ATTACHMENT 5

WCAP-17341-NP

Palisades Nuclear Power Plant Heatup and Cooldown Limit Curves for Normal Operation and Upper-Shelf Energy Evaluation

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EXECUTIVE SUMMARY

This report provides the methodology and results of the generation of heatup and cooldown pressure-temperature (P-T) limit curves for normal operation of the Palisades reactor vessel. The heatup and cooldown P-T limit curves were generated using the limiting Adjusted Reference Temperature (ART) values pertaining to Palisades. The limiting ART values, which pertain to an axially oriented weld, were those of the intermediate and lower shell axial welds 2-112 and 3-112 (Heat # W5214 using the Position 2.1 chemistry factor value with a full margin term) at both 1/4 thickness (1/4T) and 3/4 thickness (3/4T) locations. The P-T curves made use of the K_{Ic} methodology that was first incorporated into the 1998 through the 2000 Addenda Edition of the ASME Code, Section XI, Appendix G, and ASME Code Case N-641.

The P-T limit curves were generated for an End-of-License Extension (EOLE) calendar date of March 24, 2031, which corresponded to 42.1 Effective Full Power Years (EFPY), using heatup rates of 0, 20, 40, 60, 80 and 100°F/hr, and cooldown rates of 0, 20, 40, 60, 80 and 100°F/hr. The curves were developed without margins for instrumentation errors and with a delta pressure correction for static and dynamic head loss. These curves can be found in Figures 5-1 and 5-2. Appendix A contains the thermal stress intensity factors for the maximum heatup and cooldown rates at 42.1 EFPY. Appendix B contains the determination of the Low Temperature Overpressure Protection (LTOP) system minimum enable temperature at 42.1 EFPY.

Appendix C contains heatup and cooldown limit curves that were developed with margins for instrumentation errors and with a delta pressure correction for static and dynamic head loss. These can be found in Figures C-1 and C-2.

Additionally, the curves documented in this report were compared to the current Palisades heatup and cooldown limit curves to determine if adequate margin exists to justify continued operation of the current curves. The current P-T limit curves for Palisades, including a ten-percent increase in pressure to account for changes between the K_{Ic} and K_{Ia} methodology, remain conservative through EOLE when compared to the curves documented in this report using the latest methodologies detailed in the 1998 through the 2000 Addenda Edition of the ASME Code, Section XI, Appendix G, and ASME Code Case N-641. This ten-percent increase to the pressure values is for comparison purposes <u>only</u> and is <u>not</u> to be used in actual plant operation. This comparison can be found in Figures 6-1 through 6-4. A summary of the available margin is contained in Tables 6-5 and 6-6 for heatup and cooldown, respectively. Finally, the current Technical Specification P-T limit curves for Palisades have been recreated, with the inclusion of the basis information and applicability term, in Figures 7-1 and 7-2.

Furthermore, Appendix D contains the Upper-Shelf Energy evaluation for Palisades at 42.1 EFPY. The limiting plate and weld materials (lower shell plate D-3804-1 and intermediate to lower shell circumferential weld 9-112 (Heat # 27204), using Position 1.2 data) are predicted to drop below 50 ft-lb in December of 2016 for the plate and November of 2027 for the weld. Per 10 CFR 50, Appendix G, an Equivalent Margins Analysis needs to be submitted to the NRC at least three years prior to the date when the predicted Charpy upper-shelf energy values are predicted to drop below 50 ft-lb. All of the remaining reactor vessel beltline materials are predicted to meet the 10 CFR 50, Appendix G, limits at EOLE.

1 INTRODUCTION

Heatup and cooldown P-T limit curves are calculated using the adjusted RT_{NDT} (reference nil-ductility transition 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" [Reference 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 surface, 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 heatup and cooldown pressure-temperature (P-T) limit curves documented in this report were generated using the ART values pertaining to the most limiting beltline material in the Palisades reactor vessel and the NRC-approved methodology documented in WCAP-14040-A, Revision 4 [Reference 2], "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves." Specifically, the "Axial Flaw" and "Circumferential Flaw" methodologies of the 1998 through the 2000 Addenda Edition of ASME Code, Section XI, Appendix G [Reference 3], was used, which makes use of the K_{Ic} methodology.

The calculated ART values for an EOLE date of March 24, 2031 [Reference 4], which corresponds to 42.1 EFPY, are documented in Tables 4-2 and 4-3 of this report. The design basis fluence projections are based on the values verified by Westinghouse in WCAP-15353 – Supplement 1-NP, Revision 0 [Reference 5].

The purpose of this report is to present the calculations and the development of the Palisades heatup and cooldown P-T limit curves for 42.1 EFPY. This report documents the calculated ART values and the development of the P-T limit curves for normal operation. The P-T curves herein were generated without margins for instrumentation errors. The P-T curves contain a delta pressure correction to account for static and dynamic head loss. Additionally, the P-T curves include the lowest service temperature which is distinctive to Combustion Engineering (CE) design reactor vessels and pressure-temperature limits for the vessel flange region per the requirements of 10 CFR Part 50, Appendix G [Reference 6]. Finally, the current Palisades heatup and cooldown limit curves, contained in their Technical Specifications, were compared to the curves generated in this report to determine if adequate margin exists to justify continued operation of the Palisades current P-T limits through EOLE (42.1 EFPY).

2 FRACTURE TOUGHNESS PROPERTIES

The fracture toughness properties of the ferritic materials in the Palisades reactor vessel are presented in Table 2-1. The unirradiated RT_{NDT} values for the limiting component in the balance of the reactor coolant system (RCS), the closure head flange and the vessel flange are documented in Table 2-2.

The Regulatory Guide 1.99, Revision 2, methodology used to develop the heatup and cooldown P-T limit curves documented in this report is the same as that documented in WCAP-14040-A, Revision 4 [Reference 2]. The chemistry factors (CFs) were calculated using Regulatory Guide 1.99, Revision 2, Positions 1.1 and 2.1. Position 1.1 uses the tables from the Regulatory Guide along with the best-estimate copper and nickel weight percents, which are presented in Table 2-1. Position 2.1 uses the surveillance capsule Charpy data from all capsules withdrawn and tested to date. Table 2-3 summarizes the Position 1.1 and 2.1 CFs determined for the Palisades beltline materials.

Table 2-1 Summary of the Best-Estimate Cu and Ni Weight Percent and Initial RT_{NDT} Values for the Palisades Reactor Vessel Beltline Materials

Material Description(a)		Chemical Composition(a)		Fracture Toughness Property(a)
Reactor Vessel Material	Heat Number	Cu wt. %	Ni wt. %	Initial RT_{NDT} (°F)
Intermediate Shell (IS) Plate D-3803-1	C-1279	0.24	0.50	-5(b)
IS Plate D-3803-2	A-0313	0.24	0.52	-30(b)
IS Plate D-3803-3	C-1279	0.24	0.50	-5(b)
Lower Shell (LS) Plate D-3804-1	C-1308A	0.19	0.48	0(b)
LS Plate D-3804-2	C-1308B	0.19	0.50	-30(b)
LS Plate D-3804-3	B-5294	0.12	0.55	-25(b)
IS Axial Welds 2-112 A/B/C	W5214	0.213	1.007	-56(c)
LS Axial Welds 3-112 A/B/C	34B009	0.192	0.98	-56(c)
	W5214	0.213	1.007	-56(c)
IS to LS Circ. Weld 9-112	27204	0.203	1.018	-56(c)

Notes for Table 2-1:

(a) The sources for this information are Structural Integrity Associates (SIA) reports 1000915.401, Revision 1 [Reference 7], and 1001026.401, Revision 1 [Reference 8].

(b) Initial RT_{NDT} values are based on measured data for all beltline materials.

(c) Initial RT_{NDT} values of all reactor vessel beltline welds (Heat Numbers W5214, 34B009 and 27204) are estimated.

Table 2-2 Summary of the Initial RT_{NDT} Values for the Palisades Balance of RCS, Closure Head Flange and Vessel Flange

Reactor Vessel Material	Initial RT_{NDT} (°F)
Balance of RCS (Vessel Closure Head)	72(a)
Closure Head Flange	60(b)
Vessel Flange	60(b)

Notes for Table 2-2:

(a) Value taken from the Palisades Final Safety Analysis Report (FSAR) [Reference 9], Table 1-2.

(b) Values based on the data contained in the Certified Material Test Reports (CMTRs) for the Closure Head Flange [Reference 10] and the Vessel Flange [Reference 11].

Table 2-3 Summary of the Palisades Reactor Vessel Beltline Material Chemistry Factors Per Regulatory Guide 1.99, Revision 2

Reactor Vessel Material	Heat Number	Chemistry Factor[a] (°F)	
		Position 1.1	Position 2.1[b]
IS Plate D-3803-1	C-1279	157.5	147.71
IS Plate D-3803-2	A-0313	160.4	---
IS Plate D-3803-3	C-1279	157.5	147.71
LS Plate D-3804-1	C-1308A	128.8	---
LS Plate D-3804-2	C-1308B	131	---
LS Plate D-3804-3	B-5294	82	---
IS Axial Welds 2-112 A/B/C	W5214	230.73	227.74[c]
LS Axial Welds 3-112 A/B/C	34B009	217.7	---
	W5214	230.73	227.74[c]
IS to LS Circ. Weld 9-112	27204	226.8	216.13[c]

Notes for Table 2-3:

(a) Values taken from SIA reports 1000915.401, Revision 1 [Reference 7], and 1001026.401, Revision 1 [Reference 8]. The chemistry factor values documented in References 7 and 8 were calculated per the guidance provided by the NRC Staff during the NRC/Industry workshop on RPV integrity issues, held on February 12th, 1998.

(b) Based on the interpretation of credibility in SIA Reports 0901132.401, Revision 0 [Reference 12], and 1000915.401, Revision 1 [Reference 7], surveillance data of the plate materials were considered to be non-credible, surveillance data of the weld material Heat # W5214 were considered to be not fully credible and surveillance data of the weld material Heat # 27204 were considered to be credible.

(c) It should be noted that in the calculations of Position 2.1 chemistry factors for weld Heat # W5214 and Heat # 27204, the ratio and temperature adjustment procedures described in Reference 1 were applied to account for differences in chemistry and plant operating temperatures. The Position 2.1 chemistry factor for weld Heat # W5214 was calculated using Charpy data from Palisades and sister plant Charpy data from Indian Point Units 2 and 3 and H. B. Robinson Unit 2. The Position 2.1 chemistry factor for weld Heat # 27204 was calculated using Charpy data from Palisades and sister plant Charpy data from Diablo Canyon Unit 1.

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 the 1998 Edition through the 2000 Addenda of Section XI, Appendix G, of the ASME Code [Reference 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} (ksi√in.) = 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 Class 1, SA-508-1, SA-508-2, and 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} = reference stress intensity factor as a function of the metal temperature T and the metal reference nil-ductility temperature RT_{NDT}

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:

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

where, M_m for an inside axial 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 $\sqrt{t} > 3.464$

and, M_m for an outside axial 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 $\sqrt{t} > 3.464$

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

M_m = 0.89 for $\sqrt{t} < 2$,
M_m = $0.443\sqrt{t}$ for $2 \leq \sqrt{t} \leq 3.464$,
M_m = 1.53 for $\sqrt{t} > 3.464$

Where:

p = internal pressure (ksi), R_i = vessel inner radius (in.), and t = vessel wall thickness (in.).

The maximum K_I produced by radial thermal gradient for the postulated axial or circumferential inside surface defect of G-2120 is:

$$K_{It} = 0.953 \times 10^{-3} \times CR \times t^{2.5} \qquad (4)$$

where CR is the cooldown rate in °F/hr., or for a postulated axial or circumferential outside surface defect

$$K_{It} = 0.753 \times 10^{-3} \times HU \times t^{2.5} \qquad (5)$$

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 ASME Code, Section XI, Appendix G, Fig. G-2214-1. The temperature at any radial distance from the vessel surface can be determined from ASME Code, Section XI, Appendix G, 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 axial or circumferential inside surface defect using the relationship:

$$K_{It} = (1.0359C_0 + 0.6322C_1 + 0.4753C_2 + 0.3855C_3) * \sqrt{\pi a} \tag{6}$$

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

$$K_{It} = (1.043C_0 + 0.630C_1 + 0.481C_2 + 0.401C_3) * \sqrt{\pi a} \tag{7}$$

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:

$$\sigma(x) = C_0 + C_1(x/a) + C_2(x/a)^2 + C_3(x/a)^3 \tag{8}$$

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

Note that Equation 3 and Equations 6 through 9 were implemented in the OPERLIM computer code, which is the program used to generate the pressure-temperature (P-T) limit curves (Equations 4 and 5 are not utilized by the OPERLIM code). The P-T curve methodology is the same as that described in WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves" [Reference 2], Section 2.6 (equations 2.6.2-4 and 2.6.3-1).

At any time during the heatup or cooldown transient, K_{Ic} is determined by the metal temperature at the tip of a postulated flaw (the postulated flaw has a depth of 1/4 of the section thickness, and a length of 1.5 times the section thickness per ASME Code, Section XI, paragraph G-2120), the appropriate value for RT_{NDT}, and the reference fracture toughness curve (Equation 1). 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. By substituting the appropriate equations from this section into Equation 2, the pressure stress intensity factors are obtained and, from these, the allowable pressures for Level A and B Service Conditions are calculated per Equation 9.

$$p = \frac{K_{Ic} - K_{It}}{2M_m} * \left(\frac{t}{R_i}\right) \tag{9}$$

For the calculation of the allowable pressure-versus-coolant temperature during cooldown, the reference 1/4T flaw of Appendix G to Section XI of 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 vessel wall because the thermal gradients, which increase with increasing cooldown rates, produce tensile stresses at the inside surface that would tend to open (propagate) the existing flaw. Allowable pressure-temperature curves are generated for steady state (zero-rate) and each finite cooldown rate specified. From these curves, composite limit curves are constructed as the minimum of the steady-state or finite rate curve for each cooldown rate specified.

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 1/4T 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) across the vessel wall developed during cooldown results in a higher value of K_{Ic} at the 1/4T 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 use of the composite curve 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 1/4T 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 inside 1/4T flaw during heatup is lower than the K_{Ic} for the flaw 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 1/4T 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 third portion of the heatup analysis concerns the calculation of the pressure-temperature limitations for the case in which a 1/4T flaw located at the 1/4T 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 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 least 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 [Reference 6], 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 (3110 psig for Palisades as documented in Reference 13), which is calculated to be 622 psig. The limiting unirradiated RT_{NDT} of 60°F occurs in the closure head flange and vessel flange of the Palisades reactor vessel, so the minimum allowable temperature of this region is 180°F at pressures greater than 622 psig (without margin for instrument uncertainties). This limit is shown in Figures 5-1 and 5-2 wherever applicable.

The P-T limit curves presented in Appendix C incorporate margins for instrument errors of 5°F on temperature and 30 psi on pressure. These margins for instrument errors are consistent with the values used in the P-T limit curve analysis of record (AOR) for Palisades contained in EA-A-PAL-92-095-01, Revision 0 [Reference 14]. Therefore, with the inclusion of these margins for instrument errors, the minimum allowable temperature of this region is 185°F at pressures greater than 592 psig.

3.4 DELTA PRESSURE CORRECTION

The current Palisades heatup and cooldown limit curves include a variable delta pressure correction to account for static and dynamic head loss effects, which are dependent on the number of primary coolant pumps in operation. Per Reference 14, below primary system temperatures of 300°F, since no more than two primary coolant pumps can be operating, the delta pressure correction is 35 psi. At 300°F and above, when three or more primary coolant pumps are in operation, the delta pressure correction is 54 psi. These pressure correction factors have been incorporated in the heatup and cooldown limit curves shown in Figures 5-1 and 5-2 as well as in Appendix C.

3.5 LOWEST SERVICE TEMPERATURE REQUIREMENTS

The lowest service temperature (LST) is the minimum allowable temperature at which pressure can exceed 20% of the pre-service hydrostatic test pressure (3110 psig). This temperature is defined by Paragraph NB-2332 of ASME Code Section III [Reference 15] as the most limiting RT_{NDT} for the balance of the RCS components plus 100°F. The balance of the reactor coolant system components includes consideration of the ferritic materials outside the reactor vessel beltline but within the primary system.

The most limiting RT_{NDT} for the balance of RCS is 72°F. Therefore, without margins for instrument errors, the LST for Palisades is 172°F. The curves contained in Appendix C do contain margins for instrument errors; the LST for these curves is 177°F.

3.6 BOLTUP TEMPERATURE REQUIREMENTS

The minimum boltup temperature is the minimum allowable temperature at which the reactor vessel closure head bolts can be preloaded. It is determined by the highest reference temperature, RT_{NDT}, in the closure flange region. This requirement is established in Appendix G to 10 CFR 50 [Reference 6].

The limiting unirradiated RT_{NDT} of 60°F occurs in the closure head flange and vessel flange of the Palisades reactor vessel; therefore, the minimum boltup temperature for the Palisades reactor vessel is 60°F (without margins for instrument uncertainties). This limit is shown in Figures 5-1 and 5-2. The curves contained in Appendix C do contain instrument errors; the boltup temperature for these curves is 65°F.

3.7 REACTOR VESSEL BELTLINE DIMENSIONS

Reactor vessel beltline dimensions are input to the calculations used in the development of P-T limit curves. WCAP-15353, Revision 0 [Reference 16] documents Palisades' reactor vessel as-built (measured) dimensions. Table 3-1 summarizes the vessel inner radius, 1/4T, 3/4T and outer radius dimensions along with the beltline thickness.

Table 3-1 Summary of the Reactor Vessel Beltline Dimensions for Palisades

Reactor Vessel Location	Dimension[a] (inches)
Base Metal Inner Radius	86.35
Base Metal 1/4T	88.55
Base Metal 3/4T	92.94
Base Metal Outer Radius	95.14
Beltline Thickness	8.79[b]

Notes for Table 3-1:

(a) Values taken fromWCAP-15353, Revision 0 [Reference 16], unless otherwise noted.
(b) Beltline thickness was determined using the base metal outer and inner radii.

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:

$$ART = \text{Initial } RT_{NDT} + \Delta RT_{NDT} + \text{Margin} \quad (10)$$

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 [Reference 15]. If measured values of the initial RT_{NDT} for the material in question are not available, generic mean values for that class of material may be used, provided there are sufficient test results to establish a mean and standard deviation for the class. Per Table 2-1, the Palisades reactor vessel beltline materials have both measured and generic initial RT_{NDT} values.

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

$$\Delta RT_{NDT} = CF * f^{(0.28 - 0.10 \log f)} \quad (11)$$

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.

$$f_{(depth\ x)} = f_{surface} * e^{(-0.24x)} \quad (12)$$

where x inches (vessel beltline thickness is 8.79 inches) is the depth into the vessel wall measured from the vessel clad/base metal interface. The resultant fluence is then placed in Equation 11 to calculate the ΔRT_{NDT} at the specific depth.

The projected reactor vessel neutron fluence for Palisades was updated in WCAP-15353 – Supplement 1-NP [Reference 5]. The evaluation methods used in Reference 5 are consistent with the methods presented in WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves" [Reference 2]. NUREG-1871, Revision 0 [Reference 4], specifies that the extended operating license for Palisades will expire on March 24, 2031 (EOLE). This EOLE calendar date is expected to be between end-of-cycles (EOCs) 34 and 35 per Reference 5 and was determined to correspond to 42.1 EFPY.

