UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

September 19, 2007

MEMORANDUM TO: ACRS Members

FROM: Charles G. Hammer, Senior Staff Engineer **/RA/**
Reactor Safety Branch, ACRS

SUBJECT: TRANSMITTAL OF STATUS REPORT AND PROPOSED SCHEDULE REGARDING THE DISSIMILAR METAL WELD ISSUE

The full Committee will review the subject dissimilar metal weld issue during the 546th ACRS meeting on October 4, 2007.

To prepare for this meeting, the following documents are attached:

1. Status Report
2. Proposed Schedule

In addition, the following review materials were transmitted on September 13, 2007:

1. NRC staff safety assessment of the advanced finite element analysis of primary water stress corrosion cracking in pressurizer nozzle dissimilar metal butt welds, dated September 7, 2007 (ML072430091 and ML072400199)
2. Final report by Engineering Mechanics Corporation of Columbus on the implications of the Wolf Creek indications (ML072470394)
3. "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds (MRP-216, Revision 1): Evaluation Specific to Nine Subject Plants," EPRI, Palo Alto, CA, 2007 (ML072410235)
4. August 9, 2007 meeting - EPRI slides (ML0722600290)
5. August 9, 2007 meeting - NRC slides (ML0722600300)

If you have any questions, please contact me at (301) 415-7363 or cgh@nrc.gov.

cc wo/Attachments: F. Gillespie
S. Duraiswamy
C. Santos

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
DISSIMILAR METAL WELD ISSUE
October 4, 2007
ROCKVILLE, MD

**- STATUS REPORT -**

## PURPOSE

The purpose of this meeting is for the industry and the NRC staff to provide the Committee with the results of recent analyses and evaluations used as a basis for ensuring the structural integrity of pressurizer nozzle dissimilar metal welds at nine plants. The recent staff and industry analysis and evaluation activities stem from the pressurizer nozzle weld inspection results at Wolf Creek where large flaws were discovered. Early this year, the licensees for these nine plants requested to defer flaw inspection and mitigation activities until early 2008.

## BACKGROUND

The Subcommittee on Materials, Metallurgy, and Reactor Fuels heard presentations on the pressurizer nozzle dissimilar metal weld (DMW) issue on March 6, 2007. On February 2, March 8, and July 11, 2007, the full Committee heard presentations and held discussions on this subject. The Committee issued a letter to the EDO on March 22, 2007 which supported the agreement reached between the staff and the industry on the resolution of DMW issues. The ACRS letter also stated that in the upcoming outages, the staff should encourage the industry to inspect all inspectable dissimilar metal welds on pressurizer nozzles before performing mitigation activities.

The EDO provided a response to the ACRS in a letter dated April 23, 2007, which stated that the advanced finite element analysis efforts being performed by both the industry and staff are ongoing. The letter also stated that the staff anticipates reaching conclusions by August 2007 on whether these efforts would provide reasonable assurance of detectable leakage well before rupture. The staff further committed to keep the Committee informed of this issue as these analyses proceed.

The ACRS was last briefed on this topic during the July 11, 2007 meeting where the industry provided the preliminary results from their advanced finite element analyses. At that time, the staff had not completed its review of the analysis results. Following the July 11, 2007 ACRS presentation, the Committee asked to be briefed again after the industry analyses and staff evaluation were complete.

## DISCUSSION

In October 2006, large circumferential cracking was found at Wolf Creek on three pressurizer nozzles. Wolf Creek is a Westinghouse-design four-loop PWR having austenitic stainless steel primary coolant piping and transition nickel-based alloy (dissimilar metal) welds at nozzles. Past observation of cracking in these types of welds at various plants has been characterized as primary water stress corrosion cracking (PWSCC) and were mostly axial cracks, all relatively short in length. Unlike previous inspection results, the Wolf Creek pressurizer nozzle weld flaws were long, deep, circumferential cracks. The size and location of the cracks is provided below:

| Location | Crack length | | Crack depth |
|---|---|---|---|
| | inches | % of total circumference | % of total thickness |
| Surge line nozzle | 4" | 11% | 31% |
| '' | 2.2" | 6% | 25% |
| '' | 0.8" | 2% | - |
| Relief valve nozzle | 7.7" | 47% | 26% |
| Safety valve nozzle | 2.5" | 15% | 23% |

The Wolf Creek inspections were performed in accordance with Materials Reliability Program (MRP) -139 guidance, issued in 2005. The guidance allows application of weld overlays before inspections are performed. However, the Wolf Creek licensee did inspect these welds before applying weld overlays. The last volumetric examinations of these welds were performed in 1993 (surge line nozzle) and 2000 (relief and safety valve nozzles), but the inspections were not nearly as reliable as the current MRP-139 inspections.

