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April 9, 2020

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

Nine Mile Point Nuclear Station, Unit 2
Renewed Facility Operating License No. NPF-69
NRC Docket No. 50-410

Subject: Submittal of Analytical Evaluation of Recirculation Discharge Nozzle-to-Safe End Weld Indication

In accordance with the American Society of Mechanical Engineers (ASME) Code, Section XI, 2013 Edition, IWB-3134(b) ("Review by Authorities"), Nine Mile Point Nuclear Station, Unit 2 is submitting an analytical evaluation associated with the recirculation discharge (reactor pressure vessel inlet) nozzle-to-safe end weld (N2J).

As discussed in the attached report, an analytical evaluation of an indication was performed to disposition an indication associated with one of the recirculation discharge (reactor pressure vessel inlet) nozzle-to-safe end weld (N2J). The indication is circumferentially oriented, measured by ultrasonic testing to be approximately 6.1 inches long, 0.3 inches through wall, and a surface separation distance of 0.5 inches from the outside surface. The indication is located at the weld centerline (nozzle side), which would place it in the weld material. This is an embedded flaw and does not contain any characteristics of an IGSCC flaw. Instead, this is likely a construction flaw that is now visible due to the change in ultrasonic examination technology. The nozzle-to-safe end weld is a dissimilar metal weld joining the low alloy steel nozzle to the stainless steel safe end with an Inconel 82 weld.

As concluded in this evaluation, the required safety factors will be maintained during operation with this indication over the next five operating cycles, by which time the weld/indication will be examined in accordance with BWRVIP-75A requirements.

There are no regulatory commitments in this letter.

If you have any questions concerning this letter, please contact Tom Loomis at (610) 765-5510.

Respectfully,

David T. Gudger

David T. Gudger
Senior Manager - Licensing
Exelon Generation Company, LLC

Attachment: Recirculation Inlet Nozzle DMW No. 2RPV-KB11 (N2J) Flaw Evaluation

cc: Regional Administrator, Region I, USNRC
USNRC Senior Resident Inspector, NMP
Project Manager USNRC, NMP
A. L. Peterson, NYSERDA

Attachment

Recirculation Inlet Nozzle DMW No. 2RPV-KB11 (N2J) Flaw Evaluation

File No.: **2000401.301**
Project No.: 2000401
Quality Program Type: ☒ Nuclear ☐ Commercial

CALCULATION PACKAGE

PROJECT NAME:
NMP2 N2J Nozzle Flaw Evaluation

CONTRACT NO.:
00609093, Release 120

CLIENT:
Exelon Generation

PLANT:
Nine Mile Point Nuclear Station, Unit 2

CALCULATION TITLE:
Recirculation Inlet Nozzle DMW No. 2RPV-KB11 (N2J) Flaw Evaluation

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 12 A-1 - A-2 Computer Files	Initial Issue	Richard Mattson 3/25/20	Charles Fourcade 03/25/20 Stan Tang 03/25/20 Do Jo Shim 03/25/20

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1.0 INTRODUCTION

Exelon Generation (Exelon) performed inspections of various dissimilar metal welds (DMWs) during the Spring 2020 refueling outage at the Nine Mile Point Nuclear Station, Unit 2 (NMP-2). A rejectable subsurface (embedded) non-service induced indication, which was seen in previous examinations, was reported during the inspection of the recirculation inlet nozzle DMW No. 2RPV-KB11 (N2J) in the recirculation system [1]. The flaw sizing reported during the Spring 2020 inspection was not acceptable in accordance with the acceptance standards of the ASME Code, Section XI, Subparagraph IWB-3514.4 [2]. Therefore, Exelon contracted Structural Integrity Associates, Inc. (SI) to perform an analytical flaw evaluation in accordance with the ASME Code, Section XI, Paragraph IWB-3640 [2].

2.0 OBJECTIVE

This calculation package documents the ASME Code, Section XI, Paragraph IWB-3640 [2] flaw evaluation of the indication reported in Weld No. 2RPV-KB11 (N2J) [1].

