April 10, 2008

Richard Anderson, BWROG Executive Chairman
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SUBJECT: POTENTIAL ISSUES RELATED TO EMERGENCY CORE COOLING SYSTEMS (ECCS) STRAINER PERFORMANCE AT BOILING WATER REACTORS

Dear Mr. Anderson:

This letter is a follow-up to our phone conversation on February 1, 2008. During that phone call, I requested the assistance of the Boiling Water Reactor Owners Group (BWROG) in addressing potential issues related to emergency core cooling system (ECCS) strainer performance at boiling water reactors (BWRs). This letter summarizes some of the potential issues for which the Nuclear Regulatory Commission (NRC) staff believes additional work may be warranted.

BACKGROUND

The NRC and the nuclear industry conducted research, guidance development, testing, reviews, and hardware and procedure changes from 1992 to 2001 to resolve the issue of debris blockage of BWR strainers. The NRC staff issued NRC Bulletin (NRCB) 95-02, "Unexpected Clogging of a Residual Heat Removal (RHR) Pump Strainer While Operating in Suppression Pool Cooling Mode" and NRCB 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors." Both bulletins dealt with ensuring that debris generated during a loss-of-coolant accident (LOCA) would not clog ECCS suction strainers. Such clogging could potentially prevent the ECCS from performing its safety function. Licensee measures to clean the suppression pools and establish foreign material control programs were implemented, each BWR licensee assessed its plant-specific situation and developed a plant-specific approach to resolve the issue, and larger passive strainers were installed in each plant.

The BWR Owners Group (BWROG) supported the utilities in addressing NRCBs 95-02 and 96-03 by developing resolution guidance, referred to as the Utility Resolution Guide (URG). The BWROG evaluated potential solutions and conducted tests to obtain needed data to develop the URG. The NRC staff followed the development of the URG and associated testing and reviewed the guidance. The NRC approved the URG with conditions and exceptions in a safety evaluation.

The NRC concluded that all BWR licensees had sufficiently responded to the requested actions of NRCB 95-02 and NRCB 96-03 and considered that generic and plant-specific activities associated with these bulletins were complete.

Pressurized water reactors (PWRs) Generic Safety Issue (GSI) 191 was initiated in 1996 to examine whether the events and new research being conducted for the BWR strainers warranted similar evaluations and/or changes for ensuring the adequacy of PWR recirculation performance. The NRC staff completed the GSI technical assessment and concluded that plant-specific analyses should be conducted to determine whether debris accumulation in PWR containments could impede or prevent ECCS operation during recirculation, and that appropriate corrective actions should be taken. This expectation was communicated to licensees via Generic Letter 2004-02, “Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors.” The industry developed guidance for evaluating PWR recirculation issues depended on the methods and techniques previously used in the BWROG URG. The staff issued a safety evaluation endorsing the NEI guidance with certain exceptions on December 6, 2004 (NEI 04-07 Volume 2).

RECENT DEVELOPMENTS

While addressing PWR recirculation issues, further knowledge has been developed in various disciplines that could be applicable to BWR strainer design. Additionally, several areas were treated more conservatively during the course of PWR resolution and several areas were not examined for BWRs. The NRC staff considered the potential implications for BWRs of information obtained while addressing GSI-191 for PWRs. The staff concluded that several subject areas not addressed in Bulletins 95-02 and 96-03 or by the BWR licensees during the 1990s warranted additional consideration to determine the applicability to BWR designs. The specific areas are described in detail in the Enclosure to this letter.

On November 27, 2007, the NRC staff met with representatives of the BWROG (ADAMS Accession Number ML073320404). The staff summarized its views on several example subject areas where the staff believes additional work is warranted to determine the applicability of the issue for BWRs. The BWROG presented its views on several of the issues. As noted in the meeting summary, the BWROG representatives noted several areas in which the BWROG was considering some action, and other areas in which it considered no action necessary.

Since that meeting, the staff has received additional information from observations of PWR head loss tests suggesting that head losses caused by very thin beds of fiber and particulate can be larger than had previously been expected. While the data so far are limited, these test results raise further questions regarding the reliance of BWRs on head loss correlations for strainer qualification.

