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.:	**343-8420**
SRP Section:	**12.02 - Radiation Sources**
Application Section:	**12.2**
Date of RAI Issue:	**12/22/2015**

Question No. 12.02-23

This is a follow-up to RAI 8090, Question 12.02-13.

Requirement

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.

Issue

In the response to Question 12.02-13, the applicant indicates that source terms for components are conservative because the RCS source term is based on five cycle operation. However, the applicant provides no justification for why this is conservative. Past staff experience with previous applications indicates that typically RCS activity reaches near equilibrium value after several months of operation and would not be expected to change significantly after that time (with fuel leakage and operating conditions staying the same, the RCS concentrations of most radionuclides are constant). Therefore, it is unclear why assuming five cycle operation is conservative. No justification is provided why it is conservative, versus normal fuel replacement.

In addition, the applicant indicated that the nuclides selected in the source terms in FSAR Chapters 11 and 12 are consistent with the nuclides included in ANSI/ANS 18.1. As indicated in the SRP, it is acceptable to only consider the nuclides listed in ANSI/ANS 18.1 (as well as it is acceptable to consider the additional nuclides in those source associated with the liquid waste management system, because the DIJESTER code considers the additional nuclides).

However, the applicant indicates that only the DIJESTER code considers the buildup of radioactive daughters (besides Ba-137m, which is acceptably considered to have the same activity as Cs-137 in all sources, except for in the Steam Generator Blowdown, Condensate Polishing System, and Spent Fuel Pool Demineralizer source terms). Therefore, in the other

source terms downstream of the RCS, some of the nuclide activity values listed do not provide an accurate estimation of the nuclide concentrations. Staff review indicates that the buildup of some the daughter products in some components may be significant to some of the gamma source terms in the plant (and therefore, the shielding and zoning for those components). For example, for the gaseous waste management system components, the accumulation of Rb-88 from the decay of Kr-88 would likely provide a difference in the gamma dose rates from those components. Staff analysis indicates that the daughters of noble gasses (mostly Rb-88) listed in ANSI/ANS 18.1 may contribute nearly 20% to the source terms of the guard beds and the delay beds. In addition, the decay of Te-132 to I-132, would significantly increase I-132 activity in many components. There are several other radionuclides listed in ANSI/ANS 18.1 which would also impact source terms, to a lesser extent.

SRP 12.2 indicates that the buildup of radionuclides in components and systems should be addressed. Part of the buildup in components is from daughters generated in the decay of parents. Therefore, update the source terms and plant shielding and zoning, as appropriate, to include the contribution of daughter radionuclides for daughters listed in ANSI/ANS 18.1 (including for Ba-137m in the Steam Generator Blowdown, Condensate Polishing System, and Spent Fuel Pool Demineralizer source terms in Tables 12.2-18 and 12.2-17a), or provide additional detailed justification for why due to the RCS activity source terms are already more conservative than they would be if the contribution of daughters was included.

Response – (Rev. 1)

1. Assumption of Five Cycle Operation

   Based on the calculation of RCS source term, most of the fission products and their daughters reach their equilibrium activity level within one fuel cycle. However, several of the long-lived nuclides (e.g. Kr-85, Sr-90, Cs-134, Cs-137) may not reach equilibrium before the fourth or fifth fuel cycle. Therefore, in order to insure maximum reactor coolant activities the computer modeling code (DAMSAM) is configured to run for four equilibrium fuel cycles, assuming no leakage or load maneuvering waste from the primary coolant. After the simulation of four equilibrium cycles, the maximum activity of each nuclide appearing in the RCS during fifth cycle is taken as the reactor coolant equilibrium concentration shown in DCD Table 12.2-5 in order to conservatively calculate the activities for nuclides that take a long time to reach the equilibrium level. For this reason, the duration of reactor operation is set at five fuel cycles as the basis for reactor coolant source term calculations (DCD Table 11.1-1). Table 1 shows the maximum atomic populations of the fission products in each cycle in the DAMSAM calculation for five cycles. As shown in this table, the maximum atomic populations such as Cs-134 and Cs-137 continuously increase up to fifth cycle.

   The number of APR1400 equilibrium core batches for 18-month cycle is designed to be three or less. Thus, the DAMSAM results considering five equilibrium cycles are more conservative than the actual operation. In particular, it is conservative for Cs-137, which decay to Ba-137m, the most significant daughter nuclide from a radiation shielding design.

Table 1 Maximum Atomic Populations of Fission Products in Each Cycle

(Unit : atoms)

Cycle	Kr-85		Sr-90		Cs-134		Cs-137	
	Fuel	Coolant	Fuel	Coolant	Fuel	Coolant	Fuel	Coolant
1st	2.591E+24	4.373E+21	1.704E+26	2.558E+17	7.163E+24	2.595E+19	2.451E+26	8.903E+20
2nd	2.722E+24	6.224E+21	3.052E+26	4.554E+17	1.610E+25	5.845E+19	3.584E+26	1.309E+21
3rd	2.729E+24	6.326E+21	4.118E+26	6.133E+17	2.172E+25	7.908E+19	4.107E+26	1.507E+21
4th	**2.729E+24**	**6.331E+21**	4.960E+26	7.381E+17	2.470E+25	9.024E+19	4.349E+26	1.600E+21
5th	2.729E+24	6.331E+21	**5.626E+26**	**8.368E+17**	**2.616E+25**	**9.575E+19**	**4.461E+26**	**1.643E+21**

