December 6, 2004

Mr. Alex Marion, Senior Director
Engineering/Nuclear Operations Division
Nuclear Energy Institute
1776 I Street, NW Suite 400
Washington, DC 20006-3708

SUBJECT: DAVIS-BESSE LESSONS LEARNED TASK FORCE RECOMMENDATION 3.1.1(1) REGARDING NICKEL-BASED ALLOY SUSCEPTIBILITY TO STRESS CORROSION CRACKING AND BORIC ACID CORROSION OF CARBON STEEL

Dear Mr. Marion:

Davis-Besse Lessons Learned Task Force (DBLLTF) Recommendation 3.1.1(1) states the following:

> The NRC should assemble foreign and domestic information concerning Alloy 600 (and other nickel based alloys) nozzle cracking and boric acid corrosion from technical studies, previous related generic communications, industry guidance, and operational events. Following an analysis of nickel-based alloy nozzle susceptibility to stress corrosion cracking (SCC), including other susceptible components, and boric acid corrosion of carbon steel, the NRC should propose a course of action and an implementation schedule to address the results.

In response to this recommendation the Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) developed the following summary reports: "A Survey of Worldwide Experience With the Cracking Susceptibility of Alloy 600 and Associated Welds;" "Survey of Boric Acid Corrosion Events;" and "Boric Acid Corrosion of Light Water Reactor Pressure Vessel Materials." The RES reports assemble foreign and domestic information concerning nickel based alloy nozzle susceptibility to stress corrosion cracking (SCC), including other susceptible components, and boric acid corrosion (BAC) of carbon steel.

Based on our review of these reports, correspondence on industry programs and guidance, and operating experience, the staff has concluded that additional inspections of dissimilar metal welds and high nickel alloy components are warranted for addressing primary water stress corrosion cracking (PWSCC) and for precluding BAC as a result of through-wall leakage. The attached report provides the basis for this conclusion. In summary, the current regulatory framework includes reliance on inspections beyond the ASME Code requirements that are performed as a result of NRC bulletins and industry recommendations. These vehicles, in general, involve one-time inspections and industry actions that are not "mandatory." The staff believes that definitive and expeditious actions are needed to ensure that an appropriate set of on-going visual and volumetric inspections of dissimilar metal welds and high nickel alloy components are established and put in place.

The staff requests that representatives of the Nuclear Energy Institute (NEI) and the Materials Reliability Project (MRP) meet with NRC staff as soon as possible to discuss options for ensuring that these inspections are in place. Options for addressing these concerns in the near term may include issuance of comprehensive MRP "mandatory" recommendations or regulatory action. Longer term options may include new ASME Code requirements endorsed in the regulations.

The staff is interested in determining from this meeting whether industry actions can adequately address the staff's technical concerns, be timely, and provide a mechanism for establishing a regulatory footprint.

Sincerely,

/RA/

Richard J. Barrett, Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure: As stated

cc: J. Riley, NEI

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REPORT ON ACTIONS TO ADDRESS DAVIS-BESSE LESSONS LEARNED TASK FORCE RECOMMENDATION 3.1.1(1) REGARDING NICKEL-BASED ALLOY SUSCEPTIBILITY TO STRESS CORROSION CRACKING AND BORIC ACID CORROSION OF CARBON STEEL

1.0 INTRODUCTION

Davis-Besse Lessons Learned Task Force (DBLLTF) Recommendation 3.1.1(1) states the following:

> The NRC should assemble foreign and domestic information concerning Alloy 600 (and other nickel based alloys) nozzle cracking and boric acid corrosion from technical studies, previous related generic communications, industry guidance, and operational events. Following an analysis of nickel-based alloy nozzle susceptibility to stress corrosion cracking (SCC), including other susceptible components, and boric acid corrosion (BAC) of carbon steel, the NRC should propose a course of action and an implementation schedule to address the results.

The Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) completed the review of foreign and domestic information and documented these reviews in three summary reports. The RES reports assemble foreign and domestic information concerning nickel-based alloy nozzle susceptibility to SCC, including other susceptible components, and BAC of carbon steel and low-alloy steel.

Staff of the Materials and Chemical Engineering Branch (EMCB) have reviewed these reports and other supporting information, including industry inspection activities, American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) activities, and industry materials degradation initiatives. The staff's recommended course of action to address the results of the review is documented in the following sections of this report.

2.0 NICKEL-BASED ALLOY NOZZLE SUSCEPTIBILITY TO SCC, INCLUDING OTHER SUSCEPTIBLE COMPONENTS

In connection with the action plan item on susceptibility to SCC, staff from the Office of Nuclear Reactor Regulation (NRR) reviewed the RES report titled, "A Survey of Worldwide Experience With the Cracking Susceptibility of Alloy 600 and Associated Welds." This report deals with the range of issues pertaining to ensuring the integrity of components that may be affected by SCC. Based on this review, NRR staff has concluded that the positions established by the First Revised NRC Order EA-03-009 (the Order) concerning inspection of the reactor vessel upper head, penetrations, and associated welds continue to be acceptable. This is discussed in the next paragraph. However, other susceptible nickel-based alloy components warrant additional inspection. This subject is discussed in the following paragraphs.

