NUCLEAR ENERGY INSTITUTE

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APC 09-47
October 30, 2009

To: Administrative Points of Contact

Subject: Issuance of NEI 09-10, Revision 0, *Guidelines for Effective Prevention and Management of System Gas Accumulation*

Please forward this letter and enclosures to personnel in your Design Engineering and Systems Engineering Departments.

We are providing for your use NEI 09-10, Revision 0, *Guidelines for Effective Prevention and Management of System Gas Accumulation*. The document incorporates the comments received from industry and the NRC.

NEI 09-10 outlines principles and practices designed to effectively prevent, monitor, identify and manage accumulation of gas that would challenge the operability / functionality of plant systems. This document was developed as part of the industry response to NRC Generic Letter 2008-01, *Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems*. The NRC is aware of NEI 09-10 and its content, but no commitment to follow this guidance has been made to the NRC. However, because of the NRC involvement with the development of this document, it is possible that NRC inspectors may refer to NEI 09-10 while inspecting your site for GL 2008-01 compliance. We therefore recommend that your system engineers be familiar with the content of NEI 09-10.

If you have any questions about this information, please contact me at (202) 739-8137; jhr@nei.org or Steven Hutchins at (202) 739-8025; sph@nei.org.

Sincerely,

James H. Riley

Attachment

NEI 09-10 [Rev 0]

GUIDELINES FOR EFFECTIVE PREVENTION AND MANAGEMENT OF SYSTEM GAS ACCUMULATION

October 2009

NEI 09-10 [Rev 0]

Nuclear Energy Institute

Guidelines for Effective Prevention and Management of System Gas Accumulation

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ACKNOWLEDGEMENTS

NEI acknowledges the valuable input provided, and the extensive technical support provided by the members of the guideline development core team: Lee Windham (Team Lead, Luminant Power), Glen Schinzel (STARS), Ewurabena Mensa-Wood (San Onofre), Mark Radspinner (Palo Verde), Sergio Santiago (Diablo Canyon), Richard Kersey (South Texas), Art Turner (Wolf Creek), John Duffy (PSEG Nuclear), Ken Peterson (Wolf Creek), Todd Moser (STARS), Tom Herbert (FPL), Wes McGoun (Progress Energy), ….

NEI also gratefully acknowledged the Gas Accumulation Management Team (GAT) for their detailed and valued contributions to this document. GAT members: Chris Brennen (Exelon), Doug Coleman (Energy-Northwest), Dennis Buschbaum (Luminant), Don Gregoire (Energy-Northwest), Anderson Lin (Pacific Gas & Electric), Elizabeth Newberg (Xcel Energy), Brian B. McKercher, (Dominion), Laird Bruster (Florida Power & Light), Lesley England (Entergy), Nicholas Camilli (EPRI), Ken Huffman (EPRI), Wes McGoun (Progress Energy), Mark Radspinner (Arizona Public Service), Bill Turkowski (Westinghouse), Gregory K. Holmes (GE Hitachi), Maurice Dingler (WCNOC), Bruce Cummings (DTE Energy), Frank Gaber (Arizona Public Service), Jeffrey Brown (Arizona Public Service), Tony Zimmerman (Progress Energy), Richard Faix (Florida Power & Light), Bob Sturgill (Dominion), Tony Browning (NextEra Energy, Duane Arnold), Stephen Swantner (Westinghouse), and Carl Faller (INPO).

EXECUTIVE SUMMARY

The Nuclear Power Industry has experienced instances of gas intrusion and accumulation in fluid systems for many years. The Nuclear Regulatory Commission in January 2008 issued NRC Generic Letter 2008-01 "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems." INPO also issued in January 2008 SER 2-05 Rev.1 "Gas Intrusion in Safety Systems." This document provides recommendations and guidance to nuclear generating stations for the effective implementation of programs and processes to prevent and manage gas intrusion and accumulation in plant systems. The document provides a structured approach to develop procedures and processes that will internalize principles and practices for effective station identification, management, monitoring and prevention of gas accumulation that would challenge system operability.

Topics discussed include:

- Identification of management sponsorship and single point ownership of the program
- Methods to prevent gas intrusion
- Adjustment to existing station programs
- Guidelines for determining which station systems should be in-scope
- Methods for evaluation of in-scope systems to determine locations where gas could accumulate
- Guidelines for limiting the locations that are required to be periodically monitored
- Develop acceptance criteria that are to be included in the design documentation for systems
- System filling and venting practices
- Implication of at power maintenance activities
- Guidelines for establishing periodic and additional monitoring frequencies
- Methods of gas quantification and trending practices
- Development of operability guidance when gas is detected
- Guidance for developing acceptance criteria to be used in operability determinations
- Development of training material to raise awareness of all station personnel

FOREWORD

The purpose of this document is to provide recommendations and guidance to nuclear generating stations for the effective implementation of programs and process to manage gas accumulation and intrusion into plant systems. This document will outline principles and practices designed to effectively identify, manage, monitor and prevent accumulation of gas that would challenge the operability (Operability / Functionality) of the subject systems.

