ENCLOSURE 5

MONTICELLO NUCLEAR GENERATING PLANT

LICENSE AMENDMENT REQUEST

REVISE THE TECHNICAL SPECIFICATIONS TO INCLUDE A PRESSURE TEMPERATURE LIMITS REPORT

CALCULATION CA 11-003

EVALUATION OF ADJUSTED REFERENCE TEMPERATURES AND REFERENCE TEMPERATURE SHIFTS

Non-Proprietary Version

(SIA No. 1000847.301)

(23 pages follow)

Xcel Energy — Calculation Signature Sheet

Document Information	
NSPM Calculation (Doc) No: 11-003	Revision: 0A
Title: Evaluation OF Adjusted Reference Temperatures and Reference Temperature Shifts	
Facility: ☒ MT ☐ PI	Unit: ☒ 1 ☐ 2
Safety Class: ☒ SR ☐ Aug Q ☐ Non SR	
Special Codes: ☐ Safeguards ☐ Proprietary	
Type: **Calc** Sub-Type:	

NOTE:	Print **and** sign name in signature blocks, as required.

Major Revisions		☒ N/A
EC Number:	☐ Vendor Calc	
Vendor Name or Code:	Vendor Doc No:	
Description of Revision:		
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record		☐
Prepared by: (sign) / (print)	Date:	
Reviewed by: (sign) / (print)	Date:	
Type of Review: ☐ Design Verification ☐ Tech Review ☐ Suitability Review		
Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test		
Approved by: (sign) / (print)	Date:	

Minor Revisions		☐ N/A
EC No: 18522	☒ Vendor Calc:	
Minor Rev. No: 0A		
Description of Change: The revision is to update the references section of the calculation and include the non-proprietary copies of the calculation as well as the affidavits from vendors who have proprietary information in the proprietary copy.		
Pages Affected: 12,13		
The following calculation and attachments have been reviewed and deemed acceptable as a legible QA record		☒
Prepared by: (sign) By Vendor / (print) By Vendor	Date: 7/29/2011	
Reviewed by: (sign) Wynter S. McGruder / (print) Wynter McGruder	Date: 9/6/2011	
Type of Review: ☐ Design Verification ☐ Tech Review ☒ Suitability Review		

Record Retention: Retain this form with the associated calculation for the life of the plant.

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Method Used (For DV Only): ☐ Review ☐ Alternate Calc ☐ Test	
Approved by: (sign) [signature] / (print) Paul Young	Date: 11-3-11

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NOTE:	This reference table is used for data entry into the PassPort Controlled Documents Module reference tables (C012 Panel). It may also be used as the reference section of the calculation. The input documents, output documents and other references should all be listed here. Add additional lines as needed by using the "TAB" key and filling in the appropriate information in each column.

Reference Documents (PassPort C012 Panel from C020)

#	Controlled* Doc? + Type		Document Name	Document Number	Doc Rev	Ref Type** INPUT	OUTPUT
1			DIT 17500-2: Elevation information for MNGP vessel, BWRVIP-199NP	17500-2	N/A	X	
2			DIT 18522-1: GE Non-Proprietary Document Statement	18522-1	N/A	X	
3			Email from W. McGruder (Xcel Energy) to E. Houston (SI) Subject: Contains EPRI Proprietary information, July 21, 2011	N/A	N/A	X	
4							
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* Controlled Doc marked with an "X" means the reference can be entered on the C012 panel in black. Unmarked lines will be yellow. If marked with an "X", also list the Doc Type, e.g., CALC, DRAW, VTM, PROC, etc.

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Calculation Signature Sheet

** Mark with an "X" if the calculation provides inputs and/or outputs or both. If not, leave blank. (Corresponds to PassPort "Ref Type" codes: **Inputs / Both** = "ICALC", **Outputs** = "OCALC", **Other / Unknown** = blank)

Other PassPort Data

Associated System (PassPort C011, first three columns) **OR** **Equipment References** (PassPort C025, all five columns):

Facility	Unit	System	Equipment Type	Equipment Number
MT	1	RPV		

Superseded Calculations (PassPort C019):

Facility	Calc Document Number	Title
N/A		

Description Codes - Optional (PassPort C018):

Code	Description (optional)	Code	Description (optional)

Notes (Nts) - Optional (PassPort X293 from C020):

Topic Notes	Text
☐ Calc Introduction	☐ Copy directly from the calculation Intro Paragraph **or** ☐ See write-up below
☐ (Specify)	

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Calculation Signature Sheet

Monticello Specific Information

☒ YES ☐ N/A Topic Code(s) (See MT Form 3805): PLEX, RATE
☐ YES ☒ N/A Structural Code(s) (See MT Form 3805):_______

Does the Calculation:

☐ YES ☒ No Require Fire Protection Review? (Using MT Form 3765, "Fire Protection Program Checklist", determine if a Fire Protection Review is required.) If YES, document the engineering review in the EC. If NO, then attach completed MT Form 3765 to the associated EC.

