May 23, 2011

GUIDANCE TO NRC/NRR/DSS/SRXB REVIEWERS FOR WRITING TEMPORARY INSTRUCTION (TI) 2515/177 SUGGESTIONS FOR THE REGION INSPECTIONS

This is Revision 11 of this document. Regional inspectors should use the applicable information in place of such information in plant-specific inspection guidance provided to support TI 2515/177 inspections. The principal change from Revision 10 is a rewrite of Section 1.4. We recommend that Revision 11's Section 1.4 be substituted in all older documents that contain this section.

This revision is an interim version that we plan to update when additional information is available or there is a need for providing additional guidance.

Blue is used for comments and guidance in preparing the communication to the Regions. Material in black may be used "as is" or you may modify it. Choose from material in Red as appropriate, modify it, or add anything else that you believe is needed. Green is used for licensee-specific information. This means that a color printer should be used if you want a hard copy of this communication.

The following should be a memorandum from Anthony Ulses, the SRXB Branch Chief, if to Region II and an attachment to an email from Anthony Ulses if to Regions I, III, or IV. Addressees are:

I Michael Balazik

II Binoy Desai, Chief, Engineering Branch 1, Division of Reactor Safety, Region II, cc to Shane Sandal, Senior Reactor Inspector, Engineering Branch 1, Division of Reactor Safety, Region II

III Ann Marie Stone, cc to Caroline Tilton, Nestor Feliz-Adorno,

IV Thomas Farnholtz, cc to Matthew Young,

Warren Lyon, Jennifer Gall, Diana Woodyatt, Eric Bowman, the Project Manager (PM), and the PM's Branch Chief should be on cc for all communications.

Subject: TI 2515/177 Inspection of plant name

The attachment provides the NRR Reactor Systems Branch (SRXB) suggestions for the inspection of plant name using the guidance provided in Temporary Instruction (TI) 2515/177, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems, (NRC Generic Letter 2008-01)."

ATTACHMENT

OFFICE OF NUCLEAR REACTOR REGULATION (NRR) REACTOR SYSTEMS BRANCH (SRXB) SUGGESTIONS FOR THE PLANT NAME INSPECTION USING THE GUIDANCE PROVIDED IN TEMPORARY INSTRUCTION (TI) 2515/177 (REFERENCE 1)

1 BACKGROUND

Section 1 summarizes the SRXB review approach and provides information inspectors may find useful for inspections.

1.1 SRXB Review Approach

Reference 2 described the coverage the NRC staff expected licensees to provide in their responses to Generic Letter (GL) 2008-01 (Reference 3). The initial SRXB review approach was to address all shortcomings via in-depth Requests for Additional Information (RAIs) followed by recommendations to the Regions to supplement Regional plans for TI inspection coverage. However, based on feedback from the Regions and other stakeholders, we modified the review process to focus on information needed to ensure plant operability with respect to finding and addressing voids (Reference 4). This should reduce regulatory burden and appropriately utilize Regional inspector practices and knowledge. Reference 2 continues to apply and may be used for guidance in conducting TI inspections.

We focused on the following when preparing RAIs:

a. Technical Specifications (TSs) and planned response to Technical Specifications Task Force (TSTF) documentation,
b. Surveillance requirements,
c. Procedures, and
d. Corrective action program (CAP).

This was done with the intent of establishing that any remaining issues are confirmatory and the Regions can select issues to be examined further via the TI inspection.

One of the two objectives of GL 2008-01 was “to collect the requested information to determine if additional regulatory action is required.” Recent inspections have identified that licensees are using computer codes to predict gas movement behavior but examination of the code applications has generally shown that the codes have not been acceptably verified for this purpose. We have determined that this issue requires additional regulatory action as stated in the GL objective to obtain closure, an action that will take some time. In the interim, issues associated with gas movement must be addressed during inspections in response to TI 2515/177 and when gas accumulation events occur. A principle focus of Revision 11's Section 1.4 is to provide guidance for addressing these issues until improved information is obtained.

1.2 Operability Determination

Our review and the inspections are based on guidance provided in References 5 - 7 for assessing subject system operability. The objective is to “reasonably ensure that subject system operability” is achieved and a “reasonable expectation” test applies. This means that a high degree of confidence applies but absolute assurance is not necessary. The determination can be based on analyses, test or partial test, experience, and/or engineering judgment. This is particularly applicable to determination of void transport behavior, pump response to voids, and vortexing where the reliance on judgment will vary depending upon the depth of understanding that has been developed. This is discussed further in Sections 1.4 and 1.5. Consequently, a strong reliance on engineering judgment will sometimes be necessary to support an interim finding regarding current operability[1] for these issues until improved guidance can be developed. Such guidance is expected to be available in late 2011 and will allow operability findings to be more solidly based on analyses and tests. Consequently, the need for engineering judgment should be diminished although there will likely remain circumstances where solidly based engineering judgment is both appropriate and acceptable.

1.3 The Meaning of "Full of Water"

There have been issues related to the meaning of "full of water" in TSs. Reference 8 concluded that "if the licensee can conclude through an operability determination that there is a reasonable expectation that the system in question can perform its specified safety function, the system piping can be considered filled with water such that the surveillance requirement is met." A condition where there is no void is described by such words as gas-free, free-of-gas, or water-solid.

1.4 Void Transport and Pump Response

In general, voids should be removed when found. This will eliminate an existing operability concern but consideration of past operability should still be addressed. If the void cannot be eliminated, then existing operability must be addressed. Methods to assess suction piping voids are discussed below.

