Attachment
ULNRC-05199

E170.0130



# FIGURE 14.9

# CALLAWAY PLANT

# PRESSURE AND TEMPERATURE LIMITS REPORT

**Revision 3**



C721
91-Total pgs.

## 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 Specification (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 Amendment No. [134], (Ref. 3).

The methodology listed in WCAP-14040-NP-A, Revision 2 was used with one exception:

a) ASME Code Case N-514 was used.

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 (3107 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.

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.

2.2 (continued)

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 with incorporation of 10% relaxation of the Appendix G limits in accordance with ASME Code Case N-514. 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.

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: LOWER SHELL PLATE R2708-3
LIMITING ART VALUES AT 20 EFPY: 1/4T, 100.4°F
3/4T, 84.2 °F

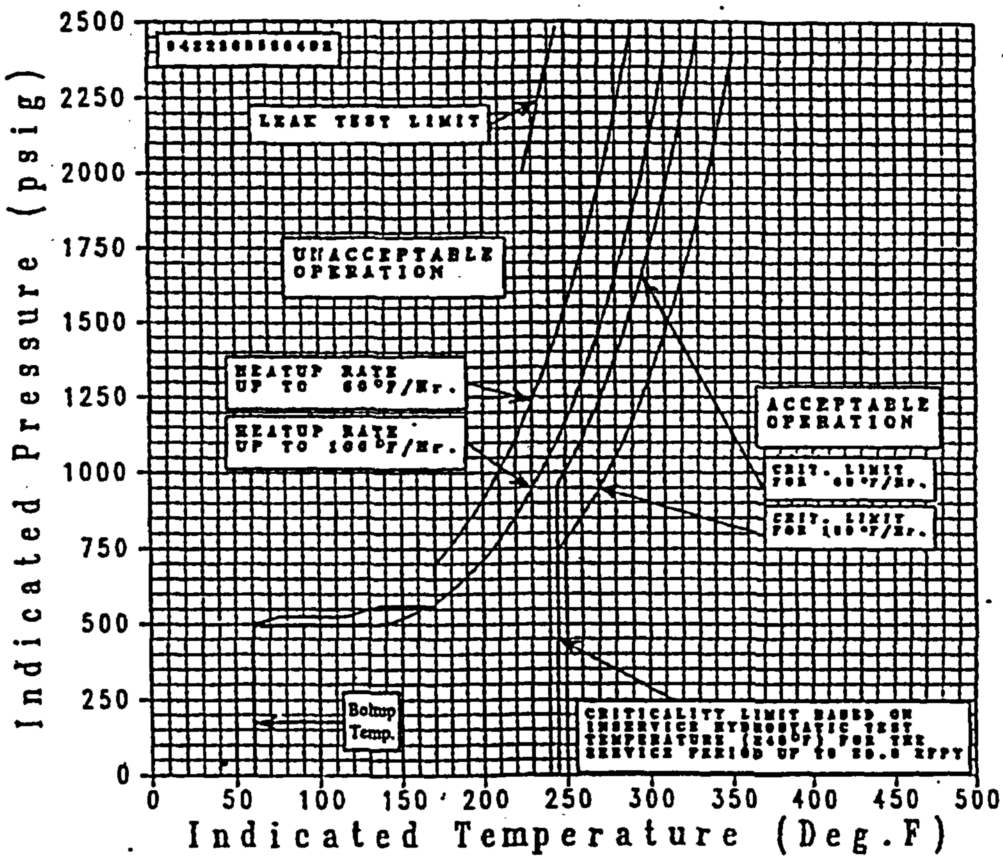


FIGURE 2.1-1 Callaway Unit 1 Reactor Coolant System Heatup Limitations (Heatup Rates of 60 and 100°F/hr) Applicable for the First 20 EFPY (With Margins for Instrumentation Errors). Includes vessel flange requirements of 170°F and 561 psig per 10CFR 50, Appendix G.

