**Dominion Energy Kewaunee, Inc.**
5000 Dominion Boulevard, Glen Allen, VA 23060

**Dominion**®

October 16, 2009

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

| | |
|---|---|
| Serial No. | 09-636 |
| LIC/JG | R0 |
| Docket No. | 50-305 |
| License No. | DPR-43 |

**DOMINION ENERGY KEWAUNEE, INC.**
**KEWAUNEE POWER STATION**
**RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING NRC GENERIC LETTER 2008-01**

The Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2008-01 (Reference 1) on January 11, 2008. The GL requested that each licensee evaluate the licensing basis, design, testing, and corrective action programs for the Emergency Core Cooling Systems, Residual Heat Removal system, and Containment Spray system, to ensure that gas accumulation is maintained less than the amount that challenges operability of these systems. The GL also requested that appropriate action be taken if conditions adverse to quality are identified.

Dominion Energy Kewaunee (DEK) responded to GL 2008-01 on October 14, 2008 (Reference 2). On July 30, 2009, the NRC staff transmitted a request for additional information (RAI) (Reference 3) to facilitate the staff review of the actions being taken in response to GL 2008-01 at Kewaunee Power Station (KPS). As discussed with the KPS NRC Project Manager on October 1, 2009, the submittal date for this response was extended to October 16, 2009. The RAI questions and associated DEK responses are provided in Attachment 1 to this letter.

If you have any questions regarding this response, please contact Mr. Jack Gadzala at (920) 388-8604.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

COMMONWEALTH OF VIRGINIA )
)
COUNTY OF HENRICO )

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Mr. J. Alan Price, who is Vice President – Nuclear Engineering of Dominion Energy Kewaunee, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 16th day of October, 2009.

My Commission Expires: 4/30/13

Ginger L. Alligood
Notary Public

GINGER L. ALLIGOOD
Notary Public
Commonwealth of Virginia
310847
My Commission Expires Apr 30, 2013

Attachment:

Response to Request for Additional Information: Generic Letter 2008-01

Commitments made in this letter: None

References:

1. NRC Generic Letter (GL) 2008-01, "Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," dated January 11, 2008.
2. Email from Peter S. Tam (NRC) to Jack Gadzala, Thomas Breene and Craig Sly (DEK), "Kewaunee - Draft RAI on Response to GL 2008-01 (TAC MD7847)," dated July 30, 2009.
3. Letter from J. Alan Price (DEK) to Document Control Desk (NRC), "Nine-Month Response to NRC Generic Letter 2008-01, Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," dated October 14, 2008.

cc: Regional Administrator, Region III
U. S. Nuclear Regulatory Commission
2443 Warrenville Road
Suite 210
Lisle, IL 60532-4352

Mr. P. S. Tam
Project Manager
U.S. Nuclear Regulatory Commission
One White Flint North, Mail Stop O8-H4A
11555 Rockville Pike
Rockville, MD 20852-2738

NRC Senior Resident Inspector
Kewaunee Power Station

# ATTACHMENT

## RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION GENERIC LETTER 2008-01

DOMINION ENERGY KEWAUNEE, INC.
KEWAUNEE POWER STATION

# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION KEWAUNEE POWER STATION

Dominion Energy Kewaunee (DEK) responded to GL 2008-01 by letter dated October 14, 2008. On July 30, 2009, the NRC staff transmitted a request for additional information (RAI) to facilitate the staff review of the actions being taken in response to GL 2008-01 at Kewaunee Power Station (KPS).

The RAI questions and associated DEK responses are provided below.

## NRC Question 1

The GL is intended for addressing all modes and all operating conditions, and it is not limited to events and accidents evaluated in the UFSAR. Please confirm that all subject systems are evaluated for all modes and all operating conditions. Justify why CVCS is not included in the subject systems. (Pages 1, 21)

## Response

As stated in the DEK response dated October 14, 2008, the KPS systems that provide the Emergency Core Cooling Systems (ECCS), Decay Heat Removal (DHR) and Containment Spray functions, are the Safety Injection (SI), Residual Heat Removal (RHR), and Internal Containment Spray (ICS) systems. These systems were evaluated with respect to GL 2008-01 for all modes and operating conditions. The KPS Chemical and Volume Control System (CVCS) does not perform any of the system functions described as within scope of the GL. In the DEK response to the GL, the RHR to CVCS interface is discussed (Page 28) as part of the Low Head Safety Injection (LHSI) discharge piping description; however, it is not associated with an ECCS, DHR or Containment Spray function. The following provides further description of the various modes of operation for each of the subject systems, the interface with the CVCS as applicable, and justification for exclusion of CVCS from the GL.

### Residual Heat Removal System (RHR)

The RHR system is in operation during normal plant cooldown, shutdown, and accident conditions when SI has actuated. During normal plant cooldown and shutdown conditions, RHR pump suction is aligned to the RCS hot legs, and flow is directed through the RHR heat exchangers and returned to the B RCS cold leg. RHR discharge is also aligned to CVCS letdown during normal plant cooldown conditions (when the RCS temperature is less than approximately 350°F) to provide the additional flow needed for RCS letdown water purification.

During SI actuation under accident conditions, RHR pump suction is initially aligned to the Refueling Water Storage Tank (RWST) and discharges to the reactor vessel. When the RWST is depleted, RHR suction is re-aligned to Containment Sump B for recirculation. During the re-circulation period, depending on plant conditions, RHR discharge can be aligned to the reactor vessel, SI pump suction, or ICS pump suction.

RHR is operated quarterly for pump and valve testing. During testing, the system is aligned to take suction from the RWST and discharge to the suction of ICS system. The ICS system then discharges back to the RWST and into the SI/RHR suction line.

The KPS evaluation addressed all current RHR system conditions of operation.

Safety Injection System (SI)

The SI system is in operation during accident conditions when safety injection has actuated. Upon actuation, SI is initially aligned to take suction from the RWST and discharge to the A and B RCS cold legs. When the RWST is depleted, the SI system suction is re-aligned to the discharge of the RHR system following Containment Sump Recirculation alignment.

SI is operated quarterly for pump and valve testing. During testing, the system is aligned to take suction from the RWST and discharge back to the RWST.

The KPS evaluation addressed all current SI system conditions of operation.

Internal Containment Spray System (ICS)

The ICS system is in operation during accident conditions when ICS actuation conditions are met. Upon actuation, ICS is initially aligned to take suction from the RWST and discharge to the containment spray ring headers. When the RWST is depleted, the ICS system is no longer needed for design basis accidents. However, the suction for the ICS pumps can be aligned to the discharge of the RHR system following Containment Sump Recirculation alignment, if desired.

ICS is operated quarterly for pump and valve testing. During testing, the system is aligned to take suction from the RWST and discharge back to the RWST and the SI/RHR suction line. As previously stated, during RHR pump and valve testing, ICS suction is aligned to RHR discharge to provide RHR a flow path greater than that of minimum recirculation.

The KPS evaluation addressed all current ICS system conditions of operation.

Chemical Volume and Control System (CVCS)

The CVCS provides the capabilities for RCS inventory control, boric acid injection, chemical additions for corrosion control, reactor cleanup and degasification, reactor coolant makeup, reprocessing of RCS letdown water, and reactor coolant pump (RCP) seal water injection.

Charging and letdown are employed to maintain a programmed water level in the pressurizer during all phases of plant operation. This is achieved by a continuous feed and bleed process. The feed rate is automatically controlled by the water level in the pressurizer, which provides a control signal for regulating the speed of the charging pumps. The bleed rate can be chosen to suit various plant operational requirements by the selection of combinations of restricting orifices in the letdown flow path.

During normal plant operation, letdown flow is established by withdrawing reactor coolant from the Loop B intermediate leg. A series of temperature and pressure reductions occur before the letdown flows through the CVCS demineralizers where soluble corrosion products, fission products, and/or boron are removed, depending upon the demineralizer lineup. Letdown then normally flows to the Volume Control Tank (VCT) or overflows to the CVCS Holdup Tanks.

The charging pumps normally take suction from the VCT and return cooled purified water to the Loop B cold leg via the charging header. The charging pumps also provide seal water injection to the RCP controlled leakage seals. Some of this water flows through the RCP labyrinth seals and into the RCS. Most of the remaining seal injection water returns to the VCT after passing through the RCP controlled leakage seals.

During normal operation, letdown flow equals charging flow plus the quantity of water injected through the RCP labyrinth seals. If for some reason the normal letdown flow path is inoperable, water injected through the RCP labyrinth seal is returned to the VCT via the excess letdown portion of the CVCS.

Makeup water to the RCS is provided by the CVCS. Reactor makeup water provides makeup when it is desired to reduce the concentration of boric acid in the RCS. When it is desired to increase the boron concentration of the RCS, the boric acid tanks provide concentrated boric acid for makeup. Reactor makeup water and concentrated boric acid are blended to match the current RCS boron concentration for normal makeup of plant leakage. The RWST supplies borated water for emergency makeup.

The CVCS is used to add the following chemicals to the RCS:

- Lithium hydroxide is used to control RCS pH.
- Hydrazine is used as an oxygen scavenging agent during plant startup from cold shutdown conditions.
- Hydrogen peroxide is added to remove "crud" prior to refueling.

These chemicals are added to the chemical mixing tank and are directed to the suction of the charging pumps.

The CVCS is used during all phases of normal power operation for reactivity control, RCS volume control, RCP seal injection, and RCS chemistry control.

During plant startup, the CVCS is used to support plant heat up and reactor startup. The CVCS provides reactivity control by adjusting the concentration of boric acid in the RCS, RCS volume control, RCP seal injection, RCS chemistry control, and RCS pressure control when the pressurizer is water solid.

During plant shutdown, the CVCS is used for reactivity control to ensure adequate shutdown margin is maintained, for RCS volume control, RCP seal injection and RCS chemistry control. The CVCS provides RCS pressure control when the pressurizer is water solid. During plant shutdown when RHR is operating, a portion of the RHR discharge can be aligned to CVCS letdown. The RHR to CVCS alignment provides RCS purification capability via the CVCS demineralizers when RCS pressure is too low to provide adequate flow through the CVCS orifice valves. Also, the RHR to CVCS alignment provides adequate letdown flow for continued CVCS operation when RCS pressure is low to allow fine RCS level control using the CVCS. The CVCS is used to drain, fill and pressurize the RCS. The VCT gas blanket can be changed from hydrogen to nitrogen prior to refueling.

In the event of RCS leakage, the CVCS increases make-up to maintain RCS inventory. The CVCS is used to adjust reactivity in response to an inadvertent reactivity change and provides a boron injection path per TS 3.2.a. In the event of failed fuel, the CVCS reduces RCS activity levels by removing fission products.

In the event SI is actuated, the charging pumps receive an auto inhibit signal that stops all running charging pumps. Following Step 10 of the SI sequence, the charging pumps may be manually restarted. Also, CVCS letdown valves receive a containment isolation signal during an SI.

Based on the KPS CVCS design and description of the CVCS functions, the CVCS does not perform an ECCS, DHR, or Containment Spray function. Therefore, the KPS CVCS is not within scope of GL 2008-01.

**NRC Question 2**

Please provide a summary of Technical Requirements Manual/ Technical Requirements Bases section similar to NUREG -1431 SR 3.5.2.3 and LCO 3.6.6. Confirm that these TRM requirements are currently implemented and provide the results of this approach for the subject systems. (Page 8)

**Response**

KPS Technical Requirements Manual (TRM), Section 3.5.6, "Emergency Core Cooling System and Containment Spray System Surveillance," became effective on January 29, 2009. TRM 3.5.6 contains administrative limiting conditions for operation, applicability, actions and surveillance requirements associated with monitoring for gas accumulation within the SI, RHR, and ICS systems.

