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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

Oyster Creek Nuclear Generating Station
Renewed Facility Operating License No. DPR-16
NRC Docket No. 50-219

Subject: Submittal of Analytical Evaluation for a Reactor Recirculation Line Weld

In accordance with the American Society of Mechanical Engineers (ASME) Code, Section XI, 1995 Edition through 1996 Addenda, IWB-3600 ("Analytical Evaluation of Flaws"), Oyster Creek Nuclear Generating Station is submitting an analytical evaluation of a circumferential indication found in reactor recirculation line weld NG-E-007 during regularly scheduled non-destructive examinations (NDE) conducted as part of the recent refueling outage. As noted in the attached evaluation, the reactor recirculation line weld NG-E-007 has been shown to be acceptable for continued operation as-is for the remainder of the current licensed plant life.

There are no new regulatory commitments contained in this letter.

If you have any questions or require additional information, please contact Tom Loomis (610-765-5510).

Respectfully,

Pamela B. Cowan

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Director - Licensing & Regulatory Affairs
Exelon Generation Company, LLC

cc: USNRC Region I, Regional Administrator
USNRC Senior Resident Inspector, OCNGS
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ATTACHMENT

Oyster Creek Nuclear Generating Station Reactor Recirculation Line Flaw Evaluation

Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 1001463.301

Project No.: 1001463

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Oyster Creek Recirculation Line Flaw Evaluation

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CLIENT:
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PLANT:
Oyster Creek Generating Station

CALCULATION TITLE:
Flaw Evaluation of Recirculation System Weld NG-E-007

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1.0 INTRODUCTION

A single circumferential indication has been identified in the Oyster Creek Generating Station (OCGS) Recirculation Line weld NG-E-007 during regularly scheduled Recirculation System non-destructive examinations (NDE) conducted as part of the 1R23 2010 refueling outage in-service inspection (ISI) scope [1]. The NG-E-007 weld is a similar metal weld joining a 26" nominal 90 degree wrought stainless steel elbow to a 26" nominal cast austenitic stainless steel (CASS) valve [1, 2].

2.0 OBJECTIVE

The purpose of this calculation is to perform a flaw evaluation of the reportable indication found in the NG-E-007 weld using the methods of the ASME Boiler and Pressure Vessel (B&PV) Code, Section XI, IWB-3600 [3].

3.0 METHODS

The flaw evaluation is performed using methods consistent with the ASME Code Section XI, IWB-3640 and Appendix C [3].

4.0 DESIGN INPUTS

This section identifies the design inputs used for the flaw evaluation.

4.1 Geometry

The nominal dimensions of the affected Recirculation system weld are summarized below:

Nominal OD at Weld:	26 inches [1]
Nominal Thickness:	1.2 inches [1]

4.2 Materials

The materials of the applicable system components are:

26" Elbow:	SA-403, WP-316NG [2]
26" Valve:	SA-351 - CF8M [2]
Weld Material:	ER308 [2]

4.3 Flaw Characterization

The flaw dimensions provided in Reference [1] are summarized below:

Length, *l*:	1.4 inches [1]
Depth, 2d:	0.3 inches [1]
Distance to surface, S:	0.08 inches [1]
Orientation:	Circumferential [1]
Location:	Heat Affected Zone (HAZ) on CASS side of weld [1].

Because of component geometry, the examinations of weld NG-E-007 were single-sided on the elbow side of the weld. No limitation of inspection of the flaw locations was noted in the NDE report on the elbow side of the weld. It is noted that the examination procedure used is not qualified for through-wall sizing of planar flaws detected on the far side of a weld [1]. The cast stainless steel valve body on the valve side of the weld is considered resistant to IGSCC. There has been no known IGSCC in cast austenitic stainless steel components in the BWR environment. The NRC has supported the fact that cast austenitic stainless steels are resistant to IGSCC in the BWR and has noted that welds joining cast pump and valve bodies to resistant piping are considered to be resistant weldments [6].