3.0 METHODOLOGY

The methods used for the flaw evaluation documented in this calculation package are described in ASME Code, Section XI:

- Paragraph IWB-3640,
- Nonmandatory Appendix A
- Nonmandatory Appendix C

Paragraph IWB-3640 [2] provides methods for analytical acceptance of flaws that are not acceptable in accordance with the acceptance standards of Paragraph IWB-3514 [2]. These methods are accepted by the U.S. Nuclear Regulatory Commission (NRC) in 10 CFR 50.55a [3].

Fatigue crack growth and allowable flaw size determination are performed using the methods of Nonmandatory Appendix C. The subsurface flaw linear elastic fracture mechanics model given in Nonmandatory Appendix A, Paragraph A-3300 [2] is used to calculate a range of stress intensity factor, ΔK_I, to be used with the fatigue crack growth (FCG) equation given in Nonmandatory Appendix C, Subsubarticle C-3210 and Subarticle C-8400 [2]. The fracture mechanics flaw evaluation is performed using the SI **pc-CRACK** software [4].

The following notes apply to the methods used for this calculation:

1. For the allowable flaw sizing, the primary membrane and bending piping stresses reported for the nozzle-to-safe end location (at nozzle N2J) [5, Table 3] are combined with the secondary stresses for each service level.
2. The yield and ultimate tensile strength material properties for the TP316L stainless steel replacement safe end [6, Page 8] are bounding (lower than the Alloy 82/182 DMW properties), and are therefore used for the allowable flaw size evaluation. The material properties are obtained from the 2013 Edition of the ASME Code, Section II, Part D [7].

3. The number of anticipated fatigue cycles applicable for the crack growth evaluation interval are obtained from Reference [8, Table 33], where 470 design cycles (12 cycles per year) will be used herein:

Transient	Design Cycles	60-year Cycles
Design Hydrotest	130	45
Startup/Turbine Roll-Shutdown/SVB	120	160
SCRAM: Other & Turbine Generator Trips	180	104
Design Seismic	10	1
Loss of Feedwater Pumps	30	45
TOTAL	470	355

4. The crack growth evaluation is performed using a bounding stress value (using the bounding stress intensity value, SINT, from the Stress Report [6]), and conservatively applied to all operating cycles shown above. Therefore, the bounding SINT is assumed to cycle 470 times over the original 40-year design life, equal to 118 cycles (rounded up to 120) per a 10-year operating interval.

4.0 ASSUMPTIONS

The following assumptions are used for the flaw evaluation documented in this calculation package:

1. To account for potential uncertainty in the UT measurement data, a value of 0.125 inch is added to the measured flaw depth, 2a (0.0625 inch added to each side of the flaw), and 0.75 inch is added to the measured flaw length (l).

2. The fracture mechanics model for a subsurface flaw in a plate is used for the fatigue crack growth evaluation. The model is consistent with ASME Code, Section XI, Appendix A methodology [4], and is therefore considered adequate to represent the subsurface flaw in a cylinder.

5.0 INPUTS

The following design inputs are used for this evaluation:

1. Initial Flaw Size: $2a_o$ = 0.276 in. [1] + 0.125 in. (assumed uncertainty)
   $2a_o$ = 0.401 in.
   l_o = 6.14 in. [1] + 0.75 in. (assumed uncertainty)
   l_o = 6.89 in.

2. Distance to Free Surface (Figure 1): S = 0.4485 in. (0.511 [1] - 0.125/2)

3. Flaw Orientation: Circumferential [1]

4. Flaw Location: In Alloy 82 weld material (not in fusion line)

5. Pipe Dimensions [5,9]: OD = 14.25 in.

   ID = 11.51 in. (using 1.37 in. [1] measured thickness)

   t = 1.37 in. (measured thickness [1])

6. TP316L Material Properties:

Yield Strength:	16.0 ksi at 550°F [7]
Ultimate Tensile Strength:	61.75 ksi at 550°F [7]
Flow Strength:	38.88 ksi at 550°F