The peak surface fluence values at the 60° and 75° azimuthal locations were interpolated in SIA report 1000915.401, Revision 1 [Reference 7] to the EOLE calendar date and summarized in Table 4-1. The Palisades intermediate and lower shell axial welds are located at 0° and 60° with respect to the coordinate system used in the fluence analysis contained in Reference 5. The fluence at the 60° azimuthal location is higher than the fluence at the 0° azimuthal location. Therefore, the fluence values used for the reactor vessel plate and circumferential weld materials are based on the 75° peak azimuthal fluence (i.e. the maximum fluence value for the Palisades beltline region) while the fluence values used for the reactor vessel axial weld materials are based on the 60° peak azimuthal fluence.

The surface fluence values, which were obtained from SIA report 1000915.401 [Reference 7], were used to calculate the 1/4T and 3/4T fluence and fluence factors, per Regulatory Guide 1.99, Revision 2, for 42.1 EFPY. Table 4-1 contains these values, which will be used to calculate the 42.1 EFPY ART values for all beltline materials in the Palisades reactor vessel.

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 available. The standard deviation for the ΔRT_{NDT} margin term, σ_Δ, is 17°F for plates or forgings when surveillance data is not used or is non-credible, and 8.5°F (half the value) for plates or forgings when credible surveillance data is used. For welds, σ_Δ is equal to 28°F when surveillance capsule data is not used or is non-credible, and is 14°F (half the value) when credible surveillance capsule data is used. The value for σ_Δ need not exceed 0.5 times the mean value of ΔRT_{NDT}.

Contained in Tables 4-2 and 4-3 are the 42.1 EFPY ART calculations and values at the 1/4T and 3/4T locations for generation of the Palisades heatup and cooldown curves.

Table 4-1 Fluence Values and Fluence Factors for the Vessel Surface, 1/4T and 3/4T Locations for the Palisades Reactor Vessel Beltline Materials at 42.1 EFPY

Reactor Vessel Material	Limiting Azimuthal Location	Surface Fluence, f[(a)] (x 10^{19} n/cm^2, E > 1.0 MeV)	1/4T f (x 10^{19} n/cm^2, E > 1.0 MeV)	1/4T FF	3/4T f (x 10^{19} n/cm^2, E > 1.0 MeV)	3/4T FF
Plates and Circumferential Welds	75°	3.429	2.024	1.1922	0.705	0.9019
Axial Welds	60°	2.161	1.275	1.0677	0.444	0.7742

Note for Table 4-1:

(a) Values taken from SIA report 1000915.401 [Reference 7].

Table 4-2 Adjusted Reference Temperature Evaluation for the Palisades Reactor Vessel Beltline Materials through 42.1 EFPY at the 1/4T Location

Reactor Vessel Material	CF (°F)	1/4T f (x 10^{19} n/cm², E > 1.0 MeV)	1/4T FF	$RT_{NDT(U)}$ (a) (°F)	ΔRT_{NDT} (°F)	σ_I (a) (°F)	σ_Δ (c) (°F)	M (°F)	ART (d) (°F)
IS Plate D-3803-1	157.5	2.024	1.1922	-5	187.8	0	17	34.0	216.8
Using Non-Credible Surveillance Data	147.71	2.024	1.1922	-5	176.1	0	17	34.0	205.1
IS Plate D-3803-2	160.4	2.024	1.1922	-30	191.2	0	17	34.0	195.2
IS Plate D-3803-3	157.5	2.024	1.1922	-5	187.8	0	17	34.0	216.8
Using Non-Credible Surveillance Data	147.71	2.024	1.1922	-5	176.1	0	17	34.0	205.1
LS Plate D-3804-1	128.8	2.024	1.1922	0	153.6	0	17	34.0	187.6
LS Plate D-3804-2	131	2.024	1.1922	-30	156.2	0	17	34.0	160.2
LS Plate D-3804-3	82	2.024	1.1922	-25	97.8	0	17	34.0	106.8
IS Axial Welds 2-112 (Heat # W5214)	230.73	1.275	1.0677	-56(b)	246.4	17(b)	28	65.5	255.9
Using Not Fully Credible Surveillance Data	227.74	1.275	1.0677	-56(b)	243.2	17(b)	28	65.5	252.7
LS Axial Welds 3-112 (Heat # 34B009)	217.7	1.275	1.0677	-56(b)	232.4	17(b)	28	65.5	242.0
LS Axial Welds 3-112 (Heat # W5214)	230.73	1.275	1.0677	-56(b)	246.4	17(b)	28	65.5	255.9
Using Not Fully Credible Surveillance Data	227.74	1.275	1.0677	-56(b)	243.2	17(b)	28	65.5	252.7
IS to LS Circ. Weld 9-112 (Heat # 27204)	226.8	2.024	1.1922	-56(b)	270.4	17(b)	28	65.5	279.9
Using Credible Surveillance Data	216.13	2.024	1.1922	-56(b)	257.7	17(b)	14	44.0	245.7

Notes for Table 4-2:

(a) Initial RT_{NDT} values are measured for all materials, except where otherwise noted; hence σ_I = 0°F.
(b) Initial RT_{NDT} of all three reactor vessel beltline welds (Heat Numbers W5214, 34B009 and 27204) are estimated; hence σ_I = 17°F.
(c) Based on the interpretation of credibility in the SIA reports, References 7 and 12, surveillance data of the plate materials were considered to be non-credible, surveillance data of the weld material Heat # W5214 were considered to be not fully credible, and surveillance data of the weld material Heat # 27204 were considered to be credible. Per the guidance of Reg. Guide 1.99, Revision 2, the base metal σ_Δ = 17°F for both Positions 1.1 and 2.1, the weld metal σ_Δ = 28°F for Positions 1.1 and 2.1 with not fully credible surveillance data, and σ_Δ = 14°F for Position 2.1 with credible surveillance data. However, σ_Δ need not exceed $0.5*\Delta RT_{NDT}$.
(d) The Regulatory Guide 1.99, Revision 2 methodology was used to calculate ART values. ART = $RT_{NDT(U)} + \Delta RT_{NDT}$ + Margin.

Table 4-3 Adjusted Reference Temperature Evaluation for the Palisades Reactor Vessel Beltline Materials through 42.1 EFPY at the 3/4T Location

Reactor Vessel Material	CF (°F)	3/4T f (x 10^{19} n/cm², E > 1.0 MeV)	3/4T FF	$RT_{NDT(U)}$ [(a)] (°F)	ΔRT_{NDT} (°F)	σ_I [(a)] (°F)	σ_Δ [(c)] (°F)	M (°F)	ART [(d)] (°F)
IS Plate D-3803-1	157.5	0.705	0.9019	-5	142.0	0	17	34.0	171.0
Using Non-Credible Surveillance Data	147.71	0.705	0.9019	-5	133.2	0	17	34.0	162.2
IS Plate D-3803-2	160.4	0.705	0.9019	-30	144.7	0	17	34.0	148.7
IS Plate D-3803-3	157.5	0.705	0.9019	-5	142.0	0	17	34.0	171.0
Using Non-Credible Surveillance Data	147.71	0.705	0.9019	-5	133.2	0	17	34.0	162.2
LS Plate D-3804-1	128.8	0.705	0.9019	0	116.2	0	17	34.0	150.2
LS Plate D-3804-2	131	0.705	0.9019	-30	118.1	0	17	34.0	122.1
LS Plate D-3804-3	82	0.705	0.9019	-25	74.0	0	17	34.0	83.0
IS Axial Weld 2-112 (Heat # W5214)	230.73	0.444	0.7742	-56[(b)]	178.6	17[(b)]	28	65.5	188.2
Using Not Fully Credible Surveillance Data	227.74	0.444	0.7742	-56[(b)]	176.3	17[(b)]	28	65.5	185.8
LS Axial Welds 3-112 (Heat # 34B009)	217.7	0.444	0.7742	-56[(b)]	168.6	17[(b)]	28	65.5	178.1
LS Axial Welds 3-112 (Heat # W5214)	230.73	0.444	0.7742	-56[(b)]	178.6	17[(b)]	28	65.5	188.2
Using Not Fully Credible Surveillance Data	227.74	0.444	0.7742	-56[(b)]	176.3	17[(b)]	28	65.5	185.8
IS to LS Circ. Weld 9-112 (Heat # 27204)	226.8	0.705	0.9019	-56[(b)]	204.5	17[(b)]	28	65.5	214.1
Using Credible Surveillance Data	216.13	0.705	0.9019	-56[(b)]	194.9	17[(b)]	14	44.0	183.0

Notes for Table 4-3:

(a) Initial RT_{NDT} values are measured for all materials, except where otherwise noted; hence $\sigma_I = 0$°F.

(b) Initial RT_{NDT} of all three reactor vessel beltline welds (Heat Numbers W5214, 34B009 and 27204) are estimated; hence $\sigma_I = 17$°F.

(c) Based on the interpretation of credibility in the SIA reports, References 7 and 12, surveillance data of the plate materials were considered to be non-credible, surveillance data of the weld material Heat # W5214 were considered to be not fully credible, and surveillance data of the weld material Heat # 27204 were considered to be credible. Per the guidance of Reg. Guide 1.99, Revision 2, the base metal $\sigma_\Delta = 17$°F for both Positions 1.1 and 2.1, the weld metal $\sigma_\Delta = 28$°F for Positions 1.1 and 2.1 with not fully credible surveillance data, and $\sigma_\Delta = 14$°F for Position 2.1 with credible surveillance data. However, σ_Δ need not exceed $0.5 * \Delta RT_{NDT}$.

(d) The Regulatory Guide 1.99, Revision 2 methodology was used to calculate ART values. ART = $RT_{NDT(U)} + \Delta RT_{NDT}$ + Margin.

Contained in Table 4-4 is a summary of the limiting ART values that are used in the generation of the Palisades reactor vessel heatup and cooldown curves. The limiting ART values for the axially oriented welds and plates correspond to Axial Welds 2-112 and 3-112 (Heat # W5214) using Position 2.1. These Position 2.1 ART values were determined using not fully credible surveillance data. Per SIA Report 1000915.401, Revision 1 [Reference 7], the Position 2.1 chemistry factor value, with full margin term, was used in the PTS calculations because the surveillance data credibility evaluation in SIA Report 0901132.401, Revision 0 [Reference 12] deemed that all the data points fell within the two standard deviation scatter band of 56°F for welds.

The limiting ART values for the circumferentially oriented welds correspond to the IS to LS Circ. Weld 9-112 (Heat # 27204) using Position 2.1 with credible surveillance data. Note that this material resulted in higher ART values when surveillance data was not used (Position 1.1); however, credit was taken for the surveillance data being credible.

The ART values corresponding to the axially oriented weld material (Heat # W5214) are higher than the ART values corresponding to the circumferentially oriented weld material (Heat # 27204) (See Tables 4-2 and 4-3). In general, axial weld/plate/forging materials, which consider an axially oriented reference flaw, are more limiting for P-T limit curves in the lower-pressure regions, while circumferential weld materials, which consider a circumferentially oriented flaw, are more limiting in the higher-pressure regions. However, in general, axial flaws are more limiting than circumferential flaws based on the higher-pressure stresses that occur in those regions. Therefore, since the highest ART values are for weld Heat # W5214, which corresponds to an axially oriented flaw, the P-T limit curves for Palisades will be limited by this material only.

Table 4-4 Summary of the Limiting ART Values Used in the Generation of the Palisades Heatup/Cooldown Curves at 42.1 EFPY

Limiting ART	
1/4T	**3/4T**
Axial Welds 2-112 and 3-112 (Heat # W5214) Using the Position 2.1 Chemistry Factor Value Based on Not Fully Credible Surveillance Data with Full Margin Term (Limiting Axial Flaw Material)	
252.7°F	185.8°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 pressure and temperature in 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-A, Revision 4.

Figure 5-1 presents the limiting heatup curves without margins for possible instrumentation errors using heatup rates of 0, 20, 40, 60, 80 and 100°F/hr applicable for 42.1 EFPY, with the "Flange-Notch" requirement and using the "Axial Flaw" methodology only (See explanation in Section 4). Figure 5-2 presents the limiting cooldown curves without margins for possible instrumentation errors using cooldown rates of 0, 20, 40, 60, 80 and 100°F/hr applicable for 42.1 EFPY, with the "Flange-Notch" requirement and using the "Axial Flaw" methodology (See explanation in Section 4). The heatup and cooldown curves were generated using the 1998 through the 2000 Addenda ASME Code Section XI, Appendix G. Finally, these curves incorporate a pressure correction of 35 psi for temperatures less than 300°F, and 54 psi for temperatures greater than or equal to 300°F, associated with the number of primary coolant pumps in operation [Reference 14].

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 and 5-2. This is in addition to other criteria, which must be met before the reactor is made critical, as discussed below 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 Figure 5-1 (heatup curve only). 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 the 1998 through the 2000 Addenda ASME Code Section XI, Appendix G, as follows:

$1.5\ K_{Im} < K_{Ic}$

where,

K_{Im} is the stress intensity factor covered by membrane (pressure) stress,

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

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 in order to provide additional margin during actual power production. The pressure-temperature limits for core operation (except for low-power physics tests) are that: 1) the reactor vessel must be at a temperature equal to or higher than the minimum temperature required for the inservice hydrostatic test, and 2) the reactor vessel must be 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. For the heatup and cooldown curves without margins for instrumentation errors, the minimum temperature for the inservice hydrostatic leak tests for the Palisades reactor vessel at 42.1 EFPY is 312°F. However, per Reference 14, margins for instrument errors for pressure and temperature (30 psi and 5°F) were included in the determination of the minimum temperature for the inservice hydrostatic leak tests for the Palisades reactor vessel. Therefore, the minimum temperature for the hydrostatic leak test limits, which is shown on Figure 5-1, is 317°F. This temperature is also used for the criticality limit at 42.1 EFPY. Note that the leak test limits as well as the criticality temperature used for the *without margin for instrument error curves* is equivalent to those used in the *with margin for instrument error curves* documented in Appendix C. 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.

The LST is labeled on Figures 5-1 and 5-2. However, since the 10 CFR 50, Appendix G, "Flange-Notch" requirements are more limiting; the traditional vertical line defining this temperature has been omitted from the Figures for clarity.

Figures 5-1 and 5-2 define all of the above limits for ensuring prevention of non-ductile failure for the Palisades reactor vessel for 42.1 EFPY with the "Flange-Notch" requirement, without instrumentation uncertainties, and with pressure correction. The data points used for developing the heatup and cooldown pressure-temperature limit curves shown in Figures 5-1 and 5-2 are presented in Tables 5-1 and 5-2.

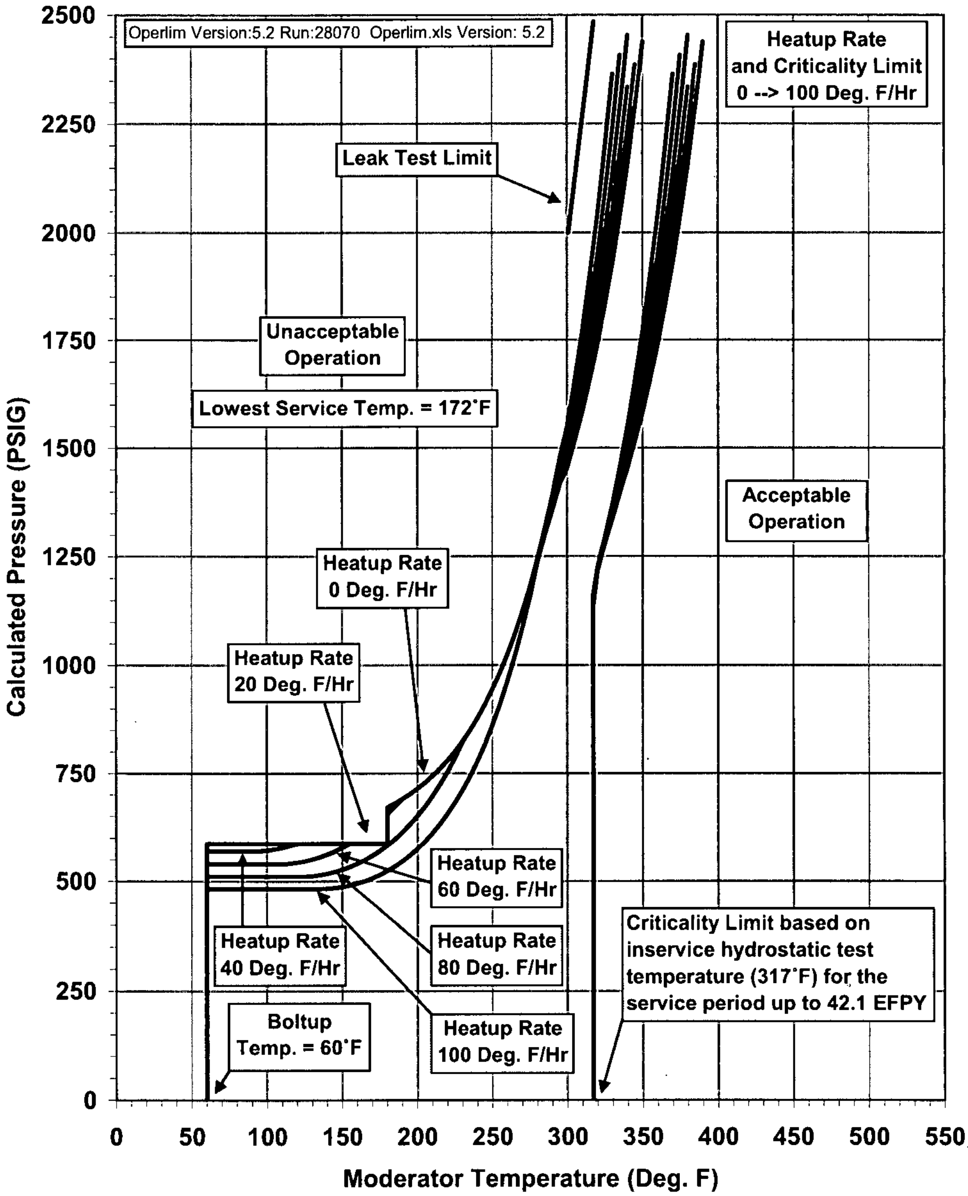
See Appendix C for the figures and data tables corresponding to the P-T curves developed with margins for instrument errors.

