March 14, 2008

MEMORANDUM TO: Catherine Haney, Director
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Michele G. Evans, Director **/RA/ J. Lubinski for**
Division of Component Integrity
Office of Nuclear Reactor Regulation

SUBJECT: Assessment of Inspections of Dissimilar Metal Butt Welds in a Retired Pressurizer

Background

On October 13, 2006, the Wolf Creek Nuclear Operating Corporation performed pre-weld overlay inspections using ultrasonic testing (UT) techniques on the surge, spray, relief, and safety nozzle-to-safe end dissimilar metal and safe end-to-pipe stainless steel butt welds. The inspection identified five circumferential indications in the surge, relief, and safety nozzle-to-safe end dissimilar metal (DM) butt welds that the licensee attributed to primary water stress corrosion cracking (PWSCC) [ML063380456] and were significantly larger and more extensive than previously seen in the industry.

During public meetings with the industry on November 30, 2006, and December 20, 2006, the Nuclear Regulatory Commission (NRC) staff presented the results of a fracture mechanics based scoping study that assessed the safety significance of the UT indications found at Wolf Creek. As a result of these analyses, the staff concluded that there may be little or no time margin between the onset of leakage and rupture in pressurizer nozzle DM butt welds containing flaws similar to those found at Wolf Creek.

In March 2007 the NRC issued Confirmatory Action Letters (CALs) to 40 nuclear power plant licensees with pressurized water reactors (PWR), confirming commitments from those licensees to resolve concerns regarding potential flaws in specific reactor coolant system (RCS) DM butt welds by the end of 2007. The remaining 29 PWR plants had either completed the requisite actions or do not have welds susceptible to these flaws.

Nine of the plants receiving CALs did not have outages scheduled in 2007. These plants committed to accelerate outages into 2007 if the industry was not able to demonstrate an adequate level of safety to the NRC. The nine plants are Braidwood 2, Comanche Peak 2, Diablo Canyon 2, Palo Verde 2, Seabrook, South Texas Project 1, V. C. Summer, Vogtle 1, and Waterford 3.

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By letter dated February 14, 2007, the Nuclear Energy Institute indicated that the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) would be undertaking a task to refine the crack growth analyses pertaining to the Wolf Creek pressurizer DM weld ultrasonic indications. These additional advanced finite element (AFE) analyses were performed toaddress the NRC staff's concerns regarding the potential for rupture without prior evidence of leakage from circumferentially oriented PWSCC in pressurizer nozzle welds. The goal of these studies was to demonstrate that PWSCC in pressurizer DM butt welds will progress through-wall and exhibit detectable leakage prior to causing a possible rupture event, through reduction of conservatisms and uncertainties in previous analyses.

Industry completed these analyses and documented the results in MRP-216, Revision 1, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds: Evaluations Specific to Nine Subject Plants" [ML072410235]. These results were provided to the NRC staff by letter dated August 13, 2007.

The NRC staff completed independent analyses to enable the staff to perform an in-depth review and critique of the industry's analyses and to extend the industry's analyses in some key respects. The NRC staff documented its safety assessment on the industry's analyses in a memorandum to Catherine Haney on September 7, 2007 [ML072430836]. The conclusion of the NRC staff's safety assessment was that there is reasonable assurance that the nine plants addressed by the evaluation can operate safely until their next scheduled refueling outages in the Spring of 2008. This conclusion was based on the results of advanced finite element analyses of the fabrication, loading and postulated flaw growth in the pressurizer nozzle welds. Through reduction of uncertainties and unnecessary conservatisms in previous analyses, it was concluded that PWSCC in pressurizer DM butt welds would progress through-wall and exhibit detectable leakage prior to causing a possible rupture event.

In mid-February 2008 the NRC staff received the results of inspections of the nozzles of a retired pressurizer [ML080701017]. This pressurizer was removed from service to eliminate the possibility of extended plant outages because of degradation issues in various welded components in the pressurizer. The pressurizer was donated to NRC for research purposes and the inspections were performed to determine the research value of the nozzle welds. These inspections found indications by dye penetrant (PT) and manual phased array ultrasonic examination (UT). Circumferential and axial indications were found in five of six nozzles. The nozzle welds of most interest were the safety nozzles. The inspection concluded that these nozzles had 360° indications with non-uniform depths around circumference. The deepest indications found were sized at 80% throughwall on the 'A' safety nozzle. The deepest indication found in the 'B' and 'C' safety nozzles were 75% and 69% throughwall, respectively.

