January 15, 2009

MEMORANDUM TO: Martin C. Murphy, Chief
Generic Communications and Power Uprate Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

FROM: David P. Beaulieu, Project Manager **/RA/**
Generic Communications and Power Uprate Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

SUBJECT: FORTHCOMING MEETING WITH THE NUCLEAR ENERGY INSTITUTE (NEI) TO DISCUSS NRC GENERIC LETTER 2008-01, "MANAGING GAS ACCUMULATION IN EMERGENCY CORE COOLING, DECAY HEAT REMOVAL, AND CONTAINMENT SPRAY SYSTEMS"

DATE & TIME: Friday, January 30, 2009
8:30 a.m. – 4:00 p.m.

LOCATION: Westinghouse Twinbrook Office
12300 Twinbrook Parkway, Suite 330
Rockville, MD 20852
(Phone: 301-881-7040)

PURPOSE: To discuss NRC Generic Letter 2008-01, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems." See enclosed agenda for details.

CATEGORY 2*: This is a Category 2 Meeting. The public is invited to participate in this meeting by discussing regulatory issues with the NRC at designated points identified on the agenda. Certain portions of this meeting will be closed to the public because the NRC staff has determined that the information is proprietary in nature.

*Commission's Policy Statement on "Enhancing Public Participation in NRC Meetings," 67 *Federal Register* 36920, May 28, 2002. For information regarding participating via teleconference, please contact David Beaulieu at (301) 415-3243 or David.Beaulieu@nrc.gov.

PARTICIPANTS: Participants from the NRC include members from the Office of Nuclear Reactor Regulation (NRR), the Boiling-Water Reactor Owners Group, and the Pressurized Water Reactor Owners Group.

NRC	Industry
David Beaulieu, NRR	Michael Melton, NEI
Warren Lyon, NRR	Additional industry representatives
Diana Woodyatt, NRR	
Gregory Cranston, NRR	

MEETING CONTACT: David P. Beaulieu, NRR
301-415-3243, David.Beaulieu@nrc.gov

Enclosures:
1. Meeting Agenda
2. NRC Staff Criteria For Accessing Gas Movement In Suction Lines And Pump Response To Gas – Revision 1; For NRC Staff Review Of Responses To Generic Letter 2008-01
3. NRC Preliminary Assessment Of "Testing And Evaluation Of Gas Transport To The Suction Of ECCS (Emergency Core Cooling System) Pumps," Westinghouse Electric Company LLC, WCAP-16631-NP, Revision 0, October 2006.

cc w/encl: See next page

PARTICIPANTS: Participants from the NRC include members from the Office of Nuclear Reactor Regulation (NRR), the Boiling-Water Reactor Owners Group, and the Pressurized Water Reactor Owners Group.

NRC	Industry
David Beaulieu, NRR	Michael Melton, NEI
Warren Lyon, NRR	Additional industry representatives
Diana Woodyatt, NRR	
Gregory Cranston, NRR	

MEETING CONTACT: David P. Beaulieu, NRR
301-415-3243, David.Beaulieu@nrc.gov

Enclosures:
1. Meeting Agenda
2. NRC Staff Criteria For Accessing Gas Movement In Suction Lines And Pump Response To Gas – Revision 1; For NRC Staff Review Of Responses To Generic Letter 2008-01
3. NRC Preliminary Assessment Of "Testing And Evaluation Of Gas Transport To The Suction Of ECCS (Emergency Core Cooling System) Pumps," Westinghouse Electric Company LLC, WCAP-16631-NP, Revision 0, October 2006.

cc w/encl: See next page

DISTRIBUTION:

PUBLIC	PMNS	mam@nei.org
PGCB Reading File	RidsNrrAdro	DWCOLEMAN@energy-northwest.com
RidsNrrDpr	RidsNrrDprPgcb	Dennis.Buschbaum@luminant.com
RidsNrrLACHawes	RidsNrrPMDBeaulieu	
RidsOpaMail	RidsNrrDss	
RidsOgcMail	Warren Lyon	
Diana Woodyatt	Gregory Cranston	