Administrative Limiting Condition for Operation (ACLO) 3.5.6 requires that two Safety Injection (SI), Residual Heat Removal (RHR) and Containment Spray (CS) trains shall be sufficiently full of water to be OPERABLE when the reactor is critical, except when performing LOW POWER PHYSICS TESTS. Also, one train may be inoperable for up to 72 hours for recovery from an inadvertent trip per TS 3.3.b.2 for the SI and RHR systems and TS 3.3.c.1.A.3 for the CS system.

TRM 3.5.6 specifies the following actions:

A. If one train of any system is inoperable, immediately apply the applicable Technical Specification (TS) requirement, TS 3.3.b.2 for SI system, TS 3.3.b.2 for RHR system, or TS 3.3.c.1.A.3(ii) for CS system.

B. If two trains of any system are inoperable, immediately apply TS 3.0.c, and TS 3.1.a.2 if the condition applies to RHR.

C. If the required action and associated completion time of Condition A are not met, immediately apply the applicable Technical Specification (TS) requirement, TS 3.3.b.2.A. for SI system, TS 3.3.b.2.B for RHR system, or TS 3.3.c.1.A.3 for CS system.

TRM 3.5.6 Administrative Surveillance Requirement (ASR) 3.5.6.1 requires verification that the SI, RHR and CS piping is sufficiently full of water at a frequency of 92 days.

The ECCS and CS System pumps are normally in a standby non-operating mode. As such, some flow path piping has the potential to develop pockets of entrained gases. Plant operating experience and analysis has shown that after proper system filling (following maintenance or refueling outages), some entrained non-condensable gases remain. These gases will form small voids, which remain stable in the system in both normal and transient operation. Mechanisms postulated to increase the void size are gradual in nature, and the system is operated in accordance with procedures to preclude growth in these voids. In addition, other mechanisms, such as valve seat leakage into the stagnant systems from other gas-laden sources, system fluid velocities and physical geometries can cause a gradual increase in the size of gas voids.

The system is sufficiently full of water when the voids and pockets of entrained gases in the ECCS and CS piping are small enough in size and number to not interfere with the proper operation of the ECCS and CS systems. Verification that the ECCS and CS piping is sufficiently full of water can be performed by venting the necessary accessible high point ECCS and CS vents, through the use of non-destructive evaluation (NDE), or by using other engineering-justified means.

Maintaining the piping and components from the ECCS pump suction sources to the final isolation valve before connection to the RCS sufficiently full of water ensures that the system will perform properly, injecting its full capacity into the RCS upon demand. This will also prevent pump cavitation and air binding, water hammer, and pumping of excess non-condensable gas (e.g., air, nitrogen, or hydrogen) into the reactor vessel following an SI signal or during shutdown cooling.

Maintaining the piping and components from the CS pump suction sources to the discharge to containment sufficiently full of water ensures that the system will perform properly, injecting its full capacity into containment upon demand.

The 92-day frequency for verification takes into consideration the gradual nature of the postulated gas accumulation mechanisms, including the system design and operating practices.

Repetitive tasks have been established to implement the TRM monitoring requirements. The selected monitoring locations are based on:

- Accessibility for verification during at power operations.
- Proximity to potential gas intrusion sources.
- System configurations where gas is postulated to potentially accumulate.

The scope of the current monitoring program includes quarterly monitoring at selected portions of both trains of SI suction and discharge piping and both trains of RHR suction and discharge piping. The only gas intrusion mechanism identified for the ICS system is performance of RHR system pump testing (which cross-connects to the ICS system) when gas is present in the RHR piping. Therefore, monitoring each train of ICS is only performed after testing of the associated RHR train with gas known to be present in RHR.

The locations and implementation of the current monitoring locations are specified in the following procedures and work order system repetitive tasks:

- ER-KW-NSP-RHR-001, "Monitoring RHR Cooldown Piping for Gas Accumulation (RE89381/PM34-578)"

- ER-KW-NSP-SI-001A, "Monitoring SI Containment Penetrations and SI Pump A (RE89379/PM33-622)"
- ER-KW-NSP-SI-001B, "Monitoring SI Pump B Discharge Piping for Gas Accumulation (RE90457/PM33-626)"
- ER-KW-NSP-SI-002, "Monitoring of SI Common Train Piping for Gas Accumulation (RE89380/PM33-623)"
- SP-34-099A, "Train A RHR Pump and Valve Test – IST (RE303416/PM34-537)"
- SP-34-099B, "Train B RHR Pump and Valve Test – IST (RE306480/PM34-539)"

Performance of these surveillance procedures confirms that the subject systems remained sufficiently full of water to perform their required functions. Monitoring of the gas volumes reported in the original nine-month response to GL 2008-01 (page 18), has, for the most part, found that the gas volumes are stable. The major exception was a void located in the RHR Train A mini-flow recirculation branch line, where gas continued to accumulate. The monitoring frequency of this line has been increased at this location to ensure the gas volume does not exceed the operability criterion (see additional discussion in response to Question 6). The gas at this location is swept each quarter during inservice testing (IST) of the RHR pump. Therefore, if gas was present, additional ultrasonic testing (UT) would be performed after the pump test to ensure any new gas accumulations would be located and evaluated. The additionally specified UT includes locations in the RHR, SI, and ICS systems because these systems are cross-connected during the test. This process has led to identification of small gas accumulations in the SI/RHR common suction piping and ICS discharge piping. Modifications (to add vent valves to allow these gas accumulations to be removed) are either completed, in progress, or planned for the fall 2009 refueling outage.

Because of the inability to access some locations in the LHSI piping in the containment for periodic UT, pressure pulse testing has been incorporated into the quarterly RHR pump tests. More discussion on this test (with results for Train A, which is known to have voids present) is provided in the response to Question 3. Performance of this quarterly test provides reasonable assurance that total voids in the RHR pump discharge piping are not excessive.

Further validation of the pulse testing results was confirmed by UT following plant entry into hot shutdown during the fall 2009 refueling outage. UT was performed in the areas of the LHSI and HHSI systems that are inaccessible during power operation. It was confirmed that gas had not collected in the HHSI piping during the current operating cycle. However, a gas void of approximately 1.13 $ft^3$ was found in the RHR (LHSI) train B piping in containment. It was determined that this void did not affect system operability. A plant modification is planned during the fall 2009 refueling outage to install a vent valve at this location. The vent valve will allow venting during power operation.

**NRC Question 3**

Please summarize the methodology and applicable limits for gas accumulation in the discharge piping of the low head safety injection (RHR) and ICS systems for Kewaunee. (Page 13)

**Response**

RHR (LHSI) Pump Discharge Side Evaluation

For a discussion of the actions associated with voids in the RHR discharge piping see the Response to Question 7, item 8.

To assist the industry in GL 2008-01 evaluations, Fauske & Associates was commissioned to develop a methodology that can be used to evaluate conservative peak pressures and maximum transient gas-water hammer forces in piping due to pump start transients with gas accumulations in the discharge piping of pumped piping systems (Reference 6). The method allows determination of conservative maximum peak gas-water hammer pressures for a given gas void volume in the discharge piping and the maximum peak axial force imbalances as a function of the piping highpoint length and the gas void volume.

The Fauske methodology was utilized to calculate conservative maximum peak pressures and maximum piping forces for various gas void volumes in the KPS RHR system discharge piping. The results of this parametric study were used to develop a preliminary acceptance criterion for the total gas void that might be found in the RHR discharge piping (LHSI). This evaluation is documented in Reference 10.

First, the void size that would cause the system relief valves to lift at 600 psig was computed. In the portion of the system using 8-inch piping, this void size was found to be about 2.2 $ft^3$. For the 6-inch piping, the 600 psig pressure would occur with a void size of about 0.4 $ft^3$. For the 4-inch piping, the 600 psig pressure would occur with a void size of about 0.14 $ft^3$. The effect of a 0.087 $ft^3$ void in the "A" Train 2-inch mini-flow recirculation line was evaluated using the Fauske methodology; the result was a peak force of 12 $lb_f$ and a peak piping pressure of 560 psia. The force of the collapse of the void was judged by the evaluations in KPS operability determination (OD) 198 (Reference 9) to be insignificant on the integrity of the piping and supports; and, the peak pressures remain below the relief valve set point and design pressure of the system.

Similarly, for initial evaluations of the voids found in the letdown cross-connect line and the CVCS cross-connect line, the Fauske analysis method was applied and produced acceptable results (as documented in earlier revisions of OD 198). However, the Fauske method was developed for gas voids in the main pump discharge pipe of a single diameter and is not directly applicable to analysis of multiple voids in various size lines and in branch lines from the main piping header. Because of the complex geometry of the mini-flow recirculation line, the letdown cross-connect line, and the spent fuel pool (SFP) cooling cross-connect line, the results of the Fauske method are judged to be very conservative.

To determine the effect of larger voids, additional analysis was performed. For RHR Train B, a void of 5 $ft^3$ was assumed to exist in the 6-inch pipe identified as the longest horizontal run of pipe in the system. This location was selected because the small diameter pipe and long length maximizes the effect on peak fluid pressure and unbalanced forces on the piping. This bounds conditions for either RHR train.

The initial assumed void size of 5 $ft^3$ is at normal system pressure in the standby condition (i.e., at RWST static head pressure). The Fauske method analysis for 5 $ft^3$ in the 6-inch RHR discharge piping determined a conservative resultant peak pressure of approximately 2100 psia upon starting the RHR pump. This peak pressure exceeds the system design pressure and relief valve setpoint of 600 psig, but is within the design capacity of the pipe. The Fauske method analysis also determined a conservative maximum peak transient unbalanced force (2070 lbs) due to the resulting gas-water hammer on the RHR discharge piping system with the 5 $ft^3$ gas void. The DEK engineering staff evaluated these piping system transient loads and concluded that the loads have an insignificant impact on the pipe stress analysis or pipe support capability (Reference 9). The DEK engineering staff also evaluated the impact on RHR system function with a postulated relief valve lift resulting from the 2100 psia pressure peak during the transient and concluded that the RHR system would have reasonable assurance of performing its safety functions following this assumed transient (Reference 9).

Following the preliminary assessment of the RHR system voids found during the September 8, 2008 UT inspections (in OD 198, Revision 2), Reference 1 was developed. As discussed above, Reference 1 concluded that the complete analysis of transient peak pressures and forces when multiple gas voids are present at various locations would require a detailed transient analysis. Further, since UT cannot be performed at some inaccessible locations, there may be additional voids present that have not been located. Therefore, in addition to UT at accessible locations, Reference 1 recommended performance of a pressure pulse test during each quarterly RHR IST to ensure that any potential gas void accumulation in the RHR discharge piping is of small enough volume to result in a pump start transient peak pressure of less than 600 psig, and thus preclude the potential for relief valve lifting.

Pressure pulse testing has been incorporated into the quarterly IST performed per SP-34-099A and B. The results of the tests performed for RHR Train A in January, April, and July 2009 are shown in Figures 1, 2, and 3 below.

