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.:	**142-8090**
SRP Section:	**12.02 - Radiation Sources**
Application Section:	**12.2**
Date of RAI Issue:	**08/07/2015**

Question No. 12.02-13

QUESTIONS

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.

10 CFR 50, Appendix A, Criterion 61, requires that the fuel storage and handling, radioactive waste, and other systems which may contain radioactivity be designed to assure adequate safety under normal and postulated accident conditions, with suitable shielding for radiation protection, and with appropriate containment, confinement, and filtering systems.

SRP Section 12.2 indicates that the reviewer will consider whether source strengths, concentrations of airborne radioactivity, and quantitative source descriptions are consistent with the assumptions made and the methods used by the applicant. SRP Section 12.2 also indicates that unless described within other sections of the SAR, source descriptions should include the methods, models, and assumptions used as the bases for all values provided in SAR Section 12.2.

In a clarification call with the applicant, to clarify source term information, the applicant verified that the Shield APR computer code, which is used to calculate the inventories of radionuclides within systems and components downstream of the reactor coolant system, does not consider the buildup of daughters within the components from the decay of the parents. Staff review of the purification ion exchanger source term, in FSAR Table 12.2-11, using equations within the Shield APR code manual and staff confirmatory calculations, confirms that for Technetium-99m the source term accounts only for Technetium-99m accumulated in the ion exchanger directly from RCS fluid and not the decay of Molybdenum-99 within the ion exchanger. This appears to result in a Technetium-99m source term significantly lower than what it would be if generation of Technetium-99m from the decay of

Molybdenum-99 within the ion exchanger was considered. Similar underestimations appear to occur with other daughter radionuclides.

However, for Ba-137m, which decays from Caesium-137 the applicant does not appear to follow the methodology within the Shield APR manual. For example, if the equations within the Shield APR manual are used, the activity of Barium-137m within the purification ion exchanger would be several orders of magnitude less than what is provided in the FSAR. It appears that the applicant simply assumes that the activity of Barium-137m is equivalent to that of Caesium-137, regardless of the Shield APR code. In reality staff would expect the activity of Barium-137m to be near the same activity as Caesium-137, however, staff could not find any information indicating that the Shield APR code methodology should not be used for Barium-137m (for any other isotopes), or anything saying what assumptions should be made for Barium-137m.

In addition, there are other anomalies in source term information indicating that the buildup of daughters are not being appropriately accounted for. For example, even though there is Sr-90 in all of the liquid waste and solid waste management systems, the applicant reports a concentration of 0 Bq for Y-90 for most of these components. Since Y-90 is the direct decay product of Sr-90, there is no way there would be no Y-90 within the spent resin storage tank. Similar anomalies occur with other isotopes in the waste management systems, such as Rh-106 (decay product of Ru-106) and Pr-143 (decay product of Ce-143).

Please revise the methodology for calculating source terms to include consideration for the buildup of daughter products within components and revise the Chapter 11 and 12 sources to include the corrected information.

Response

The ShieldAPR code does not consider the buildup of daughter nuclides for calculating the shielding source term. The shielding source terms are calculated based on the RCS design bases source terms. Each nuclide activity for RCS design bases source terms is determined by choosing the maximum value during five cycle operation period. Therefore, the RCS design bases source terms are conservative. In addition, SRP 12.2 states that “the quantities will be acceptable if the specific values given in the tables are consistent with ANSI/ANS-18.1 and RG 1.112 for coolant and corrosion activation products source terms.” Tables 11.1-2 and 12.2-5 include the same nuclides listed in ANSI/ANS-18.1.

The Ba-137m activity is assumed to be identical with Cs-137 activity because these nuclides are in secular equilibrium. A note will be added at each applicable table to notify this in the DCD Chapter 12.

As described in the response to the RAI RPAC 103-7998 (Question No. 12.02-10), the source terms for LWMS and SWMS are calculated using the RCS source terms. However, since the DIJESTER code used to determine the LWMS source term is capable of considering daughter nuclides such as Y-90 and Pr-143, which are produced from Sr-90 and Ce-143, respectively, these nuclides are included in the LWMS source term. In addition, since the SWMS source term includes the resins and sludge generated from the LWMS, the SWMS source term also includes daughter nuclides. However, since the source term for spent resin long term storage tank (SRLST) is determined based on the assumptions that the spent resins from CVCS ion exchangers are stored directly, the daughter nuclides are not considered as those in the CVCS ion exchanger inventories in DCD Table 12.2-11.

