Enclosure

Alternate Pressurized Thermal Shock (PTS) Rule Evaluation for Palisades

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Alternate Pressurized Thermal Shock (PTS) Rule Evaluation for Palisades

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EXECUTIVE SUMMARY

The Alternate Pressurized Thermal Shock (PTS) Rule (10 CFR 50.61a) was approved by the U.S. Nuclear Regulatory Commission (NRC) and included in the Federal Register, with an effective date of February 3, 2010. This Alternate Rule provides a new metric and screening criteria for PTS. This metric, RT_{MAX-X}, and the corresponding screening criteria are far less restrictive than the RT_{PTS} metrics and screening criteria in the original PTS Rule (10 CFR 50.61).

The purpose of this report is to provide Palisades with the basis for implementation of the Alternate PTS Rule up to the end of the 60-year operating license. The evaluation described in this report led to the following conclusions:

1. The Palisades reactor vessel (RV) beltline and extended beltline materials have end-of-license extension (EOLE), 42.1 effective full-power years (EFPY), RT_{MAX-X} values below the Alternate PTS Rule screening criteria;
2. The Palisades surveillance data for the vessel passed all of the surveillance data statistical tests for each material; and
3. The Palisades RV beltline and extended beltline weld flaw density and size distribution are acceptable based on the latest Palisades vessel inservice inspection (ISI) results from an ASME Section XI, Appendix VIII qualified examination.

1 INTRODUCTION

A Pressurized Thermal Shock (PTS) Event is an event or transient in pressurized water reactors (PWRs) causing severe overcooling (thermal shock) concurrent with or followed by significant pressure in the reactor vessel (RV). A PTS concern arises if one of these transients acts on the beltline region of an RV where a reduced fracture resistance exists because of neutron irradiation. Such an event may initiate and propagate an existing flaw or cause the propagation of a flaw postulated to exist near the inner wall surface, thereby potentially affecting the integrity of the vessel.

The purpose of this report is to document evaluations performed for the Palisades RV to meet the requirements of 10 CFR 50.61a, "Alternate fracture toughness requirements for protection against pressurized thermal shock events" (Reference 1). Section 2 discusses the Alternate PTS Rule and its requirements. Section 3 provides the methodology for calculating RT_{MAX-X} and performing the examination and flaw assessment required per the Alternate PTS Rule. Sections 4 through 7 provide inputs necessary to conduct the Alternate PTS Rule evaluations described in Section 3. Specifically, these sections provide the material properties, neutron fluence values, surveillance capsule analysis results, and inservice inspection (ISI) data of the RV beltline and extended beltline materials. The results of the RT_{MAX-X} calculations and flaw assessment are presented in Section 8. The conclusion and references for the PTS evaluation follow in Sections 9 and 10, respectively.

Note that the evaluation contained in this report is focused on the RV beltline and extended beltline regions of the RV. For the purposes of this evaluation, the RV beltline is defined as the region immediately adjacent to the reactor core. This definition is consistent with the definition in the original and Alternate PTS Rules (References 2 and 1), which is as follows:

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

The RV extended beltline for Palisades is defined as the region of materials that meet or exceed a neutron fluence exposure of 1.0×10^{17} n/cm^2 (E > 1.0 MeV). These materials were identified within the Palisades extended beltline RV integrity evaluation (Reference 3).

Please note that the Alternate PTS Rule was developed to apply only to materials within the RV beltline. Requirements of the Rule and other U.S. Nuclear Regulatory Commission (NRC) documents are provided throughout the following sections and often refer to the materials in the beltline region. For this analysis, when referring to beltline region materials, the reader should understand that the materials within the Palisades extended beltline projected to exceed a neutron fluence exposure of 1.0×10^{17} n/cm^2 (E > 1.0 MeV), per Reference 3, are also included.

2 ALTERNATE PRESSURIZED THERMAL SHOCK RULE

The Alternate PTS Rule (Reference 1) primary requirements consist of the following:

- Each licensee shall have projected values of RT_{MAX-X} for each reactor vessel beltline material for the end-of-license (EOL) fluence of the material. The assessment of RT_{MAX-X} values must use the calculation procedures described in Section 3.1 of this report. The assessment must specify the bases for the projected value of RT_{MAX-X} for each reactor vessel beltline material, including the assumptions regarding future plant operation (e.g., core loading patterns, projected capacity factors); the copper (Cu), phosphorus (P), manganese (Mn), and nickel (Ni) contents; the reactor cold leg temperature (T_C); and the neutron flux and fluence values used in the calculation for each beltline material.

- Each licensee shall evaluate the results from a plant-specific or integrated surveillance program if the surveillance data satisfy the criteria described in paragraphs (f)(6)(i)(A) and (f)(6)(i)(B) of 10 CFR 50.61a.

- Each licensee shall perform an examination and an assessment of flaws in the reactor vessel beltline as described in Section 3.3 of this report. The licensee shall verify that the requirements described in Section 3.3 have been met.

- Each licensee shall compare the projected RT_{MAX-X} values for plates, forgings, axial welds, and circumferential welds to the PTS screening criteria in Table 3-2 of this report, for the purpose of evaluating a reactor vessel's susceptibility to fracture due to a PTS event.

- If any of the projected RT_{MAX-X} values are greater than the PTS screening criteria in Table 3-2, then the licensee may propose the compensatory actions or plant-specific analyses as required in paragraphs (d)(3) through (d)(7) of 10 CFR 50.61a, as applicable, to justify operation beyond the PTS screening criteria in Table 3-2. The licensee shall implement those flux reduction programs that are reasonably practicable to avoid exceeding the PTS screening criteria. If this analysis indicates that no reasonably practicable flux reduction program will prevent the RT_{MAX-X} value for one or more of the reactor vessel beltline materials from exceeding the PTS screening criteria, then the licensee shall perform a safety analysis to determine what, if any, modifications to equipment, systems, and operation are necessary to prevent the potential for an unacceptably high probability of failure of the reactor vessel as a result of postulated PTS events. In the analysis, the licensee may determine the properties of the reactor vessel materials based on available information, research results and plant surveillance data, and may use probabilistic fracture mechanics techniques.

The Alternate PTS Rule subsequent requirements consist of the following:

- Whenever there is a significant change in projected values of RT_{MAX-X}, so that the previous value, the current value, or both values, exceed the screening criteria before the expiration of the plant operating license; or upon the licensee's request for a change in the expiration date for operation of the facility; a re-assessment of RT_{MAX-X} values must be conducted. If the surveillance data used to perform the re-assessment of RT_{MAX-X} values meet the requirements discussed in Section 3.2 of this report, the data must be analyzed in accordance with the Alternate PTS Rule and the RT_{MAX-X} values must be recalculated and resubmitted for approval.

- The licensee shall verify that the requirements of paragraphs (e), (e)(1), (e)(2), and (e)(3) of 10 CFR 50.61a have been met. The licensee must submit, within 120 days after completing a volumetric examination of reactor vessel beltline materials as required by ASME Code, Section XI, the adjustments made to the volumetric test data to account for NDE-related uncertainties as described in paragraph (e)(1) of 10 CFR 50.61a and all information required by paragraph (e)(1)(iii) of 10 CFR 50.61a for review and approval. If a licensee is required to implement paragraphs (e)(4), (e)(5), and (e)(6) of 10 CFR 50.61a, the information required in these paragraphs must be submitted within one year after completing a volumetric examination of reactor vessel materials as required by ASME Code, Section XI.

3 METHOD DISCUSSION

3.1 CALCULATION OF RT_{MAX-X} VALUES

In accordance with paragraph (f) of 10 CFR 50.61a, each licensee shall calculate RT_{MAX-X} values for each reactor vessel beltline material using φt. Note that the Palisades RV materials determined to be located in the extended beltline (Reference 3) are also included in this evaluation.

The values of RT_{MAX-AW} (Axial Welds), RT_{MAX-PL} (Plates), RT_{MAX-FO} (Forgings), and RT_{MAX-CW} (Circumferential Welds) must be determined using Equations 1 through 4 (Reference 1). NUREG-1874 (Reference 4) provides additional information on these equations, which are included below. RT_{MAX-X} values are calculated in degrees Fahrenheit (°F) as follows:

$$RT_{MAX-AW} \equiv \underset{i=1}{\overset{n_{AWFL}}{MAX}}\left[MAX_{AWFL(i)} \begin{Bmatrix} \left(RT_{NDT(u)}^{adj-aw(i)} + \Delta T_{30}^{adj-aw(i)}\left(\phi t_{FL}\right)\right), \\ \left(RT_{NDT(u)}^{adj-pl(i)} + \Delta T_{30}^{adj-pl(i)}\left(\phi t_{FL}\right)\right) \end{Bmatrix} \right] \qquad (1)$$

Where:

n_{AWFL}	is the number of axial weld fusion lines in the beltline region of the vessel,
i	is a counter that ranges from 1 to n_{AWFL},
ϕt_{FL}	is the maximum fluence occurring on the vessel inner diameter (ID) along a particular axial weld fusion line,
$RT_{NDT(u)}^{adj-aw(i)}$	is the unirradiated RT_{NDT} of the weld adjacent to the i^{th} axial weld fusion line,
$RT_{NDT(u)}^{adj-pl(i)}$	is the unirradiated RT_{NDT} of the plate adjacent to the i^{th} axial weld fusion line,
$\Delta T_{30}^{adj-aw(i)}$	is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation to ϕt_{FL} of the weld adjacent to the i^{th} axial weld fusion line, and
$\Delta T_{30}^{adj-pl(i)}$	is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation due to ϕt_{FL} of the plate adjacent to the i^{th} axial weld fusion line.

$$RT_{MAX-PL} \equiv \underset{i=1}{\overset{n_{PL}}{MAX}}\left[RT_{NDT(u)}^{PL(i)} + \Delta T_{30}^{PL(i)}\left(\phi t_{MAX}^{PL(i)}\right)\right] \qquad (2)$$

Where:

n_{PL}	is the number of plates in the beltline region of the vessel,
i	is a counter that ranges from 1 to n_{PL},
$\phi t_{MAX}^{PL(i)}$	is the maximum fluence occurring over the vessel ID occupied by a particular plate,

$RT_{NDT(u)}^{PL(i)}$ is the unirradiated RT_{NDT} of a particular plate, and

$\Delta T_{30}^{PL(i)}$ is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation to $\phi t_{MAX}^{PL(i)}$ of a particular plate.

$$RT_{MAX\text{-}FO} \equiv \underset{i=1}{\overset{n_{FO}}{\mathrm{MAX}}}\left[RT_{NDT(u)}^{FO(i)} + \Delta T_{30}^{FO(i)}\left(\phi t_{MAX}^{FO(i)}\right)\right] \tag{3}$$

Where:

n_{FO} is the number of forgings in the beltline region of the vessel,

i is a counter that ranges from 1 to n_{FO},

$\phi t_{MAX}^{FO(i)}$ is the maximum fluence occurring over the vessel ID occupied by a particular forging,