☐ YES ☒ No Affect piping or supports? (If Yes, Attach MT Form 3544.)

☐ YES ☒ No Affect IST Program Valve or Pump Reference Values, and/or Acceptance Criteria? (If Yes, inform IST Coordinator and provide copy of calculation.)

Record Retention: Retain this form with the associated calculation for the life of the plant.

Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 1000847.301

Project No.: 1100730

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Monticello P-T Curves Revision According to the PTLR Methodology

CONTRACT NO.:
1005, Release 29

CLIENT:
Xcel Energy, Inc.

PLANT:
Monticello Nuclear Generating Plant

CALCULATION TITLE:
Evaluation of Adjusted Reference Temperatures and Reference Temperature Shifts

Non-Proprietary Version

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 11 A-1 – A-3	Initial Issue	Eric J. Houston 10/09/2010	Mark J. Jaeger 10/08/2010 Vikram Marthandam 10/08/2010
1	1 – 13 A-1 – A-4 Computer files	Added additional evaluation for two intermediate fluence values corresponding to 36 and 40 EFPY	Eric J. Houston EJH 1/11/2011	Nadia Crisan NC 1/07/2011 Eric J. Houston EJH 1/07/2011 Mark J. Jaeger 1/07/2011
2	1 - 13 A-1 – A-4 Computer files	Modify References and Identification of Proprietary Information	Eric J. Houston EJH 7/29/2011	Eric J. Houston EJH 7/28/2011 Mark J. Jaeger 7/29/2011

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1.0 INTRODUCTION

Radiation embrittlement of reactor pressure vessel (RPV) materials causes a decrease in fracture toughness. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.99, Revision 2 (RG1.99) describes general procedures to evaluate the effects of neutron irradiation embrittlement on the alloy steel used in RPV's. In order to perform this evaluation, RG1.99 requires calculation of Adjusted Reference Temperature (ART) and Reference Temperature Shift (ΔRT_{NDT}) values [1]. The ART values are then used to determine the local fracture toughness of the RPV wall, according to ASME Code, Section XI, Non-mandatory Appendix G [2] evaluations.

The purpose of this calculation is to develop ART and ΔRT_{NDT} values for the Monticello Nuclear Generation Plant (MNGP). In accordance with RG1.99, the ART and ΔRT_{NDT} values are developed for all Reactor Pressure Vessel (RPV) plates, welds and nozzles exposed to fluence levels greater than $1.0x10^{17}$ n/cm^2 [1]. This value is considered a lower bound, below which material effects due to irradiation are negligible, based on 10CFR50 Appendix H, Section III.A [3]. Based on updated fluence calculations, ART and ΔRT_{NDT} values are provided at 36, 40, and 54 effective full power years (EFPY). The reported valued for 54 EFPY are applicable until the end of MNGP's extended operation period (60 years). The intermediate values at 36 and 40 EFPY are provided due to operational challenges presented by the leak test temperature at 54 EFPY.

The application of assumptions is indicated throughout the document using a set of braces containing the appropriate reference number; for example, Assumption #3 would be indicated as {3, Section 4.0}.

2.0 METHODOLOGY

When surveillance data is limited or not available, RG1.99 [1] specifies that ART is calculated with the following equation:

$$ART = InitialRT_{NDT} + \Delta RT_{NDT} + Margin \quad (1)$$

The "Initial RT_{NDT}" term refers to the reference temperature of nil ductility transition for the non-irradiated material.

The reference temperature shift, ΔRT_{NDT}, is defined in RG1.99 [1] as the shift in the reference temperature resulting from neutron irradiation. ΔRT_{NDT} is calculated from the product of the chemistry factor (CF) and fluence factor (FF) as follows:

$$\Delta RT_{NDT} = CF \cdot FF \quad (2)$$

The CF is a function of the weight percent copper (Cu) and weight percent nickel (Ni) of the weld and base metal (plate or forging) materials. Tables 1 and 2 of RG1.99 [1] provide the standard CF values used in this calculation.

