<u>ENCLOSURE 3</u>

MONTICELLO NUCLEAR GENERATING PLANT

SUPPLEMENTAL INFORMATION REGARDING
CYCLE 25 INSERVICE INSPECTION SUMMARY REPORT –
CORE SHROUD SUPPORT FLAW EVALUATION

EC-18051
EVALUATION OF THE MONTICELLO SHROUD SUPPORT LEG INDICATIONS
CONSIDERING INDICATIONS AT WELDS H8 AND H9
(NON-PROPRIETARY VERSION)

(18 pages follow)

Structural Integrity Associates, Inc.

CALCULATION PACKAGE

File No.: 1100560.301

Project No.: 1100560
Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
Evaluation of the Monticello Shroud Support Leg Indications Considering Indications at Welds H8 and H9

CONTRACT NO.:
00001005, Release 00027

CLIENT:
XCEL Energy

PLANT:
Monticello Nuclear Generating Plant

CALCULATION TITLE:
Evaluation of the Monticello Shroud with Indications at Welds H8 and H9

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 11 A-1 - A-7 Computer Files		Marcos Herrera 04/15/11	**Preparer:** Jim Wu 04/15/11 **Checker:** Marcos Herrera 04/15/11

~~**Contains Vendor Proprietary Information**~~

Table of Contents

List of Tables

List of Figures

~~This document contains vendor proprietary information. Proprietary information is indicated by a bar in the right hand margin.~~

1.0 OBJECTIVE

During the Spring 2011 inspections of the reactor internals at Monticello, Xcel Energy visually discovered indications at the H8 (shroud support-to-shroud) weld and the H9 (shroud support-to-vessel) weld. Previously, in Spring 2009, indications had been observed in 11 of the 14 shroud support legs. Indications were observed in one or both ends of the H10 welds at the top end of the support legs at the following azimuths: 10°, 30°, 60°, 120°, 150°, 170°, 190°, 210°, 240°, 270°, and 300°. Full characterization of the indications in the H8 and H9 welds is not available but this evaluation takes no credit for integrity of these welds. Visual photographs obtained from the examination performed by Xcel Energy are documented in Reference 1.

A crack–like indication at the 240° support leg is shown in Figure 1 as an example. Per Figure 1, the indication runs across the Alloy 182 fillet weld. It is noteworthy that the flaw runs in a fillet weld applied to reduce stress between the H10 weld and support cylinder.

The objective of this calculation is to evaluate the integrity of the shroud with the indications at the H8 and H9 welds and with the indications in the shroud support legs found during the Spring 2009 inspection. Figure 2 shows a schematic of the Monticello configuration [11, Figure 5-59].

The current calculation assumes no credit for the H8 and H9 welds, i.e., they are conservatively assumed to be fully cracked. Integrity of the shroud with the indications at the H10 weld without credit for the H8 and H9 welds is the focus of this calculation. The geometry of the support legs are provided in Table 3 [5]. One case was evaluated where 40.0% of each leg width (in circumferential direction) was assumed to be flawed through-wall. These are very conservative assumptions regarding the flaw length given the observed indications that appear to be limited to a fillet weld applied to reduce the stress concentration between the H10 weld and the bottom of the shroud support cylinder.

Because no credit is taken for either the H8 or H9 welds, the observed indications at these locations do not impact these results. Taking no credit for these welds is essentially equal to assuming through-wall flaws.

2.0 DESIGN INPUTS

Since the focus of this evaluation is whether all of the loads can be taken by the shroud support legs, the design input focuses on the support legs only. The shroud support design implemented at Monticello is the Chicago Bridge & Iron Nuclear (CBIN) flat plate design with support legs that connect to the reactor pressure vessel (RPV) bottom head. A stub is welded to an attachment pad on the inside of the RPV lower head, and the leg is welded to the top of the stub and to the bottom face of the shroud support cylinder (refers to Figure 2.9.2.4 of Reference 4). There are fourteen support legs, each with a thickness of 1.75 inches [5], located 20° or 30° apart (see Tables 2 & 3). The legs are fabricated from Alloy 600 material (S_m = 23.3 ksi) with multiple Alloy 182 welds joining the various leg sections to each other, and joining the legs to the low alloy steel RPV and the Alloy 600 shroud support cylinder. The weld of interest for this analysis, as designated in BWRVIP-15 [4], is the weld attaching the leg to the shroud support cylinder (weld H10).

