Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

Phenomena and Detection of Gas Accumulation in Piping Systems

D. Y. Lee [a*], S. S. Jeon [a], S. J. Hong [a], Y. J. Song [b]
[a] *FNC Technology Co. Ltd., Rm.308, Bldg.135, Seoul National Univ. Shilim9-dong, Gwanak-gu, Seoul, 151-742, Korea*
[b] *Westinghouse Electric Co., Nuclear Power Plant., 1000 Westinghouse Dr., Cranberry Twp, PA 16066*
[*] *Corresponding author:dylee@fnctech.com*

1. Introduction

U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2008-01 which provides recommendation and guidance to nuclear power plants for managing gas intrusion and accumulation in safety systems such as Emergency Core Cooling (ECC), Decay Heat Removal (DHR) and Containment Spray (CS) systems [1]. Following the GL2008-01, Nuclear Energy Institute (NEI) reported NEI 09-10 that gives industry guidance for effective prevention and management of system gas accumulation. All of U.S. utilities responded to the GL2008-01 with evaluation results for gas accumulation in safety systems mentioned above [2]. This paper summarizes key phenomena to be evaluated against gas accumulation in safety systems and detection methods for gas accumulation in subjected systems.

2. Phenomena

Gas can be accumulated in safety systems due to following various reasons [3].

(1) Leakage from accumulators or other high pressure sources
(2) Leakage from Reactor Coolant System (RCS)
(3) Pressure reduction by elevation change or venting
(4) Inadvertent draining, system realignment, and incorrect maintenance and test procedure
(5) Failure of level instruments
(6) Leakage through multiple in-series isolation valves or through multiple in-series check valves
(7) Leakage through vent valves
(8) Temperature at or above saturation temperature
(9) Formation of air entraining vortices
(10) Cavitations due to the pressure drops in pipes

Accumulated gas due to above reasons makes safety systems vulnerable to be affected by several phenomena shown in Fig. 1.

2.1 Void Transport and Pump Gas Ingestion

Void accumulated at pump suction piping can affect pump performance. Void transports to pumps when these on safety systems are operated and then degrade pump operational capacity. NEI 09-10 proposed allowable average non-condensable gas void fractions for BWR and PWR typical pumps as shown in Table 1[2].

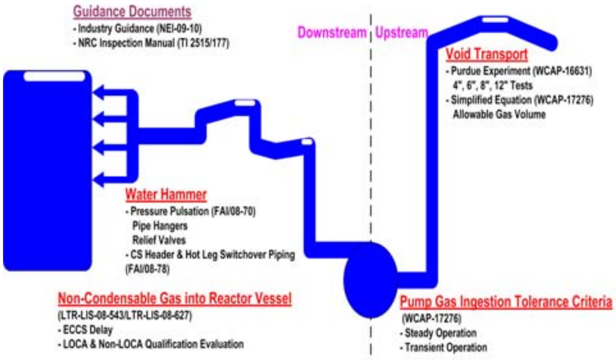

Fig. 1. Key phenomena on gas accumulation in safety systems.

Table 1. Allowable average non-condensable gas void fractions for BWR and PWR typical pumps

		$\% \frac{Q}{Q_{BEP}}$	BWR Typical Pumps	PWR Typical Pumps		
				Single Stage (WDF)	Multi-Stage Stiff Shaft (CA)	Multi-Stage Flexible Shaft (RLIJ, JHF)
A	Steady State Operation	40%-120%	2%	2%	2%	2%
B	Steady State Operation	< 40% or > 120%	1%	1%	1%	1%
C	Transient Operation	70%-120%	10% for ≤ 5 sec	5% for ≤ 20 sec	20% for ≤ 20 sec	10% for ≤ 5 sec
D	Transient Operation	< 70% or > 120%	5% for ≤ 5 sec	5% for ≤ 20 sec	5% for ≤ 20 sec	5% for ≤ 5 sec

Gas transport in pump suction side is modeled to determine the amount of void fraction would be at the pump suction for a given void fraction present at the accumulation location. WEC proposed the Simplified Equation (SE) that enables the determination of allowable gas fraction at high point locations in pump suction piping based on specified allowable gas void fraction criteria at the pump inlet, system flows, and system pressures [4].

