November 9, 2016

Mr. James H. Riley
Sr. Technical Advisor
Nuclear Energy Institute
1201 F Street, NW, Suite 1100
Washington, DC 20004

SUBJECT: REGULATORY AUDIT REPORT FOR AUGUST 31, 2016, AND SEPTEMBER 1, 2016, AUDIT OF PWROG-15060, "PUMP SUCTION GAS ACCUMULATION OPERABILITY CRITERIA GUIDANCE" (TAC NO. MF8075)

Dear Mr. Riley:

By letters dated May 5 and 9, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML16147A079 and ML16147A123, respectively), the Nuclear Energy Institute (NEI) submitted nonproprietary and proprietary versions of topical report (TR) PWROG-15060, "Pump Suction Gas Accumulation Operability Criteria Guidance" (ADAMS Accession Nos. ML16147A080 and ML16147A124 (proprietary)). The TR is supported by documentation that includes detailed report information.

On August 31 and September 2, 2016, the U.S. Nuclear Regulatory Commission (NRC) staff performed a regulatory audit at the Westinghouse offices at 11333 Woodglen Drive, Rockville, MD. The audit was conducted to support the NRC staff evaluation of the PWROG-15060 TR.

The purpose of this letter is to provide NEI with the results of the regulatory audit. Documented in the enclosed report are the observations the NRC staff identified during the audit.

If you any questions or require any additional information, please feel free to contact me at 301-415-7297 or Joseph.Holonich@nrc.gov.

Sincerely,

/RA by Jonathan Rowley for/

Joseph J. Holonich, Sr. Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 689

Enclosure:
As stated

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DATE	10/12/2016	10/19/2016	10/21/2016	11/4/2016	11/9/2016

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AUDIT REPORT

AUGUST 31, 2016, AND SEPTEMBER 1, 2016, ASPECTS OF

PWROG-15060, "PUMP SUCTION GAS ACCUMULATION OPERABILITY CRITERIA

GUIDANCE," TOPICAL REPORT (TAC NO. MF8705)

1. Introduction and Summary

By letters dated May 5 and 9, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML16147A079 and ML16147A123, respectively), the Nuclear Energy Institute (NEI) submitted nonproprietary and proprietary versions of topical report (TR) PWROG-15060, "Pump Suction Gas Accumulation Operability Criteria Guidance" (ADAMS Accession Nos. ML16147A080 and ML16147A124 (proprietary)).

The purpose of PWROG-15060 is to provide methodologies for addressing gas movement from high point locations in system piping to pump inlets. Specifically, the report addresses applying the correlations in WCAP–17271, "Testing and Evaluation of Gas Transport to the Suction of ECCS [emergency core cooling system] Pumps" (ADAMS Accession Nos. ML110490341 and ML110490342, (publicly available) and ML110490308, ML110490343 and ML110490389 (not publicly available)), and in WCAP-17276, "Testing and Evaluation of Gas Transport to the Suction of ECCS Pumps" (ADAMS Accession No. ML110480383, (publicly available) and ML110480384 (not publicly available)), in a manner which meets the limitations and conditions imposed by the safety evaluation (SE) for NEI 09-10, "Guidelines for Effective Prevention and Management of System Gas Accumulation," Rev. 1a-A (ADAMS Accession No. ML13136A129).

On August 17, 2016, the U.S. Nuclear Regulatory Commission (NRC) described a planned audit to be performed at the Westinghouse offices at 11333 Woodglen Drive, Rockville, MD 20852 on August 31, 2016, and September 1, 2016 (ADAMS Accession No. ML16217A062). The audit was conducted as planned, and all subjects identified in the August 17, 2016, communication were acceptably discussed. Formal responses associated with the topical areas discussed below will be submitted separately to the NRC.

2. Participants

The following personnel participated in the audit:

Eric Oesterle, Acting Chief, Reactor Systems Branch, NRC
Warren Lyon, Team Lead, Reactor Systems Branch, NRC
Diana Woodyatt, Reviewer, Reactor Systems Branch, NRC
Steve Swantner, Westinghouse
Jim Andrachek, Westinghouse
Matt Swartz, Westinghouse
Jay Boardman, Pressurized Water Reactor Owners Group (PWROG)
Joseph Holonich (via telephone)

Enclosure

3. Planned Discussion Topics

In the following list, the topics identified in the August 17, 2016, communication are copied or summarized in **bold** followed by a summary of the discussion during the audit meeting.