Assessing current operability requires addressing all aspects of the behavior. This includes but is not necessarily limited to:

1. Variation in pump flow rate and discharge head encountered.
2. Suction transport.
3. Pump ingestion.
4. Discharge effects.
5. Behavior within the reactor coolant system (RCS) including delay in delivery of water.

Selected aspects of these considerations are addressed in the following subsections to Section 1.4. Development of other aspects is continuing and will be addressed in future revisions of Section 1.4.

[1] "Currently operable" is a determination made on the basis of currently available information with the understanding that later information may affect the conclusion.

1.4.1 Pump Suction Void Criteria

A basic consideration is the response of pumps to voids entering the pumps under both steady state and transient conditions. The NRC and industry have agreed that the following criteria for the void fraction entering a pump, Φ, are acceptable without further justification for not jeopardizing operability of a subject system pump, as qualified in the discussion following the table (References 9, 10, and 11):

	$\% \frac{Q}{Q_{BEP}}$	**Φ for BWR Typical Pumps**	**Φ for PWR Typical Pumps**		
			Single Stage	Multi-Stage Stiff Shaft	Multi-Stage Flexible Shaft
Steady State Operation	40%-120%	0.02	0.02	0.02	0.02
Steady State Operation	< 40% or > 120%	0.01	0.01	0.01	0.01
Transient Operation	70%-120%	0.10 for ≤5 sec	0.05 for ≤20 sec	0.20 for ≤20 sec	0.10 for ≤5 sec
Transient Operation	< 70% or > 120%	0.05 for ≤5 sec	0.05 for ≤20 sec	0.05 for ≤20 sec	0.05 for ≤5 sec

where: Q = water volumetric flow rate
BEP = best efficiency point
Transient Φ is averaged over the specified time span
Instantaneous Φ < 1.7 times the listed value

The transient operation criteria are based on the premise that the initial void fraction in the pump does not exceed 0.05, that full head will be recovered after the gas has passed through the pump as substantiated by pump operation experience and the judgment that the short times associated with the transients will not result in pump damage. Further, the most likely condition that would result in pump damage would be associated with an insufficient flow rate during the transient time, a condition that is not judged to occur during the listed transient times in conjunction with the Φ < 1.7 criterion that precludes momentary large void fractions and precludes slug flow with respect to applying the criteria.

Meeting the steady state criteria should (1) preclude pump damage provided pump miniflow requirements are met so that pump cooling is ensured and (2) reasonably ensure that operability requirements will be met if the pump head, H, satisfies the following:

$$(H_{\text{un-degraded}} - H_{\text{required to meet operability requirements}}) / H_{\text{un-degraded}} > 0.03$$

Head degradation due to gas should be addressed if this relationship is not satisfied.

The pump void criteria are applicable when the upstream suction piping has a circular cross section and the velocity is generally parallel to the pipe centerline as flow enters the pump unless acceptable qualifications are provided.

1.4.2 Net positive suction head (NPSH)

NPSH margin for consideration of cavitation will be captured in design basis analyses for loss-of-coolant accidents (LOCAs). Consequently, consideration of the effect of gas on NPSH is not necessary with respect to GL 2008-01 inspections.

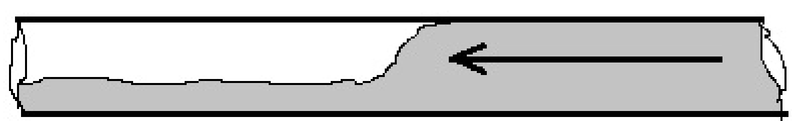
1.4.3 Use of Froude Number to Predict Void Movement

At low flow rates, gas may be assumed to not move in a horizontal pipe or downward in a vertical pipe if the Froude Number, N_{FR}, is ≤ 0.31 and the average void fraction in a plane perpendicular to the pipe centerline, Φ, is ≤ 0.20, where:

$$N_{FR} = \frac{V}{\sqrt{\frac{D g_c (\rho_L - \rho_g)}{\rho_L}}}$$

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

In an initially stagnant condition where flow is initiated, little gas movement will occur in a horizontal pipe for N_{FR} ≤ 0.31 with Φ ≤ 0.20. As N_{FR} is increased above 0.31, the interaction of gas and liquid will increase and gas will move more rapidly toward the downstream end of a horizontal pipe. For N_{FR} > 0.54, a hydraulic jump (kinematic shock) may occur where the pipe is water-solid upstream of the jump and all gas will be moved toward the downstream end of the horizontal pipe as illustrated in the following sketch:



Note that the 0.54 criterion cannot be applied to conclude that gas will be removed from the downstream end of a horizontal pipe unless gas can flow freely from the end of the pipe. Further, if a horizontal pipe terminates at a void, such as in the top of a tank, the end region of the pipe will not run full during steady state flow unless N_{FR} > ~ 1.2.

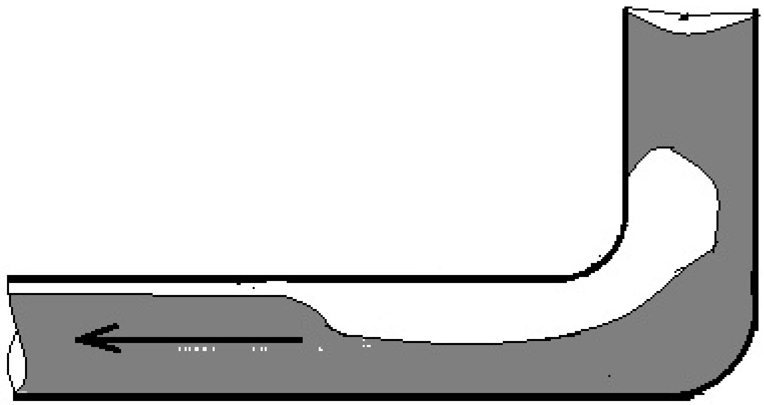
In a connection from a horizontal pipe to a vertically downward pipe, some gas will move downward when the water velocity is greater than the bubble rise velocity. The applicable bubble rise velocity is about 1 ft/sec and, for N_{FR} = 0.54, the velocity will exceed this value in pipes with an inner diameter > ~1 1/4 inches.