This information led to NRC staff questions regarding the relationship of these inspection results to the AFE analyses that were used to support the continued operation of 9 plants with pressurizer welds that had not yet been inspected. The NRC staff requested additional information about these results, specifically the NRC staff requested information on the flaw profiles and UT signals. EPRI provided this information to the NRC staff by letter MRP 2008-014, dated March 4, 2008 [ML080670004]. EPRI provided the profile for the inspection of the 'A' safety nozzle weld which depicted a continuous deep indication 360° around the circumference. This information caused NRC staff to question the continued applicability of the AFE analysis results. The NRC staff discussed those questions with industry executives. Industry representatives took actions to rapidly put in place a comprehensive inspection effort consisting of more advanced UT examinations, specifically American Society of Mechanical Engineers (ASME) Code, Section XI, Appendix VIII qualified automated phased array and radiographic testing (RT) examinations, followed a few days later by eddy current testing (ET) examinations. These inspections commenced on March 8, 2008 at the Studsvik-Race facility in Memphis, the location of the nozzles from the retired pressurizer. At the same time NRC staff sent a regional inspector to the location where the pressurizer welds were being inspected, along with an outside NRC contracted UT expert.

Activities of the NRC Representatives on Site

On March 9, 2008 an NRC inspector from Region I, Timothy O'Hara, and a contracted expert in non-destructive examination, Michael Anderson, arrived at the Studsvik-Race facility in Memphis. They immediately began auditing the weld inspection activities by the industry. Their audit included review of the UT inspection procedure, adherence to the UT procedure by the industry inspectors, the validity of the qualification of the inspection procedure by the Performance Demonstrative Initiative (PDI) to ASME requirements, and evaluation of the UT inspection data. The inspectors concluded that the UT procedure was a qualified procedure with one exception noted and addressed below. The NRC representatives verified that the industry inspectors followed the requirements of the UT procedure.

With respect to the qualification of the procedure, the NRC representatives observed that the wedge used to transmit sound beams from the probe transmitters to the weld were not in accordance with the specifications for the UT procedure used to inspect the safety nozzle welds. The wedges were sized for a weld diameter larger than the diameter of the safety nozzle welds and this sizing was outside the limitations specified for the procedure. The industry inspectors noted that the data quality with the oversized wedges was good and continued to scan the welds with this equipment, gathering UT data for evaluation. Subsequently, industry shipped a controlled mockup of the safety nozzle welds to the Studsvik-Race facility. The mockup contains cracks or crack like reflectors with known sizes that are held as confidential. The mockup was fabricated to use in the qualification of UT procedures, equipment, and personnel. An inspection of the mockup was performed with the oversized wedge-probe and it was concluded from the results of the inspection of the mockup that the use of the automated phased array UT procedure with the oversized wedge-probe satisfied the criteria specified in the ASME Code. Based on information provided by industry, the NRC representative concluded that the UT procedure was a qualified procedure in accordance with ASME requirements.

Based on the documentation provided by industry and their observations of the industry inspection, the NRC representatives also concluded that the automated phased array UT procedure was properly implemented.

Description of Automated Phased Array Inspection and Results

As recommended in EPRI letter MRP 2008-012, EPRI and NRC staff agreed that a PDI qualified automated phased array UT technique would provide a more accurate profile of any potential degradation in the welds than a PDI qualified manual phased array UT technique.

Phased array ultrasonic inspection provides an excellent means to detect critical flaws especially in welds with limited access and difficult microstructures. As with conventional manual ultrasonics, with manual phased array ultrasonics the inspector is physically scanning the weld while looking at the equipment screen and doing data evaluation in real time. Though screen shots of areas of interest can be recorded, all data analysis is done in real time. In comparison, with automated (encoded) phased array ultrasonics, the weld is scanned and a full set of position encoded ultrasonic data is recorded. This means that the equipment is recording everything that the inspector performing the manual scan was seeing, but each ultrasonic waveform is recorded along with the position information. This is a critical difference between the two methods in that the inspector can go back and carefully process and review the data and create a set of images that enable clearer interpretations of the data. These images include "B", "C" and "D" scans where the "B" scan shows a projected side view of the weld, the "C" scan is shows a projected top view of the weld and the "D" scan shows a projected end view of the weld. In all three views, the software can project a more three dimensional like profile of the weld on top of the ultrasonic data so that using these views, the inspector can easily visualize and analyze the data (locate and size flaws in the material). Thus, the ability of the automated (encoded) phased array ultrasonic inspection to characterize an indication is superior to that of the manual phased array ultrasonic inspection to provide accurate representations of the flaws in the inspection volume.

