VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

July 14, 2005

United States Nuclear Regulatory Commission		Serial No.	05-384
Attention: Document Control Desk		NLOS/GDM	R0
Washington, D.C. 20555		Docket No.	50-281
		License No.	DPR-37

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNIT 2
ASME SECTION XI INSERVICE INSPECTION PROGRAM
EMBEDDED FLAW EVALUATION

During the ten-year reactor vessel inservice inspections performed during the recently completed Surry Unit 2 Spring 2005 refueling outage, an embedded circumferential indication was detected in the Unit 2 reactor vessel inlet nozzle to shell weld region. The dimensions of the embedded flaw exceeded the allowable flaw size specified in ASME Section XI paragraph IWB-3512, and consequently required a flaw evaluation to be performed to determine whether the detected flaw is acceptable for continued plant operation without being repaired. The flaw evaluation was performed by Westinghouse Electric Company in accordance with the guidelines of paragraph IWB-3600 of the code and concluded that the detected indication in the Surry Unit 2 inlet nozzle to shell weld is acceptable for continued operation without repair. The flaw evaluation was previously provided to the Surry NRC Senior Resident Inspector and is included in the attachment for your information.

If you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771.

Very truly yours,

Leslie N. Hartz
Vice President – Nuclear Engineering

Attachment

Commitments made by this letter: None

cc: U. S. Nuclear Regulatory Commission
Region II
Sam Nunn Atlanta Federal Center
61 Forsyth St., SW, Suite 23T85
Atlanta, Georgia 30303

Mr. S. R. Monarque
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Mail Stop 8H12
Rockville, MD 20852

Mr. R. E. Martin
NRC Lead Project Manager – North Anna and Surry
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, Maryland 20852

Mr. N. P. Garrett
NRC Senior Resident Inspector
Surry Power Station

Mr. R. A. Smith
Authorized Nuclear Inspector
Surry Power Station

Serial No. 05-384
Docket 50-281

Attachment

Embedded Flaw Evaluation for the Surry Unit 2 Reactor Vessel Inlet Nozzle to Shell Weld Region

Virginia Electric and Power Company
(Dominion)
Surry Power Station Unit 2

Embedded Flaw Evaluation For The Surry Unit 2 Reactor Vessel Inlet Nozzle To Shell Weld Region

Revision 1

June 2005

Author:

C. K. Ng,

Piping Analysis & Fracture Mechanics

Verifier:

S. Jirawongkraisorn,

Piping Analysis & Fracture Mechanics

Approved:

S. Swamy,

Manager, Piping Analysis & Fracture Mechanics

1.0 Introduction

During the Spring 2005 Outage, an embedded circumferential indication was detected in Surry Unit 2 reactor vessel inlet nozzle to shell weld region. The indication is classified as an embedded flaw since it meets the ASME Section XI IWA-3300 guidelines [1]. The embedded indication is located near the outside surface and can be detected from outside the reactor vessel shell and the inlet nozzle bore region. The dimensions of the embedded flaw detected exceeded the allowable flaw size given in Section XI Table IWB-3512 [1]. The purpose of this flaw evaluation is to demonstrate using the Section XI IWB 3600 flaw evaluation guidelines that the detected embedded flaw is acceptable for continual plant operation without repair.

Record of Revision

Revision	Description	Date
0	Original Issue	May 2005
1	Revised the ASME code edition to 1989 Edition	June 2005

2.0 ASME Code Acceptance Criteria

There are two alternative sets of flaw acceptance criteria for continued service without repair in paragraph IWB-3600 of ASME Code Section XI. Either of the criteria below may be used, at the convenience of the analyst.

1. Acceptance Criteria Based on Flaw Size (IWB-3611)
2. Acceptance Criteria Based on Stress Intensity Factor (IWB-3612)

The most beneficial criteria have been used in generating the flaw evaluation chart for the as-found indication in the inlet nozzle to shell weld region of the Surry Unit 2 reactor vessel.

2.1 Criteria Based on Flaw Size

The code acceptance criteria stated in IWB-3611 of Section XI are:

$a_f < .1\ a_c$ For Normal Conditions (Upset & Test Conditions Inclusive)

and $a_f < .5\ a_i$ For Faulted Conditions (Emergency Condition Inclusive)

where a_f = The maximum size to which the detected flaw is calculated to grow at the end of a specified period, or until the next inspection time.

a_c = The minimum critical flaw size under normal operating conditions (Upset And Test Conditions Inclusive)

a_i = The minimum critical flaw size for initiation of nonarresting growth under postulated faulted conditions. (Emergency Conditions Inclusive)

To determine whether a surface flaw is acceptable for continued service without repair, both normal and faulted condition criteria must be met.