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ATTACHMENTS

ACRONYMS

BWR	Boiling Water Reactor
CCP	Centrifugal Charging Pump
CS	Containment Spray
DHR	Decay Heat Removal
ECCS	Emergency Core Cooling System
GAT	Gas Accumulation Management Team
GL	Generic Letter
INPO	Institute of Nuclear Power Operation
NRC	Nuclear Regulatory Commission
OE	Operating Experience
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
SER	Significant Event Report
SIP	Safety Injection Pump
SOER	Significant Operating Experiences Report
UT	Ultrasonic Testing
VCT	Volume Control Tank

GUIDELINES FOR EFFECTIVE PREVENTION AND MANAGEMENT OF SYSTEM GAS ACCUMULATION

1 BACKGROUND

Instances of gas accumulation in nuclear power plant fluid systems have occurred since the beginning of commercial nuclear power plant operation. The NRC has published 20 Information Notices, two Generic Letters, and a NUREG related to this issue and has interacted with the nuclear industry many times in relation to these publications and in response to gas accumulation events. Several gas intrusion mechanisms can result in gas accumulation in system piping, and some gas may come out of solution due to changes in temperature and pressure during normal operation. However, the existence of gas in system piping is not a condition that was accounted for in the initial analyses of system performance during transients and accidents.

The objective of gas control measures is to limit the volume of gas accumulation to a quantity that does not jeopardize system operability. An acceptable volume depends on a variety of factors including, but not limited to, total volume, location, flow rate, type of pump, gas volume fraction at the pump impeller, pressure changes experienced by the system when it is activated, obstacles to flow down stream from the accumulated gas, and the effects of the gas on core cooling. The amount and location of gas are both important in addressing system operability. An evaluation to develop and apply criteria is necessary to determine the amount of gas that could impact operability.

1.1 GL 2008-01

NRC Generic Letter 2008-01 "requests that each licensee evaluate its ECCS, DHR system, and containment spray system licensing basis, design, testing and corrective actions to ensure that gas accumulation is maintained less than the amount that challenges operability of these systems, and that appropriate action is taken when conditions adverse to quality are identified."

1.2 INPO SER 2-05 REV 1

INPO Significant Event Report (SER) 2-05, Rev 1 was "issued due to continuing problems with gas intrusion events in the industry. The reporting of approximately 30 events since the issuance of SER 2-05 in March 2005 indicates continuing problems, which reflect inadequate actions by some plants and the need for continuing industry attention to gas intrusion that affects safety systems. The introduction of gases in safety systems may result in unanalyzed conditions that could adversely affect the ability of systems to perform their intended functions."

1.3 TECHNICAL DESCRIPTION OF THE PROBLEM

1.3.1 Causes of Gas

The causes of this issue include designs that allow gas introduction and accumulation, equipment issues that allow unanticipated transfer of gas-saturated fluids between systems, failure to properly fill and vent the system following drain-down or maintenance, improper controls on gas accumulation during operation, inappropriate programmatic controls, and unanticipated problems with keep-full systems.

1.3.2 Effects of Gas

The introduction of gas into a pump can cause the pump to become air bound with little or no flow, rendering the pump inoperable and possible damaging the pump.

Although gas may not air bind the pump: the pump can be rendered inoperable because pump discharge pressure and flow capacity can be reduced to the point that the pump cannot perform its design function. Loss of developed head and resulting loss of flow based on the system response curve and downstream back pressure may make the pump incapable of delivering the flow assumed in accident analyses.

Gas accumulation can result in a system pressure transient; particularly in pump discharge piping following a pump start, which can cause piping and component damage or failure. Pressure pulses may lift relief valves in the system that then may fail to reseat.

Gas accumulation can result in pumping non-condensable gas into the reactor vessel that may affect core-cooling flow.

The time needed to fill voided discharge piping can delay delivery of water beyond the timeframe assumed in the accident analysis.

2 PURPOSE AND SCOPE

This document provides insights and attributes to implement an acceptable approach to effectively prevent and manage gas intrusion and accumulation in plant systems. This document is intended to aid in the identification of susceptible systems, outline principles and practices designed to effectively prevent, identify, manage and monitor accumulation of gas that would challenge the capability of a system to satisfy its design functional requirement(s), and identify training to ensure plant personnel can readily recognize and effectively respond to gas intrusion and accumulation in susceptible systems.

The approach identified in this document is intended to ensure that the fluid systems susceptible to gas accumulation are operated and maintained within their design bases and remain ready to perform their intended design basis function when required.

It is expected that systems will be designed, operated, and maintained in a manner to prevent accumulation of gas. Where accumulated gas cannot be reasonably prevented, engineering technical evaluations must account for the presence of such gas and its impact on system performance.

Systems considered within the scope of this program are those fluid systems that are necessary to reasonably ensure continued core cooling and prevention of significant release of radioactive material. Where applicable, systems should also be addressed with respect to both typical single failure assumptions and for operation without failures. This list of systems will include affected safety related systems and should consider non-safety related systems as appropriate. The scope of affected systems within this program may differ based on the degree of susceptibility for gas intrusion and its consequence.

The approach identified in this document is intended to satisfy 10 CFR 50 Appendix B Quality Assurance requirements. Criterion III requires measures to ensure that applicable regulatory requirements and the design basis, as defined in 10 CFR 50.2, “Definitions,” and as specified in the license, are correctly translated into controlled specifications, drawings, procedures, and instructions. Criterion V requires important activities to be prescribed by documented instructions, procedures, or drawings, which must include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished. Criterion XI requires a test program to ensure that the subject systems will perform satisfactorily in service. Test results shall be documented and evaluated to ensure that test requirements have been satisfied.