All of the relevant load [3], and shroud geometry [5] for the Monticello support legs are summarized in Table 1 for upset and faulted conditions. Primary stresses calculated for use in the structural evaluation of the support legs are included in Table 2. The methodology used to compute these stresses is described in detail below. Note that no credit is taken for the H8 and H9 welds and therefore details of the shroud support plate are not necessary.

3.0 METHODOLOGY

3.1 Shroud Support Leg Safety Factor Evaluation

Access to the shroud support legs is severely limited because of their location in the RPV bottom head region beneath the shroud support structure. For this reason, the structural analyses performed as a basis for the "BWR Shroud Support Inspection and Flaw Evaluation Guidelines (BWRVIP-38)" [7] conservatively assumed the presence of 40% through-wall cracking in all shroud support legs.

However, Xcel Energy has performed a visual inspection of the legs via access through the jet pump assemblies. Provision for inspecting the support legs in lieu of a detailed inspection of welds H8 and H9 was also addressed in BWRVIP-38. Flaw tolerance evaluations are provided in Section A.2.7 of BWRVIP-38 that can be used to structurally evaluate the support legs. The methodology conservatively assumes that all of the applied loading is structurally taken by the legs. Therefore, welds H8 and H9 are not structurally required, other than to maintain the support structure configuration (i.e., jet pump support, shroud repair, etc.). As a result, analyses similar to those shown in Section A.2.7 of BWRVIP-38 were performed for Monticello to confirm the structural adequacy of the support legs, for upset and faulted conditions, conservatively including assumptions regarding the support leg flaws. Structural acceptability was demonstrated by maintaining minimum ASME Code, Section XI safety factors [10], as per the recommended approach documented in Section A.2.7 of BWRVIP-38 [7]. This reflects the condition of assuming no credit for the H8 and H9 welds at Monticello.

The shroud support legs are located sufficiently below the core such that they do not receive significant amounts of radiation. Therefore, linear elastic fracture mechanics (LEFM) techniques are not necessary, and limit load techniques are valid due to material ductility. Since the shroud support legs are essentially "a cylindrical shell with holes," a limit load solution applicable to cylinders may be used. Therefore, the ANSC computer program [8] was selected for use. The ANSC program was used because of its ability to analyze cracks in cylindrical structures without taking benefit of the cracks taking compression. This was important for this evaluation since the spaces between legs, which are effectively treated as flaws in this analysis, have no capability to take compression.

Consistent with limit load techniques, two stresses were computed for use in the analysis: (1) the primary membrane stress, P_m, and (2) the primary bending stress, P_b. Consistent with BWRVIP-38 methodology, calculation of these stresses was based on the stresses for the shroud

H7 weld, as provided in Reference 3. The determination of each of these stresses is detailed below:

P_m: $$P_{m\text{-legs}} = P_{m\text{-shroud}} (t/t_{legs})$$

where:

$P_{m\text{-legs}}$	=	primary membrane stress in the legs (psi).
$P_{m\text{-shroud}}$	=	primary membrane stress in the shroud at weld H7 (psi), $4F_a/\pi(D_o-D_i)^2$ F_a is the axial resultant force.
t	=	shroud thickness at weld H7 (inches).
t_{legs}	=	support legs minimum thickness (inches).

P_b: $$P_{b\text{-legs}} = (P_{b\text{-shroud}} + M_s/Z) (t/t_{legs})$$

where:

$P_{b\text{-legs}}$	=	primary bending stress in the legs (psi).
$P_{b\text{-shroud}}$	=	primary bending stress in the shroud at weld H7 (psi) M/Z where M is the bending moment in (in-kips).
M_s	=	additional moment for legs due to the shear load applied at weld H7 (inch-lbs).
	=	$S_s (2\pi Rt) H$
S_s	=	shear stress at weld H7 (psi)
H	=	"lever arm" between shroud weld H7 and limiting leg cross section (inches).
Z	=	section modulus for unflawed shroud cross section (inches^3).
	=	$\pi R^2 t$
R	=	shroud mean radius (inches).
t	=	shroud thickness at weld H7 (inches).
t_{legs}	=	support legs minimum thickness (inches).

