TVA TENNESSEE VALLEY AUTHORITY

Post Office Box 2000, Spring City, Tennessee 37381

WBL-21-056

December 9, 2021

10 CFR 50.36

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Watts Bar Nuclear Plant, Unit 1
Facility Operating License No. NPF-90
NRC Docket No. 50-390

Subject: **Watts Bar Nuclear Plant Unit 1 – Revised Pressure and Temperature Limits Report (PTLR)**

The purpose of this letter is to provide the enclosed copy of the Watts Bar Unit 1 Pressure and Temperature Limits Report (PTLR), Revision 13, in accordance with Technical Specification Section 5.9.6.c.

There are no new regulatory commitments in this letter. Should you have questions regarding this submittal, please contact Tony Brown, Site Licensing Manager, at (423) 365-7720.

Respectfully,

Anthony L. Williams IV
Site Vice President
Watts Bar Nuclear Plant

Enclosure

Watts Bar Nuclear Plant, Unit 1 Pressure and Temperature Limits Report (PTLR), Revision 13.

cc: (Enclosure)

NRC Regional Administrator – Region II
NRC Senior Resident Inspector - Watts Bar Nuclear Plant
NRC Project Manager - Watts Bar Nuclear Plant

Enclosure
Watts Bar Nuclear Plant,
Unit 1 Pressure and Temperature Limits Report (PTLR),
Revision 13

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Watts Bar Unit 1 - RCS Pressure and Temperature Limits Report (PTLR) - Revision 13

APPENDIX “A”

TO RCS SYSTEM DESCRIPTION N3-68-4001

WATTS BAR UNIT 1

RCS PRESSURE AND TEMPERATURE LIMITS REPORT (PTLR)

REVISION 13

Prepared by:	C. S. Kerlin
Checked by	S. E. Nolan
Approved by:	M. R. Smith

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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) using the NRC-approved methodologies (Ref. 4) that are specified in Technical 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°F per hour.

B. A maximum cooldown Rate 100°F per hour.

C. A maximum temperature change of 10°F in any 1-hour period during inservice hydrostatic and leak testing operations above the heatup and cooldown limit curves.

2.1.2 RCS P/T Limits for Heatup, Cooldown, Inservice Hydrostatic and Leak Testing, and Criticality

The RCS P/T limits for heatup, cooldown, inservice hydrostatic and leak testing, and criticality are specified by Figures 2.1-1 thru 2.1-3 (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. 9). 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.

NOTE: Steady-state conditions (0°F per hour heatup or cooldown curves) are achieved after maintaining a constant temperature for a duration of 1 hour (Ref. 1). Steady state conditions are maintained if temperature fluctuations remain within ± 9.2°F (Ref. 1).

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 Technical Specification 5.9.6.

3.1 Pressurizer PORV Lift Setting Limits

The pressurizer PORV lift setpoints in Table 3.1-1 were specified by the Westinghouse Cold Overpressure Mitigation Setpoint Analysis (Ref. 9). Per ASME Code N-514, the limits for the COMS setpoints are based on 110% of the Steady State 32 EFPY curves (Table 2.1-2) (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. 9).

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 (Ref. 10, 11) contain the adjusted curves compensated for pressure differential and instrument inaccuracy which provides the PORV lift limits for the COMS utilizing the 32 EFPY data.

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 4-1. The results of the most recent examination (Ref. 8) was used to update Figures 2.1-1 through 2.1-3 and the corresponding data points in Table 2.1-1 through 2.1-2 as well as the supplemental data tables in Section 5.0.

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 E23. The empirical relationship between RT_{NDT} and the fracture toughness of the reactor vessel steel is developed in accordance with Appendix G, "Fracture Toughness Criteria for Protection Against Failure", to Section XI of the ASME Boiler and Pressure Vessel Code. The surveillance capsule removal schedule meets the requirements of ASTM E185-82.

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.

- Table 5-2 shows calculations of the surveillance material chemistry factors using surveillance capsule data.

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5.0 SUPPLEMENTAL DATA TABLES (continued)

- Table 5-3 provides the required Watts Bar Unit 1 reactor vessel toughness data, along with the unirradiated & best estimate average chemistry, respectively. 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 and in the Pressurized Thermal Shock (PTS) evaluation.
- 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 32 EFPY.
- Table 5-6 shows example calculations of the adjusted reference temperature (ART) values at 32 EFPY for the limiting Watts Bar Unit 1 reactor vessel material (*Intermediate Shell Forging 05*).
- Table 5-7 provides RT_{PTS} values for Watts Bar Unit 1 for 32 EFPY.

