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.:	**13-7856**
SRP Section:	**12.02 – Radiation Sources**
Application Section:	**12.2**
Date of RAI Issue:	**05/22/2015**

Question No. 12.02-2

REQUIREMENTS

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 radiation sources should be determined and provided for all radiation sources that require (1) shielding, (2) special ventilation systems, (3) special storage locations and conditions, (4) traffic or access control, (5) special plans or procedures, or (6) monitoring equipment. The source descriptions should include all pertinent information required for (1) input to shielding codes used in the design process, (2) establishment of related facility design features, (3) development of plans and procedures, (4) assessment of occupational exposure and (5) determination of radiation dose to electrical equipment important to safety as described in 10 CFR 50.49.

SRP Section 12.2 also indicates that source descriptions should include the methods, models and assumptions used as the bases for all values provided in SAR Section 12.2. A listing of isotope, quantity, form, and use of all required radiation sources containing byproduct, source, and special nuclear material exceeding 3.7 E+9 Bq (100 millicuries) that may warrant shielding design consideration, should be provided.

ISSUE

Source terms for numerous significant radiation sources in the plant are not provided in FSAR Section 12.2 and for many of the sources, the description of the basis for the source term is incomplete.

INFORMATION NEEDED

1. Staff cannot locate any source term information on the following radiation sources in FSAR Section 12.2;

    - the hold-up volume tank (listed as an area possibly exceeding 1 Gy/hr, in FSAR Section 12.3),
    - pressurizer, and
    - in-containment refueling water storage tank (IRWST).

    These sources would likely each contain a liquid and gaseous phase source term. In accordance with 10 CFR 52.47(a)(5) staff requests the following:

    a. Please include the liquid and gaseous phase 0.25% failed fuel percentage source term for each of these sources in the FSAR, or provide justification for not including them.

    b. Include the methods, models, and assumptions used in calculating these sources in the FSAR, or provide justification otherwise.

    c. Include the relevant dimensions and parameters used in the shielding analysis of these sources in FSAR Table 12.2-25.

    d. Include any other missing significant discrete sources of radiation which meet the criteria in SRP Section 12.2 of sources that should be provided, as well as the methods, models, and assumptions used for determining the source terms, in the FSAR.

2. Typically, the volume control tank (VCT) contains a significant radioactive source term for both the gaseous and liquid phase with different isotopic composition and activities for each phase. FSAR Table 12.2-13 contains only one source term for the VCT, and it does not indicate if that source term represents the gas or liquid phase. FSAR Table 12.2-25 indicates that the VCT is 60% vapor, but again, it does not indicate what the source term in Table 12.2-13 represents.

    a. Please calculate and provide in the FSAR the liquid and gaseous (vapor) source term for the VCT. This source terms should be based on the worst case operating source term for the VCT (i.e. the physical conditions that result in the largest total source term (including both liquid and gaseous) that would be anticipated during normal operation of the VCT with 0.25% failed fuel). The source terms should be provided in Section 12.2. Table 12.2-25 should provide source characteristics (percent liquid and gaseous), based on the maximum source term. Providing the maximum source term allows staff to verify the adequacy of the shielding design.

b. Update the text of FSAR 12.2 to provide the methods, models, and assumptions used to calculate the VCT source term.

c. Ensure that the ratios provided in Table 12.2-25 for the liquid and vapor phases are adequate for the maximum source term.

3. For many of the sources in FSAR Section 12.2 the applicant does not provide all the methods, models, and assumptions used as the basis for the source terms provided. Therefore, please ensure that the methods, models, and assumptions used as the basis for the source terms in FSAR Section 12.2 are provided within FSAR Section 12.2, or justify an alternative to the SRP. Sources needing a more detailed description of how they were calculated include each individual CVCS tank and each component in the boric acid concentrator package. For example, the information provided should include all assumptions made in calculating the source terms, such as, all inputs and flow rates into each tank, dilution rates, removal rates, etc.and all processing parameters, including any pertinent equations or factors needed to perform the calculations of the source terms in FSAR Section 12.2.

   In addition to providing this information for the CVCS tanks and boric acid concentrator package, the staff requests that the applicant identify any additional areas where additional information will be needed for staff to perform confirmatory calculations and verify that the assumptions used in calculating the source terms are adequate and provide that information in the FSAR.

Response – (Rev. 2)

1.

a. The holdup volume tank (HVT) is designed to collect water during post-accident conditions and dissolve the tri-sodium phosphate (TSP), so that the pH in the IRWST water is maintained at greater than 7.0. Therefore, the HVT does not contain any radioactive sources during normal operation.