$RT_{NDT(u)}^{FO(i)}$ is the unirradiated RT_{NDT} of a particular forging, and

$\Delta T_{30}^{FO(i)}$ is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation to $\phi t_{MAX}^{FO(i)}$ of a particular forging.

$$RT_{MAX\text{-}CW} \equiv \underset{i=1}{\overset{n_{CWFL}}{\mathrm{MAX}}}\left[\mathrm{MAX}_{CWFL(i)}\left\{\begin{array}{l}\left(RT_{NDT(u)}^{adj-cw(i)} + \Delta T_{30}^{adj-cw(i)}\left(\phi t_{FL}\right)\right),\\ \left(RT_{NDT(u)}^{adj-pl(i)} + \Delta T_{30}^{adj-pl(i)}\left(\phi t_{FL}\right)\right),\\ \left(RT_{NDT(u)}^{adj-fo(i)} + \Delta T_{30}^{adj-fo(i)}\left(\phi t_{FL}\right)\right)\end{array}\right\}\right] \tag{4}$$

Where:

n_{CWFL} is the number of circumferential weld fusion lines in the beltline region of the vessel,

i is a counter that ranges from 1 to n_{CWFL},

ϕt_{FL} is the maximum fluence occurring on the vessel ID along a particular circumferential weld fusion line,

$RT_{NDT(u)}^{adj-cw(i)}$ is the unirradiated RT_{NDT} of the weld adjacent to the i^{th} circumferential weld fusion line,

$RT_{NDT(u)}^{adj-pl(i)}$ is the unirradiated RT_{NDT} of the plate adjacent to the i^{th} circumferential weld fusion line (if there is no adjacent plate this term is ignored),

$RT_{NDT(u)}^{adj-fo(i)}$ is the unirradiated RT_{NDT} of the forging adjacent to the i^{th} circumferential weld fusion line (if there is no adjacent forging this term is ignored),

$\Delta T_{30}^{adj-cw(i)}$ is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation due to ϕt_{FL} of the weld adjacent to the ith circumferential weld fusion line,

$\Delta T_{30}^{adj-pl(i)}$ is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation to ϕt_{FL} of the plate adjacent to the ith circumferential weld fusion line (if there is no adjacent plate this term is ignored), and

$\Delta T_{30}^{adj-fo(i)}$ is the shift in the Charpy V-Notch 30-foot-pound (ft-lb) energy produced by irradiation to ϕt_{FL} of the forging adjacent to the ith circumferential weld fusion line (if there is no adjacent forging this term is ignored).

The values of ΔT_{30} must be determined using Equations 5, 6, and 7 for each axial weld, plate, forging, and circumferential weld. The ΔT_{30} value for each axial weld calculated as specified by Equation 1 must be calculated for the maximum fluence occurring along a particular axial weld (φt_{FL}) at the clad-to-base metal interface. The ΔT_{30} value for each adjacent plate calculated as specified by Equation 1 must also be calculated using the same value of φt_{FL} used for the axial weld. The ΔT_{30} value for each plate or forging calculated as specified by Equations 2 and 3 must be calculated for the maximum fluence (φt_{MAX}) occurring at the clad-to-base metal interface over the entire area of each plate or forging. In Equation 4, the fluence (φt_{FL}) value used for calculating the circumferential weld ΔT_{30} value is the maximum fluence occurring along the circumferential weld at the clad-to-base metal interface. The ΔT_{30} values in Equation 4 shall also be calculated for the adjoining plates or forgings using the same maximum circumferential weld fluence. If the conditions for the surveillance capsule data specified in Section 3.2 are not met, licensees must propose ΔT_{30} and RT_{MAX-X} values in accordance with paragraph (f)(6)(vi) of 10 CFR 50.61a (Reference 1).

The equation used to calculate the ΔT_{30} shift is displayed below:

$$\Delta T_{30} = MD + CRP \qquad (5)$$

Where:

$$MD = A(1-0.001718T_C)(1+6.13PMn^{2.471})\,\varphi t_e^{0.5} \qquad (6)$$

$$CRP = B(1+3.77Ni^{1.191})\,f(Cu_e,P)g(Cu_e,Ni,\varphi t_e) \qquad (7)$$

A = 1.140×10^{-7} for forgings
1.561×10^{-7} for plates
1.417×10^{-7} for welds

B = 102.3 for forgings
102.5 for plates in non-Combustion Engineering (CE) manufactured vessels
135.2 for plates in CE manufactured vessels
155.0 for welds

$\varphi t_e =$	φt for $\varphi \geq 4.39\text{x}10^{10}$ n/cm^2/sec $\varphi t(4.39\text{x}10^{10}/\ \varphi)^{0.2595}$ for $\varphi < 4.39 \times 10^{10}$ n/cm^2/sec
$f(Cu_e, P) =$	0 for Cu ≤ 0.072 $[Cu_e - 0.072]^{0.668}$ for Cu > 0.072 and P ≤ 0.008 $[Cu_e - 0.072+1.359(P-0.008)]^{0.668}$ for Cu > 0.072 and P > 0.008
$Cu_e =$	0 for Cu ≤ 0.072 MIN (Cu, Maximum Cu_e) for Cu > 0.072
Max. $Cu_e =$	0.243 for Linde 80 welds 0.301 for all other materials
$g(Cu_e, Ni, \varphi t_e) =$	$\frac{1}{2}+\frac{1}{2}\tanh\left[\frac{\log_{10}(\varphi t_e)+1.1390Cu_e-0.448Ni-18.120}{0.629}\right]$
$T_C =$	Cold leg temperature under normal full power operating conditions (°F) as a time-weighted average
$\varphi =$	Average neutron flux (n/cm^2/sec)
$t =$	Time that the reactor has been in full power operation (sec)
φt	Neutron Fluence (n/cm^2)
$P=$	Phosphorous content (wt%)
$Ni=$	Nickel content (wt%)
$Cu=$	Copper content (wt%)
$Mn=$	Manganese content (wt%)

The values of Cu, Mn, P, and Ni in Equations 6 and 7 must represent the best estimate values for the material. For a plate or forging, the best estimate value is normally the mean of the measured values for that plate or forging. For a weld, the best estimate value is normally the mean of the measured values for a weld deposit made using the same weld wire heat number as the critical vessel weld. If these values are not available, either the upper limiting values given in the material specifications to which the vessel material was fabricated, or conservative estimates (i.e., mean plus one standard deviation) based on generic data as shown in Table 3-1 for P and Mn, must be used.

Table 3-1 Conservative Estimates for Chemical Element Weight Percentages (Reference 1)

Materials	P	Mn
Plates	0.014	1.45
Forgings	0.016	1.11
Welds	0.019	1.63

The values of $RT_{NDT(U)}$ must be evaluated according to the procedures in the ASME Code, Section III, paragraph NB–2331. If any other method is used for this evaluation, the licensee shall submit the proposed method for review and approval by the Director along with the calculation of RT_{MAX-X} values.

- If a measured value of $RT_{NDT(U)}$ is not available, a generic mean value of $RT_{NDT(U)}$ for the class of material must be used if there are sufficient test results to establish a mean.
- The following generic mean values of $RT_{NDT(U)}$ must be used unless justification for different values is provided: 0°F for welds made with Linde 80 weld flux; and -56°F for welds made with Linde 0091, 1092, and 124 and ARCOS B–5 weld fluxes.

The value of T_C in Equation 6 of this section must represent the time-weighted average of the reactor cold leg temperature under normal operating full power conditions from the beginning of full power operation through the end of licensed operation. For the surveillance capsule statistical tests, T_C is a time-weighted average from the beginning of full power operation up to the time of capsule withdrawal.

If any of the calculated RT_{MAX-X} values for Palisades are greater than the PTS screening criteria, defined in Table 3-2, further evaluation or action, consistent with paragraphs (d)(3) through (d)(7) of the Rule, is required.

Table 3-2 PTS Screening Criteria

Product form and RT_{MAX-X} values	RT_{MAX-X} limits [°F] for different vessel wall thicknesses[1] (T_{WALL})		
	$T_{WALL} \leq 9.5$ in.	9.5 in. < T_{WALL} ≤ 10.5 in.	10.5 in. < T_{WALL} ≤ 11.5 in.
Axial Weld—RT_{MAX-AW}	269	230	222
Plate—RT_{MAX-PL}	356	305	293
Forging without underclad cracks—RT_{MAX-FO}[2]	356	305	293
Axial Weld and Plate—RT_{MAX-AW} + RT_{MAX-PL}	538	476	445
Circumferential Weld—RT_{MAX-CW}[3]	312	277	269
Forging with underclad cracks—RT_{MAX-FO}[4]	246	241	239

Notes:
1. Wall thickness is the beltline wall thickness including the clad thickness.
2. Forgings without underclad cracks apply to forgings for which no underclad cracks have been detected and that were fabricated in accordance with Regulatory Guide 1.43.
3. RT_{PTS} limits contribute 1×10^{-8} per reactor year to the reactor vessel TWCF.
4. Forgings with underclad cracks apply to forgings that have detected underclad cracking or were not fabricated in accordance with Regulatory Guide 1.43.

3.2 SURVEILLANCE CAPSULE DATA STATISTICAL CHECKS

As a condition of the Alternate PTS Rule, the licensee must consider plant-specific information that could affect the use of this equation for the determination of a material's ΔT_{30} value. In order to make this determination, the Alternate PTS Rule provides requirements for evaluation of surveillance capsule data. These requirements are specified in paragraphs (f)(6)(i), (f)(6)(ii), (f)(6)(iii), and (f)(6)(iv) of Reference 1. The requirements consist of a Mean Deviation Test, a Slope Deviation Test, and an Outlier Deviation Test.

Specifically, the Rule states that the licensee shall verify that an appropriate RT_{MAX-X} value has been calculated for each reactor vessel beltline material by considering plant-specific information that could

affect the use of the model (i.e., Equations 5, 6, and 7) for the determination of a material's ΔT_{30} value.

The licensee shall evaluate the results from a plant-specific or integrated surveillance program if the surveillance data satisfy the following criteria:

- The surveillance material must be a heat-specific match for one or more of the materials for which RT_{MAX-X} is being calculated. The 30-foot-pound transition temperature must be determined as specified by the requirements of 10 CFR part 50, Appendix H.
- If three or more surveillance data points measured at three or more different neutron fluences exist for a specific material, the licensee shall determine if the surveillance data show a significantly different trend than the embrittlement model predicts. If fewer than three surveillance data points exist for a specific material, then the embrittlement model must be used without performing the consistency check.

The licensee shall estimate the mean deviation from the embrittlement model for the specific data set (i.e., a group of surveillance data points representative of a given material). The mean deviation from the embrittlement model for a given data set must be calculated using Equations 8 and 9. The mean deviation for the data set must be compared to the maximum heat-average residual given in Table 3-3 or derived using Equation 10. The maximum heat-average residual is based on the material group into which the surveillance material falls and the number of surveillance data points. For surveillance data sets with greater than 8 data points, the maximum credible heat-average residual must be calculated using Equation 10. The value of σ used in Equation 10 must be obtained from Table 3-3.

$$Residual\ (r) = Measured\ \Delta T_{30} - Predicted\ \Delta T_{30} \quad (8)$$

$$Mean\ deviation\ for\ a\ data\ set\ of\ n\ data\ points = (1/n) \times \sum_{i=1}^{n} r_i \quad (9)$$

$$Maximum\ credible\ heat\text{-}average\ residual = 2.33\sigma/n^{0.5} \quad (10)$$

Where:

n = number of surveillance data points (sample size) in the specific data set

σ = standard deviation of the residuals about the model for a relevant material group given in Table 3-3.