4.4 Loads

The loads applicable for this weld joint for the purposes of a circumferential flaw evaluation are:

Maximum Pressure: 1200 psig [4]

Reference [4] provides four sets of loads at the weld location; the bounding loads for all sets are selected for consideration in this analysis. The loads are excerpted from Reference [4] and listed in Table 1 below.

Table 1: Piping Loads for Recirculation Line Weld NG-E-007 [4].

		(Moments in ft-lb)					(Stress in psi		)
Point name	Load combination	Ma (Sus.)	Mb (Occ.)	Mc (Exp.)	S.I.F	Eq. no.	Load type	Code Stress	Code Allow.
AT2AN-	GR + Max P	12092			1.00	(11)	SUST	8238	17250
	Cold to T1			13005	1.00	(13)	DISP	335	27813
	Sus. + R1	12092	16673		1.00	(12)	OCC	8667	17250
	Sus. + R2	12092	26516		1.00	(12)	OCC	8921	20700
AT2AN+	GR + Max P	12092			2.30	(11)	SUST	8463	17250
	Cold to T1			13005	2.30	(13)	DISP	769	27813
	Sus. + R1	12092	16632		2.30	(12)	OCC	9201	17250
	Sus. + R2	12092	26464		2.30	(12)	OCC	9637	20700
AT2AN-	GR + Max P	12135			1.00	(11)	SUST	8239	17250
	Cold to T1			133148	1.00	(13)	DISP	3428	27813
AT2AN+	GR + Max P	12135			2.30	(11)	SUST	8465	17250
	Cold to T1			133148	2.30	(13)	DISP	7874	27813
AT2AN-	GR + Max P	12114			1.00	(11)	SUST	8239	17250
	Cold to T1			132464	1.00	(13)	DISP	3411	27813
AT2AN+	GR + Max P	12114			2.30	(11)	SUST	8464	17250
	Cold to T1			132464	2.30	(13)	DISP	7834	27813

AT2AN-	GR + Max P	12135		1.00	(11)	SUST	8239	17250
	Cold to T1		95829	1.00	(13)	DISP	2467	27813
AT2AN+	GR + Max P	12135		2.30	(11)	SUST	8465	17250
	Cold to T1		95829	2.30	(13)	DISP	5667	27813

Where:
- Gr is the Deadweight load [4]
- Max P is the maximum internal pressure [4]
- T1 is the normal operating thermal displacement load [4]
- R1 is the OBE load [4]
- R2 is the SSE load [4]
- Sus. is the summation of GR + Max P [4]

4.5 Applicable Codes

The applicable Codes for the affected weld are [2]:

Design Code : ASME B&PV Code Section I, 1965 Edition, ASA B31.1 1955

Repair/Replacement Code: ASME B&PV Code Section XI, 1995 Ed. through 1996 Addenda

4.6 Mitigation History

The affected weld joint was treated with Induction Heating Stress Improvement (IHSI) in 1986 [2].

This weld location is considered mitigated with respect to inter-granular stress corrosion cracking (IGSCC) with effective hydrogen and noble metal chemical addition (NMCA) [2] in addition to the beneficial effects of IHSI.

4.7 Remaining Design Life

OCGS is currently in the 41st year of operation of a 60 year licensed operating term [2].

5.0 ASSUMPTIONS

The following assumptions are conservatively made for this analysis:

1. The fatigue cycle assumed for this flaw evaluation is the full range of mechanical and thermal load specified as Gr + Max P + R2 + Cold to T1 [4]. This represents the summation of the deadweight, maximum internal pressure, Safe Shutdown Earthquake (SSE), and normal operating thermal expansion loads. This assumption is very conservative compared to the anticipated thermal transients for the system such as a sudden start of a cold recirculation loop in that the entire pressure, deadweight, thermal, and seismic loads are being treated as a membrane stress cycle.
2. 100 fatigue cycles are conservatively assumed to occur over the remainder 19 years of plant operation. This assumption is conservative since it assumes approximately 11 startup-shutdown cycles occur every two year operating period and that a seismic event occurs during every startup-shutdown cycle.
3. The weld is conservatively assumed to be applied using a submerged arc weld (SAW) process.