7. Evaluation Interval: 10 years [assumed]

8. Fatigue Cycles in Evaluation Interval: 120 cycles [8] → Rounded 470/4 design cycles/10 years

9. Piping Loads: Obtained from [5, Table 3], as shown below.
   Bounding values for Service Levels A, B, C, and D

The following primary-plus-secondary piping loads are used in the allowable flaw size evaluation, along with the appropriate safety factors, for each Service Level [5, Table 3]:

Service Level	Case	Primary σ_m (ksi)	Primary σ_b (ksi)	Secondary S_e (1) (ksi)				SF_m (2)	SF_b (2)
				σ_m (ksi)	σ_b (ksi)	TE-1 (ksi)	Total (ksi)		
A	Prim2+Sec2	2.672	4.891	2.683	6.704	1.064	10.451	2.7	2.3
B	Prim2+Sec2	2.672	4.891	2.683	6.704	1.064	10.451	2.4	2.0
C	Prim10/12+Sec5	2.797	9.315	2.801	11.69 5	1.064	15.560	1.8	1.6
D	Prim10/12+Sec5	2.797	9.315	2.801	11.69 5	1.064	15.560	1.3	1.4

Notes: 1. S_e includes the addition of thermal expansion case TE-1 = 1.064 ksi. All stress values are increased by a factor of 1.4/1.37 since the stress results in Reference [5, Table 3] were determined for a thickness of 1.4 inches; whereas, this evaluation conservatively uses the 1.37 inch measured value [1].

2. From Section XI of the ASME Code, Paragraph C-2621 [2].

Per Reference [10, Section 4.1], the original design basis normal and upset temperatures and pressures are not exceeded under EPU operating conditions, and therefore, the original loads given above remain bounding. Per Reference [12, Page 3], the comparison ratio, New/Old, for all the Service Level C/D piping stresses and the snubber loads are less than 1.0. Therefore, the original stresses remain bounding for analysis.

10. The bounding normal/upset alternating SINT stress range of 38.1 ksi [6, Page 6] is used for the crack growth calculation, based on the updated stress analysis report [6]. The bounding S_n value (SINT = 38.1/2 = 19.1 ksi) is conservatively used to bound the needed axial stresses (due to thermal transient events) acting on the circumferential crack.

6.0 CALCULATIONS

Fatigue crack growth is performed to determine the flaw size at the end of the 10-year evaluation interval. The final flaw size is then compared to the allowable flaw size to determine acceptability.

6.1 Crack Growth

The fatigue crack growth analysis is performed to determine the final crack size for a 10-year evaluation period. The crack growth evaluation is performed using the SI **pc-CRACK** [4] fracture mechanics software. The bounding normal/upset SINT alternating stress range (38.1 ksi [6, page 6]) is conservatively used to calculate stress intensity factors, using the subsurface flaw model shown in Figure 2 (**pc-CRACK** Model 208). As shown in Figure 2, the K values are calculated at both Point 1 and Point 2 of the subsurface flaw. The higher K value from Point 1 and Point 2 is used for the crack growth calculation in the thickness direction. The crack growth in the length direction is assumed to be equal to the growth in the depth direction.

The normal/upset (Service Level A/B) stress used for the maximum stress state is, therefore, assumed to be +/-(19.1 ksi). The minimum stress state (to define the crack growth ΔK range) is represented by the negative value (-19.1 ksi) in order to maximize the stress range and ΔK.