   Tables 1 and 2 of this response provide the liquid and vapor source terms in the pressurizer and IRWST based on 0.25% fuel failure. These source terms will be included in DCD Section 12.2, Tables 12.2-27 and 12.2-13 (5/5) as indicated in Attachment 1.

b. The method, models, and assumptions used in calculating these sources will be included in DCD Ch. 12.2.1.1.2 (Pressurizer) and Ch. 12.2.1.1.5.1.d (IRWST) as indicated in Attachment 1.

c. Relevant dimensions and parameters used in the shielding analysis of IRWST and pressurizer are shown in Table 3. DCD Table 12.2-25 will be updated to include this information. Additional typographic errors in Table 12.2-25 will also be corrected. Refer to Attachment 2 for the DCD markups.

d. The methods and parameters used in the CVCS source terms will be described in DCD Ch. 12.2.1.1.5.1 and Table 12.2-28 as indicated in Attachment 1. In addition, the DCD will be updated to provide additional source terms for SFPCCS demineralizer and filter. Refer to Attachment 3 for the DCD markups.

Table 1. Vapor Activities in Pressurizer

Parameters Used in Pressurizer Vapor Activity Calculation

Parameter	Value
Liquid Volume (cm^3)	3.32E+07
Vapor Volume (cm^3)	3.57E+07
Liquid Mass (gram)	1.99E+07
Vapor Mass (gram)	3.52E+06
Temperature (°K)	619.44
Henry's Constant (Xe), atm	9.21E+03
Henry's Constant (Kr), atm	1.84E+03
Liquid specific volume, (cm^3/g)(1)	1.67
Vapor specific volume, (cm^3/g)(1)	10.16

Pressurizer Vapor Activities

Nuclide	Activity (Bq/g)
Kr-85m	7.5E+04
Kr-85	3.2E+05
Kr-87	5.9E+04
Kr-88	1.6E+05
Xe-131m	8.0E+06
Xe-133m	4.9E+05
Xe-133	5.2E+08
Xe-135m	1.1E+06
Xe-135	1.1E+07
Xe-137	2.5E+05
Xe-138	9.3E+05

(1) Saturation condition at 154.7 kg/cm^3A (2200 psia)

Table 2. Radioactive Source Terms in IRWST

Nuclide	Total (Bq)	Liquid (Bq)	Vapor (Bq)	Nuclide	Total (Bq)	Liquid (Bq)	Vapor (Bq)
H-3	1.7E+14	1.7E+14	2.7E+10	Te-129	3.1E-03	3.1E-03	0.0E+00
N-16	0.0E+00	0.0E+00	0.0E+00	I-131	3.6E+11	3.6E+11	3.5E+05
Kr-85m	5.1E+08	5.1E+08	0.0E+00	Te-131m	1.6E+09	1.6E+09	2.5E-03
Kr-85	1.3E+12	1.3E+12	4.0E+09	Te-131	0.0E+00	0.0E+00	0.0E+00
Kr-87	2.2E+01	2.2E+01	0.0E+00	Te-132	2.2E+10	2.2E+10	2.1E+02
Kr-88	2.3E+07	2.3E+07	0.0E+00	I-132	2.1E+05	2.1E+05	0.0E+00
Xe-131m	1.2E+12	1.2E+12	3.6E+06	I-133	1.4E+11	1.4E+11	2.4E-03
Xe-133m	5.0E+10	5.0E+10	4.7E+01	I-134	7.0E-05	7.0E-05	0.0E+00
Xe-133	7.0E+13	7.0E+13	7.1E+06	Cs-134	1.6E+12	1.6E+12	2.3E+08
Xe-135m	0.0E+00	0.0E+00	0.0E+00	I-135	3.7E+09	3.7E+09	0.0E+00
Xe-135	8.8E+10	8.8E+10	0.0E+00	Cs-136	1.4E+10	1.4E+10	2.0E+04
Xe-137	0.0E+00	0.0E+00	0.0E+00	Cs-137	2.7E+12	2.7E+12	4.1E+08
Xe-138	0.0E+00	0.0E+00	0.0E+00	Ba-140	6.6E+08	6.6E+08	3.6E+03
Br-84	0.0E+00	0.0E+00	0.0E+00	La-140	1.1E+08	1.1E+08	6.7E-03
Rb-88	0.0E+00	0.0E+00	0.0E+00	Ce-141	4.1E+07	4.1E+07	2.2E+03
Sr-89	1.5E+09	1.5E+09	1.4E+05	Ce-143	2.7E+07	2.7E+07	2.2E-04
Sr-90	3.3E+09	3.3E+09	5.4E+05	Ce-144	2.4E+09	2.4E+09	3.7E+05
Sr-91	3.6E+07	3.6E+07	0.0E+00	Na-24	4.1E+09	4.1E+09	2.1E-07
Y-91m	4.0E-07	4.0E-07	0.0E+00	Cr-51	1.3E+10	1.3E+10	5.2E+05
Y-91	2.0E+10	2.0E+10	2.6E+06	Mn-54	3.7E+10	3.7E+10	5.8E+06
Y-93	3.8E+06	3.8E+06	0.0E+00	Fe-55	5.4E+10	5.4E+10	8.6E+06
Zr-95	1.1E+09	1.1E+09	1.2E+05	Fe-59	4.7E+08	4.7E+08	3.8E+04
Nb-95	1.5E+08	1.5E+08	9.0E+03	Co-58	1.4E+10	1.4E+10	1.7E+06
Tc-99m	1.8E+08	1.8E+08	0.0E+00	Co-60	2.8E+10	2.8E+10	4.5E+06
Mo-99	3.0E+10	3.0E+10	1.1E+02	Zn-65	9.3E+09	9.3E+09	1.4E+06
Ru-103	5.9E+07	5.9E+07	4.1E+03	Ba-137m	2.7E+12	0.0E+00	0.0E+00
Ru-106	5.0E+08	5.0E+08	7.8E+04	W-187	4.6E+08	4.6E+08	6.8E-05
Ag-110m	2.4E+10	2.4E+10	3.7E+06	Np-239	8.5E+08	8.5E+08	9.3E-01
Te-129m	1.6E+09	1.6E+09	8.9E+04				

