Figure 14.9

CALLAWAY PLANT

PRESSURE AND TEMPERATURE LIMITS REPORT

Revision 6

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

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1.0 Reactor Coolant System (RCS) Pressure and Temperature Limits Report (PTLR)

This PTLR for Callaway Plant has been prepared in accordance with the requirements of Technical Specifications (TS) 5.6.6. The TS addressed in 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 Operating Limits

The parameter limits for the specifications listed in Section 1.0 are presented in the following subsections. The limits were developed in accordance with the NRC-approved methodology specified in Specification 5.6.6 (Ref. 1). NRC approval of this methodology was received in a Safety Evaluation Report dated February 27, 2004 from NRC to Westinghouse (TAC No. MB5754). The three provisions listed for acceptability of the methodology are met by this report and WCAP-14040-A, Revision 4, which describes the employed methodology.

This report meets the requirements of GL 96-03 Attachment 1, provision 2.

The revised P/T Limit curves account for a requirement of 10 CFR 50, Appendix G that the temperature of the closure head flange and vessel flange regions must be at least 120°F higher than the limiting RT_{NDT} for these regions when the pressure exceeds 20% of the preservice hydrostatic test pressure (3106 psig).

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

2.1.1 The RCS temperature rate-of-change limits are:

a. A maximum heatup of 100°F in any 1-hour period.

b. A maximum cooldown of 100°F in any 1-hour period.

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 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.

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2.2 Cold Overpressure Mitigation System (COMS) Setpoints (LCO 3.4.12)

The pressurizer power-operated relief valves (PORVs) shall each have lift settings in accordance with Figure 2.2-1. The (COMS) arming temperature is 275°F. These lift setpoints have been developed using the NRC approved methodologies specified in Technical Specification 5.6.6.

The maximum allowed PORV setpoint for COMS is derived by analysis which models the performance of the COMS assuming limiting mass and heat input transients. Operation with a PORV setpoint less than or equal to the maximum setpoint ensures that Appendix G criteria will not be violated with consideration for: (1) pressure and temperature instrumentation uncertainties; (2) single failure of one PORV; and (3) effects of reactor coolant pump operation.

To ensure mass and heat input transients more severe than those assumed cannot occur, Technical Specifications place limitations on the number of safety injection pumps and centrifugal charging pumps that are capable of injecting, unisolating accumulators, and starting reactor coolant pumps during the appropriate COMS MODES. These limitations are outlined in TS LCO 3.4.6, LCO 3.4.7, and LCO 3.4.12.

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

MATERIAL PROPERTIES BASIS

LIMITING MATERIAL: Lower Shell Plate R2708-1
LIMITING ART VALUES AT 28 EFPY: ¼T, 128°F
¾ T, 112°F