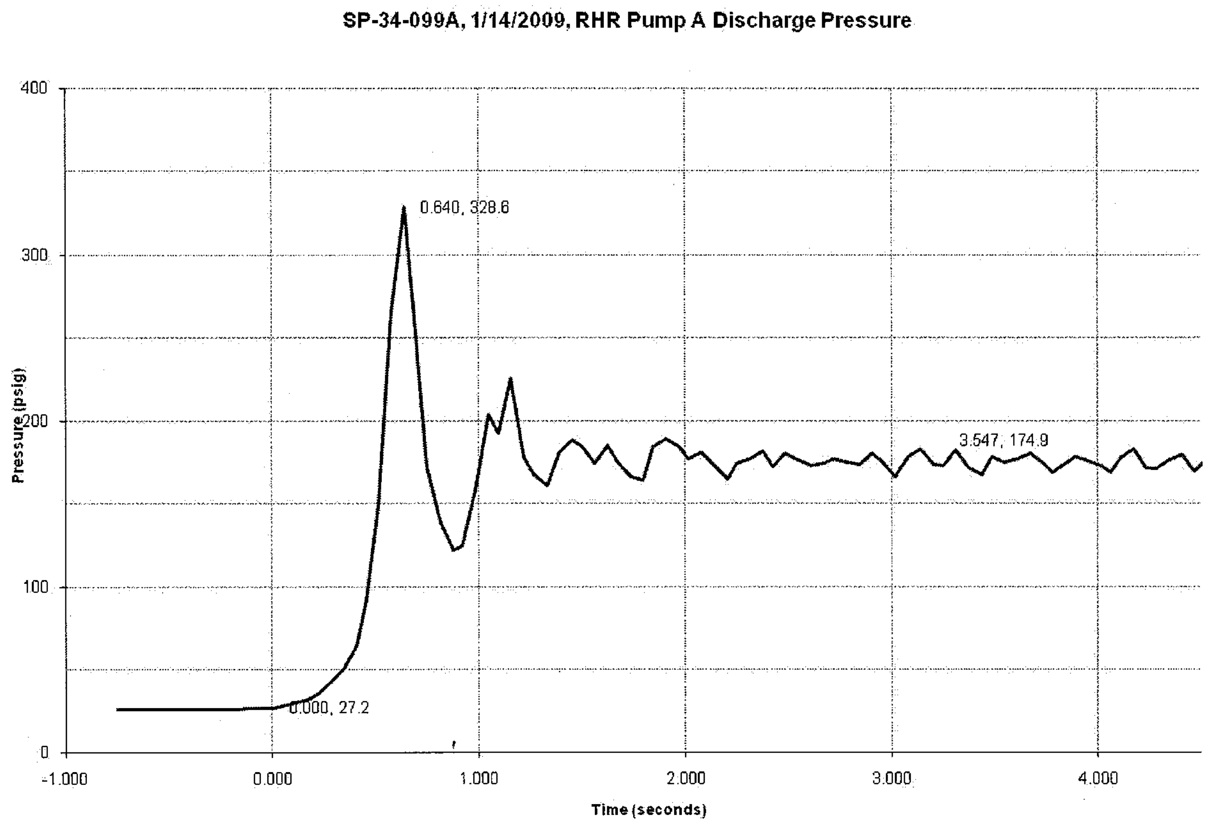


**Figure 1, Pulse Test 1/14/09, Known Void Total = 0.494 $ft^3$**

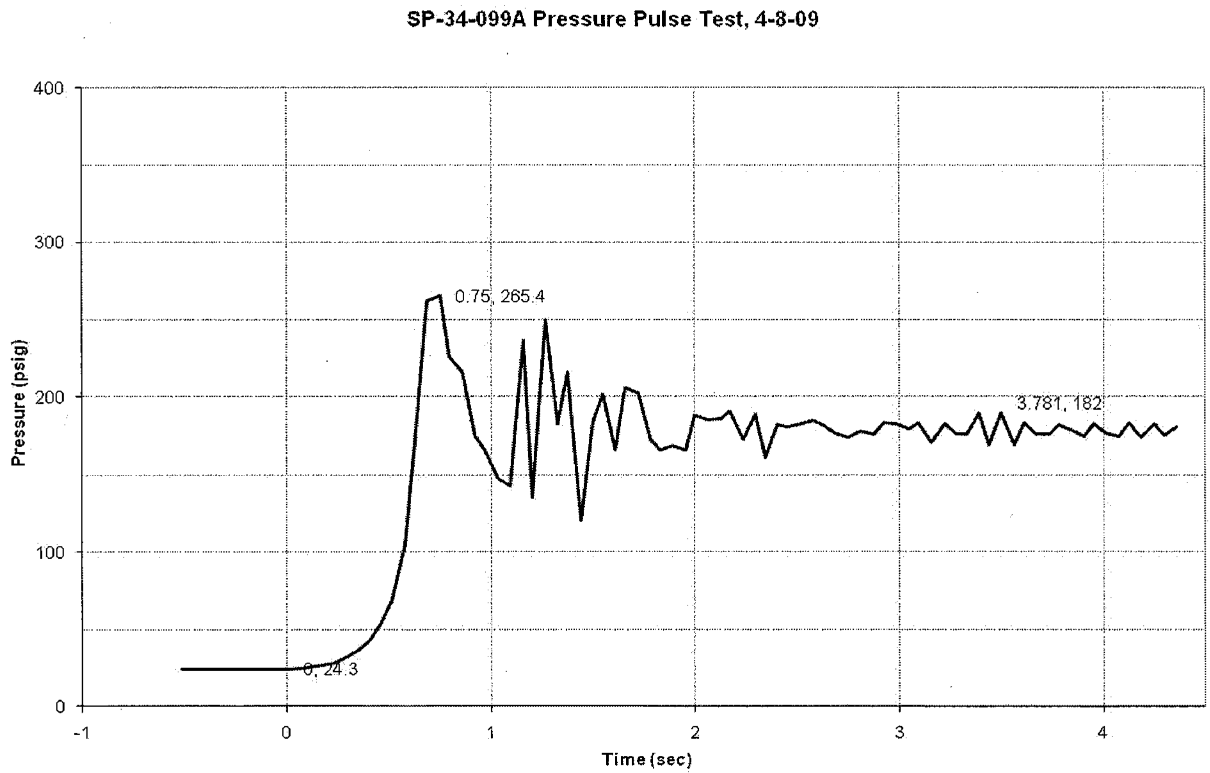


**Figure 2, Pulse Test, 4/8/09, Known Void Total = 0.747 ft$^3$**

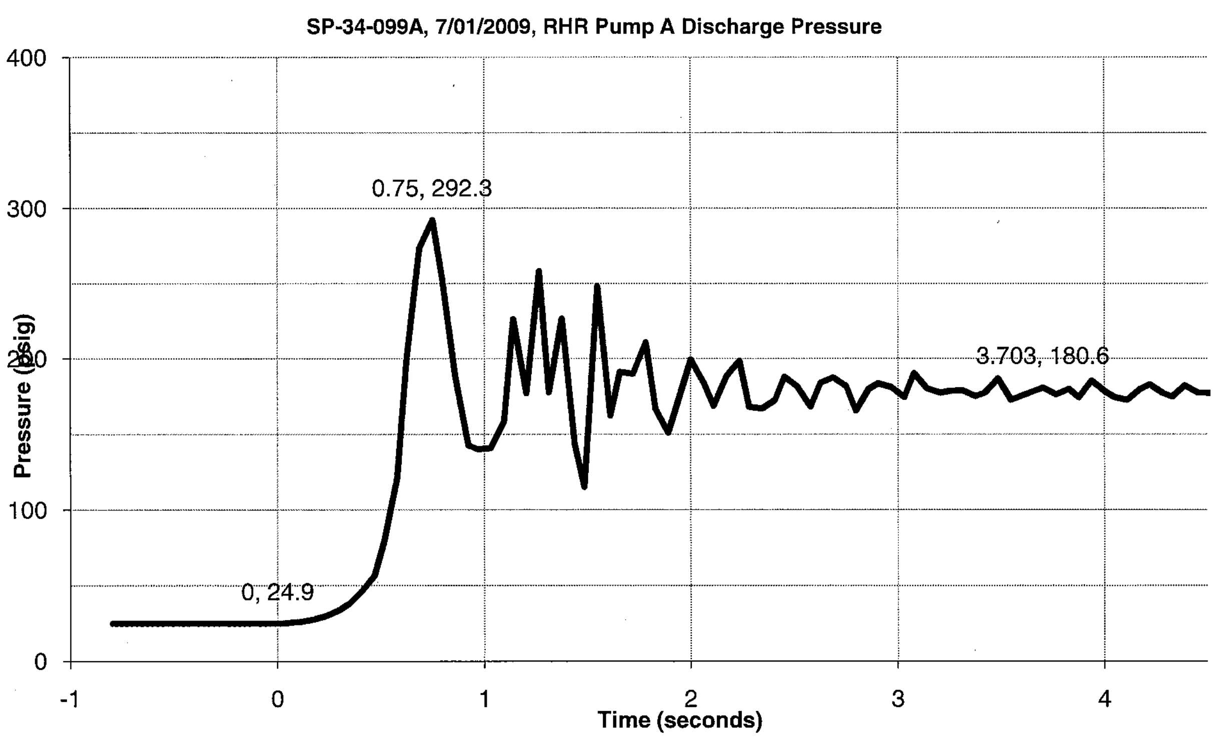


**Figure 3, Pulse Test, 7/10/09, Known Void Total = 0.494 ft$^3$**

The results of these pulse tests confirm that the peak pressures predicted by the Fauske method are extremely conservative. The Fauske method predicted a peak pressure of 560 psia (545 psig) with a 0.087 $ft^3$ void in the mini-flow recirculation piping. During the pulse test on January 14, 2009, this size void was present, along with suspected voids of 0.098 $ft^3$ in the letdown cross-connect line and 0.309 $ft^3$ in the SFP cooling cross-connect line. The measured peak pressure was only 343.3 psia (328.6 psig). On April 8, 2009, the void in the mini-flow recirculation line had extended into the main RHR header with a size of 0.34 $ft^3$. The voids in the letdown and SFP cooling lines were also assumed to still have been present, for a total void size of 0.747 $ft^3$. The resulting measured peak pressure was 280.1 psia (265.4 psig). Note that the true peak pressure was not captured due to the sampling frequency of the instrumentation. However, the general characteristics of the pressure response were similar to the pulse test on January 14, 2009, giving confidence that the peak pressure was similar. Testing on July 10, 2009 produced results similar to the previous tests.

Additional insight into the expected response of the KPS RHR (LHSI) system to a pump start with gas present in the discharge piping can be gained from review of detailed analysis performed for the LHSI system at the North Anna Power Station (References 10 and 11). This analysis is summarized in Reference 12. It states that:

> *"Two independent consultants, Stoner and Martin, were hired to perform the transient analyses on the LHSI system, and both consultants reached the same general conclusions. Both consultants performed sensitivity analyses to assess the effect of air quantity and its location in the worst case configuration of the LHSI branch line RCS cold leg isolation check valves closed against RCS pressure and the LHSI pump discharge to HHSI pump suction piggy back line isolation MOVs closed during a LHSI pump startup transient. Stoner's sensitivity analyses showed that peak pressures in the LHSI system increase with increasing air volume up to about 6 $ft^3$ and the maximum peak pressures for an air volume of 6 $ft^3$ may approach 600 psig. Stoner's analysis predicted that for an air volume of 4.05 $ft^3$ in the LHSI discharge piping, the maximum peak pressure at the relief valve would be approximately 370 psig. This analysis accurately duplicated field test measurements taken during LHSI pump testing. Both consultants' evaluations concluded that peak pressures at the pump discharge and in the LHSI pump discharge header will remain below 220 psig to prevent relief valve lifting for air volumes of 0.75 $ft^3$ and that the amount of air, rather than its location, is the most critical parameter."*

Reference 12 also summarizes the Reference 10 and 11 transient analysis studies of gas volumes greater than 6 $ft^3$ in the North Anna LHSI discharge piping. The pump start transient discharge pressure reaches its peak at approximately pump run-up time (typically in approximately 1 second) for gas volumes of 6 $ft^3$ or less. The transient peak pressure will continue to increase to a maximum as the gas volume increases, then at even larger gas volumes, the peak will begin to decrease and start to occur later in the transient. At even larger still gas volumes (on the order of 20 $ft^3$) the pressure will not peak, but rather will ramp up to its steady state value over a relatively longer period of time (typically 5 – 7 seconds).