Table 3-3 Maximum Heat-Average Residual [°F] for Relevant Material Groups by Number of Available Data Points (Significance Level = 1%)

Material group	σ [°F]	Number of available data points					
		3	4	5	6	7	8
Welds, for Cu > 0.072	26.4	35.5	30.8	27.5	25.1	23.2	21.7
Plates, for Cu > 0.072	21.2	28.5	24.7	22.1	20.2	18.7	17.5
Forgings, for Cu > 0.072	19.6	26.4	22.8	20.4	18.6	17.3	16.1
Weld, Plate or Forging, for Cu ≤ 0.072	18.6	25.0	21.7	19.4	17.7	16.4	15.3

The licensee shall estimate the slope of the embrittlement model residuals (estimated using Equation 8) plotted as a function of the base 10 logarithm of neutron fluence for the specific data set. The licensee shall estimate the T-statistic for this slope (T_{SURV}) using Equation 11 and compare this value to the maximum permissible T-statistic (T_{MAX}) in Table 3-4. For surveillance data sets with greater than 15 data points, the T_{MAX} value must be calculated using Student's T distribution with a significance level (α) of 1 percent for a one-tailed test.

$$T_{SURV} = \frac{m}{(se(m))} \quad (11)$$

Where:

m = The slope of a plot of all of the *r* values (estimated using Equation 8) versus the base 10 logarithm of the neutron fluence for each *r* value. The slope shall be estimated using the method of least squares.

(se(m)) = The least-squares estimate of the standard-error associated with the estimated slope value *m*.

Table 3-4 T_{MAX} Values for the Slope Deviation Test (Significance Level = 1%)

Number of available data points (n)	T_{MAX}
3	31.82
4	6.96
5	4.54
6	3.75
7	3.36
8	3.14
9	3.00
10	2.90
11	2.82
12	2.76
13	2.72
14	2.68
15	2.65

The licensee shall estimate the two largest positive deviations (i.e., outliers) from the embrittlement model for the specific data set using Equations 8 and 12. The licensee shall compare the largest normalized residual (r *) to the appropriate allowable value from the third column in Table 3-5 and the second largest normalized residual to the appropriate allowable value from the second column in Table 3-5.

$$r^* = \frac{r}{\sigma} \quad (12)$$

Where r is defined using Equation 8 and σ is given in Table 3-3.

Table 3-5 Threshold Values for the Outlier Deviation Test (Significance Level = 1%)		
Number of available data points (n)	Second largest allowable normalized residual value (r*)	Largest allowable normalized residual value (r*)
3	1.55	2.71
4	1.73	2.81
5	1.84	2.88
6	1.93	2.93
7	2.00	2.98
8	2.05	3.02
9	2.11	3.06
10	2.16	3.09
11	2.19	3.12
12	2.23	3.14
13	2.26	3.17
14	2.29	3.19
15	2.32	3.21

The ΔT_{30} value must be determined using Equations 5, 6, and 7 if all three of the following criteria are satisfied:

- The mean deviation from the embrittlement model for the data set is equal to or less than the value in Table 3-3 or the value derived using Equation 10 of this section;
- The T-statistic for the slope (T_{SURV}) estimated using Equation 11 is equal to or less than the maximum permissible T-statistic (T_{MAX}) in Table 3-4; and
- The largest normalized residual value is equal to or less than the appropriate allowable value from the third column in Table 3-5 and the second largest normalized residual value is equal to or less than the appropriate allowable value from the second column in Table 3-5.

If any of these criteria are not satisfied, the licensee shall review the data base for that heat in detail, including all parameters used in Equations 5, 6, and 7 of this section and the data used to determine the baseline Charpy V-notch curve for the material in an unirradiated condition. The licensee shall propose ΔT_{30} and RT_{MAX-X} values, considering their plant-specific surveillance data, to be used for evaluation relative to the acceptance criteria of this rule.

3.3 REACTOR VESSEL BELTLINE ISI DATA EVALUATION

The licensee must have performed an examination of the RV beltline welds using procedures, equipment, and personnel that have been qualified under the ASME Code Section XI, Appendix VIII, Supplement 4 and Supplement 6, as specified in 10 CFR 50.55a(b)(2)(xv). The licensee shall verify that the flaw density and size distributions within the volume described in ASME Code, Section XI (Reference 5), Figures IWB–2500–1 and IWB–2500–2 and limited to a depth from the clad-to-base metal interface of 1-inch or 10 percent of the vessel thickness, whichever is greater, do not exceed the limits in Tables 3-6 and 3-7 based on the test results from the volumetric examination. The verification of the flaw density and size distributions shall be performed line-by-line for Tables 3-6 and 3-7.

Table 3-6 Allowable Number of Flaws in Welds		
Through-Wall Extent (TWE) of Flaw (in.)		Maximum number of flaws per 1000 inches of weld length in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}
TWE_{MIN}	TWE_{MAX}	
0	0.075	No Limit
0.075	0.475	166.70
0.125	0.475	90.80
0.175	0.475	22.82
0.225	0.475	8.66
0.275	0.475	4.01
0.325	0.475	3.01
0.375	0.475	1.49
0.425	0.475	1.00
0.475	Infinite	0.00

The licensee shall determine the allowable number of weld flaws in the reactor vessel beltline by multiplying the values in Table 3-6 by the total length of the reactor vessel beltline welds that were volumetrically inspected and dividing by 1000 inches of weld length.

Table 3-7 Allowable Number of Flaws in Plates or Forgings		
Through-Wall Extent (TWE) of Flaw (in.)		Maximum number of flaws per 1000 square inches of inside surface area in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}
TWE_{MIN}	TWE_{MAX}	
0	0.075	No Limit
0.075	0.375	8.05
0.125	0.375	3.15
0.175	0.375	0.85
0.225	0.375	0.29
0.275	0.375	0.08
0.325	0.375	0.01
0.375	Infinite	0.00

The licensee shall determine the allowable number of plate or forging flaws in their reactor vessel beltline by multiplying the values in Table 3-7 by the total surface area of the reactor vessel beltline plates or forgings that were volumetrically inspected and dividing by 1000 square inches.

For each flaw detected within the greater of 1-inch or 10 percent of the vessel thickness inspection volume, measured from the clad-to-base metal interface, with a through-wall extent equal to or greater than 0.075 inches, the licensee shall document the dimensions of the flaw, including through-wall extent and length, whether the flaw is axial or circumferential in orientation and its location within the reactor vessel, including its azimuthal and axial positions and its depth embedded from the clad-to-base metal interface.

The licensee shall verify that axially oriented flaws located at the clad-to-base metal interface do not open to the vessel inside surface using surface or visual examination techniques capable of detecting and characterizing service induced cracking of the reactor vessel cladding. The licensee shall verify that all flaws between the clad-to-base metal interface and three-eighths of the reactor vessel thickness from the interior surface are within the allowable values in ASME Code, Section XI, Table IWB–3510–1.

The licensee shall perform analyses to demonstrate that the reactor vessel will have a through-wall cracking frequency (TWCF) of less than 1×10^{-6} per reactor year if the ASME Code, Section XI volumetric examination indicates any of the following:

- The flaw density and size in the inspection volume exceed the limits in Tables 3-6 and 3-7;
- There are axial flaws that penetrate through the clad into the low alloy steel reactor vessel shell, at a depth equal to or greater than 0.075 inches in through-wall extent from the clad-to-base metal interface; or
- Any flaws between the clad-to-base metal interface and three-eighths of the vessel thickness exceed the size allowable in ASME Code, Section XI, Table IWB–3510–1.

If required, these analyses must address the effects on TWCF of the known sizes and locations of all flaws detected by the ASME Code, Section XI, Appendix VIII, Supplement 4 and Supplement 6 ultrasonic examination out to three-eighths of the vessel thickness from the inner surface, and may also take into account other reactor vessel-specific information, including fracture toughness information. The licensee shall also prepare and submit a neutron fluence map, projected to the date of license expiration, for the reactor vessel beltline clad-to-base metal interface and indexed in a manner that allows the determination of the neutron fluence at the location of the detected flaws.

4 PLANT-SPECIFIC RV MATERIAL PROPERTIES AND DIMENSIONS

Before performing the Alternate PTS evaluation, a review of the latest plant-specific beltline and extended beltline region material properties for the Palisades RV was performed. See Section 1 for the definition of the beltline and extended beltline regions.

Table 4-1 summarizes the best estimate copper, manganese, phosphorus, and nickel contents and $RT_{NDT(U)}$ values of the beltline and extended beltline materials for the Palisades RV. $RT_{NDT(U)}$ values for the Palisades RV plate materials were determined in accordance with the fracture toughness requirements in NUREG-0800, Revision 2, Branch Technical Position MTEB 5-3 (Reference 6); and the requirements of Subparagraph NB-2331 of Section III of the ASME B&PV Code (Reference 7). $RT_{NDT(U)}$ values for the weld materials are generic values for Linde 1092 and 124 weld fluxes per Reference 1.

The Palisades RV was fabricated by CE. Table 4-2 provides the dimensions of the Palisades RV necessary for the Alternate PTS Rule evaluation. This table includes wall thicknesses for the RV shell courses, RV inner diameter, and dimensions necessary to determine the location of the extended beltline region. Per Reference 8, the Palisades extended beltline region extends approximately 245 cm (96.5 inches) above and below the core midplane. The location of the extended beltline was then determined using these dimensions. Figure 4-1 shows the location of the beltline and extended beltline materials.

