REVISED 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.:	**207-8247**
SRP Section:	**12.02 - Radiation Sources**
Application Section:	**12.2**
Date of RAI Issue:	**09/11/2015**

Question No. 12.02-15

10 CFR 52.47(a)(5) requires that the FSAR contain the kinds and quantities of radioactive materials expected to be produced in the operation and the means for controlling and limiting radioactive effluents and radiation exposures within the limits set forth in 10 CFR 20.

SRP Section 12.2 indicates that the FSAR should contain the methods, models, and assumptions for the sources provided within FSAR Section 12.2.

As a result of an FSAR Chapter 12 source term audit (see ML15208A492 for audit plan), the staff identified several assumptions made in the Chapter 12 source terms that should be included in the FSAR, but are not.

1. For all filters and demineralizers for which source terms are provided in FSAR Chapter 12, please include the replacement frequencies assumed in developing the source terms in FSAR Chapter 12, unless already provided (for example, the assumed replacement frequency used in developing the source terms for the steam generator blowdown prefilter, post-filter, and demineralizer and spent pool cleaning filter and demineralizer should be included in the FSAR).

2. Please include the basic assumptions used for developing the source terms for the solid radwaste system tanks in FSAR Table 12.2-22 in the FSAR. For example, for the spent resin long-term storage tank, indicate that the spent resin long-term storage tank provided in FSAR Table 12.2-22 is based on storing ten years of CVCS system resins.

Response – (Rev. 2)

1. The buildup times assumed in developing the source terms for the filters and the demineralizers for the steam generator blowdown system, condensate polishing system, and spent fuel pool cooling and cleanup system are as follows:

SGBDS:

FSAR Subsection 12.2.1.1.5.2 describes the major assumptions and parameters for the development of the source terms for SGBDS filters and demineralizers. A sentence will be inserted at the end of the subsection to include the radioactivity accumulation as follows:

"The nuclide accumulation in the SGBD pre-filter, post-filters, and mixed beds are calculated based on radioactive crud and nuclide buildup of 6 months of processing."

It should be noted that this approach for radioactivity accumulation is conservative and bounding. The replacement of filters and resin are determined by system operation and are likely to be based on differential pressure drops; but the source terms for the filters and resin are expected to be lower because of conservative basis built into the calculation model.

CPS:

FSAR Subsection 12.2.1.1.5.3 describes the major assumptions and parameters for the development of the source terms for CPS Cation and Mixed Bed demineralizers. A sentence will be inserted at the end of the subsection to include the radioactivity accumulation as follows:

"The nuclide accumulation in the CPS cation bed and the mixed bed are based on radioactivity buildup at the end of their corresponding processing cycle. The nuclide accumulation times for the cation bed and the mixed bed ion exchangers are about 3 days and 30 days, respectively. The cation and mixed bed ion exchange resins are then replaced at the end of the processing times accordingly."

FSAR Subsection 10.4.6.5 discusses the provisions of pressure and differential indicators for operation of the cation and mixed beds. The replacement of resin is determined by system operation and is likely to be based on differential pressure drops. Based on industry operating experience, the spent resin is expected to contain a low level of contamination, due to design primary-to-secondary leakage. The calculation basis includes the use of design basis primary source term (0.25% failed fuel), a primary to secondary leakage rate of 0.6 gallons per minute is assumed. Hence the calculation model for the nuclide accumulation is considered conservative.

The design of the APR1400 does not include any provisions for regeneration of CP spent resin; and the SWMS does not include any piping connections for receipt of CP spent resin. The CP spent resin is transferred to one of the two CP spent resin holding tanks, from which the spent resin is sampled and analyzed for radiological contamination. Because the APR1400 design includes N-16 radiation monitors, and the blowdown radiation detection instruments to continuously monitor the potential radiological contamination of the main steam and the secondary water. In the event of SG leakage, the instruments will initiate alarms at the predetermined setpoint and actions to close the main steam valves will be taken. This design minimizes and/or prevents contamination of the condensate and the CP resin. The condensate and the CP resin are therefore considered to have a very low level of contamination, if any. When the CP spent resin is confirmed through the sample analysis to have

contamination below the specified limits, the CP spent resin is then transferred to shipping containers for offsite regeneration, treatment, and/or disposal.