The configuration of the North Anna LHSI system and LHSI pumps is similar to that of the KPS RHR (LHSI) system and pumps. Therefore, the results at KPS would be expected to be similar for void sizes of about 6 $ft^3$ (i.e., pump start transient discharge peak pressure pulses near 600 psig occurring at approximately pump run-up time).

In addition to the effects of a pressure pulse, other effects of gas accumulation in the discharge piping must be considered. The PWROG contracted Westinghouse to qualitatively evaluate the impact of non-condensable gases entering the RCS on the post-accident core cooling functions of ECCS (Reference 3). This evaluation assumed that 5 $ft^3$ of non-condensable gas at 400 psia was present in the high head safety injection (HHSI) discharge piping concurrent with 5 $ft^3$ of non-condensable gas at 100 psia in the LHSI discharge piping. The qualitative evaluation concluded that these quantities of gas would not prevent the ECCS from performing its core cooling function. Five cubic feet of gas at 100 psia is equivalent to 5 x (100 psia / 38.3 psia) = 13.1 $ft^3$ at 38.3 psia, the initial pressure of the void volume due to RWST head. KPS has established the limit for gas in RHR discharge piping at 5 $ft^3$ at RWST static head. Since this is much less than the amount shown by Reference 3 to be acceptable, the impact on core cooling from RHR discharge piping void volumes of less than or equal to 5 $ft^3$ would be insignificant.

The presence of voids in the RHR discharge line must also be evaluated for impact on the time delay of SI injection. A void of 5.0 $ft^3$ at pump discharge pressure has been evaluated to result in an acceptable increase in the time delay before delivery of LHSI. Five cubic feet corresponds to approximately 42 gallons. At a 2000 gpm nominal flow rate for an RHR pump, the additional time required to fill 42 gallons is 1.3 seconds. The pump has a ramp-up time of approximately 1 second. Therefore, a conservative assumption is that the fill time is twice 1.3 seconds (i.e., 2.6 seconds). The KPS safety analyses (USAR 14.3.3.3.5) assumes the LHSI pumps begin injecting cold ECCS water into the upper plenum at approximately 39 seconds after an SI signal (assuming a delay of 35 seconds for the loss of offsite power case). A review of RHR pump motor test results indicates the pumps come up to speed and begin delivering flow in 1 to 2 seconds. Therefore, an additional 2.6 seconds for flow initiation would not delay flow initiation beyond that assumed in the safety analysis. Under actual conditions, the emergency diesel generator is ready to load in 10 seconds and RHR pumps start in step 2 of the SI sequence (in 9 to 11 seconds). Thus, there is significant margin available when accounting for the time delay attributed to the existence of the largest acceptable void in the RHR discharge piping. As such, the impact of the acceptable voids given by the Fauske method results, or found acceptable by a successful pressure pulse test, would be within the margins of LHSI injection time delay.

In conclusion, while the Fauske methodology can be used for conservative preliminary acceptance of known gas void volumes, the acceptance criteria for total gas void volume in the RHR discharge piping is defined by successful performance of pressure pulse testing of the RHR discharge system, with a peak pressure of less than 600 psig, with the peak occurring in approximately one second.

Internal Containment Spray Pumps Discharge Side Evaluation

Flow from each internal containment spray (ICS) pump 6-inch Schedule 40 discharge piping splits into two lines and passes through a pair of normally closed motor operated valves (MOVs) in parallel (ICS-5A/B and ICS-6A/B), then recombines into one line and continues on to the containment penetration. A pair of check valves (ICS-8A/B and ICS-9A/B), one outside and one inside containment, perform the containment isolation function. Each train continues on to a pair of spray ring headers at the top of containment. When the ICS system is in standby during normal power operation, the spray rings and their respective headers are nominally dry. Any water accumulation in this normally dry section of piping (e.g., due to boundary valve leakage) would not adversely impact system operation. Upon a high containment pressure signal and subsequent pump start, any remaining air in the initially dry portion of the ICS pump discharge piping will be displaced by the flow from the pump. The motive force of the pump will continue to move the water up the spray ring riser and to the spray ring displacing the air into the containment atmosphere via the spray ring nozzles near the top of the containment.

The portion of the ICS pump discharge piping upstream of the normally closed pump discharge isolation valves is procedurally filled and vented following drain-down after maintenance or during outages. Any gas potentially remaining in this piping after filling and venting would be removed by the flow sweep that occurs during full flow quarterly IST of the ICS pumps. The quarterly IST opens the ICS-5A/B and 6A/B isolation MOVs and closes the normally open downstream ICS-7A/B isolation valves. Small quantities of air could potentially remain in the local high point loops downstream of the normally closed isolation MOVs (ICS-5A/B and 6A/B).

Even though the discharge piping is stagnant during normal operation with potential for ambient temperature changes, air would not degas from solution in the non-flowing discharge line because the head pressure from the RWST produces a greater air solubility effect on the water in the discharge line (which is air saturated at atmospheric pressure in the RWST) than the dissolution effect of the potential increase of ambient temperature of the water in the non-flowing line (analysis performed in Attachment 2 of Technical Report ME-0181(Reference 1)). Furthermore, there are no external sources that can introduce gas into the ICS system on either the pump suction or discharge side, except for air transported into the ICS system from the RHR system during quarterly RHR pump testing or maintenance activities. The flow rates during the RHR testing are high enough to sweep any gas completely through the ICS pump suction and discharge piping into the ICS header. Consequently, the only gas that can be in the normally full discharge piping (upstream of the normal water level elevation in the open piping) would be downstream of the normally closed pump discharge isolation valves as a small quantity of air that could potentially remain in the local high point loops following the fill procedure prior to returning the system to service after a drain-down and after the quarterly IST performance.

Analysis using the Froude Number ($N_{Fr}$) relative to the system velocities in the discharge piping during accident conditions shows that the minimum ICS flow to the spray ring (1,170 gpm) produces a minimum velocity of approximately 12.98 fps in the 6-inch Schedule 40S discharge piping and spray ring piping, resulting in a minimum $N_{Fr} = 3.2$. The ICS pump discharge piping flow values are high enough (minimum $N_{Fr} = 3.2$, which is much greater than 1.0) to ensure that the initial air in the discharge piping, spray ring risers, and spray rings will be transported out of the system, discharging through the spray nozzles.

Therefore, upon initiation of ICS flow, any air initially present in the discharge piping will be transported out of the system through the spray nozzles, thus ensuring that the piping is totally full during fulfillment of the ICS safety function. The discharge piping fill time delay is accounted for in the accident analyses. In addition, the KPS USAR states that discharge system piping and pipe supports are designed for the loads generated by the filling process.

In Reference 2, Fauske and Associates analyzed the scenarios of transient loads produced by filling a containment spray ring riser and header which are open to the containment atmosphere via the spray nozzles, and the transient loads related to a gas void in the discharge header downstream of the discharge isolation MOVs and upstream of the spray ring riser. Evaluations of a typical containment spray ring header showed that: 1) the net force resulting from the pressurization of the spray ring header during the filling transient is much less than 10% of the dead weight of the full header, and; 2) the transient can be assumed to be well within the margin of the piping hangers. Reference 2 also concluded that, "It is expected that all plants will calculate that the force imbalance (due to the filling transient) is well within the acceptance criteria." The dimensions of the Kewaunee spray ring header and the ICS flow rate are similar to those used in the Reference 2 generic analysis. Therefore, it can be concluded by similarity to the Reference 2 generic analysis that the fill loads of the Kewaunee ICS spray ring header piping are bounded by the normal operating loads for the piping.

Reference 2 also evaluated the potential for transient piping loads assuming gas accumulation in the discharge header downstream of the discharge isolation MOVs (ICS-5A, 5B, 6A, & 6B) and upstream of the spray ring riser. Reference 2 concluded that all of the gas volume in the horizontal piping would be swept along with the water flow once the Froude number in the pipe approaches 0.54. For 6.065-inch ID pipe, a flow rate of approximately 196 gpm equates to a Froude number of 0.54. Since the minimum ICS flow rate is 1,170 gpm, the potential for compressing a gas void volume by the ICS pump discharge flow could only occur for a brief time period early in the development of the spray filling process when the flow rate is less than 196 gpm. Note also that partial sweeping of the gas volume in the horizontal piping high points would begin when the Froude number reaches approximately 0.3. Consequently, as the ICS flow initiates and increases after the pump starts and MOV opens, any gas volume in the piping would quickly begin to break up and mix in the flowing water and be swept into the riser and out the spray nozzles. Engineering judgment and experience indicate that gas accumulation in the discharge header downstream of the discharge isolation MOVs and upstream of the spray ring riser would result in essentially insignificant transient loads during ICS flow initiation. However, a conservative evaluation using the Reference 2 methodology is given below for gas accumulation impact on the ICS discharge header downstream of the isolation MOVs and upstream of the spray ring riser.

Reference 2 developed a simplified formula for the compression rate of the gas volume after flow initiation (ICS pump start and discharge MOV opening). The model is based on the compression of a stationary gas volume occupying the entire cross-section of the piping:

$dp/dt = -n \times (p_{avg} / V_{gas}) \times Q$, where;

$n$ = polytropic gas constant = 1.4

$p_{avg}$ = average pressure of the gas during the pressurization event = average of initial pressure of the gas volume and the final pressure of the gas volume. Initial pressure of the gas volume is assumed to be the pressure resulting from a full RWST (approximately 44 psia). The final pressure of the gas volume is assumed to be the ICS pump discharge pressure at 400 gpm (approximately 255 psid + 44 psia = 299 psia). Thus, for this evaluation $p_{avg}$ = 171.5 psia.

$V_{gas}$ = initial gas volume

$Q$ = water filling rate causing the gas compression (assume 196 gpm or 0.44 $ft^3$ / sec for this evaluation).

The Reference 2 methodology then determines the force imbalance in the piping header by determining the differential pressure from multiplying the compression rate by the propagation interval:

$\Delta p = dp/dt \times \Delta t$, where;

$\Delta t = L / c_w$, and

$L$ = length of the piping run from the pump discharge to the gas void,

$c_w$ = speed of sound in water = approximately 4,500 ft/sec,

Substituting results in the equation:

$\Delta p / L = dp/dt / c_w = -n \times (p_{avg} / V_{gas}) \times Q / c_w$.

The imbalanced force is then determined by:

$F = \Delta p \times A$, where;

$A$ = the cross-sectional area of the piping = 28.98 $in^2$ for 6.065-inch ID pipe, Dividing by L and substituting results in the equation:

$$F/L = \Delta p / L \times A = -n \times p_{avg} / V_{gas} \times Q / c_w \times A .$$

The acceptance criteria for gas water hammer transient force in Reference 2 is 10% of the dead weight load of the piping section. The dead weight load per foot of the 6.065-inch ID ICS discharge piping full of water is the weight of water in the piping per foot (12.51 lb/ft) plus the weight of the piping per foot (18.97 lb/ft) plus 10% to account for components such as fittings and valves. Consequently, the assumed maximum acceptable imbalanced force per foot of piping for a gas water hammer transient in this ICS discharge piping is 34.6 lb/ft. Thus, maximum acceptable F/L = -34.6 lb/ft.