CONCLUSION

Throughout the activities addressing GSI-191, significant new knowledge has been gained regarding various technical aspects of strainer performance. For example, chemical effects have been more problematic than expected. Similarly, a thin bed of debris on a strainer may cause a more limiting head loss than could a much thicker bed developed under different conditions. The Office of Nuclear Regulatory Research has initiated action to evaluate the applicability of several of these issues for BWR strainer performance. While the BWROG has agreed to undertake certain actions to address some of the issues, we believe that a more comprehensive and integrated effort is necessary to evaluate the issues. The NRC staff’s guidance documents for GSI-191, which can be found on our PWR sump performance web page, provide references for the state of knowledge regarding the relevant issues.

We believe the industry shares a common goal with the NRC, to address strainer performance issues with an appropriate level of technical rigor to ensure safety of BWRs is not degraded. We encourage the BWROG to develop a comprehensive evaluation plan integrated with the efforts of the NRC to address these issues regarding BWR strainer performance. We look forward to continuing interactions with the BWROG staff on this subject. Please contact

Mr. Michael Scott (mls3@nrc.gov, 301-415-0565) as necessary to further discuss these matters in advance of the next meeting currently scheduled for June 5, 2008.

Sincerely,

/RA/

John A. Grobe, Associate Director
for Engineering and Safety Systems
Office of Nuclear Reactor Regulation

Enclosure: as stated

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John A. Grobe, Associate Director
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Enclosure: as stated

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SUBJECT AREAS REGARDING BWR RECIRCULATION WARRANTING FURTHER CONSIDERATION

Chemical Effects

Although testing in representative PWR environments has shown that products can form from chemical interactions among plant materials, the potential chemical effects in a BWR environment are unknown. Potential chemical effects involve corrosion products, gelatinous material, or other chemical reaction products that could form as a result of interaction between the BWR containment environment and containment materials after a loss-of-coolant accident (LOCA). Currently, most BWR licensees do not use any pH buffer agent during a postulated LOCA. It is unknown what chemical by-products would form in this environment. A few licensees have been approved in conjunction with alternate source term amendments to inject sodium pentaborate solution from the standby liquid control system into the reactor vessel for purposes of retaining iodine. To our knowledge, the possible chemical interaction between the containment debris and the pH-buffered standby liquid control system fluid has not been evaluated.

If generated, chemical products could be transported to the suppression pool through transport methods such as entrainment in the steam/water flows issuing from the break and containment spray washdown. Subsequently, when the ECCS pumps take suction from the suppression pool, the suspended debris could begin to accumulate on the suction strainer or be transported through the strainer and into the ECCS system. If sufficient chemical products accumulate on a debris bed, the head loss across the debris bed could exceed the net positive suction head (NPSH) margin required to ensure the successful operation of the ECCS. Chemical effects were not considered when BWR strainer clogging was previously evaluated.

Chemical effects have proven to be a complex issue for PWRs. The impact of chemical effects on BWRs is largely unknown, and a database similar to that developed from the NRC staff-sponsored Integrated Chemical Effects Tests (ICET) does not exist for BWRs. Absent such a database, it is not possible to rigorously assess whether chemical effects are a significant issue for BWRs. For example, chemical effects have been observed in neutral water for PWRs, so the staff does not consider absence of a buffer sufficient to support a conclusion that chemical effects are not an issue for BWRs. At the November 27, 2007, meeting, the BWROG discussed the view that the large volume of water in the suppression pool and the lack of a buffer render chemical effects at BWRs not in need of additional attention.

In-Vessel Downstream Effects

Downstream effects related to debris intrusion in the reactor vessel are of potential concern for BWRs because BWRs use channeled fuel assemblies. The channels in BWR fuel inhibit crossflow among fuel assemblies, versus open cores in PWRs which allow for crossflow. The staff has not seen a written evaluation of the potential for downstream effects of debris on BWR fuel. The BWROG stated at the November 2007 meeting that the core remains fully cooled throughout the transient, principally due to core spray flow which arrives from above the core. They agreed to provide an evaluation that would demonstrate that in-vessel downstream effects are not an issue for BWRs. They subsequently contacted the NRC staff to confirm what the staff believes is appropriate focus for the documentation to be provided. The staff provided feedback as requested. Pending receipt and staff evaluation of the documentation, the BWROG actions in this area appear to be on target.