MATERIAL PROPERTY BASIS

LIMITING MATERIALS: IS and LS Axial Welds 2-112 and 3-112 (Heat # W5214) Using the Position 2.1 Chemistry Factor Value Based on Not Fully Credible Surveillance Data with Full Margin Term

LIMITING ART VALUES AT 42.1 EFPY: 1/4T, 252.7°F (Axial Flaw)
3/4T, 185.8°F (Axial Flaw)

Figure 5-1 Palisades Reactor Coolant System Steady State and Heatup Curves for 20, 40, 60, 80 and 100°F/hr Applicable to 42.1 EFPY Based on the K_{Ic} Methodology of the 1998 through the Summer 2000 Addenda Edition of ASME Code, Section XI, App. G, Without Margins for Instrumentation Errors (Except for the Hydrostatic Leak Test), and With Delta Pressure Correction



MATERIAL PROPERTY BASIS

LIMITING MATERIALS: IS and LS Axial Welds 2-112 and 3-112 (Heat # W5214) Using the Position 2.1 Chemistry Factor Value Based on Not Fully Credible Surveillance Data with Full Margin Term

LIMITING ART VALUES AT 42.1 EFPY: 1/4T, 252.7°F (Axial Flaw)
3/4T, 185.8°F (Axial Flaw)

Figure 5-2 Palisades Reactor Coolant System Steady State and Cooldown Curves for 20, 40, 60, 80 and 100°F/hr Applicable to 42.1 EFPY Based on the K_{Ic} Methodology of the 1998 through the Summer 2000 Addenda Edition of ASME Code, Section XI, App. G, Without Margins for Instrumentation Errors, and With Delta Pressure Correction

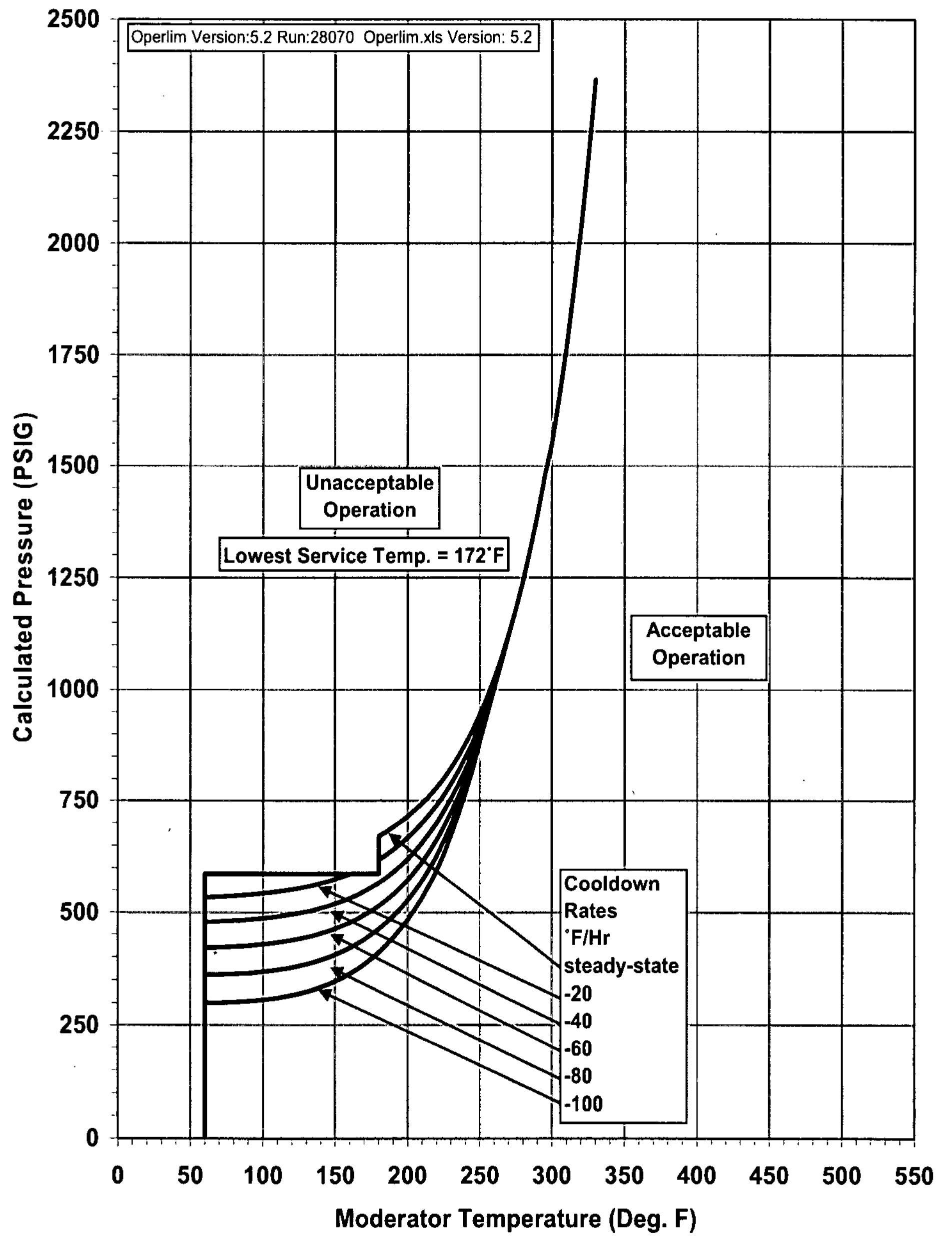


Table 5-1 Palisades 42.1 EFPY Heatup Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, Without Margin for Instrument Errors (Except for the Hydrostatic Leak Test) and With Delta Pressure Correction

Leak Test Limit		Steady State Heatup		Steady State Criticality[a]		20°F/hr Heatup		20°F/hr Criticality[a]		40°F/hr Heatup		40°F/hr Criticality[a]	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
301	2000	60	0	317	0	60	0	317	0	60	0	317	0
301	2000	60	587	317	568	60	587	317	568	60	570	317	551
301	2000	65	587	317	568	65	587	317	568	65	570	317	551
301	2000	70	587	317	568	70	587	317	568	70	570	317	551
301	2000	75	587	317	568	75	587	317	568	75	570	317	551
317	2485	80	587	317	568	80	587	317	568	80	570	317	551
317	2485	85	587	317	568	85	587	317	568	85	570	317	551
317	2485	90	587	317	568	90	587	317	568	90	570	317	551
317	2485	95	587	317	568	95	587	317	568	95	570	317	551
317	2485	100	587	317	568	100	587	317	568	100	571	317	552
		105	587	317	568	105	587	317	568	105	574	317	555
		110	587	317	568	110	587	317	568	110	578	317	559
		115	587	317	568	115	587	317	568	115	582	317	563
		120	587	317	568	120	587	317	568	120	587	317	568
		125	587	317	568	125	587	317	568	125	587	317	568
		130	587	317	568	130	587	317	568	130	587	317	568
		135	587	317	568	135	587	317	568	135	587	317	568
		140	587	317	568	140	587	317	568	140	587	317	568
		145	587	317	568	145	587	317	568	145	587	317	568
		150	587	317	568	150	587	317	568	150	587	317	568
		155	587	317	568	155	587	317	568	155	587	317	568
		160	587	317	568	160	587	317	568	160	587	317	568
		165	587	317	568	165	587	317	568	165	587	317	568

Leak Test Limit		Steady State Heatup		Steady State Criticality[a]		20°F/hr Heatup		20°F/hr Criticality[a]		40°F/hr Heatup		40°F/hr Criticality[a]	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
		170	587	317	568	170	587	317	568	170	587	317	568
		175	587	317	568	175	587	317	568	175	587	317	568
		180	587	317	651	180	587	317	651	180	587	317	651
		180	587	317	661	180	587	317	661	180	587	317	661
		180	670	317	671	180	670	317	671	180	670	317	671
		185	680	317	683	185	680	317	683	185	680	317	683
		190	690	317	695	190	690	317	695	190	690	317	695
		195	702	317	709	195	702	317	709	195	702	317	709
		200	714	317	725	200	714	317	725	200	714	317	725
		205	728	317	742	205	728	317	742	205	728	317	742
		210	744	317	761	210	744	317	761	210	744	317	761
		215	761	317	782	215	761	317	782	215	761	317	782
		220	780	317	806	220	780	317	806	220	780	317	806
		225	801	317	831	225	801	317	831	225	801	317	831
		230	825	317	860	230	825	317	860	230	825	317	860
		235	850	317	891	235	850	317	891	235	850	317	891
		240	879	317	926	240	879	317	926	240	879	317	926
		245	910	317	964	245	910	317	964	245	910	317	964
		250	945	317	1006	250	945	317	1006	250	945	317	1006
		255	983	317	1053	255	983	317	1053	255	983	317	1053
		260	1025	317	1105	260	1025	317	1105	260	1025	317	1105
		265	1072	317	1162	265	1072	317	1162	265	1072	317	1162
		270	1124	320	1225	270	1124	320	1221	270	1124	320	1221
		275	1181	325	1295	275	1181	325	1284	275	1181	325	1281
		280	1244	330	1372	280	1240	330	1353	280	1240	330	1343
		285	1314	335	1457	285	1303	335	1429	285	1300	335	1411
		290	1391	340	1551	290	1372	340	1514	290	1362	340	1487

Leak Test Limit		**Steady State Heatup**		**Steady State Criticality[a]**		**20°F/hr Heatup**		**20°F/hr Criticality[a]**		**40°F/hr Heatup**		**40°F/hr Criticality[a]**	
T (°F)	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**
		295	1476	345	1655	295	1448	345	1607	295	1430	345	1570
		300	1551	350	1771	300	1514	350	1709	300	1487	350	1662
		305	1655	355	1898	305	1607	355	1823	305	1570	355	1764
		310	1771	360	2038	310	1709	360	1948	310	1662	360	1876
		315	1898	365	2194	315	1823	365	2087	315	1764	365	2000
		320	2038	370	2365	320	1948	370	2240	320	1876	370	2136
		325	2194			325	2087	375	2409	325	2000	375	2287
		330	2365			330	2240			330	2136	380	2454
						335	2409			335	2287		
										340	2454		

Note for Table 5-1:

(a) Data in Table 5-1 is associated with the without margin for instrument error heatup curves (Figure 5-1). However, margins for instrument error (5°F and 30 psi) were included on the inservice hydrostatic leak test limits. The inservice hydrostatic leak test temperature is also reflected on the criticality limits; therefore, the criticality limits include margin on the criticality temperature as well.

Table 5-1-Cont. Palisades 42.1 EFPY Heatup Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, Without Margin for Instrument Errors (Except for the Hydrostatic Leak Test) and With Delta Pressure Correction

60°F/hr Heatup		60°F/hr Criticality[(a)]		80°F/hr Heatup		80°F/hr Criticality[(a)]		100°F/hr Heatup		100°F/hr Criticality[(a)]	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
60	0	317	0	60	0	317	0	60	0	317	0
60	540	317	521	60	511	317	492	60	483	317	464
65	540	317	521	65	511	317	492	65	483	317	464
70	540	317	521	70	511	317	492	70	483	317	464
75	540	317	521	75	511	317	492	75	483	317	464
80	540	317	521	80	511	317	492	80	483	317	464
85	540	317	521	85	511	317	492	85	483	317	464
90	540	317	521	90	511	317	492	90	483	317	464
95	540	317	521	95	511	317	492	95	483	317	464
100	540	317	521	100	511	317	492	100	483	317	464
105	540	317	521	105	511	317	492	105	483	317	464
110	540	317	521	110	511	317	492	110	483	317	464
115	541	317	522	115	511	317	492	115	483	317	464
120	543	317	524	120	511	317	492	120	483	317	464
125	547	317	528	125	511	317	492	125	483	317	464
130	551	317	532	130	512	317	493	130	483	317	464
135	556	317	537	135	515	317	496	135	483	317	464
140	562	317	543	140	518	317	499	140	483	317	464
145	569	317	550	145	522	317	503	145	485	317	466
150	578	317	559	150	527	317	508	150	487	317	468
155	587	317	568	155	533	317	514	155	491	317	472
160	587	317	568	160	541	317	522	160	495	317	476
165	587	317	568	165	549	317	530	165	500	317	481

60°F/hr Heatup		**60°F/hr Criticality[(a)]**		**80°F/hr Heatup**		**80°F/hr Criticality[(a)]**		**100°F/hr Heatup**		**100°F/hr Criticality[(a)]**	
T (°F)	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**
170	587	317	568	170	559	317	540	170	507	317	488
175	587	317	568	175	570	317	551	175	515	317	496
180	587	317	636	180	583	317	564	180	524	317	505
180	587	317	654	180	583	317	578	180	524	317	515
180	655	317	671	180	583	317	594	180	524	317	527
185	673	317	683	185	597	317	612	185	534	317	541
190	690	317	695	190	613	317	631	190	546	317	556
195	702	317	709	195	631	317	653	195	560	317	573
200	714	317	725	200	650	317	678	200	575	317	592
205	728	317	742	205	672	317	705	205	592	317	613
210	744	317	761	210	697	317	735	210	611	317	636
215	761	317	782	215	724	317	768	215	632	317	663
220	780	317	806	220	754	317	804	220	655	317	692
225	801	317	831	225	787	317	831	225	682	317	724
230	825	317	860	230	823	317	860	230	711	317	760
235	850	317	891	235	850	317	891	235	743	317	799
240	879	317	926	240	879	317	926	240	779	317	843
245	910	317	964	245	910	317	964	245	818	317	891
250	945	317	1006	250	945	317	1006	250	862	317	944
255	983	317	1053	255	983	317	1053	255	910	317	1003
260	1025	317	1105	260	1025	317	1105	260	963	317	1068
265	1072	317	1162	265	1072	317	1162	265	1022	317	1139
270	1124	320	1221	270	1124	320	1221	270	1087	320	1218
275	1181	325	1281	275	1181	325	1281	275	1158	325	1281
280	1240	330	1340	280	1240	330	1340	280	1237	330	1340
285	1300	335	1401	285	1300	335	1398	285	1300	335	1398
290	1359	340	1469	290	1359	340	1460	290	1359	340	1457

60°F/hr Heatup		**60°F/hr Criticality[(a)]**		**80°F/hr Heatup**		**80°F/hr Criticality[(a)]**		**100°F/hr Heatup**		**100°F/hr Criticality[(a)]**	
T (°F)	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**
295	1420	345	1544	295	1417	345	1527	295	1417	345	1518
300	1469	350	1627	300	1460	350	1602	300	1457	350	1585
305	1544	355	1718	305	1527	355	1684	305	1518	355	1659
310	1627	360	1819	310	1602	360	1774	310	1585	360	1741
315	1718	365	1930	315	1684	365	1874	315	1659	365	1831
320	1819	370	2052	320	1774	370	1984	320	1741	370	1930
325	1930	375	2187	325	1874	375	2105	325	1831	375	2039
330	2052	380	2336	330	1984	380	2239	330	1930	380	2160
335	2187			335	2105	385	2387	335	2039	385	2292
340	2336			340	2239			340	2160	390	2438
				345	2387			345	2292		
								350	2438		

Note for Table 5-1-Cont.:

(a) Data in Table 5-1-Cont. is associated with the without margin for instrument error heatup curves (Figure 5-1). However, margins for instrument error (5°F and 30 psi) were included on the inservice hydrostatic leak test limits. The inservice hydrostatic leak test temperature is also reflected on the criticality limits; therefore, the criticality limits include margin on the criticality temperature as well.

Table 5-2 Palisades 42.1 EFPY Cooldown Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, Without Margin for Instrument Errors and With Delta Pressure Correction

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
60	0	60	0	60	0	60	0	60	0	60	0
60	587	60	534	60	478	60	420	60	361	60	300
65	587	65	535	65	478	65	421	65	361	65	300
70	587	70	535	70	479	70	421	70	362	70	300
75	587	75	536	75	480	75	422	75	362	75	301
80	587	80	537	80	481	80	423	80	363	80	301
85	587	85	539	85	482	85	424	85	364	85	302
90	587	90	540	90	483	90	425	90	365	90	303
95	587	95	541	95	484	95	426	95	366	95	305
100	587	100	543	100	486	100	428	100	368	100	306
105	587	105	545	105	488	105	429	105	370	105	308
110	587	110	547	110	490	110	432	110	372	110	311
115	587	115	549	115	492	115	434	115	374	115	313
120	587	120	552	120	495	120	437	120	377	120	316
125	587	125	555	125	498	125	440	125	381	125	320
130	587	130	558	130	501	130	444	130	384	130	324
135	587	135	562	135	505	135	448	135	389	135	329
140	587	140	566	140	509	140	452	140	394	140	334
145	587	145	570	145	514	145	457	145	399	145	340
150	587	150	575	150	519	150	463	150	405	150	347
155	587	155	581	155	525	155	469	155	412	155	355
160	587	160	587	160	532	160	476	160	420	160	363
165	587	165	587	165	539	165	484	165	429	165	373
170	587	170	587	170	548	170	493	170	439	170	384

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
175	587	175	587	175	557	175	503	175	450	175	396
180	587	180	587	180	567	180	515	180	462	180	410
180	587	180	587	180	567	180	515	180	462	180	410
180	670	180	619	180	567	180	515	180	462	180	410
185	680	185	629	185	578	185	527	185	476	185	426
190	690	190	640	190	591	190	541	190	491	190	443
195	702	195	653	195	604	195	556	195	508	195	462
200	714	200	667	200	620	200	573	200	527	200	483
205	728	205	682	205	637	205	592	205	549	205	507
210	744	210	700	210	656	210	613	210	572	210	534
215	761	215	719	215	677	215	637	215	598	215	563
220	780	220	740	220	700	220	663	220	628	220	596
225	801	225	763	225	726	225	692	225	660	225	632
230	825	230	789	230	755	230	724	230	696	230	673
235	850	235	817	235	786	235	759	235	736	235	718
240	879	240	849	240	822	240	798	240	780	240	767
245	910	245	883	245	861	245	842	245	829	245	823
250	945	250	922	250	904	250	890	250	883	250	883
255	983	255	965	255	951	255	944	255	944	255	944
260	1025	260	1012	260	1004	260	1003	260	1003	260	1003
265	1072	265	1064	265	1063	265	1063	265	1063	265	1063
270	1124	270	1122	270	1122	270	1122	270	1122	270	1122
275	1181	275	1181	275	1181	275	1181	275	1181	275	1181
280	1244	280	1244	280	1244	280	1244	280	1244	280	1244
285	1314	285	1314	285	1314	285	1314	285	1314	285	1314
290	1391	290	1391	290	1391	290	1391	290	1391	290	1391
295	1476	295	1476	295	1476	295	1476	295	1476	295	1476

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**
300	1551	300	1551	300	1551	300	1551	300	1551	300	1551
305	1655	305	1655	305	1655	305	1655	305	1655	305	1655
310	1771	310	1771	310	1771	310	1771	310	1771	310	1771
315	1898	315	1898	315	1898	315	1898	315	1898	315	1898
320	2038	320	2038	320	2038	320	2038	320	2038	320	2038
325	2194	325	2194	325	2194	325	2194	325	2194	325	2194
330	2365	330	2365	330	2365	330	2365	330	2365	330	2365

6 APPLICABILITY OF CURRENT HEATUP AND COOLDOWN LIMITS

The applicability of the current Palisades P-T limit curves was determined based on a comparison of the available operating margin between the P-T limits developed in this report at 42.1 EFPY with those contained in EA-A-PAL-92-095-01 [Reference 14], which documents the development of the current Palisades P-T limit curves that are contained in the Palisades Technical Specifications (Figures 3.4.3-1 and 3.4.3-2). The P-T limit curves presented in Figures 3.4.3-1 and 3.4.3-2 of the Palisades Technical Specifications do not contain margins for instrumentation error.

The methodology of the 1998 through the 2000 Addenda Edition of the ASME B&PV Code, Section XI, Appendix G, along with ASME Code Case N-641 was used in the development of the P-T limit curves contained in this report. Code Case N-641 removes some of the conservatism in P-T limit curves by allowing the use of the K_{Ic} reference stress intensity factor, instead of the older, more conservative K_{Ia} reference stress intensity factor, which was used in the development of the Palisades current P-T limit curves. Additionally, the 1998 through the Summer 2000 Addenda Edition of the ASME Code Section XI, Appendix G methodology allows use of the less restrictive "Circ-Flaw" methodology, which postulates circumferentially oriented reference defects in circumferential weld materials. Therefore, the P-T limit curves developed in this report took advantage of these updates to the ASME P-T limit methodology and are predicted to contain additional operating margin not present in the curves developed using the older K_{Ia} methodology.

However, when K_{Ic} methodology is used, the LTOP system shall limit the maximum pressure in the vessel to 100% of the pressure determined to satisfy Equation 2 of Section 3. Previously, while using K_{Ia}, the maximum pressure determined from Equation 2 of Section 3 could be exceeded by 10% by the LTOP system. Therefore, since the current curves utilized the K_{Ia} reference stress intensity factor, the P-T limit curve pressure values (without margins for instrumentation error) contained in the analysis of record (AOR), EA-A-PAL-92-095-01 were increased by 10% in order to determine if margin exists between this data and the P-T limit curves developed herein using the K_{Ic} reference stress intensity factor. This 10% increase to the pressure values contained in the AOR is for comparison purposes only. The increased pressure values are not to be used in actual plant operation. Furthermore, the current Palisades P-T limit curve data points were converted to units of psig (from psia) so that direct comparison could be made between these pressure values (current curves plus 10% margin) and the pressure values for the curves developed in this report. These adjusted values are shown below in Tables 6-1 and 6-2, for heatup and cooldown, respectively.