N_{FR} ≥ 1 is sufficient to sweep air out the tubes in an inverted "U" tube heat exchanger under steady state flow conditions that have lasted for a few minutes. This is also sufficient for downward flow in a straight pipe that has no geometry changes that may perturb the flow.

However, behavior at the bottom of a vertical pipe that connects to a horizontal pipe is not well understood, as discussed in the next paragraph, and the $N_{FR} \geq 1$ criterion is questionable.

At $N_{FR} \geq 2.0$, all gas will be carried out of a pipe with the flowing water although localized gas pockets may remain where full flow conditions may not exist such as in the vicinity of valves or orifices. These criteria are applicable for "dynamic venting" where gas is removed by flushing from the system provided sufficient time is allowed for the flushing to be completed.

There are flow regions where using N_{FR} may not provide clear guidance. For example, for $N_{FR} \geq$ ~0.8 a horizontal pipe that is receiving a two phase mixture from a downward oriented vertical pipe may involve behavior illustrated in the following sketch:



A void is illustrated along the inside of the elbow and a kinematic shock is shown toward the left where the void fraction decreases and the void fraction flowing toward a pump located to the left of the sketch would be less than occurring near the elbow. Simultaneously, some of the void may or may not migrate upward in the vertical pipe. If the pump entrance was located in the region near the elbow, pump response may differ from a location to the left of the sketch. As previously stated, behavior in this region is not clearly understood.

Complex behavior may also occur in flow from a horizontal pipe to a downward oriented vertical pipe where a void may collect in the vicinity of the elbow and the top of the vertical pipe. Here, a kinematic shock may occur at the bottom of the void and water may fall through the void and impact water at the bottom of the void. This impact will cause gas bubbles to be carried down into the water some distance before an equilibrium gas - water condition is established. If the bottom of the vertical pipe terminates at an elbow to a horizontal pipe at a distance where the "waterfall" is affecting the void fraction, N_{FR} may be insufficient to determine behavior. In general, if the vertical pipe volume is at least four times as large as the initial gas volume, then there is sufficient vertical pipe length for homogeneous bubbly flow to be established at the bottom of the vertical pipe provided that downstream conditions have no effect on the vertical pipe.

1.4.4 An Acceptable Suction Void Volume Determination Method

Predictions of pump suction void behavior and experimental data due to an upstream void exhibit significant noise and a preliminary method for assessing behavior is to assume an average pump suction void fraction based on 0.5 second intervals. If the average void fractions are less than or equal to the acceptance criteria provided in the above table, then the void is judged not to jeopardize pump operation. An acceptable conservative method of determining the size of a void upstream of a pump that will not jeopardize current operability that also eliminates slug flow concerns is to assume the entire void passes through the pump within 0.5 seconds and compare this to the acceptable pump suction criteria. Hence, the acceptable upstream void can be obtained by multiplying the void fraction given in the above table times the total volumetric flow rate times 0.5 seconds. For example, assume a suction pipe high point exists upstream of a PWR RHR pump, the pressure at the pump suction is 35 psia, the pressure at the high point is 15 psia, the flow rate is 6 ft^3/sec, the pump is operating at close to its best efficiency point, and the time when the void reaches the pump until it has cleared the pump is less than 20 seconds. The maximum permissible void volume at the high point is:

$$(0.05)(6\ ft^3/sec)(0.5\ sec)(35\ psia\ /\ 15\ psia) = 0.35\ ft^3$$

1.4.5 Use of Computer Codes to Predict Void Transport Behavior

At present, there is no acceptable generic methodology for assessing pipe void size and void transport behavior other than the above, and extrapolations to conditions not addressed by the above information should be addressed on a plant-specific basis.[2] Therefore, inspectors may find it necessary to rely on judgment in conjunction with guidance provided in the following paragraphs to determine that licensees have an acceptable justification to support conclusions regarding movement of gas in pipes.

Several licensees have analyzed gas movement by applying codes such as RELAP5, GOTHIC, TRAC, and TRACE to perform a two-phase, two component analysis of gas movement. Others have applied codes where the NRC has no experience or information for this type of application, such as SYSFLO and AIRDST. The NRC has observed acceptable applications and others that did not have an acceptable basis for the applications. However, the NRC's reviews have been for plant-specific applications and no generic conclusions have been made.

A plant-specific process that the NRC determined to be acceptable to address gas movement upstream of multi-stage pumps involved a Millstone 3 void issue that was addressed using RELAP5 Mod 3.3 (References 12 and 13) in combination with a ¼ scale test facility that provided data for the plant configuration. Comparison of the test data and the predictions led to modifications of the RELAP5 input parameters and recalculations of the tests resulted in reasonable agreement. An understanding of some of the expected phenomena that supplemented the RELAP5 predictions or compensated for RELAP5 inadequacies was obtained via consideration of such areas as the following:

1. Froude number to assess gas transport and for test scaling,

2. bubble rise velocity to assess vertical gas/water separation (Reference 14),

3. the Harleman et al correlation (Reference 15) to assess the potential for gas being pulled into suction flow due to radial inflow,

4. reference to Knauss (Reference 16) for vortex formation, and

[2] NEI and other industry reports that cover gas transport and associated phenomena have been provided to the NRC and are under review. These are identified in NEI 09-10 (Reference 11). The NRC plans to provide assessments of these reports during 2011 as part of the NEI 09-10 acceptance review.

