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

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:

<u>SGBDS:</u>

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 at the end 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 resins are expected to be lower because of conservative assumptions built into the calculation model and possibly shorter processing time.

<u>CPS:</u>

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."

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, if any. Hence the calculation model for the nuclide accumulation is considered conservative and is independent from replacement frequency.

<u>SFPCCS,</u>

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 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 storage tank in Table 12.2-22 are calculated based on the cumulative activity of LWMS demineralizer resins for 1 year."

   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 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 based on the cumulative activity of LWMS demineralizer resins for 1 year.

Impact on DCD

DCD section 12.2.1 will be revised as indicated in the Attachment.

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.

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

e. Boric acid concentrator

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

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.

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.

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 storage tank in Table 12.2-22 are calculated based on the cumulative activity of LWMS demineralizer resins for 1 year.

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.

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 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 based on the cumulative activity of LWMS demineralizer resins for 1 year.

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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 source terms used for plant shielding are to be based on an assumed 0.25% failed fuel fraction.

A review of the FSAR and audit material (see ML15208A492 for the audit plan) reveals that the source terms for the liquid waste management system are based on inputs of liquid waste from various sources. The average RCS concentration of the sources used in the calculation is 44% of the 0.25% failed fuel RCS source term. This is acceptable for calculating activity concentrations for buildup in the liquid waste management system demineralizers and reverse osmosis packages because activity in those components builds up over time and it is reasonable to assume that some of the input pathways are less than full RCS concentration and the average concentration of 44% is reasonable. However, for the monitor tanks, the source term would be based on the concentrations recently processed by the liquid waste management system. It is reasonable to assume that on a given day a monitor tank could be filled with fluid that initially contained a source term concentration equivalent to RCS fluid concentrations.

1. Please increase the design basis monitor tank source term in the FSAR to account for the monitor tank being filled with fluid that was initially at the 0.25% failed fuel RCS concentration and was processed through the liquid waste management system.

2. Please update the FSAR Chapter 12 to include general assumptions that were used for liquid waste management system source terms, such as that the demineralizers and reverse osmosis package are based on processing an average liquid concentration of 44% the RCS source term over the given time period and that the monitor tanks are based on processing 100% of the RCS source term through the RCS over the given time period.

Response

1. In the DCD, the monitor tank source term was calculated assuming that the liquid waste contains 44% of the RCS fluid concentrations. However, as pointed out by the staff, in any given day, the liquid waste coming into LWMS could contain a source term concentration equivalent to the RCS fluid concentrations. Monitor tank source terms processed by the liquid waste management system were recalculated and the results are presented in Table 1 below. Based on these results, there are no impacts on radiation zoning and shield wall thicknesses. DCD Table 12.2-20 will be updated.

Table 1 Source terms of Monitor Tank (0.25% Fuel failure)

Nuclide	Activity [Ci/cc](1)	Nuclide	Activity [Ci/cc]
Br-84	5.40E-14	Y-91	1.35E-14
I-131	5.87E-10	Y-93	6.06E-16
I-132	1.17E-11	Zr-95	4.09E-14
I-133	3.52E-10	Nb-95	1.48E-14
I-134	1.83E-12	Mo-99	5.28E-12
I-135	6.97E-11	Tc-99m	4.73E-12
Rb-88	1.76E-11	Ru-103	4.57E-15
Cs-134	4.75E-10	Ru-106	1.99E-14
Cs-136	5.98E-11	Ag-110m	1.38E-13
Cs-137	5.50E-10	Te-129m	1.55E-13
Na-24	1.37E-12	Te-129	1.01E-13
Cr-51	1.42E-12	Te-131m	3.60E-13
Mn-54	1.71E-13	Te-131	6.71E-14
Fe-55	1.28E-13	Te-132	3.87E-12
Fe-59	3.14E-14	Ba-137m	5.13E-10
Co-58	4.84E-13	Ba-140	1.01E-13
Co-60	5.67E-14	La-140	6.61E-14
Zn-65	5.43E-14	Ce-141	3.97E-15
Sr-89	8.62E-14	Ce-143	5.54E-15
Sr-90	5.89E-15	Ce-144	1.19E-14
Sr-91	2.41E-14	W-187	1.07E-13
Y-91m	1.53E-14	Np-239	1.52E-13

Note 1: The radionuclide concentration in this Table is based on 100% of RCS equilibrium concentration and processed through the LWMS.

2. General assumptions used for the calculation of source terms will be added.

Impact on DCD

DCD Section 12.2.1.4, Table 12.2-20 will be updated as indicated in Attachment.