2. Effects of Daughter Products Buildup in RCS and CVCS

In order to estimate the effects on the buildup of the daughter products in the RCS and CVCS component radiation source terms, the methodology of DAMSAM/SHIELD-APR code system and the conservatism included in the results were reviewed in several ways. This review demonstrated that the conservatisms in the results of DAMSAM/SHIELD-APR code system are substantially larger than the effect of the non-modeled contribution of daughter products in the calculation of the RCS and CVCS component source terms. The detailed review and its conclusions will be provided in the report of “DAMSAM/SHIELD-APR Code Methodology – Daughter Product Issue.”

3. Effects of Daughter Products Buildup in BOP systems

KHNP performed a review of the source term for the shielding calculations of BOP systems, such as the Steam Generator Blowdown (SGBD), Condensate Polishing System (CPS), and Spent Fuel Pool Cooling and Clean up System (SFPCCS), and evaluated the impact of the daughter nuclides on dose rate based on the comparison of the shielding calculation results. The evaluation for the Gaseous Radwaste System (GRS) will be provided in the response to RAI 343-8420, Question No. 12.02-25.

This evaluation is divided into two parts; the source term analysis and the shielding analysis. In the source term analysis, KHNP calculated the daughter nuclide build-up for BOP systems using the modified balance equations for source terms. The daughter nuclides considered in this evaluation are the fourteen radionuclides listed in ANSI/ANS 18.1. One level decay from the parent nuclide is assumed. The detailed explanation of the decay cases considered for the production of daughter nuclides is included in Attachment 1. The detailed balance equations for daughter nuclide build-up for each of the BOP system components are also included in Attachment 1.

Using the results of the source term analysis considering the daughter nuclide build-up activity, the shielding analyses were reevaluated to determine dose rates and radiation zones for BOP cubicles and areas.

The impact of the daughter nuclides build-up is evaluated based on the comparison of the reevaluation shielding calculation results to the original shielding calculation results, which were based on input source terms that did not consider daughter nuclide build-

up. Also, an additional shielding calculation is performed to demonstrate the impact of Ba-137m build-up, as Ba-137m is the only daughter nuclide whose build-up was shown to be significant for the primary system source term calculation.

As shown in Table 2, dose rates for the SGBD and SFPCCS increased up to 1.7% from the original dose rate calculation result, due to the inclusion of the daughter nuclides build-up. The dose rate increase for the SGBD and SFPCCS are significantly less than those for CPS because the Ba-137m activity is already assumed to be the same as Cs-137 activity in the original shielding calculations as shown in Attachment 2.

The daughter nuclide build-up in the CPS cation bed has an apparently large impact on the shielding analysis because the cation source term consists of a relatively small number of nuclides. However, it is found that the radiation zone for the cation bed remains zone 1, even considering the increased dose due to the added daughter nuclide build-up activity.

Also, it is found that the dominant contributing daughter nuclide for the dose rate increase is caused by Ba-137m, and the impact of other daughter nuclides on the dose rate is so small as to be negligible, considering the conservative assumptions and margins contained in the original shielding analysis.

KHNP will update the source term for BOP systems including Ba-137m build-up only as shown in Attachment 3. This approach is consistent with the source term analysis for the primary system components.

Table 2 Shielding Analysis Results

Component	Contact Dose Rates (mSv/hr)		
	w/o DNs	w/ Ba-137m only	w/ all DNs
SGBD Demineralizer	8.330E+01	8.330E+1	8.453E+01 (+1.5%)
SGBD Flash Tank	7.158E-01	7.160E-01 (+0.03%)	7.161E-01 (+0.04%)
CPS Cation Bed	1.812E-03	2.268E-03 (+25.2%)	2.276E-03 (+25.6%)
CPS Mixed Bed	1.362E-02	1.411E-02 (+3.5%)	1.417E-02 (+4.0%)
SFPCCS Demineralizer	3.703E+01	3.703E+01	3.769E+01 (+1.7%)

Note: DN refer to daughter nuclide.

Impact on DCD

DCD Tables 11.1-6, 11.1-10, 12.2-17a and 12.2-18 will be revised as indicated in Attachment 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.

Source Term Analysis Considering Additional Daughter Nuclides

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Table 11.1-6

Design Basis Radionuclide Concentrations
in the Secondary System (Bq/g) (1 % Fuel Defect)

Nuclide	Steam Generator	
	Liquid	Steam
Kr-85m	-	3.71E-01
Kr-85	-	9.16E-03
Kr-87	-	3.61E-01
Kr-88	-	9.16E-01
Xe-131m	-	9.16E-02
Xe-133m	-	2.38E-02
Xe-133	-	1.19E+01
Xe-135m	-	2.83E-01
Xe-135	-	1.61E+00
Xe-137	-	6.87E-02
Xe-138	-	2.43E-01
Br-84	3.03E-01	3.03E-03
I-131	1.20E+02	1.20E+00
I-132	2.17E+01	2.17E-01
I-133	1.62E+02	1.62E+00
I-134	8.86E+00	8.86E-02
I-135	8.08E+01	8.08E-01
Rb-88	1.93E+01	9.64E-02
Cs-134	1.91E+01	9.56E-02
Cs-136	2.55E+00	1.28E-02
Cs-137	2.21E+01	1.11E-01
Cr-51	6.78E-01	3.39E-03
Mn-54	7.85E-02	3.93E-04
Fe-55	5.88E-02	2.94E-04
Fe-59	1.47E-02	7.36E-05
Co-58	2.25E-01	1.13E-03
Co-60	2.60E-02	1.30E-04
Zr-95	2.97E-02	1.49E-04
Zn-65	2.50E-02	1.25E-04

