Detection and Removal of Gas Voids

Discussion of Alternative Methods - Rev 6.0

There are a number of alternate methods that can be employed to detect and/or remove gas voids from ECCS, Containment Spray, Auxiliary Feed Water and Decay Heat Removal systems.

Not only does NRC GL08-01 specifically call the periodic detection of these gas voids, but it also requires the elimination of the gas voids. With the exception of Nuccorp's Nuclear Grade Air Trap none of these alternative methods do both.

Each of these methods requires the pre-determination of the local high points in each piping system. These high points are the locations where the gas voids would accumulate in a static system.

With the exception of Nuccorp's Nuclear Grade Air Trap (NGAT) , each of the other methods still require that vents be installed at each local high point; thus if vents are already installed at a nuclear plant one of the alternative methods must still be employed on a continuous basis.

A brief review of existing systems follows as well as the relative disadvantages of each.

1. Ultrasonic Testing

The traditional method of void detection involves having technicians routinely perform a manual ultrasonic test at each local high point to determine if there is a gas void in the pipe. This is a time and labor intensive method that often requires multiple technicians to implement, elevated platforms and/or scaffolding to be erected for access in safety-related areas, and it exposes personnel to unnecessary dosages of radiation (not copasetic with ALARA principles). This method has been known to lead to false-positive alerts due to improper procedures being followed. (NRC Event 45812 at Farley) Accordingly, false-negatives should also be a concern. Furthermore, with UT, if air/gas is detected, it is already in the piping system itself. In contrast, the NGAT accumulates and traps the air away from the main safety-related piping, where no harm can occur.

Ultrasonic testing still requires the installation of vents to allow any detected gas voids to be released, else costly plant shutdowns could follow.

2. Venting

Once a gas void is found at a local high point (using Ultrasonic Testing or some other method), it is typical to drill a hole at the high point and to install a vent. A vent is typically a welded t-connector and/or a flange connected to a valve. That valve can then be opened to bleed off the void.

3. Simplified Equation

The Simplified Equation does not detect nor does it remove gas voids, but it is one of the nuclear industry's answers to the problem. It is the industry's attempt to justify the existence of a gas void that is sufficiently small based on its relative location within the piping system.

The Simplified Equation was developed at Diablo Canyon. It is a mathematical method of justification if a gas void is small enough to disperse into liquid solution to an acceptable degree before reaching a critical point in the piping system. The critical point is typically a pump that might cavitate or fail if subjected to a gas void during service.

The Simplified Equation attempts to calculate that a void of a given size may be deemed harmless if it is pumped far enough, fast enough and through piping of sufficient geometry such that it can pass through a pump with relatively minimal compressive properties when compared to the fluid it has been turbulently mixed with.

The Simplified Equation came under considerable fire from the NRC at the NEI Gas Accumulation conference in Savannah, GA in January of 2010. This was primarily because the equation is highly dependent on pipe geometry and allows for the justification of the existence of the gas voids. NRC GL08-01 specifically calls for the elimination of the voids, not the justification of a void that is theoretically, sufficiently small.

Using the Simplified Equation still requires the detection of a void and elimination of a large void via some other means. It could be used to decide an existing void (detected by some other means) is sufficiently small such that venting is not yet required.

4. Guided Wave Method

The Guided wave method was published in EPRI Report TR-1018608 titled "Detection of Gas Voids in Pipe Using Guided Wave Ultrasonic", May 2009 This is a 106 page study that suggests the installation of a sending transducer, a receiving transducer and a permanent UT probe at each location of interest. Complex mathematics is needed at each location to determine how to interpret the signals received. It uses terms such as "Phase Velocity Spectrum", "Dispersion Curves", and the "Energy Feature Calculation".

This is how the "Energy Feature Calculation" is computed:

> *To obtain the value of the energy, a couple of signal processing steps are necessary. The first step is the calculation of the analytic envelope of the received signal. Analytic envelope is calculated by taking the Hilbert transform of the received signal. Energy is calculated by integrating over time the square of the envelope.*

The software provided to make the calculations is a standard $2,500 copy of a National Instruments software product called LabView. LabView is modern digital version of the old HP Spectrum Analyzer (Oscilloscope) that was a highly versatile, but also an extremely generic tool for signal analysis.