After the simplifications,

P_b: $$P_{b\text{-legs}} = (P_{b\text{-shroud}} + 2S_s H / R) (t/t_{legs})$$

The calculated values for each of the above stresses are included in Table 2. It should be noted that the shear term in the calculation of P_b was conservatively taken to the bottom of the shroud support legs (weld H11) versus weld H10. This is consistent with the BWRVIP-38 methodology.

Table 3 summarized the computed azimuths for each support leg. This information, combined with the appropriate stress information in Table 1, was input to ANSC to determine whether the assumed leg configuration maintains minimum required ASME Code, Section XI safety factors [10] (2.77 for upset conditions, 1.39 for faulted conditions). Evaluations were performed for both the upset and faulted conditions, and the resulting ANSC output is included in Appendix A. It is noted from the output that through-wall flaws were placed in the spaces between the legs and the leg with the indication to represent the fact that there is actually no material present in these regions.

From the ANSC results, the safety factor was calculated using the following relationship:

$$\text{Safety Factor, SF} = \frac{P_b{}' + P_m}{P_b + P_m}$$

where: P_b' = minimum failure bending stress from ANSC output (psi).

The resulting safety factors are shown in Table 4. In Table 4, it was assumed that 40% of each leg width (in circumferential direction) was flawed through-wall and one leg was cracked 100% (consistent with the Reference 2 evaluation). These are very conservative assumptions regarding the flaw length given the observed indications that appear to be limited to a fillet weld applied to reduce the stress concentration between the H10 weld and the bottom of the shroud support cylinder.

3.2 Future Crack Growth Predictions

An evaluation of current operating conditions at Monticello was performed relative to predicted growth of the identified indication, with the results documented in Appendix B of Reference 9. The current water chemistry conditions in the Monticello lower plenum were considered, and it is concluded that growth of the identified indication should be bounded by a crack growth rate of 5×10^{-6} inches/hour, or 0.086" for one twenty-four month operating cycle. Use the leg width of 7" from Table 3, and conservatively assume that crack grows from both ends of a leg, the number of years cracks can grow before they reach 40% of the total width is given as:

$$40\% \times 7" / (5\times10^{-6} \text{ inches/hour} \times 2) = 31.9 \text{ years}$$

4.0 CONCLUSIONS

Based on the safety factors shown in Table 4, the required safety factor was reached when 40% of the leg width was assumed cracked through-wall along with one leg cracked 100%. These results are considered to be extremely conservative because no structural support from welds H8 and H9 was considered. Therefore, if some structural support from welds H8 and H9 is considered, it is expected that significantly larger margins would be obtained. Assuming no credit for the H8 and H9 welds is equivalent to assuming a through-wall flaw at H8 and H9 welds.

Based on the results of this conservative evaluation, up to 40% of each support leg H10 weld may be flawed (with one leg totally flawed) and still meet the required safety factors of BWRVIP-38. The current indications at H10 are relatively small and essentially not propagating. Even if crack growth is postulated (@5×10^{-6} in/hr) per Reference 9, the required safety factors would be met for several operating cycles.

5.0 REFERENCES

1. E-mail from David J. Potter (Xcel Energy) to Marcos Herrera (SI), "Official transmittal of Indications," Received on 4/13/09, SI File No. 0900485.201.
2. Structural Integrity Associates Calculation No. 0900485.301, Revision 0, "Evaluation of the Monticello Shroud Support Leg Indications: 2009 Inspection," 4/24/09.
3. Design Information Transmittal (DIT), DIT 13638-05, EC 13638, Extended Power Uprate (EPU), GE Hitachi Report No. 0000-0122-2954, R1, Structural Integrity Associates, SI File No. 1001207.201.
4. EPRI Report No. TR-106368, BWR Vessel and Internals Project, "Configurations of Safety-Related BWR Reactor Internals (BWRVIP-15)," EPRI PROPRIETARY, March 1996, SI File No. BWRVIP-01-215P.
5. Structural Integrity Associates Calculation No. EPRI-98Q-314, Revision 1, "Shroud Support Legs Structural Evaluation," 6/16/97.
6. Email from Verne Thompson (XCEL Energy) to Jim Wu (SI), "RIPD Load verification," 11/22/2010, SI File No. 1001207.202.
7. EPRI Report No. TR-108823, BWR Vessel and Internals Project, "BWR Shroud Support Inspection and Flaw Evaluation Guidelines (BWRVIP-38)," EPRI PROPRIETARY, SI File No. BWRVIP-01-238P.
8. ANSC, "Arbitrary Net Section Collapse for Thin Cylinder," Version 2.0, Structural Integrity Associates, SI File No. QA-1900.
9. Structural Integrity Associates Report SIR-00-008, "Evaluation of the Monticello Shroud Support Leg Indication," January 21, 2000, SI File No. NSP-40Q-401.
10. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1995 Edition with Addenda through 1996.
11. EPRI Report No. NP-7139-D, "Reactor Pressure Vessel Attachment Welds: Degradation Assessment," May 1991

