RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**80-8040**
SRP Section:	**05.02.05 - Reactor Coolant Pressure Boundary Leakage Detection**
Application Section:	**05.02.05**
Date of RAI Issued:	**07/16/2015**

Question No. 05.02.05-1

Leakage Detection Capability

10 CFR 52.47(a)(2) requires that a standard design certification applicant provide a description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished. RG 1.45, "Guidance on Monitoring and Responding to Reactor Coolant System Leakage," states that the functional requirements for leakage monitoring systems should include the detector response time. It also states that plants should use multiple instrument locations to ensure that the transport delay time of the leakage effluent from its source to the detector will yield an acceptable overall system response time.

In DCD Tier 2, Section 5.2.5.1.1, "Unidentified Leakage," and TS LCO 3.4.14, “RCS Leakage Detection Instrumentation,” the applicant identified the following leakage detection methods: containment sump level, containment airborne particulate radioactivity, and containment atmosphere humidity. DCD Tier 2, Sections 5.2.5.1.1.2 and 5.2.5.1.1.3 state that containment sump level and flow method and containment air particulate monitoring can detect RCS leakage of 0.5 gpm within one hour at full power. Such information is not provided regarding the containment atmosphere humidity monitoring systems. Also missing is information about the number of these detectors and their location.

The applicant is requested to provide the following information:

a) Clarify whether the containment atmosphere humidity monitoring also has the capability to detect reactor coolant system (RCS) leakage of 0.5 gpm within one hour. Please identify how many humidity detectors there are in the containment and where they are located. Also, provide the correlation between the RCS leakage and containment atmosphere humidity with respect to time to demonstrate the capability of detecting 0.5 gpm within one hour.

b) Identify how many containment air particulate monitoring detectors there are in the containment and where they are located. Also, provide the correlation between the RCS leakage and containment air particulate radiation level with respect to time to demonstrate the capability of detecting 0.5 gpm within one hour. State the assumption being used for the primary coolant radioactivity concentration to derive the correlation. It should be noted that RG 1.45 states that the analysis of the capabilities of leakage monitoring systems that measure radioactivity should use a realistic primary coolant radioactivity concentration assumption consistent with normal plant operations (as opposed to the maximum concentration permitted by plant technical specifications or used in accident analysis).

Response

a) Humidity sensor capability:

An increase in humidity of the containment atmosphere would indicate release of water vapor to the containment. Dew point temperature measurements can thus be used to monitor humidity levels of the containment atmosphere as an indicator of potential RCS leakage. Since the humidity level is influenced by several factors, the sensitivity or accuracy of the measured value is not comparable to that of the sump level measurement or the containment radiation particulate measurement. Therefore humidity level monitoring is considered most useful as an indirect alarm or indication to alert the operator to a potential problem. This is in accordance with Regulatory position 2.3 of Regulatory Guide 1.45, even if it does not have the capabilities specified in Regulatory position 2.2. This view also is supported by NUREG/CR-6861, as well as ISA-S67.03. Significant improvements in leak detection capability have been made in recent years. A system such "FLUS" by F-ANP could detect leakage much lower than 0.5 gpm. However a system such as FLUS is not part of the current APR1400 design.

To clarify the capability of the humidity sensor provided in the APR1400 design used to detect leakage, the following statement will be added after the list on page 5.2-39 before the paragraph starting with "additionally, ~ ." in the Subsection 5.2.5.1.1, "Unidentified Leakage".

DCD Tier 2, Subsection 5.2.5.1.1:

Current description: None

To be added as follows: The humidity sensor is designed to indicate a sudden and significant increase of humidity level by annunciating an alarm in the MCR due to unidentified leakage.

Quantity and location of humidity sensor

Four (4) humidity sensors are provided in the containment and each sensor is installed at the intake of each of the four (4) reactor containment fan coolers (RCFCs). This is to take advantage of maximized air mixing for representative sample of containment air. An RCFC is located in each quadrant of the containment operating area of the containment building.