Cost of the Guided Wave Method:

> *The estimated system cost of $41,000 is for all required hardware to monitor one section of pipe. The cost for monitoring another section of pipe is drastically reduced as the only components needed are additional transducers, transducer mounting fixture, and wedges.*

The concerns with using the Guided Wave Method are:

- The Guided Wave Method does not provide a means of venting.
- Each Guided Wave location must be expertly calibrated for a given geometry between two points in the pipe, one before and one after the suspected void location.
- Calibration appears to be almost impossible for most locations because there is no way to establish transducer signal boundary conditions. How do we KNOW the pipe it is full, 90% full or half full during initial calibration at each location? While this calibration method may work in a laboratory, in the field it is not feasible to introduce a series of voids of known volumes at each local high point to chart the signal responses at each level for custom calibration of each location.
- While it is not certain that initial calibration outside of a laboratory is even possible, if an operator changes the frequency response between the transducers at any local high point, any system using the Guided Wave Method would have to be recalibrated. The system would be out of calibration if any of the following occurred:

  If there is any change in piping geometry such as an inline valve being turned.

  If a wrench or other foreign object is placed on top of the pipe by a technician.

  If a strap, tie-down or attachment of any kind makes contact with the pipe.

  If there is any change in the composition of the fluid being pumped.

  If there is any change in the composition of the void.

  If there is a temperature change of the system.

- If recalibration is necessary (assuming it is even possible), then the underlying system must be taken offline so new boundary condition signals can be established.
- The electronics to interpret the Guided Wave Method results have yet to be standardized.
- The Guided Wave Method requires electricity which instantly almost doubles the price of a modification in a nuclear facility.
- The Guided Wave Method introduces multiple additional failure modes.
- The training and cross-training required for Guided Wave Method use is not trivial.
- The signals received from each installation at each local high point will be unique to that location, thus there is no instant answer or conclusion based on the output. The data obtained from each test must be compared to the ranges established during calibration before a the pipe can be declared “full”.
- A battery operated, station-to-station mobile data collection versions of the Guided Wave Method require the technician to manually approach each high point in the system or reach for the installed leads to plug them into the source voltage and the LabView analyzer. This remains a labor intensive, time intensive process that exposes technicians to unnecessary radiation.

- The engineers at VC Summer reviewed the Guided Wave Method and declined saying "way too complicated".

- The Guided Wave system appears to still be experimental.

UPDATE: An EPRI publication dated March 18, 2011, (EPRI Product ID: 1022654) concluded "The results of the testing and concepts presented in this report indicate that guided wave techniques can be used for the detection and quantification of gas voids in piping systems with a proper understanding of the technique's limitations. However, because of its complexity, cost, and limitations, it is believed that the use of guided waves is not a viable solution to routine gas void detection in a nuclear power plant."

5. Cameron Linewatch (Formerly offered by Caldon, Inc)

Cameron's offering appears to be very similar to the Guided Wave Method. They have taken an older product offering (sold via their ML109 brochure, Rev 2) and have retrofitted it to perform similarly to the Guided Wave Method.

While the Linewatch disclosure is not specific, all of the detractors of the Guided Wave Method appear to apply to the Linewatch system with the addition of two more concerns. The Linewatch system appears to have custom machined mounting frames that could prove to be an additional expense over the Guided Wave disclosure. Also, the Linewatch system mounts one of the transducers on top of the pipe in question. The Linewatch transducers are mounted above each other – on the top and bottom of the pipe. The top location would interfere with the installation of a vent at the local high point. Also, there may be interferences along the horizontal piping run such that it would be impossible to install.