6.0 REFERENCES

1. WCAP-16761-NP, Revision 0, “Watts Bar Unit 1 Heatup and Cooldown Curves for Normal Operation,” November 2007.
2. Deleted.
3. WCAP-9298, Revision 1, "Watts Bar Unit 1 Reactor Vessel Radiation Surveillance Program," April 1993.
4. WCAP-14040, Revision 1, “Methodology Used To Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves,” December 1994.
5. Deleted.
6. BWXT SERVICES, Inc., “Analysis of Capsule W From The Tennessee Valley Authority Watts Bar Unit 1 Reactor Vessel Material Surveillance Program,” September 2001.
7. Deleted.
8. WCAP-16760-NP, Revision 0, “Analysis of Capsule Z from the Tennessee Valley Authority, Watts Bar Unit 1 Reactor Vessel Radiation Surveillance Program2,” November 2007.
9. LTR-SCS-15-31, Rev 0, ”Watts Bar Unit 1 PORV Replacement – Cold Overpressure Mitigation System (COMS) Setpoint Analysis”, 1/4/2017
10. NE SSD 1-T-68-1B, COMS Setpoint and Scaling Document for PORV 1-PCV-68-340A Instrument Loop Components.

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6.0 REFERENCES (continued)

11. NE SSD 1-T-68-43B, COMS Setpoint and Scaling Document for PORV 1-PCV-68-334 Instrument Loop Components.

12. Structural Integrity Associates Report, No. SIR 01 140, Revision 1, “Heatup and Cooldown Limit Curves for Normal Operation for Watts Bar Unit 1”, July 2002.

13 MRP-326, Revision 1, “Coordinated PWR Reactor Vessel Surveillance Program (CRVSP)” June 2021.

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7.0 FIGURES AND TABLES

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

LIMITING ART AT 32 EFPY: 1/4-T, 205.74 °F

3/4-T, 171.15 °F

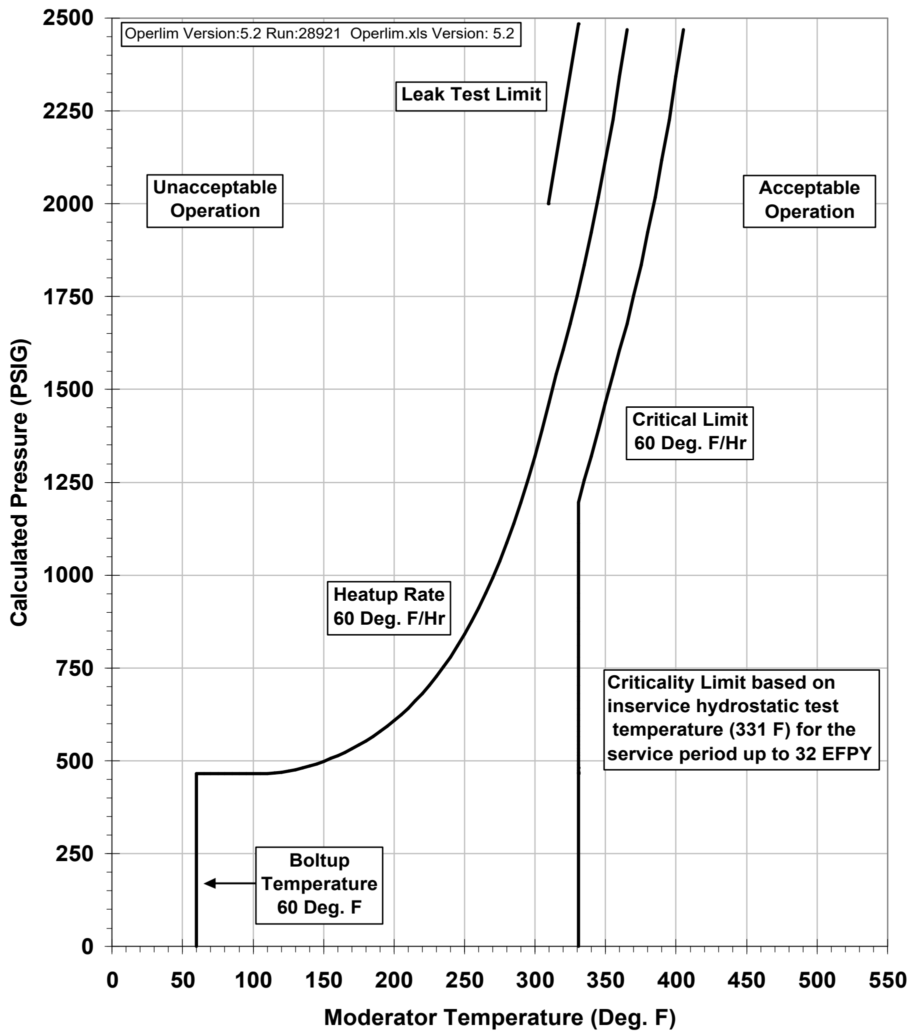

Figure 2.1-1: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate of 60°F/hr) Applicable for 32 EFPY (with the “Flange-Notch” & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})

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

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7.0 FIGURES AND TABLES (continued)