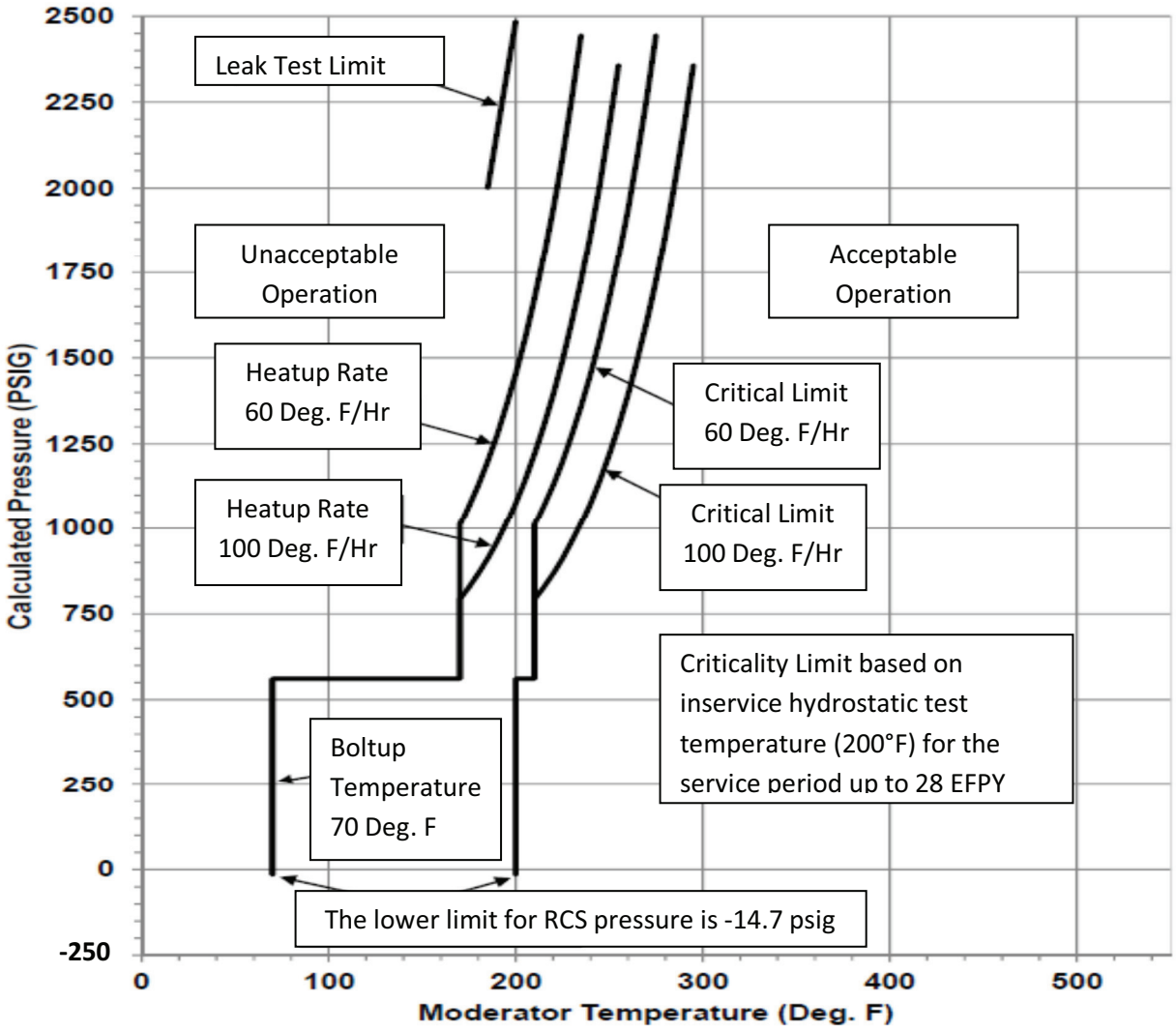

Figure 2.1-1 Callaway Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rates of 60°F and 100°F/hr). Applicable for 28 EFPY (With Margins for Instrumentation Errors). Includes vessel flange requirements of 170°F and 561 psig per 10 CFR 50, Appendix G.

Boltup temperature includes 10 °F instrument uncertainty

Figure 14.9
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Table 2.1-1

Callaway Plant Heatup Limits at 28 EFPY
With Margins for Instrumentation Errors

60°F/hr Heatup		Criticality Limit		100°F/hr Heatup		Criticality Limit	
T (°F)	p (psig)	T (°F)	p (psig)	T (°F)	p (psig)	T (°F)	p (psig)
70	-14.7	200	-14.7	70	-14.7	200	-14.7
70	561	200	561	70	561	200	561
75	561	200	561	75	561	200	561
80	561	200	561	80	561	200	561
85	561	200	561	85	561	200	561
90	561	200	561	90	561	200	561
95	561	200	561	95	561	200	561
100	561	200	561	100	561	200	561
105	561	200	561	105	561	200	561
110	561	200	561	110	561	200	561
115	561	200	561	115	561	200	561
120	561	200	561	120	561	200	561
125	561	200	561	125	561	200	561
130	561	200	561	130	561	200	561
135	561	200	561	135	561	200	561
140	561	200	561	140	561	200	561
145	561	200	561	145	561	200	561
150	561	200	561	150	561	200	561
155	561	200	561	155	561	200	561
160	561	205	561	160	561	205	561
165	561	210	561	165	561	210	561
170	561	210	1010	170	561	210	792
170	1010	215	1067	170	792	215	827
175	1067	220	1129	175	827	220	867
180	1129	225	1199	180	867	225	911
185	1199	230	1275	185	911	230	961
190	1275	235	1360	190	961	235	1016
195	1360	240	1453	195	1016	240	1076
200	1453	245	1557	200	1076	245	1144
205	1557	250	1671	205	1144	250	1218
210	1671	255	1797	210	1218	255	1301
215	1797	260	1936	215	1301	260	1392
220	1936	265	2089	220	1392	265	1493
225	2089	270	2258	225	1493	270	1604
230	2258	275	2445	230	1604	275	1726
235	2445			235	1726	280	1862
				240	1862	285	2011
				245	2011	290	2176
				250	2176	295	2358
				255	2358		

Leak Test Limit				
	Temperature (°F)	185	200	
	Pressure (psig)	2000	2485	

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MATERIAL PROPERTIES BASIS

LIMITING MATERIAL: Lower Shell Plate R2708-1
LIMITING ART VALUES AT 28 EFPY: ¼ T, 128°F
¾ T, 112°F