## Figure 14.9
## PRESSURE AND TEMPERATURE LIMITS REPORT

**TABLE 2.1-1**
**Callaway Plant Heatup Limits at 20 EFPY With Margins for Instrumentation Errors**

| 60°F/hr | | 60°F/hr Crit. Limit | | 100°F/hr | | 100°F/hr Crit. Limit | | Leak Test Limit | |
|---|---|---|---|---|---|---|---|---|---|
| Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) |
| 60 | 0 | 245 | 0 | 60 | 0 | 245 | 0 | 225 | 2000 |
| 60 | 500 | 245 | 544 | 60 | 494 | 245 | 546 | 245 | 2485 |
| 65 | 507 | 245 | 533 | 65 | 494 | 245 | 531 | | |
| 70 | 516 | 245 | 527 | 70 | 494 | 245 | 519 | | |
| 75 | 524 | 245 | 524 | 75 | 494 | 245 | 509 | | |
| 80 | 524 | 245 | 524 | 80 | 494 | 245 | 502 | | |
| 85 | 524 | 245 | 527 | 85 | 494 | 245 | 497 | | |
| 90 | 524 | 245 | 533 | 90 | 494 | 245 | 494 | | |
| 95 | 524 | 245 | 541 | 95 | 494 | 245 | 494 | | |
| 100 | 524 | 245 | 551 | 100 | 494 | 245 | 495 | | |
| 105 | 524 | 245 | 563 | 105 | 494 | 245 | 499 | | |
| 110 | 524 | 245 | 577 | 110 | 494 | 245 | 504 | | |
| 115 | 527 | 245 | 593 | 115 | 494 | 245 | 511 | | |
| 120 | 533 | 245 | 611 | 120 | 494 | 245 | 520 | | |
| 125 | 541 | 245 | 631 | 125 | 494 | 245 | 531 | | |
| 130 | 551 | 245 | 653 | 130 | 495 | 245 | 543 | | |
| 135 | 561 | 245 | 677 | 135 | 499 | 245 | 557 | | |
| 140 | 561 | 245 | 703 | 140 | 504 | 245 | 574 | | |
| 145 | 561 | 245 | 732 | 145 | 511 | 245 | 592 | | |
| 150 | 561 | 245 | 763 | 150 | 520 | 245 | 612 | | |
| 155 | 561 | 245 | 796 | 155 | 531 | 245 | 634 | | |
| 160 | 561 | 245 | 832 | 160 | 543 | 245 | 658 | | |
| 165 | 561 | 245 | 871 | 165 | 557 | 245 | 685 | | |
| 170 | 561 | 245 | 912 | 170 | 561 | 245 | 714 | | |
| 170 | 703 | 245 | 957 | 170 | 574 | 245 | 745 | | |
| 175 | 732 | 250 | 1006 | 175 | 592 | 250 | 779 | | |
| 180 | 763 | 255 | 1058 | 180 | 612 | 255 | 816 | | |
| 185 | 796 | 260 | 1113 | 185 | 634 | 260 | 856 | | |
| 190 | 832 | 265 | 1173 | 190 | 658 | 265 | 899 | | |
| 195 | 871 | 270 | 1238 | 195 | 685 | 270 | 946 | | |
| 200 | 912 | 275 | 1306 | 200 | 714 | 275 | 996 | | |
| 205 | 957 | 280 | 1381 | 205 | 745 | 280 | 1049 | | |
| 210 | 1006 | 285 | 1460 | 210 | 779 | 285 | 1107 | | |
| 215 | 1058 | 290 | 1544 | 215 | 816 | 290 | 1169 | | |
| 220 | 1113 | 295 | 1636 | 220 | 856 | 295 | 1236 | | |
| 225 | 1173 | 300 | 1732 | 225 | 899 | 300 | 1307 | | |
| 230 | 1238 | 305 | 1837 | 230 | 946 | 305 | 1384 | | |
| 235 | 1306 | 310 | 1948 | 235 | 996 | 310 | 1467 | | |
| 240 | 1381 | 315 | 2066 | 240 | 1049 | 315 | 1555 | | |
| 245 | 1460 | 320 | 2193 | 245 | 1107 | 320 | 1649 | | |
| 250 | 1544 | 325 | 2328 | 250 | 1169 | 325 | 1750 | | |
| 255 | 1636 | 330 | 2472 | 255 | 1236 | 330 | 1858 | | |
| 260 | 1732 | | | 260 | 1307 | 335 | 1973 | | |
| 265 | 1837 | | | 265 | 1384 | 340 | 2096 | | |
| 270 | 1948 | | | 270 | 1467 | 345 | 2227 | | |
| 275 | 2066 | | | 275 | 1555 | 350 | 2367 | | |
| 280 | 2193 | | | 280 | 1649 | | | | |
| 285 | 2328 | | | 285 | 1750 | | | | |
| 290 | 2472 | | | 290 | 1858 | | | | |
| | | | | 295 | 1973 | | | | |
| | | | | 300 | 2096 | | | | |
| | | | | 305 | 2227 | | | | |
| | | | | 310 | 2367 | | | | |

