WCAP-15566, Revision 1, "Salem Unit 2 Heatup and Cooldown Curves for Normal Operation"

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Salem Unit 2 Heatup and Cooldown Curves for Normal Operation

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PREFACE

This report has been technically reviewed and verified by:

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Revision 1:

Revision 0 of WCAP-15566 documented heatup and cooldown limit curves that were generated without the vessel flange requirements of 10 CFR 50, Appendix G. Revision 1 of WCAP-15566 documents the heatup and cooldown limit curves with the flange requirement included.

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EXECUTIVE SUMMARY

This report documents the development of pressure-temperature limit curves for the PSEG Nuclear LLC Salem Unit 2 electric generating plant for normal operation at 32 and 48 EFPY. These pressure-temperature curves include the a 1.4% uprating fluence values and utilize the methodology from the 1995 ASME Boiler and Pressure Vessel Code, Section XI, Appendix G, through the 1996 addendum. Regulatory Guide 1.99, Revision 2[1] was used for the calculation of Adjusted Reference Temperature (ART) values at the ¼T and ¾T location. The ¼T and ¾T values are summarized in Table 4-14. The pressure-temperature limit curves were generated with margins for instrumentation errors for heatup rates of 60 and 100°F/hr and cooldown rates of 0, 20, 40, 60 and 100°F/hr. These curves can be found in Figures 5-1 through 5-4. In addition, these heatup and cooldown pressure-temperature limit curves include ASME Code Case N-640[10], which allows the use of the K_{Ic} methodology. Revision 0 of this report provides justification for the removal of the reactor vessel flange temperature-pressure requirements of Appendix G to 10 CFR Part 50[2] and documents the development of curves that do not include the flange requirements. Revision 1 of this report contains curves that include the reactor vessel flange temperature-pressure requirements of Appendix G to 10 CFR Part 50[2].

1 INTRODUCTION

Heatup and cooldown limit curves are calculated using the adjusted RT_{NDT} (reference nil-ductility temperature) corresponding to the limiting beltline region material of the reactor vessel. The adjusted RT_{NDT} of the limiting material in the core region of the reactor vessel is determined by using the unirradiated reactor vessel material fracture toughness properties, estimating the radiation-induced ΔRT_{NDT}, and adding a margin. The unirradiated RT_{NDT} is designated as the higher of either the drop weight nil-ductility transition temperature (NDTT) or the temperature at which the material exhibits at least 50 ft-lb of impact energy and 35-mil lateral expansion (normal to the major working direction) minus 60°F.

RT_{NDT} increases as the material is exposed to fast-neutron radiation. Therefore, to find the most limiting RT_{NDT} at any time period in the reactor's life, ΔRT_{NDT} due to the radiation exposure associated with that time period must be added to the unirradiated RT_{NDT} (IRT_{NDT}). The extent of the shift in RT_{NDT} is enhanced by certain chemical elements (such as copper and nickel) present in reactor vessel steels. The Nuclear Regulatory Commission (NRC) has published a method for predicting radiation embrittlement in Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials"[1]. Regulatory Guide 1.99, Revision 2, is used for the calculation of Adjusted Reference Temperature (ART) values (IRT_{NDT} + ΔRT_{NDT} + margins for uncertainties) at the 1/4T and 3/4T locations, where T is the thickness of the vessel at the beltline region measured from the clad/base metal interface. The most limiting ART values are used in the generation of the heatup and cooldown pressure-temperature limit curves for normal operation. The fluence evaluation in WCAP-13366 used the ENDF/B-IV scattering cross-section data set. This is not consistent with the methods presented in WCAP-14040-NP-A, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves"[8]. However, for the uprating evaluation, these calculations were adjusted to account for the use of ENDF/B-VI cross sections as required by WCAP-14040-NP-A. A capsule will be removed from the Salem Unit 2 reactor vessel and tested in the spring of 2001. This evaluation will include an updated fluence evaluation using the ENDF/B-VI scattering cross-section data set and re-evaluation of the pressure-temperature curves in accordance with WCAP-14040-NP-A.

The heatup and cooldown curves documented in this report were generated using the most limiting ART values and the NRC approved methodology documented in WCAP-14040-NP-A, Revision 2[8], "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves" with exception of the following: 1) The K_{Ic} critical stress intensities are used in place of the K_{Ia} critical stress intensities. This methodology is taken from approved ASME Code Case N-640[10], and 2) The 1995 Version of Appendix G to Section XI[3], through the 1996 addendum, will be used rather than the 1989 version.

2 PURPOSE

PSEG Nuclear LLC contracted Westinghouse to generate new heatup and cooldown curves for Salem Unit 2 at 32 and 48 EFPY based upon the 1.4% uprating projected fluence values using the latest Code Methodologies and the elimination of the flange requirement. The heatup and cooldown curves were generated with margins for instrumentation errors: 18°F for temperature uncertainty and 61 psig for pressure uncertainty and 2°F temperature uncertainty for boltup. The curves also include a hydrostatic leak test limit curve from 2485 to 2000 psig.

The purpose of this report is to present the calculations and the development of the PSEG Nuclear LLC Salem Unit 2 heatup and cooldown curves for 32 and 48 EFPY. This report documents the calculated adjusted reference temperature (ART) values following the methods of Regulatory Guide 1.99, Revision 2[1], for all the beltline materials and the development of the heatup and cooldown pressure-temperature limit curves for normal operation.

Revision 0 of this report documented the development of pressure-temperature limit curves for normal operation with the flange requirements of Appendix G to 10 CFR Part 50 eliminated.

The purpose of Revision 1 of this report is to document the development of pressure-temperature limit curves for normal operation with the flange requirements of Appendix G to 10 CFR Part 50 included. All other assumptions and calculations remain the same as Revision 0.

3 CRITERIA FOR ALLOWABLE PRESSURE-TEMPERATURE RELATIONSHIPS

3.1 Overall Approach

The ASME approach for calculating the allowable limit curves for various heatup and cooldown rates specifies that the total stress intensity factor, K_I, for the combined thermal and pressure stresses at any time during heatup or cooldown cannot be greater than the reference stress intensity factor, K_{Ic}, for the metal temperature at that time. K_{Ic} is obtained from the reference fracture toughness curve, defined in Code Case N-640, "Alternative Reference Fracture Toughness for Development of PT Limit Curves for Section XI"[10] of the ASME Appendix G to Section XI[3]. The K_{Ic} curve is given by the following equation:

$$K_{Ic} = 33.2 + 20.734 * e^{[0.02(T - RT_{NDT})]} \quad (1)$$

where,

K_{Ic} = reference stress intensity factor as a function of the metal temperature T and the metal reference nil-ductility temperature RT_{NDT}

This K_{Ic} curve is based on the lower bound of static critical K_I values measured as a function of temperature on specimens of SA-533 Grade B Class1, SA-508-1, SA-508-2, SA-508-3 steel.

3.2 Methodology for Pressure-Temperature Limit Curve Development

The governing equation for the heatup-cooldown analysis is defined in Appendix G of the ASME Code as follows:

$$C^* K_{Im} + K_{It} < K_{Ic} \quad (2)$$

where,

K_{Im} = stress intensity factor caused by membrane (pressure) stress

K_{It} = stress intensity factor caused by the thermal gradients

K_{Ic} = function of temperature relative to the RT_{NDT} of the material

C = 2.0 for Level A and Level B service limits

C = 1.5 for hydrostatic and leak test conditions during which the reactor core is not critical

For membrane tension, the corresponding K_I for the postulated defect is:

$$K_{Im} = M_m \times (pR_i / t) \tag{3}$$

where, M_m for an inside surface flaw is given by:

M_m = 1.85 for $\sqrt{t} < 2$,
M_m = $0.926\sqrt{t}$ for $2 \leq \sqrt{t} \leq 3.464$,
M_m = 3.21 for $\sqrt{t} > 3.464$

Similarly, M_m for an outside surface flaw is given by:

M_m = 1.77 for $\sqrt{t} < 2$,
M_m = $0.893\sqrt{t}$ for $2 \leq \sqrt{t} \leq 3.464$,
M_m = 3.09 for $\sqrt{t} > 3.464$

and p = internal pressure, Ri = vessel inner radius, and t = vessel wall thickness.

For bending stress, the corresponding K_I for the postulated defect is:

K_{Ib} = M_b * Maximum Stress, where M_b is two-thirds of M_m

The maximum K_I produced by radial thermal gradient for the postulated inside surface defect of G-2120 is $K_{It} = 0.953\text{x}10^{-3}$ x CR x $t^{2.5}$, where CR is the cooldown rate in °F/hr., or for a postulated outside surface defect, $K_{It} = 0.753\text{x}10^{-3}$ x HU x $t^{2.5}$, where HU is the heatup rate in °F/hr.

The through-wall temperature difference associated with the maximum thermal K_I can be determined from Fig. G-2214-1. The temperature at any radial distance from the vessel surface can be determined from Fig. G-2214-2 for the maximum thermal K_I.

(a) The maximum thermal K_I relationship and the temperature relationship in Fig. G-2214-1 are applicable only for the conditions given in G-2214.3(a)(1) and (2).

(b) Alternatively, the K_I for radial thermal gradient can be calculated for any thermal stress distribution and at any specified time during cooldown for a ¼-thickness inside surface defect using the relationship:

$$K_{It} = (1.0359C_0 + 0.6322C_1 + 0.4753C_2 + 0.3855C_3) * \sqrt{\pi a} \tag{4}$$

or similarly, K_{IT} during heatup for a ¼-thickness outside surface defect using the relationship:

$$K_{It} = (1.043C_0 + 0.630C_1 + 0.481C_2 + 0.401C_3) * \sqrt{\pi a} \quad (5)$$

where the coefficients C_0, C_1, C_2 and C_3 are determined from the thermal stress distribution at any specified time during the heatup or cooldown using the form:

$$\sigma(x) = C_0 + C_1(x/a) + C_2(x/a)^2 + C_3(x/a)^3 \quad (6)$$

and x is a variable that represents the radial distance from the appropriate (i.e., inside or outside) surface to any point on the crack front and a is the maximum crack depth.