Late in 2006, the staff and its contractor performed several evaluations to assess the significance of the Wolf Creek flaws. A key result of these evaluations was whether or not there is significant time required between when the cracks are predicted to leak (i.e., when cracks are predicted to propagate through the wall) and when the piping joint completely fails (i.e, gross rupture). The staff and contractor evaluations performed in late 2006 indicated that for at least the relief valve and safety valve nozzle configurations, there could be no additional time required to failure. The surge line analyses indicated some time between leakage and rupture; however, most analyses indicated that the time to failure can be less than two operating cycles. The staff also found that significant uncertainties in the analyses may dominate any potential sources of conservatism.

Most of the U.S. PWRs which have dissimilar metal welds on pressurizer nozzles are completing inspections or installing weld overlays sometime in 2007. However, there are nine plants which are currently planning to perform these activities during outages in 2008. These plants are: Braidwood 2, Comanche Peak 2, Diablo Canyon 2, Vogtle 1, Palo Verde 2, South Texas 1, Seabrook, Summer, and Waterford 3. Based on the analyses performed in late 2006, the staff determined that the performance of these activities at dates this far into the future is unacceptable without an additional basis for justifying that leak-before-break will occur for large flaws similar to those at Wolf Creek. To address the staff's concerns and provide such a basis, the industry developed an advanced finite element analysis of flaws wherein the crack shape is not constrained to remain semi-elliptical throughout its growth. This has involved development of a computer model wherein the crack growth varies with the local stress intensity along the crack front. The model was developed to allow the crack to grow through the pipe wall in a small region while providing a sufficiently large remaining ligament to prevent gross rupture of the weld. The licensees for these nine plants committed that, if the results of the advanced finite element analyses did not provide an acceptable basis for leak-before-break, they would proceed to inspect the welds before 2008.

In spring 2007, the industry provided the staff with a Phase I calculation which uses the industry's advanced FEA model to calculate crack growth for the cases which the NRC had evaluated in late 2006. The industry then performed Phase II calculations which were much more extensive and evaluated key parameter variations, such as states of residual stress due to initial fabrication and weld repairs. The Phase II effort evaluated these parameters based on plant-specific information. The industry submitted a final report (Reference 3) to the NRC with conclusions based on the Phase II calculations in August 2007.

The staff has held numerous meetings with the industry to discuss the advanced finite element analysis results. One such recent meeting was held on August 9, 2007, and the meeting presentation slides are provided in References 4 and 5. The meeting specifically covered several key technical issues such as: weld residual stress (WRS) modeling, elastic-plastic fracture mechanics (EPFM) vs. limit load analysis, the role of secondary stresses, K-solution verification, finite element modeling convergence, and the industry proposed sensitivity matrix, acceptance criteria, and necessary safety factors. To support the analysis effort, the industry gathered information regarding all of the nine plants at issue and determined the ranges of geometries, fabrications, repairs, residual stresses, and mechanical loadings which needed to be analyzed.

The staff and their contractor developed a calculational model similar to the industry model and performed confirmatory calculations to verify the industry results. The staff also made estimates of leakage from through-wall cracks predicted by the analyses to verify leakage estimates made by the industry to demonstrate that detectable leakage would occur prior to pipe rupture. The staff and contractor evaluations are provided in References 1 and 2. Following the completion of the staff's calculations and review of the industry report, the staff determined that it is acceptable for the nine plants at issue to defer performing inspection and mitigation activities until early 2008.

EXPECTED COMMITTEE ACTION

After reviewing this matter, the Committee may consider providing a report on this matter.

References


1. NRC staff safety assessment of the advanced finite element analysis of primary water stress corrosion cracking in pressurizer nozzle dissimilar metal butt welds, dated September 7, 2007 (ML072430091 and ML072400199)
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**-PROPOSED SCHEDULE-**

Cognizant Staff Engineer: Charles G. Hammer, cgh@nrc.gov (301) 415-7363

| Topics | Presenters | Time |
|---|---|---|
| **Opening Remarks** | W. Shack, ACRS | 1:30 - 1:35 pm |
| **Industry analysis of dissimilar metal weld flaws** | M. Melton, NEI<br>C. Harrington, EPRI<br>G. White, et al, DEI | 1:35 - 2:25 pm |
| **NRC staff evaluation of industry analysis of dissimilar metal weld flaws** | E. Sullivan, NRR<br>A. Csontos, RES<br>D. Rudland, EMCC | 2:25 - 2:55 pm |
| **Committee Discussion** | W. Shack, ACRS | 2:55 - 3:00 pm |

**Note**

- Presentation time should not exceed 50 percent of the total time allocated for specific items. The remaining 50 percent of the time is reserved for discussion.

- 35 copies of the presentation materials to be provided to the Committee.