## Figure 14.9
## PRESSURE AND TEMPERATURE LIMITS REPORT

<u>MATERIAL PROPERTY BASIS</u>

LIMITING MATERIAL: LOWER SHELL PLATE R2708-3
LIMITING ART VALUES AT 20 EFPY: 1/4T, 100.4°F
3/4T, 84.2 °F

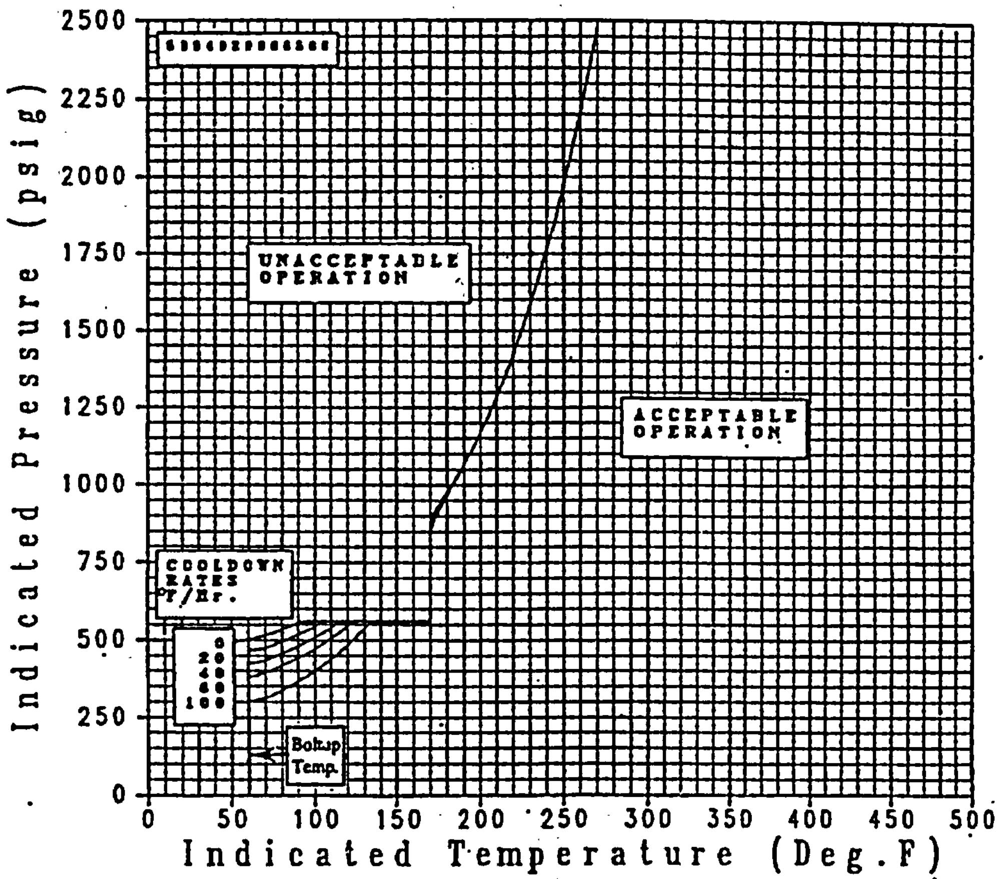


FIGURE 2.1-2 Callaway Unit 1 Reactor Coolant System Cooldown Limitations (Cooldown Rates of 0, 20, 40, 60 and 100°F/hr) Applicable for the First 20 EFPY (With Margins for Instrumentation Errors). Includes vessel flange requirements of 170°F and 561 psig per 10CFR 50, Appendix G