Table 1: Shroud Weld H7 Resultant Loads and Bending Moments

Weld	Resultant Axial Force (F_a) (kip)	Resultant Bending Moment (M) (kip)	Resultant Shear Force (F_s) (kip)
H7 Upset	463.33	41733.89	258.63
H7 Faulted	977.80	122762.13	1143.83

Note: RIPD Loads in Reference 3 is included in the above resultant forces and moment per Reference 6

Table 2: Shroud Geometry and Support Leg Load Calculations

Condition	Shroud OD (inches)	Shroud Thickness, t (inches)	Leg (=Shroud) Mean Radius, R (inches) [=(OD-t)/2]	Leg Height, Limiting Cross-Section to Weld H7, H (inches)	Loads and Stresses					
					P_m at Weld H7 (psi) [See Note 4]	P_m for Legs (psi) [See Note 1]	Shear Force F_s at Weld H7, (kips)	P_b at Weld H7 (psi) [See Note 5]	P_b Due to Shear (psi) [See Note 2]	Total P_b (psi) [See Note 3]
Upset	163.5	1.75	80.9	64.0	521	521	258.63	1173	460	1633
Faulted	163.5	1.75	80.9	64.0	1100	1100	1143.83	3450	2036	5486

Notes:

1. The P_m for the legs is the P_m at weld H7 scaled by t/t_{legs}.
2. The moment due to the shear is conservatively calculated as F_sH. Thus, the P_b due to shear is $F_sH/(\pi R^2 t)$..
3. The Total P_b is the sum of the P_b due to shear and the P_b at weld H7, scaled by t/t_{legs}.
4. $P_m=4F_a/\pi(D_o-D_i)^2$
5. $P_b=MD_o/2I$

Table 3: Shroud Support Leg Geometry

Leg No.	Leg Center Azimuth (degrees)	Leg Width, W (inches)	Min. Leg Thickness, t_{legs} (inches)	Leg Starting Azimuth (degrees) [see Note]	Leg Ending Azimuth (degrees) [see Note]
1	10	7.0	1.75	7.52	12.48
2	30	7.0	1.75	27.52	32.48
3	60	7.0	1.75	57.52	62.48
4	90	7.0	1.75	87.52	92.48
5	120	7.0	1.75	117.52	122.48
6	150	7.0	1.75	147.52	152.48
7	170	7.0	1.75	167.52	172.48
8	190	7.0	1.75	187.52	192.48
9	210	7.0	1.75	207.52	212.48
10	240	7.0	1.75	237.52	242.48
11	270	7.0	1.75	267.52	272.48
12	300	7.0	1.75	297.52	302.48
13	330	7.0	1.75	327.52	332.48
14	350	7.0	1.75	347.52	352.48

Note: The leg azimuths are estimated as $\pm \tan^{-1}[(W/(2R)]$ from the leg centerline

Table 4: Safety Factors for Monticello Shroud Support Leg Evaluation (40% of all legs cracked)

Condition	P_b' [(1)] (ksi)	Computed Safety Factor, SF	Allowable Safety Factor
Upset	8.458	4.168	2.77
Faulted	8.223	1.416	1.39

Note: (1) Refer to the ANSC output contained in Appendix A.

Date: April 9, 2009
Time: 22:00

Component Description	Component Identifier	Video References
Shroud Support Leg	H-10 @ 240° Summary No. 107714	Vid_0353.avi

Description

During the VT-3 examination of H-10 @ 240° a crack –like indication was discovered on the CW end of the weld. This weld was accessed through JP-14.