Note, that equations 1 through 6 were implemented in the OPERLIM computer code, which is the W program used to generate the pressure-temperature (P-T) limit curves. No other changes were made to the OPERLIM computer code with regard to P-T calculation methodology. Therefore, the P-T curve methodology is unchanged from that described in WCAP-14040, "Methodology used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves"[8] with the exceptions just described above.

At any time during the heatup or cooldown transient, K_{Ic} is determined by the metal temperature at the tip of a postulated flaw at the ¼T and ¾T location, the appropriate value for RT_{NDT}, and the reference fracture toughness curve. The thermal stresses resulting from the temperature gradients through the vessel wall are calculated and then the corresponding (thermal) stress intensity factors, K_{It}, for the reference flaw are computed. From Equation 2, the pressure stress intensity factors are obtained and, from these, the allowable pressures are calculated.

For the calculation of the allowable pressure versus coolant temperature during cooldown, the reference flaw of Appendix G to the ASME Code is assumed to exist at the inside of the vessel wall . During cooldown, the controlling location of the flaw is always at the inside of the wall because the thermal gradients produce tensile stresses at the inside, which increase with increasing cooldown rates. Allowable pressure-temperature relations are generated for both steady-state and finite cooldown rate situations. From these relations, composite limit curves are constructed for each cooldown rate of interest.

The use of the composite curve in the cooldown analysis is necessary because control of the cooldown procedure is based on the measurement of reactor coolant temperature, whereas the limiting pressure is actually dependent on the material temperature at the tip of the assumed flaw. During cooldown, the ¼T vessel location is at a higher temperature than the fluid adjacent to the vessel inner diameter . This condition, of course, is not true for the steady-state situation . It follows that, at any given reactor coolant temperature, the ΔT (temperature) developed during cooldown results in a higher value of K_{Ic} at the ¼T location for finite cooldown rates than for steady-state operation. Furthermore, if conditions exist so that the increase in K_{Ic} exceeds K_{It}, the calculated allowable pressure during cooldown will be greater than the steady-state value.

The above procedures are needed because there is no direct control on temperature at the ¼T location and, therefore, allowable pressures may unknowingly be violated if the rate of cooling is decreased at various intervals along a cooldown ramp. The use of the composite curve eliminates this problem and ensures conservative operation of the system for the entire cooldown period.

Three separate calculations are required to determine the limit curves for finite heatup rates. As is done in the cooldown analysis, allowable pressure-temperature relationships are developed for steady-state conditions as well as finite heatup rate conditions assuming the presence of a ¼T defect at the inside of the wall. The heatup results in compressive stresses at the inside surface that alleviate the tensile stresses produced by internal pressure. The metal temperature at the crack tip lags the coolant temperature, therefore, the K_{Ic} for the ¼T crack during heatup is lower than the K_{Ic} for the ¼T crack during steady-state conditions at the same coolant temperature. During heatup, especially at the end of the transient, conditions may exist so that the effects of compressive thermal stresses and lower K_{Ic} values do not offset each other, and the pressure-temperature curve based on steady-state conditions no longer represents a lower bound of all similar curves for finite heatup rates when the ¼T flaw is considered. Therefore, both cases have to be analyzed in order to ensure that at any coolant temperature the lower value of the allowable pressure calculated for steady-state and finite heatup rates is obtained.

The second portion of the heatup analysis concerns the calculation of the pressure-temperature limitations for the case in which a ¼T flaw located at the ¼T location from the outside surface is assumed. Unlike the situation at the vessel inside surface, the thermal gradients established at the outside surface during heatup produce stresses which are tensile in nature and therefore tend to reinforce any pressure stresses present. These thermal stresses are dependent on both the rate of heatup and the time (or coolant temperature) along the heatup ramp. Since the thermal stresses at the outside are tensile and increase with increasing heatup rates, each heatup rate must be analyzed on an individual basis.

Following the generation of pressure-temperature curves for both the steady-state and finite heatup rate situations, the final limit curves are produced by constructing a composite curve based on a point-by-point comparison of the steady-state and finite heatup rate data. At any given temperature, the allowable pressure is taken to be the lesser of the three values taken from the curves under consideration. The use of the composite curve is necessary to set conservative heatup limitations because it is possible for conditions to exist wherein, over the course of the heatup ramp, the controlling condition switches from the inside to the outside, and the pressure limit must at all times be based on analysis of the most critical criterion.

3.3 Closure Head/Vessel Flange Requirements

10 CFR Part 50, Appendix G addresses the metal temperature of the closure head flange and vessel flange regions. This rule states that the metal temperature of the closure flange regions must exceed the material unirradiated RT_{NDT} by at least 120°F for normal operation when the pressure exceeds 20 percent of the pre-service hydrostatic test pressure (3106 psig).

The limiting unirradiated RT_{NDT} of 28°F occurs in the closure head flange of the Salem Unit 2 reactor vessel, so the minimum allowable temperature of this region is 148°F at pressure greater than 621 psig with uncertainties of 18°F and 61 psig. This limit is reflected in the heatup and cooldown curves shown in Figures 5-1 through 5-4.

3.4 Minimum Boltup Temperature

The minimum boltup temperature is equal to the material RT_{NDT} of the stressed region. The RT_{NDT} is calculated in accordance with the methods described in Branch Technical Position MTEB 5-2. The Westinghouse position is that the boltup temperature be no lower than 60°F. Thus, the minimum boltup temperature should be 60°F or the initial material RT_{NDT}, whichever is higher. His limit (including a 2°F uncertainty) is reflected in the heatup and cooldown curves shown in Figures 5-1 through 5-4.

4 CALCULATION OF ADJUSTED REFERENCE TEMPERATURE

From Regulatory Guide 1.99, Revision 2, the adjusted reference temperature (ART) for each material in the beltline region is given by the following expression:

$$ART = Initial\, RT_{NDT} + \Delta RT_{NDT} + Margin \qquad (7)$$

Initial RT_{NDT} is the reference temperature for the unirradiated material as defined in paragraph NB-2331 of Section III of the ASME Boiler and Pressure Vessel Code[6]. If measured values of initial RT_{NDT} for the material in question are not available, generic mean values for that class of material may be used if there are sufficient test results to establish a mean and standard deviation for the class.

ΔRT_{NDT} is the mean value of the adjustment in reference temperature caused by irradiation and is calculated as follows:

$$\Delta RT_{NDT} = CF * f^{(0.28-0.10\log f)} \qquad (8)$$

To calculate ΔRT_{NDT} at any depth (e.g., at 1/4T or 3/4T), the following formula must first be used to attenuate the fluence at the specific depth.

$$f_{(depth x)} = f_{surface} * e^{(-0.24x)} \qquad (9)$$

where x inches (vessel beltline thickness is 8.625 inches[4]) is the depth into the vessel wall measured from the vessel clad/base metal interface. The resultant fluence is then placed in Equation 8 to calculate the ΔRT_{NDT} at the specific depth.

Evaluation of the last surveillance capsule removed from the Salem Unit 2 reactor is documented in WCAP-13366, "Analysis of Capsule X from the Public Service Electric and Gas Company Salem Unit 2 Reactor Vessel Radiation Surveillance Program". The fluence analysis provided in that report was based on the application of ENDF/B-IV neutron transport cross-section. Therefore, in the determination of the fluence projections for the Salem Unit 2 uprate program, adjustments were made to the calculated values to account for the incorporation of ENDF/B-VI cross-sections into the analysis. This adjustment was performed in order to meet the requirement of WCAP-14040-NP-A. This adjustment resulted in an increase in the calculated flux at the pressure vessel of from 10% to 12% depending on azimuthal angle. The upgrade from ENDF/B-IV to ENDF/B-VI transport cross-sections does not have a significant effect on the measurement based best estimate values reported in WCAP-13366.

In evaluating, the incremental fluence due to an uprate from 3411 MWt to 3459 MWt, the assumption was made that the uprate occurred coincident with the last surveillance capsule withdrawal (i.e. 6.2 EFPY). This assumption introduces a slight conservatism in the final projections, but does not introduce a significant overestimate of the vessel fluence. Tables 4-1 and 4-2, herein, contain the uprated vessel surface fluence values along with the Regulatory Guide 1.99, Revision 2, ¼T and ¾T uprated fluences used to calculate the ART values for all beltline materials in the Salem Unit 2 reactor vessel. Additionally, the surveillance capsule fluence values are presented in Table 4-3.

TABLE 4-1
Summary of the Peak Pressure Vessel Neutron Fluence Values
at 32 EFPY Used for the Calculation of ART Values (n/cm^2, E > 1.0 MeV)

Material	Surface*	¼ T	¾ T
Intermediate Shell B4712-1	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Intermediate Shell B4712-2	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Intermediate Shell B4712-3	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Lower Shell B4713-1	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Lower Shell B4713-2	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Lower Shell B4713-3	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	1.78×10^{19}	1.06×10^{19}	3.77×10^{18}
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	6.94×10^{18}	4.14×10^{18}	1.47×10^{18}
Intermediate Shell Longitudinal Weld Seams 2-442 B&C (Heat # 13253/20291)	1.20×10^{19}	7.15×10^{18}	2.54×10^{18}
Lower Shell Longitudinal Weld Seams 3-442 A& C (Heat # 21935/12008)	1.20×10^{19}	7.15×10^{18}	2.54×10^{18}
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	6.94×10^{18}	4.14×10^{18}	1.47×10^{18}

* Surface fluence values are best-estimate values adjusted to account for the uprate and ENDF/B-VI transport cross-sections.