Impact on DCD

Chapter 12 will be revised to add the notes for Ba-137m as indicated in the Attachment.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on Technical Specification.

Impact on Technical/Topical/Environmental Reports

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

Table 12.2-10 (2 of 2)

Nuclide	Letdown	Regenerative	CCP Miniflow
Te-129m	1.6E+07	1.6E+06	8.6E+04
Te-129	1.7E+07	1.7E+06	8.3E+04
I-131	6.7E+09	6.6E+08	3.6E+07
Te-131m	7.6E+07	7.5E+06	4.1E+05
Te-131	3.0E+07	2.9E+06	1.3E+05
Te-132	5.3E+08	5.2E+07	2.9E+06
I-132	1.8E+09	1.8E+08	9.2E+06
I-133	9.5E+09	9.4E+08	5.1E+07
I-134	1.1E+09	1.1E+08	5.3E+06
Cs-134	9.5E+08	4.0E+08	2.6E+08
I-135	5.4E+09	5.3E+08	2.9E+07
Cs-136	1.3E+08	5.4E+07	3.5E+07
Cs-137	1.1E+09	4.6E+08	3.0E+08
Ba-140	1.1E+07	1.2E+06	1.2E+05
La-140	3.7E+06	3.9E+05	4.0E+04
Ce-141	4.1E+05	4.3E+04	4.4E+03
Ce-143	1.1E+06	1.2E+05	1.2E+04
Ce-144	1.2E+06	1.3E+05	1.3E+04
Na-24	4.9E+08	5.1E+07	5.2E+06
Cr-51	1.5E+08	1.6E+07	1.6E+06
Mn-54	1.7E+07	1.8E+06	1.8E+05
Fe-55	1.3E+07	1.4E+06	1.4E+05
Fe-59	3.2E+06	3.4E+05	3.5E+04
Co-58	4.9E+07	5.2E+06	5.3E+05
Co-60	5.7E+06	6.0E+05	6.1E+04
Zn-65	5.5E+06	5.8E+05	5.9E+04
Ba-137m (1)	1.1E+09	4.6E+08	3.0E+08
W-187	2.6E+07	2.8E+06	2.8E+05
Np-239	2.3E+07	2.5E+06	2.5E+05

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).

Table 12.2-11 (2 of 2)

Nuclide	Purification	Deborating	Pre-Holdup	Boric Acid Condensate
Te-129m	1.3E+12	4.1E+09	2.6E+09	1.9E+05
Te-129	1.9E+09	1.7E+07	2.2E+06	8.1E-01
I-131	1.2E+14	9.6E+11	2.2E+11	9.3E+06
Te-131m	2.1E+11	1.9E+09	2.9E+08	2.5E+03
Te-131	1.2E+09	1.1E+07	1.4E+06	1.9E-01
Te-132	4.0E+12	3.6E+10	6.3E+09	1.3E+05
I-132	4.0E+11	3.6E+09	4.6E+08	3.5E+02
I-133	1.9E+13	1.7E+11	2.5E+10	1.6E+05
I-134	9.2E+10	8.4E+08	1.1E+08	3.1E+01
Cs-134	3.5E+14	2.0E+09	6.1E+12	1.6E+04
I-135	3.5E+12	3.2E+10	4.2E+09	9.2E+03
Cs-136	2.3E+12	2.7E+08	3.9E+10	1.3E+03
Cs-137	5.0E+14	2.3E+09	8.6E+12	1.9E+04
Ba-140	3.2E+11	9.2E+05	6.6E+08	2.4E+02
La-140	1.4E+10	3.1E+05	2.3E+07	1.4E+01
Ce-141	3.1E+10	3.4E+04	6.7E+07	1.3E+01
Ce-143	3.5E+09	9.2E+04	5.4E+06	3.4E+00
Ce-144	5.4E+11	1.0E+05	1.2E+09	4.9E+01
Na-24	7.0E+11	4.1E+07	1.0E+09	6.7E+02
Cr-51	9.4E+12	7.2E+10	2.1E+10	4.5E+03
Mn-54	8.0E+12	1.1E+10	1.9E+10	7.0E+02
Fe-55	8.3E+12	8.0E+09	1.9E+10	5.3E+02
Fe-59	3.3E+11	1.7E+09	7.4E+08	1.1E+02
Co-58	8.0E+12	2.8E+10	1.8E+10	1.8E+03
Co-60	4.0E+12	3.6E+09	9.2E+09	2.4E+02
Zn-65	2.3E+12	4.5E+05	5.2E+09	2.2E+02
Ba-137m (1)	5.0E+14	2.3E+09	8.6E+12	1.9E+04
W-187	6.0E+10	2.2E+06	8.9E+07	5.8E+01
Np-239	1.3E+11	1.9E+06	2.1E+08	1.2E+02

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).