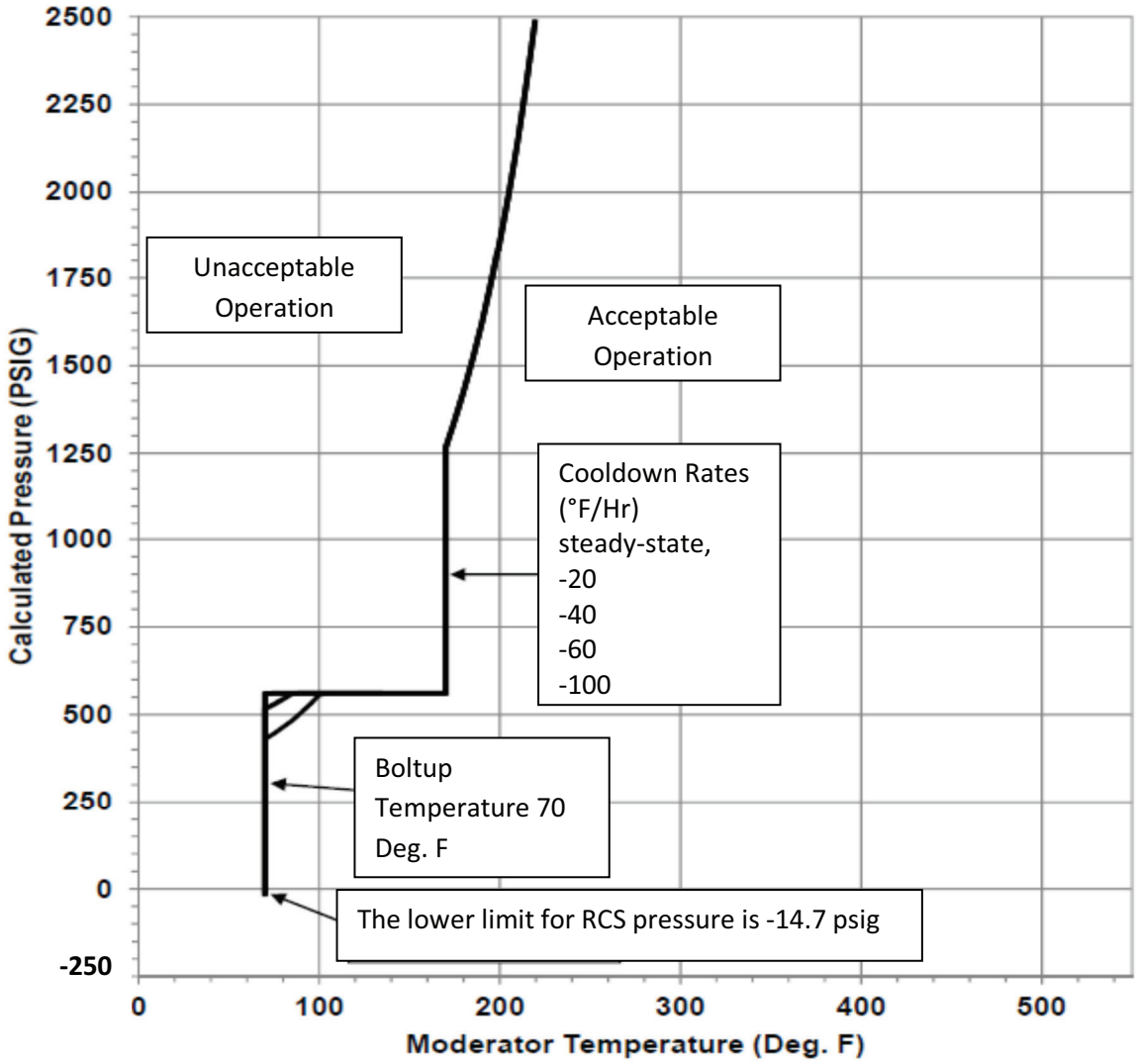

Figure 2.1-2 Callaway Unit 1 Reactor Coolant System Cooldown Limitations (Cooldown Rates of 0, 20, 40, 60, and 100°F/hr). Applicable for 28 EFPY (With Margins for Instrumentation Errors). Includes vessel flange requirements of 170°F and 561 psig per 10 CFR 50, Appendix G.

Boltup temperature includes 10°F instrument Uncertainty

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Table 2.1-2

Callaway Plant Cooldown Limits at 28 EFPY
With Margins for Instrumentation Errors

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)
70	-14.7	70	-14.7	70	-14.7	70	-14.7	70	-14.7
70	561	70	561	70	559	70	516	70	430
75	561	75	561	75	561	75	529	75	446
80	561	80	561	80	561	80	544	80	464
85	561	85	561	85	561	85	560	85	483
90	561	90	561	90	561	90	561	90	505
95	561	95	561	95	561	95	561	95	529
100	561	100	561	100	561	100	561	100	556
105	561	105	561	105	561	105	561	105	561
110	561	110	561	110	561	110	561	110	561
115	561	115	561	115	561	115	561	115	561
120	561	120	561	120	561	120	561	120	561
125	561	125	561	125	561	125	561	125	561
130	561	130	561	130	561	130	561	130	561
135	561	135	561	135	561	135	561	135	561
140	561	140	561	140	561	140	561	140	561
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155	561	155	561	155	561	155	561	155	561
160	561	160	561	160	561	160	561	160	561
165	561	165	561	165	561	165	561	165	561
170	561	170	561	170	561	170	561	170	561
170	1267	170	1267	170	1267	170	1267	170	1267
175	1343	175	1343	175	1343	175	1343	175	1343
180	1427	180	1427	180	1427	180	1427	180	1427
185	1519	185	1519	185	1519	185	1519	185	1519
190	1621	190	1621	190	1621	190	1621	190	1621
195	1734	195	1734	195	1734	195	1734	195	1734
200	1859	200	1859	200	1859	200	1859	200	1859
205	1997	205	1997	205	1997	205	1997	205	1997
210	2149	210	2149	210	2149	210	2149	210	2149
215	2318	215	2318	215	2318	215	2318	215	2318
219.5	2485	219.5	2485	219.5	2485	219.5	2485	219.5	2485

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CALLAWAY COMS
Maximum Allowable PORV Setpoints