5. reference to the American National Standard Institute (ANSI) (Reference 17) for both scaling and conservatism.

Key aspects that led to NRC acceptance were (1) the test configuration that was scaled to the plant, (2) applicable test data, (3) verification of RELAP5 by the test data and use of RELAP5 as a scaling tool, and (4) compensation for RELAP5 weaknesses by use of other information as listed above.

GOTHIC has been reported to be used at many facilities to predict gas movement associated with GL 2008-01 and other systems, such as an issue with gas accumulation in a component cooling water system.[3] GOTHIC has a broad modeling capability and is one of the most flexible thermal-hydraulic codes the NRC has examined. It is restricted to rectangular geometries and approximations are necessary to model piping systems. Modeling of cylindrical horizontal and vertical pipes is judged to be capable of reasonable approximations and error associated with the modeling can probably be reduced by tuning. Piping at an angle from horizontal must be addressed with care. Similarly, treatment of elbows and tees will vary with the orientation. For example, an elbow between a horizontal and a vertical pipe may have to be modeled differently than an elbow from one horizontal pipe to another for gas/water analyses. This means that single phase water tests will not provide enough data for a comparison to GOTHIC calculations of two phase water and gas with respect to tracing the gas behavior.

The NRC is aware of a broad range of comparisons between GOTHIC predictions and test data with a range of results. Most of the comparisons, including support for acceptance of GOTHIC for containment modeling (Reference 18), do not directly address gas movement under the conditions of concern here. The comparisons do address basic phenomena that the code can model, a topic discussed in the October 18 – 19, 2010 meeting with Nuclear Applications, Inc. (Reference 19). The NRC is not aware of any comparisons that are judged to acceptably cover plant system behavior for the plants that are the topic of NRC's Temporary Instruction 2515/177 inspections. Example plant system behavior predictions that NRC has reviewed are results provided to support inspections at Point Beach (Reference 20) that include comparisons with proprietary Purdue test data[4] and preliminary comparisons to the Reference 12 test simulation of piping from the Millstone 3 RWST. Issues associated with these applications include potential modeling inconsistency and applicability of the tests to overall plant modeling.

1.4.6 Assessment of Void Transport Methodologies

Computer codes and other representations of behavior are used to predict two-phase two-component transient void behavior. Licensee use of these methods generally should address the following:

1. The method must have a demonstrated two component (gas-liquid) analysis capability for the configurations and conditions where it is applied. Additional information pertaining to this requirement is provided in the remainder of this list.

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[3] The NRC is aware of its use or planned use at Three Mile Island, Point Beach 1 and 2, Byron 1 and 2, Braidwood 1 and 2, St. Lucie 2, Catawba 1 and 2, Salem 1 and 2, Crystal River 3, and Wolf Creek.

[4] This work was supported by many members of the Pressurized Water Reactor Owners Group and overseas plant operators and the data are available to those who provided support. A draft review of this report has been completed and transmitted to NEI for review of proprietary content and inaccuracies prior to finalization as part of the acceptance review of NEI 09-10 Rev. 1.

2. The theoretical / correlations basis of the method must be fully described. Reference to an applicable document that has been provided to the NRC is acceptable.

3. The method must be acceptably verified by comparisons of predictions to acceptable test data. Test configurations must be compared to plant configurations and differences must be addressed. This must include nodalizations if the method includes such modeling. Identical methodologies should be applied to test and plant predictions and if there are differences, they must be addressed.

4. Realistic modeling and use of safety factors to account for perceived uncertainty are preferred. Conservative assumptions may be used in combination with appropriate safety factors. Where the primary methodology does not apply, supplemental methodologies and rationale may be used. An example is compensation for weaknesses in RELAP5 when scaling the test data to the Millstone 3 plant configuration.

5. Some analysis methods may not correctly model such phenomena as the kinematic shock or void distribution that may occur downstream of an elbow between a horizontal pipe and a vertical pipe. Other methods may require in-depth modeling to address the behavior if the phenomena has a significant effect on downstream behavior. Conclusions must consider such inadequacies or requirements. To the extent practical, predictions should be further assessed with respect to basic behavior as addressed by such approaches as use of Froude number and bubble behavior correlations to confirm the accuracy of the calculations.

6. Closely related to Item 5 is the lack of data and phenomena understanding associated with such configurations as vertical-to-horizontal pipe transitions and tees. Such weaknesses must be addressed when predicting behavior.

7. If pump modeling is an important component of the void transport analysis, then correct pump modeling should be verified because understanding of two phase transient pump behavior is changing as additional data are obtained.

8. If the model includes a tank where water level can approach the drain pipe elevation or the connection between a large pipe and a smaller suction pipe such as the RHR to hot leg connection in PWRs, the treatment should be evaluated because there are questions regarding the correct modeling of vortex behavior.

9. Code modeling is strongly influenced by the modeler, typically an organization that has a demonstrated capability to apply the code. The modeler must have a demonstrated capability to fully understand the code, selection of input parameters, and the nodalization.