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

LIMITING ART AT 32 EFPY: 1/4-T, 205.74 °F

3/4-T, 171.15 °F

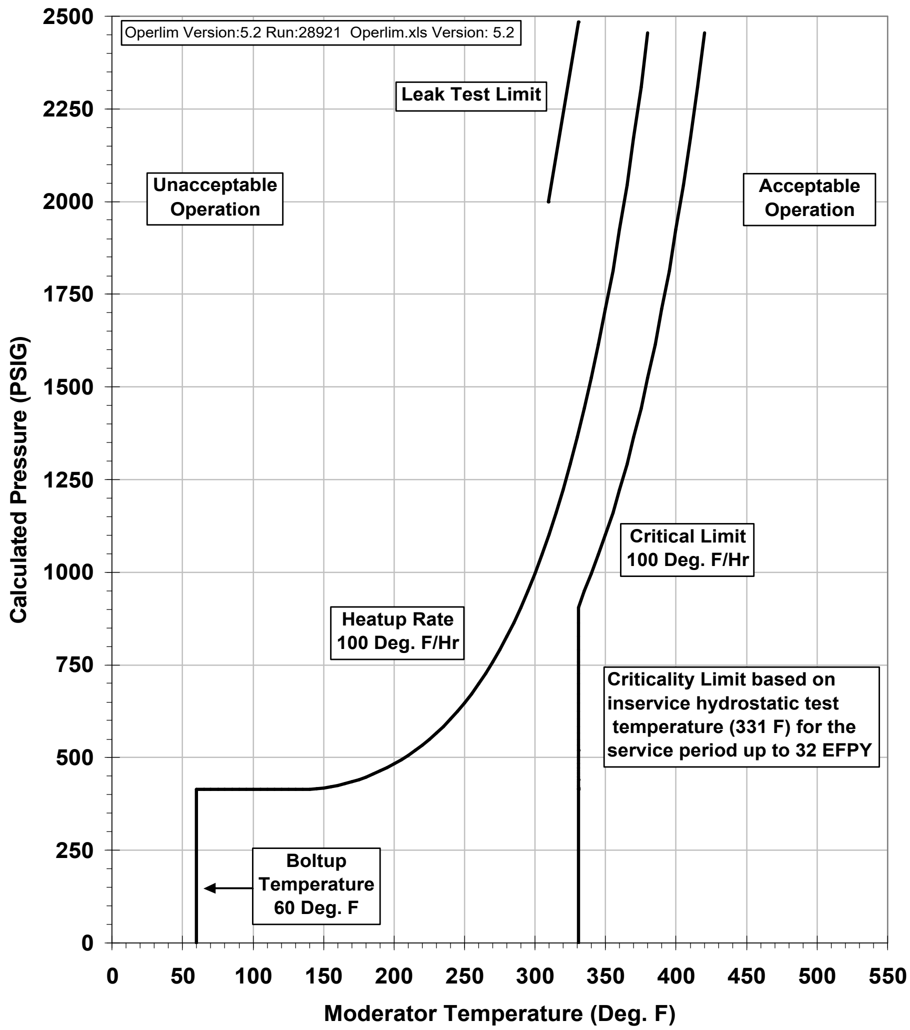

Figure 2.1-2: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate of 100°F/hr) Applicable for 32 EFPY (with the "Flange-Notch" & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})

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

7.0 FIGURES AND TABLES (continued)

Table 2.1-1: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate up to 100°F/hr) Applicable for 32 EFPY (with the "Flange-Notch" & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})
(Data points plotted on Figures 2.1-1 and 2.1-2)

60°F/hr Heatup		Critical Limit		100°F/hr Heatup		Critical Limit	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
60	0	331	0	60	0	331	0
60	465	331	465	60	413	331	413
65	465	331	465	65	413	331	413
70	465	331	466	70	413	331	414
75	465	331	467	75	413	331	414
80	465	331	467	80	413	331	416
85	465	331	470	85	413	331	416
90	465	331	470	90	413	331	418
95	465	331	473	95	413	331	419
100	465	331	474	100	413	331	421
105	465	331	477	105	413	331	422
110	466	331	481	110	413	331	425
115	467	331	481	115	413	331	427
120	470	331	487	120	413	331	429
125	473	331	490	125	413	331	433
130	477	331	492	130	413	331	435
135	481	331	499	135	413	331	440
140	487	331	501	140	414	331	441
145	492	331	506	145	416	331	447

7.0 FIGURES AND TABLES (continued)

Table 2.1-1: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate up to 100°F/hr) Applicable for 32 EFPY (with the “Flange-Notch” & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})
(Data points plotted on Figures 2.1-1 and 2.1-2)

60°F/hr Heatup		Critical Limit		100°F/hr Heatup		Critical Limit	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
150	499	331	514	150	418	331	449
155	506	331	516	155	421	331	455
160	514	331	523	160	425	331	459
165	523	331	533	165	429	331	463
170	533	331	543	170	435	331	471
175	543	331	554	175	441	331	473
180	554	331	566	180	447	331	483
185	566	331	579	185	455	331	486
190	579	331	593	190	463	331	494
195	593	331	608	195	473	331	502
200	608	331	625	200	483	331	506
205	625	331	642	205	494	331	519
210	642	331	661	210	506	331	520
215	661	331	682	215	519	331	534
220	682	331	704	220	534	331	549
225	704	331	727	225	549	331	566
230	727	331	753	230	566	331	584
235	753	331	780	235	584	331	604
240	780	331	809	240	604	331	625