Nuclide	Steam Generator	
	Liquid	Steam
N-16	7.38E-01	3.69E-03
Na-24	2.08E+00	1.04E-02
Sr-89	1.61E-01	8.04E-04
Sr-90	1.10E-02	5.50E-05
SR-91	2.13E-01	1.06E-03
Y-91m	5.81E-02	2.91E-04
Y-91	2.34E-02	1.17E-04
Y-93	4.95E-03	2.47E-05
Nb-95	2.52E-02	1.26E-04
Mo-99	1.35E+01	6.76E-02
Tc-99M	6.93E+00	3.46E-02
Ru-103	8.70E-03	4.35E-05
Ru-106	3.72E-03	1.86E-05
Ag-110m	6.38E-02	3.19E-04
Te-129m	2.93E-01	1.47E-03
Te-129	1.57E-01	7.84E-04
Te-131m	1.32E+00	6.62E-03
Te-131	1.48E-01	7.38E-04
Te-132	9.49E+00	4.74E-02
Ba-137m	6.92E-01	3.46E-03
Ba-140	1.96E-01	9.81E-04
La-140	6.69E-02	3.34E-04
Ce-141	7.32E-03	3.66E-05
Ce-143	2.00E-02	1.00E-04
Ce-144	2.11E-02	1.05E-04
W-187	1.15E-01	5.73E-04
Np-239	1.05E-01	5.23E-04
H-3	1.69E+04	1.69E+04

RAI 110-7919 Question 11.01-2

RAI 343-8420 - Question 12-02-23_Rev.1

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Table 11.1-6

Design Basis Radionuclide Concentrations
in the Secondary System (1 % Fuel Defect)

Nuclide	Steam Generator			
	Liquid		Steam	
	(μCi/g)	(Bq/g)	(μCi/g)	(Bq/g)
Kr-85m	-	-	1.00E-05	3.71E-01
Kr-85	-	-	2.48E-07	9.16E-03
Kr-87	-	-	9.76E-06	3.61E-01
Kr-88	-	-	2.48E-05	9.16E-01
Xe-131m	-	-	2.48E-06	9.16E-02
Xe-133m	-	-	6.43E-07	2.38E-02
Xe-133	-	-	3.22E-04	1.19E+01
Xe-135m	-	-	7.65E-06	2.83E-01
Xe-135	-	-	4.35E-05	1.61E+00
Xe-137	-	-	1.86E-06	6.87E-02
Xe-138	-	-	6.57E-06	2.43E-01
Br-84	8.19E-06	3.03E-01	8.19E-08	3.03E-03
I-131	3.24E-03	1.20E+02	3.24E-05	1.20E+00
I-132	5.86E-04	2.17E+01	5.86E-06	2.17E-01
I-133	4.38E-03	1.62E+02	4.38E-05	1.62E+00
I-134	2.39E-04	8.86E+00	2.39E-06	8.86E-02
I-135	2.18E-03	8.08E+01	2.18E-05	8.08E-01
Rb-88	5.22E-04	1.93E+01	2.61E-06	9.64E-02
Cs-134	5.16E-04	1.91E+01	2.58E-06	9.56E-02
Cs-136	6.89E-05	2.55E+00	3.46E-07	1.28E-02
Cs-137	5.97E-04	2.21E+01	3.00E-06	1.11E-01
Cr-51	1.83E-05	6.78E-01	9.16E-08	3.39E-03
Mn-54	2.12E-06	7.85E-02	1.06E-08	3.93E-04
Fe-55	1.59E-06	5.88E-02	7.95E-09	2.94E-04
Fe-59	3.97E-07	1.47E-02	1.99E-09	7.36E-05
Co-58	6.08E-06	2.25E-01	3.05E-08	1.13E-03
Co-60	7.03E-07	2.60E-02	3.51E-09	1.30E-04
Zr-95	8.03E-07	2.97E-02	4.03E-09	1.49E-04
Zn-65	6.76E-07	2.50E-02	3.38E-09	1.25E-04