3 GAS ACCUMULATION MANAGEMENT OWNERSHIP

3.1 SITE OWNERSHIP

Sponsorship and commitment by senior level management at each station supports effective implementation of a process or program to prevent and manage gas intrusion and accumulation. Portions of the effort may be owned and performed by various departments as appropriate within the utility's organizational structure at each station, but single point management sponsorship and support is essential.

Additionally, each utility should designate an owner to effectively implement and manage the approach to minimize and control system gas accumulation. The designated owner should have appropriate training and experience to provide clear determinations on which systems are impacted and which areas are susceptible to gas accumulation. This responsibility should not be left to each System Engineer which likely would result in various interpretations and an overall inconsistency in the effective management of this issue.

3.2 CONSIDERATION OF SITE-WIDE CONCERNS

Utilities should realize that prevention and management of gas intrusion and accumulation is a site-wide issue and impacts many functions. Representatives from all appropriate departments should participate with the owner in establishing required parameters, programmatic direction, identifying procedures and potential void monitoring needs, and other process activities. Operations, Maintenance, Engineering, Licensing and Training are key stakeholders.

4 IDENTIFY GAS INTRUSION MECHANISMS

Each utility should create a list of site specific sources that could result in gas intrusion and/or accumulation in a fluid piping system. These may include, but are not limited to:

- ineffective fill and vent
- leakage from accumulators
- leakage from the RCS
- out-gassing of dissolved gas when gas saturated liquid passes from piping at high pressure into piping at lower pressure
- draining, system realignments, deficient maintenance procedures, and failure to follow procedures
- failure of level instruments to indicate correct level
- leakage through valves, including leakage through a series of nominally closed valves
- leakage through faulty vent system components when local internal pressure is less than external pressure
- temperatures at or above saturation temperature at the lowest system pressure that will be experienced when the system is used
- vortexing in suction sources or gas introduced from suction sources
- design deficiencies that may contribute to gas intrusion during accident conditions
- keep-full system malfunctions
- leakage of bladder material installed in positive displacement pump hydraulic pulsation dampener accumulators
- cooling of an isolated section of piping

5 GAS INTRUSION AND ACCUMULATION PREVENTION

5.1 PRACTICES TO MINIMIZE GAS

5.1.1 Examples of Practices to Avoid

- Filling from a tank source with a water level lower than the high point of the system to be filled
- System venting that reduces the system pressure at any point in the system below saturation pressure
- Operation or maintenance evolutions that reduce system pressure below saturation pressure

5.1.2 Examples of Practices to Prevent or Minimize Gas Intrusion

- Use a pressurized source with sufficiently higher pressure than the required static head needed to fill and vent the system
- Vent slowly and deliberately while using a adequate pressure source to maintain system pressure
- Form a loop seal with water in the vent hose to prevent gas ingestion
- Repeat venting after allowing time for any remaining gas to accumulate at a high point

5.2 DESIGN PROCESS IMPACT REVIEWS

The station design change process should include provision for impact review of those design changes that could affect in-scope systems and the potential for gas intrusion and or accumulation at the high points identified in those systems. Additionally, impact review should be performed for design changes that could introduce new high point locations or gas intrusion mechanisms.

The design change process should provide for identification of gas intrusion/accumulation as a design input for those design changes that involve piping and/or piping components in in-scope systems.

5.3 IDENTIFICATION OF REPEAT LOCATIONS

Locations where gas continues to accumulate should be evaluated for possible remedies which could prevent or minimize future gas intrusion. This could be through plant modification or operating procedure and practice changes. An important aspect of correcting such conditions is to have a clear understanding of the gas intrusion mechanism. If changes cannot be made to remedy these locations then enhanced monitoring should be considered to identify early onset of gas accumulation.

5.4 DESIGN SOLUTIONS (ADDITIONAL VENTS, PIPING MODIFICATIONS…)

Utilities should consider installation of additional vents in locations that are evaluated to be potential gas accumulation points where the gas cannot be removed by other methods and/or where gas volumes may accumulate that would affect the ability of the system to perform a required function. It may be beneficial to have a generic plant modification package prepared for installation of vents when new locations are identified that put the station at risk.

Some utilities have made piping modifications that route or capture gas voids in a location that prevents the void from having an adverse effect on the system. Such modifications may be considered for locations that present difficulties removing gas by other means.

5.5 INCLUDE GAS INTRUSION PRECURSORS IN PROCEDURES

Operating, testing and maintenance procedures should include warnings about potential gas intrusion and or accumulation for those evolutions that have been identified during the evaluations of the plant systems. For precursor conditions that are monitored, criteria for when action is required to evaluate gas intrusion should be included in procedures. Section 12.8 of this document provides guidance for identification of these gas intrusion precursors.

6 REVIEW AND INCORPORATE OPERATING EXPERIENCE (OE)

When evaluating OE associated with gas intrusion and/or accumulation it is important that the mechanism be understood. It is possible that the station may not have that specific problem on the OE specific system but may identify a new gas intrusion mechanism that is applicable to a very different system. It is often important to seek more detailed information after an initial screen to be able to completely determine the impact on station systems or programs.

