March 31, 2010

Mr. Anthony Nowinowski, Manager
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SUBJECT: NUCLEAR REGULATORY COMMISSION CONCLUSIONS REGARDING PRESSURIZED WATER REACTOR OWNERS GROUP RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION DATED JANUARY 25, 2010 REGARDING LICENSEE DEBRIS GENERATION ASSUMPTIONS FOR GSI-191

Dear Mr. Nowinowski:

As you are aware, the U.S. Nuclear Regulatory Commission (NRC) staff had questions regarding certain assumptions that some licensees have made regarding the generation of debris following a design basis accident. These questions were based on staff review of two industry technical reports referenced by some licensees in submittals to the NRC: WCAP-16710-P, Revision 0, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON® Insulation for Wolf Creek and Callaway Nuclear Operating Plants," and WCAP-16851-P, Revision 0, "Florida Power and Light (FPL) Jet Impingement Testing of Cal-Sil Insulation." The reports documented jet impingement testing performed at Wyle Laboratories, and were intended to justify a reduced ZOI (volume around a hypothetical reactor coolant system break within which insulation could be damaged and potentially travel to the emergency core cooling system strainer following a loss-of-coolant accident). During a teleconference on February 20, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML090570671), the Pressurized Water Reactor Owners Group (PWROG), on behalf of affected licensees, requested that the NRC staff's questions regarding these technical reports be resolved generically through the PWROG to the extent feasible. Based on this request, the NRC staff discussed questions regarding the technical reports with the PWROG during the teleconference. Additional detailed technical discussions with the PWROG have been ongoing since February 2009.

As a result of NRC staff questions, on December 11, 2009, Westinghouse identified several locations in the Wyle test loop where the inside diameter of the piping was significantly smaller than the nozzle. For example, the nozzle size used to calculate the jet pressures at most of the jet impingement targets was 3.54 inches in diameter; however the smallest piping diameter was 2.313 inches and was located approximately 26 inches upstream of the nozzle exit. In addition, on February 12, 2010, Westinghouse submitted a letter to the NRC (ADAMS ML100480138) that concluded the following reports had the same or similar small diameter locations upstream of the test nozzle:

- WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings"

- WCAP-16720-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOIs) for Diablo Canyon Power Plant"
- WCAP-16727-NP, "Evaluation of Jet Impingement and High Temperature Soak Tests of Lead Blankets for Use Inside Containment of Westinghouse Pressurized Water Reactors"
- WCAP-16783-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and 3M® Fire Barrier Insulation for Watts Bar Nuclear Plant"
- WCAP-16836-P, "Arkansas Nuclear One – Jet Impingement Testing of Insulating Materials"

During a public meeting between NRC staff and the PWROG on December 16, 2009, the PWROG agreed to formally respond to the NRC staff concerns regarding the technical reports by March 1, 2010. To facilitate this response, the NRC staff sent a request for additional information (RAI) to the PWROG via letter dated January 25, 2010 (ADAMS ML100060467). The PWROG responded to the RAI via letter dated March 5, 2010 (ADAMS ML100710710). The NRC staff has reviewed the PWROG RAI responses. The purpose of this letter is to transmit the NRC staff's conclusions regarding WCAP-16710-P, WCAP-16851-P, and similar technical reports as listed above.

The NRC staff has concluded that the small diameter locations upstream of the test nozzle constitute significant test design errors, and, absent substantial additional information, render all recommended ZOIs in similar test reports invalid. The NRC staff notes that empirically derived damage pressures (i.e. measured) may be obtained for a target centerline through testing and subsequently used as an input to the American National Standard Institute/American Nuclear Society (ANSI/ANS) 58.2-1988 model for calculating a ZOI. This approach, as long as appropriate test scaling is considered for jacketed insulation, is consistent with the staff safety evaluation (SE) of Nuclear Energy Institute (NEI) guidance report 04-07, "Pressurized Water Reactor Sump Performance Methodology" (ADAMS ML043280007).

While the NRC staff has concluded that the test report ZOIs are not valid based on the available information, the PWROG has resolved some of the staff's RAI questions. A discussion of the PWROG responses to the RAIs, and the NRC staff's conclusions regarding the status of each issue identified in the RAI letter, are provided below.