In general, the user must provide a comparison of the test and plant geometry and conditions and establish that acceptable scaling is achieved. Since there is a significance difference in density of a gas void and water, in general, elevation differences may be more important than horizontal ones. For example, water may act as a piston and push gas ahead of it (a hydraulic jump) in a small diameter pipe where the water would flow below a volume of gas in a large diameter pipe when the velocities and void fractions are the same. An example of a critical elevation difference parameter is flow from a horizontal pipe downward into and through a vertical pipe. If sufficient gas accumulates at the horizontal to vertical turn, a hydraulic jump or waterfall may occur where the momentum of water spilling over into the vertical pipe causes gas to be pushed further down in the pipe than may be predicted by a method that does not take this into account. Thus, a test where this occurs in a long length of vertical pipe may show that no gas is propagated to the end of the pipe whereas if the plant has a shorter vertical pipe, gas propagation may be quite different.

1.4.7 General Inspection Guidance

The basic requirement is a reasonable substantiation of operability. If the gas is vented, existing operability has been addressed and the remaining issue is past operability that can be addressed on a longer-term basis. If the gas cannot be vented, and the gas volume meets the 0.5 second criterion, then existing operability is not an issue. If neither of these conditions can be achieved, then, depending upon judgment regarding the gas volume and the potential for jeopardizing functionality, some delay in providing an in-depth substantiation may be justified while more substantial assessment of the effect of the gas is achieved. This assessment may involve one of the following conditions:

1. A code-based analysis has been performed that the NRC has previously determined to be acceptable that addresses the condition.

2. A code-based analysis is available but must be determined to be acceptable by the NRC resident inspectors with consultation with NRR as needed. An example of this process is covered in the Point Beach Inspection report. (Reference 20)

3. A code-based analysis is not available and alternate methods, such as described above, is used.

The best approach is one in which voids are prevented and, when voids are found, they should be much smaller than a void that could challenge operability and should be removed unless removal is impractical. In all cases where a void is found, the CAP should be entered to address the condition. Further, any void that potentially challenges operability must be removed or reduced so that it is no longer a concern.

Industry has developed a simplified conservative methodology designed to address gas movement to cover many cases of concern. We are reviewing this methodology and are sharing our review results with industry. We do not anticipate this process will result in an acceptable simplified methodology until at least the end of 2011. Industry is also considering an approach that may reduce the concern with acceptable void volumes based on the maximum void fraction that could cause a problem under any conditions. We will continue to follow this development and will incorporate results as applicable and acceptable.

1.5 Vortexing

NRC inspectors often encounter plant conditions where vortexing may result in entrainment of gas into systems that are required for plant operation or to respond to accident conditions. In assessing these conditions, they are finding that licensees may rely on non-conservative analysis methodologies, yet the inspectors have little guidance upon which to base their assessments. Instead, they have found that several methodologies exist to determine whether a vortex will form and contradictory results have been obtained from the different testing methods, configurations evaluated, and interpretation and extrapolation of results. Likewise, inspectors have a difficult time in determining the amount of air entrainment due to vortexing and the effect on pumps. This has led to such situations as inconsistent assessment of vortices, challenging of previously reviewed vortex analyses, potential inappropriate selection of which methodology to use, and questions regarding the impact on pump operability.

Industry has commented that vortices are categorized as Types 1 through 6 with Type 1 being a surface dimple and Type 6 having a continuous gas core that extends into the suction port. To obtain a 0.01 void fraction in the suction flow, the diameter of the gas core needs to be at least 10% of the suction port diameter. This is only obtained with a Type 6 vortex. Much of the confusion arises because it is not clear that only a Type 6 vortex of this scale would challenge pump operation. This vortex guidance must be consistent with the above table of allowable pump inlet gas volume fraction.

We plan to develop a formal position and generic guidance regarding vortex formation and acceptable analytical methods for assessing vortex formation by (TAC ME1306). The best approach is one in which plant operation prevents approaching conditions where vortexing can result in gas ingestion.

1.6 Nuclear Energy Institute (NEI) Guidance

Reference 11 provides excellent coverage of many aspects of the GL 2008-01 issues and extends industry guidance to cover all systems where gas accumulation may be a concern. We recommend you read this document for background information before conducting the TI inspection. We are pursuing endorsing Reference 11, assuming it is acceptable, by issuing a safety evaluation and regulatory issue summary (RIS) in 2012.

1.7 Accessible Versus Non-Accessible Locations and Surveillance Requirements

All locations are considered to be accessible unless actual environmental conditions constitute a hazard to personnel or are such that conducting the surveillance in the specific locations will result in an unacceptable dose. Surveillance locations in a posted high radiation area are considered to be accessible if the surveillance(s) can be conducted without exceeding an acceptable dose with respect to ALARA considerations. For example, suppose six surveillance locations are in a high radiation area and five can be completed with minimal exposure to radiation. The locations where the five surveillances are to be conducted are accessible. Consideration of such aspects as high environmental temperatures or local high temperatures that constitute a burn hazard also apply to determination of non-accessibility.

Surveillance is required for all locations of concern unless it is acceptably determined that the surveillance is not necessary to reasonably ensure operability. However, the NRC staff will allow more flexibility in determination of operability for non-accessible locations with respect to consideration of such aspects as the likelihood that gas can accumulate in the locations of concern in contrast to the impact of gas at those locations.

1.8 Surveillance Frequency and Requirements

The NRC staff is studying general surveillance requirements as part of the TSTF evaluation but, for now, the scheduled surveillance frequency should be every 31 days unless a greater surveillance frequency has been justified. Typical considerations for a greater surveillance frequency could include such items as:

1. All potential sources of gas are monitored and trended and applicable parameters remain within specified limits. Potential monitoring may include but not be limited to such items as accumulator level and pressure, RCS leakage, ECCS and RHR system piping pressure, RHR temperature versus saturation temperature when RHR is initiated or suction sources are changed, volume control tank pressure for unanticipated pressure drops, reactor coolant pump seal return flow rate for unanticipated increases, and level in any tanks that are provided to accumulate gas from piping high points. Further, monitoring of locations where outgassing may occur when liquid passes from a high pressure region to one at lower pressure should be considered.

