June 4, 2010

GUIDANCE TO NRC/NRR/DSS/SRXB REVIEWERS FOR WRITING TI SUGGESTIONS FOR THE REGION INSPECTIONS

This is a revision of Section 1.4 of previous versions of this document based upon information obtained during the June 2, 2010 meeting with NEI and industry representatives. We recommend it be used in place of Section 1.4 of the plant-specific version of the document in all inspections conducted in response to TI 2515/177.

1.4 Void Transport and Pump Response

Assessing 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 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.

1.4.1 Acceptance criteria for pump response to voids

Interim criteria we will accept without further justification for not jeopardizing operability of a subject system pump, as qualified in the discussion following the table, are:

	$\% \frac{Q}{Q_{BEP}}$	**BWR Typical Pumps**	**PWR Typical Pumps**		
			Single Stage	Multi-Stage Stiff Shaft	Multi-Stage Flexible Shaft
Steady State Operation	40%-120%	2%	2%	2%	2%
Steady State Operation	< 40% or > 120%	1%	1%	1%	1%
Transient Operation	70%-120%	10% for ≤5 sec	5% for ≤20 sec	20% for ≤20 sec	10% for ≤5 sec

Transient Operation	< 70% or > 120%	5% for ≤5 sec	5% for ≤20 sec	5% for ≤20 sec	5% 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 than full head will be recovered~~developed~~ after the gas has passed through the pump and the judgment, substantiated by pump operation experiences~~data~~, 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.

Comment [AXLE1]: if we had data, we don't need "judgment"; however some pumps did have voids pass through them as after the fact experiences

Meeting the steady state criteria should preclude pump damage provided pump miniflow requirements are met so that pump cooling is ensured. Further, the steady state criteria will reasonably ensure that operability requirements will be met if the difference between the pump head required to meet operability requirements and the un-degraded pump head is greater than a few percent. If required pump head is within a few percent of un-degraded head, then degradation due to gas should be addressed.

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 Gas movement in pipes

At low flow rates, gas may be assumed to not move in a 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 ≤ 0.2, where:

$$N_{FR} = \frac{V}{\sqrt{\dfrac{Dg_c(\rho_L - \rho_g)}{\rho_L}}}$$

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

At higher flow rates, some gas may be transported at $N_{FR} \leq 0.65$ and all gas will be carried out of a pipe with the flowing water if $N_{FR} \geq 2.0$. Time to clear gas from a pipe for $0.8 < N_{FR} < 2.0$ is a function of flow rate. Dynamic venting may not be assumed effective for $N_{FR} < 0.8$. Time to clear gas as a function of time will be addressed in a later revision of this document when we have received and evaluated test data that supports clearance behavior. In the meantime, inspectors should determine that licensees that use dynamic venting have acceptable justification to support the effectiveness of their dynamic venting processes.

At present, there is no acceptable generic methodology for assessing pipe void size and void transport behavior other than the above and any extrapolations to conditions not addressed by the above information should be addressed on a plant-specific basis. Industry is developing a simplified conservative methodology to address gas movement that should cover the majority of cases of concern. This is scheduled for completion during calendar year 2010 and we will update our guidance as more information becomes available that provides an acceptable methodology. 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. In the meantime, inspectors may find it necessary to rely on judgment in conjunction with other guidance provided in Subsection 1.4.3 to determine that licensees have an acceptable justification to support conclusions regarding movement of gas in pipes.

One approach that is used by licensees is to analyze gas movement by applying codes such as RELAP 5, GOTHIC, TRAC, and TRACE to perform a two-phase, two component analysis of gas movement. We have not reviewed these codes in sufficient depth to confirm they are generically acceptable but they may provide reasonably results if properly applied. For example, Region I personnel, the licensee, and Fauske Associates did an in-depth evaluation of a void issue at Millstone 3 that provided sufficient information for the Region to conclude that historic operability had been acceptably confirmed. References 10 and 11 describe two phase, two component tests and RELAP 5 analyses of the tests, respectively. Fauske Associates and the licensee also used RELAP 5 to calculate behavior in the emergency core cooling system (ECCS) flow path at Millstone 3, but these reports are not readily available. We suggest contacting Wayne Schmidt (610-337-5315) at Region I if you need additional information. RELAP 5 has also been used to calculate two phase, two component behavior in the subject systems at other facilities. There are at least seven cautions to observe in considering this approach:

1. Modeling is strongly influenced by the modeler who must have a demonstrated capability to fully understand the code and the necessary nodalization.

2. The codes may not correctly model such phenomena as the kinematic shock (waterfall) that may occur downstream of the elbow from a horizontal pipe to a vertical pipe and any conclusions must consider such inadequacies.

3. If pump modeling is an important component of the analysis, then pump modeling may be inadequately addressed.

4. There are questions regarding the correct modeling of vortex behavior associated with water level approaching the level of a drain pipe from a tank or the connection between a large pipe and a smaller suction pipe.

5. The wide variation of pipe geometries and the above considerations may necessitate that tests be conducted and compared to calculations unless previously applicable comparisons have been performed.

6. An up-to-date version of the code should be used that has a two component (gas-liquid) analysis capability.

7. Predictions should be assessed with respect to basic behavior as addressed by such approaches as use of Froude number, bubble rise velocities, and, in some cases, tests that include applicable configurations.

With respect to the need for substantiation of a code for such applications as opposed to an industry comment that it is not necessary since engineering judgment is sufficient, we disagree. Engineering judgment must be based upon a reasonable basis and applying a code that does not have such a basis is not acceptable. This was clearly shown in the RELAP 5 work described above where the test data and associated analyses established what aspects of RELAP 5 could be applied and which were not appropriate. With respect to the time required to perform a validation test and the need to shut down in the event of a problem since insufficient time would be available, the first requirement is a reasonable substantiation of operability. This can differ with respect to the time when in-depth substantiation becomes available. For example, continued operation for a short time while a code application is substantiated for justification of long term operation may be acceptable.

Licensees sometimes begin their analyses from the viewpoint that the tabulated acceptable void criteria may be used as a starting point and that some calculational methodology may be applied to determine acceptable void volumes throughout different locations in suction piping. If acceptable consideration is given to the combined effect of the void volumes, then this is an acceptable approach to determine short term operability when provided in procedures. However, it is not acceptable to support long term operability conclusions. Our opinion is that discovery of any non-trivial void must be vented if practical and that entry into the CAP is necessary and that the CAP provides an acceptably process to assess the effect of the void.

Licensees sometimes reference industry documentation that is inconsistent with the above information and such references may not be acceptable for operability or operating considerations. In conclusion, the best approach is one in which voids are prevented and, when voids are found, they should clearly be much smaller than a void that could challenge operability and generally should be removed unless removal is impractical. Further, any void that challenges operability must be removed or reduced so that it is no longer a concern.