TABLE 4-2
Summary of the Peak Pressure Vessel Neutron Fluence Values
at 48 EFPY Used for the Calculation of ART Values (n/cm^2, E > 1.0 MeV)

Material	Surface*	¼ T	¾ T
Intermediate Shell B4712-1	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Intermediate Shell B4712-2	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Intermediate Shell B4712-3	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Lower Shell B4713-1	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Lower Shell B4713-2	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Lower Shell B4713-3	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	2.66×10^{19}	1.58×10^{19}	5.63×10^{18}
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	1.04×10^{19}	6.20×10^{18}	2.20×10^{18}
Intermediate Shell Longitudinal Weld Seam 2-442 B&C (Heat # 13253/20291)	1.80×10^{19}	1.07×10^{19}	3.81×10^{18}
Lower Shell Longitudinal Weld Seam 3-442 A & C (Heat # 21935/12008)	1.80×10^{19}	1.07×10^{19}	3.81×10^{18}
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	1.04×10^{19}	6.20×10^{18}	2.20×10^{18}

* Surface fluence values are best-estimate values adjusted to account for the uprate and ENDF/B-VI transport cross-sections.

TABLE 4-3

Best-Estimate Integrated Neutron Exposure of the Salem Unit 2
Surveillance Capsules Tested to Date

Capsule	Fluence
T	2.76 x 10^{18} n/cm^2, (E > 1.0 MeV)
U	5.07 x 10^{18} n/cm^2, (E > 1.0 MeV)
X	1.16 x 10^{19} n/cm^2, (E > 1.0 MeV)

Margin is calculated as, $M = 2\sqrt{\sigma_I^2 + \sigma_\Delta^2}$. The standard deviation for the initial RT_{NDT} margin term, σ_i, is 0°F when the initial RT_{NDT} is a measured value, and 17°F when a generic value is used. The standard deviation for the ΔRT_{NDT} margin term, σ_Δ, is 17°F for plates when surveillance capsule data is not used and 8.5°F for plates when surveillance capsule data is used. For welds, σ_Δ is 28°F when surveillance capsule data is not used and 14°F when surveillance capsule data is used. In addition, σ_Δ need not exceed one-half the mean value of ΔRT_{NDT}.

Contained in Table 4-4 is a summary of the Measured 30 ft-lb transition temperature shifts of the beltline materials. These measured shift values were obtained from Reference 4 and are based on a hand drawn curve utilizing engineering judgement.

TABLE 4-4
Measured 30 ft-lb Transition Temperature Shifts of the Beltline Materials Contained in the Surveillance Program

Material	Capsule	Measured 30 ft-lb Transition Temperature Shift
Intermediate Shell Plate B4712-2 (Longitudinal Orientation)	T	50°F
	U	70°F
	X	80°F
Intermediate Shell Plate B4712-2 (Transverse Orientation)	T	70°F
	U	95°F
	X	125°F
Surveillance Program Weld Metal	T	155°F
	U	190°F
	X	195°F

Table 4-5 contains a summary of the weight percent of copper, the weight percent of nickel and the initial RT_{NDT} of the beltline materials. The weight percent values of Cu and Ni given in Table 4-5 were used to generate the calculated chemistry factor (CF) values based on Tables 1 and 2 of Regulatory Guide 1.99, Revision 2, and presented in Table 4-7. Table 4-6 provides the calculation of the CF values based on surveillance capsule data, Regulatory Guide 1.99, Revision 2, Position 2.1, which are also summarized in Table 4-7.

TABLE 4-5

Reactor Vessel Beltline Material Unirradiated Toughness Properties[4 & 5]

Material Description	Cu (%)	Ni(%)	Initial RT_{NDT}[a]
Closure Head Flange B4702-1	- -	- -	28°F
Vessel Flange B5001	- -	- -	12°F
Intermediate Shell B4712-1[d]	0.13	0.56	0°F
Intermediate Shell B4712-2[d]	0.12	0.62	12°F
Intermediate Shell B4712-3[d]	0.11	0.57	10°F
Lower Shell B4713-1[d]	0.12	0.60	8°F
Lower Shell B4713-2[d]	0.12	0.57	8°F
Lower Shell B4713-3[d]	0.12	0.58	10°F
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heats # 90099) [c]	0.197	0.060	-56°F
Intermediate Shell Longitudinal Weld Seams 2-442 A,B & C (Heat # 13253/20291) [c]	0.219	0.735	-56°F
Lower Shell Longitudinal Weld Seams 3-442 A, B & C (Heat # 21935/12008) [c]	0.213	0.867	-56°F

Notes:

(a) The Initial RT_{NDT} values for the plate materials are measured values while the Initial RT_{NDT} value for the weld materials are generic.[5]

(b) The surveillance program weld material was fabricated with 3/16" diameter type B-4 wire, heat # 13253, Linde 1092 flux, lot #'s 3833/3774. This weld metal is only representative of the beltline welds, not identical. Hence, the weld metal surveillance data was not used in any ART calculations.

(c) Per Ref. 5.

(d) Per Ref. 4.

TABLE 4-6

Calculation of Chemistry Factors using Salem Unit 2 Surveillance Capsule Data

Material	Capsule	Capsule f[a]	FF[b]	ΔRT_{NDT}[c]	FF* ΔRT_{NDT}	FF^2
Intermediate Shell B4712-2 (Longitudinal)	T	0.276	0.649	50.00°F	32.45°F	0.42
	U	0.570	0.843	70.00°F	59.01°F	0.71
	X	1.160	1.041	80.00°F	83.28°F	1.08
Intermediate Shell B4712-2 (Transverse)	T	0.276	0.649	70.00°F	45.42°F	0.42
	U	0.570	0.843	95.00°F	80.06°F	0.71
	X	1.160	1.041	125.00°F	130.18°F	1.08
				Sum =	430.40°F	4.43
	$CF_{B4712\text{-}2} = \Sigma (FF * RT_{NDT}) \div \Sigma (FF^2) = 430.40°F \div 4.43 = 97.2°F$					
Surveillance Program Weld Material	T	0.276	0.649	155.00°F	100.60°F	0.42
	U	0.570	0.843	190.00°F	160.17°F	0.71
	X	1.160	1.041	195.00°F	203.00°F	1.08
				Sum =	463.77°F	2.22
	$CF_{SW} = \Sigma (FF * RT_{NDT}) \div \Sigma (FF^2) = 463.77°F \div 2.22 = 208.9°F$					

Notes:

(a) f = Best-estimate fluence[4 & 7] (Calculated values are not available)

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

(c) ΔRT_{NDT} values are the measured 30 ft-lb shift values [4].

TABLE 4-7
Summary of the Salem Unit 2 Reactor Vessel Beltline Material Chemistry Factors
Based on Regulatory Guide 1.99, Revision 2, Position 1.1 and Position 2.1

Material	Chemistry Factor	
	Position 1.1	Position 2.1
Intermediate Shell B4712-1	89.8°F	--
Intermediate Shell B4712-2	83.3°F	97.2°F
Intermediate Shell B4712-3	73.7°F	--
Lower Shell B4713-1	83.0°F	--
Lower Shell B4713-2	82.4°F	--
Lower Shell B4713-3	82.6°F	--
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	91.4°F	--
Intermediate Shell Longitudinal Weld Seam 2-442 A, B & C (Heat # 13253/20291)	189.0°F	--
Lower Shell Longitudinal Weld Seam 3-442 A, B & C (Heat # 21935/12008)	208.6°F	--

It should be noted here, that the Salem Unit 2 weld data is credible, however, the Salem Unit 2 plate data is not credible. Although the plate surveillance material was determined to be non-credible, the chemistry factor derived from the surveillance data is more conservative than the non-surveillance material chemistry factor (Reference 9). For this reason, the chemistry factor, plus one standard deviation, from the surveillance data will be used. Per Reference 9, the surveillance weld data is credible. However, the surveillance weld metal is only representative of the beltline welds, not identical. Hence, the weld metal surveillance data was not used in any ART calculations. It is only presented in this report for completeness.

Contained in Tables 4-8 and 4-9 are summaries of the fluence factors (FF) used in the calculation of adjusted reference temperatures for the Salem Unit 2 reactor vessel beltline materials for 32 and 48EFPY.

TABLE 4-8

Summary of the Calculated Fluence Factors used for the Generation of the 32 EFPY Heatup and Cooldown Curves

Material	¼ T f (n/cm², E > 1.0 MeV)	¼ T FF(a)	¾ T f (n/cm², E >1.0 MeV)	¾ T FF(b)
Intermediate Shell B4712-1	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Intermediate Shell B4712-2	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Intermediate Shell B4712-3	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Lower Shell B4713-1	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Lower Shell B4713-2	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Lower Shell B4713-3	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	1.06×10^{19}	1.016	3.77×10^{18}	0.729
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	4.14×10^{18}	0.760	1.47×10^{18}	0.50
Intermediate Shell Longitudinal Weld Seams 2-442 B & C (Heat # 13253/20291)	7.15×10^{18}	0.906	2.54×10^{18}	0.628
Lower Shell Longitudinal Weld Seams 3-442 A & C (Heat # 21935/12008)	7.15×10^{18}	0.906	2.54×10^{18}	0.628
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	4.14×10^{18}	0.760	1.47×10^{18}	0.50

Notes:

(a) Fluence Factor at the ¼T vessel thickness location.

(b) Fluence Factor at the ¾T vessel thickness location.

TABLE 4-9
Summary of the Calculated Fluence Factors used for the Generation of the 48 EFPY Heatup and Cooldown Curves

Material	¼ T f (n/cm^2, E > 1.0 MeV)	¼ T FF[(a)]	¾ T f (n/cm^2, E > 1.0 MeV)	¾ T FF[(b)]
Intermediate Shell B4712-1	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Intermediate Shell B4712-2	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Intermediate Shell B4712-3	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Lower Shell B4713-1	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Lower Shell B4713-2	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Lower Shell B4713-3	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	1.58×10^{19}	1.126	5.63×10^{18}	0.839
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	6.20×10^{18}	0.870	2.20×10^{18}	0.590
Intermediate Shell Longitudinal Weld Seams 2-442 B & C (Heat # 13253/20291)	1.07×10^{19}	1.019	3.81×10^{18}	0.733
Lower Shell Longitudinal Weld Seams 101-142 A & C (Heat # 21935/12008)	1.07×10^{19}	1.019	3.81×10^{18}	0.733
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	6.20×10^{18}	0.870	2.20×10^{18}	0.590

Notes:
(a) Fluence Factor at the ¼T vessel thickness location.
(b) Fluence Factor at the ¾T vessel thickness location.