It is recommended that all plant and industry OE applicable to gas intrusion or gas accumulation be reviewed by the gas intrusion program owner.

7 PLANT SYSTEM SELECTION

Due to variation in station design and operation there is not a prescribed list of systems that should be included within the scope of processes and programs to prevent and manage gas intrusion and accumulation. Each utility should evaluate their plant systems to determine which are to be in the scope of gas accumulation management. The evaluations should identify which systems may accumulate gas, the potential for gas to remain after the systems are filled and vented, and the potential degassing and intrusion paths. The following criteria should be used in determining the in-scope systems.

- Systems that were specifically listed in NRC Generic Letter 2008-01 “Managing gas accumulation in emergency core cooling, decay heat removal and containment spray systems.”
- Systems that affect safety that have susceptibility to gas intrusion or that would cause a significant adverse consequence if gas intrusion were to go undetected.
- Support systems to those identified in the first two bullets above.

The result of this evaluation should be documented in station documents or procedures to clearly delineate the in-scope systems. Additionally when the station corrective action process identifies an event that may include an element of gas intrusion or accumulation in a system that was not previously included in the scope then an evaluation should be performed to determine if that system should be added to the scope.

The scope may be narrowed to portions of a system where gas accumulation can affect the ability to perform a specific function. These scope limitations should be evaluated and documented.

One method to perform this evaluation would be to identify from the list of potential gas intrusion mechanisms those that would be applicable to a specific system. If no method of gas intrusion can be identified then the system needs no further review. Careful consideration should be made here as all systems could be subject to gas intrusion due to an incomplete fill and vent.

For those systems that have identified potential gas intrusion mechanisms, evaluation of the impact of that gas on the performance of the system function should be performed. The evaluation should document the rational that supports a determination that gas intrusion into the system would not adversely affect the ability of the system to perform its function. If such an evaluation can be performed then the system can be considered to not be an in-scope system and no further evaluation is required.

If it is determined that the gas intrusion could impact the ability of the system to perform its function then the system is in-scope and further evaluation of locations where gas could accumulate in the system should be performed.

8 SYSTEM GAS ACCUMULATION LOCATIONS

8.1 DEVELOP EVALUATION METHOD

Utilities should develop and maintain a method for determining and documenting all system high points, local high points and other potential gas void locations. Relevant dimensional information, and similar data for use in evaluating all potential gas void locations should be included in the documentation. Key elements of the evaluation method are described in the following subsections. These findings will be used to develop acceptance criteria, evaluate potential void locations, exclude locations from further evaluation, and identify additional desired vent valve locations, key monitoring points, etc.

8.2 IDENTIFY BOUNDARIES OF SUBJECT SYSTEMS

The system design information and functional requirements should be reviewed to determine the boundary of each affected fluid system. The boundaries and their basis for selection should be documented.

8.3 IDENTIFY POTENTIAL GAS VOID LOCATIONS IN SUBJECT SYSTEMS

Perform a review of system design information, including piping and instrumentation drawings, isometric drawings, plan and elevation drawings, and calculations to identify potential gas void locations. Perform walkdowns of the subject systems to validate potential void locations and identify new locations. The walkdowns should confirm the location and orientation of important components such as inverted “U” piping, heat exchangers, valves, vent locations, branch lines, orifices, relief valves, reducers, interfaces with other systems, etc., that can become sources of gas or could otherwise cause gas to be trapped or difficult to remove during system maintenance or restoration. The walkdown should also verify that installed high point vents are actually at the system high points, including field verification to ensure pipe geometry changes (such as reducers) and construction tolerances (over long runs of pipe) have not inadvertently created additional high points.

Document the location and reference elevation of all local and system high points in the affected fluid systems on the appropriate drawings (for example, simplified one-line drawings) for further evaluation. Identify the locations as either vented or unvented high points.

8.4 EVALUATE GAS ACCUMULATION LOCATIONS

8.4.1 Evaluate Locations for Gas Accumulation

The station should develop a process to evaluate all identified local high points, system high points and other potential void locations to determine if gas accumulation could occur. This evaluation process may group locations together or treat each location separately as long as criteria are developed to support the determination to group the locations. The evaluation process may document a specific void size at potential void locations below which further evaluation is not required. The justification for this conclusion shall be documented and include a discussion of the cumulative effect of multiple locations along the same line.

The potential sources of gas intrusion developed as a result of section 4 of this document should be evaluated for applicability to identified high point locations. Understanding all sources of gas that could affect the high point location is the basis for the conclusion. These local or system high point locations are then determined to be potential void locations.

8.4.2 Evaluate Potential Void Locations for Monitoring Requirements

Potential void locations require further evaluation to determine what level of void monitoring is required.

Monitoring is not required for those potential void locations (vented or unvented) where the maximum potential accumulated gas void volume has been evaluated and determined to not challenge system operability, based on the maximum acceptable void volume, location, Froude number, or other technical basis.