The staff has several ongoing activities to address the area of inspection of nickel-based alloy components' susceptibility to primary water stress corrosion cracking (PWSCC). The Order

imposes enhanced inspection requirements for reactor pressure vessel upper heads, penetrations, and associated welds. Some licensees have been requesting relaxations, as necessary, to demonstrate compliance with the Order. The ASME Code is deliberating a code case to establish a recommended inspection plan for reactor pressure vessel upper heads and associated penetration nozzles, as an alternative, and, potentially in the long-term, a replacement for the Order. Participation of NRC staff in ASME Code committee meetings on the code case is providing feedback on the proposal. NRC staff approval would be required prior to licensee implementation of the proposed ASME Code case. Completion of this activity is based on the progress of this ASME Code activity, and it is unclear at this time if the staff will find the proposal to be acceptable. Therefore, it is not possible at this time to establish a completion schedule for either the ASME Code activity or eventual incorporation of code changes in NRC regulations. In the meantime, implementation of the Order continues to provide inspections that are acceptable to the staff.

In regards to other susceptible components, on August 21, 2003, NRC issued NRC Bulletin 2003-02, "Leakage from Reactor Pressure Vessel Lower Head Penetrations and Reactor Coolant Pressure Boundary Integrity," to address, in part, the issue of the susceptibility to PWSCC of nickel-based alloy penetrations in the lower reactor pressure vessel head. On May 24, 2004, NRC issued NRC Bulletin 2004-01, “Inspection of Alloy 82/182/600 Materials Used in the Fabrication of Pressurizer Penetrations and Steam Space Piping Connections at Pressurized-Water Reactors,” to address, in part, the issue of the susceptibility to PWSCC of nickel-based alloy pressurizer penetrations and pressurizer steam space piping connections.

On January 20, 2004, the Materials Reliability Program (MRP) issued a letter that recommended direct visual inspection of the bare metal or equivalent alternative examinations be performed at all Alloy 600/82/182 pressure boundary locations normally operated at greater than or equal to 350E F in the primary system within the next two refueling outages at each plant, unless performed during the most recent refueling outage.

On April 2, 2004, the MRP issued a letter that contained the “needed action” for each PWR to perform a direct visual inspection of the bare metal or an equivalent alternative examination at all Alloy 82/182 pressure boundary butt weld locations that normally operate at greater than or equal to 350E F in the primary system within the next two refueling outages, unless an examination was performed during the most recent refueling outage.

These actions provide confidence that appropriate visual inspections are being conducted to identify leakage that may potentially occur as a result of PWSCC in Alloy 600/82/182 components. Nevertheless, these actions do not provide for long-term inspections to ensure that potential PWSCC in nickel-based alloy components in the primary system will be promptly identified and corrected. While the bulletins discussed above request information on inspection plans, they may not ensure that visual inspections will continue to be performed over the long-term. As noted above, the MRP letters provide recommendations for inspections but these recommendations are applicable for a limited time period and are not “mandatory.”

In July 2004, MRP released their latest report titled, “Alloy 82/182 Pipe Butt Weld Safety Assessment for U.S. PWR Plant Designs (MRP-113),” to address ongoing discussions between the staff and the MRP on the generic issue of nickel-based weld metal alloy susceptibility in reactor coolant system pipe butt welds. It is our understanding that the industry is developing

recommendations to manage potential degradation of dissimilar metal butt welds. These recommendations may be issued by the MRP early in 2005.

3.0 BORIC ACID CORROSION OF CARBON STEEL

RES has issued two reports on boric acid corrosion of carbon steel: "Survey of Boric Acid Corrosion Events," prepared by Samantha Crane and William Cullen of RES; and, "Boric Acid Corrosion of Light Water Reactor Pressure Vessel Materials," prepared by Argonne National Laboratory (ANL).

The report by Crane and Cullen discusses foreign and domestic events involving boric acid corrosion and NRC actions to address boric acid corrosion issues since 1980. The report discusses the Davis-Besse reactor head corrosion event including industry's understanding of contributing factors and suggested scenarios leading up to the conditions found. Finally, the report presents a review of current NRC and industry test programs. The report points to the fact that while many research programs have been conducted to study the effects of boric acid corrosion of reactor components, these studies fall short in many areas. Examples pointed out in this study are the subject of the second report prepared by ANL. The report notes that while information was lacking in regards to specific conditions studied by ANL, the overall consequences of boric acid corrosion have been well-known and reasonably well-documented.