7.0 FIGURES AND TABLES (continued)

Table 2.1-1: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate up to 100°F/hr) Applicable for 32 EFPY (with the "Flange-Notch" & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})
(Data points plotted on Figures 2.1-1 and 2.1-2)

60°F/hr Heatup		Critical Limit		100°F/hr Heatup		Critical Limit	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
245	809	331	841	245	625	331	648
250	841	331	875	250	648	331	672
255	875	331	912	255	672	331	699
260	912	331	951	260	699	331	727
265	951	331	993	265	727	331	758
270	993	331	1038	270	758	331	791
275	1038	331	1087	275	791	331	826
280	1087	331	1139	280	826	331	864
285	1139	331	1195	285	864	331	905
290	1195	335	1256	290	905	335	949
295	1256	340	1321	295	949	340	996
300	1321	345	1390	300	996	345	1047
305	1390	350	1465	305	1047	350	1102
310	1465	355	1540	310	1102	355	1160
315	1540	360	1606	315	1160	360	1223
320	1606	365	1677	320	1223	365	1291
325	1677	370	1753	325	1291	370	1363
330	1753	375	1835	330	1363	375	1441
335	1835	380	1922	335	1441	380	1525

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7.0 FIGURES AND TABLES (continued)

Table 2.1-1: Watts Bar Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rate up to 100°F/hr) Applicable for 32 EFPY (with the "Flange-Notch" & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})
(Data points plotted on Figures 2.1-1 and 2.1-2)

60°F/hr Heatup		Critical Limit		100°F/hr Heatup		Critical Limit	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
340	1922	385	2017	340	1525	385	1614
345	2017	390	2118	345	1614	390	1710
350	2118	395	2227	350	1710	395	1814
355	2227	400	2343	355	1814	400	1925
360	2343	405	2469	360	1925	405	2044
365	2469			365	2044	410	2171
				370	2171	415	2308
				375	2308	420	2455
				380	2455		
Leak Test Limit		Temp. [°F]		310	331		
		Pressure [psig]		2000	2485		

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7.0 FIGURES AND TABLES (continued)

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: INTERMEDIATE SHELL FORGING 05

LIMITING ART AT 32 EFPY: 1/4-T, 205.74 °F

3/4-T, 171.15 °F

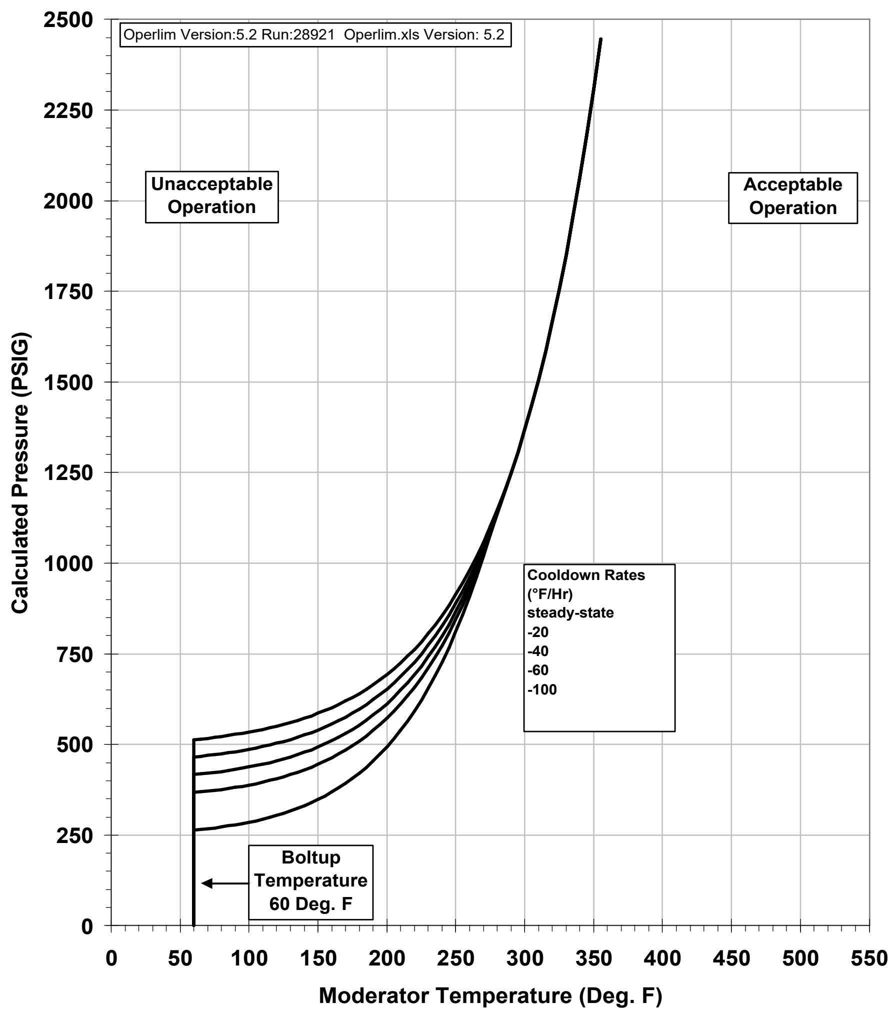

Figure 2.1-3: Watts Bar Unit 1 Reactor Coolant System Cooldown Limitations (Cooldown Rates up to 100°F/hr) Applicable for 32 EFPY (with the "Flange-Notch" & without Margins for Instrumentation Errors) Using 1996 App. G Methodology (w/K_{IA})