6.0 ANALYSIS

The flaw evaluation is performed using the MathCAD computer program. The equations and results of the evaluation are contained in Appendix A. The MathCAD file used to perform the evaluation is archived in the project records.

The following bounding loads are selected from Table 1 and Reference [4]:

Max Pressure:	1200 psig.
Sustained Loads:	12,135 ft-lbs.
Occasional Loads (OBE or R1):	16,673 ft-lbs.
Occasional Loads (SSE or R2):	26,516 ft-lbs.
Thermal Loads:	133,148 ft-lbs.

The following stresses are selected from Table 1 and Reference [4]:

Sustained (P_m):	8465 psi
Sustained + R1 (P_m+P_b):	9201 psi
Sustained + R2 (P_m+P_b):	9637 psi
Thermal (P_e):	3428 psi

Moments and calculated section properties are used to calculate stresses based on dimensions given in the NDE report [1]. The bounding stresses based upon those listed in Table 1 [4] and calculated in this analysis are used for the flaw evaluation.

Since the flaw is embedded and the materials are resistant to IGSCC no specific credit for IGSCC mitigation is credited in this analysis; it is mentioned in the design inputs section for completeness.

7.0 RESULTS

The end-of-evaluation interval flaw size is conservatively calculated to be:

2a	= 0.324 inches	(Note: The FCG calculation shown in Appendix A is conservatively performed by treating the flaw as an edge crack; therefore, these results are applicable to the case where the flaw is conservatively treated as an ID connected flaw as well.)
l	= 1.424 inches	
S	= 0.068 inches	(Note: This exceeds the Figure IWA-3310-1 flaw proximity criteria; therefore, the flaw remains an embedded flaw at the end of the evaluation interval; S > 0.4a, where 0.4a = 0.065)

For an end-of-interval flaw length less than or equal to 8.2 inches, the allowable flaw size is controlled by the ASME XI upper limit of flaw depth to pipe thickness ratio of 0.75; therefore, the allowable flaw size is:

$a_{allowable} = 0.75(1.2) = 0.9$ inches

The margin on allowable flaw size, whether the flaw is treated as an embedded flaw or an ID connected flaw is 0.9/0.324 = 2.78.

The margin on flaw length for which the allowable flaw size is applicable is 8.2/1.424 = 5.76.

It is important to note that although the NDE procedure used for sizing of the indication is not qualified for through-wall sizing for the location of the indication, this analysis shows substantial margin to the ASME Code Section XI allowable flaw size even considering the very conservative assumptions used for fatigue crack growth calculations. Since the flaw exists in the HAZ in the CASS adjacent to the weld material, both of which are not susceptible to inter-granular stress corrosion cracking (IGSCC), IGSCC would not be a relevant crack growth mechanism even if the flaw were argued to be connected to the inside surface of the pipe (ID connected). It should also be noted that the affected weld location had an IHSI treatment in 1986 and has effective hydrogen water chemistry (HWC) and NMCA; thus, there are also two mitigation techniques which have been applied at this location. Further, the very conservative fracture mechanics model used to calculate the applied stress intensity factor bounds the stress intensity factor which would be calculated if the flaw were treated either as an embedded flaw in a pipe or as an ID connected flaw in a pipe. Consequently, the conclusions of this flaw evaluation are considered conservative and bounding whether the flaw is treated as a subsurface or surface flaw and despite the lack of a qualified through-wall sizing procedure.

8.0 CONCLUSIONS

The OCGS Recirculation System weld NG-E-007 is shown to be acceptable for continued operation as-is, with the indication reported in Reference [1] for the remainder of the current licensed plant life. The flaw remains an embedded flaw for the entire evaluation period.