By solving the above equation for $V_{gas}$, the gas volume at any location in the ICS discharge piping that would result in the maximum acceptable F/L can be determined.

$$V_{gas} = -n \times p_{avg} \times Q / c_w \times A / (\text{max. acceptable } F/L) = -1.4 \times 171.5 \times 0.44 / 4{,}500 \times 28.98 / -34.6 = 0.01966 \text{ ft}^3 = 34 \text{ in}^3.$$

The simplified equations predict that larger gas volumes result in lower transient piping loadings. Therefore, 34 in$^3$ is the lower limit of gas volume in the ICS discharge header upstream of the spray riser that will ensure acceptably low transient piping loadings. However, 34 in$^3$ (approximately 0.02 ft$^3$) is a very small gas volume in a 6-inch pipe. For example, the volume would be equivalent to just slightly more than a 1 inch long slice of the piping cross-section, which has an area of 28.98 in$^2$. The compressed gas volume should also be considered. The compression ratio is: $p_{final} / p_{initial}$ = 299 psia / 44 psia = 6.8. Therefore, the compressed volume would only be equivalent to an approximately 1/6-inch long slice of the piping cross-section.

The Reference 2 methodology and resulting equations are based on compression of a stationary gas volume in the piping cross section by the water flow. Following flow initiation, flow through an open pipe at sufficiently high Froude numbers almost immediately begins to transport the gas volume with the flow in the ICS discharge piping and would not allow gas volumes of these small sizes to form into a stationary volume that would be large enough to cover the entire cross-section of the pipe. Therefore, it can be concluded that these gas volumes are too small to achieve the required compression necessary for producing any significant gas water hammer loads. As additional confirmation of this conclusion, pressure pulse testing of the closed end RHR (LHSI) discharge piping at Kewaunee, as well as the North Anna and Surry plants, has shown that small (less than 0.1 ft$^3$) gas volumes in the discharge piping has had no measureable impact on the recorded pressure transient during pump start.

The Reference 2 methodology and resulting equations are based on compression of a stationary gas volume in the piping cross-section by the water flow. Flow in the open-ended ICS discharge piping at Froude numbers corresponding to even the minimum ICS flow results in transport of the gas volume with the flow almost immediately upon flow initiation. Consequently this transport of the gas with the flow would not permit small volumes of 34 $in^3$ or less residing in the top of the pipe to coalesce into an initially stationary gas volume that would be large enough to cover the entire cross-section of the pipe. Therefore, it can be concluded that gas volumes small enough to result in unacceptable transient forces are too small to achieve the required compression necessary for producing any significant gas water hammer loads. As additional confirmation of this conclusion it can be noted that pressure pulse testing of the closed end RHR (LHSI) discharge piping at Kewaunee (as well as the North Anna and Surry plants) has shown that small (less than 0.1 $ft^3$) gas volumes in the discharge piping has had no measureable impact on the recorded pressure transient during pump start.

The conclusions drawn from the evaluations discussed above are that the scenario of filling the containment spray ring riser and header (which are open to the containment atmosphere via the spray nozzles), and the scenario of a gas void in the discharge header downstream of the discharge isolation MOVs and upstream of the spray ring riser, will not produce loads that are problematic for the ICS discharge piping system.

Since the ICS pumps have a nominal capacity of 1300 gpm, the time to fill the entire system is 45 seconds. For the minimum flow of 1170 gpm, the fill time for the entire system would be approximately 50 seconds. This is well below the required time of 135 seconds in the accident analysis. Therefore, the presence of any small voids in this portion of the ICS discharge piping will have a negligible effect on spray initiation time.

In conclusion, any size gas voids that can be postulated to be present in the ICS discharge piping will have insignificant impact on the ICS discharge piping design loading due to potential gas water hammer or on the ability of the ICS system to perform its safety function.

References:

1. Technical Report ME-0181, Rev. 0, "Evaluation of Gas Accumulation in ECCS, Containment Spray and RHR Systems for GL 2008-01 Response," Kewaunee Power Station.
2. Fauske & Associates Report, FAI/08-78, Rev. 0, "Methodology for Evaluating Waterhammer in the Containment Spray Header and Hot Leg Switchover Piping," Prepared for Pressurized Water Reactor Owner's Group (PWROG), Prepared by Fauske & Associates, LLC, Burr Ridge, Illinois, July, 2008.
3. Westinghouse Draft Report, "Non-condensable Gas Voids in ECCS Piping; Qualitative Assessment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events."
4. Calculation C11843, Rev. 0, "Maximum Potential Void Volumes for High Points in the SI, RHR, and ICS Systems."
5. Work Order KW07-008213, "Perform Field Walkdowns to determine locations required for additional vent valves (ICS)."

6. Fauske & Associates Report, FAI/08-70, Rev. 1, "Gas-Voids Pressure Pulsations Program," Prepared for Pressurized Water Reactor Owner's Group (PWROG), Prepared by Fauske & Associates, LLC, Burr Ridge, Illinois, September, 2008.
7. Water and Waste Treatment Data Book, U.S. Filter / Permutit, 15th Printing.
8. Fluid Transients in Pipeline Systems, A. R. D. Thorley, first published in 1991 by D. & L. George LTD, Herts, England.
9. Kewaunee Power Station Prompt Operability Determination, OD Number 198, Revision 3, Condition Report Number CR336950.
10. Vendor Technical Report, "Hydraulic Transient Analysis of the North Anna Unit 1 Low Head Safety Injection System," for Virginia Power Company by Stoner Associates, Inc., Carlisle, PA by Richard A. Humphreys, P.E., April 1992.
11. Vendor Technical Report, "Final Report – Review of North Anna Power Station Units 1 and 2 LHSI Water Hammer and System Modeling," Prepared for Virginia Power, July 1992, by Dr. C. Samuel Martin, Consulting Engineer, Atlanta, Georgia.
12. Technical Report ME-0178, Revision 1, "Evaluation of Gas Accumulation in ECCS, Containment Spray and RHR Systems for GL 2008-01 Response," North Anna Power Station.

**NRC Question 4**

DEK performed calculations to identify the maximum potential void volumes at local high point locations and in valve bonnets in the SI, RHR and ICS systems. (Page 15)

Please summarize the results of these calculations and how they are going to be used for future modifications.

**Response**

Calculation C11843 was prepared to: 1) support the KPS response to GL 2008-01; 2) provide insight on the static venting capabilities of the SI, RHR, and ICS systems, and; 3) assist in determining if modifications are necessary. This calculation is based on a series of walk downs that measured the slopes of most of the SI, RHR, and ICS system piping. This slope data, which was used to determine where the local high points are located in these systems, showed that over 200 high points exist. The calculation then determined the void sizes that would remain at each high point assuming a static fill and vent of the systems. These are theoretical void sizes based on physical geometries only and do not represent the actual voids that could be present in the piping. This is because the calculation assumes that only static venting has been completed. If there is a continuous source of gas intrusion into the system before venting is performed, the void size could be larger. Additionally, during outage operations and testing, many portions of these systems have flow, which would sweep gas out of the piping. Therefore, calculation C11843 does not reflect actual voids and is not intended for this purpose.

This calculation assigns an identifying number to every local high point in the SI, RHR, and ICS systems. Isometric drawings attached to the calculation show the location of these high points. This information is used when performing UT examinations to check for voids. The plant procedures that are used to perform these examinations refer to the high points by number.

As stated above, the calculation shows that over 200 high points exist in piping in the SI, RHR, and ICS systems. This calculation has also determined the void volumes that could be present in valve bonnets. The void volumes for these valve bonnets are listed in the calculation.

After completion of the calculation, each high point was reviewed to determine whether a potential void at that location could be swept. Most locations are capable of being swept, but several locations were identified where sweeping was difficult or there was the potential for a continuous source of gas accumulation. These locations were listed and prioritized based on the likelihood of gas accumulation and the associated consequences. Nine locations were chosen to install new vent valves before or during refueling outage KR30 (fall 2009). Of these nine locations, six are known to have voids. The installation of new vent valves allows the associated locations to be vented as needed to maintain system operability.

This calculation also documents the estimated voids that could exist in valve bonnets from a static fill of the system. Most valve bonnets cannot be vented or swept and cannot be examined to check for voids. However, these voids will tend to remain in the bonnets and do not represent a significant challenge to operability. No modifications are currently planned to address valve bonnet voids. Three of the nine locations where new vent valves were installed prior to and during the fall 2009 refueling outage are in valve bonnets. However, these vent locations were chosen for the purpose of venting the piping, not the valves.

Additional modifications are also planned for installation during the fall 2009 refueling outage to eliminate the likelihood of gas accumulation in the common SI system piping. These modifications were selected based on the fact that voiding of the common SI piping affects the operability of both trains of SI. These modifications were chosen during the detailed review of the high points documented in calculation C11843.

**NRC Question 5**

Please demonstrate that adequate NPSH margin exists when air ingestion effects are considered in the revised calculations for SI, RHR and ICS pumps and also provide the revised calculations. (Page 15)

**Response**

The net positive suction head (NPSH) analysis for the ECCS pumps during SI injection mode operation is given in Calculation C10996, Rev. 0, "NPSH (Available) to the RHR, SI, and ICS Pumps When Drawing a Suction from the RWST," and its Addendum A, C10996 Revision 0, "Incorporate RWST Level TLEs and Elevated Water Temperature into the ECCS Pump NPSH available (NPSHa) Calculation" (Reference 1).

C10996, Addendum A determines the minimum NPSHa and compares it to the maximum NPSH required (NPSHr) (at maximum flow) for the ECCS pumps during two pump operation (at 37% RWST level) and one pump operation (at 4% RWST level). These values then determine the margin factor (NPSHa to NPSHr ratio) as the following:

| **NPSH Margin Evaluation<br>Two ECCS Pump Operation at 37% RWST Level** | | | | |
|---|---|---|---|---|
| ECCS Pump | Max. Flow (gpm/pump) | Max. NPSHr (ft.) | Min. NPSHa, (ft.) | Margin Factor (NPSHa to NPSHr ratio) |
| RHR | 2,100 | 8.5 | 28.985 | 3.410 |
| SI | 780 | 18.0 | 30.924 | 1.718 |
| ICS | 1,500 | 22.5 | 32.335 | 1.437 |
| **NPSH Margin Evaluation<br>Single ECCS Pump Operation at 4% RWST Level** | | | | |
| ECCS Pump | Max. Flow (gpm/pump) | Max. NPSHr (ft.) | Min. NPSHa (ft.) | Margin Factor (NPSHa to NPSHr ratio) |
| RHR | 2,100 | 8.5 | 38.839 | 4.569 |
| SI | 780 | 18.0 | 24.496 | 1.361 |
| ICS | 1,500 | 22.5 | 25.666 | 1.141 |

The NPSH ratio indicates the margin available for evaluation of gas void volumes transported to the ECCS pumps. The evaluation in Reference 1 shows that adequate NPSH margin is available for all ECCS pumps during SI operation assuming no gas voids are present in the suction flow. Gas voids in the pump suction lines at maximum flow transport to the pumps early in the RWST drawdown period during the SI injection mode when suction is taken from the nominally full RWST. Therefore, NPSH margin for the ECCS pumps at maximum flow with gas voids present in the suction piping can be properly evaluated during the gas transport period when the RWST is approximately at the Technical Specification (TS) minimum level.