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

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7.0 FIGURES AND TABLES (continued)

Table 2.1-2: 32 EFPY Cooldown Curve Data Points Using 1996 App. G Methodology (w/K_{IA}, w/Flange Notch & w/o Uncertainties for Instrumentation Errors)

(Data points plotted on Figure 2.1-3)

Steady State		20°F/hr		40°F/hr		60°F/hr		100°F/hr	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
60	0	60	0	60	0	60	0	60	0
60	513	60	465	60	417	60	367	60	264
65	515	65	467	65	419	65	369	65	266
70	517	70	469	70	421	70	371	70	268
75	519	75	472	75	423	75	373	75	270
80	522	80	474	80	426	80	376	80	272
85	525	85	477	85	428	85	378	85	275
90	528	90	480	90	431	90	381	90	278
95	531	95	483	95	434	95	385	95	281
100	534	100	486	100	438	100	388	100	285
105	538	105	490	105	442	105	392	105	289
110	542	110	494	110	446	110	396	110	294
115	546	115	499	115	450	115	401	115	299
120	550	120	503	120	455	120	406	120	304
125	555	125	508	125	460	125	411	125	310
130	561	130	514	130	466	130	417	130	316
135	566	135	519	135	472	135	423	135	323
140	572	140	526	140	478	140	430	140	331
145	579	145	533	145	485	145	438	145	339
150	586	150	540	150	493	150	446	150	349

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7.0 FIGURES AND TABLES (continued)

Table 2.1-2: 32 EFPY Cooldown Curve Data Points Using 1996 App. G Methodology (w/K_{IA}, w/Flange Notch & w/o Uncertainties for Instrumentation Errors)

(Data points plotted on Figure 2.1-3)

Steady State		20°F/hr		40°F/hr		60°F/hr		100°F/hr	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
155	593	155	548	155	501	155	454	155	358
160	602	160	556	160	510	160	464	160	369
165	610	165	565	165	520	165	474	165	381
170	620	170	575	170	530	170	485	170	393
175	630	175	586	175	542	175	497	175	407
180	641	180	597	180	554	180	510	180	422
185	652	185	610	185	567	185	524	185	437
190	665	190	623	190	581	190	539	190	455
195	678	195	637	195	596	195	555	195	473
200	693	200	653	200	613	200	573	200	494
205	708	205	669	205	630	205	592	205	516
210	725	210	687	210	649	210	612	210	539
215	743	215	706	215	670	215	634	215	565
220	763	220	727	220	692	220	658	220	592
225	783	225	749	225	716	225	683	225	622
230	806	230	773	230	741	230	711	230	654
235	830	235	799	235	769	235	741	235	689
240	856	240	827	240	799	240	773	240	726
245	884	245	857	245	831	245	807	245	767
250	913	250	889	250	865	250	844	250	810

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7.0 FIGURES AND TABLES (continued)

Table 2.1-2: 32 EFPY Cooldown Curve Data Points Using 1996 App. G Methodology (w/K_{IA}, w/Flange Notch & w/o Uncertainties for Instrumentation Errors)

(Data points plotted on Figure 2.1-3)

Steady State		20°F/hr		40°F/hr		60°F/hr		100°F/hr	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
255	946	255	923	255	903	255	884	255	857
260	980	260	960	260	943	260	928	260	908
265	1017	265	1000	265	986	265	974	265	962
270	1057	270	1043	270	1032	270	1024	270	1021
275	1100	275	1090	275	1082	275	1078	275	1078
280	1147	280	1139	280	1136	280	1136	280	1136
285	1196	285	1193	285	1193	285	1193	285	1193
290	1250	290	1250	290	1250	290	1250	290	1250
295	1307	295	1307	295	1307	295	1307	295	1307
300	1369	300	1369	300	1369	300	1369	300	1369
305	1435	305	1435	305	1435	305	1435	305	1435
310	1507	310	1507	310	1507	310	1507	310	1507
315	1583	315	1583	315	1583	315	1583	315	1583
320	1666	320	1666	320	1666	320	1666	320	1666
325	1755	325	1755	325	1755	325	1755	325	1755
330	1850	330	1850	330	1850	330	1850	330	1850
335	1953	335	1953	335	1953	335	1953	335	1953
340	2063	340	2063	340	2063	340	2063	340	2063
345	2181	345	2181	345	2181	345	2181	345	2181
350	2309	350	2309	350	2309	350	2309	350	2309