Head Loss Evaluation

Research and analysis conducted since BWR strainer clogging was addressed have enhanced the staff's understanding of the prediction of head loss across debris beds that may form on ECCS strainers. A number of BWRs contain microporous insulation or other types of particulate debris sources that have recently been shown to cause (or are suspected of causing) head losses within a fibrous matrix that are significantly higher than those caused by iron oxide particulates as previously evaluated for BWRs. Also, the staff notes that a head loss correlation in NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," was used extensively in determining both the sizing and the design basis for the BWR ECCS strainers. Based on currently available information, the correlation might have yielded nonconservative results, particularly for BWRs containing microporous debris. For PWRs, use of this correlation was restricted to preliminary scoping because of concerns related to how well the correlation predicted certain head loss tests (e.g., calcium silicate insulation and latent debris), temperature effects that could possibly affect the debris bed morphology, and other concerns regarding the form of the correlation. Therefore, the staff's 2004 safety evaluation (SE) in support of Generic Letter 2004-02 called for plant-specific evaluations and testing to assess the actual plant strainers to be installed. Finally, the treatment of thin fibrous/particulate beds appears to be more conservative as implemented for PWRs. Specific testing is being pursued by all PWR strainer vendors for low-fiber cases, since thin fiber beds accumulating on strainers are recognized as potentially representing a limiting head loss condition. Recent results of conservative head loss testing suggest that thin debris beds may lead to high head losses for some debris loadings.

For BWRs, the focus was mainly on high debris loading cases. Given the present state of knowledge, this assumption may not be valid. Recent results of conservative head loss testing suggest that thin debris beds may lead to high head losses for some debris loadings. At the November 2007 meeting, the BWROG agreed to provide a position on the questions raised by the NRC staff regarding this subject area by spring 2008.

Latent Debris

Most BWRs do not chemically control or de-oxygenate their suppression pools. Many have seen corrosion of their suppression pools, particularly at the water line. This often results in the buildup of debris from corrosion products on exposed carbon steel surfaces and at the bottom of the suppression pool (even over one operating cycle). As compared with PWRs, BWRs have smaller containments and pressure-suppression containment designs that are much more likely to be congested (potentially leading to a higher latent debris source term), likely resulting in higher transport of debris both to the suppression pool (resulting in a higher debris concentration in the ECCS water supply) and to the strainer (due to high levels of turbulence for a fairly long time in the suppression pool). These factors potentially raise the significance of treatment of latent debris for BWRs.

To address the quantity of latent debris, the BWR SE approved use of a generic value of 150 lbs., based on a calculation described in the BWROG URG. If a plant chose to use a lesser quantity, a plant-specific evaluation was necessary. There is no guidance related to the form of the latent debris in BWRs. However, the staff understands that BWRs generally increased the particulate debris source term to address the issue of latent debris. This treatment of latent debris may be non-conservative, especially for low-fiber plants with small strainers. This is because latent debris may be in a different form from that assumed in BWR analyses (i.e., fibrous). For PWRs, a nominal 200 lbs. was discussed in the NEI 04-07 guidance report (GR), but the staff's accompanying SE stated that licensees cannot use this value and must evaluate the loading on a plant-specific basis. Continuous validity of this latent debris term is addressed in the SE through a call for programmatic controls for containment cleanliness inspections and verifications; such controls may not be in place for BWRs. The potential presence of corrosion products in BWRs, in the staff's judgment, warrants additional work to evaluate whether the BWR assumption regarding latent debris is conservative, and, if not, whether additional action (e.g., programmatic monitoring of latent debris) is needed. At the November 2007 meeting, the BWROG did not address this topic, but agreed to discuss it at a follow-on meeting with the NRC staff in spring 2008.

Zone-of-Influence (ZOI) Adjustment for Air Jet Testing

The NEI PWR GR proposed using the same set of debris destruction pressures for insulation that was approved for use by BWRs in the URG SE. These destruction pressures, and the corresponding spherical ZOIs calculated using ANSI 58.2-1988 isobars to establish equivalent volumes, were based on air jet impact testing conducted by the industry in support of the URG. One exception for the PWR GR was that it proposed using a reduced destruction pressure of 24 psi for aluminum-jacketed calcium silicate insulation, versus the 160 psi approved for the URG, based on two-phase steam/water testing completed in CY 2001 by Ontario Power Generation.

During review of the PWR GR, the staff questioned whether it was valid to use air jet testing data to determine destruction pressures based on two-phase breaks. To conservatively address this concern, the staff SE imposed a 40 percent reduction in the destruction pressure identified during air jet testing as the value to be used in establishing ZOIs. This represents an approximate tripling (270 percent) of the ZOI volume for materials whose destruction pressure was based on air jet testing.