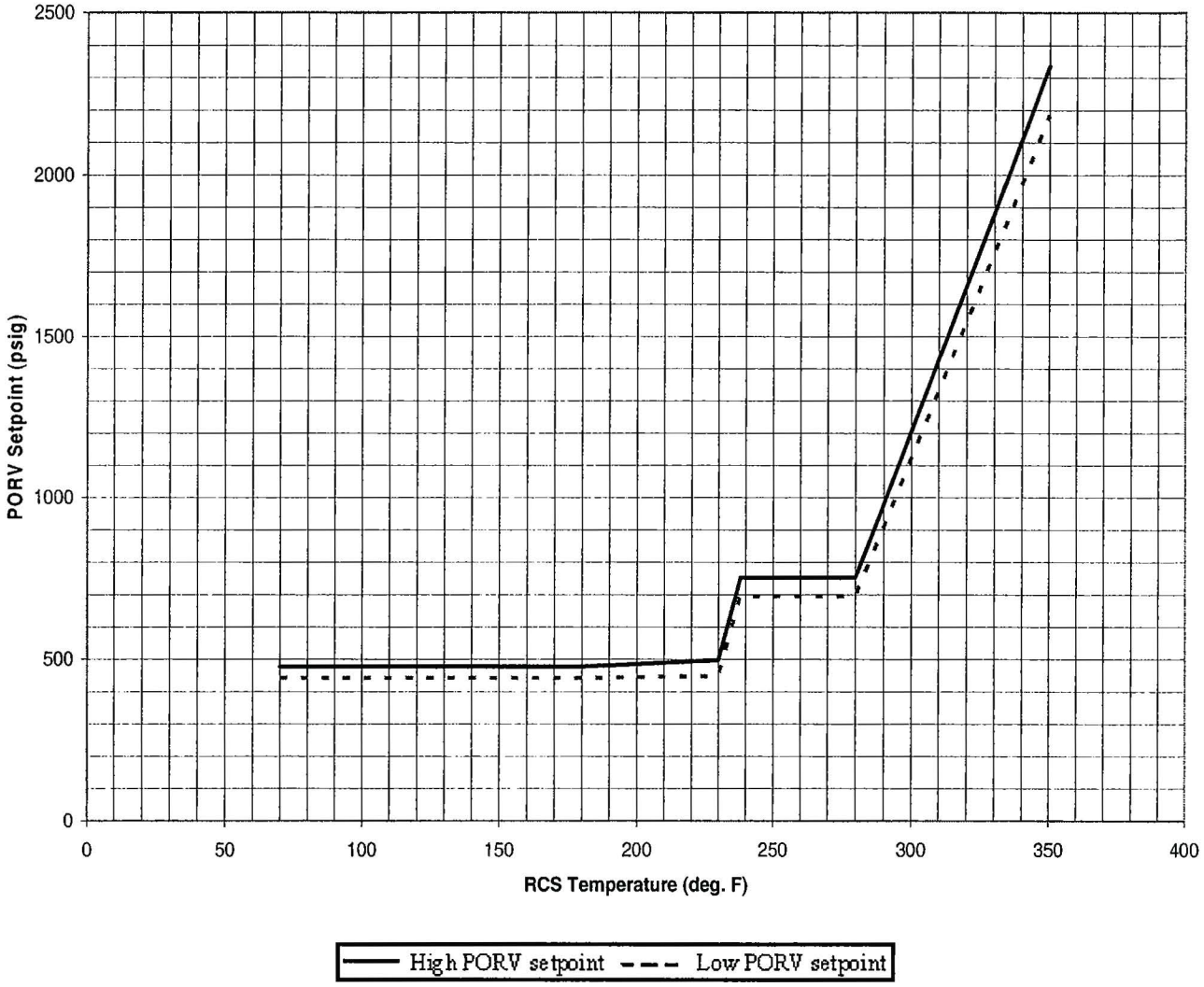

Figure 2.2-1 Maximum Allowed PORV Setpoint for the Cold Overpressure Mitigation System

Figure 14.9
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Table 2.2-1
Callaway Plant COMS Maximum Allowable PORV Setpoints at 28 EFPY

Maximum Allowable Function Generator Setpoints (Breakpoints)			
Breakpoint Number	**Temperature RCS (°F)**	**High Setpoint (psig)**	**Low Setpoint (psig)**
1	70	477	442
2	80	477	442
3	90	477	442
4	100	477	442
5	180	477	442
6	230	498	449
7	238	752	695
8	280	752	695
9	350	2335	2185

Note: Setpoints assume that all 4 or less RCP's are in operation.

3.0 Reactor Vessel Material Surveillance Program

The reactor vessel material surveillance program is in compliance with Appendix H to 10 CFR 50, entitled "Reactor Vessel Material Surveillance Program Requirements" and Section 5.3 of the Callaway Final Safety Analysis Report. The surveillance capsule withdrawal schedule is presented in FSAR Table 5.3-10. The surveillance capsule reports are as follows:

1. WCAP-11374, Revision 1, June 1987, "Analysis of Capsule U from the Union Electric Company Callaway Unit 1 Reactor Vessel Radiation Surveillance Program."

2. WCAP-12946, June 1991, "Analysis of Capsule Y from the Union Electric Company Callaway Unit 1 Reactor Vessel Radiation Surveillance Program."

3. WCAP-14895, July 1997, ""Analysis of Capsule V from the Union Electric Company Callaway Unit 1 Reactor Vessel Radiation Surveillance Program."

4. WCAP-15400, June 2000, ""Analysis of Capsule X from the AmerenUE Callaway Unit 1 Reactor Vessel Radiation Surveillance Program."

4.0 Reactor Vessel Surveillance Data Credibility

Regulatory Guide 1.99, Revision 2, describes general procedures acceptable to the NRC staff for calculating the effects of neutron radiation embrittlement of the low-alloy steels currently used for light-water-cooled reactor vessels. Position C.2 of Regulatory Guide 1.99, Revision 2, describes the method for calculating the adjusted reference temperature and Charpy upper-shelf energy of reactor vessel beltline materials using surveillance capsule data. The methods of Position C.2 can only be applied when two or more credible surveillance data sets become available from the reactor in question.

To date four surveillance capsules have been removed and analyzed from the Callaway Plant reactor vessel. To use these surveillance data sets, they must be shown to be credible. In accordance with the discussion of Regulatory Guide 1.99, Revision 2, there are five requirements that must be met for the surveillance data to be judged credible.

The purpose of this evaluation is to apply the credibility requirements of the Regulatory Guide 1.99, Revision 2, to the Callaway Plant reactor vessel surveillance data and determine if the Callaway Plant surveillance data is credible.

Criterion 1: Materials in the capsules should be those judged most likely to be controlling with regard to radiation embrittlement.

The beltline region of the reactor vessel is defined in Appendix G to 10 CFR Part 50, "Fracture Toughness Requirements," as follows:

> "the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage."

The Callaway Plant reactor vessel consists of the following beltline region materials:

- Intermediate shell plate R2707-1,
- Intermediate shell plate R2707-2,
- Intermediate shell plate R2707-3,
- Lower shell plate R2708-1,
- Lower shell plate R2708-2,
- Lower shell plate R2708-3, and
- Intermediate shell longitudinal weld seams, lower shell longitudinal weld seams, and an intermediate to lower shell circumferential weld seam. All vessel beltline weld seams were fabricated with weld wire heat number 90077. The intermediate to lower shell circumferential welds seam 101-171 was fabricated with Flux Type 124 Lot Number 1061. The intermediate and lower shell longitudinal weld seams were fabricated with Flux Type 0091 Lot Number 0842.

The Callaway Plant surveillance program utilizes longitudinal and transverse test specimens from lower shell plate R2708-1. The surveillance weld metal was fabricated with weld wire heat number 90077, Flux Type 124, Lot Number 1061.