The FF is based on the accumulated fast neutron exposure (E > 1 MeV), and is typically corrected by the thickness at the location of interest. The FF can be read directly from Figure 1 of RG1.99, or calculated using the following equation [1]:

$$FF = f^{0.28-0.10\log(f)} \qquad (3)$$

Due to attenuation effects, the fluence decreases with distance into the RPV wall. Per RG1.99 [1], the calculated or measured fluence from the inside surface of the RPV is attenuated using the following formula:

$$f = f_{surf} \cdot e^{-0.24x} \qquad (4)$$

Where: f = fast neutron fluence (10^{19} n/cm^2, E > 1 MeV)
f_{surf} = fast neutron fluence at the RPV inside surface (i.e., at base metal / cladding interface, same units as f)
x = depth into the RPV wall from the inside surface (inches)

For ASME Code, Section XI, non-mandatory Appendix G [2] evaluations, the "x" value is taken at one-quarter of the base metal thickness (1/4t). The fast neutron fluence can be attenuated through the stainless steel cladding on the inside surface of the RPV. By design, however, the cladding is treated purely as a lining, and not as a load-bearing member. Thus, for the purposes of this evaluation, the inside surface neutron fluence is considered to be at the base metal / cladding interface.

Margin (M), a conservative term defined in RG1.99 [1], accounts for uncertainty in the initial reference temperature and for variance in ΔRT_{NDT}. The margin is calculated using the following formula:

$$Margin = 2 \cdot \sqrt{\sigma_I^2 + \sigma_\Delta^2} \qquad (5)$$

Where: σ_I = the standard deviation for the initial RT_{NDT} (°F)
σ_Δ = the standard deviation for ΔRT_{NDT} (°F)

RG1.99 [1] states that the standard value of σ_Δ is 28 °F for welds and 17 °F for base metal (plates or forgings), and σ_Δ need not exceed 0.5 times the mean reference temperature shift (0.5* ΔRT_{NDT}).

The σ_I term, which is related to the uncertainty in the precision of the Initial RT_{NDT}, is applied for values that are determined by measurement and also when generic or default values are used. For MNGP components where a σ_I value is not explicitly identified, σ_I is assumed to be equal to 0 °F {1, Section 4.0}.

When surveillance data exists (e.g., the ISP Representative Material or other Supplemental Surveillance Program (SSP) material) containing an identical match for the heat number of the vessel beltline material being evaluated, a separate procedure is used to evaluate the ART. This procedure first determines the credibility of the data and, using best estimate chemistry values, calculates a fitted CF. The fitted CF is then compared to the Table CF (defined above in Equation 2), and the greater of the two is used in subsequent ART calculations. If the surveillance data is credible, the margin (σ_Δ) may be cut in half, as specified in RG1.99 [1]. Detailed procedures to evaluate surveillance data in the manner described above can be found in Section 3 of Reference [4].

3.0 DESIGN INPUT

The fluence values obtained from Reference [5] for 54 EFPY account for extended power uprate (EPU) operation at 2004 MWT from Cycle 22 on. Specific fluence values for RPV beltline components (i.e. shell plates, welds, and nozzles) are not provided, as the table in Section 4.0 of Reference [5] merely lists the peak fluence value of 6.43×10^{18} n/cm^2 at the inner surface of the RPV. Location specific fluence values for all EFPY must be calculated, along with peak fluence values for 36 and 40 EFPY. The required input into these calculations is the flux and axial distribution of relative flux for both pre-EPU and post-EPU operation. The pre-EPU input is obtained from Reference [17] and the post-EPU input is obtained from Reference [5]. The fluence values are calculated in Appendix A, and summarized in Table A-1. Note that although references [5 and 17] are listed as proprietary in Section7, no proprietary information for those documents was used herein [20].

The MNGP RPV is constructed of a series of plates, numbered 10 through 17 from top to bottom [7]. Two plates are joined at each elevation via circumferential and vertical welds. According to Section 4.0 of Reference [5], at 54 EFPY the upper elevation of the RG1.99 fluence threshold (1.0×10^{17} n/cm^2) is 168.7 inches above the bottom of active fuel (BAF). Reference [19] specifies that the BAF is at an elevation of 207.5 inches in the RPV, so the top of the beltline at 54 EFPY is at an elevation of 376.2 inches. Reference [7] specifies that the weld separating the lower intermediate shell plates (14 and 15) from the upper intermediate shell plates (12 and 13) is located at an elevation of 366.125 inches. Therefore, the upper intermediate plates must be included in the ART evaluation.

The chemical composition of the MNGP RPV plates is obtained from several sources. The nickel content of the lower plates (C2193-1 and A0946-1) and upper intermediate plates (C2613-1 and C2089-1) is obtained from Reference [8]. The copper content of the lower plates is obtained from Table 4-1 of Reference [9]. Copper content is not available for the upper-intermediate plates; for conservatism, the bounding value of 0.35% copper specified in Section 1.1 of RG1.99 [1] is applied to these components {2, Section 4.0}.