Nuclide	Steam Generator			
	Liquid		Steam	
	(μCi/g)	(Bq/g)	(μCi/g)	(Bq/g)
N-16	1.99E-05	7.38E-01	9.97E-08	3.69E-03
Na-24	5.62E-05	2.08E+00	2.81E-07	1.04E-02
Sr-89	4.35E-06	1.61E-01	2.17E-08	8.04E-04
Sr-90	2.97E-07	1.10E-02	1.49E-09	5.50E-05
SR-91	5.76E-06	2.13E-01	2.86E-08	1.06E-03
Y-91m	1.57E-06	5.81E-02	7.86E-09	2.91E-04
Y-91	6.32E-07	2.34E-02	3.16E-09	1.17E-04
Y-93	1.34E-07	4.95E-03	6.68E-10	2.47E-05
Nb-95	6.81E-07	2.52E-02	3.41E-09	1.26E-04
Mo-99	3.65E-04	1.35E+01	1.83E-06	6.76E-02
Tc-99M	1.87E-04	6.93E+00	9.35E-07	3.46E-02
Ru-103	2.35E-07	8.70E-03	1.18E-09	4.35E-05
Ru-106	1.01E-07	3.72E-03	5.03E-10	1.86E-05
Ag-110m	1.72E-06	6.38E-02	8.62E-09	3.19E-04
Te-129m	7.92E-06	2.93E-01	3.97E-08	1.47E-03
Te-129	4.24E-06	1.57E-01	2.12E-08	7.84E-04
Te-131m	3.57E-05	1.32E+00	1.79E-07	6.62E-03
Te-131	4.00E-06	1.48E-01	1.99E-08	7.38E-04
Te-132	2.56E-04	9.49E+00	1.28E-06	4.74E-02
Ba-137m	~~1.87E-05~~	~~6.92E-01~~	~~9.35E-08~~	~~3.46E-03~~
Ba-140	5.30E-06	1.96E-01	2.65E-08	9.81E-04
La-140	1.81E-06	6.69E-02	9.03E-09	3.34E-04
Ce-141	1.98E-07	7.32E-03	9.89E-10	3.66E-05
Ce-143	5.41E-07	2.00E-02	2.70E-09	1.00E-04
Ce-144	5.70E-07	2.11E-02	2.84E-09	1.05E-04
W-187	3.11E-06	1.15E-01	1.55E-08	5.73E-04
Np-239	2.84E-06	1.05E-01	1.41E-08	5.23E-04
H-3	4.57E-01	1.69E+04	4.57E-01	1.69E+04

5.97E-04 2.21E+01 3.00E-06 1.11E-01

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Table 11.1-10

Expected Radionuclide Concentrations in the Secondary System (Bq/g)

Nuclide	Steam Generator	
	Liquid	Steam
Kr-85M	-	1.04E-04
Kr-85	-	7.54E-03
Kr-87	-	1.10E-04
Kr-88	-	1.17E-04
Xe-131m	-	5.69E-03
Xe-133 m	-	4.72E-04
Xe-133	-	2.05E-04
Xe-135 m	-	8.41E-04
Xe-135	-	4.37E-04
Xe-137	-	2.19E-04
Xe-138	-	3.95E-04
Br-84	3.28E-03	3.28E-05
I-131	1.39E-03	1.39E-05
I-132	2.61E-02	2.61E-04
I-133	1.68E-02	1.68E-04
I-134	2.79E-02	2.79E-04
I-135	3.12E-02	3.12E-04
Rb-88	2.59E-02	1.30E-04
Cs-134	3.03E-05	1.52E-07
Cs-136	7.03E-04	3.52E-06
Cs-137	4.33E-05	2.17E-07
Cr-51	2.14E-03	1.07E-05
Mn-54	1.10E-03	5.52E-06
Fe-55	8.28E-04	4.14E-06
Fe-59	2.07E-04	1.04E-06
Co-58	3.17E-03	1.58E-05
Co-60	3.66E-04	1.83E-06
Zr-95	2.68E-04	1.34E-06
Zn-65	3.52E-04	1.76E-06

Nuclide	Steam Generator	
	Liquid	Steam
N-16	1.87E-03	9.35E-06
Na-24	2.93E-02	1.47E-04
Sr-89	9.65E-05	4.82E-07
Sr-90	8.28E-06	4.14E-08
Sr-91	5.72E-04	2.86E-06
Y-91m	1.27E-04	6.33E-07
Y-91	3.59E-06	1.79E-08
Y-93	2.52E-03	1.26E-05
Nb-95	1.93E-04	9.66E-07
Mo-99	4.30E-03	2.15E-05
Tc-99m	2.62E-03	1.31E-05
Ru-103	5.17E-03	2.58E-05
Ru-106	6.22E-02	3.11E-04
Ag-110m	8.97E-04	4.49E-06
Te-129m	1.31E-04	6.54E-07
Te-129	7.86E-03	3.93E-05
Te-131m	9.81E-04	4.90E-06
Te-131	1.34E-03	6.71E-06
Te-132	1.15E-03	5.74E-06
Ba-137m	1.43E-06	7.13E-09
Ba-140	8.92E-03	4.46E-05
La-140	1.66E-02	8.28E-05
Ce-141	1.03E-04	5.17E-07
Ce-143	1.84E-03	9.18E-06
Ce-144	2.75E-03	1.38E-05
W-187	1.61E-03	8.07E-06
Np-239	1.47E-03	7.36E-06
H-3	6.81E+01	6.81E+01