Contained in Tables 4-10 through 4-13 are the calculations of the ART values used for the generation of the 32 EFPY and 48 EFPY heatup and cooldown curves.

TABLE 4-10

Calculation of the ART Values for the ¼T Location @ 32 EFPY

Material	CF (°F)	FF	IRT_{NDT}[(a)] (°F)	ΔRT_{NDT}[(b)] (°F)	Margin	ART[(c)] (°F)
Intermediate Shell B4712-1	89.8	1.016	0	91.2	34	125
Intermediate Shell B4712-2	83.3	1.016	12	84.6	34	131
→ Using Surveillance Data[(d)]	97.2	1.016	12	98.8	34	145
Intermediate Shell B4712-3	73.7	1.016	10	74.9	34	119
Lower Shell B4713-1	83.0	1.016	8	84.3	34	126
Lower Shell B4713-2	82.4	1.016	8	83.7	34	126
Lower Shell B4713-3	82.6	1.016	10	83.9	34	128
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	91.4	1.016	-56	92.9	65.5	102
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	189	0.76	-56	143.6	65.5	153
Intermediate Shell Longitudinal Weld Seams 2-442 B&C (Heat # 13253/20291)	189	0.906	-56	171.2	65.5	181
Lower Shell Longitudinal Weld Seams 3-442 A&C (Heat # 21935/12008)	208.6	0.906	-56	189.0	65.5	**199**
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	208.6	0.76	-56	158.5	65.5	168

<u>NOTES:</u>

(a) Initial RT_{NDT} values are measured values for the plate materials while the Initial RT_{NDT} values for the weld materials are generic.

(b) $\Delta RT_{NDT} = CF * FF$

(c) $ART = I + \Delta RT_{NDT} + M$ (This value was rounded per ASTM E29, using the "Rounding Method".)

(d) The Salem Unit 2 surveillance plate data is not credible (See Reference 9). However, the chemistry factor derived from the plate surveillance data is more conservative than the non-surveillance data chemistry factor. Hence, the plate surveillance data are reported here with a full $1\sigma_{\Delta}$.

TABLE 4-11

Calculation of the ART Values for the ¾T Location @ 32 EFPY

Material	CF (°F)	FF	IRT_{NDT}[(a)] (°F)	ΔRT_{NDT}[(b)] (°F)	Margin (°F)	ART[(c)] (°F)
Intermediate Shell B4712-1	89.8	0.729	0	65.5	34	100
Intermediate Shell B4712-2	83.3	0.729	12	60.7	34	107
→ Using Surveillance Data[(d)]	97.2	0.729	12	70.9	34	117
Intermediate Shell B4712-3	73.7	0.729	10	53.7	34	98
Lower Shell B4713-1	83.0	0.729	8	60.5	34	103
Lower Shell B4713-2	82.4	0.729	8	60.1	34	102
Lower Shell B4713-3	82.6	0.729	10	60.2	34	104
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	91.4	0.729	-56	66.6	65.5	76
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	189	0.500	-56	94.5	65.5	104
Intermediate Shell Longitudinal Weld Seams 2-442 B&C (Heat # 13253/20291)	189	0.628	-56	118.7	65.5	128
Lower Shell Longitudinal Weld Seams 3-442 A&C (Heat # 21935/12008)	208.6	0.628	-56	131	65.5	**140**
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	208.6	0.500	-56	104.3	65.5	114

NOTES:

(a) Initial RT_{NDT} values are measured values for the plate materials while the Initial RT_{NDT} values for the weld materials are generic.

(b) $\Delta RT_{NDT} = CF * FF$

(c) $ART = I + \Delta RT_{NDT} + M$ (This value was rounded per ASTM E29, using the "Rounding Method".)

(d) The Salem Unit 2 surveillance plate data is not credible (See Reference 9). However, the chemistry factor derived from the plate surveillance data is more conservative than the non-surveillance data chemistry factor. Hence, the plate surveillance data are reported here with a full $1\sigma_{\Delta}$.

TABLE 4-12

Calculation of the ART Values for the ¼T Location @ 48 EFPY

Material	CF (°F)	FF	IRT_{NDT}[(a)] (°F)	ΔRT_{NDT}[(b)] (°F)	Margin (°F)	ART[(c)] (°F)
Intermediate Shell B4712-1	89.8	1.126	0	101.1	34	135
Intermediate Shell B4712-2	83.2	1.126	12	93.7	34	140
→ Using Surveillance Data[(d)]	97.2	1.126	12	109.4	34	155
Intermediate Shell B4712-3	73.7	1.126	10	83	34	127
Lower Shell B4713-1	83.0	1.126	8	93.5	34	136
Lower Shell B4713-2	82.4	1.126	8	92.8	34	135
Lower Shell B4713-3	82.6	1.126	10	93.0	34	137
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	91.4	1.126	-56	102.9	65.5	112
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	189	0.870	-56	164.4	65.5	174
Intermediate Shell Longitudinal Weld Seams 2-442 A,B & C (Heat # 13253/20291)	189	1.019	-56	192.6	65.5	202
Lower Shell Longitudinal Weld Seams 3-442 A&C (Heat # 21935/12008)	208.6	1.019	-56	212.6	65.5	**222**
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	208.6	0.870	-56	181.5	65.5	191

NOTES:

(a) Initial RT_{NDT} values are measured values for the plate materials while the Initial RT_{NDT} values for the weld materials are generic.

(b) $\Delta RT_{NDT} = CF * FF$

(c) $ART = I + \Delta RT_{NDT} + M$ (This value was rounded per ASTM E29, using the "Rounding Method".)

(d) The Salem Unit 2 surveillance plate data is not credible (See Reference 9). However, the chemistry factor derived from the plate surveillance data is more conservative than the non-surveillance data chemistry factor. Hence, the plate surveillance data are reported here with a full $1\sigma_{\Delta}$.

TABLE 4-13

Calculation of the ART Values for the ¾T Location @ 48 EFPY

Material	**CF (°F)**	**FF**	**IRT_{NDT}[(a)] (°F)**	**ΔRT_{NDT}[(b)] (°F)**	**Margin (°F)**	**ART[(c)] (°F)**
Intermediate Shell B4712-1	89.8	0.839	0	75.3	34	109
Intermediate Shell B4712-2	83.2	0.839	12	69.8	34	116
→ Using Surveillance Data[(d)]	97.2	0.839	12	81.6	34	128
Intermediate Shell B4712-3	73.7	0.839	10	61.8	34	106
Lower Shell B4713-1	83.0	0.839	8	69.6	34	112
Lower Shell B4713-2	82.4	0.839	8	69.1	34	111
Lower Shell B4713-3	82.6	0.839	10	69.3	34	113
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heats # 90099)	91.4	0.839	-56	76.7	65.5	86
Intermediate Shell Longitudinal Weld Seam 2-442 A (Heat # 13253/20291)	189	0.590	-56	111.5	65.5	121
Intermediate Shell Longitudinal Weld Seams 2-442 B & C (Heat # 13253/20291)	189	0.733	-56	138.5	65.5	148
Lower Shell Longitudinal Weld Seams 3-442 A&C (Heat # 21935/12008)	208.6	0.733	-56	152.9	65.5	**162**
Lower Shell Longitudinal Weld Seam 3-442 B (Heat # 21935/12008)	208.6	0.590	-56	123.1	65.5	133

NOTES:

(a) Initial RT_{NDT} values are measured values for the plate materials while the Initial RT_{NDT} values for the weld materials are generic.

(b) $\Delta RT_{NDT} = CF * FF$

(c) $ART = I + \Delta RT_{NDT} + M$ (This value was rounded per ASTM E29, using the "Rounding Method".)

(d) The Salem Unit 2 surveillance plate data is not credible (See Reference 9). However, the chemistry factor derived from the plate surveillance data is more conservative than the non-surveillance data chemistry factor. Hence, the plate surveillance data are reported here with a full $1\sigma_{\Delta}$.

The longitudinal weld seams 3-442 A&C are the limiting beltline material for all heatup and cooldown curves to be generated. Contained in Table 4-14 is a summary of the limiting ARTs to be used in the generation of Salem Unit 2 reactor vessel heatup and cooldown curves.

TABLE 4-14
Summary of the Limiting ART Values Used in the
Generation of the Salem Unit 2 Heatup/Cooldown Curves

EFPY	1/4T Limiting ART	3/4T Limiting ART
32	199°F	140°F
48	222°F	162°F

5 HEATUP AND COOLDOWN PRESSURE-TEMPERATURE LIMIT CURVES

Pressure-temperature limit curves for normal heatup and cooldown of the primary reactor coolant system have been calculated for the reactor vessel beltline region using the methods discussed in Sections 3 and 4 of this report. This approved methodology is also presented in WCAP-14040-NP-A[8], dated January 1996.

Figures 5-1 and 5-3 present the heatup curves with margins of 18°F and 61 psig for possible instrumentation errors for heatup rates of 60 and 100°F/hr. These heatup curves are applicable for 32 EFPY and 48 EFPY, respectively, for the Salem Unit 2 reactor vessel. Additionally, Figures 5-2 and 5-4 present the cooldown curves with margins of 18°F and 61 psig for possible instrumentation errors for cooldown rates of 0, 20, 40, 60, and 100°F/hr. These cooldown curves are also applicable for 32 EFPY and 48 EFPY, respectively, for the Salem Unit 2 reactor vessel. Figures 5-1 through 5-4 include the boltup temperature of 60°F with a margin of 2°F for measurement uncertainty. Allowable combinations of temperature and pressure for specific temperature change rates are below and to the right of the limit lines shown in Figures 5-1 through 5-4. This is in addition to other criteria which must be met before the reactor is made critical, as discussed in the following paragraphs.