Monitoring is not required for a potential void location bounded by another monitored potential void location in the same piping segment. The bounding evaluation is based upon maximum self limiting size, location, Froude number or other technical basis. The evaluation must be documented and the total potential gas volume from such a location reduces the overall system corrective action acceptance criteria for that pipe segment. The process could require additional monitoring for these locations if gas is found at the bounding monitored potential void location.

The remaining potential void locations will have a monitoring frequency determined and are subject to additional monitoring as described in section 12.1 and 12.2 of this document.

9 ACCEPTANCE CRITERIA (DESIGN)

This section addresses acceptance criteria (design). Acceptance criteria (corrective action) are not addressed in this section, but are addressed in Section 13 below.

In general the acceptance criteria (design) for gas accumulation in a fluid system may be stated or, if not stated in a requirement, may be derived from an engineering analysis of the impact of the gas on system and component performance. If there is no specified acceptance requirement (design) then the acceptance requirement (design) is no gas present.

There may be potential gas void locations where it is desirable to determine an acceptance criterion (design) that would determine that the system is sufficiently full to perform its design function. In these cases where a non-zero gas volume acceptance criterion (design) is desired, design change documentation shall be processed to support associated procedure changes to incorporate the potential gas void monitoring acceptance criteria (design). This is required by 10 CFR 50, Appendix B, Criterion III and Criterion V. Considerations for permanently acceptable conditions should include:

- Documenting in design output documents (e.g. design calculation)
- Updating system design criteria and descriptions
- Updating system monitoring procedures to include the criteria

Acceptance criteria should ensure, as a minimum:

- Pumps do not become air bound or degraded to a performance level that impacts design basis flow requirements or accident analysis assumptions
- Gas that can be swept into the reactor coolant system will not adversely impact flow through the core during operation, shutdown or accident conditions
- Gas that has accumulated in piping downstream of pumps will not cause an unacceptable pressure surge in the piping when the pump starts in a recirculation lineup or during accident conditions. The pressure surge must be limited to a value that does not damage piping, pipe supports, or other system components, or result in lifting of relief valves where system pressure exceeds reseat pressure.

10 FILL AND VENT PROCESSES

10.1 GENERAL FILL AND VENT REQUIREMENTS

Fill and vent activities are performed to restore a system, portion of a system or instrumentation to service following maintenance, modification, or for any reason the system may have been drained or gas may have accumulated.

10.2 PROCEDURE REQUIREMENTS

Fill and vent procedures should contain guidance on filling and venting methods to restore the systems as full based on the system configuration. Venting methods may include static venting through a valve, dynamic (flow induced) venting, and vacuum venting. Verification that the system piping is full of water following fill and vent is recommended.

Fill and vent procedures should:

- Specify vent locations to support operating and maintenance activities, the venting method, and the criteria to determine when adequately filled.
- Specify adequate steps that ensure the subject systems are free of accumulated gas and will perform their intended functions.
- Be revised as necessary to incorporate operating experience and to control gas voids that may be introduced by maintenance and/or operational activities.
- Be specific for the condition and alignment of the system at the time of the activity and any limitations on available vents from isolation boundaries.
- Include the following:
    - Use the appropriate fill source and fill location
    - Provide the proper sequencing of valve operations to maximize gas void removal. Vent sequencing from lower high points to the higher elevation high points is recommended.
    - Provide specific acceptance criteria for venting based on potential void locations and the duration of flow required to transfer the void to a vent location.
    - Include filling or backfilling instrumentation lines when applicable
    - Provide instructions (e.g., system alignment, minimum required flow rate) to perform dynamic venting if necessary
    - Perform verification after fill and venting, and re-verification if additional venting is required that the piping is sufficiently full
    - Document void identification and quantification information, including no void present.
    - Use the corrective action program if verification identifies weaknesses in prior fill and vent activities

10.3 DYNAMIC VENTING

Use of dynamic venting has been found to be an effective means to remove gas from local high points and traps in piping. It involves pumping water through the system to force accumulated gas to a location that can be vented or removed. When static fill and vent efforts are not effective in removing all trapped gas during system restoration, procedures should provide for use of dynamic venting when it is allowed by the system configuration. Dynamic venting should be performed in accordance with written procedures. Procedures should consider the following:

- Acceptability of the location to which the gas will be transported
- Effect of transporting voids through pumps
- Required flow rate (Froud No.) to sweep the gas from the high point
- Time that flow should be maintained to ensure sweeping the gas

10.4 VACUUM FILL

Vacuum filling may be an effective method for removal of trapped gas. Provisions for use of vacuum fill, as an option, should be included in applicable procedures. Vacuum fill should be done in accordance with written procedures. Appropriate evaluations of the effect of vacuum on the system should be performed and documented.

10.5 VERIFICATION

Fill and vent procedures should include requirements for verification of effectiveness (including quantification of any remaining gas found, e.g., UT examinations for voids). If the fill and vent is performed for system restoration following maintenance on an isolated portion of the system, verification should include quantitative inspection to find gas accumulation that may be transported outside the isolation boundary once the system is restored (e.g., at system or local high point vents above the boundary valves).

10.6 CORRECTIVE ACTION

The corrective action program should be used to resolve identified deficiencies in procedures. The final system condition should be verified to meet acceptance criteria or be resolved by appropriate corrective action. Any voids found following completion of fill and vent activities should be recorded, tracked, and trended for evaluation of gas intrusion management effectiveness.