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7.0 FIGURES AND TABLES (continued)

Table 2.1-2: 32 EFPY Cooldown Curve Data Points Using 1996 App. G Methodology (w/K_{IA}, w/Flange Notch & w/o Uncertainties for Instrumentation Errors)

(Data points plotted on Figure 2.1-3)

Steady State		20°F/hr		40°F/hr		60°F/hr		100°F/hr	
T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]	T [°F]	P [psig]
355	2446	355	2446	355	2446	355	2446	355	2446

7.0 FIGURES AND TABLES (continued)

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

The COMS analysis considers the following RCP operating restrictions:

RCS Temperature < 105 F, maximum of 2 RCPs in operation

RCS Temperature > 105 F, maximum of 4 RCPs in operation

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7.0 FIGURES AND TABLES (continued)

Table 3.1-1

Watts Bar Unit 1 Maximum Allowable COMS PORV Setpoints

Indicated Cold Leg Temperature °F	Maximum Allowable PORV Setpoint (psig)
60	462
105	462
125	481
200	566
225	604
250	664
300	688
350	688

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7.0 FIGURES AND TABLES (continued)

Table 4-1 Surveillance Capsule Removal Schedule				
Capsule	Capsule Location	Lead Factor[(a)]	Withdrawal EFPY[(b)]	Fluence (n/cm^2)[(a)]
U	56°	5.00	1.20	4.47×10^{18} (c)
W	124°	5.05	3.88	1.08×10^{19} (c)
X	236°	5.03	6.63	1.71×10^{19} (c)
Z	304°	5.06	9.37	2.40×10^{19} (c)
V	58.5°	4.31	(d)	6.02×10^{19}
Y	238.5°	4.31	(e)	Standby

(Notes):

(a) Updated from Capsule Z dosimetry analysis.

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

(c) Plant specific evaluation.

(d) Capsule V will be removed during the last scheduled outage before estimated capsule exposure to a neutron fluence equal to two times the peak RPV neutron fluence at 60 years of operation (i.e. 54 EFPY).

(e) Capsule Y shall remain inserted in the reactor vessel on standby until needed to fulfill future 10 CFR 50, Appendix H or license renewal requirements.

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7.0 FIGURES AND TABLES (continued)

TABLE 5-1

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

Material	Capsule	Fluence[d] (x 10^{19} n/cm^2, E > 1.0 MeV)	30 ft-lb Transition Temperature Shift		Upper Shelf Energy Decrease	
			Predicted (°F)[a]	Measured (°F)[b]	Predicted (%)[a]	Measured (%)[c]
Intermediate Shell Forging 05 (Tangential)	U	0.447	95.4	98.3	21	19
	W	1.08	125.6	111.4	26	26
	X	1.71	141.2	94.7	29	20
	Z	2.40	152.0	144.5	31	23
Intermediate Shell Forging 05 (Axial)	U	0.447	95.4	28.7	21	--
	W	1.08	125.6	79.0	26	3.2
	X	1.71	141.2	115.9	29	--
	Z	2.40	152.0	104.9	31	0
Surveillance Program Weld Metal	U	0.447	31.8	0.0[e]	16	---
	W	1.08	41.9	30.5	19	15
	X	1.71	47.1	25.8	22	---
	Z	2.40	50.7	13.9	23	---
Heat Affected Zone Material	U	0.447	---	50.9	---	11
	W	1.08	---	48.8	---	13
	X	1.71	---	74.5	---	7.9
	Z	2.40	---	67.7	---	11

7.0 FIGURES AND TABLES (continued)

TABLE 5-1

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

(Notes):

(a) Based on Regulatory Guide 1.99, Revision 2, methodology using the mean weight percent values of copper and nickel of the surveillance material.

(b) Calculated using measured Charpy data plotted using CVGRAPH, Version 5.0.2.

(c) Values are based on the definition of upper shelf energy given in ASTM E185-82.

(d) The fluence values presented here are the “calculated” values.

(e) Due to the scatter in the Capsule U Weld Charpy test results, a true Hyperbolic Tangent Curve fit resulted in ΔT_{30} values of –6.4°F when compared to unirradiated Charpy test data. A conservative value of 0°F was used in RT_{NDT} calculations.

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7.0 FIGURES AND TABLES (continued)

TABLE 5-2
Calculation of Chemistry Factors using Watts Bar Unit 1 Surveillance Capsule Data

Material	Capsule	Capsule f[(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	FF*ΔRT_{NDT}	FF^2
Inter. Shell Forging 05 (Tangential)	U	0.447	0.776	98.3	76.28	0.602
	W	1.08	1.022	111.4	113.80	1.044
	X	1.71	1.148	94.7	108.68	1.317
	Z	2.40	1.236	144.5	178.60	1.528
Inter. Shell Forging 05 (Axial)	U	0.447	0.776	28.7	22.27	0.602
	W	1.08	1.022	79.0	80.70	1.044
	X	1.71	1.148	115.9	133.01	1.317
	Z	2.40	1.236	104.9	129.65	1.528
SUM:					842.99	8.981