In the unlikely event that the contamination of the CP spent resin is significant and/or above the specification limit, the spent resin in packaged into High Integrity Containers (HICs) for disposal as low activity radioactive solid waste. A COL item (COL 10.4(12)) is added for the COL applicant to provide temporary shielding, if required, and mobile equipment, including the spent resin fill-head, for packaging of the spent resin, provisions of temporary storage, and shipment of contaminated spent resin for off-site treatment and disposal.

DCD Tier 2, Subsection 10.4.6.2.3 will be revised.

As indicated in Figure 12.3-17, the radiation zone at EL. 73'-0" is designated as Zone 2 and this area contains CPS demineralizers and the spent resin hold tanks. Shielding is provided around this area. KHNP will update Figure 12.3-17 to indicate the locations of the CPS demineralizers and the spent resin hold tanks in this area.

SFPCCS,

FSAR Subsection 12.2.1.2.4 describes the major assumptions and parameters for the development of the source terms for SFPCCS filters and demineralizers. A sentence will be inserted at the end of the subsection to include the radioactivity accumulation as follows:

"The source terms for the SFP demineralizers and filters are provided in Table12.2-17a. The activities are integrated over the cleanup time for normal (expected) operation and are determined to be at maximum at about 265 hours and 290 hours for the SFP filter and demineralizer respectively, after which time the source terms decrease due to decay of short half-life nuclides."

FSAR Subsection 9.1.3.2.2.2 describes that the cleanup operation is intermittent and is manually actuated after transfer of the irradiated fuel to the spent fuel pool. FSAR Subsection 9.1.3.5.2 describes the provisions of the pressure differential instruments to control the cleanup operation. Hence, the replacement of filters and resin is determined by system operation and is likely to be based on differential pressure drops. The source terms for the filter and resin thus analyzed are expected to be conservative because of the conservative assumptions built into the calculation model and are independent of the replacement frequency.

2. FSAR Subsection 12.2.1.4, 2nd paragraph on Page 12.2-10, describes SWMS source terms for the spent resin long-term storage tank and the low-activity spent resin storage tank will be revised as follows:

"Solid waste management system (SWMS) source terms are provided in Table 12.2-22. Source terms for the spent resin long-term storage tank are calculated based on a maximum of 10 years of cumulative radioactive resin batches from the CVCS demineralizers with reduced decay time for subsequent resin batches.

Source terms for the LWMS demineralizers are presented in Table 12.2-21, based on a processing time of 1 year. The source terms for the low-activity spent resin tank (LASRT) in Table 12.2-22 are calculated using the source term for the LWMS spent resin and multiplying by a factor of 3 for conservative of shielding design. Since the LASRT is filled with resins from the LWMS, SGBD, and SFPCCS for 1 year and the source terms for the LWMS are highest, it is conservative that the LASRT is only filled with LWMS resin."

In addition, the following footnotes will be added to Table 12.2-22.

(1) *Source terms for the spent resin long-term storage tank are calculated based on a maximum of 10 years of cumulative radioactive resin batches from the CVCS demineralizers with decay.*

(2) *Source terms for the low-activity spent resin storage tank are calculated using the source term for LWMS spent resin and multiplying by a factor of 3 for conservative shielding design.*

Impact on DCD

DCD section 12.2.1, 10.4.6.2.3, and Figure 12.3-17 will be revised as indicated in the Attachment 1, 2, and 3.

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 Report.

e. Boric acid concentrator

The maximum values for BAC radionuclide inventories are presented in Table 12.2-14.

The nuclide accumulation in the SGBDS pre-filter, post-filters, and the mixed beds are calculated based on radioactive crud and nuclide buildup of 6 months of processing.

The total radioactivity inventories in the BAC package are based on a concentration factor of 100.

