ENCLOSURE 3

Monticello Nuclear Generating Plant

MNGP Evaluation
EC-22537

2013 H8-H9 Shroud Support Structure Indications Update

(7 pages follow)

EC 22537 - 2013 H8-H9 Shroud Support Structure Indications Update

Executive Summary

In 2011, during the RFO25 IVVI inspections, several indications were discovered on the underside of the shroud support plate. The indications were in the alloy 182 welds connecting the shroud support plate to the vessel via weld pad (H9 weld) and the weld connecting the plate to the shroud (H8 weld). It was initially believed that the indications were in the scale layer that tends to accumulate on the underside of the shroud support plate. However, attempts to clean the surface of the welds during RFO25 were unsuccessful.

The visual inspection of the welds on both the topside and underside was completed. UT inspection of the low alloy steel of the reactor vessel near the H9 weld in the N1B nozzle window was also performed during RFO25. Indications were only noted by visual examination on the underside of the welds

Monticello analyzed the indications and performed evaluations to demonstrate the structural integrity of the shroud support plate. The evaluations also conclude that the indications would not grow into the low allow steel of the reactor vessel. Over the course of the following cycle, a plan was developed to perform a more thorough cleaning and inspection of the indications. The inspection was to characterize the indications as relevant or non relevant and determine the origin of the indications. The follow-up inspection was planned and performed for RFO26 in 2013. Activities included cleaning and visual inspection of the H8 and H9 welds on the underside of the plate, a visual inspection without cleaning on the topside of the plate and a UT inspection of the low allow steel of the reactor vessel in the N1A nozzle window. The RFO26 inspection included a thorough cleaning of the underside of the surface at 4 selected locations on the welds, 2 on the H8 weld and 2 on the H9 weld, prior to the visual inspection.

The inspection revealed the indications were relevant flaws and not just indications in the scale layer. Additional inspections were also performed on the H10 welds of the shroud support legs where similar indications in similar welds have been discovered since 2000. The evaluations performed in 2011 to document the structural integrity of the shroud support welds and shroud support legs were updated in 2013 to include the new inspection data as well as additional loads not considered in the initial evaluation. Future inspections will be planned and executed based on the ASME re-inspection requirements and opportunities to obtain additional inspection data. Based on the inspection results and the evaluations, the Monticello shroud support structure is acceptable for several cycles of operation.

Purpose

The purpose of this evaluation is to provide an update to the current status of the indications found on the H8 and H9 welds in 2011 and inspected again in 2013. EC 18068 provides extensive background regarding the shroud support structure including the design, inspection requirements and inspection history through 2011 and background on the weld material and inspection techniques and requirements. This engineering evaluation will only summarize the preparation and findings from the re-inspection of the indications in 2013.

Preparation for the 2013 Inspection

After the completion of the 2011 outage, extensive research was done to determine the appropriate inspection technique and availability of the inspection tooling to perform this inspection. There was significant industry involvement from EPRI, other reactor vessel integrity program owners at other plants, nuclear professionals from overseas including Japan, Switzerland and Denmark and industry vendors such as Westinghouse, General Electric and Areva. Based on input from the Xcel Energy fleet, NDE personnel and the industry as well as operating experience and tooling availability, it was determined cleaning the welds and performing a follow-up visual inspection was the best course of action.

The cleaning tool developed during the 2011 outage to clean the H8 and H9 welds was determined to be inadequate due to the lack of balance of the reaction forces on the hydrolasing nozzle and pressure drop. In order to correct these issues, it was determined that a new tool would need to be developed.

Hennigan Engineering was contracted to develop the tooling to perform the hydrolasing of the both the H8 and H9 welds. Hennigan Engineering had done extensive work with other nuclear plants on designing hydrolasing equipment for cleaning nozzles and other components. They have also worked with Monticello's NSSS supplier, General Electric-Hitachi (GEH).

Hennigan designed a hydrolasing nozzle and lance configuration and orchestrated the rental of the hydro pump that would be used for the rental.