Additionally, in order for the current Palisades P-T limit curves to be bounded by the curves developed in this report, the criticality temperature shown in Section 5 must be found to be lower than the criticality temperature determined in EA-PAL-92-095-01 [Reference 14]. The criticality temperature determined in Section 5 is 317°F, with consideration for margins for instrument errors on the inservice hydrostatic leak test limit. In EA-PAL-92-095-01, the criticality temperature was determined to be 385°F. Reference 14 also states that the Palisades reactor vessel will not be made critical below a temperature of 525°F. Therefore, based on this analysis, significant margin exists between the current Palisades criticality temperature and the criticality temperature determined in this report.

The pressure and temperature values contained in Tables 6-1 and 6-2 (current curves plus 10% margin) were plotted together with the data points from Tables 5-1 and 5-2 of this report, which were developed using the K_{Ic} reference stress intensity factor, in Figures 6-1 through 6-4. In Figures 6-1 through 6-4, the curves developed in this report (through 42.1 EFPY; without margins for instrumentation errors) are shown as solid lines while the curves developed from the data points in Tables 6-1 and 6-2 (current curves plus 10% margin) are shown as dashed lines. The color scheme in the Figures correlates so that the solid and dashed lines have an identical color for each heatup or cooldown rate.

Figure 6-1 shows the comparison of the heatup curves. Figure 6-2 shows a magnified version of Figure 6-1 in the lower pressure and temperature region. The corresponding data points, along with the additional margin between the *current Palisades P-T limit curves +10% margin* and the *P-T limit curves developed in this report* are contained in Table 6-3.

Figure 6-3 shows the comparison of the cooldown curves. Figure 6-4 shows a magnified version of Figure 6-3 in the lower pressure and temperature region. The corresponding data points, along with the additional margin between the *current Palisades P-T limit curves +10% margin* and the *P-T limit curves developed in this report* are contained in Table 6-4.

Pressure values for the current curves at 60°F and at the highest temperature, which corresponds to the final temperature of the P-T limit curves developed in this report, were interpolated from the data contained in Tables 6-1 and 6-2. Furthermore, the pressures for the current curves at 180°F, which is the limiting temperature for the flange-notch region, were also determined using interpolation from the data contained in Tables 6-1 and 6-2. These interpolations are needed to accurately compare the current P-T limit curves with the P-T limit curves developed in this report at the end of the heatup, the beginning of the cooldown or at the limiting temperature for the flange-notch region.

Finally, Tables 6-5 and 6-6 contain a summary of the available margin between the P-T limits developed in Section 5 of this report (through 42.1 EFPY; without margins for instrumentation errors) and the current Palisades P-T limits, contained in Reference 14, plus 10% margin.

P-T Limit Curve Applicability Conclusion

Tables 6-5 and 6-6 show that adequate margin exists between the current Palisades P-T limit curves plus 10% margin (to account for the methodology change between K_{Ia} to K_{Ic}) and the P-T limit curves developed in this report for 42.1 EFPY (EOLE). Therefore, the continued use of the current Palisades P-T limit curves is justified through EOLE.

Low Temperature Overpressure Protection (LTOP) Applicability Conclusion

The primary coolant system (PCS) pressures permitted by the new set of pressure-temperature limit curves are demonstrated to be less restrictive than the PCS pressures permitted by the current heatup and cooldown figures as adjusted in Tables 6-1 and 6-2. Palisades Nuclear Plant Technical Specification Figure 3.4.12-1 provides the upper limit on the power operated relief valves (PORV) setpoints for the LTOP system, which assures protection for LTOP transients which may approach the pressure of the current Palisades P-T limit curves plus 10%.

Per LTR-SEE-II-10-98 [Reference 17], in order for the implemented LTOP setpoint curve to remain valid, the PCS pressures permitted by the new set of pressure-temperature limit curves must be less restrictive (or no more restrictive) than the historical PCS pressure limits increased by 10%, to compensate for the methodology change between K_{Ia} to K_{Ic}, for the maximum heatup and cooldown rates. Furthermore, the new isothermal limit curves must be less restrictive (or no more restrictive) than the historical PCS pressure limits increased by 10% to support the Primary Coolant Pump (PCP) start transient results.

Per Tables 6-5 and 6-6, adequate margin exists between the current Palisades P-T limit curves plus 10% margin (to account for the methodology change between K_{Ia} to K_{Ic}) and the P-T limit curves developed in this report for 42.1 EFPY (EOLE). Therefore, the continued use of the current Palisades LTOP setpoint curve, PORV setpoints, and LTOP enabling temperature (See Appendix B) are justified through EOLE.

Table 6-1 Current Palisades P-T Limit Curve Data Points Plus 10% Margin for Heatup

Temperature[a] (°F)	Pressure[a] (psig)					
	0°F/hr Heatup	20°F/hr Heatup	40°F/hr Heatup	60°F/hr Heatup	80°F/hr Heatup	100°F/hr Heatup
50	493	436	336	241	144	54
100	493	465	360	261	161	68
150	519	511	410	303	195	98
200	574	574	499	389	267	158
250	687	687	687	552	415	282
300	899	899	899	890	680	504
350	1381	1381	1381	1381	1294	1022
400	2091	2091	2091	2091	2091	2091
416[b]	2450	2450	2450	2450	2450	2450
450	3223	3223	3223	3223	3223	3223

Notes for Table 6-1:

(a) Data is associated with the Palisades current heatup curves contained in the AOR, EA-A-PAL-92-095-01. Ten-percent margin was added to the pressure values after converting to units of psig from psia. This ten-percent margin on the pressure values is for comparison purposes only and is not to be used in actual plant operation. These data points do not contain margins for instrumentation error.

(b) Values were interpolated to an arbitrary pressure below the design pressure. This is for visual comparison purposes only. See Figure 6-1.

Table 6-2 Current Palisades P-T Limit Curve Data Points Plus 10% Margin for Cooldown

Temperature[(a)] (°F)	Pressure[(a)] (psig)					
	0°F/hr Cooldown	20°F/hr Cooldown	40°F/hr Cooldown	60°F/hr Cooldown	80°F/hr Cooldown	100°F/hr Cooldown
50	493	427	360	286	219	142
100	493	441	375	302	236	161
150	519	470	406	336	271	199
200	574	516	470	404	345	278
250	687	636	586	531	483	441
300	899	864	831	796	767	737
350	1381	1378	1378	1378	1378	1378
400	2333	2333	2333	2333	2333	2333

Note for Table 6-2:

(a) Data is associated with the Palisades current cooldown curves contained in the AOR, EA-A-PAL-92-095-01. Ten-percent margin was added to the pressure values after converting to units of psig from psia. This ten-percent margin on the pressure values is for comparison purposes only and is not to be used in actual plant operation. These data points do not contain margins for instrumentation error.

Figure 6-1 Palisades Heatup P-T Limit Curve Comparison between the Current P-T Limit Curves + 10% Margin and the New P-T Limit Curves to 42.1 EFPY

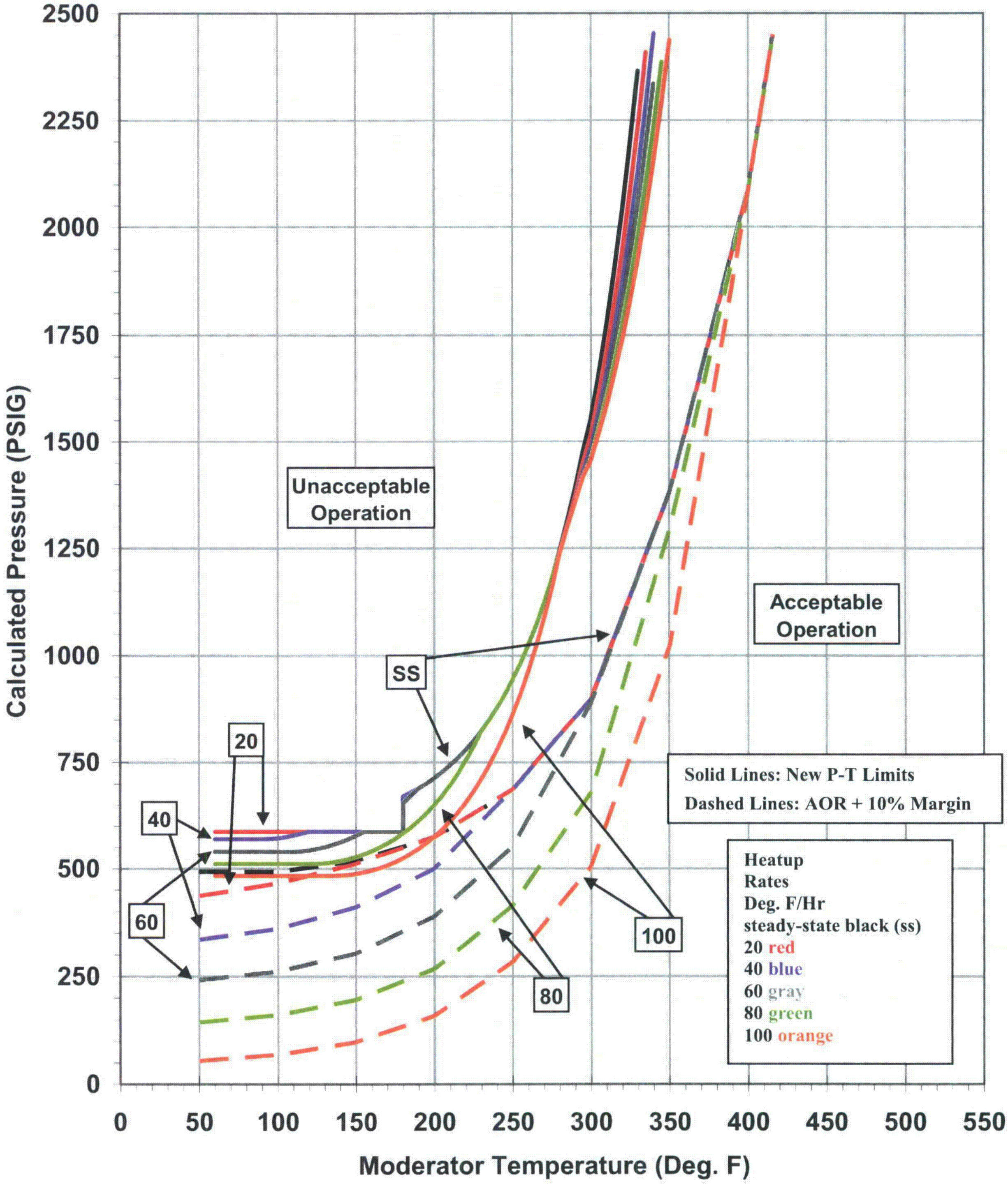


Figure 6-2 Palisades Heatup P-T Limit Curve Comparison between the Current P-T Limit Curves + 10% Margin and the New P-T Limit Curves to 42.1 EFPY Magnified

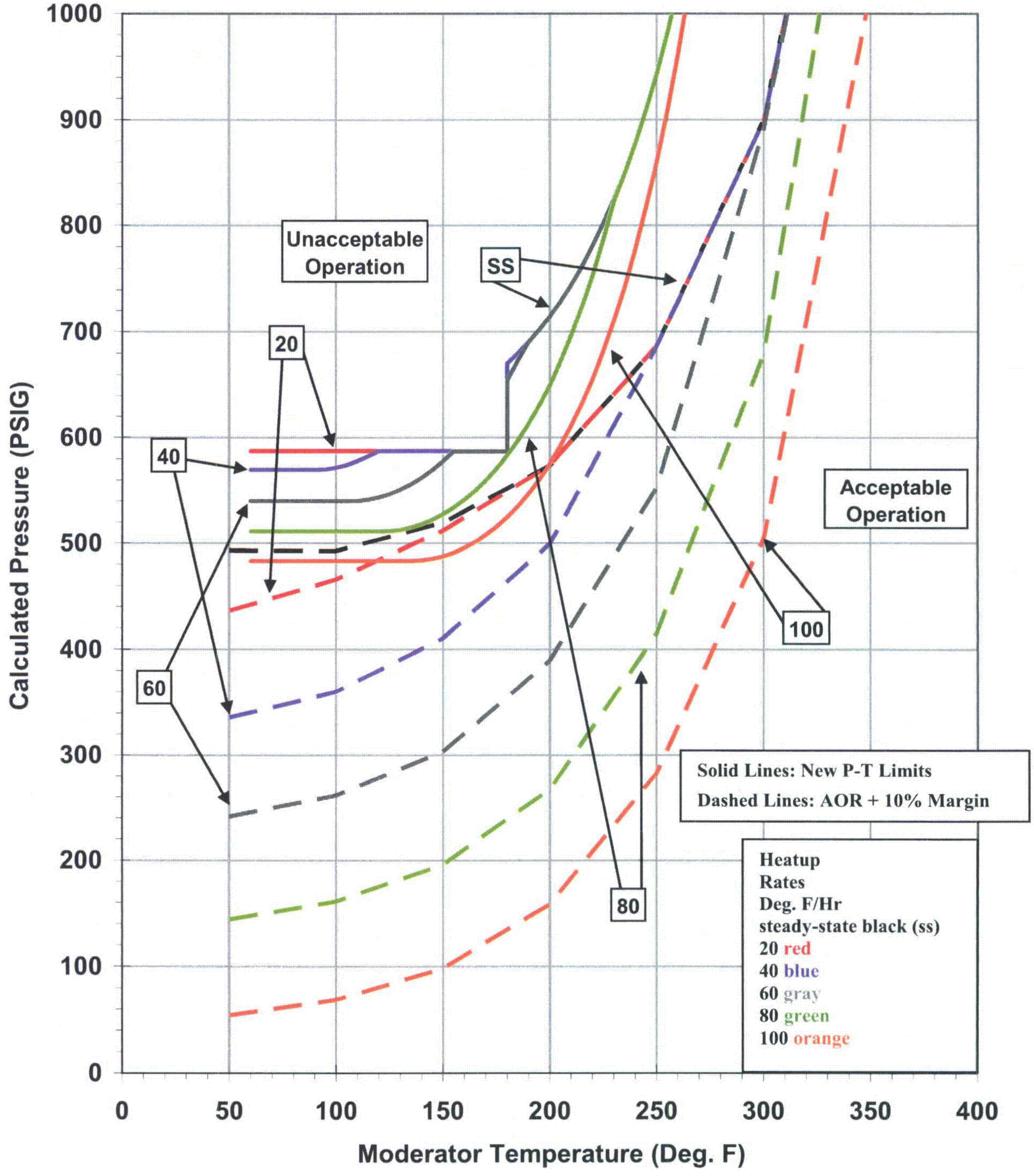


Figure 6-3 Palisades Cooldown P-T Limit Curve Comparison between the Current P-T Limit Curves + 10% Margin and the New P-T Limit Curves to 42.1 EFPY

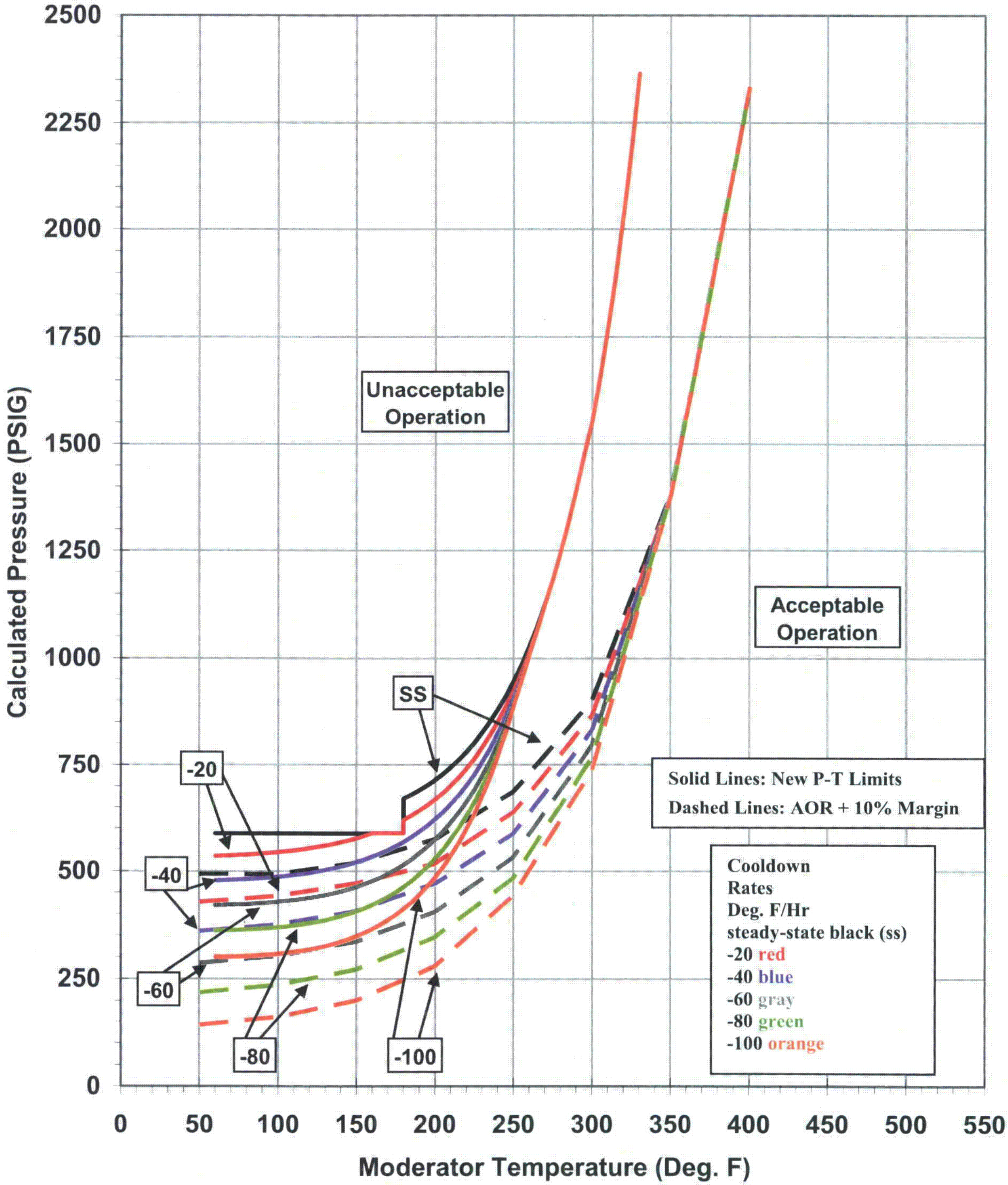


Figure 6-4 Palisades Cooldown P-T Limit Curve Comparison between the Current P-T Limit Curves + 10% Margin and the New P-T Limit Curves to 42.1 EFPY Magnified

