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Anthony J. Vitale
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PNP 2013-046

June 25, 2013

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Updated Palisades Nuclear Plant Reactor Vessel Fluence Evaluation

Palisades Nuclear Plant
Docket 50-255
License No. DPR-20

References:

1. Entergy Nuclear Operations, Inc. letter, "Updated Palisades Reactor Vessel Pressurized Thermal Shock Evaluation," dated December 20, 2010 (ADAMS Accession No. ML110060692)
2. NRC letter, "Updated Reactor Pressure Vessel Pressurized Thermal Shock Evaluation for Palisades Nuclear Plant (TAC No. ME5263)," dated December 7, 2011 (ADAMS Accession No. ML112870050)

Dear Sir or Madam:

As documented in Reference 1, Entergy Nuclear Operations, Inc. (ENO) submitted an updated reactor vessel pressurized thermal shock (PTS) evaluation for Palisades Nuclear Plant (PNP). The submittal included an updated reactor vessel fluence evaluation, WCAP-15353 – Supplement 1 – NP, Revision 0, "Palisades Reactor Pressure Vessel Fluence Evaluation," that calculated fluence based on actual plant operation through Cycle 20 and the finalized design for Cycle 21, with future fluence based on planned future operations. Using data from the fluence calculation, the PTS evaluation concluded that the PNP reactor vessel would not reach the 10 CFR 50.61 PTS screening criteria limit until April 2017, during Cycle 26.

In Reference 2, the Nuclear Regulatory Commission (NRC) concluded that the updated PNP PTS evaluation was in accordance with 10 CFR 50.61 and that the PTS screening criteria limit would not be reached until April 2017.

ENO has re-calculated PNP reactor vessel fluence, based on actual reactor operation through Cycle 22, and future fluence based on planned operations through Cycle 26. This is documented in the attached "Palisades Reactor Pressure Vessel Fluence Evaluation," WCAP-15353 – Supplement 3 – NP, Revision 0. The evaluation concludes that the PNP reactor vessel would not reach the 10 CFR 50.61 PTS screening criteria limit until August 2017.

The attachment contains no proprietary information.

This letter identifies no new commitments and no revisions to existing commitments.

ENO requests that, by December 31, 2013, the NRC complete review and approval of the attached fluence evaluation, and endorse the new date at which the PNP reactor vessel is estimated to reach the PTS screening criteria limit.

I declare under penalty of perjury that the foregoing is true and correct. Executed on June 25, 2013.

Sincerely,

ajv/jse

Attachment: 1. Palisades Reactor Pressure Vessel Fluence Evaluation, WCAP-15353 – Supplement 3 – NP, Revision 0

cc: Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ATTACHMENT 1

PALISADES REACTOR PRESSURE VESSEL FLUENCE EVALUATION

WCAP-15353 – SUPPLEMENT 3 – NP

REVISION 0

18 pages follow

Westinghouse Non-Proprietary Class 3

WCAP-15353 – Supplement 3 – NP
Revision 0

June 2013

Palisades Reactor Pressure Vessel Fluence Evaluation

Westinghouse

WCAP-15353 – Supplement 3 - NP, Revision 0

Palisades Reactor Pressure Vessel Fluence Evaluation

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June 2013

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Work Performed Under Shop Order 450
Sales Order No. 94483
Prepared by Westinghouse for Entergy Nuclear Operations Inc

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* Electronically approved records are authenticated in the electronic document management system.

EXECUTIVE SUMMARY

In early 2000, WCAP-15353, Revision 0[1] describing the methodology used in the fluence evaluations for the Palisades plant was submitted to the NRC staff for review. Following that review and a further exchange of information documented in Reference 2, the methodology described in WCAP-15353, Revision 0 was approved for application to the Palisades reactor pressure vessel[3]. Subsequent to that approval, additional submittals[4,5] in support of the benchmarking of this fluence methodology were reviewed and approved by the NRC Staff as being in compliance with the requirements of Regulatory Guide 1.190[6].