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Table 11.1-10

Expected Radionuclide Concentrations in the Secondary System

Nuclide	Steam Generator			
	Liquid		Steam	
	(μCi/g)	(Bq/g)	(μCi/g)	(Bq/g)
Kr-85M	-	-	2.81E-09	1.04E-04
Kr-85	-	-	2.04E-07	7.54E-03
Kr-87	-	-	2.97E-09	1.10E-04
Kr-88	-	-	3.16E-09	1.17E-04
Xe-131m	-	-	1.54E-07	5.69E-03
Xe-133 m	-	-	1.28E-08	4.72E-04
Xe-133	-	-	5.54E-09	2.05E-04
Xe-135 m	-	-	2.27E-08	8.41E-04
Xe-135	-	-	1.18E-08	4.37E-04
Xe-137	-	-	5.92E-09	2.19E-04
Xe-138	-	-	1.07E-08	3.95E-04
Br-84	8.86E-08	3.28E-03	8.86E-10	3.28E-05
I-131	3.76E-08	1.39E-03	3.76E-10	1.39E-05
I-132	7.05E-07	2.61E-02	7.05E-09	2.61E-04
I-133	4.54E-07	1.68E-02	4.54E-09	1.68E-04
I-134	7.54E-07	2.79E-02	7.54E-09	2.79E-04
I-135	8.43E-07	3.12E-02	8.43E-09	3.12E-04
Rb-88	7.00E-07	2.59E-02	3.51E-09	1.30E-04
Cs-134	8.19E-10	3.03E-05	4.11E-12	1.52E-07
Cs-136	1.90E-08	7.03E-04	9.51E-11	3.52E-06
Cs-137	1.17E-09	4.33E-05	5.86E-12	2.17E-07
Cr-51	5.78E-08	2.14E-03	2.89E-10	1.07E-05
Mn-54	2.97E-08	1.10E-03	1.49E-10	5.52E-06
Fe-55	2.24E-08	8.28E-04	1.12E-10	4.14E-06
Fe-59	5.59E-09	2.07E-04	2.81E-11	1.04E-06
Co-58	8.57E-08	3.17E-03	4.27E-10	1.58E-05
Co-60	9.89E-09	3.66E-04	4.95E-11	1.83E-06
Zr-95	7.24E-09	2.68E-04	3.62E-11	1.34E-06
Zn-65	9.51E-09	3.52E-04	4.76E-11	1.76E-06

Nuclide	Steam Generator			
	Liquid		Steam	
	(μCi/g)	(Bq/g)	(μCi/g)	(Bq/g)
N-16	5.05E-08	1.87E-03	2.53E-10	9.35E-06
Na-24	7.92E-07	2.93E-02	3.97E-09	1.47E-04
Sr-89	2.61E-09	9.65E-05	1.30E-11	4.82E-07
Sr-90	2.24E-10	8.28E-06	1.12E-12	4.14E-08
Sr-91	1.55E-08	5.72E-04	7.73E-11	2.86E-06
Y-91m	3.43E-09	1.27E-04	1.71E-11	6.33E-07
Y-91	9.70E-11	3.59E-06	4.84E-13	1.79E-08
Y-93	6.81E-08	2.52E-03	3.41E-10	1.26E-05
Nb-95	5.22E-09	1.93E-04	2.61E-11	9.66E-07
Mo-99	1.16E-07	4.30E-03	5.81E-10	2.15E-05
Tc-99m	7.08E-08	2.62E-03	3.54E-10	1.31E-05
Ru-103	1.40E-07	5.17E-03	6.97E-10	2.58E-05
Ru-106	1.68E-06	6.22E-02	8.41E-09	3.11E-04
Ag-110m	2.42E-08	8.97E-04	1.21E-10	4.49E-06
Te-129m	3.54E-09	1.31E-04	1.77E-11	6.54E-07
Te-129	2.12E-07	7.86E-03	1.06E-09	3.93E-05
Te-131m	2.65E-08	9.81E-04	1.32E-10	4.90E-06
Te-131	3.62E-08	1.34E-03	1.81E-10	6.71E-06
Te-132	3.11E-08	1.15E-03	1.55E-10	5.74E-06
Ba-137m	~~3.86E-11~~	~~1.43E-06~~	~~1.93E-13~~	~~7.13E-09~~
Ba-140	2.41E-07	8.92E-03	1.21E-09	4.46E-05
La-140	4.49E-07	1.66E-02	2.24E-09	8.28E-05
Ce-141	2.78E-09	1.03E-04	1.40E-11	5.17E-07
Ce-143	4.97E-08	1.84E-03	2.48E-10	9.18E-06
Ce-144	7.43E-08	2.75E-03	3.73E-10	1.38E-05
W-187	4.35E-08	1.61E-03	2.18E-10	8.07E-06
Np-239	3.97E-08	1.47E-03	1.99E-10	7.36E-06
H-3	1.84E-03	6.81E+01	1.84E-03	6.81E+01

1.17E-09 4.33E-05 5.86E-12 2.17E-07

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This table will be added following Table 12.2-17.

