ATTACHMENT 1

Structural Integrity Evaluation of Circumferential Indication in Ginna BMI Nozzle No. A86, Westinghouse Report LTR-PAFM-11-69, Revision 0, dated July 2011

R.E. Ginna Nuclear Power Plant, LLC
March 16, 2012

Attachment 1

Westinghouse Non-Proprietary Class 3

LTR-PAFM-11-69
Revision 0

Structural Integrity Evaluation of Circumferential Indication in Ginna BMI Nozzle No. A86

July 2011

Author: C. Ng*, Piping Analysis and Fracture Mechanics

Verifier: A. Udyawar*, Piping Analysis and Fracture Mechanics

Approved: S. A. Swamy*, Manager, Piping Analysis and Fracture Mechanics

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Background

An outside circumferential indication was identified in Bottom Mounted Instrumentation (BMI) Nozzle No. A86 as a result of Ultrasonic Testing (UT) of the BMI nozzles at Ginna during the Spring 2011 outage. The flaw parameters for the indication of interest are shown in Figure 1 as well as a small lack of fusion indication resulting from the fabrication process. The circumferential indication of interest has been determined to be a fabrication related flaw and is most likely the result of grinding into the BMI nozzle outside surface during the weld fabrication process with weld material subsequently deposited into the ground area. This circumferential indication is not exposed to the primary water environment and therefore it is not subjected to primary water stress corrosion cracking (PWSCC) mechanism and fatigue crack growth is the only credible crack growth mechanism. It should be noted that the circumferential indication of interest is probably not a flaw but evaluated as such for conservatism.

The purpose of this evaluation is to evaluate the structural integrity of BMI Nozzle No. A86 and determine the remaining service life of the affected nozzle. The following provides a discussion of the technical approach, evaluation methodology and acceptance criteria as well as the results of the evaluation.

Technical Approach

The flaw parameters of the detected outside circumferential indication shown in Appendix A obtained during the Spring 2011 outage (References 1) are as follows:

Flaw Depth = 0.161″
Flaw Length = 1.35″
Flaw Circumferential Location: (318° - 56°) with 0° being the uphill side of the weld
Flaw Axial Location: At J-weld elevation

In accordance with Table IWB-3663-1 in 2004 Edition of the ASME Section XI Code (Reference 2), case-by-case evaluation with acceptance criteria to be justified by the Owner is required for the detected outside circumferential flaw in the BMI nozzle at the weld elevation. The evaluation procedure and acceptance criteria given in paragraph IWB-3640 of the 2004 Edition of the ASME Section XI code is used to determine the maximum end-of-evaluation period allowable flaw size since the detected circumferential indication is a non-PWSCC related indication. A more detailed discussion on the use of the evaluation procedure and acceptance criteria in paragraph IWB-3640 for the BMI nozzle is provided later in this letter report.

Once the maximum end-of-evaluation period allowable circumferential flaw size is determined, it can then be compared with the predicted flaw size for a given plant operation duration taking into account fatigue crack growth during that period of plant operation. The stress input to the fatigue crack growth analysis will be determined using the same methodology as used in the original BMI nozzle fatigue evaluation documented in the Babcock & Wilcox Company stress report (Reference 3). Impact of the pressure/thermal transients due to the Steam Generator Replacement program and Extended Power Uprate (EPU) program will be considered in the fatigue crack growth evaluation. The fatigue crack growth law for the Alloy 600 BMI nozzle base metal material in air environment is obtained from NUREG/CR-6721 (Reference 4) and used in the fatigue crack growth analysis. Structural integrity of the affected BMI nozzle can then be determined by comparing the predicted flaw size for a given plant operation duration with the maximum end-of-evaluation period flaw depth.

<u>Maximum End-of-Evaluation Period Allowable Flaw size</u>

Table IWB-3663-1 allows the end-of evaluation period flaw size for an axial flaw to be 75% of the wall thickness. Although this table does not provide an end-of-evaluation period allowable flaw size for circumferential flaw, the use of 75% of the wall thickness as the maximum end-of-evaluation period allowable circumferential flaw depth is acceptable since the hoop stress acting on an axial flaw is higher than the axial stress acting on a circumferential flaw. The choice of 75% of the wall thickness as the maximum end-of-evaluation period allowable flaw size is reasonable because the loads acting on the BMI nozzle of interest are very low and primarily due to internal pressure and external mechanical loading. This allowable flaw depth is also consistent with the maximum allowable flaw depth in the ASME Section XI code.

