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Development of Regulatory Evaluation Methods for ECCS Gas Accumulation

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1. Introduction

Gas accumulation in the safety system piping has been believed to occur since the beginning of commercial operation of the nuclear power plants in the United States. More than 110 instances were reported from various commercial operating reactors in the United States. The objective of this study is to review the USNRC regulatory evaluation methods and procedures as well as the research activities of the US nuclear industry to resolve the safety issues of the accumulated gas in the safety systems of the operating nuclear reactors, and then recommend regulatory evaluation methods and regulatory measures for potential gas accumulation in the safety systems of the operating nuclear power plants in Korea.

2. Regulatory Evaluation Methods

USNRC has published 20 information notices, two GLs, and a NUREG report related to the safety issues of the gas accumulation in the safety systems.

On January 11, 2008, the U.S. Nuclear Regulatory Commission (USNRC) issued Generic Letter, GL 2008-01 for managing gas accumulation in ECCS (Emergency Core Cooling System), DHRS (Decay Heat Removal System), and CSS (Containment Spray Systems)[1]. The stated purpose of GL 2008-01 was (1) to request the Utilities to submit information to demonstrate that the subject systems are in compliance with the current licensing, design and applicable regulatory requirements and that suitable design, operational, and testing control measures are in place for maintaining this compliance, and (2) to collect the requested information to determine if additional regulatory action is required. Also, INPO (Institute of Nuclear Power Operation) issued SER 2-05, Rev 1 to address continuing problems with gas intrusion instances in the industry. USNRC and the industry have established a procedure to resolve gas accumulation issues as illustrated in Figure 1. Upon the issuance of GL 2008-01, the Utilities submitted NMR (Nine Month Report) and formed an owner's group task force team to perform analytical and experimental research to address the cause and effects of the gas accumulation in the subject safety systems, especially for the gas transportation phenomena and analysis methodology. Various tests were performed and NEI is developing guidelines for effective prevention and management of system gas accumulation. Also, USNRC and the industry have been working closely for the USNRC temporary inspection and revision of the Technical Specifications and USNRC closed the issue with GL Closure memo[2] in July 2011.

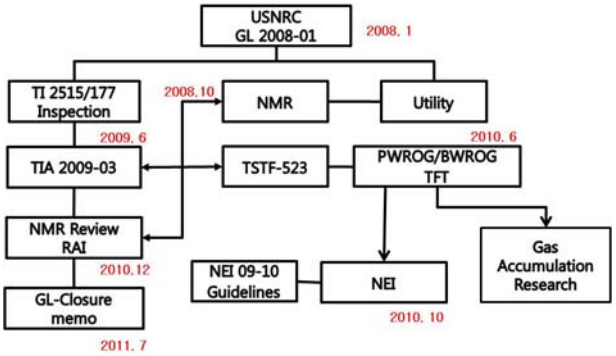

Figure 1. Procedure for Resolution of the Issues for the Gas Accumulation in Safety Systems

The Utilities submitted requested information to the USNRC and performed corrective actions and planning to revise the Technical Specifications. For the specific insight of the US regulatory procedures of the related gas accumulation issues, the regulatory interfaces and procedures of the PVNGS Units 1/2/3 were reviewed for benchmarking OPR1000 plants operating in Korea. It is evaluated that similar regulatory measures and procedures for the gas accumulation in the safety systems are necessary for the operating plants in Korea. Similar regulatory measures and procedures were developed and recommended to KINS for the regulatory evaluation of the safety issues related to the gas accumulation in the safety systems for the operating nuclear power plants in Korea[3].