Figure 1. Indication Found in Shroud Support Leg H-10 @ 240°(obtained from [1])

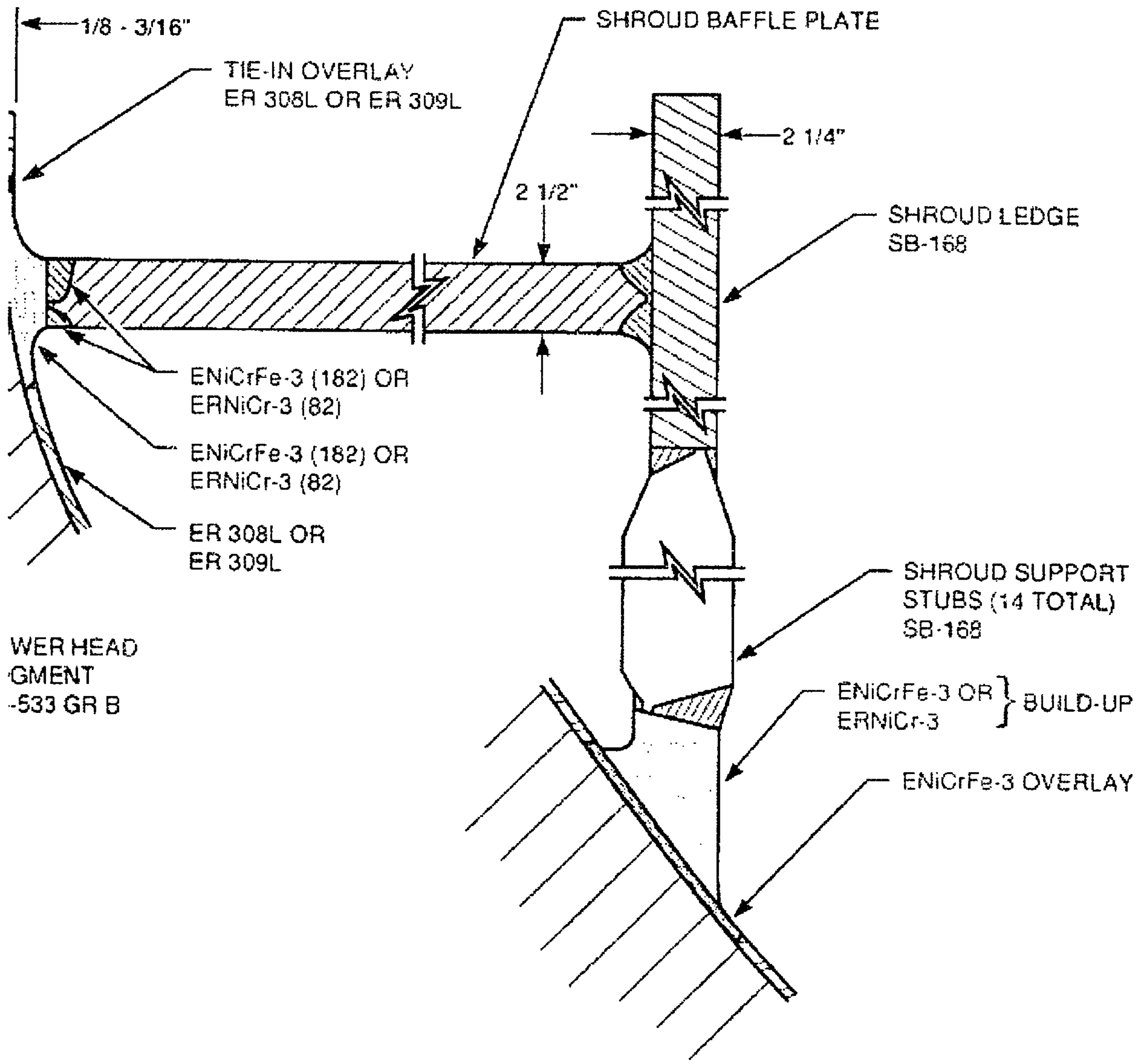

Figure 2: Schematic of CBIN/CB&I Vessel Shroud Support Structure Attachment Configuration [11]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]