9.0 REFERENCES

1. General Electric – Hitachi Nuclear Energy, Americas NDE Examination Report excerpts provided in Exelon Transmittal of Design Information (TODI) 1141202-06, November 18, 2010. SI File No. 1001463.201.
2. Exelon Transmittal of Design Information (TODI) 1141202-06, November 18, 2010. SI File No. 1001463.201.
3. American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, 1995 Edition with Addenda through 1996.
4. Excerpts from Exelon Nuclear Design Analysis No. C-1302-223-E540-036, Rev. 3a., "OC NSR Piping Analysis – Recirculation Loop E,", provided in Exelon Transmittal of Design Information (TODI) 1141202-06, November 18, 2010. SI File No. 1001463.201.
5. Tada, Hiroshi, Paris, Paul C., Irwin, George R., The Stress Analysis of Cracks Handbook, 3rd Ed. ASME Press, 2000.
6. Koo, W. H., Hazelton, W. H., "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," U. S. Nuclear Regulatory Commission, NUREG 0313, Rev. 2.

APPENDIX A: MATHCAD FLAW EVALUATION ANALYSIS

DESIGN INPUTS:

Input Loads:

$P := 1200$ psig

$DW := 12135$ ft-lbs

$OBE := 16673$ ft-lbs

$SSE := 26516$ ft-lbs

$T1 := 133148$ ft-lbs

Geometry:

$OD := 26$ in

$t := 1.2$ in

Flaw Characterization:

$d := 0.15$ $2d = 0.3$ in

$l := 1.4$ in

$S := 0.08$ in

Material Properties:

$Sm := 17000$ psi Taken at 550 F, minimum for elbow, valve and weld material obtained for SA-403, WP-316LN.

ANALYSIS:

Per the flaw proximity criteria given in Figure IWA-3310-1, the flaw must be considered a surface flaw if S < 0.4d, where d is the half depth of the flaw.

$0.4d = 0.06$ thus, S=0.08 is greater than 0.4d=0.06. The flaw can be treated as a subsurface flaw.

Since the indication is in the heat affected zonce (HAZ) of a 26" austenitic stainless steel pipe to cast austenitic stainless steel valve weld, the methods of IWB-3640 are used for the flaw evaluation. The allowable end of evaluation period flaw depth to thickness ratio for circumferentia flaws is obtained from Table IWB-3641-1 for normal operating conditions and from Table IWB-3641-2 for emergency and faulted conditions.

Assuming the weld process is a SAW process a Z factor per Table IWB-3641-1 and -2 is calculated:

$Z := 1.3 \cdot [1 + 0.010(OD - 4)]$ $\qquad Z = 1.586$

Section properties of the pipe location are:

$$A := \pi \cdot \frac{OD^2 - (OD - 2 \cdot t)^2}{4} \qquad A = 93.494 \quad in^2$$

$$Zm := \pi \cdot \frac{OD^4 - (OD - 2 \cdot t)^4}{64} \cdot \frac{2}{OD} \qquad Zm = 554.202 \quad in^3$$

$$Pm := \frac{P}{A} \cdot \pi \cdot \frac{(OD - 2t)^2}{4} \qquad Pm = 5615 \quad psi$$

$$Pb1 := \frac{(DW + OBE) \cdot 12}{Zm} \qquad Pb1 = 624 \quad psi$$

$$Pb2 := \frac{(DW + SSE) \cdot 12}{Zm} \qquad Pb2 = 837 \quad psi$$

$$Pe := \frac{T1 \cdot 12}{Zm} \qquad Pe = 2883 \quad psi$$

The stresses reported in [4] bound those calculated here indicating that additional conservatisms have been applied in the existing piping analysis; therefore, the Reference [4] stresses are used for the flaw evaluation:

$Pm := 8465$ psi

$Pb := 9637 - Pm$ $\qquad Pb = 1172$ psi $\qquad$ SSE values are conservatively used here.