11 SYSTEM MAINTENANCE

Any system maintenance activity that will result in a reduction in fluid inventory of a fluid system in the scope of gas accumulation management should be evaluated to determine the required fill, vent and verification inspection. The work processes should include provision for engineering review and evaluation of such evolutions. If the specific evolution has been previously evaluated and the fill, vent and verification requirement identified then engineering review if required could be limited to verifying applicability.

11.1 DOCUMENTED FILL AND VENT RESTORATION PLAN

For each specific activity a fill and vent plan should be documented either in procedures or in the work document.

11.2 ENGINEERING REVIEW OF WORK ORDER AND PLAN

Engineering should be included in the review process of any procedure or work document that breaches an applicable system.

11.3 ENGINEERING IDENTIFY REQUIRED CONFIRMATORY VERIFICATIONS

Engineering should either specify as part of their review or confirm the procedure that the selected verification locations will demonstrate that the system is sufficiently full to perform its functions. This includes the specification of appropriate verification locations and methods.

12 GAS MONITORING

12.1 PERIODIC MONITORING

Utilities should determine the appropriate monitoring frequency for each monitored potential void location. The monitoring plan must be developed to ensure the system meets the acceptance criteria (design) and must ensure the system is capable of performing its design function throughout the next monitoring interval. The monitoring frequency for each location determined in section 8 to require periodic monitoring should be documented in station procedures. The monitoring frequency may be changed based on the system, location, function, and results of previous monitoring, and should be established considering:

- Probability of gas intrusion due to known gas generation rates at that location (such as those identified in 12.8).
- Probability of gas intrusion due to normal plant maneuvers and equipment manipulation.
- Ability to detect gas intrusion caused by equipment failure or degraded equipment conditions.

- Consequence of a gas intrusion event at that location (some locations may tolerate more gas than others).
- Long term system history of gas accumulation.
- Integration of monitoring frequencies into normal plant work schedules (e.g. 31 days, 90 days, 6 months, refueling).

12.2 ADDITIONAL MONITORING BASED UPON POTENTIAL OR ACTUAL GAS INTRUSION

When an actual gas intrusion event has occurred or there exists an increased possibility that gas intrusion may occur in a given location or system the condition should be documented in the corrective action program. The corrective actions should include additional monitoring.

Additional monitoring or increased monitoring frequencies should be established when potential problems are observed, until the root cause of gas accumulation can be identified and corrected. The monitoring frequency should be established based on evaluation or analysis that demonstrates operability of the system within the monitoring period.

A monitoring plan with specific locations, techniques, and frequency would then be employed to verify that any gas accumulation resulting from the active gas intrusion mechanism remains less than the volume that challenges the ability of the system to perform its design function(s).

The conditional monitoring plan may be pre-established based on the system evaluations and considering accumulation rates and Operability void acceptance criteria.

An extent of condition review should be performed to identify other locations that are potentially affected by the observed gas intrusion mechanism and inspections should be performed at the locations identified by the review.

12.3 GAS VOLUME QUANTIFICATION

Gas identified should be quantified and compared to acceptance requirements for that specific location to determine operability. The accuracy of the method used for quantification should be sufficient to verify operability during the next monitoring interval and to evaluate past operability.

The water level in pipes and components can be accurately determined by using Ultrasonic Testing (UT) methods. Based on the UT measurement and system configuration drawings, engineering can calculate the volume of the gas.

An alternate method for quantification of gas volume is to “crack open” the vent valve and estimate the time necessary to vent the pipe or component. This method is subjective and requires operators to make good faith estimates of the amount of time to expel the gas present. Combined with other system information such as tank level trending or other parameters, engineering can make a gross estimate of the gas volume. When this method is used care should be taken when using the results as the variability in the method could be significant. When this method is used the degree of accuracy required at the given location should be evaluated and documented.

12.4 IDENTIFICATION OF THE GAS TYPE

Identification of the gas type can be beneficial in determining the source of the gas intrusion. Gas chemistry is not always necessary to be determined by test. Engineering judgment and past experience can be used in the evaluation to reasonably conclude whether the gas is air, nitrogen, hydrogen, or other gas. However, when gas sources cannot be definitively determined, gas chemistry should be determined by sampling. Gas analysis provides evidence to verify that assumptions regarding the intrusion mechanism are correct and should be encouraged.

12.5 VENTING REQUIREMENTS

Venting through valves at high points in a system is a method to determine whether a gas void is present.

12.6 UT EXAMINATION

UT is the preferred method to determine the quantity of gas that has accumulated at a high point or other monitoring point.

12.7 TRENDING OF GAS

Methods should be developed to trend the location and volume of gas voids found in the subject systems and identify the source of the gas.

- All monitored points should be trended, even if no void is identified. This includes locations that have greater than zero acceptance criteria (design) and the amount of gas identified is less than the criteria such that entry into the corrective action process may not be required.
- When trending a known void at a specific location, the void size calculation should be based on a normalized pressure to ensure that system pressure fluctuations do not mask void growth. By establishing a normalized pressure, void volumes that are measured at different system pressures can be directly compared to establish a trend.
- As-found and as-left void volumes should be measured and documented to determine the effectiveness of periodic venting.
- Trending of gas accumulation data will help assess the performance of high/low pressure interface boundary isolations, help identify degraded component conditions, ineffective system fill and venting, and establish criteria for implementing corrective actions when necessary.
- Results of the trending data may be used to plan operating and maintenance activities to mitigate gas intrusion, and to adjust monitoring frequencies when needed.