Table 4-1 Details of RT_{MAX-X} Calculation Inputs for Palisades

No.	Region and Component Description	Material Identification	Material Type	Material Heat No.	Cu[1] [wt%]	Ni[1] [wt%]	P [wt%]	Mn [wt%]	$RT_{NDT(u)}$ [°F][1]	$RT_{NDT(u)}$ Method
1	Upper Shell Plate	D-3802-1	SA-302BM	C-1279-2	0.21	0.48	0.016[2]	1.45[2]	10	Plant Specific
2	Upper Shell Plate	D-3802-2	SA-302BM	C-1308-2	0.19	0.52	0.019[2]	1.29[2]	19	Plant Specific
3	Upper Shell Plate	D-3802-3	SA-302BM	C-1281-1	0.25	0.57	0.018[2]	1.32[2]	10	Plant Specific
4	Intermediate Shell Plate	D-3803-1	SA-302BM	C-1279-3	0.24	0.50	0.011[2]	1.55[2]	-5	Plant Specific
5	Intermediate Shell Plate	D-3803-2	SA-302BM	A-0313-2	0.24	0.52	0.012[2]	1.43[2]	-30	Plant Specific
6	Intermediate Shell Plate	D-3803-3	SA-302BM	C-1279-1	0.24	0.50	0.010[2]	1.56[2]	-5	Plant Specific
7	Lower Shell Plate	D-3804-1	SA-302BM	C-1308-1	0.19	0.48	0.017[2]	1.22[2]	0	Plant Specific
8	Lower Shell Plate	D-3804-2	SA-302BM	C-1308-3	0.19	0.50	0.013[2]	1.27[2]	-30	Plant Specific
9	Lower Shell Plate	D-3804-3	SA-302BM	B-5294-2	0.12	0.55	0.010[2]	1.27[2]	-25	Plant Specific
10	Upper Shell Longitudinal Weld	1-112A	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic

Table 4-1 Details of RT_{MAX-X} Calculation Inputs for Palisades

No.	Region and Component Description	Material Identification	Material Type	Material Heat No.	Cu[1] [wt%]	Ni[1] [wt%]	P [wt%]	Mn [wt%]	$RT_{NDT(u)}$	
									[°F][1]	Method
11	Upper Shell Longitudinal Weld	1-112B	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
12	Upper Shell Longitudinal Weld	1-112C	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
13	Intermediate Shell Longitudinal Weld	2-112A	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
14	Intermediate Shell Longitudinal Weld	2-112B	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
15	Intermediate Shell Longitudinal Weld	2-112C	Linde 1092	W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
16	Lower Shell Longitudinal Weld	3-112A	Linde 1092	34B009	0.192	0.98	0.019[3]	1.63[3]	-56	Generic
				W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
17	Lower Shell Longitudinal Weld	3-112B	Linde 1092	34B009	0.192	0.98	0.019[3]	1.63[3]	-56	Generic
				W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
18	Lower Shell Longitudinal Weld	3-112C	Linde 1092	34B009	0.192	0.98	0.019[3]	1.63[3]	-56	Generic
				W5214	0.213	1.007	0.019[3]	1.63[3]	-56	Generic
19	Upper to Intermediate Shell Circ. Weld	8-112	Linde 1092	34B009	0.192	0.98	0.019[3]	1.63[3]	-56	Generic
20	Intermediate to Lower Shell Circ. Weld	9-112	Linde 124	27204	0.203	1.018	0.019[3]	1.63[3]	-56	Generic

Notes:

1. Material chemistry and initial RT_{NDT} obtained from WCAP-17341-NP (Reference 9) and WCAP-17403-NP (Reference 3).
2. Phosphorus and manganese content is from plant-specific certified material test reports (Reference 10).
3. Plant-specific data is not available for weld materials. Weld material phosphorus and manganese content are conservative estimates provided in Table 3-1.

Table 4-2 Palisades RV Dimensions

Parameter	Dimension (in.)	Reference No.
Inside Radius of RV (to clad/base metal interface)	86.35	9
Cladding Thickness	0.25	11
RV Thickness of Upper Shell Region (excluding cladding)	10.86	11
RV Thickness of Intermediate and Lower Shell Region (excluding cladding)	8.74[1]	11
Active Fuel Height	132	Plant-Specific Drawing
Upper to Intermediate Shell Circ. Weld (Distance downward from Flange)	133.72	11
Intermediate to Lower Shell Circ. Weld (Distance downward from Flange)	231.03	11
Bottom of Active Fuel (Distance downward from Flange)	280.4	Plant-Specific Drawing

Note:

1. The RV beltline thickness used in the ISI inspection was reported as 8.74 inches. This value is slightly less than the value (8.79 inches) used in previous reactor vessel integrity analyses. Note that the slight difference in thickness does not change the applicable PTS screening criteria (See Table 3-2).

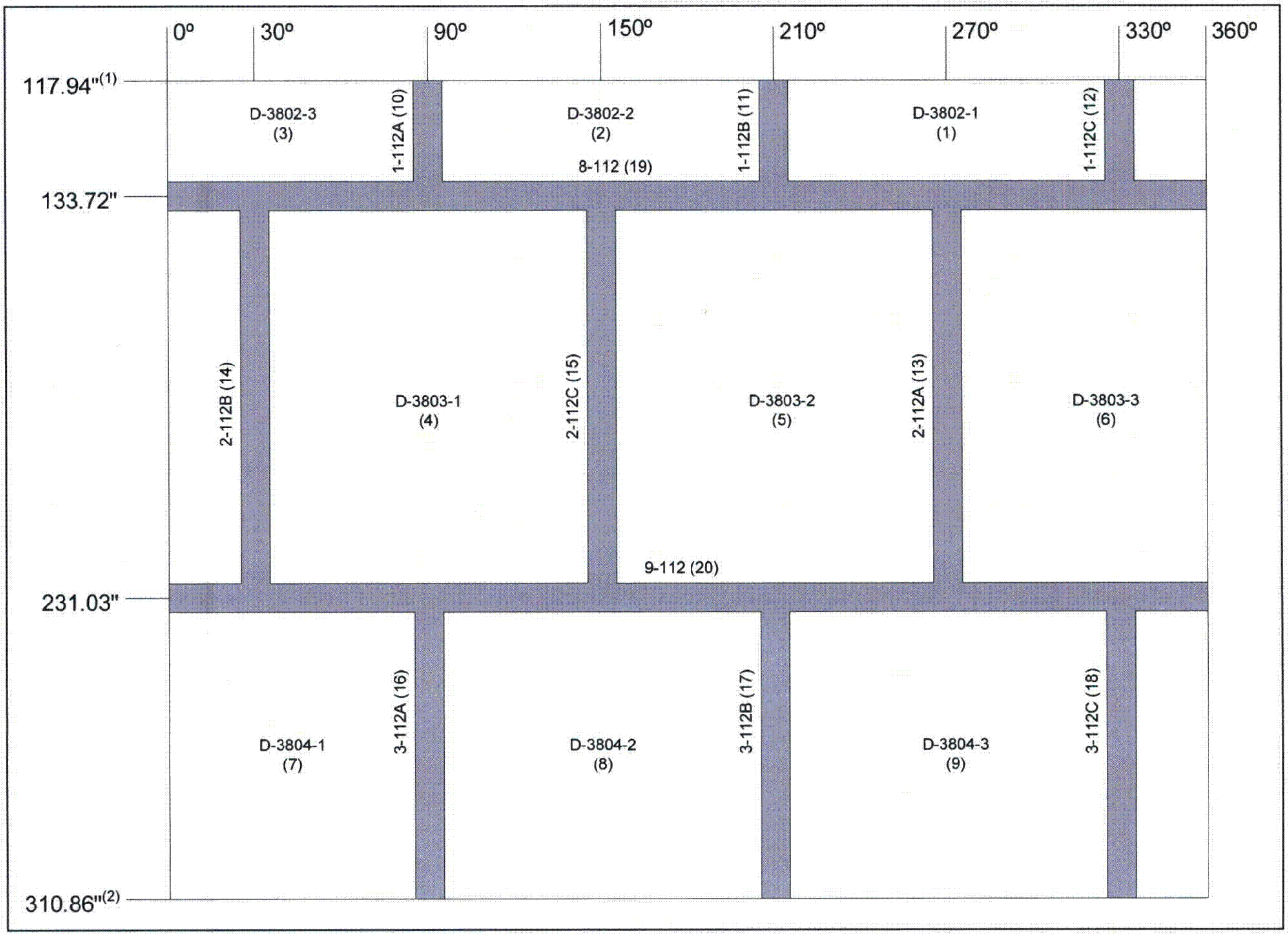

Figure 4-1 Identification and Location of Beltline Region Materials for the Palisades Reactor Vessel[3]

Notes:

1. 117.94" corresponds to the upper extent of the extended beltline region. See Table 4-2 for references used to determine this location.
2. 310.86" corresponds to the lower extent of the extended beltline region. See Table 4-2 for references used to determine this location.
3. Map is not drawn to scale. Numbers in parentheses correspond to "No." column in Table 4-1. Dimensions are measured downward from the RV flange surface.

5 RV NEUTRON FLUENCE VALUES AND COLD LEG TEMPERATURES

The projected maximum neutron fluence (E > 1.0 MeV) values at the clad-to-base metal interface of the Palisades RV for 42.1 effective full-power years (EFPY) are shown in Table 5-1 for the beltline and extended beltline materials. Palisades is projected to have a total operating time of approximately 42.1 EFPY at end-of-life extension (EOLE).

In addition to neutron fluence data, the Palisades reactor cold leg temperature under normal operating full-power conditions from the beginning of full-power operation through the last operating cycle is presented in Table 5-2. The effective full-power operation times for each cycle are also included in this table. These temperatures and cycle times will be used to determine the time-weighted average of the reactor cold leg temperature, T_C, used in Equation 6 of Reference 1. Data for this table was obtained from the latest PTS evaluation for Palisades (Reference 13).

Table 5-1 Maximum Neutron Fluence on the RV Clad-to-Base Metal Interface for Palisades at 42.1 EFPY

Region and Component Description	Maximum Fluence [10^{19} Neutron/cm^2, E > 1.0 MeV][(1)]
Upper Shell Plates	0.1529
Intermediate Shell Plates	3.429[(2)]
Lower Shell Plates	3.429[(2)]
Upper Shell Longitudinal Welds	0.09707
Intermediate Shell Longitudinal Welds	2.161
Lower Shell Longitudinal Welds	2.161
Upper to Intermediate Shell Circ. Weld	0.1529
Intermediate to Lower Shell Circ. Weld	3.429[(2)]

Notes:
1. Unless otherwise noted, the maximum fluence was obtained from WCAP-15353-Supplement 2-NP (Reference 8).
2. Maximum fluence obtained from Structural Integrity Associates (SIA) Report No. 1000915.401, Revision 1 (Reference 13).

Table 5-2 RV Cold Leg Temperature per Operating Cycle for Palisades				
Cycle	T_C (°F)	Cycle Time (EFPD)	Cycle Time (EFPY)	Cumulative Cycle Time (EFPY)
1	523	371.7	1.018	1.0
2	529	440.1	1.205	2.2
3	534	342.5	0.938	3.2
4	536	321.0	0.879	4.0
5	536	386.7	1.059	5.1
6	536	326.7	0.894	6.0
7	536	362.5	0.992	7.0
8	537	366.1	1.002	8.0
9	534	292.5	0.801	8.8
10	534	349.7	0.957	9.7
11	533	421.9	1.155	10.9
12	534	399.3	1.093	12.0
13	536	419.6	1.149	13.1
14	537	449.3	1.230	14.4
15	537	401.3	1.099	15.5
16	537	444.3	1.216	16.7
17	537	493.1	1.350	18.0
18	537	472	1.292	19.3
19	537	459.2	1.257	20.6
20	537	499.8	1.368	22.0
21	537	519.2	1.422	23.4
22	537	498.8	1.366	24.7

6 SURVEILLANCE CAPSULE DATA

There are three surveillance materials that are representative of the Palisades RV. The base metal surveillance material is a heat-specific match for upper shell plate D-3802-1 and intermediate shell plates D-3803-1 and D-3803-3 (Heat C-1279). The weld wire surveillance materials are heat-specific matches for the upper, intermediate, and lower shell longitudinal welds (Heat W5214) and the intermediate to lower shell circumferential weld (Heat 27204). The 30-foot-pound transition temperatures for each capsule were determined using measured Charpy V-notch data plotted using the requirements of 10 CFR part 50, Appendix H.