IWB-3640 evaluation is actually not necessary since Table IWB-3663-1 can solely be used to justify the use of 75% of the wall thickness as the maximum end-of-evaluation period allowable flaw size for circumferential flaw. However, as further confirmation of the above result, the methodology of IWB-3640 is used to determine the maximum end-of-evaluation period allowable circumferential flaw size even though IWB-3641 stated that the evaluation procedure and acceptance criteria are applicable to piping NPS 4" or greater. It should be noted that the application of IWB-3640 methodology is conservative for piping NPS less than 4".

The parameters for limit load evaluation using Tables C-5310-1, C-5310-2, C-5310-3 and C-5310-4 in Article C-5000 of the ASME Section XI code are shown as follows:

$$\text{Stress Ratio} = (\sigma_m + \sigma_b)/\ \sigma_f$$

where
σ_m = Membrane Stress
σ_b = Bending Stress
σ_f = Flow Stress

The stress ratio above is calculated based on the axial membrane and bending stresses due to internal pressure and external mechanical loads on the BMI nozzle. The axial membrane stress resulting from internal pressure is approximated by $PR_m/2t$, where

P = Internal Pressure

R_m = Nozzle Mean Radius
t = Nozzle Wall Thickness

and the bending stress due to internal pressure is negligible. The resulting stress ratio calculated is 0.13 (Reference 5) after taking into account the axial membrane and bending stress of 6.2 ksi resulting from the external mechanical loads due to deadweight and seismic loading on the BMI nozzle from Reference 6 as well as those due to an internal pressure of 2.5 ksia.

In accordance with Tables C-5310-1, C-5310-2, C-5310-3 and C-5310-4, the maximum end-of-evaluation period allowable circumferential flaw depth is 75% of the wall thickness since the final flaw length will not reach 75% of the pipe circumference for the plant operation duration of interest as demonstrated later in the fatigue crack growth analysis. This confirms the use of the allowable flaw depth of 75% of the wall thickness from Table IWB-3663-1 of the ASME Section XI code.

Fatigue Crack Growth Analysis

Using the same methodology as used in the original fatigue evaluation of the BMI nozzle in Reference 3, the axial stress ranges for the BMI nozzle are calculated and used to perform the fatigue crack growth analysis. The axial stress ranges calculated reflect the effects of the pressure/thermal transients resulting from the Steam Generator Replacement program and Extended Power Uprate program. For conservatism, the axial stress ranges used represent the outside surface peak stress which included a fatigue reduction factor of 4.0 (Reference 5). It should be noted that the use of peak stress is not necessary in fatigue crack growth analysis but is used here solely for conservatism only. In addition, the resulting stress ranges are conservatively assumed to be constant through the BMI nozzle wall thickness for simplicity.

The fatigue crack growth analysis procedure involves predicting the growth of the indication of interest resulting from the applicable pressure/thermal transients. The input required for a fatigue crack growth analysis is essentially the information necessary to calculate the range of crack tip stress intensity factors, ΔK, which depends on the crack size and shape, geometry of the structural component where the crack is postulated, and the applied cyclic stresses. Also, the load ratio, $R = K_{min}/K_{max}$, is required as one of the scaling parameters in the fatigue crack growth rate equation. The fatigue crack growth rate for the Alloy 600 material is shown below (Reference 4):

$$\frac{da}{dN} = C(T)\ S(R)\ (\Delta K)^n$$

$$C(T) = 4.835 \text{ X } 10^{-14} + (1.622 \text{ x } 10^{-16})T - (1.490 \text{ x } 10^{-18})T^2 + (4.355 \text{ x } 10^{-21})T^3$$

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

where,

C(T)	=	Scaling Factor for Temperature Effects for Alloy 600 in Air Environment
T	=	Temperature (°C)
ΔK	=	Stress Intensity Factor Range, K_{max} - K_{min}, MPa $\sqrt{m}$
K_{max}	=	Maximum Stress Intensity Factor, MPa $\sqrt{m}$
K_{min}	=	Minimum Stress Intensity Factor, MPa $\sqrt{m}$
n	=	Crack Growth Law Exponent (= 4.1)
S(R)	=	Scaling Factor for Load Ratio Effects
R	=	Load Ratio, K_{min} / K_{max}
$\frac{da}{dN}$	=	Crack Growth Rate in Environment, m/cycle

Once R and ΔK are calculated, the crack growth due to any given stress cycle can be calculated. This increment of crack growth is then added to the original crack size, and the analysis proceeds to the next transient. The procedure is continued in this manner until all the transients known to occur in the period of evaluation have been analyzed.