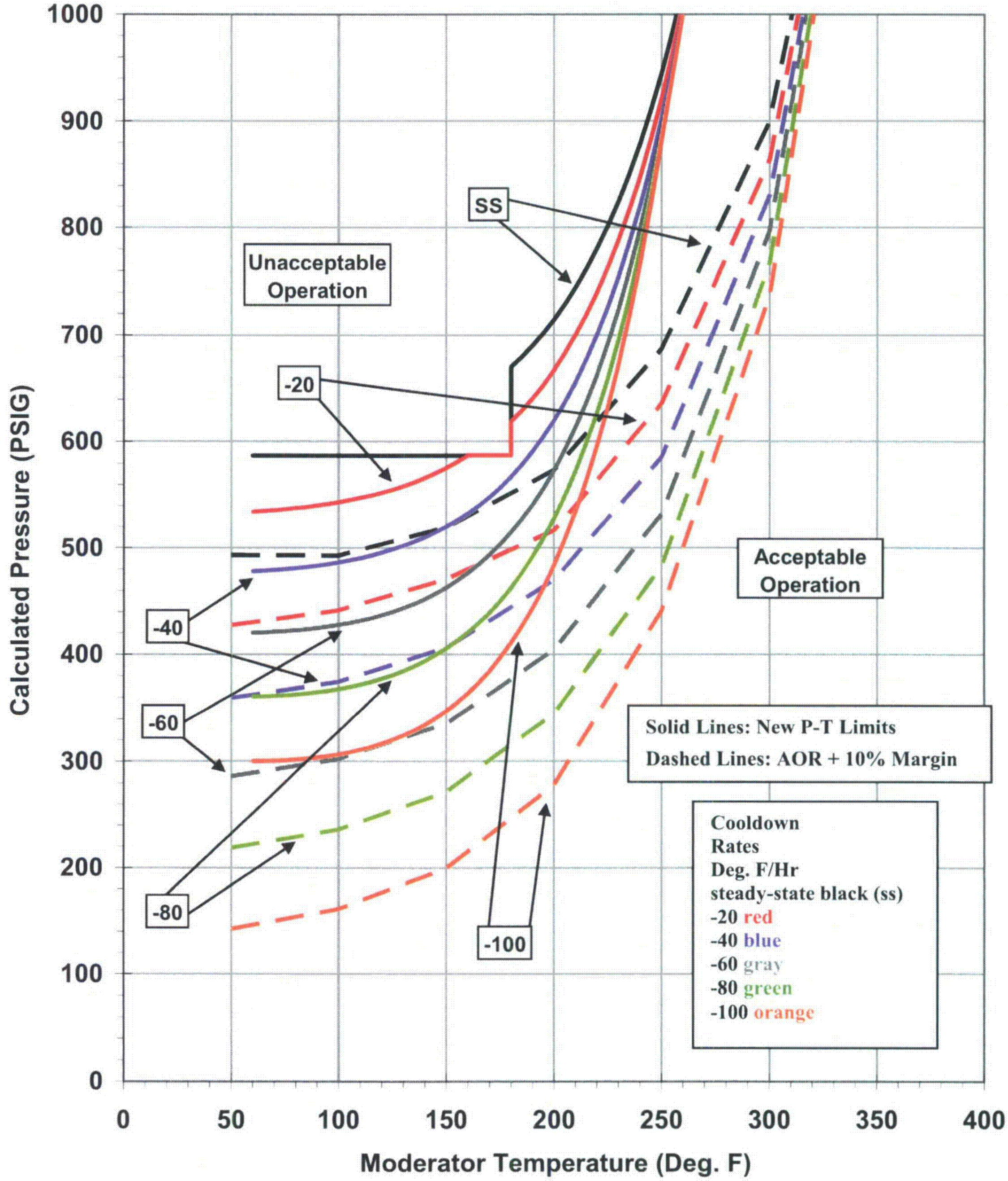


Table 6-3 Data Points for Palisades Heatup P-T Limit Curve Comparison between the Current P-T Limit Curves + 10 % Margin and the New P-T Limit Curves to 42.1 EFPY

0°F/hr				20°F/hr				40°F/hr			
T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)
60	493[a]	587	94	60	442[a]	587	145	60	340[a]	570	229
100	493	587	94	100	465	587	122	100	360	571	212
150	519	587	68	150	511	587	76	150	410	587	177
180	552[a]	587	35	180	549[a]	587	38	180	463[a]	587	124
200	574	714	141	200	574	714	141	200	499	714	215
250	687	945	258	250	687	945	258	250	687	945	258
300	899	1551	652	300	899	1514	614	300	899	1487	588
330	1188[a]	2365	1177	335	1237[a]	2409	1172	340	1285[a]	2454	1169

60°F/hr				80°F/hr				100°F/hr			
T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)
60	245[a]	540	295	60	147[a]	511	364	60	57[a]	483	426
100	261	540	278	100	161	511	350	100	68	483	414
150	303	578	274	150	195	527	332	150	98	487	390
180	355[a]	587	232	180	238	583	345	180	134[a]	524	390
200	389	714	325	200	267	650	383	200	158	575	417
250	552	945	392	250	415[a]	945	530	250	282	862	579
300	890	1469	580	300	680	1460	780	300	504	1457	952
340	1283[a]	2336	1053	345	1233[a]	2387	1154	350	1022	2438	1416

<u>Notes for Table 6-3:</u>

(a) Pressure values at temperatures of 60°F, 180°F, and the final temperature (varies per heatup rate) were interpolated from the current Palisades P-T limit data points for direct comparison to the data points developed in this report.

(b) Margin equals *New P-T limit curve* data point minus *the current P-T limit curves + 10 %* data point for each temperature and rate.

Table 6-4 Data Points for Palisades Cooldown P-T Limit Curve Comparison between the Current P-T Limit Curves + 10 % Margin and the New P-T Limit Curves to 42.1 EFPY

0°F/hr				20°F/hr				40°F/hr			
T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)
60	493[a]	587	94	60	430[a]	534	104	60	363[a]	478	115
100	493	587	94	100	441	543	102	100	375	486	111
150	519	587	68	150	470	575	105	150	406	519	114
180	552[a]	587	35	180	498[a]	587	89	180	444[a]	567	123
200	574	714	141	200	516	667	151	200	470	620	150
250	687	945	258	250	636	922	286	250	586	904	318
300	899	1551	652	300	864	1551	687	300	831	1551	721
330	1188[a]	2365	1177	330	1172[a]	2365	1193	330	1159[a]	2365	1206
60°F/hr				80°F/hr				100°F/hr			
T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)	T (°F)	+ 10% Current Curves (psig)	New P-T Curves (psig)	Margin[b] (psi)
60	289[a]	420	131	60	222[a]	361	139	60	146[a]	300	154
100	302	428	125	100	236	368	132	100	161	306	146
150	336	463	127	150	271	405	134	150	199	347	148
180	377[a]	515	138	180	316[a]	462	147	180	246[a]	410	164
200	404	573	169	200	345	527	183	200	278	483	205
250	531	890	359	250	483	883	400	250	441	883	442
300	796	1551	755	300	767	1551	784	300	737	1551	814
330	1145[a]	2365	1220	330	1134[a]	2365	1232	330	1121[a]	2365	1244

Notes for Table 6-4:

(a) Pressure values at temperatures of 60°F, 180°F, and 330°F were interpolated from the current Palisades P-T limit data points for direct comparison to the data points generated in this report.

(b) Margin equals *New P-T limit curve* data point minus the *current P-T limit curves + 10 %* data point for each temperature and rate.

Table 6-5 Palisades Heatup P-T Limit Curve Margin Summary between the Current P-T Limit Curves + 10 % Margin and the New P-T Limit Curves to 42.1 EFPY

0°F/hr		20°F/hr		40°F/hr		60°F/hr		80°F/hr		100°F/hr	
T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)
60	94	60	145	60	229	60	295	60	364	60	426
100	94	100	122	100	212	100	278	100	350	100	414
150	68	150	76	150	177	150	274	150	332	150	390
180	35	180	38	180	124	180	232	180	345	180	390
200	141	200	141	200	215	200	325	200	383	200	417
250	258	250	258	250	258	250	392	250	530	250	579
300	652	300	614	300	588	300	580	300	780	300	952
330	1177	335	1172	340	1169	340	1053	345	1154	350	1416

Table 6-6 Palisades Cooldown P-T Limit Curve Margin Summary between the Current P-T Limit Curves + 10 % Margin and the New P-T Limit Curves to 42.1 EFPY

0°F/hr		20°F/hr		40°F/hr		60°F/hr		80°F/hr		100°F/hr	
T (°F)	Margin (psig)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)	T (°F)	Margin (psi)
60	94	60	104	60	115	60	131	60	139	60	154
100	94	100	102	100	111	100	125	100	132	100	146
150	68	150	105	150	114	150	127	150	134	150	148
180	35	180	89	180	123	180	138	180	147	180	164
200	141	200	151	200	150	200	169	200	183	200	205
250	258	250	286	250	318	250	359	250	400	250	442
300	652	300	687	300	721	300	755	300	784	300	814
330	1177	330	1193	330	1206	330	1220	330	1232	330	1244

7 RECREATION OF PALISADES TECHNICAL SPECIFICATION P-T LIMIT CURVES

The current Palisades Nuclear Plant Technical Specification P-T limit curves (Figures 3.4.3-1 and 3.4.3-2) do not contain information to discern their development basis or applicability term. Therefore, these Technical Specification figures have been recreated as Figures 7-1 and 7-2 in this report with development basis information and applicability term included. Some or all of the additional information included on Figures 7-1 and 7-2 may be added to the Palisades Technical Specification figures for clarity. These new Figures contain identical data points to the current curves. The only changes to the new Figures are the addition of the basis information and the applicability term. For consistency with the current Palisades Technical Specification P-T limit curves, the pressure values on the resulting figures are reported in units of psia. The data points used to generate the current Technical Specification Figures, as well as Figures 7-1 and 7-2 contained in this report, were originally documented in EA-A-PAL-92-095-01, Revision 0 [Reference 14] and are summarized in Tables 7-1 and 7-2 of this report for heatup and cooldown, respectively. Note that the P-T limit curves contained in the Technical Specifications do not contain margins for instrumentation error.

Figure 7-1 Recreation of Palisades Nuclear Plant Technical Specification Figure 3.4.3-1 with Addition of Basis Information and Applicability Term

Figure 3.4.3-1 (Page 1 of 1)
Palisades Pressure – Temperature Limit Curves for Heatup Applicable through an EOLE of 42.1 EFPY

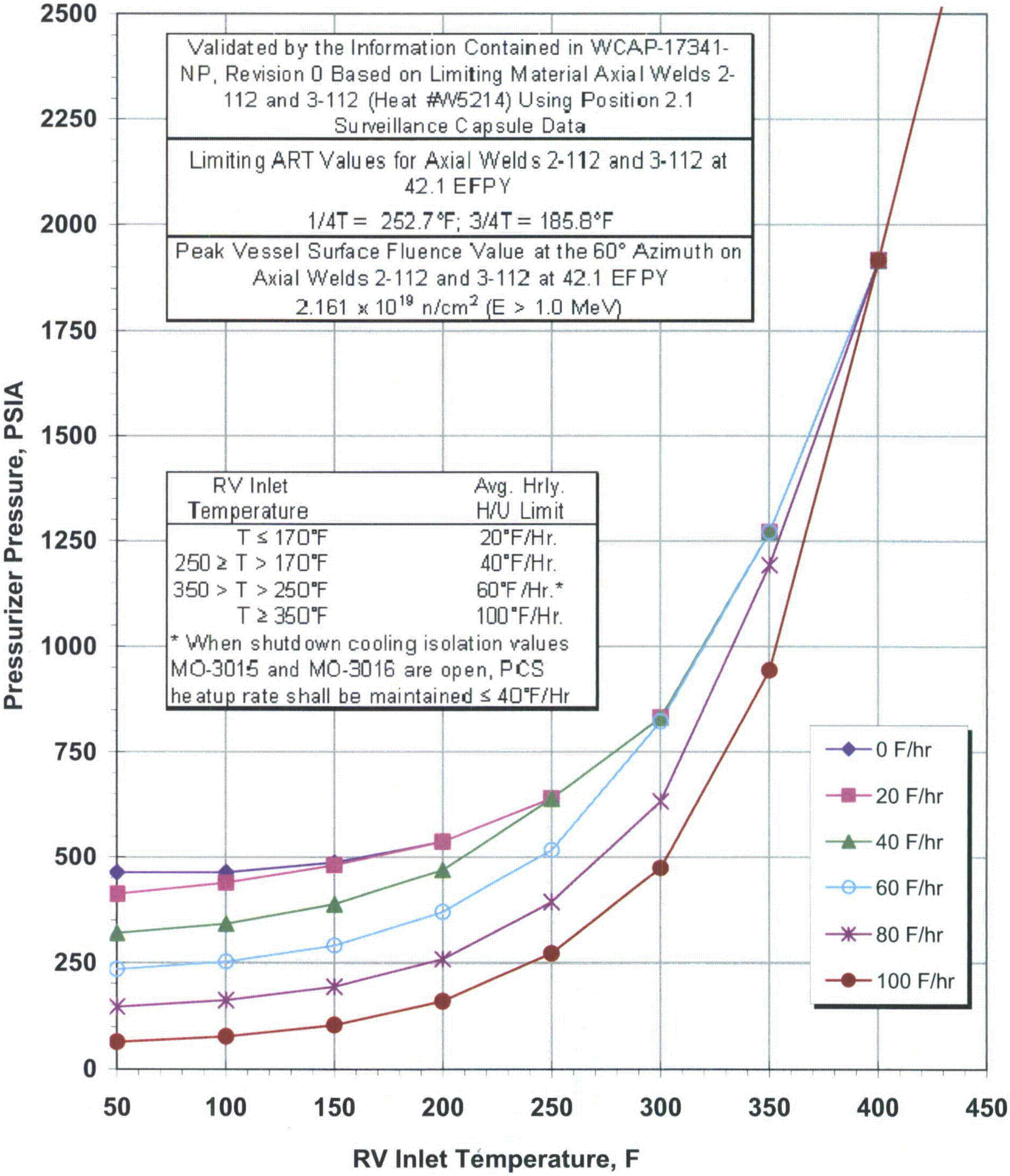


Figure 7-2 Recreation of Palisades Nuclear Plant Technical Specification Figure 3.4.3-2 with Addition of Basis Information and Applicability Term

Figure 3.4.3-2 (Page 1 of 1)
Palisades Pressure – Temperature Limit Curves for Cooldown Applicable through an EOLE of 42.1 EFPY

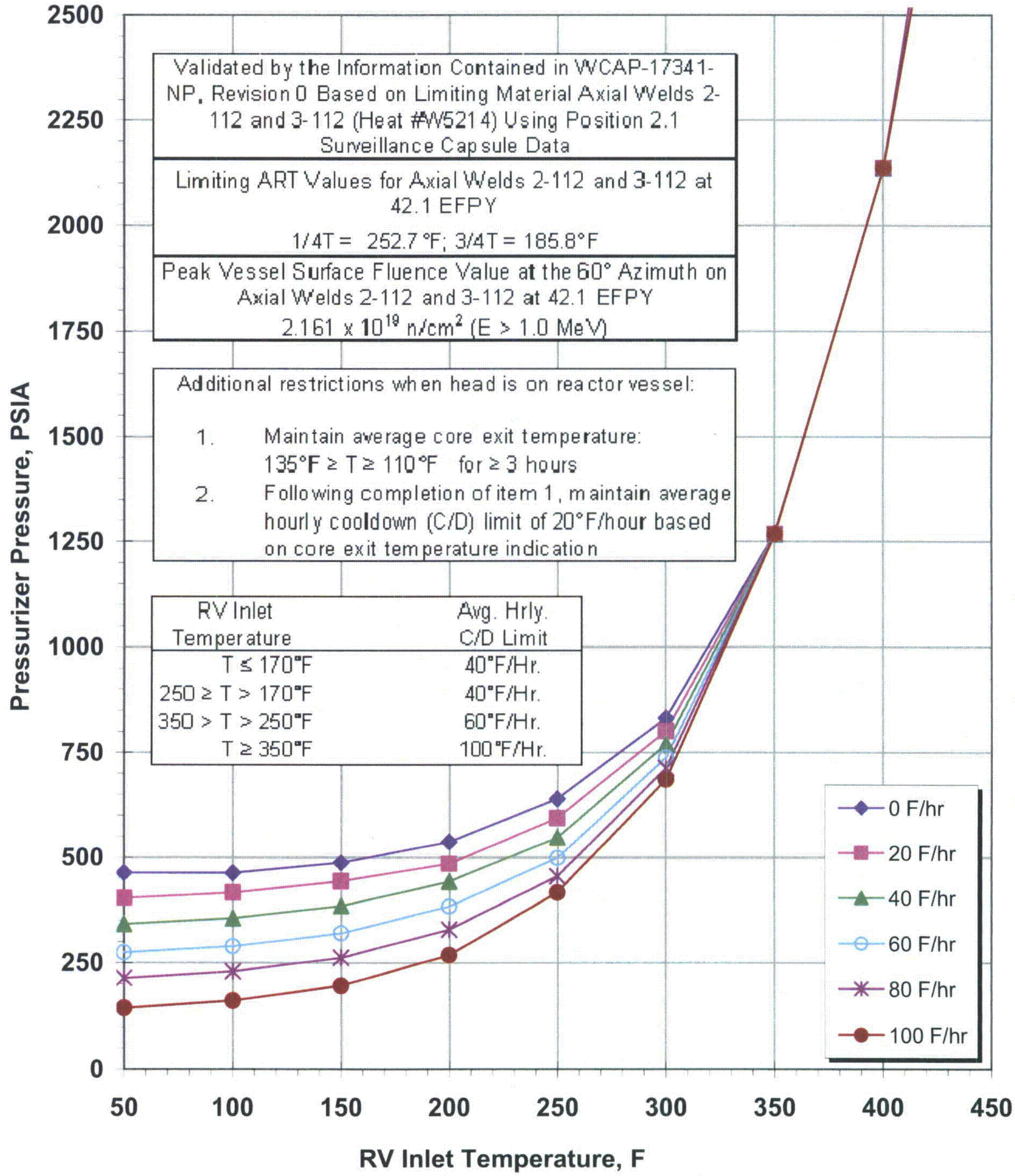


Table 7-1 Palisades Current P-T Limit Curve Data Points Used in the Recreation of Technical Specification Figure 3.4.3-1

Temperature[(a)] (°F)	Pressure[(a)] (psia)					
	0°F/hr Heatup	20°F/hr Heatup	40°F/hr Heatup	60°F/hr Heatup	80°F/hr Heatup	100°F/hr Heatup
50	462.9	410.9	319.8	234.0	145.5	63.9
100	462.5	437.5	341.8	252.4	160.8	76.8
150	486.6	479.4	387.1	290.3	192.3	103.4
200	536.3	536.3	468.3	368.7	257.4	158.2
250	639.1	639.1	639.1	516.7	391.7	271.5
300	832.2	832.2	832.2	823.4	633.0	473.2
350	1270.2	1270.2	1270.2	1270.2	1191.5	943.9
400	1915.8	1915.8	1915.8	1915.8	1915.8	1915.8
450	2944.6	2944.6	2944.6	2944.6	2944.6	2944.6

Note for Table 7-1:

(a) Data is associated with the Palisades current heatup curves contained in the Technical Specifications and originally documented in EA-A-PAL-92-095-01 [Reference 14]. The pressure values are reported in units of psia for consistency with Figure 3.4.3-1 of the Palisades Technical Specifications. These data points do not contain margins for instrumentation error.