At the time when the surveillance program was selected it was believed that copper and phosphorus were the elements most important to embrittlement of reactor vessel steels. Since all plate material had approximately the same content of copper and phosphorus, lower shell plate R2708-1 was chosen for the surveillance program since it had the highest RT_{NDT} and the lowest initial upper shelf energy of the plate material. In addition, the current pressurized thermal

shock (PTS) evaluation shows that if surveillance data is not used, lower shell plate R2708-1 is the plate that is predicted to have the highest embrittlement rate.

Per Regulatory Guide 1.99, Revision 2, "weight-percent copper" and "weight-percent nickel" are the best-estimate values for the material, which will normally be the mean of the measured values for a plate or forging or for weld samples made with the weld wire heat number that matches the critical vessel weld. Since the surveillance weld metal was made with the same weld wire heat as all of the vessel beltline weld seams, it is representative of the limiting beltline weld metal.

Based on the above discussion, the Callaway Plant surveillance materials are those judged most likely to be controlling with regard to radiation embrittlement and the Callaway Plant surveillance program meets this criteria.

Criterion 2: Scatter in the plots of Charpy energy versus temperature for the irradiated and unirradiated conditions should be small enough to permit the determination of the 30 ft-lb temperature and upper shelf energy unambiguously.

Plots of Charpy energy versus temperature for the unirradiated and irradiated condition are presented in WCAP-15400, June 2000, "Analysis of Capsule X from AmerenUE Callaway Unit 1 Reactor Vessel Radiation Surveillance Program."

Based on engineering judgment, the scatter in the data presented in these plots is small enough to permit the determination of the 30 ft-lb temperature and the upper shelf energy of the Callaway Plant surveillance materials unambiguously. Hence, the Callaway Plant surveillance program meets this criterion.

Criterion 3: When there are two or more sets of surveillance data from one reactor, the scatter of ΔRT_{NDT} values about a best fit line drawn as described in Regulatory Position 2.1 normally should be less than 28°F for welds and 17°F for base material. Even if the fluence range is large (two or more orders of magnitude), the scatter should not exceed twice those values. Even if the data fail this criterion for use in shift calculations, they may be credible for determining decrease in upper shelf energy if the upper shelf can be clearly determined, following the definition given in ASTM E185-82.

The functional form of the least squares method as described in Regulatory Position 2.1 will be utilized to determine a best-fit line for this data and to determine if the scatter of the ΔRT_{NDT} values about this line is less than 28°F for welds and less than 17°F for the plate.

Following is the calculation of the best-fit line as described in Regulatory Position 2.1 of Regulatory Guide 1.99, Revision 2.

Table 4.0-1
Callaway Plant Surveillance Capsule Data

Material	Capsule	Capsule f[(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	FF x ΔRT_{NDT}	FF^2
Lower Shell R2708-1 (Longitudinal)	U	0.331	0.696	0.0[(e)]	0.0	0.48
	Y	1.27	1.07	25.15	26.91	1.14
	V	2.52	1.25	16.45	20.56	1.56
	X	3.33	1.32	25.71	33.94	1.74
Lower Shell Plate R2708-1 (Transverse)	U	0.331	0.696	25.86	18.00	0.48
	Y	1.27	1.07	46.39	49.64	1.14
	V	2.52	1.25	44.82	56.03	1.56
	X	3.33	1.32	30.77	40.62	1.74
	Sum:		8.6411	215.15	245.7	9.84
Surveillance Weld Material[(d)]	$CF_{05} = \Sigma(FF * \Delta RT_{NDT})/\Sigma(FF^2) = (245.70°F)/(9.84) = 25.0°F$					
	U	0.331	0.696	68.53[(d)]	47.70	0.48
	Y	1.27	1.07	36.92[(d)]	39.50	1.14
	V	2.52	1.25	48.21[(d)]	60.26	1.56
	X	3.33	1.32	51.81[(d)]	68.39	1.74
	Sum:		4.32	205.47	215.85	4.92
	$CF_{Surv.\ Weld} = \Sigma(FF* \Delta RT_{NDT})/\Sigma(FF^2) = (215.85°F)/(4.92) = 43.9°F$					

Notes:

(a) f = calculated fluence from capsule X dosimetry analysis results, (x 10^{19} n/cm^2, E > 1.0 MeV). These values were reevaluated as part of capsule X analysis (See Section 6 of WCAP-15400)

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift.

(d) These measured ΔRT_{NDT} values do not include the adjustment ratio procedure of Reg. Guide 1.99, Revision 2, Position 2.1, since this calculation is based on the actual surveillance weld metal measured shift values and based on the copper and nickel content the ratio would be 1. In addition, the only surveillance data available is from the Callaway Unit 1 reactor vessel; therefore, no temperature adjustment is required.

(e) The actual value is -7.33, but for conservatism a value of zero is considered.

The scatter of ΔRT_{NDT} values about the functional form of a best-fit line drawn as described in Regulatory Position 2.1 is presented in Table 4.0-2.

Per the 27th Edition of the CRC Standard Mathematical Tables (page 497), for a straight line fit by the method of least squares, the values of b_0 and b_1 are obtained by solving the normal equations

$$nb_0 + b_1\Sigma x_i = \Sigma y_i \quad \text{and}$$

$$b_0\Sigma x_i + b_1\Sigma x_i^2 = \Sigma x_i y_i$$

These equations can be re-written as follows ($b_0 = a$ and $b_1 = b$):

$$\sum_{i=1}^{n} y_i = an + b\sum_{i=1}^{n} x_i \quad \text{and}$$

$$\sum_{i=1}^{n} x_i y_i = a\sum_{i=1}^{n} x_i + b\sum_{i=1}^{n} x_i^2$$

Lower shell plate R2708-1:

Based on the data provided in Table 4.0-1 these equations become:

$$215.15 = 3a + 8.6411b \quad \text{and}$$

$$245.70 = 8.6411 + 9.84b$$

Thus, b = 24.8405 and a = 0.1669, and the equation of the straight line which provides the best fit line in the sense of least squares is:

$$Y' = 24.8405\ (X) + 0.1669$$

The scatter in predicting a value Y corresponding to a given X value is:

$$e = Y - Y'$$

Table 4.0-2 Callaway Plant Lower Shell Plate R2708-1

Base Material	FF	Measured ΔRT_{NDT} (30 ft-lb)(°F)	Best Fit[(a)] ΔRT_{NDT} (°F)	Scatter of ΔRT_{NDT} (°F)	< 17°F (Base Metals)
Lower Shell Plate R2708-1 (Longitudinal)	0.696	0.00	17.4	-17.4	NO
	1.07	25.15	26.75	-1.6	Yes
	1.25	16.45	31.25	-14.8	Yes
	1.32	25.71	33.0	-7.29	Yes
Lower Shell Plate R2708-1 (Transverse)	0.696	25.86	17.4	8.46	Yes
	1.07	46.39	26.75	19.64	NO
	1.25	44.82	31.25	13.57	Yes
	1.32	30.77	33.0	-2.23	Yes

Notes:
(a) Best Fit Line Per Equation 2 of Reg. Guide 1.99, Rev. 2 Position 1.1

Table 4.0-2 indicates that one measured plate ΔRT_{NDT} value is below the lower bound 1σ of 17°F by less than 1°F. Meaning the best fit line is slightly over predicting this measured ΔRT_{NDT} value. Table 4.0-2 also indicates that one measured plate ΔRT_{NDT} value is above the upper bound 1σ of 17°F by less than 3°F. From a statistical point of view $\pm$ 1σ (17°F) would be expected to encompass 68% of the data. Therefore, it is still statistically acceptable to have two of the plate data points fall outside the $\pm$ 1σ bounds. The fact that two of the measured plate ΔRT_{NDT} values are outside of the 1σ bound of 17°F can be attributed to several factors, such as 1) the inherent uncertainty in Charpy test data, 2) the use of a symmetric hyperbolic tangent Charpy curve fitting program versus asymmetric tangent Charpy curve fitting program or hand drawn curves using engineering judgment, and/or 3) rounding errors.

In summary, all measured plate is within acceptable range. Therefore, the plate data meets this criteria.

Weld Metal:

Based on the data provided in Table 4.0-1 the equations become:

$$205.47 = 3a + 4.321b \quad \text{and}$$

$$215.13 = 4.321a + 4.897b$$

Thus, b = 60.9 and a = -19.3, and the equation of the straight line which provides the best fit in the sense of the least squares is:

$$Y' = 60.9\,(X) - 19.3$$

The scatter in predicting a value of Y corresponding to a given X value is:

$$E = Y - Y'$$

Table 4.0-3 Callaway Plant Surveillance Weld Metal

FF	Measured ΔRT_{NDT} (30 ft-lb) (°F)	Best Fit[(a)] ΔRT_{NDT} (°F)	Scatter of ΔRT_{NDT} (°F)	< 28°F (Weld Metal)
0.696	68.53	30.55	37.98	NO
1.07	36.92	46.97	-10.05	Yes
1.25	48.21	54.88	-6.67	Yes
1.32	51.81	57.95	-6.14	Yes

Notes:
(a) Best Fit Line Per Equation 2 of Reg. Guide 1.99, Rev. 2 Position 1.1.

One measured weld ΔRT_{NDT} value is below the lower 1σ at 28°F. The fact that one of the measured weld ΔRT_{NDT} values is out of 1σ bound of 28°F can be attributed to several factors, such as 1) the inherent uncertainty in Charpy test data, 2) the use of a symmetric hyperbolic tangent Charpy curve fitting program versus asymmetric tangent Charpy curve fitting program or hand drawn curves using engineering judgment, and/or 3) rounding errors.

Criterion 4: The irradiation temperature of the Charpy specimens in the capsule should match the vessel wall temperature at the cladding/base metal interface within $\pm$ 25°F.

The capsule specimens are located in the reactor between the neutron pads and the vessel wall and are positioned opposite the center of the core. The test capsules are in baskets attached to the neutron pads. The location of the specimens with respect to the reactor vessel beltline provides assurance that the reactor vessel wall and the specimens experience equivalent operating conditions such that the temperatures will not differ by more than 25°F. Hence this criterion is met.

Criterion 5: The surveillance data for the correlation monitor material in the capsule should fall within the scatter band of the data base for that material.

The Callaway Plant surveillance program does not contain correlation monitor material. Therefore, the criterion is not applicable to the Callaway Plant surveillance program.

Based on the preceding positive responses to all five criteria of Regulatory Guide 1.99, Revision 2, Section B, the Callaway Plant surveillance data is credible.

5.0 Supplemental Data Tables

Table 5.0-1 Comparison of Callaway Plant Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decreases with Regulatory Guide 1.99, Revision 2, Predictions.

Table 5.0-2 Calculation of Chemistry Factors Using Surveillance Capsule Data.

Table 5.0-3 Provides the unirradiated reactor vessel toughness data. The boltup temperature is also included in this Table.

Table 5.0-4 Provides a summary of the pressure vessel neutron fluence values at 28 EFPY used for the calculation of the ART values.

Table 5.0-5 Provides a summary of the adjusted reference temperature (ART) for reactor vessel beltline materials at the 1/4T and 3/4T locations for 28 EFPY.

Table 5.0-6 Shows the calculation of the ART at 28 EFPY for the limiting reactor vessel material (lower shell plate R2708-1).

Table 5.0-7 Provides RT_{PTS} values for 35 EFPY.