12.8 LIST OF GAS INTRUSION PRECURSORS

Plant conditions that may result in generation of gas are called “precursors to gas intrusion.” Each utility should evaluate and document a specific list of precursors based upon plant design and operation. These include but are not limited to:

- Unanticipated accumulator level decrease that is unaccounted for may be indicative of leakage of nitrogen saturated water into lower pressure systems where the dissolved gas will come out of solution.
- Unaccounted RCS leakage that may be indicative of system leakage into lower pressure systems. Such leakage may produce voids from gas coming out of solution or steam voids if the leaking fluid is above the saturation temperature for the lower pressure system.
- Degraded pump performance may be caused by gas intrusion causing decreased discharge pressure and/or flow, increased vibration and general poor performance.
- Unexpected low as-found pressures found in piping during testing and system walkdowns.
- Unexpected increase in system temperature or pressure.
- Rapid drop in VCT pressure.
- Increased RCP seal return flow.
- Taking a component out of service, draining it and refilling after work is complete may be a precursor to gas intrusion.

13 OPERABILITY REVIEW FOR FOUND GAS IN EXCESS OF ACCEPTANCE CRITERIA (DESIGN)

Operability determination processes are not required if the "Design Basis" establishes acceptance criteria (design) for potential gas void locations, the criteria are included in the monitoring procedure, and the as found gas volume is below the acceptance criteria (design).

13.1 CORRECTIVE ACTION PROCESS USED

Since the existence of gas accumulation in system piping exceeding the acceptance criteria (design) is not an expected condition, the discovery of gas accumulation that exceeds the acceptance criteria (design) should be entered into the station's corrective action program.

An immediate Operability determination or functionality assessment is required if discovered gas volume is greater than the monitoring procedure acceptance criterion (design).

13.2 CORRECTIVE ACTION ACCEPTANCE CRITERIA IDENTIFIED

Utilities should develop either system generic or location specific acceptance criteria (corrective action) that can be used in the operability determination processes to show that the system although degraded will continue to perform its specified function. NEI APC 09-20 provides guidance for determining the acceptance criteria to be applied for operability determination under the corrective action process.

13.3 CONSIDERATION OF COMPENSATORY MEASURES

When gas is found, the operability review should include consideration of compensatory measures to enhance or maintain operability.

Potential compensatory measures can include:

- Additional monitoring as described in section 12.2 of this document
- Increased monitoring of potential gas sources
- Temporary modifications
- Removal of gas from the system

13.4 GAS REMOVAL

In general, accumulated gas that exceeds the acceptance criteria (design) should be removed immediately or at the next available opportunity, consistent with the Technical Specifications and the station corrective action process, by using methods described in this document.

13.5 PREPARE A MODEL PROMPT OPERABILITY DETERMINATION FOR GAS EVENTS

While each station's corrective action process describes the specific process for prompt operability determination, it would be beneficial for the utility to develop a template or model prompt determination to be used following the identification of gas voids. Such a template/ model would lead to consistent application of the gas intrusion and accumulation management at the station. Items to include in the template are:

- Identification and evaluation of the specific gas intrusion source
- Review of industry testing results and other technical documents
- Identification of previous identified gas voids at this location
- Results of the gas trending data for this location

14 TRAINING

The need for training on gas accumulation and gas intrusion issues has been recognized by the industry for some time. INPO SOER 97-1 called for providing initial and continuing training for station personnel who design, operate, or maintain systems and components that are susceptible to, or may cause, gas intrusion. Later, INPO SER 2-05 reiterated the requirement for training on safety systems susceptible to gas intrusion or systems and components that may cause gas intrusion in safety systems. More recently, however, Revision 1 of INPO SER 2-05 and Generic Letter 2008-01 indicate that instances of gas accumulation continue to occur throughout the industry and that the training that has been provided has not been effective in improving plant performance.

NEI and the Owners Groups in cooperation with INPO have undertaken an effort to develop a series of training modules that utilities can use to assist in training plant personnel on gas voids in piping systems. The modules are intended for use by Engineering, Operations, Maintenance, Management, and other technical staff who may need a background on preventing and managing gas accumulation.

The training modules will be applicable to BWRs and PWRs. The modules will provide a basis for licensees to develop plant-specific training that is in accordance with the Systematic Approach to Training process.

It is anticipated the training will be repeated after two to three years to fulfill the expectation for continuing training.

A module that is a basic overview of gas accumulation issue is being developed. It will be a broad discussion of the topic to demonstrate how various organizations are affected by the issue.

Department-specific modules will also be developed that will demonstrate how each organization contributes to the prevention and management of gas voids.

Each utility will need to use the generic modules created as described above as the basis for their station specific training on gas intrusion/accumulation prevention and management.

ATTACHMENT 1
TERMS AND DEFINITIONS

Acceptance Criteria – The maximum amount of gas at a location at any time which will allow the system to continue to perform its specified function.