ADAMS ACCESSION NUMBER: ML090150637 NRR-001

OFFICE	PM:PGCB	LA:PGCB	BC:PGCB
NAME	DBeaulieu	CHawes	MMurphy
DATE	1/15/2009	1/15/2009	1/15/2009

OFFICIAL RECORD COPY

AGENDA
JANUARY 30, 2009, PUBLIC MEETING BETWEEN THE NUCLEAR ENERGY INSTITUTE (NEI) AND THE U.S. NUCLEAR REGULATORY COMMISSION (NRC) REGARDING NRC GENERIC LETTER 2008-01, "MANAGING GAS ACCUMULATION IN EMERGENCY CORE COOLING, DECAY HEAT REMOVAL, AND CONTAINMENT SPRAY SYSTEMS"

Westinghouse Twinbrook Office
12300 Twinbrook Parkway, Suite 330
Rockville, MD 20852

8:30 a.m.	Welcome and Introductions
8:35 a.m.	• Update on recent gas transport testing and recommended application of the information • Discussion of Enclosures to this meeting notice • Discussion of NRC staff review of activities related to Generic Letter 2008-01 • Coordination of NRC / NEI / Owners Groups / Industry activities
10:00 a.m.	Break
10:15 a.m.	Continuation
11:30 a.m.	Public Comment
11:45 a.m.	Lunch
12:30 p.m.	Continuation
2:00 p.m.	Break
2:15 p.m.	Continuation
3:45 p.m.	Public Comment
4:00 p.m.	Adjourn

Enclosure 1

January 7, 2009

NRC STAFF CRITERIA FOR ACCESSING GAS MOVEMENT IN SUCTION LINES AND PUMP RESPONSE TO GAS – REVISION 1; FOR NRC STAFF REVIEW OF RESPONSES TO GL 2008-01

I INTRODUCTION

This document provides acceptance criteria that the NRC staff may apply to assessment of the subject topics in such documents as responses to Generic Letter (GL) 2008-01 and licensee functional and operability evaluations. This is not an all-inclusive document. Subjects not addressed below, such as gas in pump discharge piping, are important and should be addressed when they arise.

Revision 1 addresses information received since the original criteria were provided in References 1 and 2 and it includes editorial changes to better describe the subject. As discussed in the original version, the criteria are believed to be conservative and, if the items being investigated are bounded by the criteria, then the items may be accepted by NRC staff members without further justification. Less conservative criteria may also be used if acceptable justification is provided. Industry is continuing to investigate GL issues pertaining to gas movement and pump response and future revisions to these criteria are anticipated as new information is obtained.

II CHANGES INCORPORATED INTO REVISION 1

1. Changed Item 1 in the Interim Gas Movement Criteria table from being applicable to a pipe diameter, D, from ≤ 3 inches to ≤ 8 inches on the basis of new understanding addressed in the Reference 3 tests. The remainder of the document is changed to be consistent.

2. Added qualifications to the tabulated criteria to address multi-dimensional flow configurations

3. Added qualifications to the tabulated criteria to exclude slug flow since available information indicates slug flow can cause immediate pump damage.

4. Corrected the transient times of void fractions of 100% and 50% in comparisons to the pressurized water reactor owners group (PWROG) acceptable average value of 20%.