6.0 References

1. Technical Specification 5.6.6, "Reactor Coolant System (RCS) PRESSURE AND TEMPERATURE LIMITS REPORT (PTLR)."

2. NRC letter dated [March 24, 2000], [CALLAWAY PLANT, UNIT 1 – ISSUANCE OF AMENDMENT RE: PRESSURE TEMPERATURE LIMITS REPORT]

3. WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoint and RCS Heatup and Cooldown Limit Curves," May, 2004.

4. WCAP-16654-NP, Revision 0, "Callaway Unit 1 Heatup and Cooldown Limit Curves for Normal Operation," November 2006.

5. Westinghouse Letter, SCP-06-66, "Final LTOPS Setpoint Analysis for Increased PORV stroke time", November 20, 2006.

Table 5.0-1
Comparison of Callaway Unit 1 Surveillance Material 30 ft-lb Transition Temperature Shifts and Upper Shelf Energy Decreases with Regulatory Guide 1.99, Revision 2, Predictions

Materials	Capsule	Fluence ($\times 10^{19}$ n/cm^2)	30 ft-lb Transition Temperature Shift		Upper Shelf Energy Decrease	
			Predicted (°F) [a]	Measured (°F) [b]	Predicted (%) [a]	Measured (%) [c]
Lower Shell Plate R2708-1 (Longitudinal)	U	0.331	30.62	0.0[d]	14.5	0
	Y	1.27	47.08	25.15	20	6
	V	2.52	55.0	16.45	23.5	0
	X	3.33	58.08	25.71	25	5
Lower Shell Plate R2708-1 (Transverse)	U	0.331	30.62	25.86	14.5	11
	Y	1.27	47.08	46.39	20	13
	V	2.52	55.0	44.82	23.5	3
	X	3.33	58.08	30.77	25	5
Weld Metal	U	0.331	22.13	68.53	14.5	11
	Y	1.27	34.02	36.92	20	14
	V	2.52	39.75	48.21	23.5	8
	X	3.33	41.98	51.81	25	8
HAZ Metal	U	0.331	--	65.93	--	0
	Y	1.27	--	56.38	--	14
	V	2.52	--	56.1	--	0
	X	3.33	--	42.11	--	0

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 4.1.

(c) Values are based on the definition of upper shelf energy given in ASTM E185-85.

(d) Actual measured value for ΔRT_{NDT} is -7.33. This physically should not occur; therefore for conservatism a value of zero will be used.

Figure 14.9
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Table 5.0-2
Calculation of Chemistry Factors Using Surveillance Capsule Data

Material	Capsule	Capsule f[(a)]	FF[(b)]	ΔRT_{NDT}[(c)]	FF x ΔRT_{NDT}	FF^2
Lower Shell R2708-1 (Longitudinal)	U	0.331	0.696	0.0[(e)]	0.0	0.48
	Y	1.27	1.07	25.15	26.91	1.14
	V	2.52	1.25	16.45	20.56	1.56
	X	3.33	1.32	25.71	33.94	1.74
Lower Shell Plate R2708-1 (Transverse)	U	0.331	0.696	25.86	18.00	0.48
	Y	1.27	1.07	46.39	49.64	1.14
	V	2.52	1.25	44.82	56.03	1.56
	X	3.33	1.32	30.77	40.62	1.74
	Sum:				245.70	9.84
Surveillance Weld Material[(d)]	$CF_{05} = \Sigma(FF * \Delta RT_{NDT})/\Sigma(FF^2) = (245.70°F)/(9.84) = 25.0°F$					
	U	0.331	0.696	62.36[(d)]	43.40	0.48
	Y	1.27	1.07	33.60[(d)]	35.95	1.14
	V	2.52	1.25	43.87[(d)]	54.84	1.56
	X	3.33	1.32	47.15[(d)]	62.24	1.74
	Sum:				196.43	4.92
	$CF_{Surv.\ Weld} = \Sigma(FF* \Delta RT_{NDT})/\Sigma(FF^2) = (196.43°F)/(4.92) = 39.9°F$					

Notes:

(a) f = calculated fluence from capsule X dosimetry analysis results, (x 10^{19} n/cm^2, E > 1.0 MeV). These values were reevaluated as part of capsule X analysis (See Section 6 of WCAP-15400)

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift.

(d) The surveillance weld metal ΔRT_{NDT} values have been adjusted by a ratio factor or 0.91.

(e) The actual value is -7.33, but for conservatism a value of zero is considered.

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

Table 5.0-3			
Reactor Vessel Beltline Material Unirradiated Toughness Properties			
Material Description	Cu (%)	Ni (%)	Initial RT_{NDT}[(a)]
Closure Head Flange R2704-1	--	0.73	30°F[(c)]
Vessel Flange R2701-1	--	0.74	40°F[(c)]
Intermediate Shell Plate R2707-1	0.05	0.58	40°F
Intermediate Shell Plate R2707-2	0.06	0.61	10°F
Intermediate Shell Plate R2707-3	0.06	0.62	-10°F
Lower Shell Plate R2708-1	0.07	0.58	50°F
Lower Shell Plate R2708-2	0.06	0.57	10°F
Lower Shell Plate R2708-3	0.08	0.62	20°F
Intermediate and Lower Shell Longitudinal Weld Seams[(b)]	0.04	0.05	-60°F
Intermediate to Lower Shell Circumferential Weld Seam[(b)]	0.04	0.05	-60°F
Surveillance Weld[(b)(c)]	0.045	0.065	--

Notes:

(a) The initial RT_{NDT} values for the plates and welds are based on measured data (WCAP-12948).

(b) All vessel beltline weld seams were fabricated with weld wire heat number 90077. The intermediate to lower shell circumferential weld seam 101-171 was fabricated with Flux Type 124 Lot Number 1061. The intermediate and lower shell longitudinal weld seams were fabricated with Flux Type 0091 Lot 0842. the surveillance weld metal was fabricated with weld wire heat number 90077, Flux Type 124 Lot Number 1061. Per Regulatory Guide 1.99, Revision 2, "weight percent copper" and "weight percent nickel" are the best-estimate values for the material, which will normally be the mean of the measured values for a plate or forging or for weld samples made with the weldwire heat number that matches the critical vessel weld. The surveillance weld metal was made with the same weld wire heat as all of the vessel beltline weld seams and is therefore, representative of all of the beltline weld seams.