Acceptance criteria (Design) - As used in this document applies to acceptance criterion which has been fully evaluated in the stations design control program and incorporated into applicable station design documentation.

Acceptance criteria (Corrective Action) - As used in this document applies to an acceptance criteria used during the corrective action process for a gas void location(s) that exceed the documented acceptance criteria (Design) but can be considered operable but degraded.

Dynamic Vent – The use of high velocity fluid to flush the system of voids that remain following conventional fill and vent activities. This is an expected operation in most systems with full flow test capability that require a system run prior to declaring OPERABILITY. A sufficiently high velocity is identified by a Froude number greater than or equal to one (1.0).

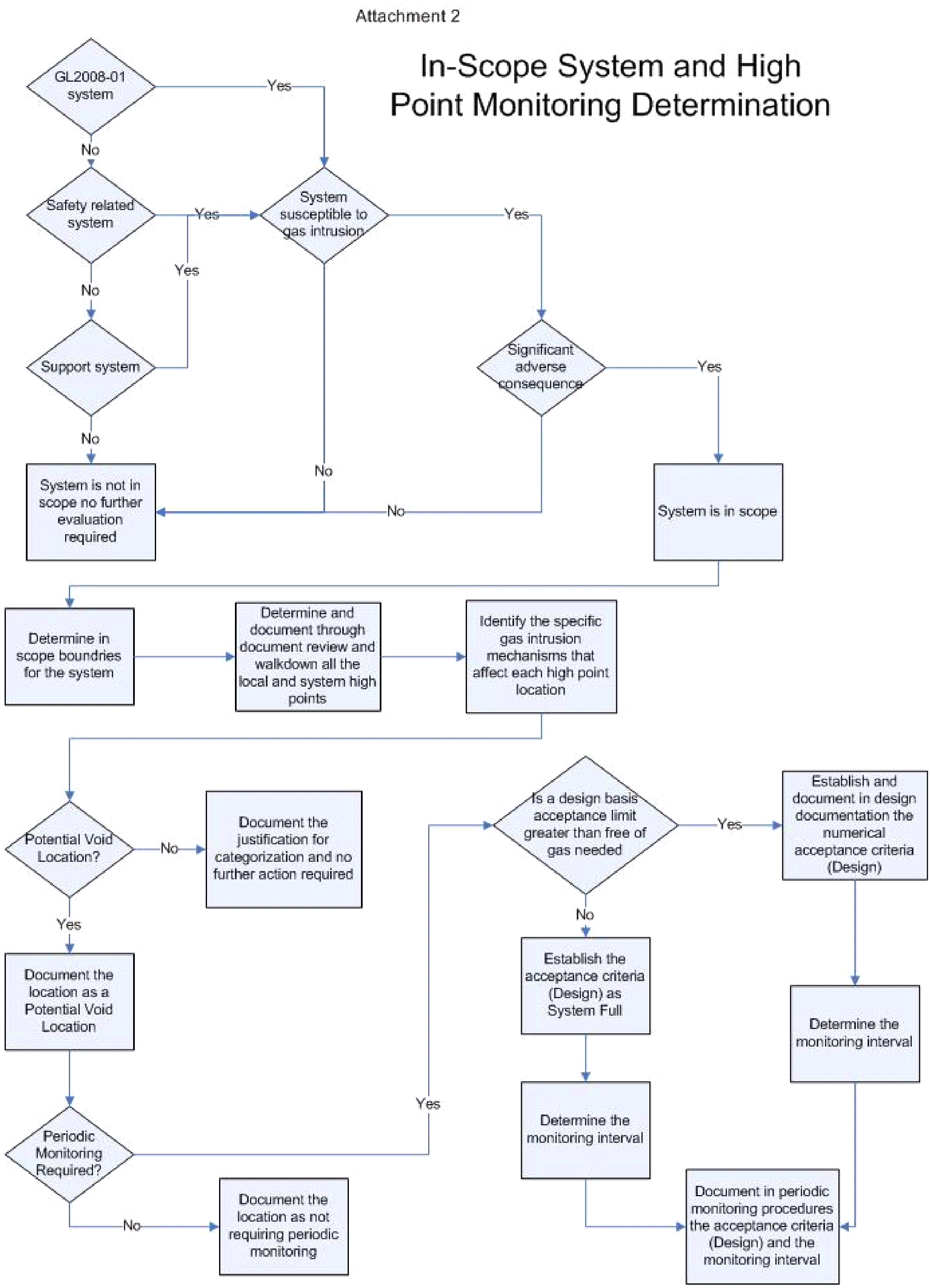
Froude Number – A dimensionless parameter which is the ratio of inertia force on a gas bubble to gravitational (buoyancy) force.

Gas – As used within the context of this document, the term includes air, nitrogen, hydrogen, or any other void that is not filled with liquid water.

Ultrasonic Testing (UT) – An acoustic technology where very short ultrasonic pulse-waves are launched into materials to detect internal flaws or to characterize materials. This technology can be used to detect water-gas interface within a piping segment or component.

Void – As used within the context of this document, the term is used essentially equivalent to "gas".

ATTACHMENT 2
IN-SCOPE SYSTEM AND HIGH POINT MONITORING DETERMINATION



ATTACHMENT 3
MONITORING AND TRENDING