Reference [10] specifies updated copper and nickel values for the lower intermediate plates (C2220-1 and C2220-2); these values supersede any prior information for these components. Reference [10] also specifies [[redacted]], which exceeds the default chemistry factor specified in the tables of Reference [1]. According to the discussion in the Attachment to Reference [10], [[redacted]] Therefore, the σ_Δ margin term is cut in half for the lower intermediate plates.

Initial RT_{NDT} values for the MNGP RPV plates are obtained from Table 5-1 of Reference [11]. In certain cases, multiple values are provided, based on different evaluation methods that are equally relevant. In such cases, it is assumed that selecting the minimum reported value is applicable for the ART calculations {3, Section 4.0}.

The vertical and circumferential welds that join the RPV plates must also be considered during the ART evaluation. Information on specific welds is not available; rather, Reference [12] provides parameters for a bounding beltline weld. Chemical composition information for the beltline weld is provided in Table 4-1 of Reference [12]. As described in Sections 3.1 and 3.2 of the same document, the Initial RT_{NDT} value for the bounding beltline weld is calculated from 45 tests performed on a sample specimen. The average calculated value is -65.6 °F, with a standard deviation of 12.7 °F. For the ART evaluation, these values are applied as the Initial RT_{NDT} and σ_I, respectively.

According to the drawing in Reference [7], the centerline N-2 recirculation inlet nozzles in the MNGP RPV are located at an elevation of 186 inches above the bottom of the reactor vessel. According to Section 4.0 of Reference [5], at 54 EFPY the lower elevation of the $1.0x10^{17}$ n/cm^2 fluence threshold will be 19.2 inches below the bottom of active fuel (BAF). This corresponds to an RPV elevation of 188.3 inches. However, the elevation of the uppermost blend radius of the N-2 nozzle is 204.3 inches, as shown in Reference [19]. Therefore, the N-2 nozzles must be included in the ART evaluation.

Similar to the upper intermediate shell plates, documentation of the copper content of the N-2 nozzles is not available. Section 3.2 of Reference [13] provides a conservative estimate of copper content based on a statistical evaluation of beltline nozzles in other BWR plants {4, Section 4.0}. Note that although Reference [13] is an EPRI proprietary document, EPRI does not consider the copper content of the N-2 nozzles proprietary [21]. Nickel content for each nozzle is identified in the RPV test reports in Reference [14]. The average of the reported values is 0.86%; this value, the best-estimate nickel content, is used to determine an N-2 ART value. The Initial RT_{NDT} value is obtained from Table 5-2 of Reference [11], where a value of 40 °F is common to all of the N-2 nozzles.

Based on the boundary of the extended beltline [5,19] and examination of the RPV drawing [7], the N-2 nozzle is the only forged nozzle in the extended beltline at 54 EFPY. There are no instrument nozzles in the extended beltline at 54 EFPY.

The design inputs described above are replicated in the ART calculation results in Table 1 for 36 EFPY, Table 2 for 40 EFPY, and Table 3 for 54 EFPY.

4.0 ASSUMPTIONS

The assumptions made in order to define the evaluation approach and perform the analysis are summarized in the following list. The application of these assumptions is indicated throughout the document using a set of braces containing the appropriate reference number; for example, Assumption #3 would be indicated as {3, Section 4.0}.