The ANL report presents the results of tests conducted at specific conditions to better understand corrosion associated with various nozzle-to-vessel annulus conditions regarding temperature, pressure, flow rate, and boric acid concentrations. A new finding from these tests is that very high corrosion rates were observed for low-alloy steel at 140 - 170E C (284 - 338E F) in molten salt solutions of boric acid with addition of water. Short-term corrosion rates up to 150 mm/yr (• 6 in/yr) were measured at 150E C (302E F). These corrosion rates are in the same range that has been observed in saturated boric acid solutions at 97.5E C (207.5E F). The molten boric acid corrosion rate finding may be an explanation for field observations of boric acid corrosion that were not understood, such as the Sequoyah Unit 2 event in 2003. This event was discussed in the NRC Information Notice 2003-02, "Recent Experience With Reactor Coolant System Leakage And Boric Acid Corrosion."

There are a number of ongoing activities to address the area of inspection of carbon steel and low-alloy steel components susceptible to boric acid corrosion and to address BAC potentially resulting from leakage through stress corrosion cracks in nickel-based alloy components. As a result of the staff's review of the responses to NRC Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," the staff issued Regulatory Issue Summary (RIS) 2003-13, "NRC Review of the Responses to Bulletin 2002-01." The staff noted in this RIS that the BAC inspections performed under the recommendations of Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants," as well as the inspections performed during ASME Code system pressure testing do not require the removal of insulation and, thus, are generally not capable of detecting leakage resulting from PWSCC. Thus, BAC could take place over an extended period of time before it is identified.

By letter dated August 19, 2002 (ML022200152), the NRC requested that ASME Section XI create a task group to re-evaluate the inspection and corrective action requirements for all systems that are potentially subject to stress corrosion cracking and boric acid corrosion. In

response to this letter, Section XI of the ASME Code chartered the Task Group on Boric Acid Corrosion. The task group noted that the 2003 Addenda to the 2001 Edition of Section XI and earlier editions and addenda of the ASME Code do not require the visual inspection of bare metal surfaces of pressure retaining components when examining these components for evidence of leakage. The degradation being experienced in the industry today includes wastage caused by boric acid attack of susceptible materials such as carbon and low-alloy steel vessels due to pressure boundary leakage resulting from PWSCC of the Alloy 600/82/182 materials. Nuclear plant operators have relied on their commitments to Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants," to detect and manage borated water leakage throughout plant borated systems. In order to ensure detection of boric acid corrosion in pressure retaining components prior to failure, the task group concluded that more rigorous inspections than those currently provided by the ASME Code must be performed in the areas most susceptible to PWSCC. The task group developed Proposed ASME Code Case N-722, "Additional Inspections for PWR Pressure Retaining Welds in Class 1 Pressure Boundary Components Fabricated with Alloy 600/82/182 Materials, Section XI, Division 1." This proposed code case was developed to enhance the current code requirements for detection of leakage and corrosion in the components considered to be susceptible to PWSCC. The bare metal visual examinations of Proposed ASME Code Case N-722 would be specified for all pressure retaining components fabricated from Alloy 600/82/182 materials regardless of the component operating temperature. This code case has been considered by the ASME Main Committee and is being revised to address ASME Main Committee comments. Pending review of the revised code case, the staff considers the scope, methods, and frequency of inspections in this code case to be suitable for identifying leakage from PWSCC and for precluding BAC as a result of such through-wall leakage. It is not clear when the proposed code case will be approved by ASME.

4.0 PROPOSED COURSE OF ACTION

As noted above, with the exception of reactor vessel upper heads, inspection of nickel-based alloy components susceptible to PWSCC warrants additional attention. Section 2.0 identifies concerns with inspection-related activities that are currently underway.

The issue of inspections for BAC is closely related to the issue of inspections for PWSCC. The concern for BAC identified by both the NRC and industry is that, except for reactor vessel upper heads, there are no long-term recommendations or requirements in place for inspection of components susceptible to PWSCC, and without suitable inspections for PWSCC, BAC could take place over an extended period of time before it is identified. The ANL test results under molten boric acid conditions reveal a new situation in which very high corrosion rates can occur under certain conditions and underscores the need for a robust inspection program.

The staff believes that definitive and expeditious actions are needed to ensure that an appropriate set of on-going visual and volumetric inspections of nickel-based alloy components are established and put in place. The staff would like to meet with representatives of the Nuclear Energy Institute (NEI) and the Materials Reliability Project (MRP) to discuss options for ensuring these inspections are in place. Options for addressing these concerns in the near term may include issuance of comprehensive MRP "mandatory" recommendations or regulatory action. Longer term options may include new ASME Code requirements endorsed in the regulations.

The staff is interested in determining from this meeting whether industry actions can adequately address the staff's technical concerns, be timely, and provide a mechanism for establishing a regulatory footprint.

5.0 REFERENCES

A Survey of Worldwide Experience with Cracking and Susceptibility of Alloy 600 and Associated Welds, T. Mintz & W. Cullen (ML040910354)

Survey of Boric Acid Corrosion Events, S. Crane & W. Cullen (ML043000274)

Boric Acid Corrosion of Light Water Reactor Pressure Vessel Materials[1] - J. H. Park, O.K. Chopra, K. Natesan & W. J. Shack, ANL

[1] This report will be issued as a NUREG/CR by early 2005.