2. The piping is maintained at a pressure higher than that of any potential source of gas in-leakage, such as some of the ECCS discharge piping in some Westinghouse designs that are maintained at pressures greater than the RCS pressure, and no locations exist where outgassing may cause gas to accumulate during operation

Potential sources of gas that should also be considered may include failure of level instruments to indicate correct level, leakage through one or a series of closed valves, vortexing, design deficiencies that may result in gas intrusion during accidents, keep-full system malfunctions, leaks in hydraulic dampeners, and cooling of an isolated section of piping that may cause a pressure decrease.

Any location that has the potential for a gas volume to be formed should be assumed to have an acceptance criterion of zero gas unless an acceptable criterion has been specifically determined for that location.

Monitoring is not required for those potential void locations where the maximum potential accumulated gas void volume has been evaluated and acceptably determined not to challenge system operability. Monitoring is not required for a potential void location that communicates with a bounding monitored potential void location in the same piping segment when the second location will show a void when the first location is full. However, any potential gas volume in unmonitored locations must be acceptably evaluated with respect to its potential contribution to the overall system response if gas accumulates in other locations. The evaluation must be documented and the total potential gas volume from such a location reduces the overall system 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. (Most material taken from Reference 11, which provides excellent insights for addressing gas concerns.)

The monitoring methodology should be documented. The documentation should include an assessment of the monitoring methodology accuracy and a justification of why the accuracy is sufficient to support a determination of operability. In the case of UT, an accuracy determination and justification is not necessary if the measurement methodology involves a relatively precise process such as determining the water level in a horizontal pipe from one side and from the other side accompanied by a circumferential measurement and suitable calculations, measuring the level in a vertical pipe, or using a widely acceptable method of measurement from the bottom or top of a horizontal pipe. These processes are expected to provide sufficient accuracy when compared to the uncertainty associated with the void criteria.

Failure to meet a gas volume acceptance criterion shall require (1) immediate entry into the CAP, (2) an immediate operability determination, and (3) a decreased scheduled surveillance frequency that is sufficiently short to ensure that the affected locations will remain within acceptance criteria until the cause of the failure is corrected.

1.9 Surveillances Associated with Outage and 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 could be limited to verifying applicability.

Some of the potential sources of gas that are of concern with outage and maintenance practices are the same as identified in Section 1.8, above. Others that should be considered include procedure errors, failure to follow procedures, ineffective fill and vent, system draining, and realignments.

Locations potentially affected by outages or maintenance operations are to be purged of gas and/or surveyed immediately upon completion of the activity and established to have no gas volumes that exceed gas volume acceptance criteria. A follow-up, completely independent surveillance of potentially affected locations and adjoining locations should be accomplished within 31 days if the scheduled surveillance frequency is greater than 31 days to ensure that the post-outage or maintenance potential impacts have been addressed. The acceptance criteria for this second surveillance should be that no gas volume acceptance criteria will be exceeded and no significant gas accumulation will have occurred since the first surveillance that was conducted upon completion of the activity. Startup of selected pumps and observation of the transient discharge pressure is an acceptable second surveillance of pump discharge piping if (1) at least one week has passed since the first test, (2) this test was conducted previously with verification that the observed transient was consistent with the previously determined volume, (3) the second surveillance established, within the sensitivity of the test, that no gas accumulated since the first test, and (4) gas volumes are less than half the gas volume acceptance criteria.

1.10 Gas Volume Acceptance Criteria

If there is no specified gas volume acceptance criterion for a location where gas may potentially exist, then the acceptance criterion is that a water-solid condition shall exist.

As discussed in Section 1.4, above, gas volume acceptance criteria are of five types:

1. Pump Inlet void fractions
2. Criteria applicable to piping upstream of pumps that may result in voids entering a pump
3. Criteria applicable to water hammer and related issues
4. Criteria applicable to RCS behavior due to injected gas
5. Criteria applicable to containment response

Water hammer effects due to potential accumulated gas or vapor must be shown to be limited to a value that does not damage piping, pipe supports, or other system components. Further, the pressure surge associated with pump starts must not result in lifting of relief valves where system pressure exceeds reseat pressure and should not result in lifting relief valves. Several industry reports have been received that address water hammer under various conditions. These are under review as part of the NEI 09-10 Rev 1 review.

RCS response to injected gas generally entails consideration of the potential delay in injecting water upon demand and the effect of the injected gas on RCS behavior. The potential delay is generally small with respect to other delays associated with initiation of injection and the amount of injected gas is often small in comparison to the voids that exist due to other causes. In such cases, a qualitative evaluation is often sufficient to establish operational acceptability. No generic guidance is anticipated to be necessary to address Item 4.

The same conclusions generally apply to Item 5.

1.11 Corrective Action Program (Taken in part from Reference 11)

The CAP should be used to resolve identified deficiencies in procedures. The final system condition should be verified to meet acceptance criteria or to 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.
If the CAP is entered because of failure to meet an acceptance criterion, an immediate review should be conducted to identify other locations that are potentially affected by the observed gas intrusion mechanism and licensee inspections should be performed at the locations identified by the review. 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 immediately to remedy these locations, then enhanced monitoring shall be implemented to identify early onset of gas accumulation.

1.12 Procedures (Taken from Reference 11 with modifications)

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.

1.12.1 Fill and Vent Procedures

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 necessary.