1. According to RG1.99, the σ_I term is equal to the standard deviation of the Initial RT_{NDT} when that quantity is estimated from physical measurements [1]. However, for the MNGP evaluation, a number of components do not have a measured Initial RT_{NDT}; rather, a bounding value is estimated via alternative means. Values calculated by this method include substantial conservatism, rendering it unnecessary to create additional conservatism via the σ_I term. Consequently, for MNGP ART calculations, σ_I is set equal to zero unless the Initial RT_{NDT} for the component in question is estimated directly from measured data.
2. The copper content of the MNGP upper intermediate RPV shell plates is not documented. RG1.99 states that in cases where chemical composition is unknown, a conservative value of 0.35% copper may be used [1]. This approach is used herein to evaluate the ART values for the upper intermediate plates.
3. The Initial RT_{NDT} values listed in Tables 5-1 and 5-2 of Reference [11] are calculated by one of four different methods, as described in the footnotes accompanying the tables. In many cases, the values reported in Reference [11] have been conservatively increased from the estimated value. Additionally, multiple evaluation methods are often applicable for a particular RPV component. All of the methods are valid, so it is assumed that the minimum initial RT_{NDT} value reported for each component may be used for the ART evaluation. The values obtained by application of this assumption are consistent with those in MNGP's licensing basis documents.
4. Documentation of the copper content of the MNGP N-2 nozzles in unavailable. However, this information is available for beltline nozzles at other BWR plants. Section 3.2 of Reference [13] offers an estimate of the copper content in nozzle forgings by means of statistical evaluation of available industry forging data. It is assumed that this approach is conservative and therefore applicable for the purposes of MNGP ART calculations.
5. MNGP intends to implement EPU after the Spring 2011 refueling outage. In order to calculate future fluence values, it is necessary to calculate the EFPY for which the RPV is exposed to pre-EPU flux. Based on MNGP's operational history [15], an 81% cumulative load factor is assumed from MNGP startup up to April of 2011 (approximate end of the next refueling outage). Thus, the EFPY corresponding to the end of the next refueling outage (41.25 years, from December 1970 to April 2011) is 33.4 (see Appendix A).
6. Intermediate fluence values are calculated for 36 and 40 EFPY. Reference [5] adds a 30% factor on the flux to account for unknown future operation. In projecting the fluence at 36 and 40 EFPY, this factor is removed from pre-EPU fluence calculations. Past operation is assumed to be bounded by pre-EPU flux without the 1.3 bounding factor.

5.0 CALCULATIONS

The methodology in Section 2.0 is used to evaluate the ART and ΔRT_{NDT} values for MNGP, based on the design inputs in Section 3.0 and consistent with the assumptions in Section 4.0. The fluence estimates calculated in Appendix A and presented in Table A-1 are applied where appropriate. The design inputs, intermediate calculations, and resultant ART values are provided for 36 EFPY in Table 1, 40 EFPY in Table 2, and 54 EFPY in Table 3.

6.0 CONCLUSIONS

This document contains ART and ΔRT_{NDT} values calculated in accordance with RG1.99 [1] for all MNGP plates, welds, and forgings exposed to fluence greater than $1.0x10^{17}$ n/cm^2. Design inputs are collected from a variety of sources, as discussed in Section 3.0. The calculated ART and ΔRT_{NDT} values are provided for 36 EFPY in Table 1, 40 EFPY in Table 2, and 54 EFPY in Table 3.

The bounding ART value for the RPV plates and welds is 147.4 °F at 36 EFPY, 156.0 °F at 40 EFPY, and 186.6 °F at 54 EFPY. The ART value for the N-2 nozzles is 106.1 °F at 36 EFPY, 110.0 °F at 40 EFPY, and 125.2 °F at 54 EFPY.

Table 1: ART Values for MNGP RPV Components at 36 EFPY

Description	Heat No.	Lot Number	Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_I (°F)	ART_{NDT} (°F)
Upper/Int Shell I-12	C2089-1	N/A	0.0	0.35	0.50	199.50	28.0	14.0	0.0	56.1
Upper/Int Shell I-13	C2613-1	N/A	27.0	0.35	0.49	198.25	27.9	13.9	0.0	82.7
Lower/Int Shell I-14	**C2220-1**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**103.4**	**8.5**	**0.0**	**147.4**
Lower/Int Shell I-15	**C2220-2**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**103.4**	**8.5**	**0.0**	**147.4**
Lower Shell I-16	A0946-1	N/A	27.0	0.14	0.56	98.20	47.3	17.0	0.0	108.3
Lower Shell I-17	C2193-1	N/A	0.0	0.17	0.50	118.50	57.1	17.0	0.0	91.1

Description	Heat No.	Filler Material	Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_I (°F)	ART_{NDT} (°F)
Limiting Weld - Beltline	**-**	**E8018N**	**-65.6**	**0.10**	**0.99**	**134.90**	**77.5**	**28.0**	**12.7**	**73.4**

Description	Heat No.	Plate Location	Initial RT_{NDT} (°F)	Chemistry Cu (wt %)	Chemistry Ni (wt %)	Chemistry Factor (°F)	Adjustments For 1/4t ΔRT_{NDT} (°F)	Margin Terms σ_Δ (°F)	Margin Terms σ_I (°F)	ART_{NDT} (°F)
Bounding N-2 Nozzle	**E21VW**	**Plate I-16 / I-17**	**40.0**	**0.18**	**0.86**	**141.90**	**32.1**	**16.0**	**0.0**	**104.1**