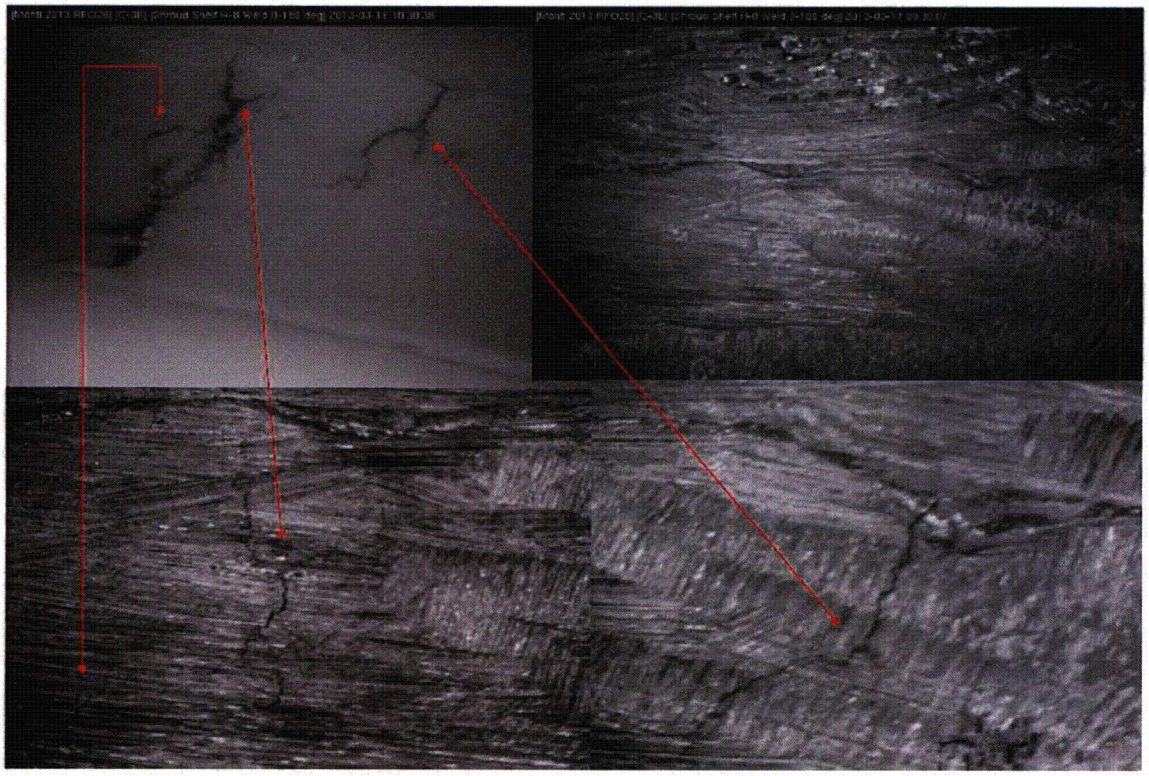
The nozzle head had openings that accommodate a variety of interchangeable nozzle sizes to change the force applied either on the weld areas for cleaning or the reaction force end for balance.

A mock-up of the jet pump and shroud support plate was built at the Westinghouse facility in Chattanooga, TN using an inlet nozzle and mixer Monticello had in storage. The mock-up was used for preliminary testing of both the hydro pump and the nozzle head configuration. Mock-up testing was successfully completed in February 2013. The lance and nozzle configuration was able to be successfully navigated down through the inlet nozzle of the jet pump. Hydro pump pressure got up to approximately 17, 500 psi.

Results of the 2013 RFO26 Shroud Support Structure Inspection

Underside of the Shroud Support Plate – H8-H9 Welds

Four locations were selected for cleaning and visual inspection on the underside of the shroud support plate on the H8 and H9 welds. Two locations on the underside of the H8 weld at the 68° and 210° vessel azimuths and two locations on the underside of the H9 weld at the 142° and 292° vessel azimuths. Each of the four locations was cleaned using the hydrolasing tool deployed through the inlet nozzle of the jet pump for approximately 30 minutes at 17, 500 psi. Pre-cleaning visual inspections were performed at each of the locations. The pre-cleaning was completed and both the site and Westinghouse NDE personnel determined that the cleaning was acceptable for post cleaning final visual inspection. Below are photos of H8 weld, both pre- and post-cleaning. The top left photo is the weld before cleaning. The other 3 photos are the weld location post-cleaning and are representative of the other areas cleaned. It can be seen in the photos that the cleaning was highly effective in removing the scale on the locations. (e.g. grinding marks from original fabrication are visible) .



As shown above, the cleaning and visual inspection at the four locations confirmed the presence of flaws in both the H8 and H9 welds.

The indications were primarily transverse to the weld with some flaws oriented circumferentially. Most flaws had different variations of branching indicative of IGSCC. Alloy 182, the weld metal used for the H8, H9 and H10 welds, is susceptible to IGSCC. The residual stress from the welding and the clear evidence of grinding on the weld would be sufficient to provide the stress necessary for IGSCC flaw initiation and propagation.

Monticello has had hydrogen water chemistry (HWC) since 1987. Prior to the HWC installation, the environment would have had sufficient oxygen content to assist in IGSCC initiation. IGSCC flaws require 3 elements to continue to propagate: stress, poor environment and susceptible material. Given that the material was susceptible, that sufficient residual stress was present and that there was sufficient oxygen present and the morphology of the indications, the most likely cause was IGSCC.