1. **How is the use of Froude number (N_{FR}) in the PWROG-15060 report correlations consistent with gas passing through some monitored locations during the Purdue University tests in less time than it took to reach the stated value of N_{FR}?**

   The design of the Purdue test loop was based on modeling the emergency core cooling system (ECCS) suction piping, which is in a stand-by mode during normal plant operation. The cycle times of the valves, which transitioned flow from the Purdue start-up bypass loop to the test loop, were chosen to represent flow initiation times in a typical ECCS. During data analysis, the gas transport correlations were based on the final steady state measured flow rates achieved in each test run. This method was used to facilitate application of the correlations to practical plant situations where the steady-state flow rate is known as a function of system line-up and boundary conditions.

2. **WCAP-17271-P reports intended initial void fractions (Φ) in the upper horizontal pipe and planned volumetric flow rates (Q) that appear to be used in the correlations. Please discuss if using the reported values may introduce an apparent stochastic data scatter and may bias predicted results**.

   Measured values were used for the basis of the correlations as opposed to planned values. Further, the acceptance criteria in the PWROG gas voids methodology was not expressed in terms of an acceptable initial fraction of gas and compliance with planned parameters.

3. **PWROG-15060 stated that the off-take criteria will be applied well upstream of the pump suction and it is not necessary to ensure that the flow regime is in the dispersed bubbly regime as long as the flow rate is sufficient to ensure that gas bubbles will not coalesce into a stratified flow regime that could result in vortex formation at the off-take or a significant level depression at the off-take. Please substantiate this statement.**

   A downcomer (DC) must exist between the offtake and the pump that is sufficiently long to assure bubbly flow from the DC.

4. **PWROG-15060 stated that as long as N_{FR} and the average volumetric flux ratio (β) are within established limits, it can be assumed that gas (1) is moving with the liquid in either a bubbly or incipient plug flow regime and will not accumulate or stratify at a tee, and (2) the gas is transported though the off-take in the flow direction being considered. Please address this for potential configurations.**

   A concern is that gas may accumulate in a stagnant location that is later placed in service. NEI 09-10, Section 4, discusses that utilities should consider system alignments when evaluating gas intrusion mechanisms. This addresses the case where the initial gas transport process moves gas to a stagnant location that could later be placed into service.

5. **Flow behavior in the lower horizontal piping in the Purdue tests included the occurrence of kinematic shocks over a wide range of test conditions with a large void fraction upstream of the shock and, according to WCAP-17271 Volume 1, a low void fraction with dispersed, bubbly flow downstream of the shock. Yet Figure 14 in WCAP-17271 Volume 1 shows an almost water solid region downstream of the shock with a thin gas layer above the water; a stratified flow regime. Please discuss this apparent inconsistency.**

   Figure 14 shows a momentary snapshot that is not representative of the overall behavior during the transient. Visual observation of this region throughout the entire transient identifies a dispersed flow regime downstream of the kinematic shock in the horizontal header.

6. **The acceptable pump inlet criteria are based on existence of homogeneous bubbly flow. Discuss how this is consistent with the stratified flow regime identified in Item 5.**

   As identified in the Item 5 response, a bubbly flow regime generally exists during the transient.

7. **PWROG-15060 describes Equation 6-6 as applicable beyond the range of N_{FR} used to formulate the equation. Part of the extrapolation may be non-conservative because it would be expected to increase the β prediction required to form a kinematic shock to a value that is smaller than would result from extrapolation of the data used to formulate Equation 6-6. Please justify the described extrapolation.**

   The experimental data support a linear curve fit that can be extrapolated beyond the data. Assuming that the β ratio required to form a kinematic shock is constant above $N_{FR} > 2.25$ is more conservative than assuming it continues to linearly increase.