## Figure 14.9
## PRESSURE AND TEMPERATURE LIMITS REPORT

| TABLE 2.1-2<br>Callaway Plant Cooldown Limits at 20 EFPY<br>With Margins for Instrumentation Errors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Steady State | | 20°F/hr | | 40°F/hr | | 60°F/hr | | 100°F/hr | |
| Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) | Temp. (°F) | Press. (psig) |
| 60 | 0 | 60 | 0 | 60 | 0 | 60 | 0 | 60 | 0 |
| 60 | 500 | 60 | 468 | 60 | 427 | 60 | 386 | 60 | 302 |
| 65 | 507 | 65 | 468 | 65 | 427 | 65 | 386 | 65 | 302 |
| 70 | 516 | 70 | 476 | 70 | 436 | 70 | 396 | 70 | 313 |
| 75 | 525 | 75 | 486 | 75 | 446 | 75 | 406 | 75 | 325 |
| 80 | 534 | 80 | 496 | 80 | 457 | 80 | 418 | 80 | 338 |
| 85 | 544 | 85 | 506 | 85 | 468 | 85 | 430 | 85 | 351 |
| 90 | 555 | 90 | 518 | 90 | 481 | 90 | 443 | 90 | 366 |
| 95 | 561 | 95 | 531 | 95 | 494 | 95 | 457 | 95 | 382 |
| 100 | 561 | 100 | 544 | 100 | 508 | 100 | 472 | 100 | 400 |
| 105 | 561 | 105 | 559 | 105 | 524 | 105 | 489 | 105 | 419 |
| 110 | 561 | 110 | 561 | 110 | 540 | 110 | 506 | 110 | 439 |
| 115 | 561 | 115 | 561 | 115 | 558 | 115 | 526 | 115 | 461 |
| 120 | 561 | 120 | 561 | 120 | 561 | 120 | 546 | 120 | 485 |
| 125 | 561 | 125 | 561 | 125 | 561 | 125 | 561 | 125 | 511 |
| 130 | 561 | 130 | 561 | 130 | 561 | 130 | 561 | 130 | 539 |
| 135 | 561 | 135 | 561 | 135 | 561 | 135 | 561 | 135 | 561 |
| 140 | 561 | 140 | 561 | 140 | 561 | 140 | 561 | 140 | 561 |
| 145 | 561 | 145 | 561 | 145 | 561 | 145 | 561 | 145 | 561 |
| 150 | 561 | 150 | 561 | 150 | 561 | 150 | 561 | 150 | 561 |
| 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 | 899 | 170 | 885 | 170 | 873 | 170 | 864 | 170 | 856 |
| 175 | 937 | 175 | 925 | 175 | 917 | 175 | 911 | 175 | 910 |
| 180 | 977 | 180 | 969 | 180 | 963 | 180 | 961 | 180 | 969 |
| 185 | 1020 | 185 | 1015 | 185 | 1014 | 185 | 1016 | | |
| 190 | 1066 | 190 | 1065 | | | | | | |
| 195 | 1116 | | | | | | | | |
| 200 | 1170 | | | | | | | | |
| 205 | 1228 | | | | | | | | |
| 210 | 1289 | | | | | | | | |
| 215 | 1355 | | | | | | | | |
| 220 | 1426 | | | | | | | | |
| 225 | 1503 | | | | | | | | |
| 230 | 1584 | | | | | | | | |
| 235 | 1672 | | | | | | | | |
| 240 | 1766 | | | | | | | | |
| 245 | 1866 | | | | | | | | |
| 250 | 1973 | | | | | | | | |
| 255 | 2088 | | | | | | | | |
| 260 | 2211 | | | | | | | | |
| 265 | 2342 | | | | | | | | |
| 270 | 2482 | | | | | | | | |