Table 7-2 Palisades Current P-T Limit Curve Data Points Used in the Recreation of Technical Specification Figure 3.4.3-2

Temperature[(a)] (°F)	Pressure[(a)] (psia)					
	0°F/hr Cooldown	20°F/hr Cooldown	40°F/hr Cooldown	60°F/hr Cooldown	80°F/hr Cooldown	100°F/hr Cooldown
50	462.9	403.1	341.6	274.8	213.5	143.9
100	462.5	415.8	355.2	289.5	229.1	160.8
150	486.6	442.2	383.4	319.7	261.5	195.6
200	536.3	483.7	441.6	382.2	328.2	267.4
250	639.1	593.2	547.1	497.8	453.8	415.8
300	832.2	800.3	769.8	738.3	712.3	684.6
350	1270.2	1267.2	1267.2	1267.2	1267.2	1267.2
400	2135.8	2135.8	2135.8	2135.8	2135.8	2135.8
450	3769.8	3769.8	3769.8	3769.8	3761.8	3590.7

Note for Table 7-2:

(a) Data is associated with the Palisades current cooldown curves contained in the Technical Specifications and originally documented in EA-A-PAL-92-095-01 [Reference 14]. The pressure values are reported in units of psia for consistency with Figure 3.4.3-2 of the Palisades Technical Specifications. These data points do not contain margins for instrumentation error.

8 REFERENCES

1. Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," U. S. Nuclear Regulatory Commission, May 1988.
2. WCAP-14040-A, Revision 4, "Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves," J. D. Andrachek, et al., May 2004.
3. Appendix G to the 1998 through the 2000 Addenda Edition of the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, Division 1, "Fracture Toughness Criteria for Protection Against Failure."
4. NUREG-1871, Revision 0, "Safety Evaluation Report Related to the License Renewal of Palisades Nuclear Plant," Docket No. 50-255, Nuclear Management Company LLC, January 2007
5. WCAP-15353 – Supplement 1-NP, Revision 0, "Palisades Reactor Pressure Vessel Fluence Evaluation," S. L. Anderson, May 2010.
6. Code of Federal Regulations, 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements," U.S. Nuclear Regulatory Commission, Washington, D. C., Federal Register, Volume 60, No. 243, dated December 19, 1995.
7. SIA Report No. 1000915.401, Revision 1, "Revised Pressurized Thermal Shock Evaluation for the Palisades Reactor Pressure Vessel," T. J. Griesbach, November 2010.
8. SIA Report No. 1001026.401, Revision 1, "Basis for Period of Validity of the Palisades Pressure-Temperature (P-T) Limit Curves," T. J. Griesbach, November 2010.
9. Final Safety Analysis Report (FSAR), Palisades Nuclear Power Plant, Revision 28.
10. Certified Material Test Report (CMTR) – Palisades Closure Head Flange, Bethlehem Steel Corporation Order #3109-784.
11. Certified Material Test Report (CMTR) – Palisades Vessel Flange, Bethlehem Steel Corporation Order #3109-610.
12. SIA Report No. 0901132.401, Revision 0, "Evaluation of Surveillance Data for Weld Heat No. W5214 for Application to Palisades PTS Analysis," T. J. Griesbach, April 2010.
13. "Reactor Vessel Assembly Instruction Manual – Palisades Plant, Consumers Power Company," C. E. Book No. 2966-A, May 1969.
14. Consumers Power Calculation EA-A-PAL-92-095-01, Revision 0, "Pressure-Temperature Curves and LTOP Setpoint Curve for Maximum Reactor Vessel Fluence of 2.192 x 10^{19} Neutrons/cm^2," G. F. Pratt, August 1994.
15. ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, Subsection NB, Section NB-2300, "Fracture Toughness Requirements for Material."
16. WCAP-15353, Revision 0, "Palisades Reactor Pressure Vessel Neutron Fluence Evaluation," S. L. Anderson et al., January 2000.
17. Westinghouse Letter LTR-SEE-II-10-98, Revision 0, "Westinghouse Review of LTOP Analyses and LTOP Controls Assumptions for Palisades Nuclear Plant," February 2011.

APPENDIX A THERMAL STRESS INTENSITY FACTORS (K_{IT})

Tables A-1 and A-2 contain the thermal stress intensity factors (K_{It}) for the maximum heatup and cooldown rates. The vessel radii to the 1/4T and 3/4T locations are as follows:

- 1/4T Radius = 88.55”
- 3/4T Radius = 92.94”

Table A-1 K_{It} Values for Palisades 42.1 EFPY 100°F/hr Heatup Curves (w/o Margins for Instrument Errors)

Water Temp. (°F)	Vessel Temperature @ 1/4T Location for 100°F/hr Heatup (°F)	1/4T Thermal Stress Intensity Factor (KSI√in.)	Vessel Temperature @ 3/4T Location for 100°F/hr Heatup (°F)	3/4T Thermal Stress Intensity Factor (KSI√in.)
60	55.956	-0.996	55.039	0.468
65	58.480	-2.466	55.271	1.431
70	61.512	-3.749	55.897	2.430
75	64.756	-4.974	56.977	3.380
80	68.274	-6.040	58.464	4.237
85	71.903	-7.018	60.324	5.009
90	75.713	-7.873	62.520	5.696
95	79.621	-8.655	65.013	6.314
100	83.660	-9.345	67.772	6.866
105	87.787	-9.974	70.766	7.361
110	92.008	-10.530	73.966	7.804
115	96.305	-11.039	77.349	8.204
120	100.673	-11.492	80.893	8.566
125	105.102	-11.908	84.580	8.892
130	109.584	-12.280	88.394	9.188
135	114.116	-12.623	92.320	9.457
140	118.689	-12.930	96.347	9.701
145	123.302	-13.215	100.463	9.924
150	127.946	-13.472	104.657	10.127
155	132.624	-13.711	108.921	10.314
160	137.324	-13.928	113.247	10.486
165	142.051	-14.131	117.628	10.644
170	146.797	-14.317	122.058	10.790
175	151.563	-14.492	126.531	10.926
180	156.344	-14.653	131.043	11.052
185	161.141	-14.805	135.589	11.170
190	165.950	-14.946	140.166	11.281
195	170.772	-15.081	144.770	11.385
200	175.602	-15.207	149.397	11.483
205	180.444	-15.328	154.047	11.576
210	185.292	-15.442	158.715	11.665

Table A-2 K_{It} Values for Palisades 42.1 EFPY 100°F/hr Cooldown Curves (w/o Margins for Instrument Errors)

Water Temp. (°F)	Vessel Temperature @ 1/4T Location for 100°F/hr Cooldown (°F)	100°F/hr Cooldown 1/4T Thermal Stress Intensity Factor (KSI√in.)
210	238.150	18.024
205	233.063	17.953
200	227.974	17.882
195	222.886	17.810
190	217.797	17.739
185	212.707	17.666
180	207.617	17.594
175	202.527	17.522
170	197.437	17.449
165	192.347	17.376
160	187.256	17.304
155	182.165	17.231
150	177.075	17.158
145	171.984	17.086
140	166.893	17.013
135	161.802	16.940
130	156.711	16.867
125	151.620	16.795
120	146.529	16.722
115	141.439	16.650
110	136.348	16.577
105	131.257	16.505
100	126.166	16.433
95	121.076	16.360
90	115.985	16.289
85	110.895	16.216
80	105.805	16.145
75	100.715	16.073
70	95.625	16.002
65	90.535	15.930
60	85.446	15.858

APPENDIX B LTOP SYSTEM ENABLE TEMPERATURE

ASME Code Case N-641 [Reference B-1] presents alternative procedures for calculating pressure-temperature relationships and low temperature overpressure protection (LTOP) system effective temperatures and allowable pressures. The procedures provided in Code Case N-641 take into account alternative fracture toughness properties, circumferential and axial reference flaws, and plant-specific LTOP effective temperature calculations.

Per ASME Code Case N-641, the LTOP system shall be effective below the higher temperature determined in accordance with (1) and (2) below. Alternatively, LTOP systems shall be effective below the higher temperature determined in accordance with (1) and (3) below.

(1) a coolant temperature[(a)] of 200°F

(2) a coolant temperature[(a)] corresponding to a reactor vessel metal temperature[(b)] for all vessel beltline materials, where T_e is defined for inside axial surface flaws as RT_{NDT} + 40°F, and T_e is defined for inside circumferential surface flaws as RT_{NDT} - 85°F.

(3) a coolant temperature[(a)] corresponding to a reactor vessel metal temperature[(b)], for all vessel beltline materials, where T_e is calculated on a plant-specific basis for axial and circumferential reference flaws using the following equation:

$$T_e = RT_{NDT} + 50 \ln [((F * M_m (pR_i / t)) - 33.2) / 20.734]$$

Where,

F = 1.1, accumulation factor for safety relief valves

M_m = the value of M_m determined in accordance with G-2214.1

p= vessel design pressure, ksi

R_i = vessel inner radius, in.

t= vessel wall thickness, in.

Notes:

(a) The coolant temperature is the reactor coolant inlet temperature.

(b) The vessel metal temperature is the temperature at a distance 1/4 of the vessel section thickness from the clad/base metal interface in the vessel beltline region. RT_{NDT} is the highest adjusted reference temperature (for weld or base metal in the beltline region) at a distance 1/4 of the vessel section thickness from the vessel clad/base metal interface as determined by Regulatory Guide 1.99, Revision 2 [Reference B-2].

Using the ASME Code Case N-641 equations and the following inputs, the Palisades LTOP system minimum enable temperature using Cases 2 and 3 was determined.

F = 1.1

M_m = 2.745 (See Section 3 for equations used to calculated M_m)

p = 2.485 ksi

R_i = 86.35 inches

t = 8.79 inches

RT_{NDT} = 252.7°F (at 1/4T per Table 4-4)

The LTOP system shall be effective below the higher temperature determined in accordance with (1) and (2) above, which has been determined to be 319.8°F. Alternatively, LTOP systems shall be effective below the higher temperature determined in accordance with (1) and (3) above, which has been determined to be 313.2°F.

Therefore, the minimum required enable temperature (without margins for instrument uncertainty) for the Palisades reactor vessel will be chosen to be 313.2°F at 42.1 EFPY. Per LTR-SEE-II-10-98 [Reference B-3], the current Limiting Condition for Operation (LCO) 3.4.12 dictates LTOP System operability requirements when the primary coolant system (PCS) is less than 430°F. This 430°F must bound the LTOP enable range associated with the new set of pressure-temperature limit curves for plant heatup and cooldown. Since the LTOP enable temperature (313.2°F) developed in this Appendix for 42.1 EFPY, is less than the value prescribed by LTR-SEE-II-10-98, the LTOP System operability requirements of the current LCO 3.4.12 will continue to be met through 42.1 EFPY.

B.1 REFERENCES

B-1 ASME Code Case N-641, "Alternative Pressure-Temperature Relationship and Low Temperature Overpressure Protection System Requirements Section XI, Division 1," January 17, 2000.

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

B-3 Westinghouse Letter LTR-SEE-II-10-98, Revision 0, "Westinghouse Review of LTOP Analyses and LTOP Controls Assumptions for Palisades Nuclear Plant," February 2011.

APPENDIX C HEATUP AND COOLDOWN LIMITS WITH MARGINS FOR INSTRUMENT ERRORS

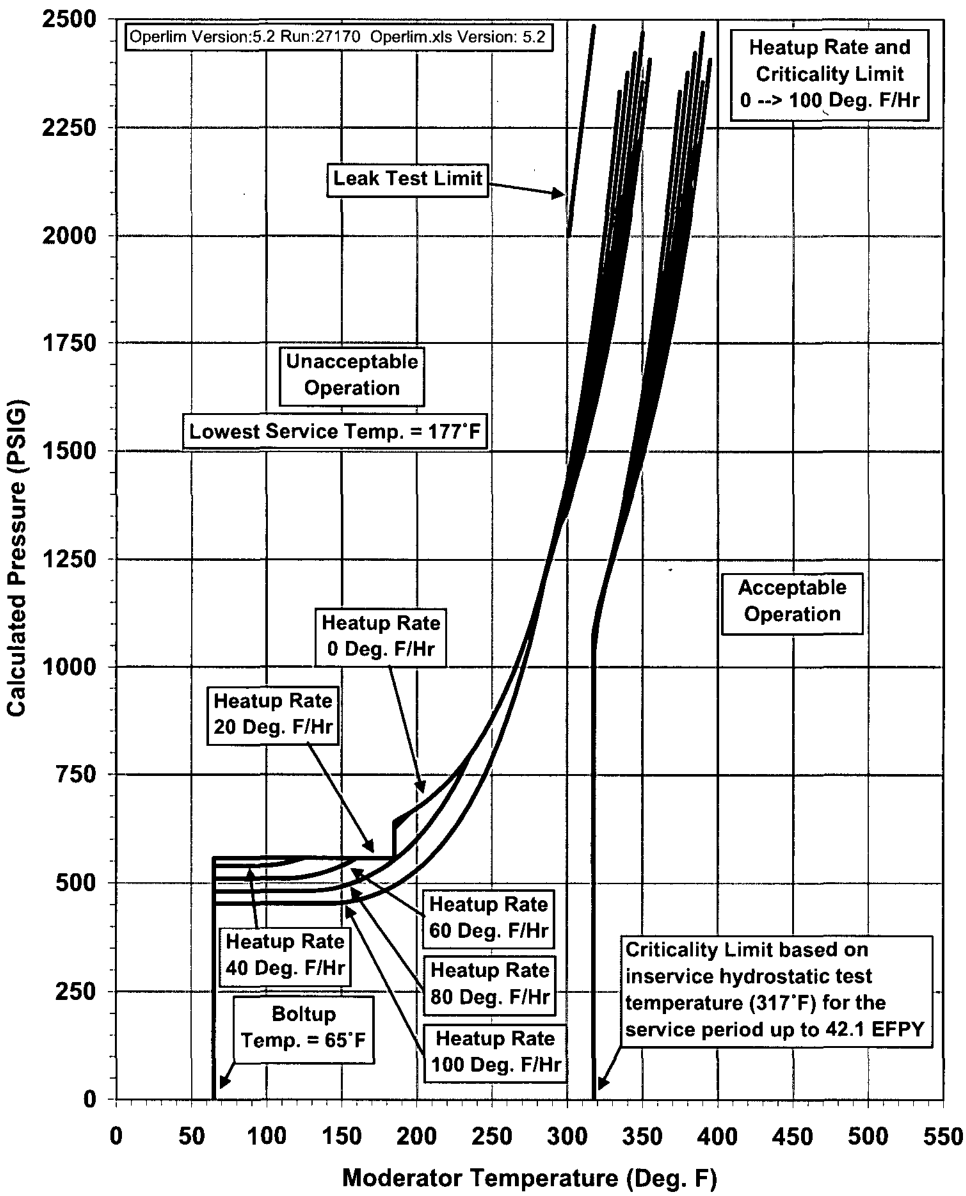
Figures C-1 and C-2 define all the limits described in Section 5.0 for ensuring prevention of non-ductile failure for the Palisades reactor vessel for 42.1 EFPY including the "Flange-Notch" requirements and with pressure correction for static and dynamic head loss. In addition, these curves contain margins for instrument errors of 5°F on temperature and 30 psi on pressure. The data points used for developing the heatup and cooldown pressure-temperature limit curves, with margins for instrument uncertainties, shown in Figures C-1 and C-2 are presented in Tables C-1 and C-2.

MATERIAL PROPERTY BASIS

LIMITING MATERIALS: IS and LS Axial Welds 2-112 and 3-112 (Heat # W5214) Using the Position 2.1 Chemistry Factor Value Based on Not Fully Credible Surveillance Data with Full Margin Term

LIMITING ART VALUES AT 42.1 EFPY: 1/4T, 252.7°F (Axial Flaw)
3/4T, 185.8°F (Axial Flaw)

Figure C-1 Palisades Reactor Coolant System Steady State and Heatup Curves for 20, 40, 60, 80 and 100°F/hr Applicable to 42.1 EFPY Based on the K_{Ic} Methodology of the 1998 through the Summer 2000 Addenda Edition of ASME Code, Section XI, App. G, With Margins for Instrumentation Errors, and With Delta Pressure Correction



MATERIAL PROPERTY BASIS

LIMITING MATERIALS: IS and LS Axial Welds 2-112 and 3-112 (Heat # W5214) Using the Position 2.1 Chemistry Factor Value Based on Not Fully Credible Surveillance Data with Full Margin Term

LIMITING ART VALUES AT 42.1 EFPY: 1/4T, 252.7°F (Axial Flaw)
3/4T, 185.8°F (Axial Flaw)

Figure C-2 Palisades Reactor Coolant System Steady State and Cooldown Curves for 20, 40, 60, 80 and 100°F/hr Applicable to 42.1 EFPY Based on the K_{Ic} Methodology of the 1998 through the Summer 2000 Addenda Edition of ASME Code, Section XI, App. G, With Margins for Instrumentation Errors, and With Delta Pressure Correction

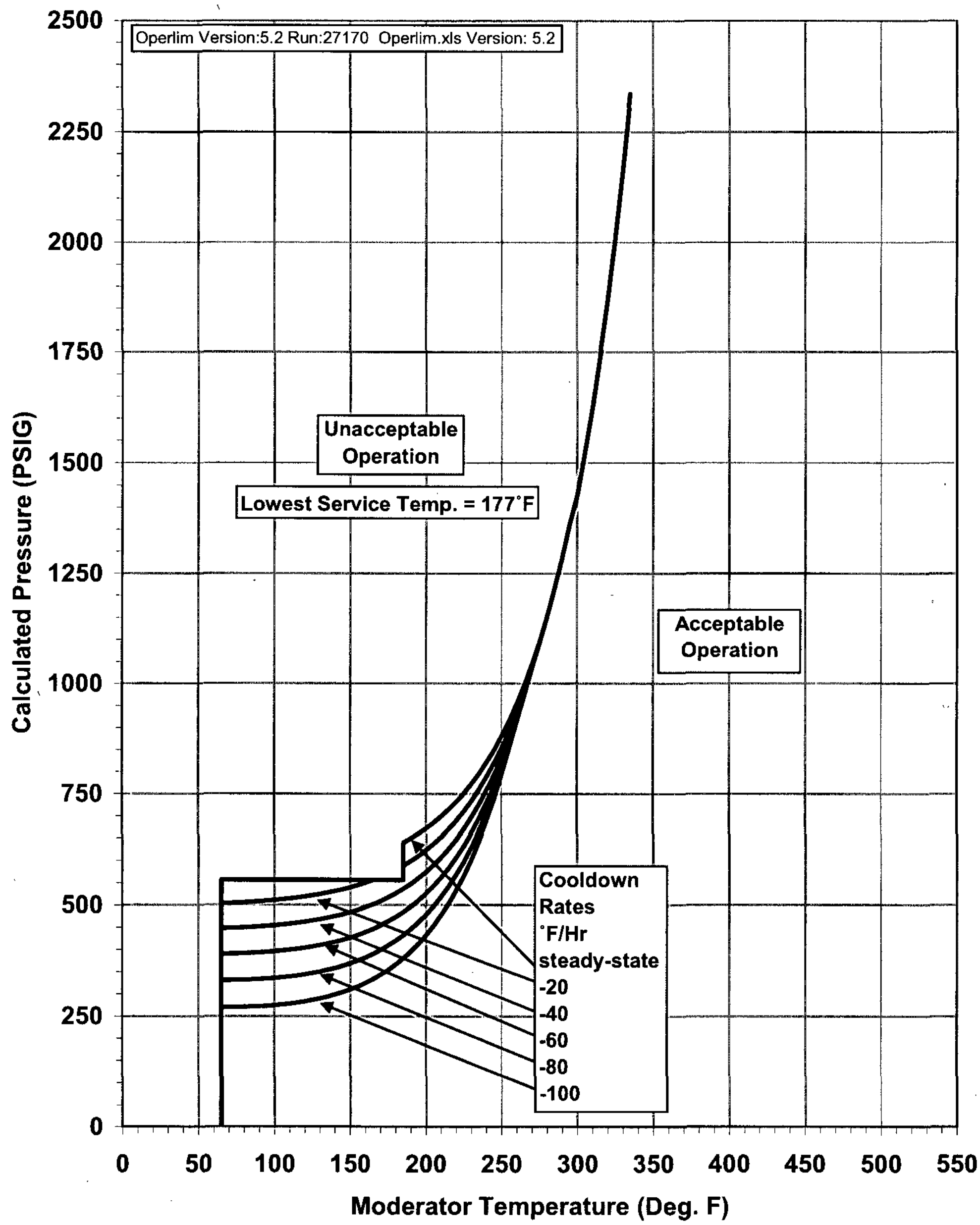


Table C-1 Palisades 42.1 EFPY Heatup Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, With Margin for Instrument Errors and With Delta Pressure Correction