2.2 Criteria Based on Stress Intensity Factor

The term stress intensity factor (K_I) is defined as the driving force on a crack. It is a function of the size of the crack and the applied stresses, as well as the overall geometry of the structure. In contrast, the fracture toughness (K_{Ia}, K_{Ic}) is a measure of the resistance of the material to crack propagation. It is a material property and a function of temperature.

The criteria are:

$$K_I < \frac{K_{Ia}}{\sqrt{10}}$$ For normal conditions (upset & test conditions inclusive)

$$K_I < \frac{K_{Ic}}{\sqrt{2}}$$ For faulted conditions (emergency conditions inclusive)

where

K_I = The maximum applied stress intensity factor for the flaw size a_f to which a detected flaw will grow, during the conditions under consideration, for a specified period, or to the next inspection.

K_{Ia} = Fracture toughness based on crack arrest for the corresponding crack tip temperature.

K_{Ic} = Fracture toughness based on fracture initiation for the corresponding crack tip temperature.

To determine whether a flaw is acceptable for continued service without repair, both normal and faulted condition criteria must be met.

3.0 Allowable Flaw Size Determination

3.1 Critical Flaw Size

One of the key parameters used in the evaluation of the indication discovered are two critical flaw depths. The first of these critical flaw depths is calculated using the thermal transient stresses from the governing normal, upset, and test conditions. The second is calculated based on stresses for the governing emergency and faulted conditions. The thermal transient stresses used were obtained from the Westinghouse generic 3-loop plant thermal transient stress database [2]. Thermal transient stresses were selected from the generic stress database to provide a conservative flaw evaluation for Surry Unit 2. Critical flaw depths are calculated based on the two sets of conditions using the ASME Code criteria as discussed in Section 2.0.

3.2 Fracture Toughness

The other key element in the evaluation of the indication discovered is the fracture toughness of the material. The fracture toughness for ferritic steel has been taken directly from the reference curves of Appendix A in Section XI of the ASME Code. In the transition temperature region, these curves can be represented by the following equations:

$$K_{Ic} = 33.2 + 2.806 \text{ exp. } [0.02 (T\text{-}RT_{NDT} + 100°F)]$$

$$K_{Ia} = 26.8 + 1.233 \text{ exp. } [0.0145 (T\text{-}RT_{NDT} + 160°F)]$$

where K_{Ic} and K_{Ia} are in $\text{ksi}\sqrt{\text{in}}$.

The upper shelf temperature regime requires utilization of a shelf toughness which is not specified in the ASME Code and a value of 200 $\text{ksi}\sqrt{\text{in}}$ is used here This value is consistent with general practice in such evaluations, as shown for example in Reference [3], which provides the background and technical basis of Appendix A in ASME Section XI Code.

Once the critical flaw sizes, such as a_c under normal operating conditions, or a_i under faulted conditions for the IWB-3611 criteria and the stress intensity factors, K_I, for the IWB-3612 criteria have been determined, the allowable flaw size can then be obtained based on the most beneficial results from both the flaw size and stress intensity factor criteria.

4.0 Fatigue Crack Growth

In applying the ASME Code acceptance criteria as introduced in Section 2.0, the final flaw size (a_f) is defined as the maximum flaw size to which the detected flaw is calculated to grow at the end of a specified period, or until the next inspection time. The allowable initial flaw size at the time of detection is obtained by taking into account the fatigue crack growth of this initial flaw for a given time duration. Fatigue crack growth analysis has been performed for the vessel inlet nozzle to shell region to determine crack growth as a function of service life. The design thermal transients and cycles for Surry Unit 2 have been considered in the fatigue crack growth analysis.