Table 12.2-17a

SFP Demineralizer and Filter Source Terms

3.81E+11

Nuclide	Demin.(Bq)	Filter(Bq)	Nuclide	Demin.(Bq)	Filter(Bq)
BR-84	0.00E+00	0.00E+00	RU-106	6.00E+07	0.00E+00
I-131	2.83E+11	0.00E+00	AG-110M	3.39E+09	0.00E+00
I-132	1.96E-23	0.00E+00	TE-129M	1.40E+09	0.00E+00
I-133	1.89E+08	0.00E+00	TE-129	0.00E+00	0.00E+00
I-134	0.00E+00	0.00E+00	TE-131M	1.89E+07	0.00E+00
I-135	1.33E+00	0.00E+00	TE-131	0.00E+00	0.00E+00
RB-88	0.00E+00	0.00E+00	TE-132	5.56E+09	0.00E+00
CS-134	2.78E+11	0.00E+00	BA-137M	~~0.00E+00~~	0.00E+00
CS-136	1.33E+10	0.00E+00	BA-140	6.56E+08	0.00E+00
CS-137	3.81E+11	0.00E+00	LA-140	4.51E+06	0.00E+00
NA-24	3.18E+05	0.00E+00	CE-141	3.48E+07	0.00E+00
SR-89	8.80E+08	0.00E+00	CE-143	4.92E+05	0.00E+00
SR-90	3.24E+08	0.00E+00	CE-144	3.14E+08	0.00E+00
SR-91	1.16E+01	0.00E+00	W-187	1.53E+06	0.00E+00
Y-91M	0.00E+00	0.00E+00	NP-239	1.02E+08	0.00E+00
Y-91	2.23E+09	0.00E+00	CR-51	1.22E+10	1.21E+10
Y-93	2.79E+00	0.00E+00	MN-54	4.86E+09	4.88E+09
ZR-95	4.51E+08	4.50E+08	FE-55	5.69E+09	5.71E+09
NB-95	1.25E+08	0.00E+00	FE-59	3.12E+08	3.11E+08
MO-99	5.31E+09	0.00E+00	CO-58	5.59E+09	5.59E+09
TC-99M	4.46E-03	0.00E+00	CO-60	2.82E+09	2.82E+09
RU-103	4.24E+07	0.00E+00	ZN-65	1.30E+09	1.30E+09

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Add "A" after this last column

Table 12.2-18 (1 of 3)

Steam Generator Blowdown and Condensate Polishing System Source Terms (0.25 % Fuel Defect)

Isotope	SG Water (Bq/g)	SG Steam (Bq/g)	Blowdown Mixed Bed (Bq)	Blowdown Pre-Filter (Bq)	Blowdown Post-Filter (Bq)	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Kr-85m	0.00E+00	1.29E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	5.49E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-87	0.00E+00	1.01E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	2.80E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-131m	0.00E+00	5.49E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	3.34E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	3.58E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	7.32E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	7.32E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-137	0.00E+00	1.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	6.41E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	7.65E-02	7.65E-04	4.71E+06	0.00E+00	0.00E+00	2.43E-04	0.00E+00	1.28E+05
I-131	2.99E+01	2.99E-01	6.73E+11	0.00E+00	0.00E+00	9.50E-02	0.00E+00	1.71E+10
I-132	5.44E+00	5.44E-02	1.46E+09	0.00E+00	0.00E+00	1.73E-02	0.00E+00	3.97E+07
I-133	4.05E+01	4.05E-01	9.90E+10	0.00E+00	0.00E+00	1.29E-01	0.00E+00	2.70E+09
I-134	2.16E+00	2.16E-02	2.18E+08	0.00E+00	0.00E+00	6.87E-03	0.00E+00	5.94E+06
I-135	2.08E+01	2.08E-01	1.63E+10	0.00E+00	0.00E+00	6.61E-02	0.00E+00	4.44E+08
Rb-88	5.96E+00	2.98E-02	2.06E+08	0.00E+00	0.00E+00	1.36E-02	4.00E+06	4.00E+05

Replace these columns with "B"

Add "A" after this last column

Table 12.2-18 (2 of 3)

Isotope	SG Water (Bq/g)	SG Steam (Bq/g)	Blowdown Mixed Bed (Bq)	Blowdown Pre-Filter (Bq)	Blowdown Post-Filter (Bq)	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Cs-134	4.77E+00	2.39E-02	1.55E+12	0.00E+00	0.00E+00	1.08E-02	5.27E+08	5.63E+08
Cs-136	6.50E-01	3.25E-03	2.36E+10	0.00E+00	0.00E+00	1.48E-03	6.65E+07	3.75E+07
Cs-137	5.52E+00	2.76E-02	1.94E+12	0.00E+00	0.00E+00	1.25E-02	6.10E+08	6.61E+08
Cr-51	6.78E-01	3.39E-03	5.20E+10	4.73E+10	4.73E+08	1.54E-03	7.23E+07	5.60E+07
Mn-54	7.85E-02	3.93E-04	2.28E+10	2.07E+10	2.07E+08	7.14E-05	3.46E+06	3.63E+06
Fe-55	5.88E-02	2.94E-04	1.95E+10	1.77E+10	1.77E+08	5.35E-05	2.60E+06	2.79E+06
Fe-59	1.47E-02	7.36E-05	1.73E+09	1.57E+09	1.57E+07	1.34E-05	6.37E+05	5.57E+05
Co-58	2.25E-01	1.13E-03	3.71E+10	3.37E+10	3.37E+08	2.05E-04	9.82E+06	9.28E+06
Co-60	2.60E-02	1.30E-04	8.90E+09	8.09E+09	8.09E+07	2.36E-05	1.15E+06	1.24E+06
Zr-95	1.91E-02	9.53E-05	2.96E+09	2.69E+09	2.69E+07	2.70E-05	1.29E+06	1.21E+06
Zn-65	2.50E-02	1.25E-04	6.90E+09	6.27E+09	6.27E+07	2.27E-05	1.10E+06	1.15E+06
N-16	7.38E-01	3.69E-03	7.09E+03	0.00E+00	0.00E+00	6.71E-04	5.52E+01	5.52E+00
Na-24	2.08E+00	1.04E-02	3.64E+09	0.00E+00	0.00E+00	1.89E-03	2.72E+07	2.83E+06
Sr-89	4.03E-02	2.02E-04	5.35E+09	0.00E+00	0.00E+00	1.46E-04	6.98E+06	6.28E+06
Sr-90	2.70E-03	1.35E-05	9.48E+08	0.00E+00	0.00E+00	1.00E-05	4.87E+05	5.27E+05
Sr-91	5.33E-02	2.67E-04	6.01E+07	0.00E+00	0.00E+00	1.93E-04	1.85E+06	1.87E+05
Y-91m	1.47E-02	7.36E-05	1.43E+06	0.00E+00	0.00E+00	5.28E-05	4.39E+04	4.39E+03
Y-91	5.95E-03	2.98E-05	8.64E+08	0.00E+00	0.00E+00	2.13E-05	1.02E+06	9.35E+05
Y-93	1.28E-03	6.41E-06	1.52E+06	0.00E+00	0.00E+00	4.50E-06	4.54E+04	4.58E+03
Nb-95	6.41E-03	3.20E-05	6.11E+08	0.00E+00	0.00E+00	2.29E-05	1.08E+06	8.98E+05