<u>Issue 1 - Resolved</u>

This issue refers to the potential for formation of a damaging blast wave. Based on the technical references reviewed by the staff, several of which were provided by the PWROG, the NRC staff agrees that a blast wave is not likely to form during a hypothetical loss-of-coolant accident where the fluid upstream of the break location is sub-cooled. In addition, the NRC staff agrees that the PWROG has shown that if a blast wave did form during the initial moments of a sub-cooled pipe break, it would be insignificant compared to the forces exhibited by the subsequent jet blowdown. As such the NRC staff considers Issue 1 resolved for sub-cooled breaks. The NRC staff also agreed with the statements and conclusions made by the PWROG in response to sub-issue 1.d. The staff did not find information provided by the PWROG sufficient to address the details of sub-issues 1.a, 1.b, 1.c, and 1.e. However, the staff's conclusion that a blast wave would be insignificant for a sub-cooled liquid renders these questions irrelevant to resolution of Issue 1.

While the staff agrees that blast waves are not likely to form during breaks involving flashing of sub-cooled jets (hot leg, cold leg, and surge line breaks), this conclusion does not apply to postulated breaks of steam-bearing piping, where blast waves are likely to occur.

Issue 2 and 4 - Unresolved

The NRC staff has grouped Issues 2 and 4 together to maintain clarity when comparing NRC staff positions in this letter to the PWROG responses. In addition, the PWROG RAI response discussed sub-issues 2.c and 2.e prior to the remaining aspects of Issue 2 and 4. The NRC staff has elected to mirror this approach in this letter as well for clarity.

Sub-issue 2.c – Resolved (Plant-specific)

The NRC staff agrees that pressurizer insulation may be excluded as a debris source above a support skirt for a break below the support skirt as long as a licensee has a support skirt that would physically block any jet associated with the break.

Sub-issue 2.e – Resolved

During the WCAP-16710-P tests of jacketed NUKON® on piping, the test target had three latches holding a jacket section in place. During three different tests, at various distances, latches disengaged. However, in all three tests, at least one of the three latches remained engaged and the jacketing remained on the target. Considered as an entire latch system, the staff agrees that this behavior is repeatable for jacketing sections held in place by sets of three latches. Licensees seeking this credit should conduct multiple tests using the number of latches per section applicable to their installation if different from the three latches per section tested in WCAP-16710-P. This conclusion does not imply acceptance of the jacketed NUKON® ZOIs cited in WCAP-16710-P, due to the test loop design error identified by Westinghouse.

The PWROG did not address the remaining questions related to Issue 2 or Issue 4. Instead, the PWROG provided an overall response to these two issues that is intended to provide a framework for addressing the concerns in Issue 2 and Issue 4 under a possible future submittal. As a result, the NRC staff conclusion is that the PWROG has not provided sufficient technical justification to address Issue 2 and Issue 4. The exceptions to this conclusion are sub-issues 2.c and 2.e, as previously discussed.

In addition, the NRC staff has reached the following conclusions with respect to the overall response provided by the PWROG for Issues 2 and 4:

1. The NRC staff agrees that the method described in Appendix B of the NRC's SE of Topical Report NEDO-32686-A, "Utility Resolution Guidance for ECCS Suction Strainer Blockage" (ADAMS ML092530482), may be used to scale jacketed insulation test results to larger diameter pipes. The staff notes that target scaling is only required for jacketed insulation systems and would not be required where failure of a material would result from a local force (i.e. tearing of cover) versus a total force on a pipe jacket.

2. The staff does not accept the concept of an "effective jet nozzle diameter." The test design error represents significant uncertainty in attempting to make any comparisons to free jet expansion models, much less refinements.

3. Similarly, the NRC staff does not recognize the Wyle January 2010 instrumented tests as “free-jet expansion tests.” This conclusion is a result of the test design error in the test loop.

4. The ANSI/ANS 58.2-1988 model has been accepted in the SE to NEI 04-07 for determining jet volumes at different pressure isobars. The NRC staff acknowledges that the model is expected to over predict axial pressure because jet expansion is artificially constrained within the model. However, this overestimation of axial pressure comes in part at the expense of the jet’s radial expansion. Specifically, where the ANSI/ANS 58.2-1988 model over predicts the pressure isobar at a given axial location in the far field due to artificial expansion constraints, it also under predicts the pressure isobar at a given radial location in the near field for the same reason. These model uncertainties may not cancel each other out completely. However, the Westinghouse method discussed in the RAI response of equating an axial target distance to a calculated isobar using the ANSI/ANS 58.2-1988 model removes conservatism axially but does not address non-conservatism radially and is thus likely to under calculate the jet isobar volumes for any given pressure.

5. The NRC staff also acknowledges that the ANSI/ANS 58.2-1988 model will over predict the total isobar volume at very low pressures because the model is unbounded as it approaches ambient pressure. It is in this range of very low pressures where the NRC staff believes refinements to the model would be beneficial in reducing excessive conservatisms in calculated ZOIs for materials with comparatively low destruction pressures.