The methodology for calculating the circumferential crack tip stress intensity factors is given in (Reference 7). The crack tip stress intensity factor (K) calculations for the flaw can utilize a representation of the actual stress profile rather than a linearization between data points. The through-wall stress distribution profiles can be represented by a fourth order polynomial:

$$\sigma\left(\frac{a}{t}\right) = \sigma_0 + \sigma_1\left(\frac{a}{t}\right) + \sigma_2\left(\frac{a}{t}\right)^2 + \sigma_3\left(\frac{a}{t}\right)^3 + \sigma_4\left(\frac{a}{t}\right)^4$$

where:

σ_i	:	σ_0, σ_1, σ_2, σ_3, and σ_4 Are Stress Profile Curve Fitting Coefficients
a	:	Distance From the Wall Surface Where the Crack Initiates
t	:	Wall Thickness
σ	:	Stress Perpendicular To the Plane of the Crack

The crack tip stress intensity factor can be expressed in the general form as follows:

$$K_I = \sqrt{\frac{\pi a}{Q}} \sum_{j=0}^{4} G_j\,(a/c, a/t, t/R, \Phi)\, \sigma_j \left(\frac{a}{t}\right)^j$$

where:

a	:	Crack Depth
c	:	Half of the Crack Length Along The Surface
t	:	Thickness of The Pipe

R : Inside Radius of The Pipe

Φ : Angular Position of A Point on The Crack Front

(Φ= 0° At The Surface Point; 90° At The Deepest Point Of The Crack)

G_j : G_0, G_1, G_2, G_3 and G_4 Are Boundary Correction Factors (Reference 7)

σ_i : σ_0, σ_1, σ_2, σ_3, and σ_4 Are Stress Profile Curve Fitting Coefficients

Q : Shape Factor of An Elliptical Crack and is approximated by:

$$Q = 1 + 1.464(a/c)^{1.65} \text{ for } a/c \leq 1,$$

or

$$Q = 1 + 1.464(c/a)^{1.65} \text{ for } a/c > 1.$$

Since the pressure/thermal transient stress used is conservatively assumed to be constant through the wall thickness, the coefficients σ_1, σ_2, σ_3, and σ_4 as well as the boundary correction factor G_1, G_2, G_3 and G_4 are not used. For conservatism, a load ratio, (K_{min}/K_{max}) of 1 is used to determine the fatigue crack growth rate in order to account for any impact of welding residual stress on the load ratio although post weld heat treatment had been performed for the Ginna BMI nozzles. The resulting fatigue crack growth (Reference 5) for the indication of interest for plant operation duration of 10, 20 and 40 years are shown below:

	After 10 years	After 20 years	After 40 years
Predicted Fatigue Crack Growth (inch)	0.006	0.013	0.027

Even though there are significant amount of conservatism introduced in the fatigue crack growth analysis as discussed above, the resulting fatigue crack growth for the remaining plant operation duration is still very small.

Structural Integrity Evaluation

Since fatigue crack growth is the only credible crack growth mechanism for the indication of interest and based on the fatigue crack growth results shown above, the predicted circumferential flaw depth for a given plant operation duration is shown below:

	Plant Operation Duration		
	10 years	20 years	40 years
Predicted Flaw Depth (inch)	0.167	0.174	0.188
Maximum End-of-Evaluation Period Allowable Flaw Depth (inch)	0.446	0.446	0.446

As shown above, there is significant margin between the predicted flaw depth of 0.188 inch and the maximum end-of-evaluation period allowable flaw depth of 0.446 inch even for plant operation duration up to 40 years. Continued operation without repair is therefore technically justified and there will not be any impact on the structural integrity of the BMI nozzle of interest.

Summary and Conclusion

Structural integrity of BMI Nozzle No. A86 with the non-PWSCC circumferential indication has been performed. Since the primary axial loads due to internal pressure and other external primary mechanical loading are small for the BMI nozzle of interest, the maximum end-of-evaluation period allowable flaw depth is 0.446 inch, i.e. 75% of the wall thickness, per the IWB-3640 acceptance criteria. Fatigue crack growth is the only credible crack growth mechanism for the detected flaw and the resulting fatigue crack growth has been shown to be very small. As a result, the indication of interest will not exceed the maximum end-of-evaluation period allowable flaw depth for the remaining plant operation duration. Continued operation without repair is therefore technically justified for the non-PWSCC circumferential indication in BMI Nozzle No. A86 and there will not be any impact on the structural integrity of the affected BMI nozzle.

