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Performance Evaluation of RCS Leak Detection System for Kori Units 3 and 4

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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 detection systems should be adequate in accordance with the regulatory requirements. In this paper, the RCS leak detection systems for Kori units 3&4 are evaluated to determine their compliance to the regulatory requirements as well as to improve the system.

2. Evaluation and Results

2.1 Regulatory Requirements

According to the standard review plan(SRP) 3.6.3, LBB evaluation procedures, if the leak detection 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 Detection Systems

Kori units 3&4 are equipped with the containment sump level monitor, containment airborne particulate/ gaseous radiation monitor, and containment humidity detector as RCS leak detection systems.

2.2.1 Containment Sump Level Monitor

The containment sump consists of 2 containment normal sumps, 1 reactor cavity sump, and 1 reactor drain tank sump. The sumps are located at the lowest point of the containment, and leakage from all sources eventually is collected in the sumps. Indication of increasing sump levels is transmitted from the sumps to the control room level indicators and recorders by means of the level transmitters. The level increase above setpoint initiates an alarm in the control room. The amount and rate of leakage can be determined using the sump level increase and the measured time interval.

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 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.

2.2.3 Containment Humidity Detector

The humidity increase resulting from leakage is detected by 3 temperature compensated humidity sensors for Kori units 3&4. For both units, the measured humidity level is indicated and alarmed in the control room.

2.3 Performance Evaluation of Leak Detection Systems

Provided in this section are the performance evaluation results for compliance of the leak detection capability to R.G 1.45 for Kori units 3&4.

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 leakage based on the sump level instrument uncertainty was 27.77 gallons, which corresponds to 0.47 gpm. Accordingly, the leak monitoring capability for Kori units 3&4 can be judged adequate to detect the leakage of 1 gpm in less than 1 hour, required by R.G 1.45.

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 radiation monitors for Kori units 3&4 are 10^{-6} ~ 10^{-1} µCi/cc and 10^{-9} ~ 10^{-4} µCi/cc for gaseous and particulate, respectively, which meet the R.G 1.45 recommended detector sensitivity of 10^{-6} µCi/cc for gaseous activity, 10^{-9} µCi/cc for particulate activity.

Also, the radioactivity increase in the containment atmosphere was calculated in the case of 1 gpm leak rate for 1 hour using a conservative model assuming 1% fuel defect for Kori units 3&4. Calculation results showed that radioactive nuclide activities increased to 1.503×10^{-5} µCi/cc for gaseous and 3.243×10^{-7} µCi/cc for particulate, which are well above the minimum detectable radioactivity level of the radiation monitors in Kori units 3&4. Therefore, it is judged that the radiation monitors for Kori units 3&4 are sensitive enough to detect 1 gpm leak rate.

2.3.3 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. By using the sensitivity of humidity detector (2%) and Psychrometric chart, it was calculated that 0.179 gpm leakage could be detected for Kori units 3&4. Therefore, the leak detection capability of the humidity detector is judged to be acceptable to the sensitivity requirement of R.G 1.45. However, the humidity level is influenced by several factors such as the direction of the wind, structure, temperature and pressure in containment, a quantitative evaluation of an indicated leakage rate may not represent the actual value, thus is recommended to be used as indirect device indicating the leakage occurrence.

2.4 Separation for Leak Detection Systems

According to R.G 1.45, at least 3 separate detection methods are required to detect the RCS leakage. However, the containment airborne particulate monitor shares the air inlet piping with the containment airborne gaseous monitor on the same skid for Kori units 3&4. In the case of the air inlet piping failure or loss of power, the function for both containment airborne particulate monitor and the containment airborne gaseous monitor will be lost simultaneously. Therefore, an additional leak detection system is required from licensing experience for Yonggwang units 1&2 and OPR 1000.

A design change 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 detection systems for Kori units 3&4 meet the requirements for the leak detection capability of R.G 1.45 except separation requirement for radiation monitor.

In order to satisfy the separation requirement for the containment airborne particulate monitor and the containment airborne gaseous monitor based on Yonggwang units 1&2 licensing experience, an RCS leak rate calculation program was equipped on the plant computer system, which has high reliability on-line leakage calculation capability with continuous trend display.

Therefore, necessary bases have been established for the application of the LBB to the RCS main loop piping to exclude the structural influence due to a guillotine break.

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