Correlation between the unidentified RCS leakage and the humidity sensor

It is explained above that the accuracy and sensitivity of the humidity sensor used in the APR1400 design is not sufficient enough to establish a quantitative correlation between the unidentified RCS leakage and the humidity sensor to detect the level of detail of 0.5 gpm within one hour. This humidity sensor is intended only to detect a significant increase of humidity level resulting from an unidentified source of RCS leakage by providing an MCR alarm when such a leak occurs.

b) Quantity and location of containment air particulate monitoring detector

Two (2) radiation monitors (RE-039A, 040B) are provided and the sample line inlet for these radiation monitors is located on the operating level between two RCFC air intakes for a representative sample of containment air.

Correlation between the unidentified RCS leakage and the containment air particulate radiation level

There are two containment air monitors which provide detecting particulate, iodine and noble gas activities in containment atmosphere. These monitors continuously draw containment air in a closed system. The containment air passes through a separate sample line and a containment penetration. Sampled air is returned to the containment atmosphere. The particulate detector channel serve as Reactor Coolant Pressure Boundary (RCPB) leak detection in accordance with RG 1.45.

The time to detect RCS unidentified leakage of 0.5 gpm is the sum of (1) the air travel time from the location of leakage to the location of air suction nozzles of the monitor, which can be assumed to be equal to the time for the airborne activity vaporized at the leak point is mixed with containment air homogeneously, (2) the time for the airborne activity to reach lowest range of the detector assuming that the containment air is mixed homogeneously, and (3) the response time of the detector. Since the Containment Air Monitors are operated continuously and the response time of the radiation monitors are relatively short compared to 1 hour, the response time can be ignored in the calculation.

The air travel time or time for the airborne activity to be mixed with containment air homogeneously can be simply calculated using the containment free volume and the air flow rate by the Containment Building HVAC System as follows

$$\text{Air Mixing Time (min)} = V_{ctmt}/F_{ctmt}$$

Where,

V_{ctmt} : Containment free volume of APR1400 = (3.128E+06 ft^3)

F_{ctmt} : Containment HVAC Flow Rate (ft^3/min) = (3.96E+05 ft^3/min)

The containment HVAC flow rate (F_{ctmt}) of 3.98E+05 ft^3/min is calculated using the following air flow sources:

Air Flow Sources	Flow Rate [cfm]
Reactor Containment Fan Cooler	2.0E+05
Annulus Area Recir. Fan	3.6E+04
Reactor Cavity AHU	4.0E+04
S/G Enclosure Recir. Fan	1.2E+05
Total	3.96E+05

Therefore, it is expected to take 7.89 minutes for the airborne activity leaked from the RCS to be homogeneously mixed with the entire containment volume.

The detection ranges for each channel of Containment Air Monitor that are commercially available in the industry are as follows;

- 3.7E-05 ~ 3.7E+01 Bq/cm^3 for Particulate
- 3.7E-05 ~ 3.7E+01 Bq/cm^3 for Iodine
- 3.7E-02 ~ 3.7E+05 Bq/cm^3 for Noble Gas

In accordance with RG 1.45, the only channel required to use to detect RCS unidentified leakage is particulate. Therefore, only the particulate channel is considered in this calculation, even though the monitors are capable of detecting three types of radioacitvities.

The time for the airborne activity to reach lowest range of the detector for particulate can be calculated assuming that the airborne activity is mixed with the containment air instantaneously. The containment airborne concentration of each nuclide can be derived by solving the following differential equation:

$$V_{ctmt}\frac{dC_{ctmt,i}(t)}{dt}=R_i-\lambda_{eff}\cdot C_{ctmt,i}(t) \qquad \text{(Eq. 1)}$$

Where,

$C_{ctmt,i}(t)$	:	Airborne activity of particulates in containment atmosphere at time t (Bq/cm^3)
R_i	:	Leak rate of activity from RCS to containment atmosphere (Bq/hr)
λ_{eff}	:	Effective removal rate in containment by decay and purge (hr^{-1})
V_{ctmt}	:	Containment volume (cm^3)