References

1. WesDyne Report WDI-PJF-1304966-FSR-001, "Constellation Energy, R. E. Ginna Nuclear Power Plant, 10 Year Reactor Vessel ISI Final Report Review, May 2011 Outage G1R36," May 26, 2011.

2. ASME Code Section XI 2004 Edition, "Rules for Inservice Inspection of Nuclear Power Plant Components," The American Society of Mechanical Engineers, New York, New York, USA.

3. Babcock & Wilcox Company Report#10 for Westinghouse APD, Westinghouse Order No. 54-F-49758-BP and B&W Contract No. 610-0110-51, "Stress Analysis of Instrumentation Tubes." Revision 1, 11-6-69.

4. NUREG/CR-6721, ANL-01/07, "Effects of Alloy Chemistry, Cold Work, and Water Chemistry on Corrosion Fatigue and Stress Corrosion Cracking of Nickel Alloys and Welds," April 2001.

5. Westinghouse Calculation Note CN-PAFM-11-41, Rev. 0, "Structural Integrity Evaluation of Circumferential Indication in Ginna BMI Nozzle No. A86."

6. ALTRAN Corporation Technical Report 88105-C-01, Revision 3, "Evaluation of Reactor Bottom Mounted Instrumentation (BMI) System Tubing & Supports," dated August 1990.

7. American Petroleum Institute, API 579-1/ASME FFS-1 (API 579 Second Edition), "Fitness-For-Service," June 2007.

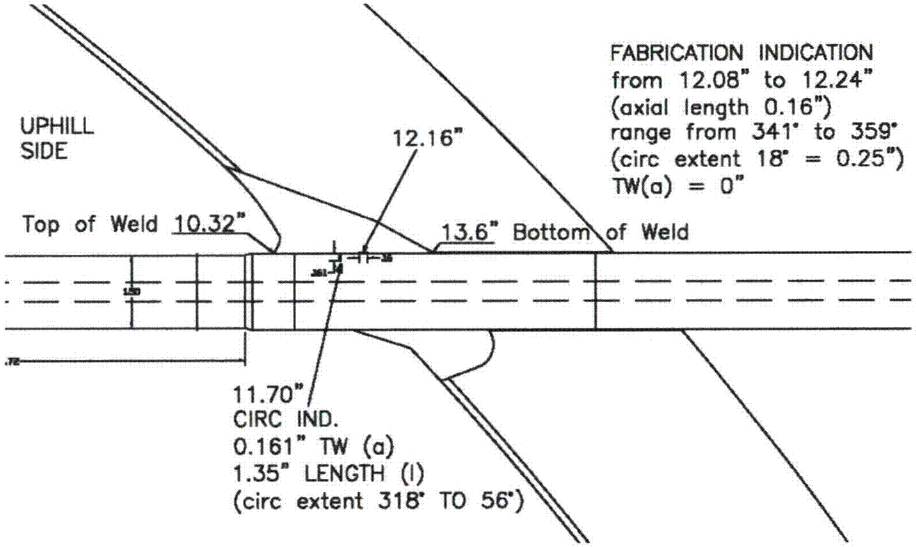

Figure 1 Circumferential Indication in BMI Nozzle No. A86

Appendix A

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ULTRASONIC INDICATION ASSESSMENT SHEET

				Procedure No:	WDI-STD-141, Rev. 00000
Plant :	GINNA	Unit:	1	File Name:	RGE1-31-02
Date:	5/17/2011				
Penetration No:	A86 (W31)			Analyst:	J. D. Funyak
Level :	II				
Probe Type:	BMI			Signature:	C L Wyffels For J.D. Funyak

IND #	CH / PR	L @ max	Ø @ max	L 1	L 2	L 3	L 4	Ø 1	Ø 2	d I	d 0	IND	RESO	Evaluation Comments
1	2	11.7"	34°	11.66"	11.70"	10.50"	13.22"	318°	56°	N/A	0.161"	RI / PTI	N/A	CIRC
2	3/11	12.16"	351°	12.08"	12.24"	10.40"	13.24"	341°	359°	N/A	0	RI / FAB	N/A	FABRICATION