There have been four surveillance capsule analyses conducted for the Palisades base metal heat C-1279. As a result, there are seven surveillance data points measured in the longitudinal and transverse directions. There have been eleven surveillance capsule analyses conducted for weld wire heat W5214 within the domestic PWR fleet, including Palisades. Lastly, there have been five surveillance capsule analyses conducted for weld wire heat 27204 within the domestic PWR fleet, including Palisades.

Tables 6-1 through 6-3 contain surveillance data of the Palisades beltline and extended beltline materials required to perform the surveillance data evaluation. Tables 6-2 and 6-3 contain sister plant material data from H. B. Robinson Unit 2 (HB2), Indian Point Units 2 and 3 (IP2 and IP3), and Diablo Canyon Unit 1 (DC1). A majority of the data in these tables was obtained from the latest PTS evaluation (Reference 13). References for additional data are noted in the tables.

Table 6-1 Surveillance Data for Palisades Base Metal Heat C-1279

Plant	Capsule	Chemical Composition				Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	EFPY	Withdraw Cycle	Time-Averaged Coolant Temperature (°F)[3]	Measured ΔT_{30} Transition Temperature (°F)[3]	
		Cu [wt%][1]	Ni [wt%][1]	P [wt%][1]	Mn [wt%][1]					Longitudinal	Transverse
Palisades	A-240	0.25	0.53	0.011	1.55	4.09	2.2	2	526	205.0	205.0
Palisades	W-290	0.25	0.53	0.011	1.55	0.938	5.1	5	531	155.0	175.0
Palisades	W-110	0.25	0.53	0.011	1.55	1.64	9.7	10	533	180.0	[2]
Palisades	W-100	0.25	0.53	0.011	1.55	2.09	16.7	16[1]	534	159.1	142.5

Notes:

1. Data obtained from Palisades W-100 capsule analysis (Reference 14).
2. No reported value for Transverse ΔT_{30} (Reference 13).
3. Values are reported to the precision level calculated in Reference 13.

Table 6-2 Surveillance Data for Palisades Weld Wire Heat W5214

Plant	Capsule	Chemical Composition				Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	EFPY	Withdraw Cycle	Time-Averaged Coolant Temperature (°F)[7]	Measured ΔT_{30} Transition Temperature (°F)[7]
		Cu [wt%]	Ni [wt%]	P [wt%]	Mn [wt%]					
Palisades	SA-60-1[6]	0.307	1.045	0.009[1]	1.161[1]	1.50	2.2[6]	13[6]	535.0	259
Palisades	SA-240-1[6]	0.307	1.045	0.009[1]	1.161[1]	2.38	3.5[6]	14[6]	535.7	280.1
HB2	T	0.34	0.66	0.021[2]	0.98[2]	3.87	7.27[2]	8[2]	547	289.1
HB2	V	0.34	0.66	0.021[2]	0.98[2]	0.530	3.18[2]	3[2]	547	208.8
HB2	X	0.34	0.66	0.021[2]	0.98[2]	4.49	20.39[2]	20[2]	547	265.6
IP2	V	0.20	1.03	0.019[3]	1.63[3]	0.492	8.622[5]	8[5]	524	197.5
IP2	Y	0.20	1.03	0.019[3]	1.63[3]	0.455	2.337[5]	2B[5]	529.1	193.9
IP3	T	0.16	1.12	0.019[4]	1.18[4]	0.263	1.342[5]	1A[5]	539.4	149.8
IP3	Y	0.16	1.12	0.019[4]	1.18[4]	0.692	3.3[5]	3[5]	539.5	171.1
IP3	Z	0.16	1.12	0.019[4]	1.18[4]	1.04	5.566[5]	5[5]	538.9	228.3
IP3	X	0.16	1.12	0.019[4]	1.18[4]	0.874	15.601[5]	12B[5]	539.7	192.5

Notes:

1. Phosphorous and manganese content obtained from Palisades Capsule SA-240-1 analysis (Reference 15).
2. Surveillance material data obtained from H. B. Robinson Capsule X analysis (Reference 16).
3. Data not available. Conservative estimate per Reference 1.
4. Phosphorous and manganese content obtained from Indian Point Unit 3 Capsule X analysis (Reference 17).
5. Surveillance capsule information obtained from SIA Report No. 0901132.401 (Reference 18).
6. Palisades Capsules SA-60-1 and SA-240-1 were installed at the end of cycle 11 in the RV. Capsule-accrued EFPY values were calculated using EFPD data provided in Table 5-2.
7. Values are reported to the precision level calculated in Reference 13.

Table 6-3 Surveillance Data for Palisades Weld Wire Heat 27204

Plant	Capsule	Chemical Composition				Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	EFPY	Withdraw Cycle	Time-Averaged Coolant Temperature (°F)(4)	Measured ΔT_{30} Transition Temperature (°F)(4)
		Cu [wt%]	Ni [wt%]	P [wt%]	Mn [wt%]					
DC1	Y	0.198	0.999	0.016(1)	1.360(1)	1.05	5.87(1)	5(1)	542	232.59
DC1	S	0.198	0.999	0.016(1)	1.360(1)	0.284	1.25(1)	1(1)	544	110.79
Palisades	SA-240-1(3)	0.194	1.067	0.009(2)	1.281(2)	2.38	3.5(3)	14(3)	535.7	267.8
Palisades	SA-60-1(3)	0.194	1.067	0.009(2)	1.281(2)	1.50	2.2(3)	13(3)	535.0	253.1
DC1	V	0.198	0.999	0.016(1)	1.360(1)	1.37	14.27(1)	11(1)	541.5	201.07

Notes:

1. Surveillance material data obtained from Diablo Canyon Unit 1 Capsule V analysis (Reference 19)
2. Phosphorous and manganese content obtained from Palisades Capsule SA-240-1 analysis (Reference 15).
3. Palisades Capsules SA-60-1 and SA-240-1 were installed at the end of cycle 11 in the RV. Capsule-accrued EFPY values were calculated using EFPD data provided in Table 5-2.
4. Values are reported to the precision level used in Reference 13.

7 INSERVICE INSPECTION DATA

Three 10-year ISIs have been performed for the Palisades RV welds. The most recent ISI (Interval 3, Period 3) was conducted in accordance with the ASME Code, Section XI, Appendix VIII, 2001 Edition with the 2003 Addenda (Reference 5) as modified by 10 CFR 50.55a(b)(2)(xiv, xv, and xvi). Examinations of the Category B-A welds were governed by the ASME Code Section XI, 1989 Edition, no addenda. An ASME Section XI, Performance Demonstration Initiative (PDI) qualified supplement 4 examination was completed using a dual 45 degree ultrasonic longitudinal wave transducer operated at a center frequency of 3.6 MHz. The contact examination from the reactor vessel inside diameter (ID) uses water as a couplant. This PDI technique is effective in detection of planar flaws oriented axially or circumferentially in the reactor vessel.

All of the recorded indications were assessed in accordance with the criteria in the ASME Code Section XI, 1989 Edition, no addenda, Article IWB-3000, Paragraph IWB-3500; and were found to be within the allowable limits specified with no further evaluation required. Tables 7-1 and 7-2 contain data on the welds and the characteristics of any indications within the beltline and extended beltline regions of the RV obtained from the latest ISI report (Reference 11).

A supplemental eddy current examination was performed at the location of ultrasonic identified flaws reported within 1.0" of the reactor vessel ID surface to validate that these flaws do not open to the vessel inside surface. The eddy current probe for this inspection was the Plus-Point coil operated at 250 KHz in the Driver/Pick-up mode. This technique is normally used in reactor vessel nozzle examinations to detect and characterize surface flaws in the clad material. This examination was conducted to detect flaws oriented axially or circumferentially in the reactor vessel. No surface indications were revealed by the eddy current examinations in the locations where ultrasonic flaws were reported.

Table 7-1 Reactor Vessel ISI History for Palisades Beltline and Extended Beltline Materials

Weld ISI No.	Region and Component Description	Date Last Inspected	Number of Recordable Indications	Number of Reportable Flaws[1]
1-112A	Upper Shell Longitudinal Weld at 90°	2014	6	None
1-112B	Upper Shell Longitudinal Weld at 210°	2014	4	None
1-112C	Upper Shell Longitudinal Weld at 330°	2014	3	None
2-112A	Intermediate Shell Longitudinal Weld at 270°	2014	2	None
2-112B	Intermediate Shell Longitudinal Weld at 30°	2014	18	None
2-112C	Intermediate Shell Longitudinal Weld at 150°	2014	No Indications	None
3-112A	Lower Shell Longitudinal Weld at 90°	2014	No Indications	None
3-112B	Lower Shell Longitudinal Weld at 210°	2014	1	None
3-112C	Lower Shell Longitudinal Weld at 330°	2014	1	None
8-112	Upper to Intermediate Shell Circ. Weld	2014	1	None
9-112	Intermediate to Lower Shell Circ. Weld	2014	6	None

Note:
1. Flaws that are reportable are those that exceed the ASME Section XI Table IWB-3510-1 acceptance standards.

Weld ISI No.	Weld Type (A or C)(1)	Weld Width (in.)	Indication No.	UT Beam Direction(1)	t (in.)	L (in.)	S (in.)	2a (in.)	a (in.)	Table IWB-3510-1 Disposition
1-112A	A	1.44	1	CW	10.86	0.60	0.512	0.125	0.063	Allowable
			2	CW	10.86	0.60	1.372	0.125	0.063	Allowable
			3	CW	10.86	0.60	0.835	0.125	0.0625	Allowable
			4	CCW	10.86	1.50	10.11	0.417	0.2085	Allowable
			5	CCW	10.86	2.00	10.86	(2)	0.125	Allowable
			6	DN	10.86	1.60	0.103	0.176	0.088	Allowable
1-112B	A	1.44	1	CCW	10.86	0.6	0.08	0.08	0.040	Allowable
			2	CW	10.86	0.6	0.50	0.10	0.050	Allowable
			3	CW	10.86	21.75	2.50	0.41	0.203	Allowable
			4	CCW	10.86	1.75	3.04	0.16	0.081	Allowable
1-112C	A	1.44	1	UP	10.86	3.0	9.70	0.125	0.063	Allowable
			2	CCW	10.86	1.6	0.36	0.118	0.059	Allowable
			3	CW	10.86	2.25	2.74	0.081	0.041	Allowable
2-112A	A	1.44	1	CW	8.74	1.1	0.34	0.14	0.07	Allowable
			2	CW	8.74	0.6	0.34	0.13	0.06	Allowable
2-112B	A	1.44	1	CCW	8.74	0.75	3.23	0.26	0.13	Allowable
			2	CCW	8.74	0.6	0.30	0.06	0.03	Allowable
			3	CCW	8.74	0.6	0.24	0.06	0.03	Allowable
			4	CCW	8.74	0.6	0.36	0.06	0.03	Allowable
			5	CCW	8.74	0.6	0.34	0.06	0.03	Allowable
			6	CCW	8.74	0.6	0.24	0.06	0.03	Allowable
			7	CCW	8.74	0.6	0.22	0.06	0.03	Allowable
			8	CCW	8.74	0.6	0.42	0.06	0.03	Allowable
			9	CCW	8.74	0.6	0.44	0.06	0.03	Allowable
			10	CCW	8.74	0.6	0.44	0.06	0.03	Allowable
			11	CCW	8.74	0.6	0.42	0.06	0.03	Allowable
			12	CCW	8.74	0.6	0.28	0.06	0.03	Allowable
			13	CCW	8.74	0.6	0.32	0.06	0.03	Allowable
			14	CCW	8.74	0.6	0.26	0.06	0.03	Allowable
			15	CCW	8.74	0.6	0.32	0.06	0.03	Allowable
			16	CCW	8.74	0.6	0.34	0.06	0.03	Allowable
			17	CCW	8.74	0.6	0.30	0.06	0.03	Allowable
			18	CCW	8.74	0.6	0.22	0.06	0.03	Allowable
3-112B	A	1.44	1	CCW	8.74	1.25	3.69	0.37	0.185	Allowable
3-112C	A	1.44	1	CCW	8.74	1.6	0.40	0.26	0.129	Allowable
8-112	C	1.31	1	CCW	8.74	0.6	0.16	0.20	0.10	Allowable

