From: Nilesh Chokshi RES
To: INTERNET:koc@nei.org
Date: 8/5/02 12:44PM
Subject: Research Write-up

Kurt,

A brief write-up on our proposed research is attached for use in our confereence call of Wednesday. Please let me know if you need any other information or have any questions.

Regards,

Nilesh

CC: Bill Bateman; Deborah Jackson; Jack Strosnider; John Grobe; Kenneth Karwoski; Michael Marshall; Michael Mayfield; Richard Barrett; Wallace Norris; William Cullen; William Dean

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NRC Research Activity Related to Vessel Head Penetrations and Head Wastage

As part of an overall program dealing with the CRDM inspection, leakage and the consequences of vessel head degradation, the Materials Engineering Branch (MEB) has produced a research plan titled "Degradation of Reactor Pressure Vessel Boundary Components in Concentrated Boric Acid Solutions." The research plan includes model development, stress-corrosion crack growth rate measurements, and corrosion rate measurements of low-alloy steel in normal and concentrated boric acid solutions. The MEB is encouraging industry cooperation through associated research and testing programs.

There are two encompassing objectives that will be met by completion of this research. The overall objective of the research is development of an independent integrated, probabilistic calculational model leading to evaluation of inspection techniques and intervals for vessel penetrations for long term management of the issue, and for incorporation in overall risk assessment. The second objective is to clarify the role of annulus environments and corrosion rates, since unplugging of the annulus changes many inspection-related criteria, such as corrosion rates of the low-alloy steel head, leakage rates of the reactor coolant, and appearance of the boric acid residues.

The NRC plans to initiate work related to the degradation of the reactor pressure vessel head as described below. While the impetus for this research program was provided by the discovery of leakage, cracking and wastage at the Davis-Besse Plant, the tasks have been designed more generically to address vessel head penetration and leakage issues. Components of this effort represent a good opportunity for cooperation between the NRC and industry to develop information which can be used for both regulatory and industry purposes.

The following describes general nature of work under consideration in three topical areas:

Development of an Integrated Crack Growth Rate and Inspection Frequency Determination Model

The probabilistic model will incorporate uncertainties in factors, such as: (a) sizing of cracks as determined through non-destructive inspections; (b) probability of detection; (c) variation in crack growth rates, due to microstructural and environmental conditions; (d) variations in stress intensity factor, due principally to residual stresses; (e) variations in leakage rates; and (f) structural integrity evaluations. The NRC is already conducting work on improving the probabilistic model for determining the failure probability from the time of leakage. Some work is being planned to evaluate the effectiveness of inspection techniques using a reactor vessel head cutout. Work is also in progress in evaluating emerging techniques for interrogating the area in and around the J-groove weld and nozzle area of the reactor vessel head.

Crack Initiation and Growth Rates of Alloys 600 and 182:

The objective of this effort is to supplement the conduct of stress-corrosion crack initiation and crack growth rate tests in simulated PWR coolant of CRDM and J-weld alloys. The additional testing will be conducted on CRDM and J-weld alloys removed from the head of the Davis-Besse plant. While the observation of leakage at the Davis-Besse plant was within the expected time frame (based on time-at-temperature), the availability of these materials represents a unique opportunity for the testing of field-typical (and aged for fifteen years) CRDM

materials. The initiation tests will show whether cracks could have formed with little or no incubation period, and give some information about the shape of the cracks, given the particular material characteristics of superficial work hardening, intrinsic residual stress and materials microstructure. The crack growth rate tests will demonstrate how these materials compare with the existing SCC data base that will be used in the disposition of cracks discovered in CRDM housings at other plants. Test procedures will conform to a practice which will qualify the results for inclusion in the industry and NRC accepted databases for each material. As a longer-term objective, testing of Alloy 690 and 152/52 needs to be emphasized for the management of the cracking and leakage issues in replacement heads that are now being ordered and put into service.

Corrosion and Corrosion Potential of Reactor Steels in Concentrated Boric Acid Solutions:

The objective of the corrosion task is to measure the wastage rates of reactor pressure vessel steel and cladding steel in aqueous boric acid solutions of varying concentrations and at various temperatures. Testing will be conducted in both quiescent and rapidly flowing conditions, to simulate either of the two conditions that may obtain in the annulus of the CRDM penetration. Additionally, corrosion tests will be conducted in molten boric acid and boric oxide mixtures at different temperatures and under pressure and humidity conditions that provide chemical compound stability for the molten species. This information is needed specifically for the accurate completion of the Safety Assessment of the Davis-Besse vessel head corrosion, but also as input for generic modeling of CRDM leakage paths and deterioration of CRDM annulus geometries.

This task will also incorporate testing to measure the electrochemical corrosion potential of the materials found in the head and nozzles of the Davis Besse reactor. Measurements of electrochemical potential reactor pressure vessel steel, Alloy 600 and Alloy 182 in flowing and quiescent boric acid solutions over a range of applicable temperatures, and solution concentrations will be completed. Tests should be conducted in solutions both non-aerated, and containing oxygen at or near the saturation concentration for the temperature of the test. The results of these tests will allow proper evaluation of the galvanic contribution to component corrosion and crack growth rates. These data are not currently available in the reference literature.

In addition to the two topical areas previously discussed, an additional area under consideration would include construction of a mock-up of the Davis-Besse leak and wastage process to assess generic implications. The objective of this task will be to develop and test a simulated leak into a crevice and to monitor the degree of plugging of the annulus openings, as well as the progress of the corrosion of the low-alloy steel. Also, the dependence of the leak path resistance on the plugging and corrosion of the annular cavity would need to be determined. A second phase of the experiment will be to simulate a large cavity, such as that found in the Davis-Besse head, to establish temperature and solution concentration and aeration conditions believed to maximize corrosion rates of low-alloy steel and determine the linear rates of wastage and nominal growth characteristics of the cavity.

The inspection area is another major area for potential cooperation, and the MEB staff would like to learn more about the details of the industry program.

While not a part of this research plan, MEB staff have started to conceptualize another program

that would require NRC and industry cooperation. Beginning in the 2004/2005 time frame, the heads from the Oconee vessels will be removed and replaced. One of the old heads could be used as a testbed for research and testing for crack growth rate determination, development of inspection techniques specifically for J-weld and CRDM cracking, and CRDM residual stress determination.

Lastly, the MEB is planning a workshop on CRDM inspection, leakage and cracking issues in the Spring of 2003. This workshop would solicit contributions from an international audience, to take advantage of foreign, particularly European, experience in this area. The topics for this workshop are expected to include discussions of leakage-based vs. crack repair-based inspection criteria, new inspection technologies and results, crack growth rate studies, residual stress analysis of CRDM's, and the outlook for the future, including inspection plans and predictive models used internationally.

The NRC staff would like to discuss the above items and other suggestions by the industry for potential cooperation.