8. **WCAP-17271-P Volume 1 Figure 15 illustrates a β upstream of the kinematic shock in a horizontal pipe that is immediately downstream of a DC. Equation 6-6 predicts the minimum β ratio that will cause a kinematic shock in a horizontal pipe that is immediately downstream of a DC where the DC is of sufficient length to provide homogeneous bubbly flow at the DC outlet. The prediction is less than would be obtained from using Figure 15. Please discuss the reasons for this difference, cover how Equation 6-6 is considered with respect to the PWROG-15060 correlations, and include how the minimum β ratio is conservative or non-conservative with respect to calculation of gas transport time and downstream β.**

   Figure 15 illustrates void fraction, not β. The stratified gas layer upstream of the shock is stagnant and the β ratio is therefore zero. Equation 6-6 is not meant to predict the change in void fraction across the shock. It was established during the audit discussion that the PWROG-15060 method predicted that a kinematic shock would occur consistent with the experimental data.

9. **Please describe the derivation of Equation 6-19 in sufficient detail to verify its applicability to operability determinations and discuss the behavior illustrated in Figure 6-21.**

   Equation 6-19 describes head loss as a function of void fraction, pipe diameter, and N_{FR}. A derivation of Equation 6-19 was provided.

   Figure 6-21 demonstrates that void fraction upstream of the kinematic shock must decrease as N_{FR} increases to maintain the low head loss observed during the Purdue tests.

10. **Please provide a comparison of the WCAP-17271 correlation to (1) β at the bottom of the DC, (2) β at the outlet from the 90°elbow at the DC exit, and (3) for Δβ for the six inch tests with an initial void fraction of 0.20 obtained from Figures 5-35 thru 5-38 of Volume III of WCAP-17271 or, if this is not considered viable due to the 6 inch pipe slope concern, provide the corresponding information for the 8 inch test. Then discuss your conclusions with respect to the correspondence between the WCAP figures and the WCAP correlations.**

    This topic originated from an NRC staff comparison of the WCAP-17271 correlation β to values estimated from plots provided in Volume III of WCAP-17271 that illustrated a poor correlation. Discussion during the audit established that there were two significant issues with the NRC staff approach: (1) The NRC staff used N_{FR} as an independent variable when performing the comparison. This led to a poor comparison because other variables are involved such as transport time and the ideal shock length; (2) Estimates of β obtained from the WCAP-17271 Volume III figures are uncertain because they involve small values at the lower end of the figure scale. Use of the recently provided tabulated values of β alleviate this problem.

    Figures were provided to support a conclusion that the WCAP correlations are consistent with the Purdue 8 inch data.

11. **Please provide a comparison of Equation 5-7 to transport times provided in WCAP-17271.**

    The Westinghouse representatives identified that this comparison is provided in WCAP-17276 Figures 7 through 9.

12. **The WCAP-17271 and WCAP-17276 correlations are limited to $N_{FR} \leq 2.5$. Please discuss how potential slug flow is addressed if $N_{FR} > 2.5$.**

    This is addressed in PWROG-15060-P, Section 6.3.7.

13. **Please address use of the WCAP-17271 and WCAP-17276 correlations when pipe diameter changes occur.**

    The correlations are not applicable if diameter is less than 4 inches. A reducer immediately upstream of a pump suction connection is treated as part of the pump.

Gas accumulation in an offtake followed by a possible surge downstream is avoided by limiting methodology applicability to $N_{FR} \geq 1.0$. (The NRC staff uses $N_{FR} \geq 0.93$ to accomplish the same purpose while allowing more use of the Purdue test data.)

14. PWROG-15060 stated that Equation 6-1 was derived from Equation 5-6. Please provide the derivation.

The derivation was provided.

15. Please walk through the development of Equations 6-10 through 6-21.

The development of these equations was discussed.

16. Discuss the potential for control of gas volume immediately downstream of a DC exit elbow when a pump takes suction from that location.

PWROG-15060 Equation 6-21 limits the amount of gas. The Westinghouse representatives did not consider it acceptable to assume a pump suction located near the exit elbow from a DC could be assumed to remove gas due to the lack of data.

Additional discussions included the following:

- In response to questions discussed and pending formal submittal of these responses to the NRC by September 30, 2016, the NRC representatives indicated they plan to provide a draft PWROG-15060 safety evaluation for NEI review for accuracy and treatment of proprietary content by October 31, 2016, with a final version by December 30, 2016.

- The use of PWROG-15060, Equation 5-6 to compute the DC location where homogeneous bubbly flow is achieved versus sample calculations that used the top of the DC was discussed. The Westinghouse representatives explained that the lower pressure at the top of the DC results in a larger prediction of β and is therefore conservative.