The fluence analysis described in WCAP-15353, Revision 0[1] included cycle-specific evaluations through fuel Cycle 14 (the then-current operating cycle). In mid 2010, Supplement 1 to WCAP-15353, Revision 0[10] was issued to provide an updated neutron fluence assessment for the Palisades pressure vessel that included cycle-specific analysis for additional operating cycles for which the design had been finalized (Cycles 15 through 21). Supplement 1 included fluence projections for future operation through approximately 44 effective full power years (EFPY). The results of the evaluation documented in Supplement 1 were used as input to vessel materials studies that included updates to surveillance capsule credibility analysis, material chemistry factor determination, Pressurized Thermal Shock (PTS) evaluation, and generation of Pressure-Temperature (PT) limit curves.

In December of 2010, Entergy Nuclear Operations Inc submitted a request to revise the Palisades PTS evaluation to include new information on surveillance data for the limiting RPV welds (axial welds) fabricated with weld wire heat number W5214 (Weld W5214). Neutron fluence data documented in Supplement 1 to WCAP-15353, Revision 0[10] were used in support of this submittal. In December of 2011, the request for the revised PTS evaluation was approved by the USNRC Staff[14] and a limiting fluence of 1.685e19 n/cm^2 (E > 1.0 MeV) was established for Weld W5214. Based on the fluence projections provided in Supplement 1 to WCAP-15353, Revision 0[10] the limiting fluence was expected to be reached in April 2017.

In this supplement, the neutron fluence accrued by Weld W5214 during cycles 21 through 26 has been re-evaluated based on actual fuel cycle designs, fuel cycle lengths, and refueling outage schedules. The result of that re-evaluation is a movement in the date at which the fluence limit (1.685e19 n/cm^2) for Weld W5214 corresponding to the PTS screening criterion of 270° F is anticipated to be reached from April 2017 to August 2017.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1.0

INTRODUCTION

In the assessment of the state of embrittlement of light water reactor (LWR) pressure vessels, an accurate evaluation of the neutron exposure of each of the materials comprising the beltline region of the vessel is required. In Section II F of 10 CFR 50[7] Appendix G, the beltline region is defined as:

> *"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 reactor 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"*.

Each of the materials that is anticipated to experience a neutron exposure that exceeds this fluence threshold must be considered in the overall embrittlement assessments for the pressure vessel.

Regulatory Guide 1.190, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence" [6], describes state-of-the-art calculation and measurement procedures that are acceptable to the NRC staff for determining pressure vessel fluence. Also included in Regulatory Guide 1.190 is a discussion of the steps required to qualify and validate the methodology used to determine the neutron exposure of the pressure vessel wall.

In early 2000, WCAP-15353, Revision 0[1] describing the methodology used in the fluence evaluations for the Palisades plant was submitted to the NRC staff for review. Following that review and a further exchange of information documented in Reference 2, the methodology described in WCAP-15353, Revision 0 was approved for application to the Palisades reactor pressure vessel (RPV)[3]. Subsequent to that approval additional submittals[4,5] in support of the benchmarking of this fluence methodology were reviewed and approved by the NRC Staff as being in compliance with the requirements of Regulatory Guide 1.190[6].

The fluence analysis described in WCAP-15353, Revision 0[1] included cycle-specific evaluations through fuel Cycle 14 (the then-current operating cycle). In mid 2010, Supplement 1 to WCAP-15353, Revision 0[10] was issued to provide an updated neutron fluence assessment for the Palisades pressure vessel that included cycle-specific analysis for additional operating cycles for which the design had been finalized (Cycles 15 through 21). At that time, Cycle 21 was in operation, but not completed.

Supplement 1 to WCAP-15353, Revision 0[10] included fluence projections for future operation through approximately 44 effective full power years (EFPY). The results of the evaluation documented in Supplement 1 were used as input to vessel materials studies that included updates to surveillance capsule credibility analysis, material chemistry factor determination, Pressurized Thermal Shock (PTS) evaluation, and generation of Pressure-Temperature (PT) limit curves.