6. Suction Void Header

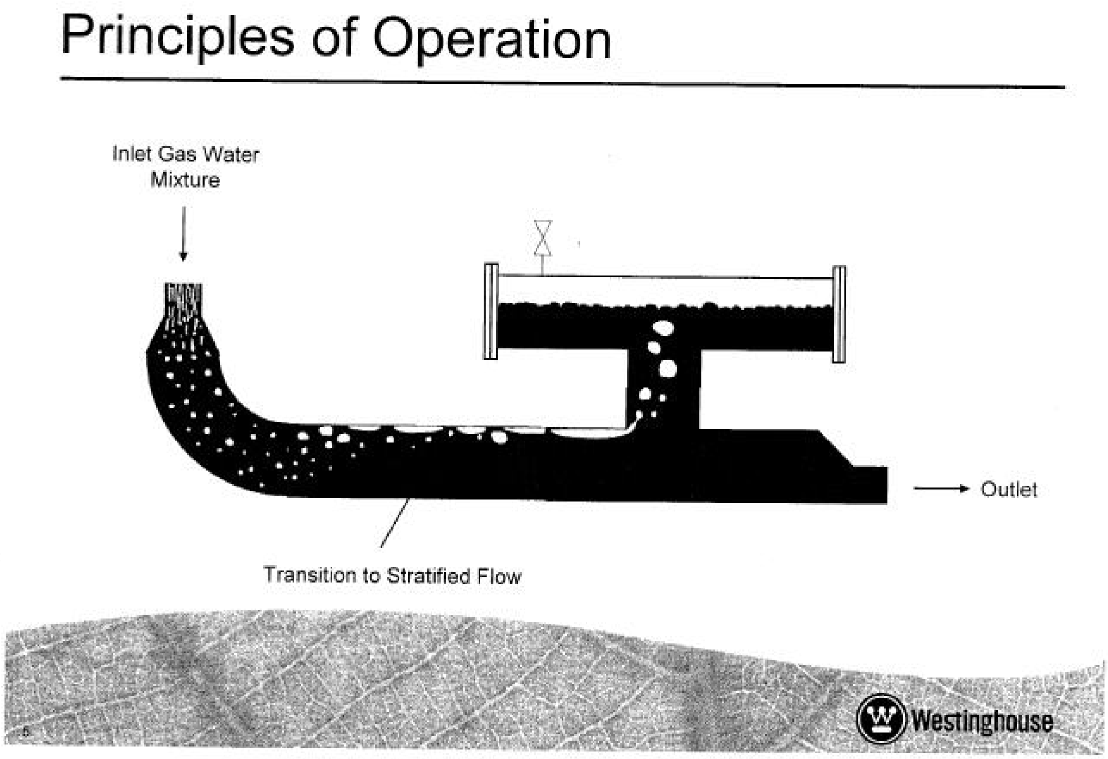
Developed at Diablo Canyon, a large tank is suspended above the high point of the pipe. This system will have seismic concerns, be expensive in implement and requires header space that may not be available in many cases. The system presents no way to measure the voids and must still use a vent to remove the voids.

Generally, if the voids are large enough to require an accumulator of this size, there are other problems within the system which needs to be addressed.

7. Westinghouse Gas Separator

This system is similar to the Suction Void Header, with the added feature of being able to remove gas from flowing liquids by slowing the flow down.

Westinghouse recommends installing a length of **large** diameter pipe to effectively decrease the velocity and allow the voids sufficient time to rise to the surface. The suggested length of this pipe is currently 12 feet. The voids can then be caught in a large holding tank which has a vent on it. At some distance past the tank the diameter of the main transport pipe reduces again.



In many cases, the addition of a 12' section of new, large diameter pipe is not geometrically feasible. If space is available, the cost of the system would then likely exceed $1 million per location. Seismic qualification of the system is likely also be prohibitive.

8. Nuclear Grade Air Trap (NGAT) – by Nuccorp

The NGAT is the only system that offers both void detection and void removal per the requirements of NRC GL08-01, and is also very accurate, with ½" resolution on the indicator, as it can detect volume changes to +/- 27.5 cc. Accuracy of measuring accumulated air/gas is also an NRC concern outlined in GL08-01. If accurate measurements can be made, the NRC has been more lenient in the prior requirements for identification of the constituents of the air/gas (which complicates the elimination of the gases).

The NGAT provides trustworthy, instant and constant visual confirmation of "system full" with no electricity, no math, no laptop computer, no team of technicians, minimal training and a few, if any, modes of failure. The NGAT is a total solution to an existing problem – and not an invitation for the utility to create new problems.

The NGAT is an elegantly simple solution that saves time, money and minimizes personnel radiation exposure.

Conclusion

Based on the above review of known technologies, Nuccorp's Nuclear Grade Air Trap is a cost effective, logical solution to NRC GL08-01 for all existing nuclear plants and new construction.