5. Incorporated Reference 3 discussion of behavior as a function of Froude number (N_{FR}).

6. Included Flowserve information in discussion of pump response to gas.

III NRC STAFF CRITERIA FOR GAS MOVEMENT IN SUCTION LINES AND PUMP RESPONSE TO GAS

Criteria the NRC staff will accept without further justification for transport of gas into an emergency core cooling system (ECCS) pump are:

Table 1. Interim Gas Movement Criteria		N_{FR}
1.	Gas is not transported down a vertical pipe if $\Phi \leq 20\%$ at the top of the pipe and $D \leq 8$ inches.	≤ 0.3
2.	Gas is not transported out of a nominally horizontal pipe under steady state conditions if the water is in the bottom of the pipe and $\Phi \leq 50\%$ at the pipe exit.	< 0.4

where: D = pipe diameter
Φ = average volumetric gas fraction measured in a plane perpendicular to the pipe centerline

$$N_{FR} = V \left[D\, g_c \,(\rho_L - \rho_g) / \rho_L \right]^{-1/2}$$

V = liquid velocity based on total pipe flow area
g_c = gravitation constant
ρ = density
subscript L indicates liquid
subscript g indicates gas

These criteria are not applicable to configurations where an equivalent diameter is applicable, such as in an annulus, because it may be necessary to consider both the liquid and the gas when calculating N_{FR}. Further, with the exception of pipes with a circular cross section and elbows that connect between horizontal and vertical pipes, the criteria do not be apply to geometries where the velocity is not single dimensional throughout the geometry because experimental data have not been provided to substantiate the criteria.

Criteria the NRC staff will accept without further justification for not jeopardizing operability of an ECCS pump are:

Table 2. Pump Operation Interim Criteria		Allowable Φ
1.	Steady state (> 20 sec following initiation of gas ingestion) with $40\% \leq Q/Q_{BEP} \leq 120\%$	2%
2.	Steady state with $Q/Q_{BEP} < 40\%$ or $>120\%$	1%
3.	Maximum during 5 second transient with $70\% \leq Q/Q_{BEP} \leq 120\%$ and slug flow does not occur	10%
4.	Maximum during 5 second transient with $Q/Q_{BEP} < 70\%$ or $>120\%$ and slug flow does not occur	5%
5.	Head reduction is negligible if steady state and $80\% \leq Q/Q_{BEP} \leq 110\%$	2%

where: Q = water volumetric flow rate
BEP = best efficiency point.

The acceptance criteria are based on available information and include conservatisms in recognition that the available data are limited and, in some cases, non-existent. This is particularly true of transient conditions that often will present the most challenge to pump operation. In some cases, meeting the criteria will be straightforward. For example:

- One criterion addresses flow rates that are small enough that gas will not be swept downward in a pipe leading to the pump suction. Meeting this criterion when the pump is initially full of water[1] leads to the conclusion that there is no concern since no gas will be carried into the pump from the suction line. A pump flow rate corresponding to flow in the miniflow line will often satisfy this criterion. If pump flow rate then increases slowly, the gas at the pump inlet may consist of small bubbles and the rate of gas movement into the pump may be small enough for the suction line gas to be cleared without significantly affecting the pump.

- Another criterion applies to a pump that develops a flow rate sufficient to sweep gas into the pump when Φ exceeds acceptance criteria that were derived from pump damage considerations. In this case the pump must be assumed lost due to presumed physical damage unless the licensee can substantiate that the criterion is overly conservative for the existing conditions.

In other cases, the assessment will present more challenges. For example, consider an ECCS pump that is initially full of water that is injecting into the reactor coolant system (RCS) at a known pressure. An initial prediction of flow rate can be determined from a flow rate versus developed head curve[2] that applies to a $\Phi = 0$ condition by calculating discharge pressure at the pump as the sum of RCS pressure and downstream differential pressure where the latter is a function of flow rate. But if this predicted flow rate will cause gas to enter the pump from an upstream gas volume, the flow rate versus developed head curve will be affected and the developed head will be less than previously determined. Using the new developed head value will result in a reduction in predicted flow rate. An iterative process results to obtain convergence of Φ and flow rate. Simultaneously, pump net positive suction head (NPSH) criteria are affected by gas entering the pump and by gas in the suction line. NPSH criteria must continue to be met for the pump to be considered operable.