In December of 2010, Entergy Nuclear Operations Inc submitted a request to revise the Palisades PTS evaluation to include new information on surveillance data for the limiting RPV welds (axial welds 2-112A/C & 3-112A/C) fabricated with weld wire heat number W5214 (Weld W5214). Neutron fluence data documented in Supplement 1 to WCAP-15353, Revision 0[10] were used in support of this submittal. In December of 2011, the request for the revised PTS evaluation was approved by the USNRC Staff[14] and a limiting fluence of 1.685e19 n/cm^2 (E > 1.0 MeV) was established for Weld W5214 corresponding to when the PTS screening criterion of 270° F would be reached. Based on the fluence data provided in Supplement 1 to WCAP-15353, Revision 0[10] the limiting fluence was expected to be reached in April 2017. This date corresponds to a time during operation of Palisades Cycle 26.

Since the approval of the revised PTS evaluation, Cycles 21 and 22 have been completed and a design for Cycle 23 has been implemented and is currently in operation. Therefore, it became possible to evaluate the neutron fluence accrued during these fuel cycles based on the more accurate data obtained from actual rather than projected reactor operation.

In this supplement, the neutron fluence accrued by the limiting Weld W5214 during Cycles 21 through Cycle 26 is re-evaluated using revised neutron flux calculations and fuel cycle lengths and based on this re-evaluation an updated time at which the PTS screening limit will be reached is determined.

SECTION 2.0

NEUTRON TRANSPORT CALCULATIONS

As noted in Section 1.0 of this report, the exposure of the Palisades pressure vessel was developed based on a series of fuel cycle-specific neutron transport calculations validated by comparison with plant-specific measurements. Measurement data used in the validation process were obtained from both in-vessel and ex-vessel capsule irradiations. These comparisons along with the benchmarking information described in References 4 and 5 demonstrate that the transport methodology provides results that meet the requirements of Regulatory Guide 1.190[6]. In this section, the neutron transport methodology is discussed in some detail, and the calculated results applicable to the PTS limit re-evaluation are provided.

2.1 – Method of Analysis

In performing the fast neutron exposure evaluations for the Palisades reactor, plant-specific forward transport calculations were carried out using the three-dimensional flux synthesis technique described in Section 1.3.4 of Regulatory Guide 1.190. In particular, the following single channel synthesis approach was employed for all fuel cycles:

$$\Phi(r,\theta,z) = \Phi(r,\theta) * \frac{\Phi(r,z)}{\Phi(r)}$$

where $\phi(r,\theta,z)$ is the synthesized three-dimensional neutron flux distribution, $\phi(r,\theta)$ is the transport solution in r,θ geometry, $\phi(r,z)$ is the two-dimensional solution for a cylindrical reactor model using the actual axial core power distribution, and $\phi(r)$ is the one-dimensional solution for a cylindrical reactor model using the same source-per-unit-height as that used in the r,θ two-dimensional calculation.

For the Palisades analysis, all of the transport calculations were carried out using the DORT two-dimensional discrete ordinates code Version 3.2[8] and the BUGLE-96 cross section library[9]. The BUGLE-96 library provides a 67-group coupled neutron-gamma ray cross-section data set produced specifically for light water reactor applications. In these analyses, anisotropic scattering was treated with a P_5 Legendre expansion and the angular discretization was modeled with an S_{16} order of angular quadrature. Energy and space dependent core power distributions as well as system operating conditions were treated on a fuel cycle-specific basis.

The geometry used for the Palisades transport analysis is discussed in some detail in Reference 1 and the geometric model established for Cycle 15 and beyond was also used for the current evaluations. A plan view of the r,θ model of the reactor geometry at the core midplane is shown in Figure 2.1-1. This model depicts a single quadrant of the reactor. A

section view of the r,z model of the Palisades reactor is shown in Figure 2.1-2. The r,z model extended radially from the centerline of the reactor core out to a location interior to the primary biological shield and over an axial span from an elevation one foot below the active fuel to an axial elevation one foot above the active fuel. The one-dimensional radial model used in the synthesis procedure consisted of the same radial mesh intervals included in the r,z model. Thus, radial synthesis factors could be determined on a meshwise basis throughout the entire geometry.