Fluence Data

Location	Wall Thickness (in) Full	Wall Thickness (in) 1/4t	Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence at 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28 - 0.10 \log f)}$
Upper/Int Shell I-12	5.063	1.266	1.97E+17	0.738	1.454E+17	0.141
Upper/Int Shell I-13	5.063	1.266	1.97E+17	0.738	1.454E+17	0.141
Lower/Int Shell I-14	5.063	1.266	2.77E+18	0.738	2.044E+18	0.575
Lower/Int Shell I-15	5.063	1.266	2.77E+18	0.738	2.044E+18	0.575
Lower Shell I-16	5.063	1.266	1.85E+18	0.738	1.365E+18	0.482
Lower Shell I-17	5.063	1.266	1.85E+18	0.738	1.365E+18	0.482
Limiting Weld - Beltline	5.063	1.266	2.77E+18	0.738	2.044E+18	0.575
Bounding N-2 Nozzle	5.063	1.266	4.27E+17	0.738	3.151E+17	0.226

Table 2: ART Values for MNGP RPV Components at 40 EFPY

Description	Heat No.	Lot Number	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
				Cu (wt %)	Ni (wt %)		ΔRT_{NDT} (°F)	Margin Terms		ART_{NDT} (°F)
								σ_Δ (°F)	σ_i (°F)	
Upper/Int Shell I-12	C2089-1	N/A	0.0	0.35	0.50	199.50	31.0	15.5	0.0	61.9
Upper/Int Shell I-13	C2613-1	N/A	27.0	0.35	0.49	198.25	30.8	15.4	0.0	88.6
Lower/Int Shell I-14	**C2220-1**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**112.0**	**8.5**	**0.0**	**156.0**
Lower/Int Shell I-15	**C2220-2**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**112.0**	**8.5**	**0.0**	**156.0**
Lower Shell I-16	A0946-1	N/A	27.0	0.14	0.56	98.20	51.9	17.0	0.0	112.9
Lower Shell I-17	C2193-1	N/A	0.0	0.17	0.50	118.50	62.7	17.0	0.0	96.7
Description	**Heat No.**	**Filler Material**	**Initial RT_{NDT} (°F)**	**Chemistry**		**Chemistry Factor (°F)**	**Adjustments For 1/4t**			
				Cu (wt %)	**Ni (wt %)**		**ΔRT_{NDT} (°F)**	**Margin Terms**		**ART_{NDT} (°F)**
								σ_Δ (°F)	**σ_i (°F)**	
Limiting Weld - Beltline	**-**	**E8018N**	**-65.6**	**0.10**	**0.99**	**134.90**	**83.9**	**28.0**	**12.7**	**79.8**
Description	**Heat No.**	**Plate Location**	**Initial RT_{NDT} (°F)**	**Chemistry**		**Chemistry Factor (°F)**	**Adjustments For 1/4t**			
				Cu (wt %)	**Ni (wt %)**		**ΔRT_{NDT} (°F)**	**Margin Terms**		**ART_{NDT} (°F)**
								σ_Δ (°F)	**σ_i (°F)**	
Bounding N-2 Nozzle	**E21VW**	**Plate I-16 / I-17**	**40.0**	**0.18**	**0.86**	**141.90**	**36.0**	**17.0**	**0.0**	**110.0**

Fluence Data

Location	Wall Thickness (in)		Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence at 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28 - 0.10 \log f)}$
	Full	1/4t				
Upper/Int Shell I-12	5.063	1.266	2.30E+17	0.738	1.698E+17	0.155
Upper/Int Shell I-13	5.063	1.266	2.30E+17	0.738	1.698E+17	0.155
Lower/Int Shell I-14	5.063	1.266	3.36E+18	0.738	2.48E+18	0.622
Lower/Int Shell I-15	5.063	1.266	3.36E+18	0.738	2.48E+18	0.622
Lower Shell I-16	5.063	1.266	2.28E+18	0.738	1.683E+18	0.529
Lower Shell I-17	5.063	1.266	2.28E+18	0.738	1.683E+18	0.529
Limiting Weld - Beltline	5.063	1.266	3.36E+18	0.738	2.48E+18	0.622
Bounding N-2 Nozzle	5.063	1.266	5.23E+17	0.738	3.86E+17	0.254

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Table 3: ART Values for MNGP RPV Components at 54 EFPY