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

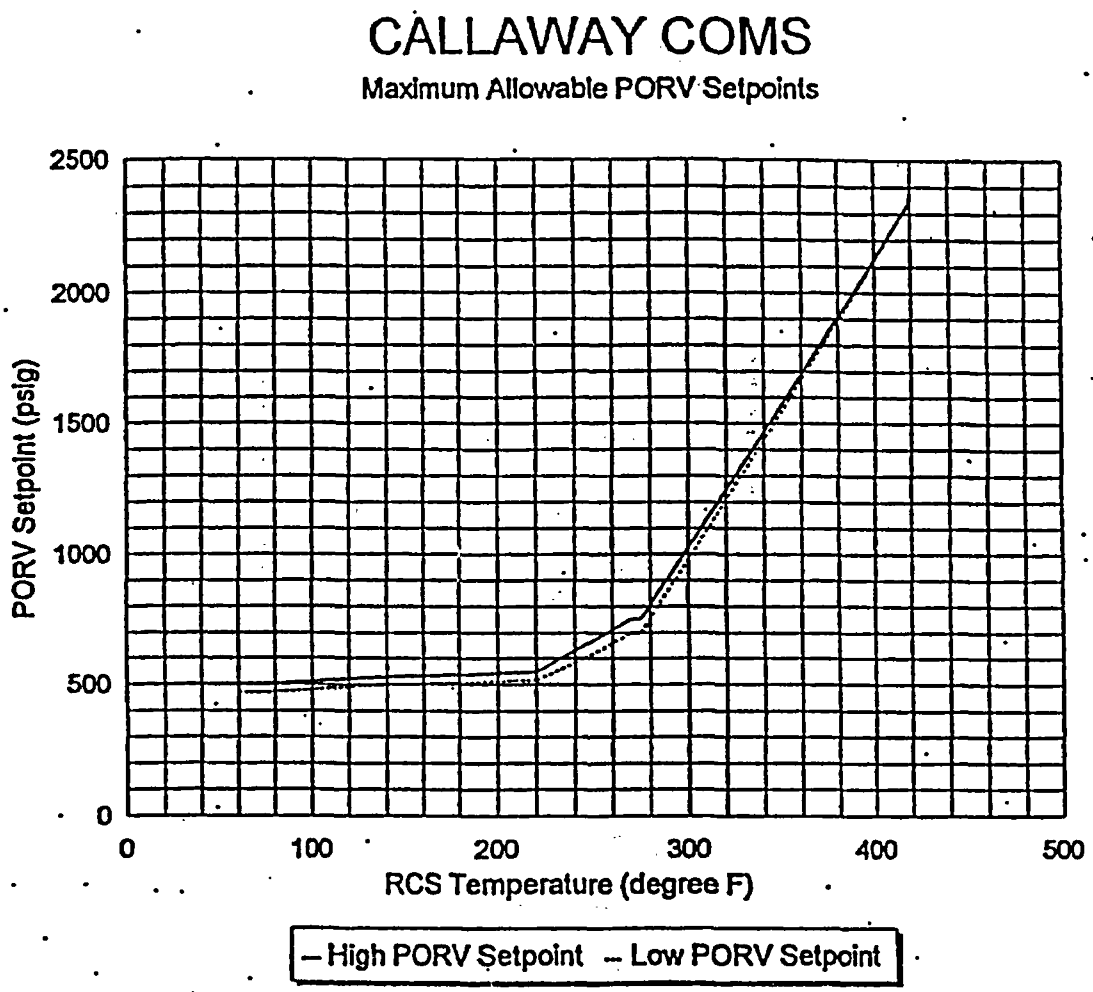


FIGURE 2.2-1 Maximum Allowed PORV Setpoint for the Cold Overpressure Mitigation System

Figure 14.9
PRESSURE AND TEMPERATURE LIMITS REPORT

TABLE 2.2-1
CALLAWAY PLANT COMS MAXIMUM ALLOWABLE PORV SETPOINTS AT 20 EFPY

| | Maximum Allowable Function Generator Setpoints (Breakpoints) | | |
|---|---|---|---|
| Breakpoint Number | Temperature – RCS (°F) | High Setpoint (psig) | Low Setpoint (psig) |
| 1 | 60 | 501 | 471 |
| 2 | 76 | 501 | 471 |
| 3 | 130 | 525 | 495 |
| 4 | 170 | 535 | 505 |
| 5 | 220 | 550 | 520 |
| 6 | 245 | 650 | 600 |
| 7 | 270 | 750 | 700 |
| 8 | 275 | 750 | 700 |
| 9 | 420 | 2350 | 2350 |

NOTE: Setpoints assume that 0 reactor coolant pumps are running for T<100°F and that 4 reactor coolant pumps are in operation for T ≥100°F.

## 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 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 a 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 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 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 materials 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 initial $RT_{NDT}$ 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 controlled 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 the AmerenUE Callaway Unit

1 Reactor Vessel Radiation Surveillance Program."

Based on engineering judgement, 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 $\Delta RT_{NDT}$ 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 metal. 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 $\Delta RT_{NDT}$ 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)] | $\Delta RT_{NDT}$[(c)] | FF X $\Delta RT_{NDT}$ | $FF^2$ |
| 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)] | $CF_{05} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (245.70) \div (9.84) = 25.0°F$ | | | | | |
| | 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 |
| | $CF_{Surv. Weld} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (215.85°F) \div (4.92) = 43.9°F$ | | | | | |

Notes:

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

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

(c) $\Delta RT_{NDT}$ values are the measured 30 ft-lb shift.