An adjustment to NPSHa for the RWST TS minimum level can be made to the NPSHa values shown in the table above. (The maximum NPSHr values shown above do not change.) From Calculation C11412-5, Revision 0 (Reference 2), the RWST volumes at the levels of interest are: TS minimum level: 272,500 gallons; 37% level: 101,395 gallons; and 4% level: 10,962 gallons. Also from C11412-5, Revision 0, the RWST volume is 3,971.61 gallons/ft of water level. Consequently, the additional elevation head which is added to the NPSHa when the RWST is at TS minimum level is 43.082 ft. when compared to the 37% level and 65.85 ft. when compared to the 4% level. The following table provides an evaluation of NPSH margin for the ECCS pumps at maximum flow with the RWST at TS minimum level.

| **NPSH Margin Evaluation<br>Two ECCS Pump Operation at TS Minimum RWST Level** | | | | |
|---|---|---|---|---|
| ECCS Pump | Max. Flow (gpm/pump) | Max. NPSHr (ft.) | NPSHa (ft.) | Margin Factor (NPSHa to NPSHr ratio) |
| RHR | 2,100 | 8.5 | 28.985 + 43.082 = 72.1 | 8.5 |
| SI | 780 | 18.0 | 30.924 + 43.082 = 74.0 | 4.1 |
| ICS | 1,500 | 22.5 | 32.335 + 43.082 = 75.4 | 3.35 |
| **NPSH Margin Evaluation<br>Single ECCS Pump Operation at TS Minimum RWST Level** | | | | |
| ECCS Pump | Max. Flow (gpm/pump) | Max. NPSHr (ft.) | NPSHa (ft.) | Margin Factor (NPSHa to NPSHr ratio) |
| RHR | 2,100 | 8.5 | 38.839 + 65.85 = 104.7 | 12.3 |
| SI | 780 | 18.0 | 24.496 + 65.85 = 90.3 | 5.0 |
| ICS | 1,500 | 22.5 | 25.666 + 65.85 = 91.5 | 4.1 |

USNRC NUREG/CR-2792, Creare TM-825, “An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions” (Reference 3), provides a conservative formula based on limited test data for adjusting NPSHr for gas void fractions entering the suction of pumps. The Reference 3 equation for conservatively estimating the correction to NPSHr due to gas ingestion, which can be used for void fractions less than or equal to 2%, is:

- NPSHr air/water = NPSHr water (1 + 0.5 x A.F.)

Note that review of the data (Reference 3) from which this equation is derived suggests that the equation may have approximately 50% conservative margin at 2% gas void fraction.

Thus, the NUREG/CR-2792 formula for NPSHr adjustment results in a doubling of the NPSHr for a 2% gas void fraction entering the pump suction. The acceptance criterion for gas void volumes in the suction piping from the RWST to the ECCS pumps is 2% or less.

During the initial RWST drawdown period of SI injection operation (which is the time period where any postulated acceptable gas voids would be transported from the RWST suction piping to the ECCS pumps at maximum flow) all of the ECCS pumps have a value of NPSH available that is greater than twice the NPSH required. Therefore, postulated acceptable gas void volumes in the RHR, SI, and ICS pump suction piping from the RWST would have negligible impact on the NPSH margin of the ECCS pumps at maximum flow conditions. Furthermore, any postulated voids in the caustic lines would be drawn into the ICS suction line separately from any postulated voids in the suction line from the RWST to the ICS pump. However, the postulated voids in the caustic line would also be transported early in the RWST drawdown, when the RWST water level is judged to be high enough to ensure NPSH available is greater than twice the NPSH required for the ICS pumps.

A worst case condition can be postulated where the ECCS pumps operate at minimum flow until the RWST reaches its minimum level (either 37% or 4%), at which time, the maximum flow condition is initiated. This could be postulated to occur for the SI and RHR pumps during small break loss of coolant accident (SB LOCA) conditions with the RCS being at a high pressure when the RWST is nominally full and subsequently depressurized at the time the RWST is at minimum level. Evaluation of the above tables shows that the RHR pump has adequate NPSH margin to accommodate acceptable gas void volumes at any RWST level. However, the SI and ICS pumps must be evaluated for gas void transport to the pump suctions at minimum flow rates with the RWST at TS minimum level.

Evaluation of SI Pumps

The 6-inch SI pump suction lines were evaluated to be the only lines with Froude numbers high enough to transport gas voids to the pump suction. The 12-inch SI suction lines will not transport their largest possible calculated (acceptable) gas void to the pump suction even at the maximum SI pump flow rate. Consequently, only the 6-inch SI suction lines need to be considered for this evaluation. The minimum SI flow condition is considered to be at an RCS pressure of 1700 psig (approximate SI signal initiation pressure) with a single degraded SI pump operating. Note that during a SB LOCA, the RCS would depressurize to a lower pressure than 1700 psig, which would result in greater SI pump flow rates. At the minimum SI pump flow rate of approximately 291 gpm the Froude number in the 6-inch line is approximately 0.7, which is > 0.55 and is sufficient to transport gas voids out of the horizontal high point and also down the relatively short vertical drop into the pump. Therefore, any postulated gas voids in the 6-inch suction line will be transported to the SI pumps during the initial stages of a minimum SI pump flow event (e. g. a SB LOCA) when the RWST is nominally full and the conclusions of the SI pump NPSH margin evaluation performed above remain valid for SB LOCA conditions.

Evaluation of ICS Pumps

The ICS pumps deliver a minimum flow of 1,170 gpm when the containment is assumed to be at maximum pressure (46 psig). The ICS pump suction lines from the RWST start out as 12-inch ID lines and then reduce down to 8-inch (7.981" ID) lines which supply the individual pumps.

At 1,170 gpm, the Froude number is approximately 0.58 for the 12-inch lines and approximately 1.6 for the 8-inch lines. Since the Froude number in the 8-inch ICS suction lines is > 1.0 at minimum flow (and there are no vertical drops in the 8-inch piping runs), any gas voids postulated to be in these suction lines will be transported to the pump suction as soon as the ICS pump starts, which is when the RWST is nominally full. The Froude number in the 12-inch line is slightly greater than 0.55 and there is a 2-inch to 4-inch vertical drop in the 12-inch piping run. Consequently, not all of the postulated gas void volume would be expected to immediately transport out of the horizontal high point and down the 2-inch to 4-inch vertical. Rather, the gas void transport from the 12-inch piping high point would be gradual and increase as the ICS flow rate increased with decreasing containment pressure. However, by the time the RWST reaches the lower levels (37% or 4%) the majority, if not all, of the gas void volume in the 12-inch piping high point would be expected to have been gradually transported through the ICS pump such that NPSH margin would not be violated. Therefore, it is concluded that the ICS pump has sufficient NPSH margin for minimum ICS flow conditions at the beginning of the containment depressurization event.

Evaluation of RHR Pumps

The RHR pumps have also been evaluated for adequate NPSH margin considering acceptable gas voids when taking suction from the containment sump during SI Recirculation Mode operation. The calculation of record for NPSH evaluation of the RHR pumps operating in SI Recirculation Mode is C11023, Revision 2, "NPSH (available) to the RHR Pumps When Taking Suction from the Containment Sump" (Reference 4). This calculation indicates that the RHR pump NPSHa is 13.813 ft at 2000 gpm with an NPSHr requirement of 8.0 ft. The minimum calculated NPSH available is only 1.73 times greater than the NPSH required, which is slightly less than the factor of 2 recommended by Reference 3 for 2% void fractions at the RHR pump suction. However, the Reference 3 NPSHr adjustment for gas void fraction formula and associated test data that recommends doubling the NPSHr for a 2% void fraction at the pump suction (see Reference 3, Figure 4-3) indicates that the formula contains significant conservatism. The 2% void fraction in the NPSHr adjustment formula suggests doubling the NPSHr, while the actual test data suggests that the NPSHr would actually increase by only a factor of approximately 1.4. Furthermore, the actual test data for a 5% void fraction suggests that the NPSHr would increase by no more than a factor of between 1.8 – 1.9 over the 0% void fraction NPSHr. Additionally, this NPSHr adjustment for gas void fraction in the pump suction flow inherently applies to long term (steady state) conditions of pump operation. Since the acceptable void volumes in the RHR pump suction line from containment are based on 2% void fraction and would pass through the pump in a relatively short period of time, the calculated NPSH margin of NPSH available being 1.73 times the NPSHr is judged sufficient.

The evaluation discussed above assumed that the initially planned actions designed to reduce the volume of air between valves SI-350 and SI-351 were complete. However, these actions were revised (see response to Question 7, items 3 and 10). Thus, the RHR suction piping currently contains an approximately 3 $ft^3$ maximum possible void volume between valves SI-350 and SI-351 and an additional 755.2 $in^3$ valve bonnet void upon valve repositioning for each valve, which when combined, exceeds 2% void fraction in the suction flow. To support operability with this piping drained an evaluation by MPR in May 2006 (Reference 5) conservatively assumed that the entire void would transport, resulting in a maximum void fraction of between 3% and 5% to the RHR pump suction during the flow initiation transient. MPR and the pump vendor concluded that the maximum 3% to 5% void fraction would pass through the pump in under 20 seconds and would not impact the performance or mechanical integrity of the pump.

MPR has developed a new design basis calculation for the current design and operating conditions. The new calculation credits the sequence and timing of operation of the valves as well as the piping slope upward toward the containment sump to determine a more accurate quantity of gas that could be entrained to the RHR pump. The calculation concludes that the gas will be substantially vented to the sump before the RHR pump is started, resulting in minimal gas entrainment.

References:

1. Calculation C10996, Revision 0, through Addendum A, "Net Positive Suction Head (Available) to the Residual Heat Removal, Safety Injection, and Internal Containment Spray Pumps When Drawing A Suction From the Refueling Water Storage Tank," Kewaunee Power Station.
2. Calculation C11412-5, Revision 0, "Refueling Water Storage Tank (RWST) Level, Control Room Indication (Loop 920)," Kewaunee Power Station.
3. USNRCNUREG/ CR-2792, Creare TM-825, "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions."
4. Calculation C11023, Revision 2, "NPSH (available) to the RHR Pumps When Taking Suction from the Containment Sump," Kewaunee Power Station.

5. MPR Letter Report, "Kewaunee Nuclear Power Plant – Evaluation of the Effect of an Air Void in the ECCS Sump Suction Piping," dated May 30, 2006.
6. Westinghouse Electric Company Report Number V-EC-1866, Revision 0, "Pump Interim Gas Ingestion Tolerance Criteria: PA-SEE-450 Task 2," Revision 0, October 2008.

**NRC Question 6**

Please summarize the following procedures briefly:

a. Fill and vent procedures with acceptance criteria to assure that piping is sufficiently full after system fill and vent activity. Also provide the details of confirmatory testing followed by fill procedures. (Pages 23-24)

b. The procedures for periodic monitoring for gas accumulation at Kewaunee. Discuss future modifications to allow monitoring in the locations which are currently inaccessible and other compensatory measures as part of monitoring program. Justify that quarterly monitoring would be adequate to assure operability of the subject systems. (Page 36)

c. Revised In-service testing procedures to provide dynamic sweeping as part of the filling of the systems where needed to assure systems are sufficiently full. (Page 43)

d. Discuss various surveillance procedures applicable to subject systems.

**Response**

Fill and Vent Procedures

KPS uses Maintenance Operating Procedures (MOP) and Normal Operating Procedures (NOP) to perform static filling and venting of systems after draining for maintenance. As noted in the initial 9-month response to GL 2008-01, these procedures for the subject systems were reviewed and were considered to provide adequate fill of the piping, with some exceptions. Revisions have been completed to ensure that a complete static vent is obtained, including utilization of all existing or newly installed vent valves. During the review process, system isometric drawings were utilized to identify any high point locations that may not be completely vented. Dynamic venting would then be used to completely fill the system.

In addition to the procedures listed in the original response to GL 2008-01, the following procedures have been developed or revised for filling and venting the subject systems. Reviews of all procedures to be used before or during the fall 2009 refueling outage have been performed.