$CF_{05} = \sum(FF * \Delta RT_{NDT}) \div \sum(FF^2) = (842.99) \div (8.981) =$ **93.9°F**

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7.0 FIGURES AND TABLES (continued)

TABLE 5-2 (Cont'd)

Calculation of Chemistry Factors using Watts Bar Unit 1 Surveillance Capsule Data

Material	Capsule	Capsule f[a]	FF[b]	ΔRT_{NDT}[c]	FF*ΔRT_{NDT}	FF^2
Surveillance Weld [d,e,f]	WB1 - U	0.447	0.776	0.0 (0.0[g])	0.00	0.602
	WB1 - W	1.08	1.022	40.26 (30.5)	41.13	1.044
	WB1 - X	1.71	1.148	34.06 (25.8)	39.08	1.317
	WB1 - Z	2.40	1.236	18.35 (13.9)	22.68	1.528
	Cat.1 – Z	0.2993	0.670	0.0[h] (1.91)	0.00	0.448
	Cat.1 – Y	1.318	1.077	8.52 (17.79)	9.18	1.160
	Cat.1 – V	2.334	1.229	15.4 (26.5)	18.93	1.510
	MG2 – V	0.323	0.689	32.51 (38.51)	22.41	0.475
	MG2 – X	1.47	1.11	29.93 (35.93)	33.13	1.225
	MG2 – U	2.04	1.19	17.81 (23.81)	21.27	1.426
	MG2 - W	3.07	1.30	37.76 (43.76)	48.94	1.680
SUM:					256.75	12.415

$CF_{Surv.\ Weld} = \sum(FF * \Delta RT_{NDT}) \div \sum(FF^2) = (256.75) \div (12.415) =$ **20.7°F**

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7.0 FIGURES AND TABLES (continued)

TABLE 5-2 (Cont'd)
Calculation of Chemistry Factors using Watts Bar Unit 1 Surveillance Capsule Data

(Notes):

(a) f = fluence. For Watts Bar Unit 1, see Table 2-2; for Catawba Unit 1, see WCAP-15117, and for McGuire Unit 2, see WCAP-15334. Fluence units are [E+19 n/cm^2, E > 1.0 MeV].

(b) FF = fluence factor = $f^{(0.28 - 0.1*\log f)}$.

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values [°F]. Watts Bar Unit 1 values are taken from WCAP-16760-NP, Catawba Unit 1 values are taken from WCAP-15117, and McGuire Unit 2 values are taken from WCAP-14799. Units are [°F]. The pre-adjusted values are shown in the parentheses; for more details on the adjusted values refer to Notes "d" and "e."

(d) The Surveillance Weld ΔRT_{NDT} values have been adjusted for temperature difference from Watts Bar Unit 1 as follows:

- Minus 7°F for Catawba Unit 1 (Note: It is more conservative to adjust for temperature 1st, then apply the ratio.)
- Minus 6°F for McGuire Unit 2

(e) The Surveillance Weld ΔRT_{NDT} values have been adjusted for chemistry difference to the best estimate Cu & Ni by a ratio of:

- 1.32 for Watts Bar Unit 1
- 0.79 for Catawba Unit 1
- 1.0 for McGuire Unit 2

(f) Surveillance data for Catawba Unit 1 and McGuire Unit 2 come from WCAP-15117 and WCAP-14799.

(g) Original value was -6.4°F, but physically a reduction should not occur, therefore a conservative value of zero will be used for Watts Bar Capsule U weld metal.

(h) After the Temperature adjustment and ratio procedure, the value of the shift comes out less than zero, but physically a reduction should not occur, therefore a conservative value of zero will be used.

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7.0 FIGURES AND TABLES (continued)

TABLE 5-3
Watts Bar Unit 1 Reactor Vessel Toughness Table
(Best Estimate Average, i.e., all data)

Material Description	Cu(%)[a]	Ni(%)[a]	Initial RT_{NDT}
Closure Head Flange 08 (*Heat # 910334 / 710402*)	0.13	0.75	-43°F
Vessel Flange 07 (*Heat # 411471*)	---	---	-40°F [d]
Intermediate Shall Forging 05 (Heat # 527536)	0.16	0.80	47°F
Lower Shell Forging 04 (Heat # 528522)	0.08	0.83	5°F
Inter. To Lower Shell Girth Weld W05 [b,c]	0.04	0.73	-43°F
Watts Bar Unit 1 Surveillance Weld Metal [b,c]	0.03	0.75	---
Watts Bar Unit 2 Surveillance Weld Metal [b,c]	0.02	0.69	---
Catawba Unit 1 Surveillance Weld Metal [b,c]	0.05	0.73	---
McGuire Unit 2 Surveillance Weld Metal [b,c]	0.04	0.74	---

NOTES:

(a) Based on measured data.

(b) The surveillance weld was made with the same weld wire and flux as the intermediate to lower shell girth weld (weld wire heat # 895075, flux type Grau L.O. # LW320, lot # P46).