The core power distributions used in the plant-specific transport analysis for the reactor were provided by Entergy[11]. The data used in the source generation included fuel assembly-specific initial enrichments, beginning-of-cycle burnups and end-of-cycle (EOC) burnups. Appropriate axial burnup distributions were also used.

For each fuel cycle of operation, the fuel assembly-specific enrichment and burnup data were used to generate the spatially dependent neutron source throughout the reactor core. This source description included the spatial variation of isotope-dependent (U-235, U-238, Pu-239, Pu-240, Pu-241, and Pu-242) fission spectra, neutron emission rate per fission, and energy release per fission based on the burnup history of individual fuel assemblies. These fuel assembly-specific neutron source strengths derived from the detailed isotopics were then converted from fuel pin Cartesian coordinates to the [r,θ], [r,z], and [r] spatial mesh arrays used in the DORT discrete ordinates calculations.

Figure 2.1-1

Palisades r,θ Reactor Geometry

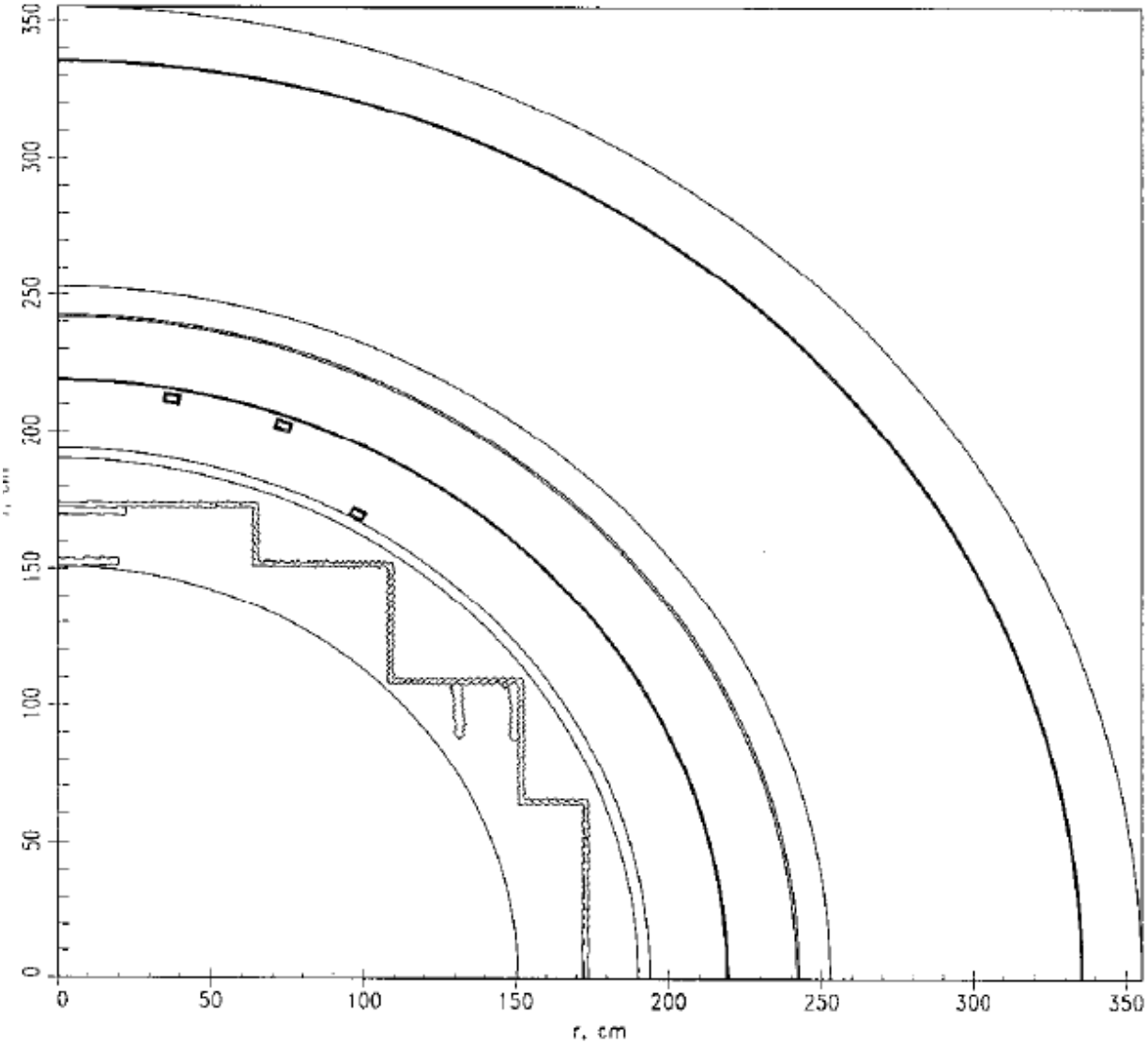
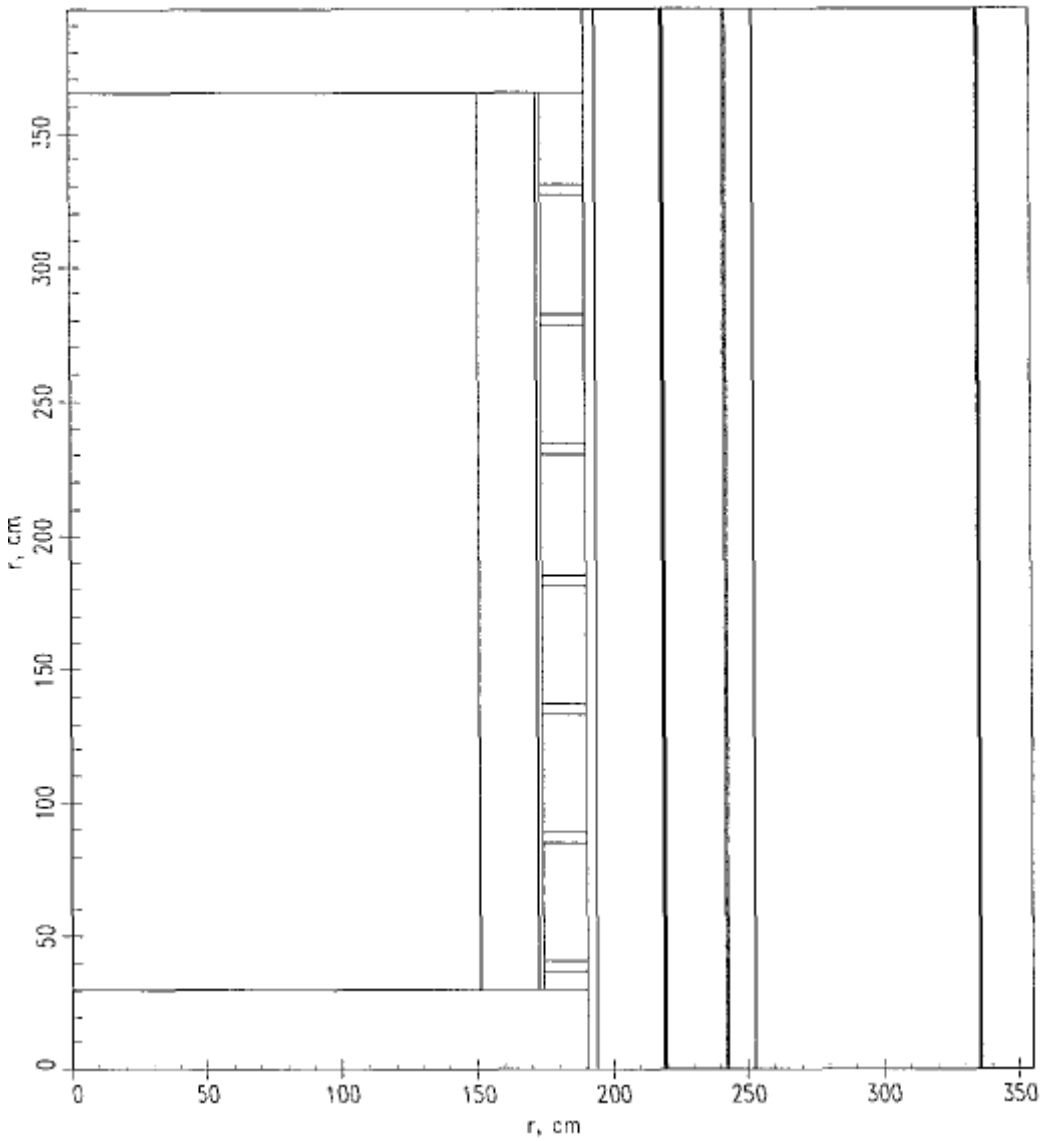