There is significant scatter in information used to correlate gas transport and a number of different flow regimes can occur in suction piping depending upon Φ, pipe orientation, flow rate, and pipe size. Further, licensees typically determine gas volumes without considering measurement uncertainties. These volumes are then used in determining the influence of Φ and gas location on pump operability. In consideration of this background, the NRC staff has incorporated selected conservatisms in its acceptance criteria as discussed below.

---

[1] The NRC staff will consider that a pump is full of water if the gas volume within the pump is less than 5% before it is started. A pump that initially contains a larger gas volume will be considered to be inoperable.
[2] Pump characteristic curves may be based on conservative assumptions to bound 10 CFR 50.46 requirements. Such curves may not be applicable here. For example, a conservative curve may provide a smaller flow rate than actual which may, in turn, cause predicted Φ at the pump inlet to be too small. Conversely, use of a flow rate that is too great may cause the gas to move through the system more rapidly and may move the applicable acceptance criterion from the steady state to a transient condition where Φ may be found acceptable as opposed to a smaller allowable Φ in the steady state.

The N_{FR} ≤ 0.3 criterion in Table 1 is almost a factor of 3 less than the value sometimes used by licensees although it is close to the < 0.35 provided by Reference 3 for gas remaining trapped in the pipe at the first elbow leading to the vertical pipe. Further, at < 0.35, Reference 3 states that bubbles will remain suspended in the upper portion of the vertical pipe. The 0.3, rounded from 0.31, was taken from Simpson's publication in *Chemical Engineering* (June 17, 1968) that is referenced in numerous other publications as a value to reasonably ensure that significant quantities of gas will not be transported downward in a vertical pipe. The D ≤ 8 inches criterion is based on potential non-applicability of N_{FR} to larger diameter pipes, a restriction that is not mentioned in industry guidance that was discussed with the NRC staff during the Nuclear Energy Institute's (NEI's) meeting on September 4, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML082770088). However, industry is conducting testing in larger diameter pipes to obtain data and develop a better understanding of behavior and the N_{FR}, D, and Φ may change when the new information becomes available. The Φ ≤ 20% criterion is to ensure that water does not drop in a waterfall configuration into a vertical pipe where momentum might carry gas to the bottom of the vertical pipe. The N_{FR} < 0.4 criterion is roughly 25% smaller than typically used to assess horizontal flow to account for gas volume determination uncertainty and to provide conservatism. The NRC staff notes that Reference 3 states that N_{FR} > 0.55 will cause a pipe to run full if discharge is to an empty plenum and that N_{FR} = 0.55 may not be sufficient to purge all gas out of a local high point. The Φ ≤ 50% criterion at the pipe exit is to ensure that there is a layer of water in the bottom of a horizontal pipe where it meets a vertical pipe that includes consideration of a decrease in level as water flows along the horizontal pipe and to account for transient variation in flow along the pipe during startup or changing conditions. Additional data and analysis will be necessary to assess gas movement for Φ > 20%, D >8 inches, or larger N_{FR}, although the NRC staff believes larger Φ's in pipe diameters larger than a few inches may be reasonable if the vertical pipe is long enough to justify that local effects at the top of the pipe no longer affect the behavior.

The 2% steady state value in Item 1 of Table 2 is consistent with the PWROG and boiling water reactor owners group Reference 4 values with the exception that the NRC staff uses a restriction of 40% ≤ Q/Q_{BEP} ≤ 120% in recognition of the increasing impact of Φ when Q is not close to Q_{BEP}, examples of which are provided in NUREG/CR-2792 that in some cases result in greater than a factor of two reduction in developed head[3]. Other industry information states that Φ = 2% is inappropriate for some conditions. The 1% in Item 2 is generally consistent with that information, although there is some information that identifies a concern that gas can accumulate in some pumps over time with Φ < 1%.