Fill and vent procedures should:

1. Specify vent locations to support operating and maintenance activities, the venting method, and the criteria to determine when adequately filled.

2. Specify adequate steps that ensure the subject systems are free of accumulated gas and will perform their intended functions.

3. Be revised as necessary to incorporate operating experience and to control gas voids that may be introduced by maintenance and / or operational activities.

4. 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.

5. Include the following:

   a. Use the appropriate fill source and fill location.

   b. Provide the proper sequencing of valve operations to maximize gas void removal. Vent sequencing from lower high points to the higher elevation high points should be accomplished unless an acceptable determination has been made that it is not necessary.

   c. Provide specific acceptance criteria for venting based on potential void locations and the duration of flow required for transfer of the void to the vent location.

   d. Include filling or backfilling instrumentation lines when applicable.

   e. Provide instructions related to system alignment and the minimum required flow rate to perform dynamic venting if necessary.

   f. Provide verification after fill and venting, and re-verification if additional venting is required, so that the piping is sufficiently full.

   g. Document void identification and quantification information, including no void present.

   h. Use the CAP if verification identifies weaknesses in prior fill and vent activities.

1.12.2 Dynamic Venting

Use of dynamic venting is 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 that consider the following:

1. Acceptability of the location to which the gas will be transported

2. Effect of transporting voids through pumps

3. Required flow rate (Froude Number) to sweep the gas from the high point

4. Time that flow should be maintained to ensure sweeping the gas

1.12.3 Vacuum Fill

Vacuum filling may be an effective method for removal of trapped gas. Vacuum fill should be done in accordance with written procedures and appropriate evaluations of the effect of vacuum on the system should be performed and documented.

1.12.4 Verification

Fill and vent procedures should include requirements for verification of effectiveness and should include quantification of any remaining gas found. 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.

1.13 Applicable systems

Select the PWR or BWR list as appropriate:

For pressurized water reactors, applicable systems will typically include:

1. Safety Injection (SI) System or ECCS. This typically includes charging pumps, high pressure coolant injection (HPCI) system, low pressure injection (LPI) system, and SI accumulators where different licensees use different nomenclature that is not listed in this report for the same function.

2. RHR, DHR, or Shutdown Cooling (SDC) System. Different licensees use different designations. Configurations typically include reactor vessel (RV) cold leg and hot leg injection, suction from the RCS, and the containment emergency sump.

3. Containment Spray (CS) System.

4. Borated Refueling Water Storage System or its equivalent with respect to potential interactions with the ECCS. (Different licensees use different designations.)

5. Chemical and Volume Control System with respect to potential interactions with the ECCS.

For boiling water reactors, this will typically include:

6. Core Spray.

7. High Pressure Coolant Injection (HPCI).

8. RHR. Functions typically include suppression pool cooling, shutdown cooling, core spray, containment cooling, decay heat removal, alternate decay heat removal, drywell / wetwell spray, suppression pool spray, ECCS keepfill system, torus spray, and low pressure core spray, depending upon the plant and the licensee's designation of the system functions.

9. Other components of the ECCS.

2 INSPECTION GUIDANCE

The status is that licensee has provided a response to GL 2008-01 (References A, B, etc) that satisfies the GL objectives and NRR/SRXB has completed a response review. There are no open items that necessitate additional NRR/SRXB follow-up although SRXB plans to provide consultation to Regional or Resident Inspectors upon request. A confirmatory inspection that uses the guidance provided in Temporary Instruction (TI) 2515/177 is the only item that remains.

Selection of inspection items and the inspection depth is a Regional decision since Regional personnel have insights and knowledge that we do not possess at Headquarters, and the TI has been written to provide this flexibility. Our suggestions are based on a selective review of the licensee's responses to the GL and those responses may not fully cover the licensee's capabilities. Our suggestions are provided for your consideration and we have not attempted to cover all aspects of the TI. You should treat the suggestions as supplementary information that may not be necessary in light of your knowledge of the actual plant condition, and you should follow the TI in whatever depth you believe is appropriate.

In general, we suggest that your inspection in response to the TI

Select one of the following three or provide your own suggestion:

be minimal since the licensee has provided an in-depth response to the GL that addresses the issues.

or

be an in-depth inspection because the licensee's response to the GL resulted in many confirmatory items that need to be addressed. We suggest that most aspects of the TI be covered with consideration of the suggestions we provide below.

or

be based on selections from the TI guidance that you believe appropriate with consideration of the suggestions we provide below.

Based upon the information we have reviewed, we suggest you consider including the following when planning the TI 2515/177 inspection:

The following should be included in all inspection suggestions documents unless there are no commitments:

- Verify that the licensee has completed or has acceptable plans for addressing commitments identified in the GL responses. We suggest that you plan to follow up to reasonably ensure outstanding commitments are acceptably addressed.

The following should be included in all PWR inspection suggestions documents:

- Many PWR licensees have found that flashing can occur in RHR suction lines when initiating RHR while the lines are at an elevated temperature. Verify that the licensee has acceptably addressed this issue if applicable to its design and operation. Note that steam bubbles do not transport like a gas. Rather, they collapse once submerged into the flow stream if the flow stream temperature is less than the saturation temperature, a process that will be accompanied by a flow stream temperature increase. Conversely, instant flashing due to a pressure decrease will result in a rapid temperature decrease.