12.2.1.1.5.2 Steam Generator Blowdown System

Radiation sources in the steam generator blowdown system (SGBDS) are shown in Table 12.2-18. The sources are based on the assumed design basis primary-to-secondary (PTS) leakage rate and the assumed fuel defect percentage described in Subsection 12.2.1.1.3. The blowdown rate is assumed to be 0.2 percent of the maximum steaming rate.

12.2.1.1.5.3 Condensate Polishing System

Radiation sources in the condensate polishing system (CPS) are shown in Table 12.2-18. The sources are based on the design basis PTS leakage and the assumed fuel defect percentage described in Subsection 12.2.1.1.3. It is assumed that 65 percent of the condensate flows through the CPS and that one out of six CPS demineralizers is used to process the condensate during normal operation.

12.2.1.1.6 Gamma Sources of Irradiated Components

The components in the reactor vessel are irradiated by the fission neutrons during the core power operation and are activated. The in-core instrument (ICI) assembly, which consists of five rhodium detectors, one background detector, one core-exit thermocouple, and a central member assembly, is enclosed in a protective sheath. Activated gamma sources of the irradiated ICI assembly are estimated assuming 6 years of irradiation. The activated gamma sources of the irradiated control element assembly (CEA) and the irradiated neutron source assembly (NSA) are estimated assuming 10 years of irradiation. In CEA, the neutron absorbing material is B_4C and the cladding material is Inconel 625. The NSA contains the primary neutron source of Cf^{252} and the secondary neutron source of Sb-Be. The activated gamma source of the irradiated surveillance capsule assembly (SCA) is

The nuclide accumulation in the CPS cation bed and the mixed bed are based on radioactivity buildup at the end of their corresponding processing cycle. The nuclide accumulation times for the cation bed and the mixed bed ion exchangers are about 3 days and 30 days, respectively. The cation and mixed bed ion exchange resins are then replaced at the end of the processing times accordingly.

reactor coolant equilibrium concentrations presented in Table 12.2-5. The SFP activities are subsequently reduced by decay during refueling as well as by operation of the SFPCCS.

There is no contribution from defective fuel elements because of low power and temperature during plant shutdown operations.

Dimensions and parameters of the radiation sources in auxiliary building used in the shielding analyses are listed in Table 12.2-25.

12.2.1.3 Turbine Generator Building

Radiation sources in the turbine generator building occur in the condensate polishing system (CPS) due to the design basis PTS leakage rate in the steam generator. Activity levels for all turbine generator building related sources are summarized in Table 12.2-18. The activities provided in Table 12.2-18 are based on normal operation reactor coolant activity levels and PTS leakage conditions. Radionuclide removal efficiencies of demineralizers in the CPS are assumed to be consistent with the guidance in NUREG-0017 (Reference 1).

12.2.1.4 Compound Building

Radioactive sources in the radwaste system components include fission and activation radionuclides produced in the core and in the reactor coolant. The level of radioactivity is dependent on the components and operating parameters of the particular radwaste system.

Gaseous radwaste system (GRS) source terms are provided in Table 12.2-19. Radiation sources for each component of the GRS are calculated using the shielding basis equilibrium reactor coolant radionuclide concentrations provided in Table 12.2-5, which are based on an assumed 0.25 percent fuel defect. Activity buildup on the process gas charcoal beds is calculated assuming maximum design basis holdup times for noble gases in accordance with NUREG-0017.

The source terms for LWMS tanks are provided in Table 12.2-20 and for the other LWMS processing equipment in Table 12.2-21. Source terms for the equipment waste tank (EWT) and floor drain tank (FDT) are calculated using reactor coolant equilibrium radionuclide

The source terms for the SFP demineralizers and filters are provided in Table12.2-17a. The activities are integrated over the cleanup time for normal (expected) operation and are determined to be at maximum at about 265 hours and 290 hours for the SFP filter and demineralizer respectively, after which time the source terms decrease due to decay of short half-life nuclides.

concentrations presented in Table 12.2-5 and the activity fractions in Table 11.2-2. Radionuclide concentrations in the LWMS are determined using the DIJESTER Code (Reference 2). The accumulation and decay of radionuclides in the LWMS can be modeled using this code.