Replace these columns with "B"

Add "A" after this last column

Table 12.2-18 (3 of 3)

Isotope	SG Water (Bq/g)	SG Steam (Bq/g)	Blowdown Mixed Bed (Bq)	Blowdown Pre-Filter (Bq)	Blowdown Post-Filter (Bq)	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Mo-99	3.42E+00	1.71E-02	2.68E+10	0.00E+00	0.00E+00	1.23E-02	4.25E+08	8.24E+07
Tc-99m	1.70E+00	8.48E-03	1.18E+09	0.00E+00	0.00E+00	6.30E-03	3.75E+07	3.75E+06
Ru-103	2.15E-03	1.08E-05	2.28E+08	0.00E+00	0.00E+00	7.91E-06	3.75E+05	3.19E+05
Ru-106	9.16E-04	4.58E-06	2.74E+08	0.00E+00	0.00E+00	3.38E-06	1.64E+05	1.73E+05
Ag-110m	6.38E-02	3.19E-04	1.77E+10	0.00E+00	0.00E+00	5.80E-05	2.81E+06	2.93E+06
Te-129m	7.32E-02	3.66E-04	6.78E+09	0.00E+00	0.00E+00	2.66E-04	1.26E+07	1.03E+07
Te-129	3.91E-02	1.96E-04	5.24E+06	0.00E+00	0.00E+00	1.43E-04	1.63E+05	1.63E+04
Te-131m	3.35E-01	1.68E-03	1.17E+09	0.00E+00	0.00E+00	1.20E-03	2.89E+07	3.60E+06
Te-131	3.69E-02	1.85E-04	1.79E+06	0.00E+00	0.00E+00	1.34E-04	5.59E+04	5.59E+03
Te-132	2.39E+00	1.20E-02	2.18E+10	0.00E+00	0.00E+00	8.62E-03	3.12E+08	6.71E+07
Ba-137m	~~1.65E-01~~	~~8.25E-04~~	~~8.17E+05~~	0.00E+00	0.00E+00	6.29E-04	2.66E+04	2.66E+03
Ba-140	5.02E-02	2.51E-04	1.79E+09	0.00E+00	0.00E+00	1.78E-04	8.02E+06	4.48E+06
La-140	1.65E-02	8.25E-05	7.74E+07	0.00E+00	0.00E+00	6.08E-05	1.71E+06	2.44E+05
Ce-141	1.88E-03	9.40E-06	1.70E+08	0.00E+00	0.00E+00	6.66E-06	3.14E+05	2.56E+05
Ce-143	4.87E-03	2.44E-05	1.87E+07	0.00E+00	0.00E+00	1.82E-05	4.62E+05	5.98E+04
Ce-144	5.50E-03	2.75E-05	1.57E+09	0.00E+00	0.00E+00	1.91E-05	9.28E+05	9.71E+05
W-187	1.15E-01	5.73E-04	3.19E+08	0.00E+00	0.00E+00	1.04E-04	2.16E+06	2.48E+05
Np-239	1.05E-01	5.23E-04	6.86E+08	0.00E+00	0.00E+00	9.51E-05	3.10E+06	5.34E+05

5.52E+00 2.76E-02 1.94E+12

Replace these columns with "B"

A

Isotope	Flash Tank (Bq)
Kr-85m	0.00E+00
Kr-85	0.00E+00
Kr-87	0.00E+00
Kr-88	0.00E+00
Xe-131m	0.00E+00
Xe-133m	0.00E+00
Xe-133	0.00E+00
Xe-135m	0.00E+00
Xe-135	0.00E+00
Xe-137	0.00E+00
Xe-138	0.00E+00
Br-84	7.48E+05
I-131	2.92E+08
I-132	5.32E+07
I-133	3.96E+08
I-134	2.11E+07
I-135	2.03E+08
Rb-88	5.83E+07