The reactor must not be made critical until pressure-temperature combinations are to the right of the criticality limit line shown in Figures 5-1 and 5-3 (for the specific heatup rate being utilized). The straight-line portion of the criticality limit is at the minimum permissible temperature for the 2485 psig inservice hydrostatic test as required by Appendix G to 10 CFR Part 50. The governing equation for the hydrostatic test is defined in Appendix G to Section XI of the ASME Code[3] as follows:

$$1.5K_{Im} < K_{Ic} \qquad (10)$$

where,

K_{Im} is the stress intensity factor covered by membrane (pressure) stress,
$K_{Ic} = 33.2 + 20.734e^{[0.02\,(T - RT_{NDT})]}$,

T is the minimum permissible metal temperature, and
RT_{NDT} is the metal reference nil-ductility temperature

The criticality limit curve specifies pressure-temperature limits for core operation to provide additional margin during actual power production as specified in Reference 2. The pressure-temperature limits for core operation (except for low power physics tests) are that the reactor vessel must be at a temperature equal to or higher than the minimum temperature required for the inservice hydrostatic test, and at least 40°F higher than the minimum permissible temperature in the corresponding pressure-temperature curve for heatup and cooldown calculated as described in Section 3 of this report. The vertical line drawn from these points on the pressure-temperature curve, intersecting a curve 40°F higher than the pressure-temperature limit curve, constitutes the limit for core operation for the reactor vessel.

Figures 5-1 through 5-4 define all of the above limits for ensuring prevention of nonductile failure for the Salem Unit 2 reactor vessel. The data points for the heatup and cooldown pressure-temperature limit curves shown in Figures 5-1 through 5-4 are presented in Tables 5-1 through 5-4, respectively.

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: Lower Shell Axial Weld Seam 3-442 A&C

LIMITING ART VALUES AT 32 EFPY: ¼T ART = 199°F
¾T ART = 140°F

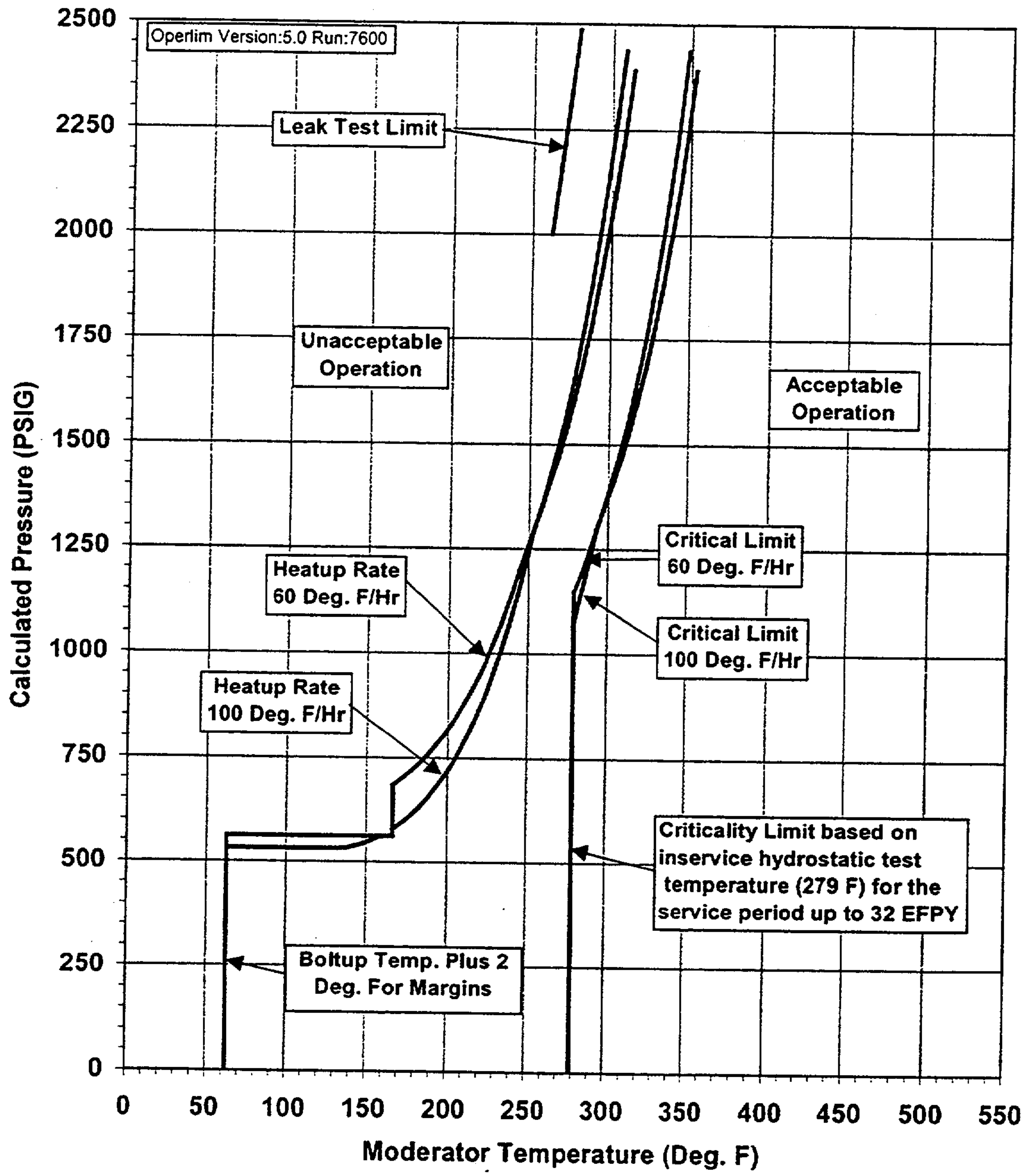

Figure 5-1. Salem Unit 2 Reactor Coolant System Heatup Limitations (Heatup Rates of 60 and 100°F/hr) Applicable to 32 EFPY (with Margins for Instrumentation Errors)

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: Lower Shell Axial Weld Seam 3-442 A&C

LIMITING ART VALUES AT 32 EFPY: ¼T ART = 199°F
¾T ART = 140°F

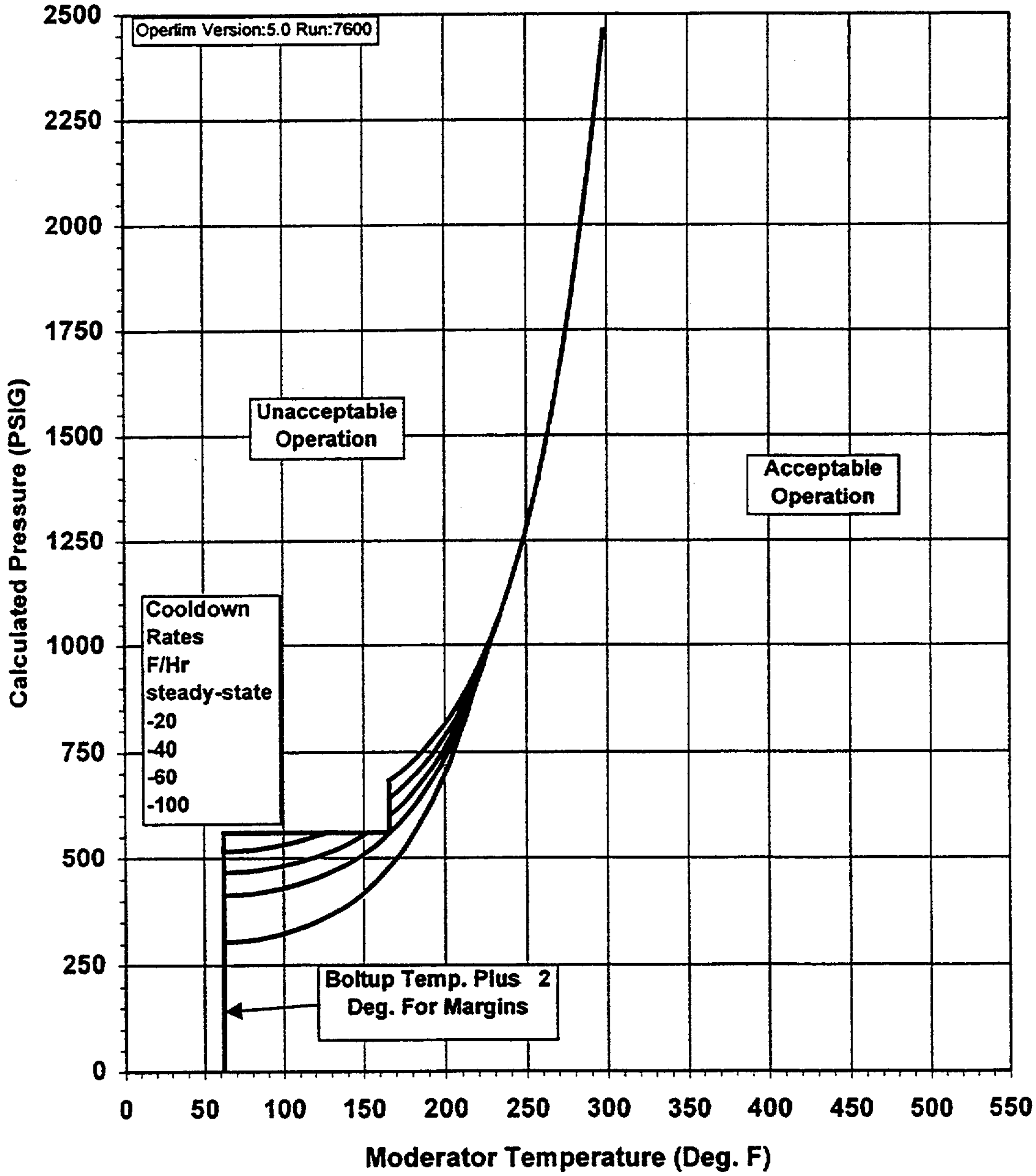

Figure 5- 2. Salem Unit 2 Reactor Coolant System Cooldown Limitations (Cooldown Rates of 0, 20, 40, 60 and 100°F/hr) Applicable to 32 EFPY (with Margins for Instrumentation Errors)

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: Lower Shell Axial Weld Seam 3-442 A&C