Depending on the information provided in the licensee's GL response and our review, the following should be considered for inclusion in our suggestions to the Regions:

- Verify that one or more procedures (1) include acceptable methods for determining void volume, (2) acceptably address a methodology for void removal, (3) have been covered in training, and (4) ensure that the licensee enters the CAP whenever voids are discovered following refill operations. TI Sections 04.01, 04.03, Reference 2 Sections 3.3.2, 3.5.1, 3.5.2, 3.5.3, 3.5.4

- Selectively verify the acceptability of the CAP process for addressing issues pertinent to GL 2008-01 and, if applicable CAP processes have been performed, then selectively verify the acceptability of the licensee's response to the identified issues. TI Sections 04.01, 04.02, 04.03c5, 04.04; Reference 2 Sections 3.4.6, 3.6

- Verify the acceptability of the licensee's processes for monitoring and trending such parameters as void volumes, accumulator level and temperature, reactor coolant system (RCS) leakage, and ECCS discharge pressure and temperature to ensure that pre-cursor parameters are addressed and that entry into the CAP will be accomplished if acceptable trending criteria are not met. See Sections 1.8 and 1.9, above, for guidance. TI Sections 04.01, 04.02e Exclude any items that do not apply, such as accumulators for BWRs.

- Verify the acceptability of the licensee's methodology for predicting void behavior and the impact on subject system operability. Pay particular attention to the licensee's determination of acceptable void volumes with respect to void volume, void transport, and pump response to voids. See Section 1.4, above, for guidance. The licensee should be consistent with the Section 1.4 criteria or should provide a justification for any differences. TI Sections 04.01, 04.02f, 04.03d; Reference 2 Sections 3.3.2, 3.4.3, 3.4.4

- Selectively verify the acceptability of the licensee's review relative to the plant configuration, walkdowns, and commitments for planned walkdowns. TI General Guidance, TI Sections 04.02c and d, 04.04; Reference 2 Sections 3.4.5, 3.4.6, 3.4.7

- Selectively verify that the licensee has acceptably performed hardware modifications, such as installing additional vent valves in upper pipe elevations and that the vent valve installation process reasonably ensures that the opening inside the pipe is sufficiently close to the upper elevation of the pipe to accomplish the venting purpose. TI Section 04.04, Reference 2 Section 3.4.8

- If training is acceptably addressed, but interim training is not covered, then: Training is stated to be accomplished at a future date. Verify that the existing applicable training background ensures that personnel are aware of gas-related concerns and will respond accordingly. TI Section 04.02c, Reference 2 Section 3.7.

- If TSTF information, such as a commitment date, is not adequate, then: Verify that the licensee has committed to assess the technical specification task force (TSTF) traveler and to implement appropriate changes in TSs within one year or less of the TSTF being issued. TI Section 04.01, Reference 2 Section 3.3.4

- If "accessible locations" is based on a broad statement such as containment and posted high radiation areas rather than actual radiation or thermal access considerations, then:

Verify that the meaning of “accessible locations” is consistent with actual accessibility and that coverage of inaccessible locations is acceptable. TI Section 04.02c, Reference 2 Section 3.3.2

- If the licensee did not adequately identify the applicable systems, then: Verify that the licensee considers all systems that should be covered consistent with the GL. Select either the PWR or the BWR item that follows. For pressurized water reactors (PWRs) this will typically include:

  - Safety Injection (SI) System or ECCS. This typically includes charging pumps, the high pressure coolant injection (HPCI) system, the low pressure injection (LPI) system, and SI accumulators. (Different licensees use different nomenclature that is not listed in this report for the same function.)

  - Residual Heat Removal (RHR), DHR, or Shutdown Cooling (SDC) System. Different licensees use different designations. Configurations typically include reactor vessel (RV) cold leg and hot leg injection, suction from the reactor coolant system (RCS), and the containment emergency sump.

  - Containment Spray (CS) System.

  - Borated Refueling Water Storage System or its equivalent with respect to potential interactions with the ECCS. (Different licensees use different designations.)

  - Chemical and Volume Control System (CVCS) with respect to potential interactions with the ECCS.

  For boiling water reactors (BWRs) this will typically include:

  - Core Spray.

  - High Pressure Coolant Injection (HPCI).

  - Residual Heat Removal (RHR). Functions typically include suppression pool cooling, shutdown cooling, core spray, containment cooling, decay heat removal, alternate decay heat removal, drywell / wetwell spray, suppression pool spray, ECCS keepfill system, torus spray, and low pressure core spray, depending upon the plant and the licensee’s designation of the system functions.

  - Other components of the ECCS.

  TI General Guidance, Reference 2 Section 3.1

- With respect to surveillance frequency and requirements, see Sections 1.8 and 1.9, above, for guidance. If the licensee did not adequately address surveillances, then: Verify that areas not covered by TSs and TS Bases, such as not providing surveillance requirements (SRs) for ECCS suction piping and not ensuring a void assessment at high points that are not equipped with a vent, are identified and the process of ensuring adequate coverage is identified. See Sections 1.8 and 1.9, above, for guidance. And / or, if the licensee uses a surveillance frequency that is greater than every 31 days and it is not acceptably justified, then: Since the licensee uses a surveillance frequency of greater than 31 days, verify that the surveillance frequency is acceptably justified. See Sections 1.8 and 1.9, above, for guidance. TI Section 04.01, Reference 2 Section 3.3.2

- If the licensee did not adequately identify potential gas intrusion mechanisms, then: Verify that the licensee has addressed the potential gas intrusion mechanisms. Depending on the plant, these typically include such items as SI accumulators, the RCS, dissolved gas coming out of solution, gas issues associated with the containment emergency sump, the refueling water storage tank, gas issues that may be caused by level instrumentation error, valve leakage, and operations such as shutdown, restart, and maintenance. TI Section 04.02e, Reference 2 Section 3.4.2 Exclude any items that do not apply, such as accumulators for BWRs.

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