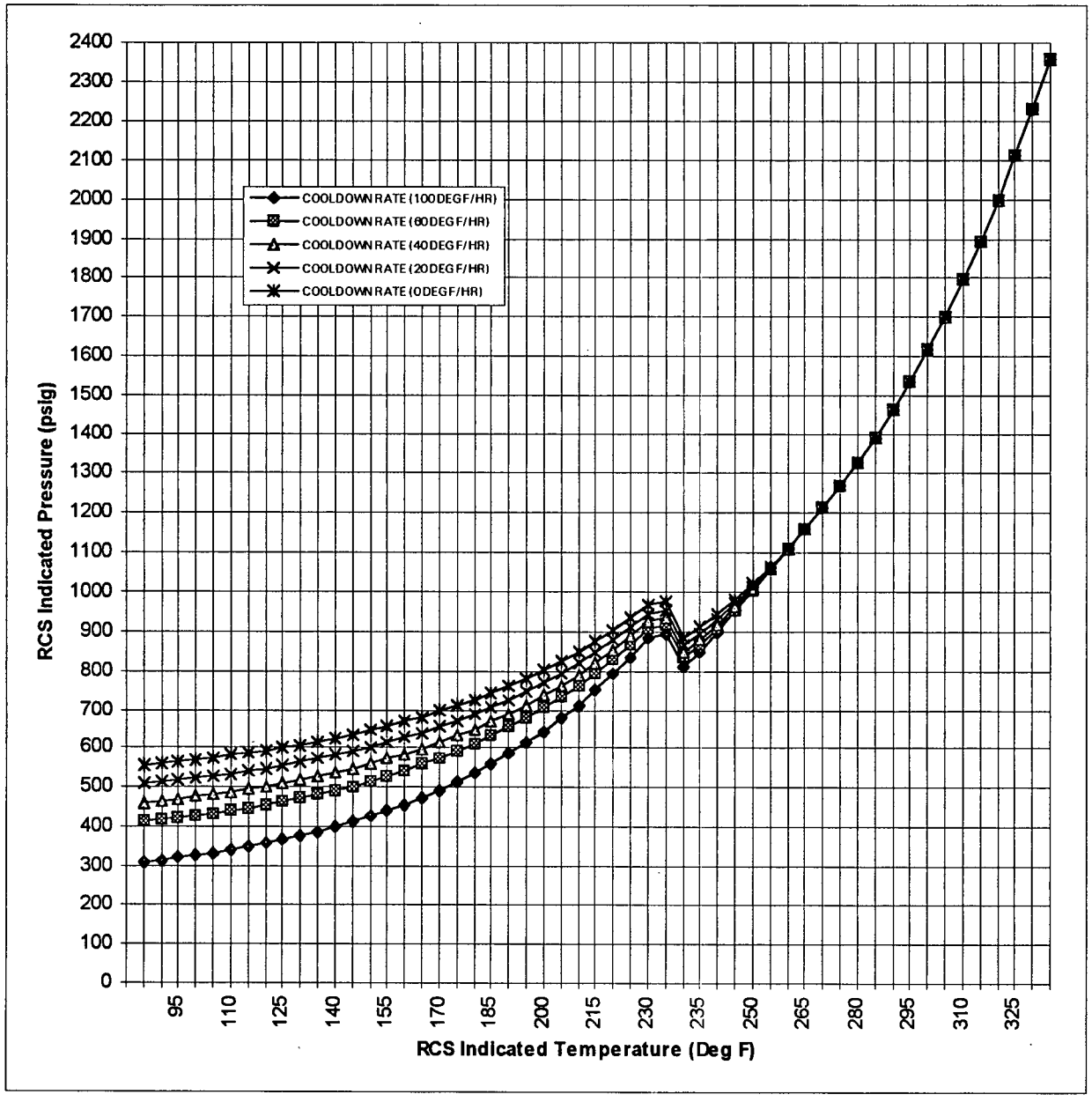

Figure 3.1-6

Watts Bar Unit 1 Reactor Coolant System Cooldown Limitations (Cooldown rates up to 100°F/hr) Applicable for the First 7 EFPY (Without Margins for Instrumentation Errors) Including 10% Relaxation in Pressure for Temperatures < 231°F per ASME Code Case N-514

(Plotted Data (Ref. 1) provided on Table 3.1-3)