4.1 Crack Growth Rate Reference Curves

The crack growth rate curves used in the analyses were taken directly from Appendix A of ASME Section XI Code [1]. The air environment curve was used for the embedded indication detected. The crack growth rate reference curve for air environment is a single curve, with growth rate being a function of applied ΔK_I.

$$da/dN = C_o(\Delta K_I)^{3.07}$$

and

$$C_o = 1.99 \times 10^{-10}\, S$$

with

$$S = 25.73(2.88 - R)^{-3.07}$$

where, $\frac{da}{dN}$ = Crack growth rate, micro-inches/cycle

ΔK_I = Stress intensity factor range, $\text{ksi}\sqrt{\text{in}}$

R = K_{Imin} / K_{Imax}

4.2 Stress Intensity Factor

The stress intensity factor for an embedded flaw was calculated using the procedures given in Section XI Article A-3000 [1] which is applicable to an embedded flaw in a finite medium subjected to an arbitrary stress profile. It is a function of the stresses at the cross-section where the indication is located, along with the material properties. This stress intensity factor can be expressed in terms of the effective membrane and bending stress components as follows:

$$K_I = (\sigma_m M_m + \sigma_b M_b)\sqrt{\pi a / Q}$$

where

σ_m, σ_b = Membrane and bending stresses
M_m, M_b= Correction factors for the membrane and bending stresses

a = Half crack depth

Q = Flaw shape parameter

4.3 Analysis Methodology

The methods used in the crack growth analysis reported here are the same as those recommended by Section XI of the ASME Code. The analysis procedure involves postulating an initial flaw at specific regions and predicting the growth of that flaw due to an imposed series of loading transients. The input required for a fatigue crack growth analysis is basically the information necessary to calculate the parameter ΔK_I which depends on the crack and structure geometry as well as the range of applied stresses in the area where the crack exists. Once ΔK_I is calculated, the growth due to that particular stress cycle can be calculated by the reference crack growth curves in Section XI Appendix A. This increment of 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 predicted to occur in the period of evaluation have been analyzed.

5.0 Flaw Evaluation

5.1 Embedded Flaw Evaluation Chart

An embedded flaw evaluation chart is generated by first determining the allowable flaw depths as a function of proximity to the surface. These flaw depths were determined directly using the flaw evaluation guidelines in ASME Section XI Appendix C as discussed in Section 2.0. The allowable flaw depths were determined based on a flaw shape aspect ratio of 20:1, which has been found to be a conservative value based on the UT inspection result at the vessel inlet nozzle to shell weld region. Note that for indications that are very close to the surface, the allowable flaw depth is small because it is limited by the surface proximity rules in Section XI IWA-3300. The initial allowable flaw depth is then determined by subtracting the fatigue crack growth for a given time duration from the final allowable flaw size determined using the methodology discussed in Section 2.0. The embedded flaw evaluation chart is then generated by plotting the initial allowable flaw depth as a function of proximity to the surface as shown in Figure 1. The maximum allowable initial flaw depth plotted on the embedded flaw evaluation chart cannot exceed the surface/embedded flaw demarcation line, because above that line, the flaw would have to be considered as a surface flaw.

5.2 Evaluation Results

Two sets of flaw parameters were obtained for the indication detected at the inlet nozzle to shell weld region. One from the outside vessel shell and the other from the inlet nozzle bore region:

Flaw Parameters	Nozzle Bore	Vessel Shell
Flaw Depth (2a)	0.65 in	0.59 in
Flaw Length (ℓ)	5.5 in	5.5 in
a / ℓ	0.06	0.05
Wall Thickness (t)	9.13 in	9.13 in
Distance from Surface (S)	4.25 in	3.71 in

Using the bounding values from both sets of flaw parameters,

$a / t = 0.33 / 9.13 = 0.036$

$a / \ell = 0.05$

$S = 3.71$ in

$\delta = S + a = 4.04$ in

$\delta / t = 0.442$

The bounding values for a/t and δ/t for the detected indication are then plotted in Figure 1. It can be seen that the indication detected is acceptable since it lies below the acceptable initial flaw size limit lines.

6.0 Conclusion

The embedded circumferential indication detected at the Surry Unit 2 inlet nozzle to shell weld have been evaluated in accordance with the ASME Section XI IWB 3600 flaw evaluation guidelines. As demonstrated in Figure 1, the detected indication is acceptable for continual operation without repair.

7.0 References

1. ASME Code Section XI 1989 Edition, “Rules for In-service Inspection of Nuclear Power Plant Components,” The American Society of Mechanical Engineers, New York, New York, USA.
2. CB&I Stress Report Contract No. 71-2632 Rev. 2 dated December 1981 including Addendum dated April 12, 1985.
3. Marston, T. U. et. al. “Flaw Evaluation Procedures: ASME Section XI” Electric Power Research Institute Report EPRI-NP-719-SR, August 1978.

Figure 1

Surry Unit 2 Sub-surface Flaw Evaluation for Reactor Vessel Inlet Nozzle to Shell Weld