- OP-KW-MOP-RHR-001A, “RHR Pump A Maintenance at Power”
- OP-KW-MOP-RHR-001B, “RHR Pump B Maintenance at Power”
- OP-KW-MOP-RHR-002A, “RHR Pump A Maintenance Shutdown (FEG 34.A1)”
- OP-KW-MOP-RHR-002B, “RHR Pump B Maintenance Shutdown (FEG 34.B1)”
- OP-KW-MOP-RHR-003A, “RHR to SFP Line Maintenance (FEG 34.A.2)”

- OP-KW-MOP-RHR-005A, “RHR Train A Loop Suction Maintenance Shutdown (FEG 34.A4)”
- OP-KW-MOP-RHR-005B, “RHR Train B Loop Suction Maintenance Shutdown (FEG 34.B4)”
- OP-KW-MOP-RHR-006, “Vacuum Fill of B Train RHR at Pen 48”
- OP-KW-MOP-RHR-006A, “Drain RHR Train A from RHR-9A to RHR-11”
- OP-KW-MOP-RHR-006B, “RHR B Vessel Injection Shutdown (FEG 34.B5)”
- OP-KW-NOP-SI-001, “Filling, Draining, Pressurizing, and Venting SI Accumulators”
- OP-KW-MOP-SI-002, “Safety Injection System Fill and Vent After Maintenance”
- OP-KW-MOP-SI-004, “Venting of Safety Injection Cold Leg and Reactor Vessel Injection Piping”
- OP-KW-MOP-ICS-001, “Fill and Vent ICS”
- OP-KW-MOP-ICS-002, “ICS Downstream of ICS-7A (FEG 23.C)”
- OP-KW-MOP-ICS-003, “ICS-8B and ICS-9B OOS MOP (FEG23.D)”

Since the systems are known to contain high point locations that cannot be fully vented using static venting through the existing or newly installed vent valves, dynamic venting is planned to complete the venting process. Dynamic venting is typically performed by various procedures. In some cases, existing surveillance procedures may be used, such as quarterly pump IST procedures or pump full flow test procedures. In other cases, existing normal operating procedures would be used or new procedures may be developed. In all cases, procedures are being reviewed to ensure that all portions of the system will be swept unless previously evaluated for acceptable gas quantities. Procedures that have been identified for use in dynamic venting are:

- OP-KW-NOP-RHR-001, “Residual Heat Removal System Operation”
- SP-34-099A, “Train A RHR Pump and Valve Test - IST “
- SP-34-099B, “Train B RHR Pump and Valve Test – IST”
- OSP-SI-005A, “Safety Injection Pump A Preservice Test – IST”

In addition, new Normal Operating Procedures have been developed and used during the fall 2009 refueling outage to ensure that all portions of the subject systems can be dynamically vented, if needed.

To ensure that all high points in the subject systems are sufficiently full of water, procedures have been developed to confirm the systems are full using UT examinations. These procedures confirm that the combination of static and dynamic venting was effective in establishing the system full of water after the maintenance activities are complete. The procedures are:

- ER-KW-NSP-RHR-002, “Monitoring RHR System for Voids after System Refill”

- ER-KW-NSP-SI-004, "Monitoring SI System for Voids after System Refill"
- ER-KW-NSP-ICS-001, "Monitoring ICS System for Voids after System Refill"

The acceptance criterion to be used in these procedures is no gas accumulations greater than 0.01 $ft^3$. The procedures will direct that any voids greater than this size be eliminated prior to declaring the system operable. Any voids larger than 0.01 $ft^3$ that cannot be eliminated will be considered non-conforming conditions (unless previously identified in the licensing basis) and will be identified and evaluated in accordance with the Corrective Action Program.

The procedures described above are planned for the fall 2009 refueling outage, as needed to ensure that the subject systems are sufficiently full of water when plant operation is resumed after the refueling outage or during any future maintenance.

Periodic Monitoring Procedures

Procedures used for periodic monitoring of gas accumulations in the subject systems are listed in the section on Surveillance Procedures, below. In general, UT monitoring is performed in all accessible portions of the subject systems where potential gas intrusion sources during power operation were identified.

Areas that are inaccessible for monitoring during power operation are as follows.

- HHSI system injection piping, near the connections to the RCS
- LHSI system injection piping, in the containment building

High Head Safety Injection (HHSI)

Monitoring is being performed on HHSI piping in the containment building and auxiliary building at accessible locations upstream of the connections to the RCS. No gas has been found at these locations. A transient thermal hydraulic analysis of the HHSI piping was performed (as described in the original GL 2008-01 response, pages 13 and 14). This analysis showed that the system would remain operable as long as the size of any voids in the accessible areas met established limits, even with the inaccessible areas completely voided.

The potential sources of gas intrusion into the HHSI system were identified as RCS leakage past the injection check valves or leakage from the SI accumulators. Because of the large quantities of gas that may be released from leakage of SI accumulator water, additional monitoring beyond the quarterly UT of HHSI piping has been established. SI accumulator level changes are recorded twice daily. Any decrease in indicated level of 1% requires UT verification that gas is not collecting at the system high point near the containment penetration or at the SI pump discharge lines. In addition, routine UT monitoring at these locations is currently being performed at a monthly frequency. Modifications are planned during the fall 2009 refueling outage that would plug the SI test lines, which were identified as a significant potential path for SI accumulator leakage into the HHSI system. In addition, manual isolation valves are also planned for installation during the fall 2009 refueling outage for the SI accumulator fill lines to allow isolation of a leaking SI accumulator remote fill valve.

Following plant entry into hot shutdown during the fall 2009 refueling outage, UT was performed in the areas of the HHSI systems that are inaccessible during power operation. It was confirmed that gas had not collected in the HHSI piping during the current operating cycle.

Low Head Safety Injection (LHSI)

The LHSI lines in containment are inaccessible due to their location high in the overhead inside containment. Because of the inability to access these locations for periodic UT, quarterly pressure pulse testing is being performed. This testing confirms that the total void size in the discharge piping of each RHR train does not challenge system operability. In Train B of LHSI, the only source of gas intrusion during plant operation is leakage of the injection check valves to the RCS. In Train A, in addition to leakage of the injection check valves, leakage from an SI accumulator or from a cross-connect to the letdown system could also result in gas intrusion. Gas from these sources could quickly collect in the unventable high point located in the mini-flow recirculation line near where the line attaches to the injection header. This point is monitored quarterly by UT. Past monitoring has identified gas collection in the mini-flow recirculation piping of RHR train A, as described in the original 9-month response to GL 2008-01 (page 18). As a compensatory measure, monitoring at this location was increased to every two weeks and venting from a nearby vent valve is used to minimize the size of the gas accumulation. Each quarter, the remaining gas is swept from this high point during the quarterly pump test. UT is used to ensure that the gas is not transferred to other locations where it might affect system operability.

Repairs are planned during the fall 2009 refueling outage to valve LD-60, which is suspected to be leaking and causing the gas intrusion into RHR train A. In addition, installation of a vent valve in the high point of the mini-flow recirculation line is planned to allow better control of any future gas intrusion to this location.

Following plant entry into hot shutdown during the fall 2009 refueling outage, UT was performed in the areas of the LHSI systems that are inaccessible during power operation. A gas void of approximately 1.13 $ft^3$ was found in the RHR (LHSI) train B piping in containment. It was determined that this void did not affect system operability. A plant modification is planned during the fall 2009 refueling outage to install a vent valve at this location that would allow venting during power operation. The UT of the inaccessible areas further confirmed the acceptability of the pressure pulse testing to provide assurance that the system is sufficiently full of water to perform its safety function.

No additional modifications are currently planned to provide expanded monitoring in inaccessible areas. Experience has shown that current quarterly UT monitoring at accessible locations and quarterly pressure pulse testing are adequate to ensure gas accumulations are controlled within operability limits. The effectiveness of quarterly UT monitoring is improved when combined with daily monitoring of SI accumulator level, increased monitoring (when gas accumulations are identified), and trending of RWST inleakage (which would identify increasing leakage past HHSI or LHSI injection check valves). The modifications and valve repairs described above will further increase confidence that quarterly monitoring is adequate.

Inservice Testing Procedures

As described in the response to 6.a, above, dynamic sweeping is being performed by various procedures, including IST procedures and normal operating procedures. Where new procedures would need to be developed, use of normal operating procedures is preferred. IST procedures may be used where existing procedures provide the desired dynamic sweeping without major changes. As discussed in 6.b above, leakage into the LHSI system can result in gas accumulating in the mini-flow recirculation line. When the RHR pumps are run each quarter per Procedure SP-34-099A and B, this gas is swept out of the mini-flow lines and into other portions of the RHR, ICS, and SI systems. Therefore, UT monitoring is performed before this quarterly test to determine if gas is present. If gas is found, additional monitoring is performed after pump run to ensure that the gas has not transferred to other locations where it may affect system operability. These procedures are also used after online maintenance to sweep gas that cannot be removed by static venting.

Surveillance Procedures

The following surveillance procedures have been established to perform UT for periodic monitoring for gas accumulation:

- ER-KW-NSP-RHR-001, "Monitoring RHR Cooldown Piping for Gas Accumulation
- ER-KW-NSP-SI-001A, "Monitoring SI Containment Penetrations and SI Pump A Discharge Piping for Gas Accumulation"
- ER-KW-NSP-SI-001B, "Monitoring SI Pump B Discharge Piping for Gas Accumulation"
- ER-KW-NSP-SI-002, "Monitoring SI Common Train Piping for Gas Accumulation"
- SP-34-099A, "Train A RHR Pump and Valve Test – IST"
- SP-34-099B, "Train B RHR Pump and Valve Test – IST"

These procedures use UT to quantify the size of any voids found and provide acceptance criteria. An 'action level' is established at 0.01 $ft^3$ at any location where gas has not been previously found. Exceeding this action level requires initiation of an operability determination. When gas is found and evaluated at a location, the action level in the procedure is adjusted to identify a small increase in the previously measured value, ensuring that the larger gas volume is documented in the corrective action process.

The procedures also provide a 'limiting value', which is the value previously established that would challenge system operability. Gas volumes exceeding the action value, but less than the limiting value, do not render the associated system immediately inoperable, pending completion of the associated operability determination. If the gas volume exceeds the limiting value, the system is declared inoperable. Any voiding greater than 0.01 $ft^3$ is documented in the corrective action program and corrective actions are established to eliminate the nonconforming condition.

As described earlier, the quarterly RHR pump and valve tests, SP-34-099A and B, are currently being used for UT examination of gas accumulation in the mini-flow recirculation lines. These procedures are also used to monitor SI and RHR suction piping at other potential gas accumulation locations. SP-34-099A and B also include the RHR pressure pulse testing, which is used to confirm total gas accumulations in the LHSI discharge piping do not challenge system operability. These procedures include follow-up activities for venting. In the procedures developed specifically for UT, venting steps are not included. However, required venting would be performed using operations procedures as a result of the associated corrective action for any identified gas voids.

**NRC Question 7**

Please summarize briefly the resolution of completed corrective actions as identified in Section II, A and B of the submittal as appropriate; and, identify any adverse conditions that were discovered. (Pages 41-43)

**Response**

The following corrective actions were identified as complete in Section II.A of GL 2008-01 response. No additional adverse conditions relevant to the GL scope were discovered as a result of their completion.

1. A calculation was developed to identify the maximum potential void volumes at local high point locations and in valve bonnets in the SI, RHR and ICS systems. This calculation used measured piping slopes, existing vent valve locations, and valve design information to determine maximum potential void volumes after static venting.

2. During review of the drawings, a preliminary determination was made of piping that might be subject to gas accumulation during operation. A representative sample of high points without vents was selected for Ultrasonic Testing (UT) examination at the start of the KPS spring 2008 refueling outage (KR29) to check for the presence of gas voids. The UT examinations resulted in the discovery of a void at one location. This location was in the RHR suction piping from the Reactor Coolant loop, between the first and second isolation valve (RHR-1A and RHR-2A). This location was filled and vented prior to placing the RHR system in operation for KR29. Monitoring remains ongoing at this location.