Description	Heat No.	Lot Number	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
				Cu (wt %)	Ni (wt %)		ΔRT_{NDT} (°F)	Margin Terms		ART_{NDT} (°F)
								σ_Δ (°F)	σ_I (°F)	
Upper/Int Shell I-12	C2089-1	N/A	0.0	0.35	0.50	199.50	43.8	17.0	0.0	77.8
Upper/Int Shell I-13	C2613-1	N/A	27.0	0.35	0.49	198.25	43.5	17.0	0.0	104.5
Lower/Int Shell I-14	**C2220-1**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**142.6**	**8.5**	**0.0**	**186.6**
Lower/Int Shell I-15	**C2220-2**	**N/A**	**27.0**	[redacted]	[redacted]	[redacted]	**142.6**	**8.5**	**0.0**	**186.6**
Lower Shell I-16	A0946-1	N/A	27.0	0.14	0.56	98.20	68.2	17.0	0.0	129.2
Lower Shell I-17	C2193-1	N/A	0.0	0.17	0.50	118.50	82.3	17.0	0.0	116.3

Description	Heat No.	Filler Material	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
				Cu (wt %)	Ni (wt %)		ΔRT_{NDT} (°F)	Margin Terms		ART_{NDT} (°F)
								σ_Δ (°F)	σ_I (°F)	
Limiting Weld - Beltline	**-**	**E8018N**	**-65.6**	**0.10**	**0.99**	**134.90**	**106.9**	**28.0**	**12.7**	**102.8**

Description	Heat No.	Plate Location	Initial RT_{NDT} (°F)	Chemistry		Chemistry Factor (°F)	Adjustments For 1/4t			
				Cu (wt %)	Ni (wt %)		ΔRT_{NDT} (°F)	Margin Terms		ART_{NDT} (°F)
								σ_Δ (°F)	σ_I (°F)	
Bounding N-2 Nozzle	**E21VW**	**Plate I-16 / I-17**	**40.0**	**0.18**	**0.86**	**141.90**	**51.2**	**17.0**	**0.0**	**125.2**

Fluence Data

Location	Wall Thickness (in)		Fluence at ID (n/cm^2)	Attenuation, 1/4t $e^{-0.24x}$	Fluence at 1/4t (n/cm^2)	Fluence Factor, FF $f^{(0.28 - 0.10 \log f)}$
	Full	1/4t				
Upper/Int Shell I-12	5.063	1.266	4.06E+17	0.738	2.996E+17	0.219
Upper/Int Shell I-13	5.063	1.266	4.06E+17	0.738	2.996E+17	0.219
Lower/Int Shell I-14	5.063	1.266	6.43E+18	0.738	4.746E+18	0.792
Lower/Int Shell I-15	5.063	1.266	6.43E+18	0.738	4.746E+18	0.792
Lower Shell I-16	5.063	1.266	4.46E+18	0.738	3.292E+18	0.694
Lower Shell I-17	5.063	1.266	4.46E+18	0.738	3.292E+18	0.694
Limiting Weld - Beltline	5.063	1.266	6.43E+18	0.738	4.746E+18	0.792
Bounding N-2 Nozzle	5.063	1.266	1.01E+18	0.738	7.454E+17	0.361

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Appendix A:

FLUENCE CALCULATION

METHODOLOGY

Reference [5] presents the peak fluence at the RPV inside surface for 54 EFPY, which is applicable until the end of MNGP's extended operation period (60 years). This peak fluence value is calculated using both the pre-EPU and post-EPU flux, with EPU implementation conservatively modeled at 28.82 EFPY [5]. Therefore, a linear interpolation of intermediate fluence values (i.e. 36 EFPY and 40 EFPY) based on 0 EFPY and 54 EFPY is overly conservative. Additionally, Reference [5] does not report specific fluence values for the RPV beltline components (i.e. shell plates, welds, and nozzles). The peak fluence at 54 EFPY is overly conservative for locations with an accumulated fluence nearer to the lower bound value of 1.0×10^{17} n/cm^2 in Reference [1]. Therefore, elevation-specific fluence values are calculated at 36 EFPY, 40 EFPY, and 54 EFPY in this Appendix. Note that the flux values in Reference [5] are calculated in accordance with NRC Regulatory Guide 1.190 [16].

The calculated peak fluence values at the RPV inner surface [5, 17] include an additional factor (*F*) of 1.3 to account for potential variation in future operation. In reproducing the 54 EFPY fluence values below, this factor is conservatively applied to both pre-EPU and post-EPU operation, consistent with Reference [5]. However, for the intermediate fluence calculations at 36 EFPY and 40 EFPY, this factor is only applied to the post-EPU fluence calculation (i.e. future operation). Past operation is assumed to be bounded by the pre-EPU flux {6, Section 4.0}.