Table 3.1-3
Watts Bar Unit 1 Cooldown Limits
(Data (Ref. 1) plotted on Fig 3.1-6)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	100 °F/HR	60 °F/HR	40 °F/HR	20 °F/HR	0 °F/HR
85	312	413	462	510	557
90	317	418	467	514	561
95	323	423	472	519	566
100	329	429	477	524	570
105	335	435	483	530	576
110	343	441	489	536	582
115	350	448	496	542	588
120	359	456	503	549	594
125	368	464	511	557	602
130	378	473	519	565	609
135	389	482	528	573	618
140	401	493	538	583	627
145	413	504	549	593	636
150	427	516	560	603	646
155	442	529	573	615	657
160	458	544	586	628	669
165	476	559	600	641	682
170	495	575	616	656	696
175	515	593	632	672	711
180	538	612	650	688	726
185	562	633	670	707	744
190	588	656	691	726	762
195	615	680	713	747	782
200	645	706	737	770	803
205	678	734	763	794	826
210	713	764	791	820	850
215	751	796	822	848	876
220	792	831	854	879	904
225	836	869	889	911	935

Table 3.1-3
Watts Bar Unit 1 Cooldown Limits
(Data (Ref. 1) plotted on Fig 3.1-6)

RCS TEMPERATURE (°F)	INDICATED PRESSURE (PSIG)				
	100 °F/HR	60 °F/HR	40 °F/HR	20 °F/HR	0 °F/HR
230	883	909	927	946	968
231	894	918	935	954	975
231	812	835	850	867	886
235	850	867	879	894	912
240	900	909	919	931	946
245	954	955	962	971	983
250	1011	1005	1007	1013	1022
255	1064	1058	1057	1059	1064
260	1110	1110	1109	1108	1110
265	1159	1159	1159	1159	1159
270	1212	1212	1212	1212	1212
275	1268	1268	1268	1268	1268
280	1329	1329	1329	1329	1329
285	1393	1393	1393	1393	1393
290	1463	1463	1463	1463	1463
295	1538	1538	1538	1538	1538
300	1618	1618	1618	1618	1618
305	1704	1704	1704	1704	1704
310	1796	1796	1796	1796	1796
315	1894	1894	1894	1894	1894
320	2000	2000	2000	2000	2000
325	2112	2112	2112	2112	2112
330	2233	2233	2233	2233	2233
335	2361	2361	2361	2361	2361

Table 4.0-1
Surveillance Capsule Removal Schedule

Capsule	Vessel Location (deg.)	Capsule Lead Factor	Removal Time (a)(b)(d)	Estimated Capsule Fluence (n/cm^2) (c)
U	56.0	3.6	1st Refueling Outage	3.60×10^{18}
W	124.0	3.6	5.4	1.90×10^{19}
X	236.0	3.6	8.9	3.19×10^{19}
Z	304.0	3.6	17.8	6.38×10^{19}
V	58.5	3.6	Stand-By	----
Y	238.5	3.6	Stand-By	----

(a) Effective Full Power Years (EFPY) from plant startup.

(b) Removal times are based on not-to-exceed criteria of E185-82, Section 7.6.2. Capsules should be removed on the last cycle prior to reaching the indicated time.

(c) Based on design basis fluence of 3.18×10^{19} n/cm^2 ($E > 1.0$ MeV).

(d) Withdraw two capsules before the vessel exceeds 5.4 EFPY. The results of the capsule analysis will be reviewed and should an amended removal schedule be required, two standby capsules are available for additional monitoring.[1] If the results of capsule testing predict an end of life use of < 50 ft-lb, TVA will perform the necessary analysis required by Appendix G, IV.A.1 to ensure adequate safety margins.[2]

TABLE 5.1

Comparison of the Watts Bar Unit 1 Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decrease with Regulatory Guide 1.99, Revision 2, Predictions

Material	Capsule	Fluence ($\times 10^{19}$ n/cm^2, E > 1.0 MeV)	30 ft-lb Transition Temperature Shift		Upper Shelf Energy Decrease	
			Predicted[a] (°F)	Measured (°F)	Predicted[a] (%)	Measured (%)
Intermediate Shell Forging 05 (tangential)						
Intermediate Shell Forging 05 (axial)						
Weld Metal						
HAZ Metal						

(a) Based on Regulatory Guide 1.99, Revision 2, methodology using average weight percent values of Cu an Ni.

NOTE: No capsules have been removed from the Watts Bar Unit 1 reactor vessel at this time.

TABLE 5.2						
Watts Bar Unit 1 Calculation of Chemistry Factors Using Surveillance Capsule Data						
Material	Capsule	Fluence (n/cm^2, E > 1.0 MeV)	FF	ΔRT_{NDT} (°F)	FF*ΔRT_{NDT} (°F)	FF^2
Intermediate Shell Forging 05 (Tangential)						
Intermediate Shell Forging 05 (Axial)						
	Sum:					
	Chemistry Factor =					
Weld Metal						
	Sum:					
	Chemistry Factor =					

NOTE: No capsules have been removed from the Watts Bar Unit 1 reactor vessel at this time.