2.2 Water Hammer

Void accumulated at pump discharge piping impacts safety systems by pressure pulsation or water hammer that has the potential damage to piping supports and other piping attachments. A significant flow transient can occur when A significant flow transient can result when a water mass is accelerated into accumulated gas volume as a result of pump start or the opening of valve. The water mass acceleration is due to a pressure difference acting on the available water mass with subsequent motion compressing the accumulated gas volume which increases the pressure [5]. Thus, this makes force imbalances on the piping segments and is sufficient to challenge the piping supports like hangers. On the other hand, the acoustic transmission of compressed pressure waves has a possibility to cause the pressure pulsation to lift system relief valves. The pressure difference is calculated by the Joukowsky-Frizell equation [5].

2.3 Void Effects on RCS Transients

WEC has qualitatively evaluated the impact on the RCS with a small amount of accumulated gas in ECCS pump discharging pipe through engineering judgment during accident conditions. RCS transients include Large Break Loss of Coolant Accident (LBLOCA) and Small Break (SB) LOCA as well as three non-LOCA events such as steam line rupture, feedwater line rupture and steam generator tube rupture. WEC concludes that the LOCA and non-LOCA analyses are not impacted as long as a plant specific evaluation of the gas volumes detected are less than value the equivalent of $5ft^3$ at 400 psia, 68^oF [6].

3. Detection

Possible phenomena due to the gas accumulation in piping systems described in chapter 2 should be evaluated with measured gas volume accumulated in subjected systems. The measurement and detection of accumulated gas volume can be achieved by Ultrasonic Testing (UT) and laser scanning when plant walkdown is conducted.

3.1 Ultrasonic Testing

NEI 09-10 recommended UT examination to identify and quantify the gas amount [2]. The water level in pipes and components can be accurately determined by using UT methods. The principle of UT examination is simple as shown in Fig. 2 that ultrasonic wave generated in a probe penetrates pipe wall and inside water and then returns to the probe when there is gas accumulated in pipe. This allows detecting water level in pipes and then accumulated gas volume can be reasonably estimated.

3.2 Laser Scanning

The location of gas accumulation is usually a high point of piping systems. The high point of system is easily identified by investigating as-built isometric drawings of the subjected systems. However, the real plant piping configuration such as a slope might be different from as-built drawings. If there is a small slope on pipe which is a horizontal configuration in as-built drawing, gas can be accumulated at the high point in pipes with wrong slope as shown in Fig. 3. The discrepancy between as-built drawing and real plant configuration can be identified by using the laser scanning system with signal post-processing.

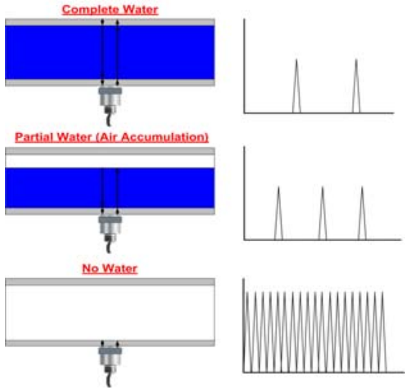

Fig. 2. Principle of UT examination.

Fig. 3. Gas accumulation in pipe with wrong slope.

4. Conclusions

Gas accumulation in piping systems impacts on the safety systems such as ECC, DHR and CS with the pump upstream phenomena based on the void transport into pump and pump downstream phenomena based on the pressure pulsation or water hammer as well as gas into RCS transients. Licensees have been asked to evaluate these effects and prove operational plant safety for the gas accumulation in safety systems based on the GL2008-01[1]. The UT and laser scanning methods can support licensee to evaluate gas accumulation issue against GL2008-01.

REFERENCES

[1] NRC Generic Letter 2008-01, Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems, Jan. 11th, 2008.
[2] Nuclear Energy Institute, Guidelines for Effective Prevention and Management of System Gas Accumulation, NEI 09-10 Rev.1, Dec., 2010.
[3] NRC Inspection Manual, Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems (NRC GL2008-01), 2515/177 Rev.1, Mar. 17th, 2010.
[4] Westinghouse Electric Company, Investigation of Simplified Equation for Gas Transport, WCAP-17276-P, Rev.0, Sep., 2010.
[5] Fauske & Associates, LLC, Gas-Void Pressure Pulsations Program, FAI/08-70, Sep., 2008.
[6] Westinghouse Electric Company, PWROG Position Paper on Non-Condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450, LTR-LIS-08-627, Sep., 2008.