The flaw model requires the following parameters:

- Initial half flaw depth, a_o = 0.201 in.
- Initial flaw length, l_o = 6.89 in.
- Wall thickness, t = 1.37 in.
- Eccentricity Ratio, 2e/t = 0.0526 (where e = 1.37/2 - {(0.8495+0.4485)/2} = 0.036), refer to Figure 1 and Figure 2. Note: UT flaw depths given at 0.511" and 0.787" [1] are modified to 0.4485" and 0.8495" (accounting for 0.125" assumed uncertainty on flaw size).
- Yield strength of Alloy 82/182 weld metal[1] = 30.1 ksi [7]
- Aspect ratio, a_o/l_o = 0.201/6.89 = 0.0291

The fatigue crack growth rate for Alloy 82/182 in air is based on NUREG/CR-6907 [11], which applied a factor of 2 on Alloy 600 fatigue crack growth in air. The crack growth is calculated using a Paris law for Alloy 600 in air (subsurface flaws) per ASME Code, Section XI, Paragraph C-8411 [2]:

$$da/dn = C_o(\Delta K)^n$$

[1] Yield strength of Alloy 82/182 is only used in calculating the plastic zone correction factor to calculate the stress intensity factor of a subsurface crack in the Alloy 82/182 material.

where, $n = 4.1$ [2, C-8411(b)]

$C_o = C_T S_R S_{ENV}$

$C_T = 2.606\times10^{-12} + 7.06\times10^{-15}\times(T) - 3.080\times10^{-17}\times(T)^2 + 4.327\times10^{-20}\times(T)^3$

$S_R = (1 - 0.82R)^{-2.2}$

$S_{ENV} = 1$ [2, C-8411(b)]

An R-ratio of 0.9 (which conservatively assumes the upper bound value given in [2, Figure C-8410-1]) is assumed for calculation of S_R. Normal operating temperature of T = 550°F is used to calculate C_T. An additional factor of 2 is applied to the crack growth C_o term of the Alloy 600 growth rate, per NUREG/CR-6907 [11, Section 5.1], to account for the Alloy 82/182 weld metal.

Therefore,

$$C_o = 2 \times 8.32382\text{x}10^{-11} = 1.66476\text{x}10^{-10}$$

$$da/dn = 1.66476\text{x}10^{-10}(\Delta K)^{4.1}$$

The crack growth is performed using the defined number of cycles in Section 5.0 (120 cycles per 10 years, equivalent to 12 cycles per year), and the flaw model shown in Figure 2. At the end of the 10-year evaluation period, the crack growth results in a final crack depth of a_f = 0.246 in. ($2a_f$ = 0.492 in.), and final crack length of l_f = 6.981 in. (6.89 + 0.091), assuming that the same amount of crack growth occurs in the length direction as in the depth direction.

6.2 Allowable Flaw Size

Calculations for the allowable flaw size are performed in Excel spreadsheet Nine_Mile_Recirc_N2J.xls". The appropriate membrane, bending, and secondary stresses are used to evaluate the flaw acceptability. Per ASME Code, Section XI, Paragraph C-4210 and Figure C-4210-1 [2], Article C-6000 methodology is applied, since Alloy 82/182 welds are assumed flux welds. Tables C-5310-1 through C-5310-5 are used along with a Z-factor load multiplier from Subsubarticle C-6330:

For Alloy 82/182 weld metal:

$Z = 2.2 \text{ x}10^{-6}(D)^3 - 2.0 \text{ x}10^{-4}(D)^2 + 0.0064*(D) + 1.1355$ (for 8 in. < D ≤ 40 in.)

Hence, for an outside pipe diameter (D) of 14.25 in., Z = 1.192.

The allowable flaw size is tabulated in Table 1, for a range of flaw depths and lengths for each Service Level. Note that the flow stress of TP316L stainless steel (38.88 ksi) was used in calculating the allowable flaw size per Subparagraph C-6330(c).

7.0 RESULTS OF ANALYSIS

The calculations contained herein use conservative methods in which the bounding stresses for Service Levels A, B, C, and D are used with the most limiting flaw acceptance tables of ASME Code, Section XI, Nonmandatory Appendix C, Table C-5310-1 [2]. A conservative approach is used in which the bounding stress (SINT stress from the stress and fatigue analysis) is treated as pure membrane stress and assumed to apply for all fatigue cycles for calculation of fatigue crack growth. Further, the design number of fatigue cycles is conservatively used, rather than actual projected cycles. The results documented in this calculation package are considered to be a bounding treatment for all applicable service levels.