Figure 2.1-2

Palisades r,z Reactor Geometry



2.2 – PTS Limit Re-evaluation

The limiting RPV axial welds (Weld W5214) are exposed to the neutron flux characteristic of the 60° azimuthal location. A summary of the neutron flux and cycle time data used in both the prior analysis and the current re-evaluation is given in Table 2.2-1. Note that the updated data include new neutron flux values for Cycles 21, 22, and 23, as well as new cycle lengths for Cycles 21, 22, 23, and 24. The projected neutron flux for Cycles 24, 25, and 26 and the projected cycle lengths for Cycles 25 and 26 remain the same as those used in Reference 10. The updated data included in Table 2.2-1 were provided via References 11 through 13.

In Table 2.2-2, a comparison of the calculated neutron fluence at the end of Cycles 20 through Cycle 26 is given for both the prior analysis and the current re-evaluation. From Table 2.2-2, it is noted that, in both cases, the limiting weld fluence of 1.685e19 n/cm^2 is reached during Cycle 26.

In Table 2.2-3, the accrued neutron fluence at the limiting Weld (W5214) is provided as a function of irradiation time through Cycle 26 for the updated irradiation conditions. In developing this exposure profile, Cycle 26 was assumed to initiate at 11:00 on November 15, 2016 and to run at 100% capacity during the cycle up to the point at which the limiting fluence is reached. Based on these projections, the limiting fluence at Weld W5214 is calculated to be reached after 11.99 days of irradiation in August 2017.

Table 2.2-1

Comparison of Fast Neutron Flux Values and Fuel Cycle Lengths used in the PTS Limit Analysis Weld W5214

Cycle	Reference 10		Current Analysis	
	Cycle Flux[1] [n/cm^2-s]	Cycle Time [EFPD]	Cycle Flux[1] [n/cm^2-s]	Cycle Time [EFPD]
21	1.172e10	519	1.169e10	508
22	1.128e10	499	1.101e10	495
23	1.172e10	499	1.021e10	527
24	1.172e10	477	1.172e10	420[2]
25	1.172e10	504	1.172e10	504
26	1.172e10	504	1.172e10	504

1- Limiting RPV axial welds (Weld W5214) are exposed to the neutron flux characteristic of the 60° azimuthal location.

2 - Cycle 24 length is based upon a spring 2015 refueling outage. That outage might be changed to Fall 2015 and the subsequent refueling outages delayed to maintain 18-month refueling cycles. Three refueling outages are still planned before reaching the limiting fluence.

Table 2.2-2

Comparison of Fast Neutron Fluence Accrued at the Conclusion of Cycles 21 Through 26
Weld W5214

Cycle	Reference 10		Current Analysis	
	Cumulative Exposure Time [EFPY]	EOC Fluence[1] [n/cm^2]	Cumulative Exposure Time [EFPY]	EOC Fluence[1] [n/cm^2]
20	22.0	1.419e19	22.0	1.419e19
21	23.4	1.472e19	23.3	1.471e19
22	24.7	1.520e19	24.7	1.518e19
23	26.1	1.571e19	26.1	1.564e19
24	27.4	1.619e19	27.3	1.607e19
25	28.8	1.670e19	28.7	1.658e19
26	30.2	1.721e19	30.1	1.709e19

1- Limiting RPV axial welds (Weld W5214) are exposed to the neutron flux characteristic of the 60° azimuthal location.