For transients, the PWROG assumes an average Φ can be used over a time that varies from 5 seconds to 20 seconds with average values of Φ that vary from 5% to 20% depending upon the pump. For the largest values, this would allow Φ = 100% for 4 seconds or Φ = 50% for 8 seconds if Φ = 0 for 16 or 12 seconds, respectively. Large values of Φ would also be permitted for other times and other maximum allowed values of Φ. The BWROG criterion is Φ = 10% for 5 seconds, which agrees with the PWROG criterion for flexible shaft multi-stage pumps although large short-term Φs are still permitted since an average Φ is used. There are also references to large gas slugs causing fatigue cracking or pump seizure, as discussed below. The NRC staff does not accept that large Φs are realistically acceptable unless substantiated by data and,

[3] Developed head must be assessed separately as discussed later in this report.

therefore, the NRC staff will use maximum values of Φ, not averages, when applying the Table 2 Items 3 and 4 criteria.

The PWROG provides a criterion of Φ = 10% for 5 seconds for a multi-stage flexible-shaft pump with the limit due to possible air binding of the first impeller that was identified by Flowserve. The PWROG limit is 20% for 20 seconds for a stiff shaft multi-stage pump. The NRC staff does not understand why the first criterion should not apply to the stiff-shaft pump as well although there may be reasons for this such as, for example, the number of impeller vanes and the vane configuration.

Flowserve, in Appendix F to Reference 3, addressed gas handling capacity of the Pacific Model JTCH high pressure safety injection (HPSI) pumps used at Indian Point 2. It stated that, for bubble flow, performance degradation would begin at Φ = 2% and that the pump could handle up to 5% without distress. At Φ = 20%, it stated there was a good chance the pump would lose prime and run gas-bound. It did not recommend operation with Φ > 5%. It also stated that slug flow was more serious and, if the slug was large enough to gas-bind the pump, pump seizure would be almost immediate. Further, if the slug was small enough to be swept through the pump, it would cause hydraulic unbalance with possible contact between the wear rings. It was not aware of any data applicable to slug flow.

Arizona Public Power data indicate that substantial Φs can be tolerated for some time in their HPSI pumps provided the flow rate remains high and the gas is suitably distributed at the pump inlet. Flow rates substantially lower than the BEP were not investigated and the licensee assumed the pumps would not be operable if low flow rates were encountered while Φ was large.

Since the uncertainty of flow characteristics entering a pump has not been established, data are limited, and pump behavior is not sufficiently understood, the NRC staff has elected the conservative approach of using the owners group's minimum Φs[4] and times for $70\% \leq Q/Q_{BEP} \leq 120\%$, and has reduced the allowable Φ to 5% for $Q/Q_{BEP} < 40\%$ or >120%.

The NRC staff has not differentiated between pumps in selecting the above criteria, in part because of the lack of data. The NRC staff notes that the PWROG provided Φ = 5% for 20 seconds for a single stage pump whereas the NRC staff stipulates that slug flow is not acceptable and uses 10% for 5 seconds or 5% for 5 seconds depending upon Q/Q_{BEP}. The NRC staff judges these selections are reasonable in light of the shortened times and the Flowserve information identified above.

The Table 2 criteria are based on a combination of potential pump damage and flow characteristics considerations, including such behavior as oscillatory flow rates at some values of Φ. However, other assessments are also necessary to establish pump operability. Head degradation and NPSH must be assessed to confirm that the Φ limits are acceptable because Φ > 0 may (1) reduce the developed head, (2) reduce the available NPSH, and (3) increase NPSH required by the pump. Either the smaller of the tabulated Φs or the value of Φ that does not reduce flow rate below an acceptable value is to be used for an acceptance determination.

---

[4] The NRC staff will use maximum values of Φ, not averages, as previously discussed.

The NPSH required for an air/water mixture can be calculated from the NUREG/CR-2792 equation that was selected by some in industry for this purpose:

$$NPSH_{Req} = NPSH_{Req\ for\ liquid}\ [\ 1 + 0.5\ \Phi\ ]$$

where $\Phi \leq 2\%$. Although the correlation is based upon meager data, it includes a substantial conservatism.