Isotope	Flash Tank (Bq)
Cs-134	4.67E+07
Cs-136	6.35E+06
Cs-137	5.40E+07
Cr-51	9.87E+08
Mn-54	5.94E+10
Fe-55	6.80E+09
Fe-59	6.89E+10
Co-58	8.52E+09
Co-60	1.07E+09
Zr-95	8.03E+08
Zn-65	1.91E+08
N-16	7.22E+06
Na-24	2.04E+07
Sr-89	3.94E+05
Sr-90	2.64E+04
Sr-91	5.21E+05
Y-91m	1.44E+05
Y-91	5.82E+04
Y-93	1.25E+04
Nb-95	6.27E+04

Isotope	Flash Tank (Bq)
Mo-99	3.35E+07
Tc-99m	1.66E+07
Ru-103	2.10E+04
Ru-106	8.96E+03
Ag-110m	6.24E+05
Te-129m	7.16E+05
Te-129	3.83E+05
Te-131m	3.28E+06
Te-131	3.61E+05
Te-132	2.34E+07
Ba-137m	~~1.61E+06~~
Ba-140	4.91E+05
La-140	1.61E+05
Ce-141	1.84E+04
Ce-143	4.77E+04
Ce-144	5.38E+04
W-187	1.12E+06
Np-239	1.02E+06

5.40E+07

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B

Isotope	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Kr-85m	0.00E+00	0.00E+00	0.00E+00
Kr-85	0.00E+00	0.00E+00	0.00E+00
Kr-87	0.00E+00	0.00E+00	0.00E+00
Kr-88	0.00E+00	0.00E+00	0.00E+00
Xe-131m	0.00E+00	0.00E+00	0.00E+00
Xe-133m	0.00E+00	0.00E+00	0.00E+00
Xe-133	0.00E+00	0.00E+00	0.00E+00
Xe-135m	0.00E+00	0.00E+00	0.00E+00
Xe-135	0.00E+00	0.00E+00	0.00E+00
Xe-137	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	0.00E+00	0.00E+00
Br-84	2.43E-04	0.00E+00	1.28E+05
I-131	9.50E-02	0.00E+00	1.71E+10
I-132	1.73E-02	0.00E+00	3.97E+07
I-133	1.29E-01	0.00E+00	2.70E+09
I-134	6.87E-03	0.00E+00	5.94E+06
I-135	6.61E-02	0.00E+00	4.44E+08
Rb-88	1.36E-02	4.00E+06	4.00E+05

Isotope	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Cs-134	1.08E-02	5.27E+08	5.63E+08
Cs-136	1.48E-03	6.65E+07	3.75E+07
Cs-137	1.25E-02	6.10E+08	6.61E+08
Cr-51	1.54E-03	7.23E+07	5.60E+07
Mn-54	7.14E-05	3.46E+06	3.63E+06
Fe-55	5.35E-05	2.60E+06	2.79E+06
Fe-59	1.34E-05	6.37E+05	5.57E+05
Co-58	2.05E-04	9.82E+06	9.28E+06
Co-60	2.36E-05	1.15E+06	1.24E+06
Zr-95	1.73E-05	8.30E+05	7.75E+05
Zn-65	2.27E-05	1.10E+06	1.15E+06
N-16	6.71E-04	5.52E+01	5.52E+00
Na-24	1.89E-03	2.72E+07	2.83E+06
Sr-89	3.67E-05	1.75E+06	1.58E+06
Sr-90	2.45E-06	1.19E+05	1.29E+05
Sr-91	4.85E-05	4.65E+05	4.68E+04
Y-91m	1.34E-05	1.11E+04	1.11E+03
Y-91	5.41E-06	2.59E+05	2.38E+05
Y-93	1.16E-06	1.18E+04	1.19E+03
Nb-95	5.82E-06	2.75E+05	2.28E+05

Isotope	Condensate (Bq/g)	CPS Cation Bed (Bq)	CPS Mixed Bed (Bq)
Mo-99	3.11E-03	1.08E+08	2.09E+07
Tc-99m	1.54E-03	9.18E+06	9.18E+05
Ru-103	1.96E-06	9.28E+04	7.91E+04
Ru-106	8.33E-07	4.04E+04	4.26E+04
Ag-110m	5.80E-05	2.81E+06	2.93E+06
Te-129m	6.66E-05	3.14E+06	2.58E+06
Te-129	3.56E-05	4.08E+04	4.08E+03
Te-131m	3.05E-04	7.33E+06	9.12E+05
Te-131	3.35E-05	1.40E+04	1.40E+03
Te-132	2.18E-03	7.87E+07	1.69E+07
Ba-137m	1.25E-02	6.10E+08	6.61E+08
Ba-140	4.57E-05	2.05E+06	1.15E+06
La-140	1.50E-05	4.23E+05	6.03E+04
Ce-141	1.71E-06	8.07E+04	6.57E+04
Ce-143	4.43E-06	1.13E+05	1.46E+04
Ce-144	5.00E-06	2.42E+05	2.54E+05
W-187	1.04E-04	2.16E+06	2.48E+05
Np-239	9.51E-05	3.10E+06	5.34E+05