LIMITING ART VALUES AT 48 EFPY: ¼T ART = 222°F
¾T ART = 162°F

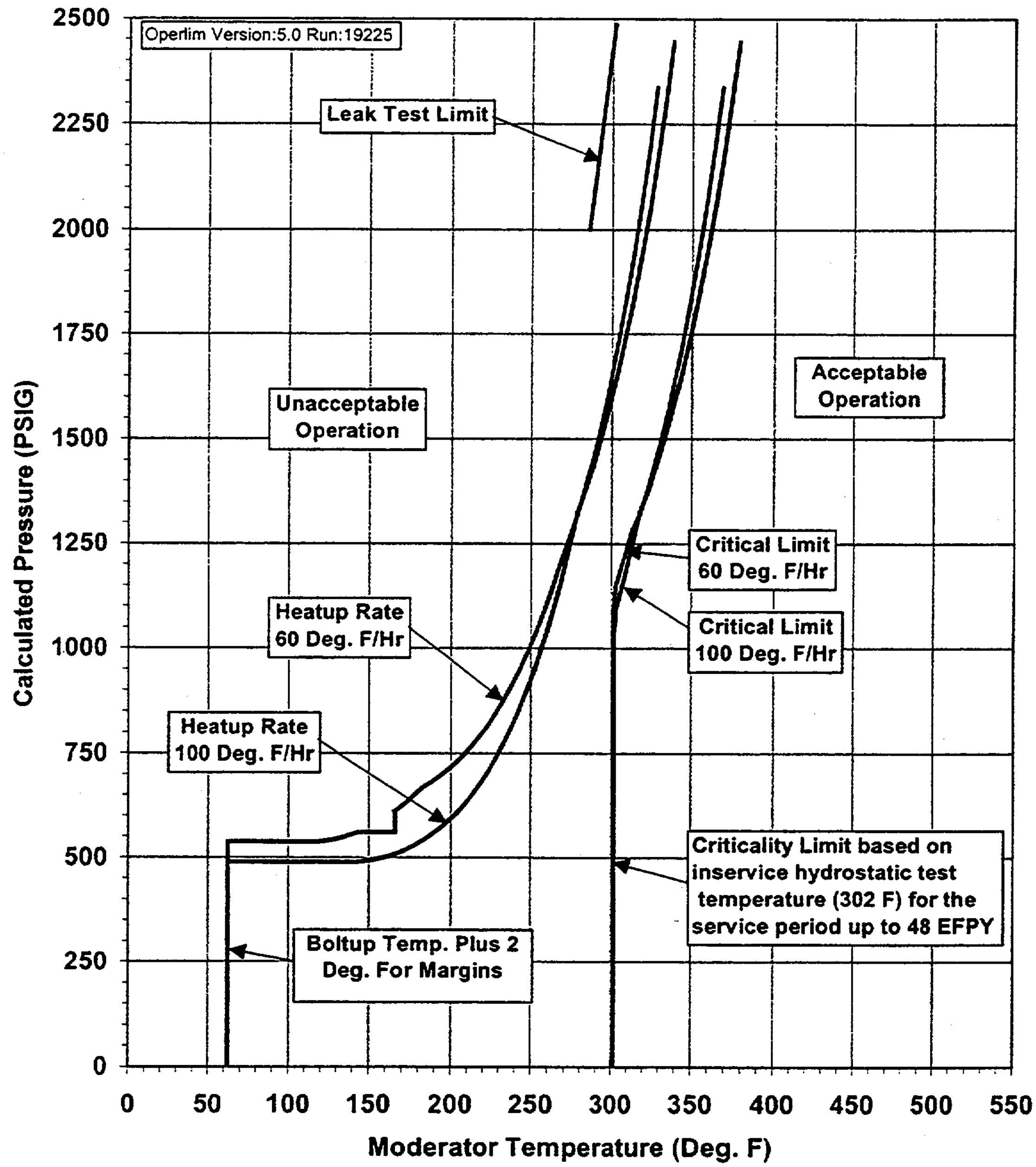

Figure 5- 3. Salem Unit 2 Rector Coolant System Heatup Limitations (Heatup Rates of 60 and 100°F/hr) Applicable to 48 EFPY (with Margins of for Instrumentation Errors)

MATERIAL PROPERTY BASIS

LIMITING MATERIAL: Lower Shell Axial Weld Seam 3-442 A&C

LIMITING ART VALUES AT 48 EFPY: ¼T ART = 222°F
¾T ART = 162°F

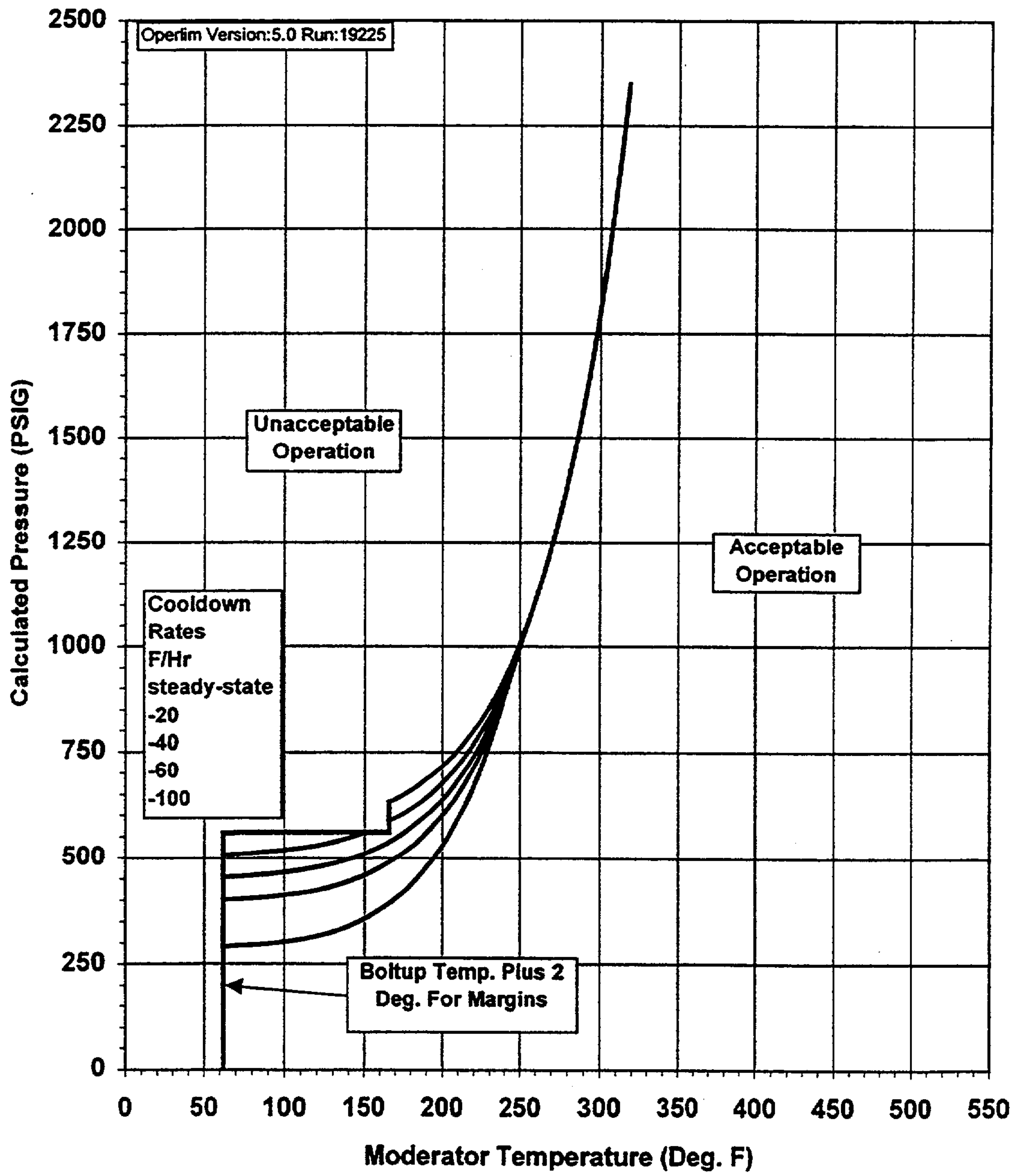

Figure 5-4. Salem Unit 2 Reactor Coolant System Cooldown Limitations (Cooldown Rates of 0, 20, 40, 60 and 100°F/hr) Applicable to 48 EFPY (With Margins for Instrumentation Errors)

TABLE 5-1
Salem Unit 2 Heatup Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
62	0	279	0	62	0	279	0	262	2000
62	560	279	560	62	531	279	531	279	2485
83	560	279	560	83	531	279	531		
88	560	279	560	88	531	279	532		
93	560	279	560	93	531	279	533		
98	560	279	560	98	531	279	535		
103	560	279	560	103	531	279	537		
108	560	279	560	108	531	279	540		
113	560	279	560	113	531	279	542		
118	560	279	560	118	531	279	546		
123	560	279	560	123	531	279	549		
128	560	279	560	128	531	279	555		
133	560	279	560	133	531	279	558		
138	560	279	560	138	533	279	560		
143	560	279	560	143	537	279	560		
148	560	279	560	148	542	279	560		
153	560	279	560	153	549	279	560		
158	560	279	560	158	558	279	560		
163	560	279	560	163	560	279	560		
166	560	279	702	166	560	279	577		
166	683	279	711	166	577	279	582		
168	688	279	737	168	582	279	596		
173	703	279	766	173	596	279	613		
178	720	279	798	178	613	279	632		

TABLE 5-1 (continued)
Salem Unit 2 Heatup Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
183	738	279	833	183	632	279	654		
188	758	279	872	188	654	279	678		
193	781	279	916	193	678	279	705		
198	805	279	963	198	705	279	736		
203	833	279	987	203	736	279	770		
208	863	279	1013	208	770	279	807		
213	896	279	1042	213	807	279	849		
218	933	279	1074	218	849	279	896		
223	973	279	1109	223	896	279	947		
228	1018	279	1147	228	947	279	1004		
233	1068	279	1147	233	1004	279	1067		
238	1123	283	1184	238	1067	283	1137		
243	1184	288	1241	243	1137	288	1213		
248	1241	293	1296	248	1213	293	1298		
253	1296	298	1356	253	1298	298	1353		
258	1356	303	1423	258	1353	303	1409		
263	1423	308	1497	263	1409	308	1470		
268	1497	313	1578	268	1470	313	1538		
273	1578	318	1668	273	1538	318	1612		
278	1668	323	1767	278	1612	323	1693		
283	1767	328	1876	283	1693	328	1783		
288	1876	333	197	288	1783	333	1882		
293	1997	338	2130	293	1882	338	1991		
298	2130	343	2276	298	1991	343	2111		