Table 7-2 ISI Information for Reactor Vessel Beltline and Extended Beltline Flaws for Palisades

Table 7-2 ISI Information for Reactor Vessel Beltline and Extended Beltline Flaws for Palisades										
Weld ISI No.	Weld Type (A or C)(1)	Weld Width (in.)	Indication No.	UT Beam Direction(1)	t (in.)	L (in.)	S (in.)	2a (in.)	a (in.)	Table IWB-3510-1 Disposition
9-112	C	1.31	1	UP	8.74	5.1	0.037	0.125	0.063	Allowable
			2	UP	8.74	12.6	0.213	0.125	0.063	Allowable
			3	UP	8.74	14.6	0.350	0.125	0.0625	Allowable
			4	UP	8.74	3.1	0.056	0.125	0.0625	Allowable
			5	UP	8.74	1.6	0.095	0.125	0.0625	Allowable
			6	UP	8.74	5.6	0.174	0.125	0.0625	Allowable

Notes:

1. A = Axial, C = Circumferential, CW = Clockwise, CCW = Counterclockwise, UT = Ultrasonic
2. Indication was reported as an outside surface indication in WesDyne ISI Report (Reference 11).

8 DETERMINATION OF RT_{MAX-X} VALUES FOR ALL BELTLINE AND EXTENDED BELTLINE REGION MATERIALS

8.1 CALCULATION OF RT_{MAX-X} VALUES

Using the Alternate PTS Rule methodology described in Section 3.1, RT_{MAX-X} values were generated for the beltline and extended beltline region materials of the Palisades RV for fluence values at the EOLE (42.1 EFPY). These values were calculated using RV beltline and extended beltline material copper, nickel, phosphorus, and manganese content, unirradiated RT_{NDT}, projected EOLE neutron fluence values, and time-weighted averaged reactor cold-leg temperature provided in Sections 4 and 5.

The Palisades RV wall thickness transitions between the intermediate and upper shell courses. The upper shell course has a total wall thickness (including the cladding) of 11.11 inches; whereas, the lower and intermediate shell courses have a total wall thickness of 8.99 inches. Since the RT_{MAX-X} limits vary depending on vessel wall thickness per 10 CFR 50.61a (Reference 1), the Palisades RT_{MAX-X} values were determined for the two vessel wall thicknesses within the beltline and extended beltline regions of the RV and compared to the applicable PTS screening criteria.

Tables 8-1 through 8-3 summarize the results of Equations 1 through 7 to calculate RT_{MAX-X} for the Palisades axial welds, plates, and circumferential welds. The calculated RT_{MAX-X} values and applicable PTS screening criteria are provided in Table 8-4.

Table 8-1 RT_{MAX-AW} Calculation Results for Palisades at 42.1 EFPY

Weld Group	RV Location	Material Heat No.	Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	ΔT_{30} (°F)	$RT_{NDT(u)}$ (°F)	Total RT_{NDT} (°F)	$RT_{MAX-AW(i)}$ (°F)
Upper Shell Longitudinal Weld 1-112A	Upper Shell Longitudinal Weld	W5214	0.09707	154.4	-56	98.4	135.2
	Upper Shell Plate	C-1308-2	0.09707	95.6	19	114.6	
	Upper Shell Plate	C-1281-1	0.09707	125.2	10	135.2	
Upper Shell Longitudinal Weld 1-112B	Upper Shell Longitudinal Weld	W5214	0.09707	154.4	-56	98.4	114.6
	Upper Shell Plate	C-1279-2	0.09707	99.8	10	109.8	
	Upper Shell Plate	C-1308-2	0.09707	95.6	19	114.6	
Upper Shell Longitudinal Weld 1-112C	Upper Shell Longitudinal Weld	W5214	0.09707	154.4	-56	98.4	135.2
	Upper Shell Plate	C-1279-2	0.09707	99.8	10	109.8	
	Upper Shell Plate	C-1281-1	0.09707	125.2	10	135.2	
Intermediate Shell Longitudinal Weld 2-112A	Intermediate Shell Longitudinal Weld	W5214	2.161	293.0	-56	237.0	237.0
	Intermediate Shell Plate	A-0313-2	2.161	191.4	-30	161.4	
	Intermediate Shell Plate	C-1279-1	2.161	187.4	-5	182.4	
Intermediate Shell Longitudinal Weld 2-112B	Intermediate Shell Longitudinal Weld	W5214	2.161	293.0	-56	237.0	237.0
	Intermediate Shell Plate	C-1279-3	2.161	189.0	-5	184.0	
	Intermediate Shell Plate	C-1279-1	2.161	187.4	-5	182.4	

Table 8-1 RT_{MAX-AW} Calculation Results for Palisades at 42.1 EFPY

Weld Group	RV Location	Material Heat No.	Fluence (x10^{19} n/cm^2, E > 1.0MeV)	ΔT_{30} (°F)	$RT_{NDT(u)}$ (°F)	Total RT_{NDT} (°F)	$RT_{MAX-AW(i)}$ (°F)
Intermediate Shell Longitudinal Weld 2-112C	Intermediate Shell Longitudinal Weld	W5214	2.161	293.0	-56	237.0	237.0
	Intermediate Shell Plate	C-1279-3	2.161	189.0	-5	184.0	
	Intermediate Shell Plate	A-0313-2	2.161	191.4	-30	161.4	
Lower Shell Longitudinal Weld 3-112A	Lower Shell Longitudinal Weld	34B009	2.161	268.7	-56	212.7	237.0
		W5214	2.161	293.0	-56	237.0	
	Lower Shell Plate	C-1308-1	2.161	165.7	0	165.7	
	Lower Shell Plate	C-1308-3	2.161	164.0	-30	134.0	
Lower Shell Longitudinal Weld 3-112B	Lower Shell Longitudinal Weld	34B009	2.161	268.7	-56	212.7	237.0
		W5214	2.161	293.0	-56	237.0	
	Lower Shell Plate	C-1308-3	2.161	164.0	-30	134.0	
	Lower Shell Plate	B-5294-2	2.161	125.3	-25	100.3	
Lower Shell Longitudinal Weld 3-112C	Lower Shell Longitudinal Weld	34B009	2.161	268.7	-56	212.7	237.0
		W5214	2.161	293.0	-56	237.0	
	Lower Shell Plate	C-1308-1	2.161	165.7	0	165.7	
	Lower Shell Plate	B-5294-2	2.161	125.3	-25	100.3	

Table 8-2 RT_{MAX-PL} Calculation Results for Palisades at 42.1 EFPY

RV Location	Material Heat No.	Fluence (x10^{19} n/cm^2, E > 1.0MeV)	ΔT_{30} (°F)	$RT_{NDT(u)}$ (°F)	Total RT_{NDT} (°F)	$RT_{MAX-PL(i)}$ (°F)
Upper Shell Plate D-3802-1	C-1279-2	0.1529	112.0	10	122.0	149.8
Upper Shell Plate D-3802-2	C-1308-2	0.1529	108.2	19	127.2	
Upper Shell Plate D-3802-3	C-1281-1	0.1529	139.8	10	149.8	
Intermediate Shell Plate D-3803-1	C-1279-3	3.429	204.4	-5	199.4	199.4
Intermediate Shell Plate D-3803-2	A-0313-2	3.429	206.5	-30	176.5	
Intermediate Shell Plate D-3803-3	C-1279-1	3.429	202.6	-5	197.6	
Lower Shell Plate D-3804-1	C-1308-1	3.429	180.6	0	180.6	
Lower Shell Plate D-3804-2	C-1308-3	3.429	178.7	-30	148.7	
Lower Shell Plate D-3804-3	B-5294-2	3.429	139.5	-25	114.5	

Table 8-3 RT_{MAX-CW} Calculation Results for Palisades at 42.1 EFPY

Weld Group	RV Location	Material Heat No.	Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	ΔT_{30} (°F)	$RT_{NDT(u)}$ (°F)	Total RT_{NDT} (°F)	$RT_{MAX-CW(i)}$ (°F)
Upper to Intermediate Shell Circ. Weld 8-112	Upper to Intermediate Shell Circ. Weld	34B009	0.1529	163.2	-56	107.2	149.8
	Upper Shell Plate	C-1279-2	0.1529	112.0	10	122.0	
	Upper Shell Plate	C-1308-2	0.1529	108.2	19	127.2	
	Upper Shell Plate	C-1281-1	0.1529	139.8	10	149.8	
	Intermediate Shell Plate	C-1279-3	0.1529	123.0	-5	118.0	
	Intermediate Shell Plate	A-0313-2	0.1529	125.3	-30	95.3	
	Intermediate Shell Plate	C-1279-1	0.1529	122.1	-5	117.1	
Intermediate to Lower Shell Circ. Weld 9-112	Intermediate to Lower Shell Circ. Weld	27204	3.429	303.6	-56	247.6	247.6
	Intermediate Shell Plate	C-1279-3	3.429	204.4	-5	199.4	
	Intermediate Shell Plate	A-0313-2	3.429	206.5	-30	176.5	
	Intermediate Shell Plate	C-1279-1	3.429	202.6	-5	197.6	
	Lower Shell Plate	C-1308-1	3.429	180.6	0	180.6	
	Lower Shell Plate	C-1308-3	3.429	178.7	-30	148.7	
	Lower Shell Plate	B-5294-2	3.429	139.5	-25	114.5	

Table 8-4 RT_{MAX-X} values for Palisades at 42.1 EFPY

	Lower and Intermediate Shell Region ($T_{WALL} \leq 9.5$ in.)[1]		Upper Shell Region (10.5 in. < $T_{WALL} \leq 11.5$ in.)[1]	
	Palisades	10 CFR 50.61a Screening Criteria	Palisades	10 CFR 50.61a Screening Criteria
Axial Weld—RT_{MAX-AW} (°F)	237.0	269	135.2	222
Plate—RT_{MAX-PL} (°F)	199.4	356	149.8	293
Axial Weld and Plate—RT_{MAX-AW} + RT_{MAX-PL} (°F)	436.4	538	285.0	445
Circumferential Weld—RT_{MAX-CW} (°F)	247.6	312	149.8	269

Note:
1. T_{WALL} is the RV wall thickness including the cladding.