Coverage %: 100

Scan # 2 Degrees: 360

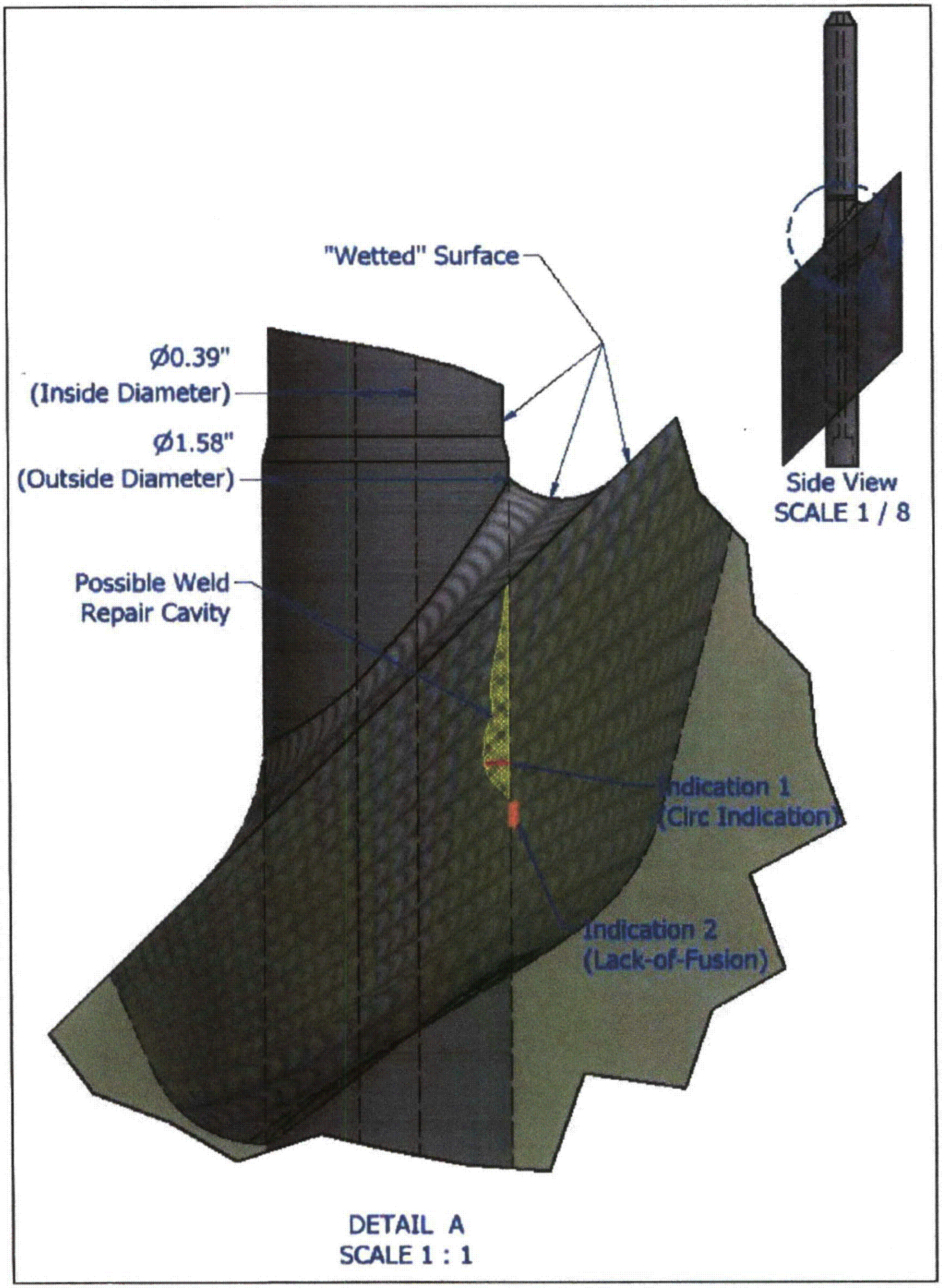
Comments:
Ind # 1 Circ Extent = 1.35"
Ind # 2 Circ Extent = .250"
T= 0.954"

Reviewer :	C.S. Wyffels C L Wyffels	Lv:	III	Date:	05/18/11
Resolution:	N / A	Lv:	N / A	Date:	N / A
Customer Review:	Michael Carey			Date:	05/26/11

ATTACHMENT 2

Location of Indications in A86 BMI Penetration – R.E. Ginna Nuclear Power Plant

R.E. Ginna Nuclear Power Plant, LLC
March 16, 2012



Location of Indications in A 86 BMI Penetration - R.E. Ginna Nuclear Power Plant