The activities of LWMS demineralizers are calculated using an activity buildup and decay model. The calculation applies the process flow rates provided in Table 11.2-2, and the process fluid activity levels provided in Table 12.2-20. The demineralizer resin is assumed to have a service life of 1 year. Although the service life of filters and resins in the LWMS may vary according to operating conditions, for radiation protection purposes, they are replaced based on the source term strength to provide reasonable assurance that occupational exposures associated with radwaste system operations remain ALARA.

~~Solid waste management system (SWMS) source terms are provided in Table 12.2-22. Source terms for the spent resin long-term storage tank are calculated based on the activity of CVCS demineralizer resins presented in Table 12.2-11. Source terms for the low-activity spent resin storage tank are calculated based on the activity of LWMS demineralizer resins presented in Table 12.2-21.~~

Dimensions and parameters of the radiation sources in compound building used in the shielding analyses are listed in Table 12.2-25.

12.2.1.5 Sources Resulting from Design Basis Accidents

Design parameters and source terms for design basis accidents (DBAs) are addressed in Chapter 15.

12.2.1.6 Stored Radioactivity

The holdup tanks, reactor makeup water tanks (RMWTs), and boric acid storage tanks (BASTs) are the principal sources of activity outside the plant buildings. The surface dose rate of these tanks is designed so that it does not exceed 2.5 μSv/hr. Administrative controls are in place to prevent personnel from occupying the immediate vicinity of the outside tanks.

Solid waste management system (SWMS) source terms are provided in Table 12.2-22. Source terms for the spent resin long-term storage tank are calculated based on 10 years of cumulative radioactive resin batches from the CVCS demineralizers with decay.
Source terms for the LWMS demineralizers are presented in Table 12.2-21, based on a processing time of 1 year. The source terms for the low-activity spent resin tank (LASRT) in Table 12.2-22 are calculated using the source term for the LWMS spent resin and multiplying by a factor of 3 for conservatism in the shielding design. Since the LASRT is filled with resins from the LWMS, SGBD, and SFPCCS for 1 year and the source terms for the LWMS are highest, it is conservative that the LASRT is only filled with LWMS resin.

Table 12.2-22

Solid Radwaste System Tank Source Terms (Bq)

Nuclide	Spent Resin Long-Term Storage Tank 1)	Low-Activity Spent Resin Tank 2)
Na-24	7.01E+11	7.16E+10
Cr-51	9.49E+12	1.86E+11
Mn-54	1.45E+13	2.37E+10
Fe-55	3.40E+13	1.79E+10
Co-58	8.28E+12	6.60E+10
Fe-59	3.34E+11	4.20E+09
Co-60	2.38E+13	7.90E+09
Zn-65	3.57E+12	7.53E+09
Br-84	2.73E+09	3.46E+08
Rb-88	1.15E+11	2.27E+10
Sr-89	1.01E+12	1.16E+10
Y-89m	0.00E+00	1.16E+06
Sr-90	3.96E+12	8.23E+08
Y-90	0.00E+00	4.97E+08
Sr-91	1.20E+10	1.23E+09
Y-91m	9.40E+07	7.83E+08
Y-91	1.63E+07	1.84E+09
Y-93	3.80E+06	3.10E+07
Zr-93	0.00E+00	3.13E-01
Zr-95	6.34E+11	5.56E+09
Nb-95m	0.00E+00	5.63E+07
Nb-95	1.10E+11	2.25E+09
Mo-99	4.81E+12	4.37E+11
Tc-99m	2.50E+11	4.03E+11
Tc-99	0.00E+00	2.33E+04
Ru-103	4.32E+10	6.10E+08
Rh-103m	0.00E+00	6.07E+08
Ru-106	2.01E+11	2.77E+09
Rh-106	0.00E+00	2.77E+09
Ag-110m	9.29E+12	1.92E+10
Ag-110	0.00E+00	2.50E+08
Te-129m	1.31E+12	2.05E+10
Te-129	1.92E+09	1.32E+10
I-129	0.00E+00	1.03E+01
Te-131m	2.12E+11	2.20E+10
Te-131	1.21E+09	4.10E+09
I-131	4.04E+11	6.61E+12
Te-132	4.04E+12	3.37E+11
I-132	4.04E+11	3.78E+11
I-133	1.92E+13	1.95E+12
I-134	9.30E+10	1.08E+10
Cs-134	1.20E+15	1.32E+12
I-135	3.54E+12	3.58E+11
Cs-136	2.34E+12	1.45E+11
Cs-137	4.60E+15	1.53E+12
Ba-137m	4.60E+15	1.43E+12
Ba-140	3.21E+11	1.23E+10
La-140	1.40E+10	1.07E+10
Ce-141	3.11E+10	5.23E+08
Ce-143	3.51E+09	3.50E+08
Pr-143	0.00E+00	1.01E+08
Ce-144	9.18E+11	1.66E+09
Pr-144	0.00E+00	1.65E+09
W-187	6.01E+10	6.07E+09
Np-239	1.30E+11	1.18E+10