Removal of any one of the elements prevents the propagation of the flaws any further. Monticello has excellent hydrogen water chemistry with availability typically greater than 95%. Monticello has also installed Noble Metal Chemistry (OLNC) for additional corrosion protection of vessel internals which will be implemented after 2013. Since the vessel environment has been consistently neutral since the late 1980s, it's most likely that the flaws initiated and propagated early in plant life and arrested after the implementation of HWC. The inert state of the vessel environment because of HWC and OLNC will prevent further growth of the flaws.

Topside of the Shroud Support Plate – H8-H9 Welds

The topside of both the H8 and H9 welds was inspected using an EVT-1 visual inspection in all accessible areas in 2013. No cleaning was performed prior to the visual inspection. The topside of the H8 and H9 welds do not have a tendency to develop the same heavy scale layer as the underside of the welds. Approximately 32% of the total circumference of the H8 weld was inspected using EVT-1. The H9 weld had approximately 35% inspection coverage using EVT-1. No relevant indications were identified on either weld. The lack of indications on the topside of the welds indicates that flaws identified on the underside of the weld are not growing through the thickness of the shroud support plate.

UT Inspection of Low Alloy Steel of the Reactor Vessel

A UT inspection was performed of approximately 57.5" of the reactor vessel low alloy steel adjacent to H9 from the RPV OD at N-1A recirculation outlet nozzle window. During RFO25, the UT was performed from the N-1B nozzle window with a similar extent. The 2013 UT was an axial scan looking for circumferential flaws but not considered a BWRVIP exam as it was not performed in accordance with BWRVIP-104 requirements. No credit was taken for UT of the H9 weld and a circumferential scan to look for axial flaws was not possible due to clearance issues. The purpose of the examination was to interrogate the base metal near H9 to determine if there was evidence that the visual indications found on the underside of the H9 weld were growing into the low alloy steel. The examination utilized PDI qualified procedures and personnel. The exams did not find any indication of flaws growing into the reactor vessel.

Visual Inspection of the Shroud Support Legs – H10 Weld

In addition to the H8 and H9 welds, Monticello has been tracking indications in the H10 alloy 182 weld on the shroud support legs. Indications in the H10 weld have been noted during IVVI exams as early as 2000 with the bulk of the indications being discovered in 2009. To date, "new" indications have been discovered on the shroud support legs every outage since 2009. However, the discovery of the "new" indications in each outage is most likely due to improved inspection equipment, better lighting and improved camera angles rather than the formation of new flaws.

The flaws in the H10 weld are also caused by IGSCC and would have initiated and propagated early in plant life and then arrested after implementation of HWC. The ASME code requirement for re-inspection of known flaws requires that the indications be inspected for the next 3 consecutive periods following initial discovery. In 2013, one additional flaw was discovered and currently all 14 shroud support legs have at least one flaw in the H10 weld. However, the flaws are all contained within the H10 weld and have minimal effect on the structural integrity of the shroud support legs. The structural integrity of the shroud support legs is demonstrated by evaluation (EC 21854) and the indications will continue to be inspected in accordance with ASME Code.

2013 Evaluations of the H8-H9 Weld

In 2011, a series of evaluations were performed to demonstrate the structural integrity of the shroud support plate and the shroud support legs. Evaluations were also performed to demonstrate that the flaws found on the H8-H9 welds would be unlikely to propagate into the low alloy steel of the reactor vessel. Below is a table of the evaluations performed related to the shroud support structure in 2011 and 2013.

Evaluation #	Evaluation Title (Year Completed)
EC 18067	Evaluation of Crack Growth into the Low Alloy Steel of the Reactor Vessel (2011)
EC 18095	Evaluation of Shear Capacity of Monticello Shroud Welds H8 and H9 (2011)
EC 18051	Evaluation of the Monticello Shroud Support Leg Indications Considering the Indications at H8 and H9 (2011)
EC 18068	Summary of 2011 Shroud Support Inspection and Evaluation Activities (2011)
EC 21839	2013 MNGP Shroud Support Evaluation Uplift Load for H8-H9 Welds (2013)
EC 21854	2013 MNGP H10 Shroud Leg Weld Structural Evaluation (2013)
EC 21892	ASME Section XI, IWB-3142.4 Acceptance, H8-H9 Welds (2013)

EC 18068 summarized the conclusions from the EC's 18067, 18095 and 18051. EC 18067 remains valid and required no update as a result of the 2013 inspection results. The shroud support leg H10 weld evaluation and shroud support plate H8 and H9 weld evaluation performed in 2011 both had to be updated in 2013. EC 21839 and 21854 are the updates to the evaluation that includes the most recent 2013 inspection data and additional consideration for shroud and shroud support acoustic loading that was not considered in the 2011 evaluations. EC 21892 addresses the non- applicability of IWA-3300 and IWB-3420 requirements for flaw characterization as they pertain to the visually identified "crack" indications on the H8-H9 welds. Below are the summaries for EC 21839, EC 21854 and EC 21892.