The fluence calculations for MNGP follow these steps:

1. Benchmark the 54 EFPY peak fluence value calculated in Reference [5].
2. Calculate peak fluence for intermediate EFPY
3. Calculate location specific fluence for intermediate EFPY

DESIGN INPUT

The following inputs are required to calculate the intermediate fluence values:

- Current availability: MNGP's cumulative load factor was 80.6% at the end of 2009 [15]. A cumulative load factor of 81% is assumed up to the next scheduled refueling outage {5, Section 4.0}. Based on a total of 41.25 years of operation (December 1970 to April 2011), the EFPY at the next scheduled refueling outage is taken as 33.4.
- Pre-EPU peak flux at RPV inner surface = 2.26×10^{9} n/cm^2-s [17, Section 3.1].
- Post-EPU peak flux at RPV inner surface = 3.70×10^{9} n/cm^2-s [5, Section 3.1].
- Pre-EPU axial distribution of relative flux at RPV inner surface at peak azimuth [17, Table A-2].
- Post-EPU axial distribution of relative flux at RPV inner surface at peak azimuth [5, Table A-2].
- The bounding elevations of various RPV components are obtained by selecting the location of highest fluence for a particular component. Elevation is given relative to bottom of active fuel (BAF) using RPV geometry information in Reference [7] and elevations given in Reference [19].

Elevations:

- Upper Intermediate Shell Plates = 158.6 inches
- Lower Intermediate Shell Plate (elevation not required, this component receives peak flux)
- Bounding Weld (elevation not required, this component receives peak flux)
- Lower Shell Plate = 27.1 inches
- N-2 Nozzles = -3.2 inches

CALCULATIONS

The following equation, which is consistent with the methodology of References [5 and 17], is used to calculate the fluence:

$$Fluence = \left[\left(flux \cdot EFPY \cdot F \cdot R_{flux}\right)_{pre-EPU} + \left(flux \cdot EFPY \cdot F \cdot R_{flux}\right)_{post-EPU}\right]\left(365.24 \cdot 24 \cdot 60^2\right)$$

Where:

flux = peak flux for either pre-EPU or post-EPU
EFPY = EFPY for either pre-EPU or post-EPU
F = factor to account for potential variation in operation
R_{flux} = relative flux, based on axial elevation above BAF

For 54 EFPY, the following values are used in the equation above:

<u>pre-EPU</u>
Flux = 2.26×10^9 n/cm^2-s
EFPY = 28.82 years
$F = 1.3$
<u>post-EPU</u>
Flux = 3.70×10^9 n/cm^2-s
EFPY = 25.18 years
$F = 1.3$

The R_{flux} term is dependent on both axial elevation above BAF and operating condition (i.e. pre-EPU or post-EPU). Therefore, fluence values are calculated for a range of elevations. A peak fluence value of 6.436×10^{18} n/cm^2 is obtained at an elevation of 80.95 inches above BAF, which compares well to the value of 6.43×10^{18} n/cm^2 calculated in Reference [5]. In order to maintain consistency with the peak end-of-life fluence, the elevation-specific fluence calculations at 54 EFPY use the inputs given above.

For 36 EFPY, the process above is repeated using the following:

pre-EPU
Flux = $2.26\text{x}10^9$ n/cm^2-s
EFPY = 33.4 years
$F = 1$
post-EPU
Flux = $3.70\text{x}10^9$ n/cm^2-s
EFPY = 2.6 years
$F = 1.3$

For 40 EFPY, the process is identical except that the post-EPU EFPY is 6.6 years.

The results of the fluence calculations are presented in Table A-1. Calculation details are provided in the Excel spreadsheet *1000847.301.R1 Supporting File.xls*, which is included with the electronic supporting files for this calculation package.

Table A-1: Fluence Values for RPV Components

RPV Component	Component Fluence		
	36 EFPY	**40 EFPY**	**54 EFPY**
	n/cm²	*n/cm²*	*n/cm²*
Upper Intermediate Shell Plates (I-12 and I-13)	$1.97\text{x}10^{17}$	$2.30\text{x}10^{17}$	$4.06\text{x}10^{17}$
Lower Intermediate Shell Plates (I-14 and I-15)	$2.77\text{x}10^{18}$	$3.36\text{x}10^{18}$	$6.43\text{x}10^{18}$
Lower Shell Plates (I-16 and I-17)	$1.85\text{x}10^{18}$	$2.28\text{x}10^{18}$	$4.46\text{x}10^{18}$
Limiting Weld	$2.77\text{x}10^{18}$	$3.36\text{x}10^{18}$	$6.43\text{x}10^{18}$
N-2 Nozzles	$4.27\text{x}10^{17}$	$5.23\text{x}10^{17}$	$1.01\text{x}10^{18}$