1) Source terms for the spent resin long-term storage tank are calculated based on a maximum of 10 years of cumulative radioactive resin batches from the CVCS demineralizers with decay.

2) Source terms for the low-activity spent resin storage tank are calculated using the source term for LWMS spent resin and multiplying by a factor of 3 for conservative shielding design.

Table 1.8-2 (17 of 29)

Item No.	Description
COL 10.4(1)	The COL applicant is to establish operational procedures and maintenance programs for leak detection and contamination control
COL 10.4(2)	The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations
COL 10.4(3)	The COL applicant is to provide the location and design of the cooling tower, basin, and CW pump house
COL 10.4(4)	The COL applicant is to provide elevation drawings
COL 10.4(5)	The COL applicant is to address the design features for the prevention of contamination
COL 10.4(6)	The COL applicant is to provide operating and maintenance procedures for the following items in accordance with NUREG-0927 and a milestone schedule for implementation of the procedures.
COL 10.4(7)	The COL applicant is to describe the nitrogen or equivalent system design for SG drain
COL 10.4(8)	The COL applicant is to prepare the Site Radiological Environmental Monitoring Program
COL 10.4(9)	The COL applicant is to determine the wet bulb temperature correction factor to account for potential interference and recirculation effects
COL 11.2(1)	The COL applicant is to prepare the site-specific ODCM in accordance with NEI 07-09A.
COL 11.2(2)	The COL applicant is to prepare operational procedures and programs related to operations, inspection, calibration, and maintenance of the contamination control program.
COL 11.2(3)	The COL applicant is to determine whether contaminated laundry is sent to an offsite facility for cleaning or for disposal.
COL 11.2(4)	The COL applicant is to prepare and provide the P&IDs.
COL 11.2(5)	The COL applicant is to perform a site-specific cost-benefit analysis following the guidance in the regulatory requirements of NRC RG 1.110.
COL 11.2(6)	The COL applicant is to provide reasonable assurance that the mobile or temporary equipment and interconnections to plant systems conform with the regulatory requirements and guidance of 10 CFR 50.34a, 10 CFR 20.1406, NRC RG 1.143, and ANSI/ANS 40.37.
COL 11.2(7)	The COL applicant is to develop the procedure for the collection and shipment of mixed wastes, if and when they are generated, for offsite treatment. The generation of mixed liquid wastes is minimized by process control and the controlled use of hazardous chemicals.
COL 11.2(8)	The COL applicant is to develop the interface design and provide the site-specific information for the LWMS effluent discharge, including radioactive release points, effluent temperature, the design (type, shape, and size) of flow orifices, and the sampling requirements following the guidance of NRC RG 1.21 and RG 4.15 and the standards incorporated therein by reference.