Leak Test Limit		Steady State Heatup		Steady State Criticality		20°F/hr Heatup		20°F/hr Criticality		40°F/hr Heatup		40°F/hr Criticality	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
301	2000	65	0	317	0	65	0	317	0	65	0	317	0
301	2000	65	557	317	538	65	557	317	538	65	540	317	521
301	2000	70	557	317	538	70	557	317	538	70	540	317	521
301	2000	75	557	317	538	75	557	317	538	75	540	317	521
301	2000	80	557	317	538	80	557	317	538	80	540	317	521
317	2485	85	557	317	538	85	557	317	538	85	540	317	521
317	2485	90	557	317	538	90	557	317	538	90	540	317	521
317	2485	95	557	317	538	95	557	317	538	95	540	317	521
317	2485	100	557	317	538	100	557	317	538	100	540	317	521
317	2485	105	557	317	538	105	557	317	538	105	541	317	522
		110	557	317	538	110	557	317	538	110	544	317	525
		115	557	317	538	115	557	317	538	115	548	317	529
		120	557	317	538	120	557	317	538	120	552	317	533
		125	557	317	538	125	557	317	538	125	557	317	538
		130	557	317	538	130	557	317	538	130	557	317	538
		135	557	317	538	135	557	317	538	135	557	317	538
		140	557	317	538	140	557	317	538	140	557	317	538
		145	557	317	538	145	557	317	538	145	557	317	538
		150	557	317	538	150	557	317	538	150	557	317	538
		155	557	317	538	155	557	317	538	155	557	317	538
		160	557	317	538	160	557	317	538	160	557	317	538
		165	557	317	538	165	557	317	538	165	557	317	538
		170	557	317	538	170	557	317	538	170	557	317	538
		175	557	317	538	175	557	317	538	175	557	317	538

Leak Test Limit		Steady State Heatup		Steady State Criticality		20°F/hr Heatup		20°F/hr Criticality		40°F/hr Heatup		40°F/hr Criticality	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
		180	557	317	538	180	557	317	538	180	557	317	538
		185	557	317	621	185	557	317	621	185	557	317	621
		185	557	317	631	185	557	317	631	185	557	317	631
		185	640	317	641	185	640	317	641	185	640	317	641
		190	650	317	653	190	650	317	653	190	650	317	653
		195	660	317	665	195	660	317	665	195	660	317	665
		200	672	317	679	200	672	317	679	200	672	317	679
		205	684	317	695	205	684	317	695	205	684	317	695
		210	698	317	712	210	698	317	712	210	698	317	712
		215	714	317	731	215	714	317	731	215	714	317	731
		220	731	317	752	220	731	317	752	220	731	317	752
		225	750	317	776	225	750	317	776	225	750	317	776
		230	771	317	801	230	771	317	801	230	771	317	801
		235	795	317	830	235	795	317	830	235	795	317	830
		240	820	317	861	240	820	317	861	240	820	317	861
		245	849	317	896	245	849	317	896	245	849	317	896
		250	880	317	934	250	880	317	934	250	880	317	934
		255	915	317	976	255	915	317	976	255	915	317	976
		260	953	317	1023	260	953	317	1023	260	953	317	1023
		265	995	317	1075	265	995	317	1075	265	995	317	1075
		270	1042	320	1132	270	1042	320	1132	270	1042	320	1132
		275	1094	325	1195	275	1094	325	1191	275	1094	325	1191
		280	1151	330	1265	280	1151	330	1254	280	1151	330	1251
		285	1214	335	1342	285	1210	335	1323	285	1210	335	1313
		290	1284	340	1427	290	1273	340	1399	290	1270	340	1381
		295	1361	345	1521	295	1342	345	1484	295	1332	345	1457
		300	1427	350	1625	300	1399	350	1577	300	1381	350	1540

Leak Test Limit		Steady State Heatup		Steady State Criticality		20°F/hr Heatup		20°F/hr Criticality		40°F/hr Heatup		40°F/hr Criticality	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
		305	1521	355	1741	305	1484	355	1679	305	1457	355	1632
		310	1625	360	1868	310	1577	360	1793	310	1540	360	1734
		315	1741	365	2008	315	1679	365	1918	315	1632	365	1846
		320	1868	370	2164	320	1793	370	2057	320	1734	370	1970
		325	2008	375	2335	325	1918	375	2210	325	1846	375	2106
		330	2164			330	2057	380	2379	330	1970	380	2257
		335	2335			335	2210			335	2106	385	2424
						340	2379			340	2257		
										345	2424		

Table C-1-Cont. Palisades 42.1 EFPY Heatup Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, With Margin for Instrument Errors and With Delta Pressure Correction

60°F/hr Heatup		60°F/hr Criticality		80°F/hr Heatup		80°F/hr Criticality		100°F/hr Heatup		100°F/hr Criticality	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
65	0	317	0	65	0	317	0	65	0	317	0
65	510	317	491	65	481	317	462	65	453	317	434
70	510	317	491	70	481	317	462	70	453	317	434
75	510	317	491	75	481	317	462	75	453	317	434
80	510	317	491	80	481	317	462	80	453	317	434
85	510	317	491	85	481	317	462	85	453	317	434
90	510	317	491	90	481	317	462	90	453	317	434
95	510	317	491	95	481	317	462	95	453	317	434
100	510	317	491	100	481	317	462	100	453	317	434
105	510	317	491	105	481	317	462	105	453	317	434
110	510	317	491	110	481	317	462	110	453	317	434
115	510	317	491	115	481	317	462	115	453	317	434
120	511	317	492	120	481	317	462	120	453	317	434
125	513	317	494	125	481	317	462	125	453	317	434
130	517	317	498	130	481	317	462	130	453	317	434
135	521	317	502	135	482	317	463	135	453	317	434
140	526	317	507	140	485	317	466	140	453	317	434
145	532	317	513	145	488	317	469	145	453	317	434
150	539	317	520	150	492	317	473	150	455	317	436
155	548	317	529	155	497	317	478	155	457	317	438
160	557	317	538	160	503	317	484	160	461	317	442
165	557	317	538	165	511	317	492	165	465	317	446
170	557	317	538	170	519	317	500	170	470	317	451
175	557	317	538	175	529	317	510	175	477	317	458

60°F/hr Heatup		60°F/hr Criticality		80°F/hr Heatup		80°F/hr Criticality		100°F/hr Heatup		100°F/hr Criticality	
T (°F)	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**	**T (°F)**	**P (psig)**
180	557	317	538	180	540	317	521	180	485	317	466
185	557	317	606	185	553	317	534	185	494	317	475
185	557	317	624	185	553	317	548	185	494	317	485
185	625	317	641	185	553	317	564	185	494	317	497
190	643	317	653	190	567	317	582	190	504	317	511
195	660	317	665	195	583	317	601	195	516	317	526
200	672	317	679	200	601	317	623	200	530	317	543
205	684	317	695	205	620	317	648	205	545	317	562
210	698	317	712	210	642	317	675	210	562	317	583
215	714	317	731	215	667	317	705	215	581	317	606
220	731	317	752	220	694	317	738	220	602	317	633
225	750	317	776	225	724	317	774	225	625	317	662
230	771	317	801	230	757	317	801	230	652	317	694
235	795	317	830	235	793	317	830	235	681	317	730
240	820	317	861	240	820	317	861	240	713	317	769
245	849	317	896	245	849	317	896	245	749	317	813
250	880	317	934	250	880	317	934	250	788	317	861
255	915	317	976	255	915	317	976	255	832	317	914
260	953	317	1023	260	953	317	1023	260	880	317	973
265	995	317	1075	265	995	317	1075	265	933	317	1038
270	1042	320	1132	270	1042	320	1132	270	992	320	1109
275	1094	325	1191	275	1094	325	1191	275	1057	325	1188
280	1151	330	1251	280	1151	330	1251	280	1128	330	1251
285	1210	335	1310	285	1210	335	1310	285	1207	335	1310
290	1270	340	1371	290	1270	340	1368	290	1270	340	1368
295	1329	345	1439	295	1329	345	1430	295	1329	345	1427
300	1371	350	1514	300	1368	350	1497	300	1368	350	1488

60°F/hr Heatup		60°F/hr Criticality		80°F/hr Heatup		80°F/hr Criticality		100°F/hr Heatup		100°F/hr Criticality	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
305	1439	355	1597	305	1430	355	1572	305	1427	355	1555
310	1514	360	1688	310	1497	360	1654	310	1488	360	1629
315	1597	365	1789	315	1572	365	1744	315	1555	365	1711
320	1688	370	1900	320	1654	370	1844	320	1629	370	1801
325	1789	375	2022	325	1744	375	1954	325	1711	375	1900
330	1900	380	2157	330	1844	380	2075	330	1801	380	2009
335	2022	385	2306	335	1954	385	2209	335	1900	385	2130
340	2157	390	2471	340	2075	390	2357	340	2009	390	2262
345	2306			345	2209			345	2130	395	2408
350	2471			350	2357			350	2262		
								355	2408		

Table C-2 Palisades 42.1 EFPY Cooldown Data Points Using the 1998 through the 2000 Addenda App. G Methodology, With K_{Ic}, With Flange Notch, With Margin for Instrument Errors and With Delta Pressure Correction

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
65	0	65	0	65	0	65	0	65	0	65	0
65	557	65	504	65	448	65	390	65	331	65	270
70	557	70	505	70	448	70	391	70	331	70	270
75	557	75	505	75	449	75	391	75	332	75	270
80	557	80	506	80	450	80	392	80	332	80	271
85	557	85	507	85	451	85	393	85	333	85	271
90	557	90	509	90	452	90	394	90	334	90	272
95	557	95	510	95	453	95	395	95	335	95	273
100	557	100	511	100	454	100	396	100	336	100	275
105	557	105	513	105	456	105	398	105	338	105	276
110	557	110	515	110	458	110	399	110	340	110	278
115	557	115	517	115	460	115	402	115	342	115	281
120	557	120	519	120	462	120	404	120	344	120	283
125	557	125	522	125	465	125	407	125	347	125	286
130	557	130	525	130	468	130	410	130	351	130	290
135	557	135	528	135	471	135	414	135	354	135	294
140	557	140	532	140	475	140	418	140	359	140	299
145	557	145	536	145	479	145	422	145	364	145	304
150	557	150	540	150	484	150	427	150	369	150	310
155	557	155	545	155	489	155	433	155	375	155	317
160	557	160	551	160	495	160	439	160	382	160	325
165	557	165	557	165	502	165	446	165	390	165	333
170	557	170	557	170	509	170	454	170	399	170	343
175	557	175	557	175	518	175	463	175	409	175	354

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
180	557	180	557	180	527	180	473	180	420	180	366
185	557	185	557	185	537	185	485	185	432	185	380
185	557	185	557	185	537	185	485	185	432	185	380
185	640	185	589	185	537	185	485	185	432	185	380
190	650	190	599	190	548	190	497	190	446	190	396
195	660	195	610	195	561	195	511	195	461	195	413
200	672	200	623	200	574	200	526	200	478	200	432
205	684	205	637	205	590	205	543	205	497	205	453
210	698	210	652	210	607	210	562	210	519	210	477
215	714	215	670	215	626	215	583	215	542	215	504
220	731	220	689	220	647	220	607	220	568	220	533
225	750	225	710	225	670	225	633	225	598	225	566
230	771	230	733	230	696	230	662	230	630	230	602
235	795	235	759	235	725	235	694	235	666	235	643
240	820	240	787	240	756	240	729	240	706	240	688
245	849	245	819	245	792	245	768	245	750	245	737
250	880	250	853	250	831	250	812	250	799	250	793
255	915	255	892	255	874	255	860	255	853	255	853
260	953	260	935	260	921	260	914	260	914	260	914
265	995	265	982	265	974	265	973	265	973	265	973
270	1042	270	1034	270	1033	270	1033	270	1033	270	1033
275	1094	275	1092	275	1092	275	1092	275	1092	275	1092
280	1151	280	1151	280	1151	280	1151	280	1151	280	1151
285	1214	285	1214	285	1214	285	1214	285	1214	285	1214
290	1284	290	1284	290	1284	290	1284	290	1284	290	1284
295	1361	295	1361	295	1361	295	1361	295	1361	295	1361
300	1427	300	1427	300	1427	300	1427	300	1427	300	1427

Steady State		20°F/hr.		40°F/hr.		60°F/hr.		80°F/hr.		100°F/hr.	
T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)	T (°F)	P (psig)
305	1521	305	1521	305	1521	305	1521	305	1521	305	1521
310	1625	310	1625	310	1625	310	1625	310	1625	310	1625
315	1741	315	1741	315	1741	315	1741	315	1741	315	1741
320	1868	320	1868	320	1868	320	1868	320	1868	320	1868
325	2008	325	2008	325	2008	325	2008	325	2008	325	2008
330	2164	330	2164	330	2164	330	2164	330	2164	330	2164
335	2335	335	2335	335	2335	335	2335	335	2335	335	2335

APPENDIX D UPPER-SHELF ENERGY CALCULATIONS

The requirements for upper-shelf energy (USE) are contained in 10 CFR 50, Appendix G [Reference D-1]. 10 CFR 50, Appendix G, requires utilities to submit an analysis at least 3 years prior to the time that the USE of any reactor vessel material is predicted to drop below 50 ft-lb.

Regulatory Guide 1.99, Revision 2, defines two methods that can be used to predict the decrease in USE due to irradiation. The method to be used depends on the availability of credible surveillance capsule data. For vessel beltline materials that are not in the surveillance program or are not credible, the Charpy USE (Position 1.2) is assumed to decrease as a function of fluence and copper content, as indicated in Regulatory Guide 1.99, Revision 2 [Reference D-2].

When two or more credible surveillance data sets become available from the reactor vessel, they may be used to determine the Charpy USE of the surveillance materials. The surveillance data are then used in conjunction with Figure 2 of the Regulatory Guide to predict the decrease in USE (Position 2.2) of the reactor vessel materials due to irradiation.

The 42.1 EFPY (EOLE) Position 1.2 USE values of the vessel materials can be predicted using the corresponding 1/4T fluence projection, the copper content, and Figure 2 in Regulatory Guide 1.99, Revision 2.

The predicted Position 2.2 USE values are determined for the beltline materials that are contained in the surveillance program by using the reduced plant surveillance data along with the corresponding 1/4T fluence projection. The reduced plant surveillance data for the Palisades beltline welds from Capsules SA-60-1 and SA-240-1 are contained in Appendix B of SIA report 1001026.401, Revision 1 [Reference D-3]. The reduced plant surveillance data for the Palisades beltline IS plates, Heat # C-1279, are contained in Appendix C of SIA report 1001026.401, Revision 1, for Capsules A-240, W-290, W-110 and W-100. The weld and plate reduced surveillance data were plotted on Reg. Guide 1.99, Revision 2, Figure 2 (see Figures D-1 and D-2 of this report) using the updated surveillance capsule fluence values originally documented in WCAP-15353 – Supplement 1-NP [Reference D-4]. These updated capsule fluence values are also documented in SIA report 1001026.401, Revision 1. This data was fitted by drawing a line parallel to the existing lines as the upper bound of all the surveillance data. These reduced lines were used instead of the existing lines to determine the Position 2.2 EOLE USE values.

The initial USE values for the Palisades beltline materials, which were obtained from Constellation Nuclear Services report CNS-04-02-01, Revision 1 [Reference D-5], are contained in Table D-1. The surveillance capsule data, as described above, for the surveillance program weld and plate materials have been summarized in Table D-2. Using the data contained in Tables D-1 and D-2 along with the 1/4T fluence values, the projected USE values were calculated to determine if the Palisades reactor vessel materials remain above the 50 ft-lb limit at EOLE. Table D-4 contains the USE calculations for the Palisades reactor vessel beltline materials.

Table D-1 Palisades Reactor Vessel Beltline Initial USE and Copper Weight Percent Values

Reactor Vessel Material	Heat # (Flux Type)	Wt. % Cu[a]	Initial USE[b] (ft-lb)
IS Plate D-3803-1	C-1279	0.24	102
IS Plate D-3803-2	A-0313	0.24	87
IS Plate D-3803-3	C-1279	0.24	91
LS Plate D-3804-1	C-1308A	0.19	72
LS Plate D-3804-2	C-1308B	0.19	76
LS Plate D-3804-3	B-5294	0.12	73
IS Axial Welds 2-112 A/B/C	W5214	0.213	118
LS Axial Welds 3-112 A/B/C	34B009	0.192	111
	W5214	0.213	118
IS to LS Circ. Weld 9-112	27204 (Linde 124)[c]	0.203	84[d]

Notes for Table D-1:

(a) Values taken from Table 2-1 of this report.

(b) Source for this information is Constellation Nuclear Services report CNS-04-02-01, Revision 1 [Reference D-5].

(c) The information source for the weld flux type used in the Palisades reactor vessel for the IS to LS Circ. Weld (Heat # 27204) is Appendix A of BAW-2398 [Reference D-6]. This is consistent with Appendix A of BAW-2341, Revision 2 [Reference D-7].

(d) The initial USE value for Heat # 27204 is based on generic data for Linde 124 flux welds as given in CEN-622-A [Reference D-8]. This initial USE value is consistent with CNS-04-02-01, Revision 1 [Reference D-5].

Table D-2 Palisades Reactor Vessel Surveillance Capsule Fluence and USE Data

Surveillance Capsule Identification	Heat # (Flux Type or Orientation)	Upper-Shelf Energy[a] (ft-lb)			Surveillance Capsule Fluence[b] ($x 10^{19}$ n/cm^2, E > 1.0 MeV)
		Unirradiated	Irradiated	Decrease	
SA-60-1	W5214	102.7	54.5	46.9%	1.50
	34B009	113.9	55.3	51.5%	
	27204 (Linde 1092)[c]	108.4	53.0	51.1%	
SA-240-1	W5214	102.7	52.5	48.9%	2.38
	34B009	113.9	57.4	49.6%	
	27204 (Linde 1092)[c]	108.4	53.8	50.4%	
A-240	C-1279[d] (Long.)	165.0	95.0	42.4%	4.09
	C-1279[d] (Trans.)	105.0	68.0	35.2%	
W-290	C-1279[d] (Long)	155.0	112.0	27.7%	0.938
	C-1279[d] (Trans.)	102.0	84.0	17.6%	
W-110	C-1279[d] (Long.)	155.0	103.0	33.5%	1.64
W-100	C-1279[d] (Long.)	154.8	102.0	34.1%	2.09
	C-1279[d] (Trans.)	101.6	73.0	28.1%	

Notes for Table D-2:

(a) Information source for the unirradiated and irradiated USE values is SIA report 1001026.401, Revision 1, Appendix B, for the weld materials and Appendix C for the plate materials.

(b) The surveillance capsule fluence values, originally documented in WCAP-15353 – Supplement 1-NP, are summarized in SIA report 1001026.401, Revision 1.

(c) CE Report No. TR-MCC-189 [Reference D-9] documented that Linde 1092 weld flux type was used in the Palisades supplemental capsules, SA-60-1 and SA-240-1, for the Heat # 27204 Charpy specimens. Therefore, the data for Heat # 27204 is provided only for completeness; however, it will be excluded from the USE evaluation. See discussion below for more information.