6. In addition to those criteria listed in the RAI response for a “successful test,” the NRC staff position is that a successful test includes no observable liberation of insulation from the test item.

7. The PWROG has not submitted a refinement method for the ANSI/ANS 58.2-1988 model to the NRC staff for review, but the RAI response notes that a possible future submittal is being evaluated. The NRC staff is unable to predict the potential for success of such a submittal, or the likely duration of an NRC review. The NRC staff notes the following items for PWROG consideration prior to any future submittal:

    A. The test loop used for any data obtained for the purpose of free jet model refinements should not include upstream choke locations.
    B. Model refinements should include sufficient spatial pressure measurements to map the actual shape of the jet isobars of pressures that are of interest for debris generation to within a tolerable degree of uncertainty.
    C. Radial pressure measurements should be performed with the instrument oriented normal to the expected direction of flow of the expanding jet at each instrument location.
    D. Model refinements should include measurements that map the boundary of the actual jet radial expansion (i.e. radial measurements about the jet centerline at small axial distances from the nozzle) such that realistic isobar volumes may be obtained for comparison to the free-jet model volumes being refined.
    E. Pressure instruments should be of an appropriate range for the expected measurement.

F. The test setup should be oriented such that the jet expansion isn't artificially altered by a robust structure (e.g. the ground).
G. The PWROG should consider using impingement plates to obtain pressure measurements as they would be deemed more suitable for refinement purposes.

8. As stated in the introduction of this letter, the NRC staff agrees that empirically derived (i.e. measured) damage pressures may be obtained for a target centerline through testing and subsequently used as an input to the ANSI/ANS 58.2-1988 model for calculating a ZOI volume. This approach, as long as appropriate test scaling is considered for jacketed items, is consistent with the staff SE of NEI guidance report 04-07, "Pressurized Water Reactor Sump Performance Methodology" (ADAMS ML043280007).

Issue 3 - Resolved

The NRC staff agrees with the PWROG response to Issue 3 with the addition that a "successful test" includes no observable liberation of insulation from the test item. In addition, the NRC staff does not recognize the ZOIs listed in WCAP-16710-P as valid plant ZOIs. The NRC staff considers Issue 3 resolved in that the PWROG response stated that the referenced test was not considered a successful test.

Issue 5 – Resolved

The PWROG provided a detailed description of the test apparatus. The NRC staff notes that resolution of this question resulted in identification of 13 inches of piping with an internal diameter of 2.9 inches as well as several locations of smaller internal diameters with the smallest location measuring 2.313 inches approximately 26 inches upstream of the 3.54 inch nozzle. The NRC staff considers Issue 5 resolved in the sense that the detailed description of the test apparatus was provided. Issues with the configuration of the test apparatus are addressed in discussions of Issues 2 and 4 above.

Issue 6 - Resolved

The NRC staff agrees with the PWROG response to Issue 6 with the addition that a "successful test" includes no observable liberation of insulation from the test item. In addition, the NRC staff does not recognize the ZOIs listed in WCAP-16710-P as valid plant ZOIs. The NRC staff considers Issue 6 resolved in that the PWROG response stated that the referenced test was not considered a successful test.

Issue 7 - Resolved

The NRC staff agrees that the test results only apply to Callaway and Wolf Creek Nuclear Plants and that these plants have performed plant-specific evaluations to determine that the Min-K panels cannot be impacted by the jet based on the insulation panel locations in the plant. The PWROG response stated that no credit was taken for jet-ejected insulation panels not being damaged due to subsequent collisions in the plant. The NRC staff considers Issue 7 resolved in that the referenced test was not credited or considered a successful test.

In summary, the PWROG has not provided sufficient technical bases to fully resolve NRC staff concerns with the technical reports. The major unresolved concerns relate to errors in the test loop design and Westinghouse's use of an unaccepted method to determine material-specific damage pressures for calculating a ZOI. As such, the NRC staff has determined that the technical report conclusions have the potential to significantly under predict the quantity of debris that could be generated during a hypothetical loss-of-coolant accident. In light of this, the NRC staff does not accept, and licensees should not credit, the ZOI conclusions made in WCAP-16710-P, WCAP-16851-P, or similar technical reports referenced in this letter.

Empirically derived (i.e. measured) damage pressures may be obtained for a target centerline through testing and subsequently used as an input to the ANSI/ANS 58.2-1988 model for calculating a ZOI. This approach, as long as appropriate test scaling is considered for jacketed insulation, is consistent with the staff SE of NEI guidance report 04-07.

Sincerely,

/RA/

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Project No. 694

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Sincerely,

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