$Pe := 3428$ psi

The stress ratio is: $SR := \frac{Z}{Sm} \cdot \left(Pm + Pb + \frac{Pe}{2.77} \right)$ $\qquad SR = 1.015$

The stress ratio is calculated using SSE loads and is used for both the Level A/B and Level C/D checks.

The flaw length to pipe circumference ratio is: $\frac{1}{\pi OD} = 0.017$

From Table IWB-3641-1, for a $l/\pi D$ ratio = 0.1, and a stress ratio of 1.1, the allowable flaw depth to thickness ratio 2a/t = 0.75.

From Table IWB-3641-2, for a $l/\pi D$ ratio = 0.1, and a stress ratio of <1.2, the allowable flaw depth to thickness ratio 2a/t = 0.75.

The normal/upset conditions are bounding for allowable flaw length and the 75% criteria controls the allowable flaw depth.

Considering the allowable flaw depth to thickness ratio of 0.75, this gives an allowable, end-of-interval flaw size, 2a of:

$$a := \frac{0.75 \cdot t}{2} \qquad a = 0.45 \qquad 2a = 0.9 \quad \text{in}$$

For the purposes of this flaw evaluation a conservative simplified flaw model will be used to calculate the applied stress intensity factor at the crack tip for calculation of expected fatigue crack growth. Rather than using an embedded flaw model, the single edge notch test specimen model [5, pg. 52] is used to determine a conservative K_I estimate for the FCG calculation; thus,

$$KI = F\sigma \cdot \sqrt{\pi a}$$

Where: $\sigma := Pm + Pb + Pe \qquad \sigma = 13065$ psi

$a\_d := 0.38$ in, conservative flaw size for FCG in depth direction, assumed as ID connected flaw

$F\_d := 1.8$ conservatively obtained for an a/b=0.38/1.2=0.32 [5, pg. 52]

$$KI\_d := F\_d \cdot \sigma \cdot \sqrt{\pi a\_d} \qquad KI\_d = 25695 \qquad psi \cdot in^{0.5}$$

This value is taken as the full range of the stress intensity factor, ΔK_I

Now, FCG can be conservatively calculated using the FCG correlations for austenitic materials in air given in C-3210:

$n := 3.3$

$T := 550$ F

$$C := 10^{\left(-10.009 + 8.12 \cdot 10^{-4} \cdot T - 1.13 \cdot 10^{-6} \cdot T^2 + 1.02 \cdot 10^{-9} \cdot T^3\right)} \qquad C = 1.843 \times 10^{-10}$$

R is conservatively assumed = 1.0 to bound all effects of residual stresses.

$$S := -43.35 + 57.97 \cdot 1 \qquad S = 14.62$$

$$dadn\_d := C \cdot S \cdot \left(\frac{KI\_d}{1000}\right)^n \qquad dadn\_d = 1.21 \times 10^{-4} \quad \frac{in}{cycle}$$ depth direction

The FCG predicted at each tip over the remainder of the plant life is:

$da\_d := dadn\_d \cdot 100 \qquad da\_d = 0.0121\ \text{in}$ in depth direction

Adding this FCG to each tip of the flaw (in the length and depth directions) gives an end of evaluation interval flaw size of:

$af := d + da\_d \qquad 2 \cdot af = 0.324 \quad \text{in}$

$lf := l + 2 \cdot da\_d \qquad lf = 1.424 \quad \text{in}$

The final flaw depth, 2af, remains less than the allowable flaw depth of 0.9 inches.

The flaw length to pipe circumference ratio used for this evaluation, 0.1 is significantly greater than the actual flaw length to pipe circumference ratio, 0.017; therefore, the allowable flaw depth to thickness ratio at the end of evaluation interval remains valid considering the small amount of predicted FCG in the length direction.

At the end of the evaluation interval, using the very conservative methods of this flaw evaluation, the flaw satisfies the Figure IWA-3310-1 criteria for being categorized as a sub-surface flaw.

$Sf := 0.08 - da\_d \qquad Sf = 0.068$

$0.4 \cdot af = 0.065$

$0.068 > 0.065$