TABLE 5.3			
Watts Bar Unit 1 Reactor Vessel Toughness Table (Unirradiated)			
Material Description	Cu (%)(a)	Ni (%)(a)	Initial RT_{NDT} (°F) (b)
Closure Head Flange	0.13	0.75	-42
Vessel Flange	--	0.92	-40 (c)
Intermediate Shell Forging 05	0.17	0.80	47
Lower Shell Forging 04	0.08	0.83	5
Circumferential Weld	0.05	0.70	-43

NOTES:

a) Average values of copper and nickel weight percent.

b) Initial RT_{NDT} values are measured values.

c) Used in the consideration of flange requirements for heatup/cooldown curves. Per methodology given in WCAP-14040, the minimum boltup temperature is 60 F.

TABLE 5.4					
Watts Bar Unit 1 Reactor Vessel Surface Fluence Values at 7 EFPY (n/cm^2, E > 1.0 MeV)					
Azimuthal	0°	15°	25°	35°	45°
Surface	4.13×10^{18}	6.15×10^{18}	6.96×10^{18}	5.67×10^{18}	6.50×10^{18}

TABLE 5.5		
Summary of ARTs for the Watts Bar Unit 1 Reactor Vessel Beltline Materials at the 1/4-T and 3/4-T Locations for 7 EFPY		
Component	7 EFPY (a)	
	1/4-T (°F)	3/4-T (°F)
Intermediate Shell Forging 05	181.11 (b)	147.70 (b)
Lower Shell Forging 04	77.68	56.54
Circumferential Weld	60.14	25.72

NOTES:
(a) Calculated using the peak vessel fluence of 6.96×10^{18} n/cm^2 (E > 1.0 MeV).
(b) Used to generate the heatup/cooldown curves.

TABLE 5.6

Calculation of Adjusted Reference Temperatures at 7 EFPY for the Limiting Watts Bar Unit 1 Reactor Vessel Material (Intermediate Shell Forging 05)

Parameter	Values	
Operating Time	7 EFPY	
Material	Inter. Shell Forging 05	Inter. Shell Forging 05
Location	1/4-T	3/4-T
Chemistry Factor (CF), °F	132	132
Fluence (f), $\div 10^{19}$ n/cm^2 (E > 1.0 MeV) (a)	0.4188	0.1517
Fluence Factor (FF) (b)	0.758	0.505
ΔRT_{NDT} = CF x FF, °F	100.1	66.7
Initial RT_{NDT} (I), °F	47	47
Margin (M), °F (c)	34	34
ART = I + (CFxFF) + M, °F per Regulatory Guide 1.99, Revision 2	181.1	147.7

NOTES:

(a) Fluence, f, is based upon $f_{surf} = 6.96 \times 10^{18}$ n/cm^2. The Watts Bar Unit 1 reactor vessel wall thickness is 8.465 inches at the beltline region.

(b) FF = f $^{(0.28 - 0.10 \log f)}$

(c) Margin is calculated as $M = 2(\sigma_i^2 + \sigma_\Delta^2)^{0.5}$. The standard deviation for the initial RT_{NDT} margin term, σ_i, is 0 °F since the initial RT_{NDT} value is a measured value. The standard deviation for the ΔRT_{NDT} margin term, σ_Δ, is 17 °F for the forging, except that σ_Δ need not exceed 0.5 times the mean value of ΔRT_{NDT} .

TABLE 5.7					
Watts Bar Unit 1 Reactor Vessel Surface Fluence Values at 32 and 48 EFPY (n/cm^2, E > 1.0 MeV)					
EFPY	0°	15°	25°	35°	45°
32	1.89×10^{19}	2.81×10^{19}	3.18×10^{19}	2.59×10^{19}	2.97×10^{19}
48	2.84×10^{19}	4.22×10^{19}	4.77×10^{19}	3.89×10^{19}	4.46×10^{19}

TABLE 5.8							
RT_{PTS} Values for Watts Bar Unit 1 for 32 EFPY							
Material	CF (°F)	Surface Fluence (n/cm^2, E > 1.0 MeV)	FF	RT_{NDT} (CF x FF) (°F)	I (°F)	M (°F)	RT_{PTS} (°F)
Inter. Shell Forging 05	132	3.18×10^{19}	1.30	171.6	47	34	253
Lower Shell Forging 04	51	3.18×10^{19}	1.30	66.3	5	34	106
Circ. Weld	68	3.18×10^{19}	1.30	88.4	-43	56	102

TABLE 5.9							
RT_{PTS} Values for Watts Bar Unit 1 for 48 EFPY							
Material	CF (°F)	Surface Fluence (n/cm^2, E > 1.0 MeV)	FF	RT_{NDT} (CF x FF) (°F)	I (°F)	M (°F)	RT_{PTS} (°F)
Inter. Shell Forging 05	132	4.77×10^{19}	1.39	185.5	47	34	265
Lower Shell Forging 04	51	4.77×10^{19}	1.39	70.9	5	34	110
Circ. Weld	68	4.77×10^{19}	1.39	94.5	-43	56	108

SOURCE NOTES

1. NCO820285003

2. NCO820285004