TABLE 5-1 (continued)
Salem Unit 2 Heatup Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
303	2276	348	2437	303	2111	348	2244		
308	2437			308	2244	353	2390		
				313	2390				

TABLE 5-2
Salem Unit 2 Cooldown Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
62	0	62	0	62	0	62	0	62	0
62	560	62	517	62	466	62	414	62	305
68	560	68	518	68	467	68	415	68	306
73	560	73	519	73	468	73	416	73	307
78	560	78	520	78	469	78	417	78	309
83	560	83	522	83	471	83	419	83	312
88	560	88	525	88	474	88	422	88	315
93	560	93	528	93	477	93	426	93	319
98	560	98	532	98	481	98	429	98	323
103	560	103	535	103	485	103	434	103	328
108	560	108	540	108	490	108	438	108	334
113	560	113	544	113	495	113	444	113	340
118	560	118	550	118	500	118	450	118	347
123	560	123	556	123	506	123	457	123	355
128	560	128	560	128	513	128	464	128	364
133	560	133	560	133	521	133	473	133	374
138	560	138	560	138	530	138	482	138	385
143	560	143	560	143	539	143	492	143	398
148	560	148	560	148	550	148	504	148	412
153	560	153	560	153	560	153	517	153	428
158	560	158	560	158	560	158	531	158	446
163	560	163	560	163	560	163	547	163	465
166	560	166	560	166	560	168	565	168	487
166	683	166	641	166	599	173	585	173	511

TABLE 5-2 (continued)
Salem Unit 2 Cooldown Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
168	688	168	647	168	606	178	607	178	539
173	703	173	663	173	624	183	631	183	569
178	720	178	681	178	644	188	658	188	602
183	738	183	701	183	666	193	688	193	640
188	758	188	724	188	690	198	722	198	681
193	781	193	748	193	717	203	759	203	727
198	805	198	775	198	747	208	800	208	778
203	833	203	805	203	780	213	845	213	834
208	863	208	839	208	817	218	895	218	897
213	896	213	875	213	858	223	951	223	967
218	933	218	916	218	903	228	1012	228	1018
223	973	223	961	223	953	233	1068	233	1068
228	1018	228	1011	228	1008	238	1123	238	1123
233	1068	233	1066	233	1068	243	1184	243	1184
238	1123	238	1123	238	1123	248	1251	248	1251
243	1184	243	1184	243	1184	253	1325	253	1325
248	1251	248	1251	248	1251	258	1407	258	1407
253	1325	253	1325	253	1325	263	1497	263	1497
258	1407	258	1407	258	1407	268	1597	268	1597
263	1497	263	1497	263	1497	273	1708	273	1708
268	1597	268	1597	268	1597	278	1830	278	1830
273	1708	273	1708	273	1708	283	1965	283	1965
278	1830	278	1830	278	1830	288	2115	288	2115
283	1965	283	1965	283	1965	293	2280	293	2280

TABLE 5-2 (continued)
Salem Unit 2 Cooldown Curve Data Points Applicable to 32 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
288	2115	288	2115	288	2115	298	2462	298	2462
293	2280	293	2280	293	2280				
298	2462	298	2462	298	2462				

TABLE 5-3
Salem Unit 2 Heatup Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
62	0	302	0	62	0	302	0	285	2000
62	537	302	537	62	489	302	489	302	2485
83	537	302	537	83	489	302	490		
88	537	302	539	88	489	302	490		
93	537	302	539	93	489	302	491		
98	537	302	542	98	489	302	493		
103	537	302	543	103	489	302	494		
108	537	302	546	108	489	302	496		
113	537	302	549	113	489	302	499		
118	537	302	552	118	489	302	501		
123	539	302	557	123	489	302	504		
128	542	302	559	128	489	302	508		
133	546	302	560	133	489	302	508		
138	552	302	560	138	489	302	511		
143	559	302	560	143	490	302	516		
148	560	302	560	148	491	302	519		
153	560	302	560	153	494	302	527		
158	560	302	560	158	499	302	529		
163	560	302	560	163	504	302	539		
166	560	302	610	166	508	302	540		
166	610	302	616	168	511	302	553		
168	616	302	632	173	519	302	553		
173	632	302	650	178	529	302	560		
178	650	302	671	183	540	302	560		

TABLE 5-3 (continued)
Salem Unit 2 Heatup Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
183	667	302	693	188	553	302	560		
188	680	302	718	193	568	302	568		
193	694	302	746	198	585	302	585		
198	710	302	776	203	604	302	604		
203	727	302	810	208	625	302	625		
208	746	302	848	213	649	302	649		
213	767	302	890	218	675	302	675		
218	790	302	935	223	704	302	704		
223	816	302	975	228	737	302	737		
228	844	302	999	233	773	302	773		
233	876	302	1026	238	813	302	813		
238	910	302	1056	243	857	302	857		
243	949	302	1089	248	906	302	906		
248	991	302	1089	253	960	302	960		
253	1038	302	1089	258	1020	302	1020		
258	1089	303	1147	263	1086	303	1086		
263	1147	308	1210	268	1159	308	1159		
268	1210	313	1280	273	1240	313	1240		
273	1263	318	1320	278	1324	318	1324		
278	1320	323	1383	283	1376	323	1376		
283	1383	328	1452	288	1434	328	1434		
288	1452	333	1528	293	1497	333	1497		
293	1528	338	1612	298	1566	338	1566		
298	1612	343	1705	303	1642	343	1642		

TABLE 5-3 (continued)
Salem Unit 2 Heatup Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

60°F/hr. Heatup		60°F/hr. Crit. Limit		100°F/hr. Heatup		100°F/hr. Crit. Limit		Inservice Leak Test	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
303	1705	348	1808	308	1727	348	1727		
308	1808	353	1921	313	1819	353	1819		
313	1921	358	2045	318	1921	358	1921		
318	2045	363	2183	323	2033	363	2033		
323	2183	368	2335	328	2157	368	2157		
328	2335			333	2292	373	2292		
				338	2444	378	2444		

TABLE 5-4
Salem Unit 2 Cooldown Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
62	0	62	0	62	0	62	0	62	0
62	558	62	507	62	455	62	402	62	291
68	559	68	508	68	456	68	403	68	293
73	560	73	509	73	457	73	404	73	294
78	560	78	510	78	458	78	405	78	295
83	560	83	512	83	460	83	406	83	296
88	560	88	513	88	461	88	408	88	298
93	560	93	515	93	463	93	410	93	300
98	560	98	517	98	465	98	412	98	302
103	560	103	520	103	468	103	414	103	304
108	560	108	522	108	470	108	417	108	307
113	560	113	525	113	473	113	420	113	311
118	560	118	528	118	477	118	424	118	315
123	560	123	532	123	480	123	428	123	320
128	560	128	536	128	485	128	432	128	325
133	560	133	540	133	489	133	437	133	331
138	560	138	545	138	495	138	443	138	337
143	560	143	551	143	501	143	449	143	345
148	560	148	557	148	507	148	456	148	353
153	560	153	560	153	514	153	464	153	363
158	560	158	560	158	523	158	473	158	374
163	560	163	560	163	532	163	483	163	386
166	560	166	560	168	542	168	494	168	399
166	632	166	585	173	553	173	506	173	414

TABLE 5-4 (continued)
Salem Unit 2 Cooldown Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
168	636	168	589	178	565	178	520	178	430
173	645	173	599	183	579	183	535	183	449
178	656	178	610	188	594	188	552	188	470
183	667	183	623	193	611	193	570	193	493
188	680	188	637	198	630	198	591	198	518
193	694	193	652	203	651	203	614	203	547
198	710	198	669	208	674	208	640	208	579
203	727	203	688	213	699	213	668	213	614
208	746	208	709	218	728	218	699	218	653
213	767	213	732	223	759	223	734	223	697
218	790	218	758	228	794	228	773	228	745
223	816	223	786	233	832	233	816	233	798
228	844	228	818	238	875	238	863	238	858
233	876	233	852	243	922	243	916	243	924
238	910	238	891	248	974	248	974	248	991
243	949	243	933	253	1032	253	1038	253	1038
248	991	248	980	258	1089	258	1089	258	1089
253	1038	253	1032	263	1147	263	1147	263	1147
258	1089	258	1089	268	1210	268	1210	268	1210
263	1147	263	1147	273	1280	273	1280	273	1280
268	1210	268	1210	278	1357	278	1357	278	1357
273	1280	273	1280	283	1442	283	1442	283	1442
278	1357	278	1357	288	1536	288	1536	288	1536
283	1442	283	1442	293	1640	293	1640	293	1640

TABLE 5-4 (continued)
Salem Unit 2 Cooldown Curve Data Points Applicable to 48 EFPY Using
1996 Appendix G and Code Case N-640
(w/Margins for instrumentation Errors and w/Flange Requirements)

Steady State		20°F/hr. Cooldown		40°F/hr. Cooldown		60°F/hr. Cooldown		100°F/hr. Cooldown	
Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.	Temp.	Press.
(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)	(°F)	(psig)
288	1536	288	1536	298	1755	298	1755	298	1755
293	1640	293	1640	303	1883	303	1883	303	1883
298	1755	298	1755	308	2023	308	2023	308	2023
303	1883	303	1883	313	2179	313	2179	313	2179
308	2023	308	2023	318	2350	318	2350	318	2350
313	2179	313	2179						
318	2350	318	2350						

6 REFERENCES

1 Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", U.S. Nuclear Regulatory Commission, May, 1988.

2 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements", Federal Register, Volume 60, No. 243, dated December 19, 1995.