Table 12.2-12 (2 of 2)

Nuclide	Seal Injection	Reactor Drain	Boric Acid	Purification	Reactor Makeup Water
Te-129m	4.5E+03	7.2E+05	3.5E+04	9.0E+05	2.9E-01
Te-129	4.3E+03	4.1E+05	0.0E+00	9.5E+05	1.9E-06
I-131	1.9E+06	2.6E+08	5.9E+05	3.8E+08	2.1E+01
Te-131m	2.1E+04	2.2E+06	2.9E-02	4.3E+06	5.9E-03
Te-131	6.8E+03	7.2E+05	0.0E+00	1.7E+06	4.6E-07
Te-132	1.5E+05	1.8E+07	9.1E+02	3.0E+07	3.1E-01
I-132	4.8E+05	4.4E+07	0.0E+00	1.0E+08	8.3E-04
I-133	2.6E+06	2.6E+08	3.7E-02	5.3E+08	3.8E-01
I-134	2.7E+05	2.6E+07	0.0E+00	6.2E+07	7.3E-05
Cs-134	1.3E+07	4.5E+07	1.0E+07	5.3E+07	2.2E+02
I-135	1.5E+06	1.4E+08	0.0E+00	3.0E+08	2.2E-02
Cs-136	1.8E+06	5.4E+06	2.1E+04	7.3E+06	4.0E+00
Cs-137	1.5E+07	5.2E+07	1.5E+07	6.2E+07	2.8E+02
Ba-140	6.2E+03	4.6E+05	3.9E+03	6.2E+05	7.5E-01
La-140	2.1E+03	1.1E+05	5.5E-02	2.1E+05	6.3E-03
Ce-141	2.3E+02	1.8E+04	9.1E+02	2.3E+04	7.8E-02
Ce-143	6.1E+02	3.2E+04	2.2E-03	6.2E+04	1.3E-03
Ce-144	6.7E+02	5.7E+04	2.3E+04	6.7E+04	6.1E-01
Na-24	2.7E+05	1.3E+07	4.6E-06	2.7E+07	1.1E-01
Cr-51	5.7E+10	1.8E+10	5.9E+08	8.6E+12	5.2E+05
Mn-54	4.9E+10	1.6E+10	6.0E+09	7.4E+12	1.4E+06
Fe-55	5.0E+10	1.7E+10	8.5E+09	7.6E+12	1.6E+06
Fe-59	2.0E+09	6.4E+08	4.3E+07	3.0E+11	2.7E+04
Co-58	4.8E+10	1.6E+10	1.9E+09	7.3E+12	8.5E+05
Co-60	2.4E+10	8.0E+09	4.4E+09	3.6E+12	8.0E+05
Zn-65	3.1E+03	2.6E+05	9.7E+04	3.1E+05	2.7E+00
Ba-137m (1)	1.5E+07	5.2E+07	1.5E+07	6.2E+07	2.8E+02
W-187	1.5E+04	7.4E+05	9.4E-04	1.5E+06	1.6E-02
Np-239	1.3E+04	7.5E+05	5.5E+00	1.3E+06	7.8E-02

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).

Table 12.2-13 (2 of 2)