EC 21839 – H8 – H9 Weld 2013 Structural Evaluation

Two crack profiles for the H8 and H9 welds were analyzed for the purpose of evaluating structural integrity. One profile is a compound crack which is defined as a through-wall crack postulated in the uninspected regions and a remaining ligament of ½ of the plate thickness postulated in the inspected region. The ½ plate thickness is used as the remaining thickness because cracks tend to arrest when area of compressive stress is entered in a component. The area of compressive stress typically begins near the center of the plate or 50% of the plate thickness.

The second profile was a full circumferential surface crack which is defined as a surface crack at the underside of the shroud support plate surface extending along the circumferential length of Weld H8 and H9 with a crack depth at 75% of the support plate thickness is postulated. This corresponds to a remaining ligament of 0.625 inches in the support plate. Note that these profiles

are highly conservative and significantly more severe than any cracking identified in the 2011 and 2013 inspections.

To justify a 24 month cycle of additional operation, 18% of the total weld length is required to be free of through-wall indications for the two conservative crack profiles analyzed. It should be noted that during the Spring 2013 inspections, an average of 34% of the H8 and H9 welds were inspected and found to be free of topside indications. The lack of topside flaws indicates that the flaws are not growing through-wall, at least in the areas inspected. Using the industry accepted crack growth rate of $5x10^{-5}$ in/hr per BWRVIP-76 combined with the same calculation method above, structural margin is maintained for at least a period of 12 years.

EC 21854 – H10 Weld 2013 Structural Evaluation

One scenario was analyzed for the H10 weld in the shroud legs. All 14 legs were assumed to be flawed 31.2% through the thickness in the circumferential direction. No credit was taken for H8 and H9 welds as they are redundant to the shroud support legs of the transfer of structural loads to the reactor vessel. Since no credit was taken, it was assumed that both H8 and H9 welds were flawed completely through wall for the purposes of the evaluation. Note that the assumption of shroud support legs and the shroud support plate welds are very conservative in comparison to the actual observed condition. The evaluation concluded that the 31.2% of each H10 weld on all the shroud support legs may be flawed through the thickness and still meet the safety factors established in BWRVIP-38.

EC -21892 - ASME Section XI, IWB-3142.4 Acceptance, H8-H9 Welds

This evaluation documents MNGP's application of the ASME code as it relates to characterization of the relevant linear indications visually identified on the H8 and H9 welds. Based on MNGP's code review, a relief request from the requirements of 10CFR50.55a as the ASME Section XI Code for analysis is not required. In addition, the extent and disposition of the relevant indications applied to date are adequate for the purpose of analytical evaluation per IWB-3142.4 and acceptability for continued service as required by IWB-3520.2. Characterization per IWB-3420 and IWA-3300 are not applicable to VT-3 exams required by Table IWB-2500-1, Category B-N-1. In the 2015 (RFO27) outage, the entire underside surface of H8 and H9 must be examined to be credited as a successive exam, as required by IWB-2420(b), unless a 10CFR50.55a Request for an alternative or hardship is approved prior to the 2015 exams. Currently, coverage of the entire underside is not possible due to obstructions and the design of the reactor vessel internals.

Conclusions

The indications on the underside of the H8 and H9 welds of the shroud support plate have been confirmed as relevant indications/flaws in the weld metal based on the 2013 RFO26 cleaning and visual inspection evolution. There is no indication the flaws are growing into the low allow steel of the reactor vessel. There is also no indication that the flaws are active and the HWC system inerts the reactor environment to prevent the propagation of the flaws. The evaluations performed demonstrate the structural integrity of the shroud support structure, including the shroud support plate and the shroud support legs, for several cycles. Future inspections will be governed by ASME Code requirements.

References

1) MNGP RFO26 IVVI of RPV Internal Components – Final Report
2) EC 18068 – Summary of 2011 Shroud Support Inspection and Evaluation Activities
3) EC 21839 – 2013 MNGP Shroud Support Evaluation Uplift Load for H8-H9 Welds
4) EC 21854 - 2013 MNGP H10 Shroud Leg Weld Structural Evaluation
5) EC 21892 – ASME Section XI, IWB-3142.4 Acceptance, H8-H9 Welds

6) BWRVIP-59A, Evaluation of Crack Growth in BWR Nickel Base Austenitic Alloys in RPV Internals
7) WO 445085 – Perform Cleaning and Inspection of H8/H9 Indications from RFO25.
8) AR 01375496 – ISI – IVVI with cleaning of H8-H9 welds confirms indications
9) AR 01377599 – RFO26 IVVI Indication on 300 degree shroud leg H10 weld