3 Section XI of the ASME Boiler and Pressure Vessel Code, Appendix G, "Fracture Toughness Criteria for Protection Against Failure.", Dated December 1995 through 1996 addendum.

4 WCAP-13366, "Analysis of Capsule X from the Public Service Electric and Gas Company Salem Unit 2 Reactor Vessel Radiation Surveillance Program", J. M. Chicots, et al., June 1992.

5 NFS-00-178, Reactor Vessel Toughness Property/Chemistry Confirmation from PSE&G.

6 1989 Section III, Division 1 of the ASME Boiler and Pressure Vessel Code, Paragraph NB-2331, "Material for Vessels".

7\. LTR-REA-00-621, "Reactor Vessel Fluences for the Salem 1.4% Uprate Project", S.L. Anderson, June 27, 2000.

8 WCAP-14040-NP-A, Revision 2, "Methodology used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves", J. D. Andrachek, et al., January 1996.

9 WCAP-15568, "Evaluation of Pressured Thermal Shock for Salem Unit-2 1.4% Uprating", E. Terek, et al., November 2000.

10 ASME Code Case N-640, "Alternative Reference Fracture Toughness for Development of P-T Limit Curves for Section XI, Division 1", February 26, 1999.

APPENDIX A

PROJECTED UPPER SHELF ENERGY VALUES

FOR SALEM UNIT 2

APPENDIX A - PREDICTED EOL USE VALUES

Per Regulatory Guide 1.99, Revision 2, the Charpy upper-shelf energy is assumed to decrease as a function of fluence and copper content as indicated in Figure 2 of the guide when surveillance data is not used. Linear interpolation is permitted. In addition, if surveillance data is to be used, the decrease in upper-shelf energy may be obtained by plotting the reduced plant surveillance data on Figure 2 of the guide and fitting the data with a line drawn parallel to the existing lines as the upper bound of all the data. This line should be used in preference to the existing graph.

The EOL (32 EFPY) and license renewal (48 EFPY) USE values can be predicted using the ¼T fluence projections at 32 and 48 EFPY, the copper content of the beltline materials and/or the results of the capsules tested to date using Figure 2 in Regulatory Guide 1.99, Revision 2. The peak vessel clad/base metal interface fluence value was used to determine the EOL (32 EFPY) and license renewal (48 EFPY) USE values of all the beltline materials.

The Salem Unit 2 reactor vessel beltline region minimum thickness is 8.625 inches.

The calculation of the ¼T peak vessel fluence value at 32 EFPY for the beltline materials is contained in Table A-1.

The calculation of the EOL USE values at 32 EFPY for the beltline materials is contained in Table A-2.

The calculation of the ¼T peak vessel fluence value at 48 EFPY for the beltline materials is contained in Table A-3.

The calculation of the EOL USE values at 48 EFPY for the beltline materials is contained in Table A-4.

TABLE A-1

EOL (32 EFPY) ¼T Fluence Values for all the Salem Unit 2 Beltline Materials

Material	f @ 32 EFPY[a]	¼T F @ 32 EFPY[b]
Intermediate Shell B4712-1	1.78	1.06
Intermediate Shell B4712-2	1.78	1.06
Intermediate Shell B4712-3	1.78	1.06
Lower Shell B4713-1	1.78	1.06
Lower Shell B4713-2	1.78	1.06
Lower Shell B4713-3	1.78	1.06
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	1.78	1.06
Intermediate Shell Longitudinal Weld Seams 2-442 A, B & C (Heat # 13253/20291)	1.78	1.06
Lower Shell Longitudinal Weld Seams 3-442 A, B & C (Heat # 21935/12008)	1.78	1.06

Notes:

(a) f @ 32 EFPY is the 32 EFPY fluence at the clad/base metal interface ($x\ 10^{19}$ n.cm^2, $E > 1.0$ MeV).

(b) ¼T f @ 32 EFPY = f @ 32 EFPY * $e^{(-0.24*X)}$ ($x\ 10^{19}$ n.cm^2, $E > 1.0$ MeV), where X is the depth into the vessel wall (X = 0.25 * 8.625 inches = 2.15625 inches).

TABLE A-2

Salem 2 Predicted End-of-License (32 EFPY) USE Calculations for all the Beltline Region Materials

Material	Weight % of Cu	1/4T EOL Fluence (10^{19} n/cm^2, E>1.0 MeV)	Unirradiate USE (ft-lb)	Projected USE Decrease (%)	Projected EOL USE (ft-lb)
Intermediate Shell B4712-1	0.13	1.06	106	22	83
Intermediate Shell B4712-2	0.12	1.06	97	14.5	83
Intermediate Shell B4712-3	0.11	1.06	107	20	86
Lower Shell B4713-1	0.12	1.06	98	21	77
Lower Shell B4713-2	0.12	1.06	103	21	81
Lower Shell B4713-3	0.12	1.06	121	21	96
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	0.197	1.06	99.7	35	65
Intermediate Shell Longitudinal Weld Seams 2-442 A, B & C (Heat # 13253/20291)	0.219	1.06	96.2	37	61
Lower Shell Longitudinal Weld Seams 3-442 A, B & C (Heat # 21935/12008)	0.213	1.06	114	37	72

TABLE A-3

EOL (48 EFPY) ¼T Fluence Values for all the Salem Unit 2 Beltline Materials

Material	f @ 32 EFPY[(a)]	¼T F @ 32 EFPY[(b)]
Intermediate Shell B4712-1	2.66	1.58
Intermediate Shell B4712-2	2.66	1.58
Intermediate Shell B4712-3	2.66	1.58
Lower Shell B4713-1	2.66	1.58
Lower Shell B4713-2	2.66	1.58
Lower Shell B4713-3	2.66	1.58
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	2.66	1.58
Intermediate Shell Longitudinal Weld Seams 2-442 A, B & C (Heat # 13253/20291)	2.66	1.58
Lower Shell Longitudinal Weld Seams 3-442 A, B & C (Heat # 21935/12008)	2.66	1.58

Notes:

(b) f @ 48 EFPY is the 48 EFPY fluence at the clad/base metal interface ($x\ 10^{19}$ $n.cm^2$, E > 1.0 MeV).

(b) ¼T f @ 48 EFPY = f @ 48 EFPY * $e^{(-0.24*X)}$ ($x\ 10^{19}$ $n.cm^2$, E > 1.0 MeV), where X is the depth into the vessel wall (X = 0.25 * 8.625 inches = 2.15625 inches).

TABLE A-4

Salem 2 Predicted Life Extension (48 EFPY) USE Calculations for all the Beltline Region Materials

Material	Weight % Cu	¼T Life Extension Fluence (10^{19} n/cm^2, E>1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected Life Extension USE (ft-lb)
Intermediate Shell B4712-1	0.13	1.58	106	24	81
Intermediate Shell B4712-2	0.12	1.58	97	16	81
Intermediate Shell B4712-3	0.11	1.58	107	22	83
Lower Shell B4713-1	0.12	1.58	98	23	75
Lower Shell B4713-2	0.12	1.58	103	23	79
Lower Shell B4713-3	0.12	1.58	121	23	93
Intermediate to Lower Shell Circumferential Weld Seam 9-442 (Heat # 90099)	0.197	1.58	99.7	38	62
Intermediate Shell Longitudinal Weld Seams 2-442 A, B & C (Heat # 13253/20291)	0.219	1.58	96.2	40	58
Lower Shell Longitudinal Weld Seams 3-442 A, B & C (Heat # 21935/12008)	0.213	1.58	114	40	58

Application and Affidavit by CE Nuclear Power LLC (CENP) for Withholding Proprietary Information Contained in Attachment 6 From Public Disclosure In Accordance With 10 CFR 2.790

AFFIDAVIT PURSUANT TO 10 CFR 2.790

I, Philip W. Richardson, depose and say that I am the Licensing Project Manager, CE Nuclear Power LLC (CENP), duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations and in conjunction with the application of Public Service Electric & Gas for withholding this information.

The information for which proprietary treatment is sought is contained in the following document:

A-SA2-PS-0001, "Feedwater Flow Measurement Using the CROSSFLOW Ultrasonic Flowmeter at PSE&G Salem Unit 2", August 31, 2000

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by CENP in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of Section 2.790(b)(4) of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1. The information sought to be withheld from public disclosure, is owned and has been held in confidence by CENP. It consists of CROSSFLOW UFM System theoretical development, design, testing, validation and installation information.
2. The information consists of test data or other similar data concerning a process, method or component, the application of which results in substantial competitive advantage to CENP.
3. The information is of a type customarily held in confidence by CENP and not customarily disclosed to the public. CENP has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence.
4. The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.790 with the understanding that it is to be received in confidence by the Commission.
5. The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.
6. Public disclosure of the information is likely to cause substantial harm to the competitive position of CENP because:
   a. A similar product is manufactured and sold by major pressurized water reactor competitors of CENP.
   b. Development of this information by CENP required hundreds of thousands of dollars and hundreds of man-hours of effort. A competitor would have to undergo similar expense in generating equivalent information.
   c. In order to acquire such information, a competitor would also require considerable time and inconvenience to develop CROSSFLOW UFM System theoretical development, design, testing, validation and installation information.
   d. The information consists of CROSSFLOW UFM System theoretical development, design, testing, validation and installation information, the application of which provides a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with CENP, take marketing or other actions to improve their product's position or impair the position of CENP's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.
   e. In pricing CENP's products and services, significant research, development, engineering, analytical, manufacturing, licensing, quality assurance and other costs and expenses must be included. The ability of CENP's competitors to utilize such information without similar expenditure of resources may enable them to sell at prices reflecting significantly lower costs.
   f. Use of the information by competitors in the international marketplace would increase their ability to market nuclear steam supply systems by reducing the costs associated with their technology development. In addition, disclosure would have an adverse economic impact on CENP 's potential for obtaining or maintaining foreign licensees.

Further the deponent sayeth not.

Philip W. Richardson, Licensing Project Manager
CE Nuclear Power LLC

Sworn to before me
this 5th day of February, 2001

Laurie J. White
Notary Public
My commission expires: 8/31/04