Assuming that $C_{ctmt,i}(0)$ is initial airborne activity in the containment atmosphere, which is assumed to be zero, the solution of Eq. (1) becomes:

$$C_{ctmt,i}(t)=\frac{R_i}{\lambda_{eff}\cdot V_{ctmt}}\cdot\left(1-\exp\left(-\lambda_{eff}\cdot t\right)\right)+C_{ctmt,i}(0)\cdot\exp(-\lambda_{eff}\cdot t) \quad \text{(Eq. 2)}$$

The leak rate (R_i) and removal rate (λ_{eff}) is calculated using Eq. (3) and Eq. (4) with RCS coolant leak rate (L), nuclide concentration in RCS ($_{Crcs,i}$), partition factor (PF) of the leaked coolant to containment atmosphere, filter efficiency of containment purge system (e_f), recirculation rate of containment purge system (f_r), and Containment purge flow rate (Q_{pg}).

$$R_i=L\cdot C_{rcs,i}\cdot PF \quad \text{(Eq. 3)}$$

$$\lambda_{eff}=\lambda_i+(1.0-(1.0-e_f)\cdot f_r)\cdot Q_{pg}/V_{ctmt} \quad \text{(Eq. 4)}$$

In order to perform a conservative evaluation, it is assumed that the reactor coolant contains the 'Expected' radioactivity concentration determined based on ANSI/ANS-18.1-1999, "Radioactive Source Terms for Normal Operation of Light Water Reactors", 1999.

Partition factors (PF) defined in NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors", Rev.1, April, 1985, are used in the calculation to minimize the vaporization of the liquid leaked from the RCS as follows :

- 1.0 for noble gases
- 0.01 for halogens
- 0.005 for particulates

With respect to evaluating the capability to detect RCS unidentified leakage, it is more conservative to assume that the Containment Purge System is in operation. The reactor containment building low volume purge exhaust ACU (air cleaning unit) has HEPA and charcoal filters. The flow rate of the low volume purge system is 1,500 cfm and the removal efficiency of the exhaust ACU for particulate and halogens is assumed to be 99.0%. It is assumed that there is no recirculation.

As a result, the time for the airborne activity to reach lowest range of the detector is calculated to be 1.8 minutes. Therefore, when the time of 7.89 minutes for airborne activity to be mixed with containment atmosphere is added, the total time to detect RCS unidentified leakage of 0.5 gpm is 9.69 minutes, which complies with the 1 hour requirement in RG 1.45. .

Impact on DCD

DCD Tier 2, Subsection 5.2.5.1.1 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Reports.

a. Containment sump level

b. Containment airborne particulate radioactivity

c. Containment atmosphere humidity

The humidity sensor is designed to indicate a sudden and significant increase of humidity level by annunciating an alarm in the MCR due to unidentified leakage.

Additionally, temperature and pressure monitoring of the containment atmosphere are used for alarms and indirect indication of leakage to the containment. They do not quantify the reactor coolant leakage.

5.2.5.1.1.1 Inventory Methods

Total leakage from the RCS can be determined by net level changes in the pressurizer and volume control tank over a measured period since the RCS and the chemical and volume control system represent a closed-loop system. Since the letdown flow and the reactor coolant pump seal controlled bleed off flow are collected and recycled back into the RCS by the CVCS, the net inventory in the RCS and CVCS under normal operating conditions is constant. Transient changes in letdown flow rate or RCS inventory are accommodated by changes in the volume control tank level. By monitoring reactor drain tank and equipment drain tank level changes within a given test period, the identified RCS leakage value can be determined. Subtracting the identified leakage value from the total leakage value (corrected for any RCS contraction) results in the RCS unidentified leak rate.

Makeup flow rate also provides a means of detecting leakage from the RCS through measurement of the net amount of makeup flow to the system. The net makeup to the system under no-leakage steady-state conditions is zero. The net makeup flow rate and the total makeup flow rate from the CVCS are continuously monitored and recorded. Analysis of the total makeup flow rate over a period of steady-state operation can determine the abnormal leakage. An increasing trend in the amount of required makeup indicates that the abnormal leakage exists and is increasing in rate. Sudden leakage induces a step increase in the amount of makeup, which does not decrease again. Sudden leakage would be the case in a purely transient condition.