The crack growth was performed for a 10-year interval. The initial flaw size ($2a_o$= 0.401", l_o = 6.89") grows to $2a_f$ = 0.492 in. and l_f = 6.981 in. The flaw remains subsurface, since S > 0.4a per Reference [2, Figure IWB-3610-1], as follows:

S = 0.4485 – (0.492 - 0.401)/2 = 0.403" (nearest flaw edge to OD surface; refer to Figure 1)

$0.4a_f$ = 0.098".

Hence, $S > 0.4a_f$

The results show that the allowable flaw depth to thickness ratio, 2a/t, for an end-of-interval (EOI) flaw of length to pipe circumference ratio, $l_f/(\pi D)$ = 0.156, is 0.622, corresponding to $2a_{allowable}$ = 0.851 in. (bounding Service Level C; see Table 1). The EOI flaw depth to thickness ratio is $2a_f/t$ = 0.492/1.37 = 0.359, which is less than the allowable ratio of 0.622; therefore, the flaw reported in NMP-2 Weld No. 2RPV-KB11 (N2J) is acceptable for the desired evaluation interval of 10 years.

8.0 CONCLUSIONS

The flaw reported in the Nine Mile Point recirculation inlet DMW No. 2RPV-KB11 (N2J) is acceptable for an evaluation interval of at least 10 years. This flaw should be re-inspected at the end of the evaluation interval.

9.0 REFERENCES

1. General Electric Hitachi, UT Examination Summary Sheet, Report No. N2R17-APR-06, SI File No. 2000401.201.

2. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 2013 Edition.

3. 10 CFR 50.55a, Codes and Standards, December 02, 2015.

4. pc-CRACK 4.3, Version Control No. 4.3.0.0, Structural Integrity Associates, November 2019.

5. SI Calculation NMPC-17Q-301, Rev. 1, "Weld Overlay Design and Allowable Flaw Size Calculation for Recirculation Inlet Nozzles."

6. General Electric Stress Report 22A6593, Rev. 0, "Reactor Vessel–Recirculation Inlet Nozzle," SI File No. NMPC-17Q-201.

7. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section II, Part D, Materials, Properties (Customary), 2013 Edition.

8. SI Calculation 1500838.301, Rev. 0, "Environmentally Assisted Fatigue for NUREG/CR-6260 Locations."

9. Nozzle drawings, SI File No. 2000401.201.

10. General Electric Hitachi Design Specification 26A7561, Rev. 2, "Reactor Vessel–Extended Power Uprate," SI File No. 2000401.201.

11. NUREG/CR-6907 (ANL-04/3), Crack Growth Rates of Nickel Alloy Welds in a PWR Environment, May 2006.

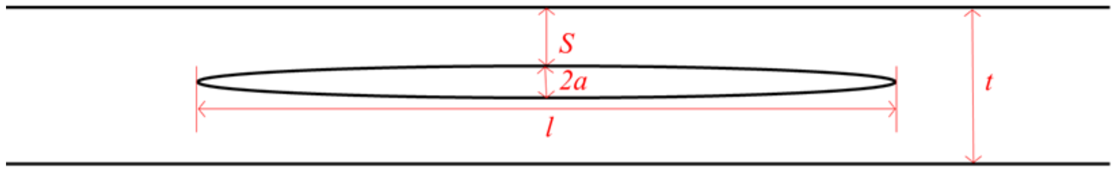
12. General Electric Hitachi, Report 0000-0098-7386-R0, "Assessment of the Effects of EPU Annulus Pressurization (AP) Amplified Response Spectra on the Recirculation Piping Systems", Revision 3, SI File No. 2000401.201.