As identified in Table 2, head reduction due to gas may be assumed negligible if steady state exists, $\Phi \leq 2\%$, and $80\% \leq Q/Q_{BEP} \leq 110\%$. If outside of these criteria, the head reduction must be assessed with respect to both Φ and the impact of operating outside the Q/Q_{BEP} range since such operation can result in a significant reduction in developed head.[5] Further, the actual NPSH available at the pump suction should be calculated to take into account the inlet pressure reduction associated with gas in pipe sections upstream of the pump.

REFERENCES

1. Beaulieu, David P., "Forthcoming Meeting With The Nuclear Energy Institute (NEI) To Discuss NRC Generic Letter 2008-01, 'Managing Gas Accumulation In Emergency Core Cooling, Decay Heat Removal, And Containment Spray Systems,'" NRC Memorandum, ADAMS Accession No. ML083250536, dated November 21, 2008.

2, Generic Letter (Gl) 2008-01: NRC Staff Criteria For Gas Movement In Suction Lines And Pump Response To Gas, Draft, dated November 18, 2008. (Provided as Enclosure 2 of Reference 1.)

3. Preliminary Assessment of "Testing And Evaluation of Gas Transport to the Suction of ECCS Pumps," Westinghouse Electric Company LLC, WCAP-16631-NP, Revision 0, dated October 2006. (This document has not been provided to NRC on the docket. Referenced information is based on notes from reading the reference.)

4. Beaulieu, David P., "Summary of the September 4, 2008, Category 2 Public Meeting with the Nuclear Energy Institute to Discuss NRC Generic Letter 2008-01, 'Managing Gas Accumulation In Emergency Core Cooling, Decay Heat Removal, And Containment Spray Systems,'" NRC Memorandum, ADAMS Accession No. ML082770088, dated October 6, 2008.

[5] We have seen correlations that predict head reduction as a function of Φ and that do not consider the effect of Q/Q_{BEP}. These correlations are not acceptable when operation is outside of the stated range.

January 4, 2009

NRC PRELIMINARY ASSESSMENT OF "TESTING AND EVALUATION OF GAS TRANSPORT TO THE SUCTION OF ECCS (EMERGENCY CORE COOLING SYSTEM) PUMPS," WESTINGHOUSE ELECTRIC COMPANY LLC, WCAP-16631-NP, REVISION 0, OCTOBER 2006

The above report was made available to the NRC staff for a preliminary review but was not submitted on the docket. It covers two phase air/water testing in 6-inch and 8-inch diameter pipes that was conducted at Purdue University and the results of that testing. It states that:

> Each PWROG (pressurized water reactor owners group) plant can use the information contained herein (Volume 1) to perform an assessment of the impact of gas on the pump header as it travels to the pump. Noting that pump suppliers currently limit permissible void fraction through ECCS pumps to around 5%, the report contains a guidance on how to estimate the expected gas volume fraction at the pump suction, taking into account the following:
>
> • Initial gas volume
> • The elevation of the gas relative to the pump suction
> • The flow rate, pipe size, and Froude number.
>
> Each plant will use the information to estimate the gas void to the pump and assess whether or not it is less than the prescribed 5% limit. It is possible that some pumps may withstand void fractions larger than 5%. However, there is no data presently available to the authors to confirm this. Actual pump tests will be the preferred way to extend the limits. Until such a test is performed the guidance provided here offers a tool to describe the expected void fraction at the pump regardless of the initial void fraction. Based on this study, it is recommended that actual pumps be tested to validate the results of this project and thereby extend the 5% void fraction limits.

The NRC staff previously provided draft guidance for review of ECCS gas issues in "Generic Letter (GL) 2008-01: NRC Staff Criteria for Gas Movement in Suction Lines and Pump Response to Gas," November 18, 2008. (Contained in Agencywide Documents Access and Management System (ADAMS) Accession No. ML083250536, dated November 21, 2008.) The draft guidance was prepared without the benefit of the WCAP information and the NRC staff therefore requested that the WCAP be made available so that the latest information could be considered.