(c) These values are used for considering flange requirements for the heatup/cooldown curves. Per the methodology given in WCAP-14040-A, the minimum boltup temperature is 70°F.

Table 5.0-4 **Fluence (10^{19} n/cm^2, E > 1.0 MeV) on the Pressure Vessel Clad/Base Metal Interface for Callaway Plant**				
EFPY	**0°**	**15°**	**30°**	**45°**
12.40	0.445	0.649	0.756	0.768
16	0.565	0.822	0.956	0.964
24	0.832	1.21	1.40	1.40
32	1.10	1.59	1.85	1.83
54	1.83	2.64	3.07	3.02

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

Table 5.0-5 Summary of Adjusted Reference Temperature (ART) Values at the 1/4T and 3/4T Locations for 28 EFPY		
Material	**28 EFPY ART[(a)]**	
	¼ T ART (°F)	**¾ T ART (°F)**
Intermediate Shell Plate R2707-1	101	84
Intermediate Shell Plate R2707-2	81	62
Intermediate Shell Plate R2707-3	61	42
Lower Shell Plate R2708-1	128[(b)]	112[(b)]
Using Surveillance Capsule Data	92	85
Lower Shell Plate R2708-2	81	62
Lower Shell Plate R2708-3	105	90
Intermediate & Lower Shell Longitudinal Weld Seams 101-124A & 101-142A (90° Azimuth)	-3	-19
Using Surveillance Capsule Data	8	-4
Intermediate & Lower Shell Longitudinal Weld Seams 101-124B&C and 101-142B&C (210° & 330° Azimuth)	-3	-19
Using Surveillance Capsule Data	8	-4
Intermediate to Lower Shell Circumferential Weld Seams 101-171	-3	-19
Using Surveillance Capsule Data	8	-4

Notes:

(a) ART = Initial RT_{NDT} + ΔRT_{NDT} + Margin (°F)

(b) These ART values are used to generate the heatup and cooldown curves.

When two or more credible surveillance data sets become available, the data sets may be used to determine ART values as described in Regulatory Guide 1.99, Revision2, Position 2.1. If the ART values based on surveillance capsule data are larger than those calculated per Regulatory Guide 1.99, Revision 2, Position 2.1, the surveillance data must be used. If the surveillance capsule data gives lower values, either may be used.

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

Table 5.0-6 **Calculation of Adjusted Reference Temperature Values at 28 EFPY for the Limiting Callaway Plant Reactor Vessel Material (Lower Shell Plate R2708-1)**		
Parameter	**ART Value**	
Location	**¼ T**	**¾ T**
Chemistry Factor, CF (°F)	44.0	44.0
Fluence, f (10^{19} n/cm^2)[(a)]	0.9682	0.3437
Fluence Factor, FF[(b)]	0.991	0.706
ΔRTNDT = CF x FF, (°F)	43.60	31.06
Initial RT_{NDT}, I (°F)	50	50
Margin, M (°F)[(c)]	34	31.06
ART = I + (CF x FF) + M (°F) Per Regulatory Guide 1.99, Rev. 2	128	112

Notes:

(a) Fluence, f, is based upon f_{surf} (10^{19} n/cm^2, E > 1.0 MeV) = 1.625 at 28 EFPY. The Callaway Plant reactor vessel wall thickness is 8.63 inches at the beltline region.

(b) Fluence Factor, FF, per Regulatory Guide 1.99, Revision 2, is defined as $FF = f^{(0.28-0.10*\log f)}$.

(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} is a measured value. The standard deviation for ΔRT_{NDT} term σ_Δ, is 17°F for the plate, except that σ_Δ need not exceed 0.5 times the mean value of ΔRT_{NDT}.

Table 5.0-7
RT_{PTS} Calculations for Callaway Plant Beltline Region Materials at 35 EFPY[d]

Material	Fluence (10^{19} n/cm^2, E > 1.0 MeV)	FF	CF (°F)	ΔRT_{PTS}[c] (°F)	Margin (°F)	$RT_{NDT(U)}$[a] (°F)	RT_{PTS}[b] (°F)
Intermediate Shell Plate R2707-1	2.074	1.20	31.0	37.2	34.0	40	111
Intermediate Shell Plate R2707-2	2.074	1.20	37.0	44.4	34.0	10	88
Intermediate Shell Plate R2707-3	2.074	1.20	37.0	44.4	34.0	-10	68
Lower Shell Plate R2708-1	2.074	1.20	44.0	52.8	34.0	50	137
Using S/C Data	2.074	1.20	25.0	30	17.0	50	97
Lower Shell Plate R2708-2	2.074	1.20	37.0	44.4	34.0	10	88
Lower Shell Plate R2708-3	2.074	1.20	51.0	61.2	34.0	20	115
Inter. & Lower Shell Long. Weld Seams 101-124A & 101-142A (90° Azimuth)	1.167	1.04	29.7	30.9	30.9	-60	2
Using S/C Data	1.167	1.04	39.9	41.49	28.0	-60	9.5
Inter. & Lower Shell Long. Weld Seams 101-124B&C and 101-142B&C (210° & 330° Azimuth)	2.042	1.19	29.7	35.3	35.3	-60	11
Using S/C Data	2.042	1.19	39.9	47.48	28.0	-60	15.48
Inter. to Lower Shell Circumferential Weld Seams 101-171	2.074	1.20	29.7	35.6	35.6	-60	11
Using S/C Data	2.074	1.20	39.9	47.88	28.0	-60	15.88

Notes:
(a) Initial RT_{NDT} values are measured values
(b) $RT_{PTS} = RT_{NDT(U)} + Margin + \Delta RT_{PTS}$
(c) $\Delta RT_{PTS} = CF * FF$
(d) Projected no. of EFPY at the EOL.