Table 1. Allowable Flaw Size

Service Level	Ratio of Flaw Length to Pipe Circumference, $l_f/\pi D_o$							
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.75
	Flaw Length, l_f (degrees)							
	0	36	72	108	144	180	216	270
	Allowable Flaw Depth, 2a/t							
A	0.75	0.75	0.75	0.65	0.52	0.46	0.42	0.41
B	0.75	0.75	0.75	0.73	0.59	0.51	0.48	0.46
C	0.75	0.75	0.52	0.37	0.29	0.26	0.24	0.24
D	0.75	0.75	0.69	0.48	0.39	0.33	0.30	0.29

Service Level	Ratio of Flaw Length to Pipe Circumference, $l_f/\pi D_o$							
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.75
	Flaw Length, l_f (inches)							
	0.0	4.5	9.0	13.4	17.9	22.4	26.9	33.6
	Allowable Flaw Depth, 2a (inch)							
A	1.03	1.03	1.03	0.89	0.71	0.63	0.58	0.57
B	1.03	1.03	1.03	1.00	0.81	0.70	0.66	0.63
C	1.03	1.03	0.71	0.50	0.40	0.35	0.33	0.32
D	1.03	1.03	0.95	0.66	0.53	0.45	0.42	0.39

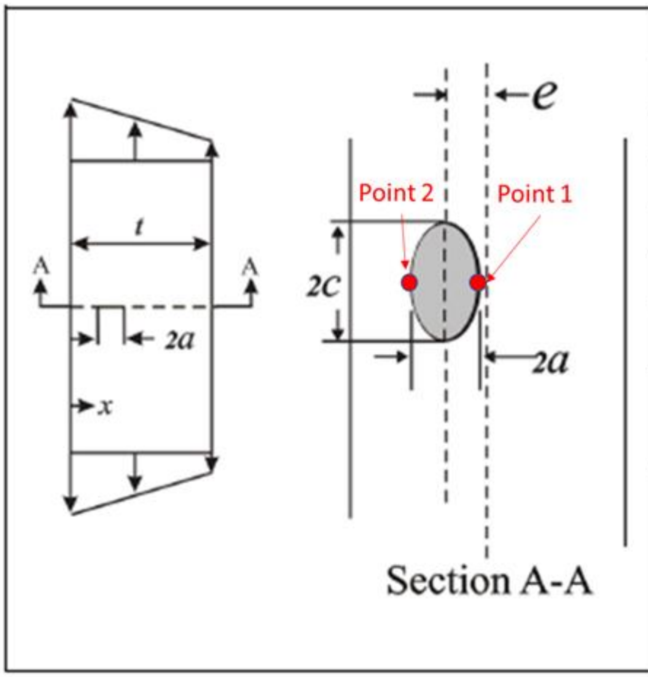
$$2a = 0.276 \text{ inch},\ \ l = 6.14 \text{ inch},\ \ t = 1.37 \text{ inch},\ \ S = 0.511 \text{ inch}$$



Note: To account for uncertainty, 0.75 inch is added to the flaw length (l), and 0.125 inch is added to the flaw depth (2a). Hence, the initial flaw size used in the present calculation is l_o = 6.89 inch and $2a_o$ = 0.401 inch, which gives S = 0.4485 inch

Figure 1. Measured Flaw Dimensions from UT Data [1]

Crack Model: 208 - Elliptical Subsurface Crack under Tension and Bending (ASME)



Stress/Load Input	
Stress Coefficients	✓
Coeffs. from Stress Table	×
Stress Table	×
Stress Intensity Factors (1D)	×
Stress Intensity Factors (2D)	×
$\sigma(x) = C_0 + C_1 x$	
Crack Dimensions: a Component Dimensions: t 2e/t a/l Other Inputs: YS	
Range: $0.0 < a/t < \text{Min}((0.95\text{-}2e/t)/2, 0.325)$ $0.0 < a/c \leq 1.0$ Source: [3]	

Figure 2. Fracture Mechanics Flaw Model

APPENDIX A

LIST OF SOFTWARE FILES

Structural Integrity Associates, Inc.
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Filename	Description
Nine_Mile_Recirc_N2J.xls	Excel spreadsheet containing allowable flaw size calculation
Sn_range.pcf	**pc-CRACK** database file
Sn_range.rpt	**pc-CRACK** result file