(d) Plate surveillance data for these capsules used material from IS Plate D-3803-1; however, IS Plate D-3803-3 is made from the same heat. Therefore, this USE data will be used for both IS Plates D-3803-1 and D-3803-3 (Heat C-1279) in the USE evaluation.

Weld Heat # 27204 Surveillance Data

Weld seam 9-112 is a circumferential weld joining the intermediate and lower shell courses of the Palisades reactor pressure vessel. The weld was fabricated by an automatic submerged arc process using wire Heat # 27204 with Linde 124 weld flux. At the time of fabrication the requirement was to perform three Charpy impact tests at 10°F. As a result, there is insufficient data to establish the initial (unirradiated) upper-shelf energy. Furthermore, there is no record of a full set of Charpy impact tests done on another weld fabricated using wire Heat # 27204 with Linde 124 weld flux. In the absence of a specific value for upper shelf, the generic initial value of 84 ft-lb is used, which was based on the data for Linde 124 flux welds as given in CEN-622-A [Reference D-8]. An initial USE of 84 ft-lb corresponds to the mean-minus-two-sigma value for Linde 124 flux welds. As noted in the Staff's safety evaluation for CEN-622-A:

> *"The staff has concluded that the arguments presented by CEOG in CEN-622 indicate that welds produced with Linde 1092, 0091 and 124 fluxes are metallurgically different with regard to the influence on USE."*

There are two sets of post-irradiation test results fabricated with the same heat (# 27204) but a different flux (Linde 1092). However, there are no reactor surveillance program data for a weld fabricated using wire Heat #27204 with Linde 124 weld flux. The Linde 1092 surveillance welds are metallurgically different from the Linde 124 Palisades vessel welds, so the irradiated Linde 1092 weld data may not correctly model the behavior of the Palisades circumferential weld 9-112, with regards to USE <u>only</u>. The irradiated upper-shelf data are reproduced in the table below. Table D-3 provides a summary of all available post-irradiation USE values for Heat # 27204 with Linde 1092 flux. In summary, the Position 2.2 surveillance data for Heat # 27204 is not fully representative of the Palisades circumferential weld 9-112 due to the different flux type used; therefore, the surveillance USE data will be excluded from the reactor vessel USE evaluation.

Table D-3 Post-Irradiation USE Measurements for Weld Heat # 27204 Using Linde 1092 Flux for Diablo Canyon Unit 1 and Palisades

Vessel[a]	Capsule[a]	Fluence[b] (x 10^{19} n/cm^2, E > 1.0 MeV)	Measured Initial USE[a] (ft-lb)	Measured Post-Irradiation USE[a] (ft-lb)
Diablo Canyon Unit 1	S	0.284	98	87
Diablo Canyon Unit 1	Y	1.05		66
Diablo Canyon Unit 1	V	1.37		66
Palisades	SA-60-1	1.50	108.4	53.0
Palisades	SA-240-1	2.38		53.8

<u>Notes for Table D-3:</u>

(a) The values shown were taken from the various capsule reports included as Appendix B to SIA Report 1001026.401, Revision 1 [Reference D-3].
(b) Fluence values are from SIA Report 1001026.401, Revision 1 [Reference D-3]

The USE calculations for the Palisades reactor vessel beltline materials are provided below in Table D-4.

Table D-4 Palisades Predicted Positions 1.2 and 2.2 USE Values at 42.1 EFPY

Reactor Vessel Material	Wt. % Cu[(a)]	1/4T EOLE Fluence[(b)] (x10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE[(a)] (ft-lb)	Projected USE Decrease[(c)] (%)	Projected EOLE USE (ft-lb)
IS Plate D-3803-1	0.24	2.024	102	39	62.2
Using Surveillance Data	0.24	2.024	102	36[(d)]	65.3
IS Plate D-3803-2	0.24	2.024	87	39	53.1
IS Plate D-3803-3	0.24	2.024	91	39	55.5
Using Surveillance Data	0.24	2.024	91	36[(d)]	58.2
LS Plate D-3804-1	0.19	2.024	72	33	**48.2**
LS Plate D-3804-2	0.19	2.024	76	33	50.9
LS Plate D-3804-3	0.12	2.024	73	25	54.8
IS Axial Welds 2-112 (Heat # W5214)	0.213	1.275	118	38	73.2
Using Surveillance Data	0.213	1.275	118	45[(d,e)]	64.9
LS Axial Welds 3-112 (Heat # 34B009)	0.192	1.275	111	35	72.2
Using Surveillance Data	0.192	1.275	111	49[(d,e)]	56.6
LS Axial Welds 3-112 (Heat #W5214)	0.213	1.275	118	38	73.2
Using Surveillance Data	0.213	1.275	118	45[(d,e)]	64.9
IS to LS Circ. Weld 9-112 (Heat # 27204)	0.203	2.024	84	41	**49.6**

Notes for Table D-4:

(a) Values taken from Table D-1 of this report.
(b) Values taken from Table 4-1 of this report.
(c) Unless otherwise noted, percentage USE decrease values are based on Position 1.2 of Regulatory Guide 1.99, Revision 2 and calculated by plotting the 1/4T fluence values on Figure 2 of the Guide. The percent USE decrease values that corresponded to each materials' specific Cu wt. % value were determined using interpolation between the existing Weld or Base Metal lines on Figure 2.
(d) Percentage USE decrease is based on Position 2.2 of Regulatory Guide 1.99, Revision 2, using data from Table D-2 of this report. Credibility Criterion 3 in the Discussion section of Regulatory Guide 1.99, Revision 2, indicates that even if the surveillance data are not considered credible for determination of ΔRT_{NDT}, "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 E 185-82." Regulatory Guide 1.99, Revision 2, Position 2.2 indicates that an upper-bound line drawn parallel to the existing lines (in Figure 2 of the Guide) through the surveillance data points should be used in preference to the existing graph lines for determining the decrease in USE.
(e) Since the limiting surveillance data fell above the limiting line on Figure 2 of the Guide, the upper-bound line was drawn parallel to the "% copper" lines, and not the "upper limit" line. This was considered to be a conservative approach for the fluence levels being used in this evaluation.

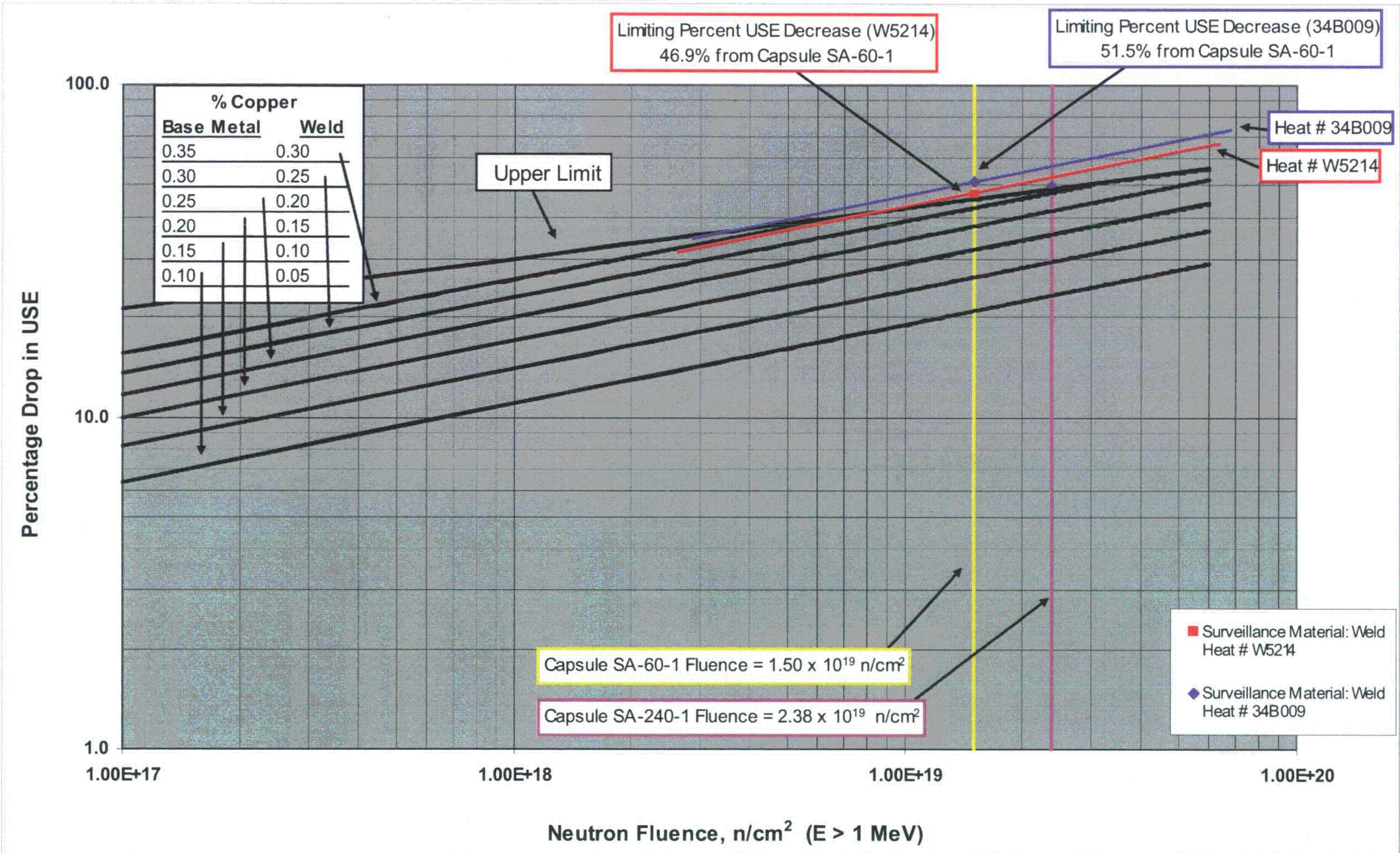


Figure D-1 Regulatory Guide 1.99, Revision 2, Predicted Decrease in USE for Welds as a Function of Copper and Fluence for Palisades

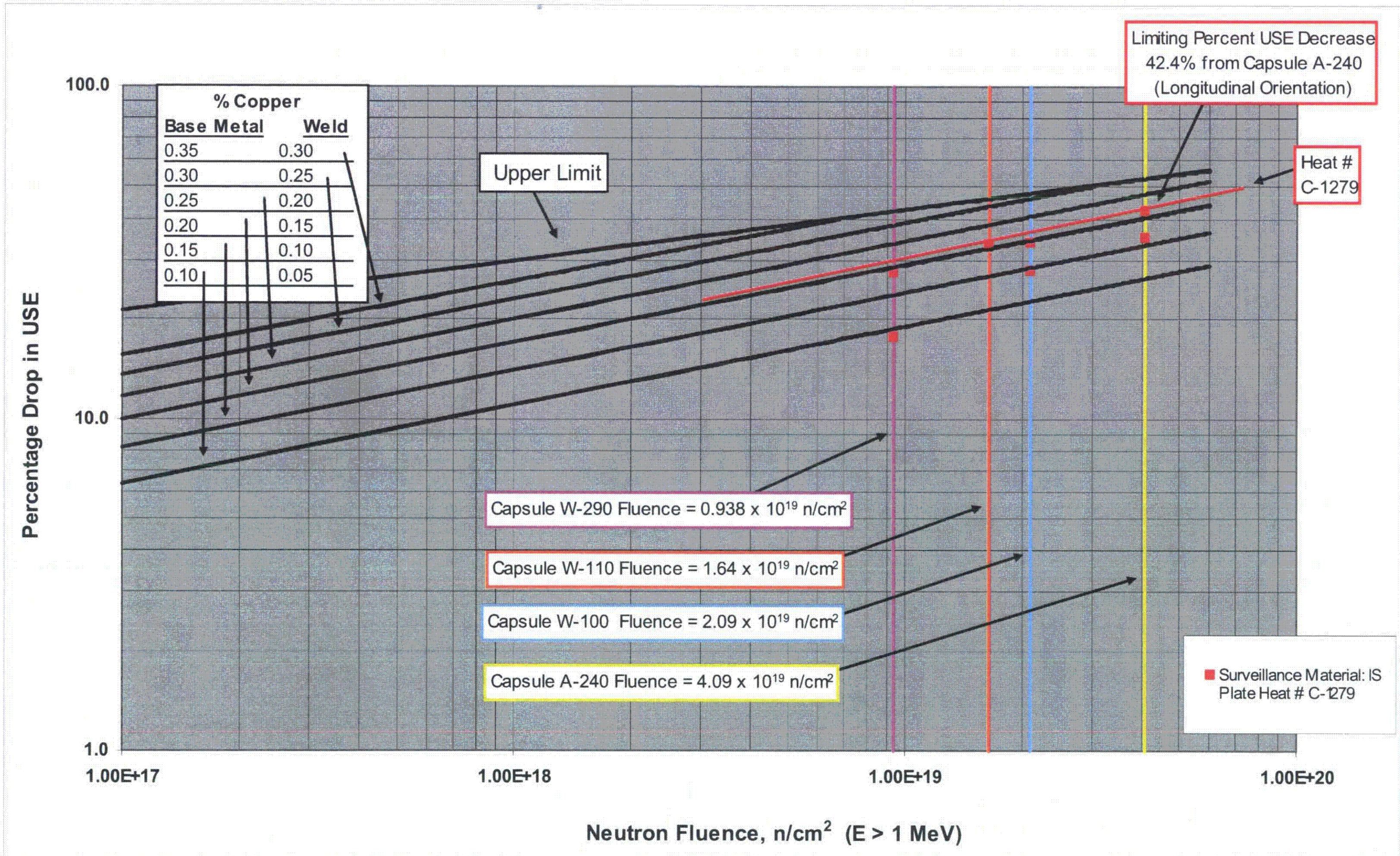


Figure D-2 Regulatory Guide 1.99, Revision 2, Predicted Decrease in USE for Plates as a Function of Copper and Fluence for Palisades

USE Conclusion

Two materials in the Palisades reactor vessel beltline, the LS Plate D-3804-1 and IS to LS Circ. Weld 9-112 (Heat # 27204) using Position 1.2 data, are predicted to drop below the 10 CFR 50, Appendix G, screening criteria prior to 42.1 EFPY (EOLE). The limiting plate material is predicted to drop below the screening limit in December of 2016 (See Tables D-5 and D-6). The limiting weld material is predicted to drop below the screening limit in November of 2027 (See Tables D-7 and D-8). Per 10 CFR 50, Appendix G, an Equivalent Margins Analysis (EMA) will need to be submitted to the NRC at least three years prior to the date when the predicted Charpy upper-shelf energy will fall below 50 ft-lb. All of the remaining beltline materials in the Palisades reactor vessel are projected to remain above the USE screening criterion value of 50 ft-lb (per 10 CFR 50, Appendix G) through EOLE (42.1 EFPY).

Table D-5 Calculation of the 1/4T Fluence Value for LS Plate D-3804-1 to Reach the 10 CFR 50, Appendix G, Screening Criteria

Reactor Vessel Material	Wt. % Cu	1/4T Fluence (x 10^{19} n/cm², E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected USE (ft-lb)
LS Plate D-3804-1	0.190	1.500[b]	72	30.5[a]	50

Notes for Table D-5:

(a) This percent USE decrease is the maximum allowable decrease for this material to reach 50 ft-lb.
(b) The 1/4T fluence value was calculated from the predicted maximum allowable percent USE decrease and Figure 2 of Regulatory Guide 1.99, Revision 2.

Table D-6 Calculation of the Surface Fluence, EFPY and Calendar Date for LS Plate D-3804-1 to Drop Below the 10 CFR 50, Appendix G, Screening Criteria

EOC	Calendar Date	EFPY	Fluence (x 10^{19} n/cm², E > 1.0 MeV)	
			Surface	1/4T
25[a]	Oct-2016	28.8	2.527	1.491[c]
(b)	**Dec-2016**	**29.0**	**2.542**	1.500[d]
26[a]	Apr-2018	30.2	2.621	1.547[c]

Notes for Table D-6:

(a) Values taken from WCAP-15353 – Supplement 1-NP [Reference D-4], unless otherwise noted.
(b) Values (in **bold**) are interpolated.
(c) The 1/4T fluence values are calculated from the surface fluence using the attenuation formula contained in Regulatory Guide 1.99, Revision 2.
(d) The predicted maximum 1/4T fluence value is taken from Table D-5.

Table D-7 Calculation of the 1/4T Fluence Value for IS to LS Circ. Weld (Heat # 27204) to Reach the 10 CFR 50, Appendix G, Screening Criteria

Reactor Vessel Material	Wt. % Cu	1/4T Fluence (x 10^{19} n/cm^2, E > 1.0 MeV)	Unirradiated USE (ft-lb)	Projected USE Decrease (%)	Projected USE (ft-lb)
IS to LS Circ. Weld 9-112 (Heat # 27204)	0.203	1.900[(b)]	84	40.4[(a)]	50

Notes for Table D-7:

(a) This percent USE decrease is the maximum allowable decrease for this material to reach 50 ft-lb.
(b) The 1/4T fluence value was calculated from the predicted maximum allowable percent USE decrease and Figure 2 of Regulatory Guide 1.99, Revision 2.

Table D-8 Calculation of the Surface Fluence, EFPY and Calendar Date for IS to LS Circ. Weld (Heat # 27204) to Drop Below the 10 CFR 50, Appendix G, Screening Criteria

EOC	Calendar Date	EFPY	Fluence (x 10^{19} n/cm^2, E > 1.0 MeV)	
			Surface	1/4T
32[(a)]	Apr-2027	38.4	3.182	1.878[(c)]
(b)	**Nov-2027**	**39.0**	**3.220**	1.900[(d)]
33[(a)]	Oct-2028	39.8	3.276	1.933[(c)]

Notes for Table D-8:

(a) Values taken from WCAP-15353 – Supplement 1-NP [Reference D-4], unless otherwise noted.
(b) Values (in **bold**) are interpolated.
(c) The 1/4T fluence values are calculated from the surface fluence using the attenuation formula contained in Regulatory Guide 1.99, Revision 2.
(d) The predicted maximum 1/4T fluence value is taken from Table D-7.

D.1 REFERENCES

D-1 Code of Federal Regulations, 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements," U.S. Nuclear Regulatory Commission, Washington, D. C., Federal Register, Volume 60, No. 243, dated December 19, 1995.

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

D-3 SIA Report No. 1001026.401, Revision 1, "Basis for Period of Validity of the Palisades Pressure-Temperature (P-T) Limit Curves," T. J. Griesbach, November 2010.

D-4 WCAP-15353 – Supplement 1-NP, Revision 0, "Palisades Reactor Pressure Vessel Fluence Evaluation," S. L. Anderson, May 2010.

D-5 Constellation Nuclear Services Report CNS-04-02-01, Revision 1, "Evaluation of Palisades Nuclear Plant Reactor Pressure Vessel Through the Period of Extended Operation," W. Pavinich, June 2004.

D-6 Framatome ANP Report BAW-2398, Revision 0, "Test Results of Capsule SA-240-1 Consumers Energy Palisades Nuclear Plant," M. J. DeVan, May 2001.

D-7 Framatome ANP Report BAW-2341, Revision 2, "Test Results of Capsule SA-60-1 Consumers Energy Palisades Nuclear Plant," M. J. DeVan, May 2001.

D-8 Combustion Engineering Report CEN-622-A, "Generic Upper Shelf Values for Linde 1092, 124 and 0091 Reactor Vessel Welds," C-E Owners Group, December 1996.

D-9 Combustion Engineering Report TR-MCC-189, Revision 0, "Fabrication of Charpy Specimens from Reactor Vessel Weld Archive Material for Electric Power Research Institute," B. C. Chang, February 1992.