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Question No. 05.02.05-2

Initial Testing Program

10 CFR 52.47(a)(2) requires that a standard design certification applicant provide a description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will accomplished.

RG 1.68, Appendix A, "Initial Test Program," provides guidance on the initial testing program for reactor coolant system (RCS) leakage detection, which includes the following relevant tests:

- The reactor coolant system leak detection systems;
- The primary to secondary leakage detection system through steam generators;
- The verification of the capability of RCS leakage detection instrumentations;
- Verification of the reactor coolant system leak rates being within specified limits;
- Calibration of the instrumentation being used for reactor coolant leak detection systems;
- The operation of computer programs used to calculate reactor coolant system leakage rates.

DCD Tier 2, Section 14.2.12.1.134, "Leakage Detection System Test," demonstrates the operation of the various leakage detection systems. It will test the sump level switches and flow monitors, airborne radioactivity monitor, and/or atmosphere humidity monitors using simulated signals. Subsection 5.0/5.1 “Acceptance Criteria” of this test states that “the leakage detection system operates as described in Subsection 5.2.6.1.”

However, the staff can’t find the referenced Subsection 5.2.6.1 in the DCD. Also, it is not clear that the initial tests include the verification of the capability of RCS leakage detection instrumentations.

The applicant is requested to provide Subsection 5.2.6.1 in the DCD Tier 2 and demonstrate that the proposed initial test program has adequately addressed the tests identified in RG 1.68, Appendix A.

Response

Regarding Subsection 5.0/5.1, “Acceptance Criteria,” of Section 14.2.12.1.134, “Leakage Detection System Test”, there is an editorial error on the referenced Subsection. The Subsection 5.0/5.1 will be revised as follows:

DCD Tier 2, Subsection 5.0/5.1 of Section 14.2.12.1.134:

Current description	:	The leakage detection system operates as described in Subsection 5.2.6.1
To be revised as follows	:	The leakage detection system operates as described in Subsection 5.2.5.1.

Subsection 5.2.5.1 “Leakage Detection Method” provides a description of the detection methods and operation of the unidentified leakage and identified leakage detection system. The unidentified leakage detection system will be tested in accordance with Section 14.2.12.1.134, “Leakage Detection System Test” including calibration and verification of the capability of leakage detection instrumentation.

The RCS leak rate measurements for unidentified leakage and identified leakage will be tested in accordance with Section 14.2.12.1.57, “Pre-Core Reactor Coolant System Leak Rate Measurement” and Section 14.2.12.2.7, “Post-Core Reactor Coolant System Leak Rate Measurement”. These tests are performed for the verification of RCS leak rates being within the limits described in Subsection 5.2.5, and include the operation of computer programs used to calculate reactor coolant system leakage rates, if applicable.

The primary to secondary leakage detection system through the steam generators will be tested in accordance with Section 14.2.12.1.106, “Process and Effluent Radiological Monitoring System (PERMS) Test” including the test described in of Appendix 11B, “Primary to Secondary leakage Detection”. The N-16 radiation monitors for detection of primary to secondary leakage are described in Subsection 11.5.2.2.m, “Gaseous PERMS”.

Impact on DCD

DCD Tier 2, Subsection 5.0/5.1 of Section 14.2.12.1.134 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Reports.

14.2.12.1.134 Leakage Detection System Test

1.0 OBJECTIVE

1.1 To demonstrate the operation of the various leakage detection system installed inside and outside reactor containment

2.0 PREREQUISITES

2.1 Construction activities on the various sumps have been completed.

2.2 Leakage detection system instrumentation is available and calibrated.

2.3 Support systems required for operation of the leakage detection system are complete and operational.

3.0 TEST METHOD

3.1 Test the sump level switches and flow monitors, airborne radioactivity monitors, and/or atmosphere humidity monitors using simulated signals.

4.0 DATA REQUIRED

4.1 Alarms, indications, and control logic for sumps instrumentation

5.0 ACCEPTANCE CRITERIA

5.1 The leakage detection system operates as described in Subsection ~~5.2.6.1.~~

5.2.5.1