The RT_{MAX-X} values calculated for Palisades are less than PTS screening criteria and therefore meet this requirement of the Alternate PTS Rule.

8.2 SURVEILLANCE CAPSULE DATA STATISTICAL CHECKS

As discussed in Section 3.2, the Alternate PTS Rule (Reference 1) requires that surveillance data that could affect the calculation of ΔT_{30} be evaluated. This requirement is only applicable for materials for which three (3) or more points of surveillance data exist at three (3) or more unique fluence values.

The Palisades and sister plant surveillance materials, along with their calculated values of ΔT_{30}, can be seen in Table 8-5. This table includes a list of the tested and analyzed capsules for each material.

Table 8-5 Surveillance Capsule Materials for Palisades

No. (1)	Region and Component Description	Material Identification (Heat No.)	Plant	Capsule	Direction	Fluence ($x10^{19}$ n/cm^2, E > 1.0MeV)	Calculated ΔT_{30} (°F)(2)
1 4 6	Upper and Intermediate Shell Plates	D-3802-1 D-3803-1 D-3803-3 (C-1279)	Palisades	A-240	Longitudinal	4.09	233.9
			Palisades	W-290	Longitudinal	0.938	163.5
			Palisades	W-110	Longitudinal	1.64	180.4
			Palisades	W-100	Longitudinal	2.09	189.0
			Palisades	A-240	Transverse	4.09	233.9
			Palisades	W-290	Transverse	0.938	163.5
			Palisades	W-100	Transverse	2.09	189.0
10 11 12 13 14 15 16 17 18	Surveillance Program Weld Metal	1-112A, B, & C 2-112A, B, & C 3-112A, B, & C (W5214)	Palisades	SA-60-1	N/A	1.50	322.7
			Palisades	SA-240-1	N/A	2.38	340.8
			HB2	T	N/A	3.87	258.7
			HB2	V	N/A	0.530	200.3
			HB2	X	N/A	4.49	263.6
			IP2	V	N/A	0.492	215.0
			IP2	Y	N/A	0.455	188.5
			IP3	T	N/A	0.263	107.2
			IP3	Y	N/A	0.692	173.0
			IP3	Z	N/A	1.04	195.4
			IP3	X	N/A	0.874	197.7
20	Surveillance Program Weld Metal	9-112 (27204)	DC1	Y	N/A	1.05	213.7
			DC1	S	N/A	0.284	133.9
			Palisades	SA-240-1	N/A	2.38	247.2
			Palisades	SA-60-1	N/A	1.50	229.0
			DC1	V	N/A	1.37	229.2

Note:

1. Numbers listed correspond to the item numbers from Table 4-1
2. Values calculated using Alternate PTS Rule correlation as described in Sections 3.1 and 3.2

All of the materials listed have at least three data points at three or more different neutron fluences; therefore, it needed to be determined if the surveillance data showed a significantly different trend than the embrittlement model predicts per the Alternate PTS Rule (Reference 1). Using the methodology described in Section 3.2, a Mean Deviation Test, a Slope Deviation Test, and an Outlier Deviation Test were conducted for each surveillance material. The inputs for the surveillance data evaluations, including the measured values of ΔT_{30}, are provided in Tables 6-1 through 6-3 for the three surveillance materials. The results of the evaluations are shown in Tables 8-6, 8-7, and 8-8.

Table 8-6 Surveillance Data Evaluation for Palisades Base Metal Heat C-1279

Plant	Capsule	Direction	Log of Fluence	Residual "r"	$(x - x_{avg})^2$	r* (r/sigma)
Palisades	A-240	Longitudinal	19.61	-28.9	0.104	-1.37
Palisades	W-290	Longitudinal	18.97	-8.5	0.100	-0.40
Palisades	W-110	Longitudinal	19.21	-0.4	0.005	-0.02
Palisades	W-100	Longitudinal	19.32	-29.9	0.001	-1.41
Palisades	A-240	Transverse	19.61	-28.9	0.104	-1.37
Palisades	W-290	Transverse	18.97	11.5	0.100	0.54
Palisades	W-100	Transverse	19.32	-46.5	0.001	-2.19

Mean Deviation Test		Slope Deviation Test		Outlier Deviation Test	
Standard Deviation (sigma)	21.2	Slope (m)	-52.84	Largest r*	0.54
Mean Deviation	-18.8	Standard Error of Fit	16.13	Largest allowable r*	2.98
Maximum Mean Residual	18.7	Standard Error of Slope	24.99	Pass/Fail?	Pass
Pass/Fail?	Pass	T-Statistic	-2.11	Second largest r*	-0.02
		Critical T-Statistic	3.36	Second largest allowable r*	2.00
		Pass/Fail?	Pass	Pass/Fail?	Pass

Table 8-7 Surveillance Data Evaluation for Palisades Weld Wire Heat W5214						
Plant	Capsule	Direction	Log of Fluence	Residual "r"	$(x - x_{avg})^2$	r* (r/sigma)
Palisades	SA-60-1	N/A	19.18	-63.7	0.0283	-2.41
Palisades	SA-240-1	N/A	19.38	-60.7	0.1360	-2.30
HB2	T	N/A	19.59	30.4	0.3363	1.15
HB2	V	N/A	18.72	8.5	0.0804	0.32
HB2	X	N/A	19.65	2.0	0.4153	0.08
IP2	V	N/A	18.69	-17.5	0.0997	-0.66
IP2	Y	N/A	18.66	5.4	0.1223	0.21
IP3	T	N/A	18.42	42.6	0.3455	1.61
IP3	Y	N/A	18.84	-1.9	0.0281	-0.07
IP3	Z	N/A	19.02	32.9	0.0001	1.24
IP3	X	N/A	18.94	-5.2	0.0044	-0.20

Mean Deviation Test		Slope Deviation Test		Outlier Deviation Test	
Standard Deviation (sigma)	26.4	Slope (m)	-23.22	Largest r*	1.61
Mean Deviation	-2.5	Standard Error of Fit	35.09	Largest allowable r*	3.12
Maximum Mean Residual	18.5	Standard Error of Slope	27.77	Pass/Fail?	Pass
Pass/Fail?	Pass	T-Statistic	-0.84	Second largest r*	1.24
		Critical T-Statistic	2.82	Second largest allowable r*	2.19
		Pass/Fail?	Pass	Pass/Fail?	Pass

Table 8-8 Surveillance Data Evaluation for Palisades Weld Wire Heat 27204

Plant	Capsule	Direction	Log of Fluence	Residual "r"	$(x - x_{avg})^2$	r* (r/sigma)
DC1	Y	N/A	19.02	18.9	0.0001	0.72
DC1	S	N/A	18.45	-23.1	0.3358	-0.87
Palisades	SA-240-1	N/A	19.38	20.6	0.1182	0.78
Palisades	SA-60-1	N/A	19.18	24.1	0.0205	0.91
DC1	V	N/A	19.14	-28.2	0.0108	-1.07

Mean Deviation Test	
Standard Deviation (sigma)	26.4
Mean Deviation	2.5
Maximum Mean Residual	27.5
Pass/Fail?	Pass

Slope Deviation Test	
Slope (m)	42.78
Standard Error of Fit	24.30
Standard Error of Slope	34.87
T-Statistic	1.23
Critical T-Statistic	4.54
Pass/Fail?	Pass

Outlier Deviation Test	
Largest r*	0.91
Largest allowable r*	2.88
Pass/Fail?	Pass
Second largest r*	0.78
Second largest allowable r*	1.84
Pass/Fail?	Pass

As shown in Tables 8-6 through 8-8, the surveillance results for the plate and weld surveillance materials satisfy the criteria in the Alternate PTS Rule for all three tests. Therefore, the use of Equations (5) to (7) in the Alternate PTS Rule (Reference 1) for calculation of ΔT_{30} is acceptable for Palisades.

8.3 REACTOR VESSEL BELTLINE ISI DATA EVALUATION

Per the requirements of Section 3.3, the results of the latest ISI of the Palisades RV were analyzed in detail to ensure that the recorded indications met the acceptance criteria. The RV ISI data specified in Section 7 indicates that the Category B-A examinations of the Palisades RV beltline and extended beltline region welds have been performed to ASME Section XI, Appendix VIII requirements. At least one inspection has been performed on each weld per Code requirements. Inspection coverage of the welds within the beltline region has been greater than 90%. All indications found in the beltline and extended beltline were reported to be either subsurface or located on the outside surface. In accordance with the Alternate PTS rule, examinations were performed during the latest Palisades RV ISI in locations where flaws were detected within the first 1.0" from the vessel inside diameter to verify that they are not open to the inside surface. Automated eddy current and ultrasonic examination techniques capable of detecting and characterizing service induced cracking of the reactor vessel cladding were used for the inspection of these flaws. No inside surface flaws were found in the beltline or extended beltline welds.

After reviewing the data from the latest ISI (Reference 11), 42 indications with the potential to be located within the beltline and extended beltline regions of the Palisades RV were recorded. Thirty of these indications were within the 1.0×10^{17} n/cm^2 neutron fluence region, and therefore within the RV beltline and extended beltline. Twenty-nine of these indications also fall within the inner 3/8th of the RV thickness and are allowable per Table IWB-3510-1 of Section XI of the ASME Code (Reference 5).

Twenty-eight of the indications fall within the inner 1 inch or 10 percent thickness of the RV, whichever is greater; therefore, further evaluation is required to confirm that they satisfy the flaw requirements provided in Section 3.3. These indications are shaded in gray in Table 8-9 and shown in Figure 8-1. These flaws are all located either adjacent to or within the weld fusion lines. However, for the purposes of this evaluation, all twenty-eight indications are considered to be in the plate material and are evaluated against the more conservative plate flaw limits.

In order to scale the number of allowable weld flaws per the Alternate PTS Rule, the total inspected plate area and weld length within the beltline and extended beltline regions of the RV were calculated as shown in Table 8-10. The acceptance criteria for plate and weld flaws based on Palisades RV dimensions are shown in Tables 8-11 and 8-12, respectively. After identifying the size, location, and orientation of the indications, it was determined that they satisfy the Alternate PTS Rule requirements provided in Section 3.3 because the number of actual flaws is less than the number allowable for all flaw size increments.

Note that RV TWCF calculations are not needed due to the following factors:

- The flaw density and size in the inspection volume are less than the limits in Tables 8-11 and 8-12;
- There are no axial flaws that penetrate through the clad into the low alloy steel reactor vessel shell, at a depth equal to or greater than 0.075 inches in through-wall extent from the clad-to-base metal interface; and
- All flaws between the clad-to-base metal interface and three-eighths of the vessel thickness meet the size allowable in ASME Code, Section XI, Table IWB–3510–1.