Pipe breaks at both PWRs and BWRs can be located at either saturated or subcooled water lines (reactor coolant system piping for PWRs or recirculation lines for BWRs). For BWRs, a large-break LOCA can be a steam break (e.g., main steam line). Large-scale jet impact testing, such as that conducted by Swedish utilities at the Siemens - KWU facilities in Karlstein, Germany in 1994-95, has clearly demonstrated that saturated water jets are far less destructive than steam jets. This suggests that single-phase air jet tests would be conservative relative to two-phase saturated water tests (e.g., similar to steam). Nonetheless, uncertainty remains regarding applying air jet test results to two-phase water breaks. The impact of differences between air and steam jets could be significant for BWRs, with their likelihood of steam breaks.

As another example of less conservative treatment (relative to the PWR SE guidance to decrease ZOI destruction pressure), the BWR URG proposed, and the NRC URG SE accepted, reduction of the destruction zone by factors of up to 60 percent in recognition of the lesser damage potential for water lines (recirculation line breaks) relative to steam line breaks.

At the November 2007 meeting, the BWROG declined to further evaluate the questions raised in this subject area.

ZOI for Coatings

Previous BWR strainer clogging evaluations used a single-value particulate term for coatings within the ZOI. The iron oxide sludge from suppression pool corrosion was estimated to be in the several hundred pound range after each operating cycle, based on calculations and suppression pool cleanup results. The 80 lbs. coatings particulate calculated to be present was considered to be insignificant or bounded by the iron oxide sludge. A generic calculation was used to determine the coatings quantities. The calculation considered a 24-inch steam line, expanding in a 10-degree half-angle cone, which results in an impingement area of 302 square feet at a distance of 10 pipe diameters (D) on an assumed coated drywell wall. The area was then doubled to consider intermediate targets. This is equivalent to a 2.45 D spherical ZOI, assuming the surface of the sphere as target area for the sphere and doubling the area for intermediate targets. The quantities of coatings were calculated for this ZOI and approved for generic use for BWR resolution. A plant-specific effort to identify a particular worst-case coatings ZOI volume was not imposed.

The PWR GR proposed using a smaller 1D spherical zone of influence for protective coatings, basing this on high-pressure water jet testing conducted by Florida Power and Light and the Westinghouse Owners Group. This testing, documented in Appendix A to the GR, yielded calculated spherical ZOIs of 0.24 D for epoxies (1000 psi destruction pressure claimed) and 0.55 D for un-topcoated inorganic zinc (333 psi destruction pressure claimed). Because of questions about the temperature and scaling, the NRC SE did not accept this testing. Instead, the staff called for a coatings ZOI that either required plant-specific analysis (implying additional testing) or use of a ZOI (10D) that was much larger than that approved for the BWRs (based on engineering judgment). The PWR guidance requires a plant-specific effort to identify a particular worst-case coatings ZOI volume, versus the generic quantity accepted for BWR analysis. Of note, plant-specific two-phase ZOI testing of coatings has resulted in smaller ZOIs than the default SE position but larger than the equivalent “ZOI” used for the BWR resolution. The prior use of generic coating ZOIs, coupled with more recent information about ZOIs for specific coating materials, raises the question of whether treatment of coatings ZOIs was sufficiently conservative for BWRs.

At the November 2007 meeting, the BWROG declined to further evaluate the questions raised in this subject area.

Debris Characteristics

The PWR guidance calls for substantiation of unknown debris characteristics or use of default highly conservative characteristics for the most fragile debris. Absent additional testing, engineering judgment was used for this area in the PWR analyses (for example, use of generic characteristics of NUKON™ fibrous insulation as a surrogate for mineral wool). No such conservative criteria existed for BWRs, with licensee judgment exercised in choosing debris characteristics.

The PWR guidance calls for significantly more conservative treatment of calcium silicate insulation, with high specific-volume numbers, compared with treatment of that material as a particulate with more benign characteristics for BWRs. An additional large difference in treatment of calcium silicate insulation for PWRs was the previously stated reduction in destruction pressure to 24 psi (based on OPG two-phase testing) versus the 160 psi approved for BWRs, thus imposing a much larger ZOI for this insulation in addition to treating its characteristics more conservatively.

At the November 2007 meeting, the BWROG took no position on the questions raised in this area.