Nuclide	Reactor Drain	Equipment Drain	Volume Control	Holdup	Reactor Makeup Water	Boric Acid Storage
Te-129m	6.7E+08	7.5E+07	9.3E+06	2.5E+08	2.8E+04	1.5E+09
Te-129	3.8E+08	6.6E+07	9.0E+06	9.6E+05	1.8E-01	0.0E+00
I-131	2.4E+11	2.9E+10	3.9E+09	7.0E+10	2.0E+06	2.5E+10
Te-131m	2.0E+09	3.0E+08	4.4E+07	2.5E+08	5.5E+02	1.2E+03
Te-131	6.6E+08	1.2E+08	1.4E+07	4.4E+05	4.3E-02	0.0E+00
Te-132	1.7E+10	2.2E+09	3.1E+08	3.6E+09	2.9E+04	3.8E+07
I-132	4.0E+10	7.0E+09	9.9E+08	2.3E+08	7.8E+01	0.0E+00
I-133	2.4E+11	3.7E+10	5.5E+09	2.2E+10	3.6E+04	1.6E+03
I-134	2.4E+10	4.2E+09	5.7E+08	4.4E+07	6.9E+00	0.0E+00
Cs-134	4.2E+10	4.7E+09	2.8E+10	7.6E+09	2.1E+07	4.4E+11
I-135	1.3E+11	2.1E+10	3.1E+09	2.3E+09	2.0E+03	1.3E-11
Cs-136	5.0E+09	5.8E+08	3.8E+09	7.2E+08	3.8E+05	9.0E+08
Cs-137	4.9E+10	5.4E+09	3.2E+10	8.9E+09	2.6E+07	6.2E+11
Ba-140	4.2E+08	4.9E+07	1.3E+07	1.5E+08	7.0E+04	1.6E+08
La-140	1.0E+08	1.5E+07	4.3E+06	1.8E+07	5.9E+02	2.3E+03
Ce-141	1.7E+07	1.9E+06	4.8E+05	6.9E+06	7.3E+03	3.8E+07
Ce-143	3.0E+07	4.4E+06	1.3E+06	4.5E+06	1.2E+02	9.3E+01
Ce-144	5.3E+07	5.9E+06	1.4E+06	2.5E+07	5.7E+04	9.8E+08
Na-24	1.2E+10	1.9E+09	5.6E+08	8.8E+08	1.1E+04	1.9E-01
Cr-51	6.1E+09	6.9E+08	1.7E+08	2.4E+09	2.3E+06	1.1E+10
Mn-54	7.5E+08	8.4E+07	2.0E+07	3.5E+08	8.3E+05	1.5E+10
Fe-55	5.7E+08	6.3E+07	1.5E+07	2.7E+08	7.1E+05	1.5E+10
Fe-59	1.4E+08	1.5E+07	3.7E+06	5.7E+07	7.3E+04	4.8E+08
Co-58	2.1E+09	2.4E+08	5.7E+07	9.2E+08	1.5E+06	1.3E+10
Co-60	2.5E+08	2.8E+07	6.6E+06	1.2E+08	3.2E+05	7.2E+09
Zn-65	2.4E+08	2.7E+07	6.4E+06	1.1E+08	2.5E+05	4.1E+09
Ba-137m (1)	4.9E+10	5.4E+09	3.2E+10	8.9E+09	2.6E+07	6.2E+11
W-187	6.8E+08	1.0E+08	3.0E+07	8.1E+07	1.5E+03	4.0E+01
Np-239	6.9E+08	9.4E+07	2.7E+07	1.4E+08	7.3E+03	2.3E+05

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).

Table 12.2-14 (2 of 2)