Table 2.2-3

Fast Neutron Fluence Accumulation as a Function of Irradiation Time During Cycle 26
Weld W5214

Month	Current Analysis	
	Monthly Exposure Time [EFPD]	Accumulated Fluence [n/cm^2]
Nov. 2016	14.54	1.659e19
Dec. 2016	31	1.662e19
Jan. 2017	31	1.665e19
Feb. 2017	28	1.668e19
Mar. 2017	31	1.671e19
Apr. 2017	30	1.674e19
May 2017	31	1.678e19
Jun. 2017	30	1.681e19
Jul. 2017	31	1.684e19
Aug. 2017	11.99	1.685e19

Notes: 1 – Assumed Cycle Start Nov. 11/15/2016 at 11:00
2 – Cycle flux = 1.172e10 n/cm^2-s (E > 1.0 MeV)
3 – Cycle 26 Capacity Factor is assumed to be 100% to the point at which the limiting fluence is reached.

SECTION 3.0

REFERENCES

1. WCAP-15353, Revision 0, “Palisades Reactor Pressure Vessel Neutron Fluence Evaluation,” G. K. Roberts et al., January 2000.

2. LTR-REA-00-630, “Transmittal of Responses to Requests for Additional Information on WCAP-15353 in Support of the Palisades Pressure Vessel Fluence Evaluation,” G. K. Roberts, July 13, 2000.

3. NRC Safety Evaluation Report (SER), Darl S. Hood (NRC) to Nathan L. Haskell (Palisades), “Palisades Plant – Reactor Vessel Neutron Fluence Evaluation and revised Schedule for Reaching Pressurized Thermal Shock Screening Criteria,” November 14, 2000.

4. WCAP-14040-NP-A, Revision 4, “Methodology Used to Develop Cold Overpressure Mitigating System Setpoints and RCS Heatup and Cooldown Limit Curves,” May 2004.

5. WCAP-16083-NP-A, Revision 0, “Benchmark Testing of the FERRET Code for Least Squares Evaluation of Light Water Reactor Dosimetry,” S. L. Anderson, May 2006.

6. Regulatory Guide 1.190, “Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence,” U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, March 2001.

7. Code of Federal Regulations Title 10 Part 50, “Domestic Licensing of Production and Utilization Facilities,” Appendix G, “Fracture Toughness Requirements” and Appendix H, “Reactor Vessel Materials Surveillance Requirements,” January 1992.

8. CCC-650, “DOORS 3.2, One-, Two-, and Three-Dimensional Discrete Ordinates Neutron/Photon Transport Code System,” April 1998. Available from the Radiation Safety Information Computational Center, Oak Ridge National Laboratory.

9. DLC-185, “BUGLE-96, Coupled 47 Neutron, 20 Gamma-Ray Group Cross Section Library Derived from ENDF/B-VI for LWR Shielding and Pressure Vessel Dosimetry Applications,” March 1996. Available from the Radiation Safety Information Computational Center, Oak Ridge National Laboratory.

10. WCAP-15353, Supplement 1 - NP, “Palisades Reactor Pressure Vessel Fluence Evaluation,” Stanwood L. Anderson, May 2010.

11. Palisades Design Input Record for Input to a Contingent Calculation, Thomas W. Allen, May 20, 2013.

12. Westinghouse Project Letter CPAL-11-20, “Pressure Vessel Flux Update – Cycles 21 and 22,” Edward P. Shields, July 29, 2011.

13. Westinghouse Project Letter CPAL-12-14, “Pressure Vessel Inner Radius Fluence Following Cycle 23,” Anthony L. Dietrich, August 21,2012.

14. NRC Safety Evaluation Report (SER), Mahesh Chawla (NRC) to Vice President Operations, Entergy Nuclear Operations Inc, Palisades Nuclear Plant, “Updated Reactor Pressure Vessel Pressurized Thermal Shock Evaluation for Palisades Nuclear Plant (TAC NO. ME5263),” December 7, 2011.