3. During drawing review, it was recognized that leakage of both check valves in each HHSI injection line could result in gas accumulation in the HHSI piping. A test procedure was developed and performed to measure leakage of both check valves in series in each injection line.

4. Two new vent valves were installed on the RHR suction line from the RCS during KR 29. These vent valves were installed to facilitate filling the piping following RHR pump maintenance.

5. To confirm that the discharge piping of the RHR system was sufficiently full, test procedures were developed and performed. Discharge pressure was monitored during the start of the RHR pumps for each LHSI train. DEK staff confirmed that the maximum pressure peak above the steady state discharge pressure of the pump was not excessive.

The following corrective actions were identified in Section II.B of the GL 2008-01 response and were not complete at the time of the GL response submittal. The following is a brief summary of each item, current status, resolution of completed actions, and if applicable, description of any additional adverse conditions identified relevant to the GL scope.

1. DEK has developed and implemented a TRM and TRM Bases section similar to NUREG-1431 SR 3.5.2.3 and LCO 3.6.6. TRM 3.5.6, Emergency Core Cooling System and Containment Spray System Surveillance, including the results of implementation, are discussed in detail in the response to Question 2. TRM 3.5.6 requires that the applicable portions of the subject systems are maintained sufficiently full of water to reliably perform their intended safety function and accessible portions of the subsystems susceptible to gas intrusion are verified sufficiently full of water on a quarterly basis. This action is complete. Potentially adverse conditions, specifically gas voids in the piping systems, were identified as a result of the implementation of the surveillance requirements of the TRM. These conditions are also discussed in detail in the response to Question 2.

2. Revisions to the KPS USAR are planned to reflect that the applicable portions of the subject systems must be verified sufficiently full of water following the opening of the systems for maintenance or testing, and by periodic monitoring of the accessible portions of the subject systems susceptible to gas intrusion, consistent with the requirements of GL 2008-01 and the supporting analysis. As discussed in the GL response, the targeted timeframe for the resolution of this item is March 1, 2010 which is within 6 months of the completion of the fall 2009 refueling outage. Therefore this item is currently incomplete. No other adverse conditions have been identified related to this activity.

3. Revision of the KPS USAR to reflect a change in the design or operating practices to maintain the containment sump suction piping between valves SI-350A/B and SI-351A/B sufficiently full of water, as stated in the DEK response to GL 2008-01, is not fully complete. However, a USAR revision is planned following final review and approval of a new calculation that justifies the current design of a voided condition in the containment sump suction piping between the first and second isolation valves (SI-350A/B and SI-351A/B). Maintaining the current design is planned for the subsequent operating cycle.

   A new calculation has been performed (discussed in Item 10 below), which indicates that the gas in this section of piping will be substantially vented to the sump before the RHR pump is started, resulting in minimal gas entrainment, consistent with the requirements of GL 2008-01. However, this item will not be fully complete until final review and approval of the new calculation and its incorporation into the USAR. When approved, this calculation is expected to be incorporated into the USAR by May 2010. No other adverse conditions have been identified related to this activity. Although not required for RHR system operability, DEK also continues to evaluate a change to the current design of the system that would maintain the containment sump suction piping between valves SI-350A/B and SI-351A/B full of water. If implemented, this design change will also be reflected in the USAR following completion.

4. DEK continues to monitor the status of the industry/NRC Technical Specifications Task Force (TSTF) Traveler to be developed as a follow-up to GL 2008-01. Following NRC approval of this TSTF, DEK plans to evaluate adopting it. On May 8, 2009, the TSTF and the Owners Group met with the NRC to present the TSTF's proposed approach. The recommended actions were that the existing surveillance requirements be removed from the TS, and management of the effects of entrained gas on the operability of the subject systems should be controlled by the existing TS requirement that a system be operable. This recommendation is currently under NRC review and the TSTF traveler has not been approved for the industry. This item remains incomplete. No other adverse conditions have been identified related to this activity.

5. DEK continues to monitor the results of industry testing and analytical programs related to gas accumulation and pump suction acceptance criteria to determine if any changes to KPS licensing basis documents are required. To date, there have been no new industry testing or analytical programs developed for evaluation and adoption. This item remains incomplete. No other adverse conditions have been identified related to this activity.

6. The impact of pump recirculation flows to the RWST with respect to air entrainment and ingestion on the operation of the SI, RHR and ICS pumps during alignment to the RWST has been evaluated. The results of the evaluation determined that recirculation return waterfall has no significant impact on the performance of the SI, RHR, or ICS pumps. Neither minimum submergence for vortex prevention, NPSH margin, nor developed head of the SI, RHR, or ICS pumps are adversely impacted throughout the full range of RWST water levels. This action is complete. No other adverse conditions have been identified related to this activity.

7. A manual RHR system valve was identified as a vent valve in plant drawings and in equipment database; however, this valve is actually installed on the bottom of the pipe. The system isometric drawing correctly showed the actual location of this valve. The associated documents, databases and labels were corrected to reflect the valve as a system drain. This item is complete. No other adverse conditions have been identified related to this activity.

8. DEK continues to evaluate actions needed to eliminate gas accumulations that were found during the initial UT examinations of subject systems. Actions to be taken include a combination of plant modifications for the installation of additional vent valves, procedure changes to ensure systems are sufficiently filled after draining for maintenance, or development of design basis documents to establish allowable limits on gas accumulation. This action is targeted for completion prior to the end of the fall 2009 refueling outage. The locations where gas accumulations have been found that will be addressed by this action, along with the current status of each, include the following:

- Train A ICS discharge piping near the containment penetration. Status: Analysis is being performed to show that these voids are inconsequential. Design basis documents revisions are being planned.
- Train A ICS discharge piping branch line associated with the full flow test line. A vent valve was installed at this location.
- Caustic addition branch line to the ICS suction piping. The void was measured and found to be smaller than 0.01 $in^3$. Therefore, no further action is planned.
- CVCS/RHR cross-connect piping from the RHR discharge piping. Gas at this location is believed to be due to leakage past valve LD-60. Repairs to this valve are planned for the fall 2009 refueling outage. Monitoring is planned to continue during the next operating cycle to ensure gas accumulation has ceased.
- RHR to Spent Fuel Pool interconnection branch line from the RHR discharge piping. A vent valve was installed that greatly reduced the size of the gas void in this line. Further corrective actions are being developed to address the remaining gas accumulation.
- Train A RHR mini-flow recirculation branch line from the RHR discharge piping. Installation of a vent valve at this location is planned for the fall 2009 refueling outage.
- SI test line branch from the SI discharge piping. A modification is planned for the fall 2009 refueling outage that will plug the SI test line, eliminating a potential path for gas intrusion into the SI system.
- Suction bypass branch to the SI suction piping. Installation of a vent valve at this location is planned for the fall 2009 refueling outage.
- RHR normal cooldown suction line from RCS loop A. Installation of a vent valve at this location is planned for the fall 2009 refueling outage.

No other adverse conditions have been identified related to this activity.

9. DEK continues to evaluate actions to address system high points that may not have an existing vent valve. Actions are still in development, but are expected to include some combination of installation of additional vent valves, procedure changes to ensure systems are sufficiently filled after draining for maintenance, or development of design basis documents to establish allowable limits on gas accumulation. This action is targeted for completion prior to the end of the fall 2009 refueling outage. No other adverse conditions have been identified related to this activity.

10. The evaluations of system modifications to change the current design and operating practices to maintain the containment sump suction piping between valves SI-350A/B and SI-351A/B sufficiently full of water, as stated in the DEK response to GL 2008-01, have been completed. However, changes to the

current design will not be implemented during the next operating cycle. The current design of a fully voided condition between the first and second isolation valves (SI-350A/B and SI-351A/B) is planned to be maintained during the next operating cycle.

To support continued RHR system operability with this section of piping essentially empty, a design basis calculation has been performed. The new calculation credits the sequence and timing of operation of the valves, and the piping slope upward toward the containment sump, to determine the actual quantity of gas that would be entrained to the RHR pump. The results of the calculation indicate that the gas would be substantially vented to the sump before the RHR pump is started, resulting in minimal gas entrainment, consistent with the requirements of GL 2008-01.

Therefore, this action is incomplete, pending final review and approval of the new calculation. Although not required for RHR system operability, DEK is continuing to evaluate system modifications and operating practices that would permit maintaining the containment sump suction piping between valves SI-350A/B and SI-351A/B filled with water. These system enhancement modifications are planned to be installed by the end of June 2011. No other adverse conditions have been identified related to this activity.

11. DEK has revised fill and vent procedures for the subject systems to provide a means and acceptance criteria to ensure that piping is sufficiently full after system fill and vent. The procedures for these systems are discussed in detail in the response to Question 6. This action was targeted for completion prior their need for system fill and vent during start up from the fall 2009 refueling outage and is complete. No other adverse conditions have been identified related to this activity.

12. DEK has revised inservice test procedures to provide dynamic sweeping as part of the filling of the systems where needed to ensure systems are sufficiently full. The procedures for these systems are discussed in detail in the response to Question 6. This action was targeted for completion prior to the end of the fall 2009 refueling outage and is complete. No other adverse conditions have been identified related to this activity.

13. DEK has established the requirements for periodic monitoring of gas accumulation within the subject systems through implementation of TRM 3.5.6, Emergency Core Cooling System and Containment Spray System Surveillance. The procedures for implementation include a combination of UT examinations and pressure pulse monitoring of the systems as described in the response to Question 2. This action is complete. Potentially adverse conditions, specifically gas voids in the piping systems, were identified as a result of the implementation of the surveillance requirements of the TRM. These conditions are also discussed in detail in the response to Question 2.

**NRC Question 8**

Training was not identified in the GL, but it is considered to be a necessary part of applying procedures and other activities when addressing issues identified in the GL.

Please discuss training briefly.

**Response**

The potential for gas intrusion in KPS systems, as well as the elements described in the KPS response to the GL, were presented to KPS Engineering and Operations personnel during the third quarter accredited training sessions. The goal of this training was to increase awareness and knowledge of gas accumulation issues (including the need to reduce the risk of gas intrusion events), to recognize the potential consequences of such conditions, and to initiate proper corrective action.

The engineering lesson plan content synopsis included:

- Review of Fundamental Theory in regards to:
  - The effects of temperature, level, and pressure on instruments.
  - The principles of gas absorption, desorption, and gas stripping.
  - The potential effect of gas accumulations in piping, including pump suction and discharge piping.
- Describe the potential sources of gas intrusion in KPS systems.
- Describe the results of the station's probabilistic safety analysis regarding common-cause failure of the safety injection/charging pumps from gas intrusion.
- Recognize instrumentation failures, degraded pump performance and other conditions related to gas binding of pumps supplied from storage tanks.
- Summarize the actions in response to GL 2008-01.
- Describe current known gas accumulations in KPS systems.
- Describe the strategies for identification, prevention, and mitigation of gas intrusion.

The operations lesson plan content synopsis focused on current plant modifications to address gas accumulation in the subject systems and included:

- Review of the purpose of KPS modifications to address GL 2008-01: Improve the ability to remove accumulated gas and to reduce the likelihood of gas accumulating in the Safety Injection, Residual Heat Removal, and Internal Containment Spray systems.
- Reviewed the modifications using drawings to show the changes to the systems.

Additional training for Operations personnel is currently planned for the first quarter of 2010. The planned training content appropriately incorporates the information presented in the third quarter Engineering training.