Nuclide	Concentrate Heater	Concentrate Cooler	Flash Tank	Vapor Separator	Concentrate Pump	Concentrate Transfer Pump
Te-129m	2.6E+07	2.0E+06	2.2E+08	5.0E+04	2.2E+06	2.2E+05
Te-129	8.1E+04	6.2E+03	7.0E+05	1.6E+02	6.8E+03	6.8E+02
I-131	5.5E+09	4.2E+08	4.7E+10	1.0E+07	4.6E+08	4.6E+07
Te-131m	9.9E+06	7.6E+05	8.6E+07	1.9E+04	8.3E+05	8.3E+04
Te-131	5.2E+04	4.0E+03	4.5E+05	1.0E+02	4.4E+03	4.4E+02
Te-132	1.9E+08	1.5E+07	1.7E+09	3.7E+05	1.6E+07	1.6E+06
I-132	1.7E+07	1.3E+06	1.5E+08	3.3E+04	1.5E+06	1.5E+05
I-133	8.8E+08	6.8E+07	7.6E+09	1.7E+06	7.4E+07	7.4E+06
I-134	4.0E+06	3.1E+05	3.5E+07	7.8E+03	3.4E+05	3.4E+04
Cs-134	8.7E+08	6.7E+07	7.5E+09	1.7E+06	7.3E+07	7.3E+06
I-135	1.6E+08	1.2E+07	1.3E+09	3.0E+05	1.3E+07	1.3E+06
Cs-136	6.9E+07	5.3E+06	6.0E+08	1.3E+05	5.8E+06	5.8E+05
Cs-137	1.0E+09	7.8E+07	8.8E+09	2.0E+06	8.5E+07	8.5E+06
Ba-140	1.3E+07	1.0E+06	1.1E+08	2.5E+04	1.1E+06	1.1E+05
La-140	7.5E+05	5.8E+04	6.5E+06	1.5E+03	6.3E+04	6.3E+03
Ce-141	7.0E+05	5.4E+04	6.1E+06	1.4E+03	5.9E+04	5.9E+03
Ce-143	1.8E+05	1.4E+04	1.6E+06	3.5E+02	1.5E+04	1.5E+03
Ce-144	2.6E+06	2.0E+05	2.3E+07	5.0E+03	2.2E+05	2.2E+04
Na-24	3.6E+07	2.8E+06	3.1E+08	6.9E+04	3.0E+06	3.0E+05
Cr-51	2.4E+08	1.9E+07	2.1E+09	4.7E+05	2.0E+07	2.0E+06
Mn-54	3.8E+07	2.9E+06	3.2E+08	7.2E+04	3.2E+06	3.2E+05
Fe-55	2.9E+07	2.2E+06	2.5E+08	5.5E+04	2.4E+06	2.4E+05
Fe-59	5.9E+06	4.6E+05	5.1E+07	1.1E+04	5.0E+05	5.0E+04
Co-58	9.7E+07	7.5E+06	8.4E+08	1.9E+05	8.2E+06	8.2E+05
Co-60	1.3E+07	9.8E+05	1.1E+08	2.5E+04	1.1E+06	1.1E+05
Zn-65	1.2E+07	9.1E+05	1.0E+08	2.3E+04	1.0E+06	1.0E+05
Ba-137m (1)	1.0E+09	7.8E+07	8.8E+09	2.0E+06	8.5E+07	8.5E+06
W-187	3.1E+06	2.4E+05	2.7E+07	6.0E+03	2.6E+05	2.6E+04
Np-239	6.7E+06	5.2E+05	5.8E+07	1.3E+04	5.6E+05	5.6E+04

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).

Table 12.2-17

Fission and Corrosion Product Activities in the Spent Fuel Pool

Nuclide	Activity (Bq/g)	Nuclide	Activity (Bq/g)
H-3	4.0E+04	Te-129	0.0E+00
N-16	0.0E+00	I-131	1.6E+02
Kr-85m	0.0E+00	Te-131m	7.3E-01
Kr-85	0.0E+00	Te-131	0.0E+00
Kr-87	0.0E+00	Te-132	9.9E+00
Kr-88	0.0E+00	I-132	9.4E-05
Xe-131m	0.0E+00	I-133	6.1E+01
Xe-133m	0.0E+00	I-134	0.0E+00
Xe-133	0.0E+00	Cs-134	8.1E+01
Xe-135m	0.0E+00	I-135	1.7E+00
Xe-135	0.0E+00	Cs-136	6.2E+00
Xe-137	0.0E+00	Cs-137	1.1E+02
Xe-138	0.0E+00	Ba-140	2.8E-01
Br-84	0.0E+00	La-140	4.9E-02
Rb-88	0.0E+00	Ce-141	1.1E-02
Sr-89	2.6E-01	Ce-143	1.2E-02
Sr-90	8.5E-02	Ce-144	8.4E-02
Sr-91	1.6E-02	Na-24	1.8E+00
Y-91m	0.0E+00	Cr-51	4.0E+00
Y-91	6.5E-01	Mn-54	1.3E+00
Y-93	1.7E-03	Fe-55	1.5E+00
Zr-95	1.3E-01	Fe-59	9.4E-02
Nb-95	3.9E-02	Co-58	1.6E+00
Tc-99m	8.1E-02	Co-60	7.4E-01
Mo-99	1.3E+01	Zn-65	3.5E-01
Ru-103	1.3E-02	Ba-137m (1)	1.1E+02
Ru-106	1.6E-02	W-187	2.1E-01
Ag-110m	9.1E-01	Np-239	3.8E-01
Te-129m	4.4E-01		

(1) This nuclide is a daughter nuclide in secular equilibrium and the activity is that of the parent nuclide (Cs-137).