The automated phased array UT examinations began on the evening of Saturday, March 8, 2008, and continued into the following week. Each of the St. Lucie pressurizer safety nozzle dissimilar metal welds was inspected. The priority was placed on the ‘A’ safety nozzle weld. The NRC UT expert contractor and various NRC staff have reviewed the UT examination results. The NRC UT expert contractor was given access at the inspection site to work with the raw recorded data from the inspections. NRC staff has had access to draft summary reports and data scans from the inspections. Additional results were communicated during daily teleconferences with EPRI staff at the inspection site and NRC staff and contract staff at the site.

On March 13, 2008, EPRI provided to the NRC a draft automated phased array UT examination results summary. This document stated, in part, that the retired pressurizer safety nozzle welds ‘A’, ‘B’ and ‘C’ had multiple embedded fabrication flaws. This document concluded that these fabrication flaws were attributed to slag, porosity, and/or lack of fusion. Also, these indications were found to be clustered as well as individual fabrication flaws. Finally the document concluded that the inspection identified no surface connected flaws. In support of this document on March 13, 2008, EPRI provided a series of UT scans of the inspection data for NRC staff and contractor interpretation.

On March 13, 2008, EPRI provided to the NRC a draft correlation of the automated phased array UT examination results to the manual phased array UT scans provided in EPRI letter MRP 2008-014. The objective of the correlation was to evaluate the manual phased array UT depth sizing measurements using the manual phased array UT data to determine if any of the reported flaws are connected to inside surface. However, as a direct correlation of the data was not available due to variations between the two techniques, EPRI evaluated the automated data at the same 1-inch intervals around the pipe as used to produce the weld flaw profile shown in the EPRI letter MRP 2008-014. In order to focus data acquisition for the comparison, EPRI identified the similar depth reflector around the same 1-inch intervals for their analysis. According to EPRI’s draft report, for 17 of the 19 points identified in the EPRI letter MRP 2008-014, the correlation shows that the tip signal, the signal from the manual phased array UT used to create the EPRI letter 2008-014 flaw profile through-wall depth, was identified by the automated phased array UT to not be surface connected in the D-scans. For 2 of the 19 points the report notes that the authors were unable to confirm a relevant signal in the area described by the manual phased array UT scan. As manual phased array UT does not have a tracked and precise method of determining location on the weld surface, this conclusion is found by the NRC staff to be reasonable. Given the results of this correlation, the NRC staff finds that the assumption made in the development of the manual flaw profile that the stacked indications identified in EPRI Letter 2008-012 were connected to the surface is incorrect.

NRC staff and its contacted UT expert have completed their review of the automated phased array UT results and the correlation of the automated phased array UT examination to the manual phased array UT scans. The NRC finds that there is sufficient data available to provide reasonable assurance that there are no structurally significant service induced flaws within the retired pressurizer safety nozzle welds ‘A’, ‘B’ and ‘C’. The NRC finds that the determination that the flaw profile provided in EPRI letter MRP 2008-014 was potentially due to service induced cracking, while being conservative, was incorrect.

Conclusions

The safety question relative to the 9 plants allowed to operate beyond December 31, 2007 due to the results of the AFE analyses was based on the flaw profile provided in EPRI Letter 2008-014 and whether flaws identified in the retired pressurizer were due to service induced cracking. The AFE analyses used detailed plant specific attributes to develop potential service induced flaw propagation profiles for each of the 9 plants. The EPRI letter MRP 2008-014 flaw profile, which was generated by data from the manual phased array inspection technique, illustrated an indication 360° around the circumference and deep at most locations. This information raised NRC staff questions regarding the continued applicability of the AFE analyses. Since the NRC finds that the flaw profile provided in EPRI letter MRP 2008-014 was incorrectly characterized as potential service induced cracking, the NRC continues to find that the AFE analyses support the continued operation of the 9 plants beyond December 31, 2007 to their respective spring outages.

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