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 Environment Report.

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.

44% of the RCS source term and

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.

Source terms for the monitor tank are calculated using reactor coolant equilibrium radionuclide concentrations with 0.25% failed fuel and processed through the LWMS.

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.

Table 12.2-20 (1 of 3)

Liquid Radwaste System Tank Source Terms (Bq/cm^3)

Nuclide	Equipment Waste Tank	Floor Drain Tank	Chemical Waste Tank	Monitor Tank
Br-84	6.27E+01	8.62E+01	1.96E+00	2.00E-03
I-131	7.94E+03	1.09E+04	2.48E+02	2.17E+01
I-132	2.13E+03	2.93E+03	6.66E+01	4.33E-01
I-133	1.13E+04	1.55E+04	3.52E+02	1.30E+01
I-134	1.30E+03	1.79E+03	4.07E+01	6.78E-02
I-135	6.40E+03	8.80E+03	2.00E+02	2.58E+00
Rb-88	7.33E+03	1.01E+04	2.29E+02	6.53E-01
Cs-134	1.13E+03	1.55E+03	3.52E+01	1.76E+01
Cs-136	1.54E+02	2.12E+02	4.81E+00	2.21E+00
Cs-137	1.30E+03	1.79E+03	4.07E+01	2.03E+01
Na-24	5.79E+02	7.96E+02	1.81E+01	5.07E-02
Cr-51	1.75E+02	2.41E+02	5.48E+00	5.27E-02
Mn-54	2.03E+01	2.79E+01	6.34E-01	6.31E-03
Fe-55	1.52E+01	2.09E+01	4.75E-01	4.74E-03
Fe-59	3.81E+00	5.24E+00	1.19E-01	1.16E-03
Co-58	5.82E+01	8.01E+01	1.82E+00	1.79E-02
Co-60	6.72E+00	9.24E+00	2.10E-01	2.10E-03
Zn-65	6.46E+00	8.89E+00	2.02E-01	2.01E-03

Table 12.2-20 (2 of 3)

Nuclide	Equipment Waste Tank	Floor Drain Tank	Chemical Waste Tank	Monitor Tank
Sr-89	1.04E+01	1.43E+01	3.26E-01	3.19E-03
Sr-90	6.98E-01	9.59E-01	2.18E-02	2.18E-04
Sr-91	1.54E+01	2.12E+01	4.81E-01	8.91E-04
Y-91m	8.99E+00	1.24E+01	2.81E-01	5.67E-04
Y-91	1.54E+00	2.12E+00	4.81E-02	5.00E-04
Y-93	3.68E-01	5.06E-01	1.15E-02	2.24E-05
Zr-95	4.93E+00	6.78E+00	1.54E-01	1.51E-03
Nb-95	1.66E+00	2.28E+00	5.18E-02	5.47E-04
Mo-99	8.99E+02	1.24E+03	2.81E+01	1.95E-01
Tc-99m	5.22E+02	7.17E+02	1.63E+01	1.75E-01
Ru-103	5.57E-01	7.66E-01	1.74E-02	1.69E-04
Ru-106	2.37E-01	3.26E-01	7.40E-03	7.37E-04
Ag-110m	1.65E+01	2.27E+01	5.15E-01	5.12E-03
Te-129m	1.89E+01	2.60E+01	5.92E-01	5.73E-03
Te-129	2.01E+01	2.77E+01	6.29E-01	3.73E-03
Te-131m	8.99E+01	1.24E+02	2.81E+00	1.33E-02
Te-131	3.55E+01	4.88E+01	1.11E+00	2.48E-03
Te-132	6.27E+02	8.62E+02	1.96E+01	1.43E-01
Ba-137m	1.18E+03	1.63E+03	3.70E+01	1.90E+01
Ba-140	1.30E+01	1.79E+01	4.07E-01	3.74E-03

Table 12.2-20 (3 of 3)

Nuclide	Equipment Waste Tank	Floor Drain Tank	Chemical Waste Tank	Monitor Tank
La-140	4.38E+00	6.03E+00	1.37E-01	2.45E-03
Ce-141	4.86E-01	6.69E-01	1.52E-02	1.47E-04
Ce-143	1.30E+00	1.79E+00	4.07E-02	2.05E-04
Ce-144	1.42E+00	1.95E+00	4.44E-02	4.42E-04
W-187	3.10E+01	4.27E+01	9.70E-01	3.95E-03
Np-239	2.76E+01	3.79E+01	8.62E-01	5.63E-03