(c) These measured $\Delta RT_{NDT}$ 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 $\Delta RT_{NDT}$ 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 $b_o$ and $b_1$ are obtained by solving the normal equations

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

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

These equations can be re-written as follows ($b_o$ = 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 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 $\Delta RT_{NDT}$ (30 ft-lb)(°F) | Best Fit[a] $\Delta RT_{NDT}$ (°F) | Scatter of $\Delta RT_{NDT}$ (°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 $\Delta RT_{NDT}$ 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 $\Delta RT_{NDT}$ value. Table 4.0-2 also indicates that one measured plate $\Delta RT_{NDT}$ value is above the upper bound 1σ of 17°F by less than 3°F. From a statistical point of view ± 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 ± 1σ bounds. The fact that two of the measured plate $\Delta RT_{NDT}$ values are outside of 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 an 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 $\Delta RT_{NDT}$ (30 ft-lb) (°F) | Best Fit[a] $\Delta RT_{NDT}$ (°F) | Scatter of $\Delta RT_{NDT}$ (°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 $\Delta RT_{NDT}$ is below the lower 1σ at 28°F. The fact that one of the measured weld $\Delta RT_{NDT}$ 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 an asymmetric tangent Charpy curve fitting program or hand drawn curves using engineering judgement, 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 +/- 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, this 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.

## Figure 14.9
## PRESSURE AND TEMPERATURE LIMITS REPORT

### 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 bolt-up temperature is also included in this Table. |
| Table 5.0-4 | Provides a summary of the pressure vessel neutron fluence values at 20 EFPY used for the calculation of ART values. |
| Table 5.0-5 | Provides a summary of the adjusted reference temperature (ARTs) for reactor vessel beltline materials at the ¼-T and ¾-T locations for 20 EFPY. |
| Table 5.0-6 | Shows the calculation of the ART at 20 EFPY for the limiting reactor vessel material (lower shell plate R-2708-3). |
| 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. License Amendment No. [134], dated [March 24, 2000], from [Jack Donohew, Senior Project Manager, Section 2] to [Garry L. Randolph, Vice President and Chief Nuclear Officer].

4. WCAP-14040-NP-A, Revision 2, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," January, 1996.

## Figure 14.9
## PRESSURE AND TEMPERATURE LIMITS REPORT

**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 ($x 10^{19}$ 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 | 1.252 | 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 | 1.252 | 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 | 1.252 | 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 | 1.252 | -- | 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 E185-82.

(d) Actual measured value for $\Delta RT_{NDT}$ is –7.33. This physically should not occur, therefore for conservatism a value of zero will be used.

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

| Material | Capsule | Capsule f[a] | FF[b] | $\Delta RT_{NDT}$[c] | FF x $\Delta RT_{NDT}$ | $FF^2$ |
|---|---|---|---|---|---|---|
| Lower Shell PlateR2708-1 (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 |
| | $CF_{05} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (245.70) \div (9.84) = 25.0°F$ | | | | | |
| Surveillance Weld Material[d] | U | 0.331 | 0.696 | 68.53[d] | 47.70 | 0.48 |
| | Y | 1.27 | 1.07 | 36.92[d] | 39.5 | 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 | 215.85 | 4.92 |
| | $CF_{Surv.\ Weld} = \Sigma(FF * RT_{NDT}) \div \Sigma(FF^2) = (215.85°F) \div (4.92) = 43.9°F$ | | | | | |

NOTES:

(a) f = calculated fluence from capsule X dosimetry analysis results, ($10^{19}$ n/cm², E > 1.0 MeV). All updated fluence values from the Capsule X analysis (Table C-1of WCAP 15400).

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

(c) $\Delta RT_{NDT}$ values are the measured 30 ft-lb shift.

(d) These measured $\Delta RT_{NDT}$ 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.

Figure 14.9
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| TABLE 5.0-3 | | | |
|---|---|---|---|
| Reactor Vessel Beltline Material Unirradiated Toughness Properties | | | |
| Material Description | Cu (%) | Ni(%) | Initial $RT_{NDT}$[a] |
| Closure Head Flange R2704-1 | -- | -- | 30°F[c] |
| Vessel Flange R2701-1 | -- | -- | 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 | 0.06 | -60°F |
| Intermediate to Lower Shell Circumferential Weld Seam[b] | 0.04 | 0.06 | -60°F |

(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 weld wire 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-NP-A (Ref. 4), the minimum boltup temperature is 60°F.