The basic test configuration is a 30-foot upper horizontal pipe that connects to a downward 26-foot vertical pipe that connects to a 16-foot lower horizontal pipe that connects to an air/water separation system that connects to a pump that in turn connects to the 30-foot horizontal pipe. Each test consists of the following steps:

1. Establish an air volume above a water volume in the 30-foot pipe with no flow at approximately atmospheric pressure.

2. Initiate a known water flow rate into the pump end of the 30-foot pipe.

3. Monitor the void fractions and pressures during the transient as the air is forced through the test pipes due to the water flow.

The NRC staff has the following observations in regard to the WCAP:

1. The 3000 page WCAP provides an in-depth description of the test facility and test data.

2. The initial pressure of approximately 15 psia immediately decreased to 6 to 9 psia following test initiation. This introduced a dynamic effect due to air expansion that would not occur in a plant where the pressure would be maintained by the head of water in the refueling water storage tank. This dynamic effect was not adequately addressed in the WCAP.

3. The 6 to 9 psia must be contrasted to the 35 to 65 psia that will typically exist in plants. This is not identified and affects the conclusions. For example, the WCAP states "the attenuation of the void due to the (vertical to horizontal) elbow (at the bottom of the vertical pipe) can be estimated as a reduction in the vertical pipe average air volume fraction by 20%" based on the void measurement near the bottom of the vertical pipe and in the lower horizontal pipe. The NRC staff estimates that half of the void fraction change is due to the elevation pressure change between the two locations and is not due to the elbow. This effect would be small in a plant due to the higher pressure. The WCAP extension of the behavior to estimating decrease in void fraction due to elbows at other plant piping locations is similarly flawed, as discussed in Items 5 and 6, below. Finally, the NRC staff notes this difference between test and plant pressures is not considered in assessing void decrease in the vertical test section.

4. Froude numbers based on velocity determined by the water flow rate divided by the pipe cross-sectional area ranged from about 0.6 to 2.5. The NRC staff believes the test purposes would have been better achieved if Froude numbers ranged from 0.3 so that test coverage would include the flow regimes where significant air would not be expected to be transported to the bottom of the vertical test section. The NRC staff also believes that the effect of considering the void fraction in determination of Froude number should have been addressed in the WCAP. [6]

5. Two phase fluid flow data typically exhibit significant scatter. This is particularly true for the tests reported in the WCAP where a transient test covered one or two minutes and some transient response that was of interest would occur over a few seconds. Purdue addressed this by running many duplicate tests and carefully examining the test results. However, this effort was not fully successful and some of the conclusions are not adequately supported by the test data due to data scatter. For example, the NRC staff does not agree with the use of the WCAP treatment of average void fraction vs. elevation change illustrated in Figure 9-1 for several reasons. The illustrated

[6] Froude number can also be based on a volumetric combination of liquid and void. The WCAP does not define the basis for its use of Froude number and the first illustration of the basis occurs in the example calculations provided in Section 9. In some situations, especially when the void fraction is high, it may be more appropriate to consider the void contribution to the flow behavior.

applications of the Figure do not address allowance for uncertainty and, as identified above, the effect of actual plant pressures in contrast to test pressures are not addressed. Further, there is no consideration of a water fall effect when the upper part of the vertical pipe is voided. Such an effect could propel air further down in the pipe than would be predicted using a single dimensional Froude number.

6. The use of an average of the slopes based on Table 8.2.3.2-1 and Figure 9-1 to determine an equivalent pipe length associated with an elbow with a void change of 0.2 is not adequately based on the data. For example, the average slope of -0.055 is obtained from slopes of -0.333, -0.15- and -0.0883 and, as previously discussed, the 0.2 factor does not consider the pressures that will be encountered in plants.

As presently understood, the NRC staff cannot apply the test results to a relaxation of the criteria provided in ADAMS Accession No. ML083250536.