(c) These values were rounded to two decimal points since the chemistry factor determination uses weight percent chemistry to two decimal points.

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

7.0 FIGURES AND TABLES (continued)

TABLE 5-4 Watts Bar Unit 1 Reactor Vessel Surface Fluence Values at 32 EFPY[(a)]			
Azimuth			
0°	15°	30°	45°
9.49×10^{18}	1.41×10^{19}	1.42×10^{19}	1.75×10^{19}

NOTES:

(a) These values are based on the new evaluation performed from the Capsule Z evaluation (Ref. 8). Units are n/cm^2 (E>1.0 MeV).

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 32 EFPY		
Component	32 EFPY[(a)]	
	1/4-T (°F)	3/4-T (°F)
Intermediate Shell Forging 05 (*Heat # 527536*)	205.74[(b)]	171.15[(b)]
> Using Surveillance Data	176.23	149.82
Lower Shell Forging 04 (*Heat # 528522*)	90.72	76.38
Intermediate to Lower Shell Girth Weld (Heat # 895075)	66.53	36.15
> Using Surveillance Data	-1.01	-12.66

NOTES:

(a) Fluence used for the PT Limit curves were based on the previous fluence analysis performed from the Capsule Z evaluation[8] (See Table 5-4 above). Units are n/cm^2 (E>1.0 MeV).

(b) Used to generate the heatup/cooldown curves.

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7.0 FIGURES AND TABLES (continued)

TABLE 5-6
Calculation of Adjusted Reference Temperatures at 32 EFPY for the Limiting Watts Bar Unit 1 Reactor Vessel Material
(*Intermediate Shell Forging 05*)

Parameter	Values	
Operating Time	32 EFPY	
Material	Inter. Shell Forging 05	Inter. Shell Forging 05
Location	1/4-T	3/4-T
Chemistry Factor (CF), °F[(a)]	123	123
Fluence (f), $*10^{19}$ n/cm^2 (E>1.0MeV)[(b)]	1.05	0.38
Fluence Factor (FF)[(c)]	1.01	0.73
ΔRT_{NDT} = CF x FF, °F	124.74	90.15
Initial RT_{NDT}(I), °F	47	47
Margin (M), °F[(d)]	34	34
ART = I + (CF*FF) + M, °F [*Per Regulatory Guide 1.99, Revision 2*]	205.74	171.15

NOTES:

(a) CF is based on the Copper and Nickel from Table 5-3.

(b) Fluence, f, is based upon $f_{surf} = 1.75 \times 10^{19}$ n/cm^2. The Watts Bar Unit 1 reactor vessel wall thickness is 8.465 inches at the beltline region.

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

(d) 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}.

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7.0 FIGURES AND TABLES (continued)

TABLE 5-7
RT_{PTS} Calculations for Watts Bar Beltline Region Materials at 32 EFPY

Material	Fluence, f[(a)]	FF[(b)]	CF[(c)]	ΔRT_{PTS}[(d)]	Margin[(e)]	$RT_{NDT(U)}$[(f)]	RT_{PTS}[(g)]
Intermediate Shell Forging 05 (*Heat # 527536*)	1.75	1.15	123	141.88	34	47	222.88
Using Surv. Cap. Data →	1.75	1.15	93.9	108.32	34[(i)]	47	189.32
Lower Shell Forging 04 (*Heat # 528522*)	1.75	1.15	51	58.83	34	5	97.83
Inter. To Lower Shell Girth Weld (*Heat # 895075*)	1.75	1.15	54	62.29	56	-43	75.29
Using Surv. Cap. Data →	1.75	1.15	20.7	23.88	24[(h)]	-43	4.76

Notes:

(a) The fluence, f, was taken from the peak azimuthal location (See Table 5-4); $*10^{19}$ n/cm^2, E>1.0 MeV.

(b) FF = $f^{(28-0.1*\log f)}$; where f is the clad/base metal interface fluence.

(c) The Position 1 (non-surveillance data) Chemistry Factor is obtained from the best estimate Cu & Ni in Table 5-3. The Position 2 (Surveillance Data) Chemistry Factor is obtained from Table 5-2. Units are °F.

(d) ΔRT_{PTS} = CF*FF; °F

(e) Margin = $2*(\sigma_\mu^2 + \sigma_\Delta^2)^{1/2}$; °F

(f) Initial RT_{NDT} values are measured values (See Table 5-3); °F

(g) $RT_{PTS} = RT_{NDT(U)} + \Delta RT_{PTS}$ + Margin (This value was rounded per ASTM E29, using the “Rounding Method”); °F

(h) σ_Δ exceeded $1/2\Delta RT_{NDT}$; thus, the calculated value of $1/2\Delta RT_{NDT}$ was used. Surveillance data is “credible”. See WCAP-16760 (Ref. 8).

(i) Surveillance Data deemed “not-credible,” thus the full σ_Δ must be applied. See WCAP-16760 (Ref. 8).

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8.0 SOURCE NOTES

1. NCO820285003

2. NCO820285004