**Figure 14.9**
**PRESSURE AND TEMPERATURE LIMITS REPORT**

| TABLE 5.0-4<br>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 ¼-T and ¾-T Locations for 20 EFPY**

| Material | 20 EFPY ART[(a)] | |
|---|---|---|
| | ¼-T ART (°F) | ¾-T ART (°F) |
| Intermediate Shell Plate R2707-1 | 96.4 | 79.0 |
| Intermediate Shell Plate R2707-2 | 77.4 | 56.6 |
| Intermediate Shell Plate R2707-3 | 57.4 | 36.6 |
| Lower Shell Plate R2708-1 | 124.0 | 105.4 |
| Using Surveillance Capsule Data | 90.9 | 83.2 |
| Lower Shell Plate R2708-2 | 77.4 | 56.6 |
| Lower Shell Plate R2708-3 | 100.4[(b)] | 84.2[(b)] |
| Intermediate & Lower Shell Longitudinal Weld Seams 101-124A & 101-142A (90° Azimuth) | -15.4 | -30.8 |
| Using Surveillance Capsule Data | 0.8 | -17.2 |
| Intermediate & Lower Shell Longitudinal weld Seams 101-124B&C and 101-142B&C (210° & 330° Azimuth) | -6.6 | -23.2 |
| Using Surveillance Capsule Data | 7.3 | -5.8 |
| Intermediate to Lower Shell Circumferential Weld Seam 101-171 | -6.0 | -22.6 |
| Using Surveillance Capsule Data | 7.8 | -5.0 |

(a) ART = Initial $RT_{NDT}$ + $\Delta RT_{NDT}$ + Margin (°F)

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

Note: 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, Revision 2, 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 1.1, 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<br>Calculation of Adjusted Reference Temperature Values at 20 EFPY for the Limiting Callaway Plant Reactor Vessel Material (Lower Shell Plate R2708-3) | | |
|---|---|---|
| **Parameter** | **ART Value** | |
| **Location** | **¼-T** | **¾-T** |
| Chemistry Factor, CF (°F) | 51.0 | 51.0 |
| Fluence, f ($10^{19}$ n/cm$^2$)[(a)] | 0.7174 | 0.2547 |
| Fluence Factor, FF[(b)] | 0.91 | 0.63 |
| $\Delta RT_{NDT}$ = CF x FF, (°F) | 46.4 | 32.1 |
| Initial $RT_{NDT}$, I (°F) | 20 | 20 |
| Margin, M (°F)[(c)] | 34 | 32.1 |
| ART = I + (CF x FF) + M (°F)<br>per Regulatory Guide 1.99, Rev. 2 | 100.4 | 84.2 |

(a) Fluence, f, is based upon $f_{surf}$ ($10^{19}$ n/cm$^2$, E > 1.0 MeV) = 1.204 at 20 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 $\sigma_I$, is 0°F since the initial $RT_{NDT}$ is a measured value. The standard deviation for $\Delta RT_{NDT}$ term $\sigma_\Delta$, is 17°F for the plate, except that $\sigma_\Delta$ need not exceed 0.5 times the mean value of $\Delta RT_{NDT}$.

**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) | $\Delta RT_{PTS}$[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 | 26.3 | 31.6 | 17.0 | 50 | 99 |
| 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. and Lower Shell Long. Weld Seams101-124A & 101-142A (90° Azimuth) | 1.167 | 1.04 | 29.7 | 30.9 | 30.9 | -60 | 2 |
| Using S/C Data | 1.167 | 1.04 | 43.7 | 45.4 | 28.0 | -60 | 13 |
| Inter. and Lower Shell Long. Weld Seams101-124B&C & 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 | 43.7 | 52.0 | 28.0 | -60 | 20 |
| Intermediate to Lower Shell Circumferential Weld Seam 101-171 | 2.074 | 1.20 | 29.7 | 35.6 | 35.6 | -60 | 11 |
| Using S/C Data | 2.074 | 1.20 | 43.7 | 52.4 | 28.0 | -60 | 20 |

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