COL 10.4(12) The COL applicant is responsible for provisions of temporary shielding, if required, and mobile equipment, including spent resin fill-head for packaging of the contaminated spent resin, provisions of temporary storage, and shipment of packaged contaminated CPS spent resin for off-site treatment and/or disposal.

mixing and holding tank is immediately returned to each ion exchanger vessel. The spent resin holding tanks hold spent resin until it is sampled and prepared for transport offsite. Spent resin is normally nonradioactive, so it does not normally require any special handling method. ~~When the resin is radioactively contaminated in a vessel, temporary shielding is installed, if required. Radioactive resin is transferred from the spent resin holding tank to the radwaste treatment area for waste management.~~

A tube leak detection system is provided to permit sampling of the condensate in the condenser hotwell as described in Subsection 9.3.2. If circulating water inleakage occurs, this design feature helps to identify which tube bundle has sustained the leakage. When condenser tube leakage exceeds the design value for the CPS, the affected condenser hotwell is manually isolated by closing the motor-operated hotwell discharge valve. Plant power is reduced as necessary. The waterbox is then drained and the affected tubes are either repaired or plugged.

10.4.6.2.4 Design Features for Minimization of Contamination

The APR1400 is designed with specific features to meet the requirements of 10 CFR 20.1406 (Reference 7) and NRC RG 4.21 (Reference 8). The basic principles of NRC RG 4.21, and the methods of controls suggested in the regulations, are specifically delineated into four design objectives and two operational objectives described in Subsection 12.4.2 of this DCD. The following evaluation summarizes the primary features to address the design and operational objectives for the CPS.

The CPS contains components that contain radioactive fluid resulting from SG leakage. In accordance with NRC RG 4.21, the CPS has been evaluated for leak identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where probable leakage may occur, and methods of control incorporated in the design of the system. The leak identification evaluation indicated that the CPS is designed to provide the capability for prompt assessment and evaluation of the responses, and sufficient space for mitigation of the leak areas. Thus, unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs, and inspection and maintenance activities.

When the spent resin is detected to be radioactively contaminated to a predetermined level, the contaminated CPS spent resin is packaged into shipping containers for off-site treatment and disposal. The COL applicant is responsible for provisions of temporary shielding, if required, and mobile equipment, including spent resin fill-head for packaging of the contaminated spent resin, provisions of temporary storage, and shipment of packaged contaminated CPS spent resin for off-site treatment and/or disposal. (COL 10.4(12))

COL 10.4(9) The COL applicant is to determine the wet bulb temperature correction factor to account for potential interference and recirculation effects.

10.4.12 References

1. HEI "Standards for Steam Surface Condensers," 9th Edition, Heat Exchanger Institute, 2006.

2. NRC RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," Rev. 4, U.S. Nuclear Regulatory Commission, March 2007.

3. NRC RG 1.28, "Quality Assurance Program Criteria (Design and Construction)," Rev. 4, U.S. Nuclear Regulatory Commission, June 2010.

4. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," The American Society of Mechanical Engineers, the 2007 Edition with 2008 Addenda.

5. ASME B31.1, "Power Piping," The American Society of Mechanical Engineers, 2010.

6. NUREG-0800, Standard Review Plan, Section 10.4.2, "Main Condenser Evacuation System," Rev. 3, U.S. Nuclear Regulatory Commission, March 2007.

7. 10 CFR 20.1406, "Radiological Criteria for Unrestricted Use," U.S. Nuclear Regulatory Commission.

8. NRC RG 4.21, "Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning," U.S. Nuclear Regulatory Commission, June 2008.

9. HEI "Performance Standards for Liquid Ring Vacuum Pumps," 3rd Edition, Heat Exchange Institute, 2005.

10. ASME B16.34, "Valves-Flanged, Threaded, and Welding End," The American Society of Mechanical Engineers, 2009.

11. ASME Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination,"

COL 10.4(12) The COL applicant is responsible for provisions of temporary shielding, if required, and mobile equipment, including spent resin fill-head for packaging of the contaminated spent resin, provisions of temporary storage, and shipment of packaged contaminated CPS spent resin for off-site treatment and/or disposal.

Figure 12.3-17 Radiation Zones (Normal) Turbine Building El. 73′-0″