3. ECCS Gas Accumulation Analysis of Cold Leg LBLOCA for Ulchin Units 3&4

The impact of gas accumulation in the ECCS of Ulchin Units 3&4 on the cold leg LBLOCA has been analyzed through sensitivity studies of the non-condensible gas content in the LPSI pump suction piping using RELAP5/MOD3.3 code[3]. The transport of the non-condensible gas through the LPSI suction piping has been analyzed for the non-condensible gas accumulation in the horizontal piping with gas accumulation between 2 and 15%. Figure 2 shows the gas transport analysis result for the 12% gas accumulation. As shown in Figure 2, less gas is accumulated as the gas transported to the downstream LPSI piping and as the elevation of the piping is lowered as expected. Figure 3 shows the gas void fraction of the LPSI pump due to the gas transport from the suction piping.

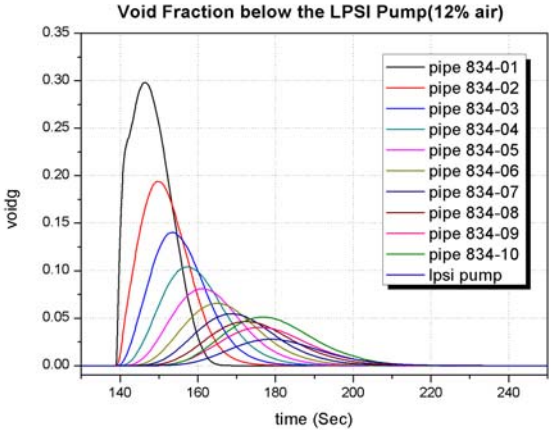

Figure 2. Gas Transport in the LPSI Suction Piping

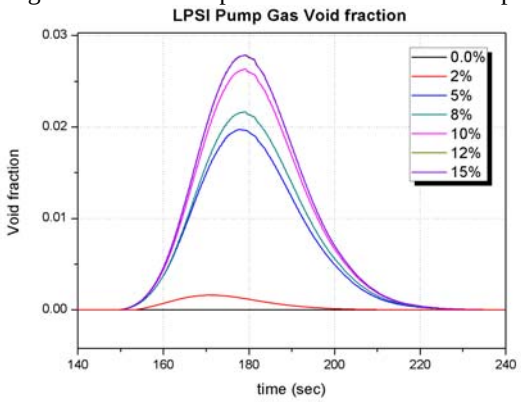

Figure 3. Gas Void Fraction of the LPSI Pump

Also, the pump performances and the impact on the pump discharge flow and pressure were analyzed. As the gas accumulation is increased the pump head and torque were reduced resulting in pump performance degradation. However, the influences of the gas accumulation on the maximum PCT and core cooling capability were not clearly seen for various content of gas accumulation due to the complexity in the heat transfer degradation phenomena due to non-condensible gas. It seems that the RELAP5/MOD3.3 qualitatively well predicts the gas transport phenomena in the ECCS piping and, however, its impact on the safety criteria of the LBLOCA should be evaluated through more detailed analysis.

4. Conclusions

USNRC regulatory evaluation methods and measures as well as the industry activities to resolve the safety issues of the accumulated gas in the safety systems of the operating nuclear reactors were reviewed. Also, the regulatory interfaces between USNRC and APS (Arizona Public Services) for PVNGS Units were investigated as a benchmark for OPR1000 plants. Similar regulatory evaluation methods and measures are expected to apply for the operating nuclear power plants in Korea as recommended to KINS in Reference 3 for the operating nuclear power plants in Korea. .

The influences of gas accumulation in the ECCS of Ulchin Units 3&4 were analytically evaluated and showed reasonable predictions for the gas transport, pump performance, and pump discharge flow and pressure for the gas accumulation in LPSI pump suction piping during the cold leg LBLOCA. However, more detailed evaluation for the influence on the maximum PCT is required due to complex phenomena of non-condensible gas in the reduction of the flow and degradation of the heat transfer. The validation of the gas transport model and analysis methodology of the gas accumulation is also required.

It is concluded that the regulatory evaluation methods and measures were required to resolve the issues related to potential gas accumulation in the safety systems of the operating nuclear power plants in Korea.

Acknowledgements

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