Table 8-9 Reactor Vessel ISI Evaluation for Potential Beltline and Extended Beltline Flaws for Palisades

Weld ISI No.	Indication No.	TWE(1) (in.)	Location(2) (Plate/Weld)	Within Beltline or Extended Beltline?	Inner (3/8)t?	Inner (1/10)t or 1"?	Flaw Orientation	Flaw Limits Evaluation Required?
1-112A	1	0.125	Plate	No	Yes	Yes	Axial	No
	2	0.125	Plate	No	Yes	No	Axial	No
	3	0.125	Plate	No	Yes	Yes	Axial	No
	4	0.417	Plate	No	No	No	Axial	No
	5	0.125	Plate	No	No	No	Axial	No
	6	0.176	Plate	Yes	Yes	Yes	Circ.	Yes
1-112B	1	0.08	Plate	No	Yes	Yes	Axial	No
	2	0.10	Plate	No	Yes	Yes	Axial	No
	3	0.41	Plate	No	Yes	No	Axial	No
	4	0.16	Plate	No	Yes	No	Axial	No
1-112C	1	0.125	Plate	No	No	No	Circ.	No
	2	0.118	Plate	No	Yes	Yes	Axial	No
	3	0.081	Plate	No	Yes	No	Axial	No
2-112A	1	0.14	Plate	Yes	Yes	Yes	Axial	Yes
	2	0.13	Plate	Yes	Yes	Yes	Axial	Yes

Table 8-9 Reactor Vessel ISI Evaluation for Potential Beltline and Extended Beltline Flaws for Palisades

Weld ISI No.	Indication No.	TWE(1) (in.)	Location(2) (Plate/Weld)	Within Beltline or Extended Beltline?	Inner (3/8)t?	Inner (1/10)t or 1"?	Flaw Orientation	Flaw Limits Evaluation Required?
2-112B	1	0.26	Plate	Yes	Yes	No	Axial	No
	2	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	3	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	4	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	5	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	6	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	7	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	8	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	9	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	10	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	11	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	12	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	13	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	14	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	15	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	16	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	17	0.06	Plate	Yes	Yes	Yes	Axial	Yes
	18	0.06	Plate	Yes	Yes	Yes	Axial	Yes
3-112B	1	0.37	Plate	Yes	No	No	Axial	No
3-112C	1	0.26	Plate	Yes	Yes	Yes	Axial	Yes
8-112	1	0.20	Plate	Yes	Yes	Yes	Axial	Yes
9-112	1	0.125	Plate	Yes	Yes	Yes	Circ.	Yes
	2	0.125	Plate	Yes	Yes	Yes	Circ.	Yes
	3	0.125	Plate	Yes	Yes	Yes	Circ.	Yes
	4	0.125	Plate	Yes	Yes	Yes	Circ.	Yes
	5	0.125	Plate	Yes	Yes	Yes	Circ.	Yes
	6	0.125	Plate	Yes	Yes	Yes	Circ.	Yes

Note:

1. TWE is the same as the dimension "2a" for subsurface indications or "a" for surface indications from Table 7-2.
2. For the purposes of this evaluation, all indications were considered to be in the plate material and are be evaluated against the more conservative plate flaw limits.

Table 8-10 Inspection Length and Area for Palisades	
Inside Diameter of RV (to clad surface)	172.2 in.
Cladding Thickness	0.25 in.
Inside Diameter of Weld Inspection Volume	172.7 in.
RV Thickness of Upper Shell Region	10.86 in.
RV Thickness of Intermediate and Lower Shell Region	8.74 in.
Number of Upper Shell Axial Welds	3
Number of Intermediate Shell Axial Welds	3
Number of Lower Shell Axial Welds	3
Number of Circumferential Welds	2
Height of Upper Shell Region (in extended beltline)	15.78 in.
Height of Intermediate Shell Region	97.31 in.
Height of Lower Shell Region (in extended beltline)	79.83 in.
Width of Upper Shell Axial Welds	1.44 in.
Width of Intermediate Shell Axial Welds	1.44 in.
Width of Lower Shell Axial Welds	1.44 in.
Width of Circumferential Welds	1.31 in.
Total Plate Area (in beltline and extended beltline)(1)	**14500 in.^{2}**
Total Weld Length (in beltline and extended beltline)(1)	**1600 in.**

Note:

1. The total calculated plate area and weld length were rounded down, which is conservative for the calculation of the 10 CFR 50.61a weld and plate flaw limits (See Tables 8-11 and 8-12).

Table 8-11 Alternate PTS Rule Allowable Number of Flaws in Plates and Forgings Scaled for Palisades

Through-Wall Extent, TWE (in.)		Scaled maximum number of flaws per 14500 square-inches of inside surface area in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}. This flaw density does not include underclad cracks in forgings	Number of Flaws (Axial/Circ.)
TWE_{MIN}	TWE_{MAX}		
0	0.075	No Limit	17 (17/0)
0.075	0.375	117	11 (4/7)
0.125	0.375	46	11 (4/7)
0.175	0.375	13	3 (2/1)
0.225	0.375	5	1 (1/0)
0.275	0.375	2	0 (0/0)
0.325	0.375	1	0 (0/0)
0.375	Infinite	0	0 (0/0)

Table 8-12 Alternate PTS Rule Allowable Number of Flaws in Welds Scaled for Palisades

Through-Wall Extent, TWE (in.)		Scaled maximum number of flaws per 1600 inches of weld length in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}.	Number of Flaws (Axial/Circ.)
TWE_{MIN}	TWE_{MAX}		
0	0.075	No Limit	0 (0/0)
0.075	0.475	267	0 (0/0)
0.125	0.475	146	0 (0/0)
0.175	0.475	37	0 (0/0)
0.225	0.475	14	0 (0/0)
0.275	0.475	7	0 (0/0)
0.325	0.475	5	0 (0/0)
0.375	0.475	3	0 (0/0)
0.425	0.475	2	0 (0/0)
0.475	Infinite	0	0 (0/0)

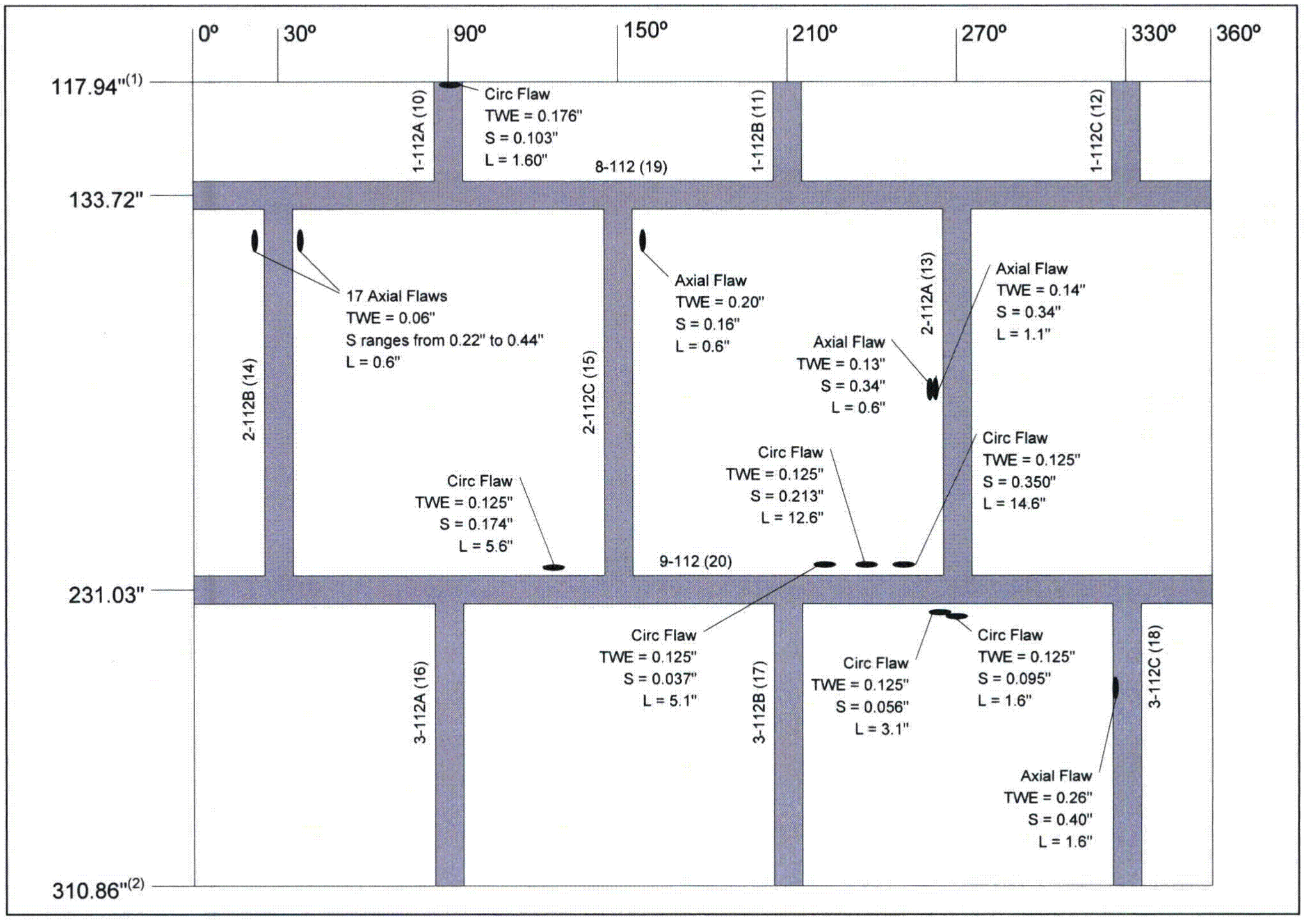

Figure 8-1 Weld and Plate Indication Map for Palisades Beltline and Extended Beltline(3)

Notes:

1. 117.94" corresponds to the upper extent of the extended beltline region. See Table 4-2 for references used to determine this location.
2. 310.86" corresponds to the lower extent of the extended beltline region. See Table 4-2 for references used to determine this location.
3. Map is not drawn to scale and indication locations are approximate. Numbers in parentheses correspond to "No." column in Table 4-1. Dimensions are measured downward from the RV flange surface.

9 CONCLUSION

After conducting this evaluation, it was concluded that the Palisades reactor pressure vessel is acceptable per the Alternate PTS Rule acceptance criteria. As shown in Section 8.1, all of the beltline and extended beltline region materials in the Palisades RV have EOLE (42.1 EFPY) RT_{MAX-X} values below the screening criteria values. After conducting surveillance data statistical tests, it was determined that the surveillance data satisfied the Alternate PTS Rule requirements. Lastly, a review of the latest RV ISI report for Palisades showed that the flaw density and size distribution is acceptable per the Alternate PTS Rule requirements.

10 REFERENCES

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