Performance Evaluation of RCS Leak Monitoring System for Ulchin Units 1 and 2

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1. Introduction

In order to apply the Leak-Before-Break(LBB) concept to the reactor coolant system(RCS) main loop piping, the capability of RCS leak monitoring system should be adequate in accordance with the regulatory requirements. In this paper, the RCS leak monitoring systems for Ulchin units 1&2 are evaluated to determine their compliance to the regulatory requirements as well as to suggest possible improvements.

2. Evaluation and Results

2.1 Regulatory Requirements

According to the standard review plan(SRP) 3.6.3, LBB evaluation procedures, if the leak monitoring systems conform to Regulatory Guide (hereafter R.G) 1.45, the application of LBB to the piping of reactor coolant system pressure boundary is permitted.

The main requirements in R.G 1.45 include that at least three separate detection methods should be employed; two of these methods should be the sump level and flow monitoring and the airborne particulate radioactivity monitoring. The third method may be selected from monitoring of condensate flow rate from air coolers or monitoring of airborne gaseous radioactivity. Humidity, temperature, or pressure monitoring of the containment atmosphere should be considered as alarms or indirect indication of leakage to the containment. The sensitivity and response time of each leakage detection system employed should be adequate to detect a leak rate or its equivalent of one gpm in less than one hour.

2.2 Design Status of Leak Monitoring Systems

Ulchin units 1&2 are equipped with the containment sump level monitor and containment airborne particulate/ gaseous radiation monitor as RCS leak monitoring systems.

2.2.1 Containment Sump Level Monitor

The containment sumps consist of 1 containment floor drain sump and 2 reactor cavity sumps. The sumps are located at the lowest point of the containment, and leakage from all sources eventually is collected in the sumps. However, indication of increasing sump levels can not be transmitted from the reactor cavity sumps to the control room level indicators and recorders because the level transmitters are not installed. Therefore, the amount and rate of leakage can not be determined for the reactor cavity sumps. The level increase above setpoint initiates an alarm in the control room.

2.2.2 Containment Airborne Particulate/Gaseous Radiation Monitor

The containment radiation monitoring system consists of a particulate, a gaseous and an iodine measurement channels on one skid. This system is designed to continuously monitor radioactivity inside the containment and to display in the main control room during normal operation. High radiation levels are alarmed, recorded and initiate containment purge isolation signal. Air sample is continuously drawn from the containment atmosphere, passed through a closed system to the monitoring in the auxiliary building, and returned back to the containment.

The detectable radioactivity ranges of radiation monitors for Ulchin units 1&2 are $10^{-6} \sim 10^{-1}$ μCi/cc and $10^{-7} \sim 10^{-4}$ Ci for gaseous and particulate, respectively.

2.2.3 Containment Humidity Detector

If the humidity increase due to a leakage is greater than the sensitivity range of humidity detector, this leakage could be detected. However, the containment humidity detector is not installed for Ulchin Units 1&2.

2.3 Evaluation of Leak Monitoring Systems

Provided in this section are the evaluation results for compliance of the leak detection capability to R.G 1.45 for Ulchin units 1&2.

2.3.1 Containment Sump Level Monitor

If the minimum detectable leakage by the sump level instruments is less than that required by R.G 1.45, the leak detection capability is acceptable. The minimum detectable leak rate is estimated based on the sensitivity of sump level monitoring instruments. The calculated minimum detectable leakages based on the sump level instrument uncertainty were 223.57 and 602.07 gallons which correspond to 3.73 and 10.03 gpm for Ulchin units 1&2, respectively. Accordingly, the leak monitoring capability for containment sump level monitor can be judged inadequate to detect the leakage of 1 gpm in less than one hour, required by R.G 1.45, for Ulchin 1&2.

2.3.2 Containment Airborne Particulate/Gaseous Radiation Monitor

The as-built radiation monitors should be sensitive enough to meet the recommendation given by R.G 1.45 as well as to detect the expected radioactivity level increase in case of 1 gpm leak rate for one hour. The detectable radioactivity ranges of gaseous radiation monitor for Ulchin units 1&2 is 10^{-6} ~ 10^{-1} μCi/cc, which meet the R.G 1.45 recommended detector sensitivity of 10^{-6} μCi/cc for gaseous activity. The detectable radioactivity ranges of particulate radiation monitor is 10^{-7} ~ 10^{-4} Ci, which can not be judged to meet the R.G 1.45 recommended detector sensitivity for particulate activity.

Accordingly, the radioactivity increase in the containment atmosphere was calculated in the case of 1 gpm leak rate for one hour using a model assuming 1% fuel defect for Ulchin units 1&2. Calculation results showed that radioactive nuclide activities increased to 1.120×10^{-3} μCi/cc for gaseous and 5.911×10^{-6} Ci for particulate, which are well above the minimum detectable radioactivity level of the radiation monitors in Ulchin units 1&2. Therefore, it is judged that the radiation monitors for Ulchin units 1&2 are capable of detecting 1 gpm leak rate.

2.4 Separation for Leak Monitoring Systems

According to R.G 1.45, at least 3 separate detection methods are required to detect the RCS leakage. However, the containment humidity detector is not installed and the containment airborne particulate monitor shares the air inlet piping with the containment airborne gaseous monitor on the same skid for Ulchin units 1&2. In the case of the air inlet piping failure, the function for both containment airborne particulate monitor and the containment airborne gaseous monitor will be lost simultaneously. Therefore, additional leak monitoring systems are required from licensing experience for Kori units 3&4, Yonggwang units 1&2 and OPR 1000.

A design change for the containment radiation monitor to meet R.G 1.45 requirements strictly may not be cost-effective because of a new containment penetration, cabling and space for installation of the radiation monitor. An alternative method could be to equip the RCS leak rate calculation program on the plant computer system, which has capabilities of detecting a small leakage and displaying leak rate continuously.

3. Conclusions

In summary, it was shown that the leak monitoring systems for Ulchin units 1&2 can meet the requirements for the leak detection capability of R.G 1.45 partially. Therefore, design improvement for containment sump level monitor and addition of containment humidity detector are required for the application of the LBB to the RCS main loop piping to exclude the structural influence due to a guillotine break.

However, to satisfy the separation requirement for the containment airborne particulate monitor and the containment airborne gaseous monitor based on Kori units 3&4 and Yonggwang 1&2 licensing experience and considering the radiation monitors can not detect 1 gpm leak rate actually because improvements in fuel cladding integrity and RCS chemistry controls have significantly reduced RCS radioactivity concentration, it is recommended an RCS leak rate calculation program be equipped on the plant computer system, which has high reliability on-line leakage calculation capability with continuous trend display.

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REFERENCES

[1] USNRC Regulatory Guide 1.45, Reactor Coolant Pressure Boundary Leakage Detection Systems, May 1973.
[2] Final Safety Analysis Reports for Ulchin Units 1&2.
[3] Michael R. Lindeburg, "Mechanical Engineering Review Manual," Seventh Edition, Professional Publications, Inc., 1984.
[4] S. J. Yune, et al., "Evaluation of RCS Leak Monitoring Systems for Kori Units 1&2," Proceedings of Korean Nuclear Society Spring Meeting, 2006.
[5] S. J. Yune, et al., "Evaluation for RCS Leak Detection Capability to Apply LBB Concept to Main Loop Piping for Yonggwang Units 1 and 2," Proceedings of Korean Nuclear Society Spring Meeting, 2007.