Table 3. Source Dimensions and Parameters Used in Shielding Analysis for Pressurizer and IRWST

<table>
<tr><th rowspan="2">Component</th><th colspan="4">Source Dimension</th><th colspan="2">Source Characteristic</th><th colspan="2">Housing</th></tr>
<tr><th>Shape</th><th>Diameter (cm)</th><th>Length (cm)</th><th>Height (cm)</th><th>Material</th><th>Partial Density (g/cm^3)</th><th>Material</th><th>Thickness (cm)</th></tr>
<tr><td rowspan="2">Pressurizer</td><td rowspan="2">Cylinder</td><td rowspan="2">244.48</td><td rowspan="2">-</td><td>700.66</td><td>Water:48%</td><td>0.59</td><td rowspan="2">Steel</td><td rowspan="2">12.38</td></tr>
<tr><td>747.71</td><td>Vapor:52%</td><td>0.0012</td></tr>
<tr><td rowspan="2">IRWST</td><td rowspan="2">Annular Cylinder</td><td rowspan="2">I.D:2987
O.D:4328</td><td rowspan="2">-</td><td>365.76</td><td>Water:75%</td><td>1.00</td><td rowspan="2" colspan="2">Not considered</td></tr>
<tr><td>121.92</td><td>Vapor:25%</td><td>0.0012</td></tr>
</table>

2.

a. The liquid and vapor source terms in the volume control tank (VCT) are evaluated based on the 0.25% fuel failure as shown in Table 4. The tables of the source terms in DCD Section 12.2 will be updated to provide the source terms of the liquid and gaseous phase in the VCT. Refer to Attachment 1 for the DCD markups.

b. The method, models, and assumptions used in calculating these sources will be included in DCD Subsection 12.2.1.1.5.1.d. Refer to Attachment 1 for the DCD markups.

The radioactive source terms for the VCT listed in Table 4 are obtained based on a conservative assumption to maximize both the liquid and the vapor source terms. The vapor source term is calculated at the minimum water level (31%) so that the volume and source term of the vapor phase is maximized. The liquid source term is determined based on the water being filled to the highest level so that the liquid source is maximized. The total source inventory is then calculated by summing the two maximum vapor and liquid source terms.

For the shielding calculations, the above total maximum source term is used along with an assumption that 100% of the noble gases exist in the vapor volume of 40%, which is the nominal operating condition of the VCT, and the other isotopes remain in the water volume of 60% as shown in Table 12.2-25 in DCD. This assumption is normally considered more conservative than direct use of the two liquid and vapor source terms provided in Table 4. Table 5 compares the contact dose rates of the two cases for six (6) CVCS tanks. The two cases are defined as follows;

1) Case 1 : Source terms calculated assuming low and high water levels of tank

2) Case 2 : Source terms with 100% of noble gases in vapor volume at nominal water level

As shown in Table 5, the contact dose rates for Case 2 are higher than those for Case 1.

Table 4. Liquid and Vapor Source Terms in Volume Control Tank

Nuclide	Total (Bq)	Liquid (Bq)	Vapor (Bq)	Nuclide	Total (Bq)	Liquid (Bq)	Vapor (Bq)
H-3	2.0E+12	2.0E+12	1.0E+09	Te-129	9.0E+06	9.0E+06	4.0E+03
N-16	0.0E+00	0.0E+00	0.0E+00	I-131	3.9E+09	3.9E+09	1.9E+06
Kr-85m	3.8E+12	1.6E+11	3.6E+12	Te-131m	4.4E+07	4.4E+07	2.2E+04
Kr-85	1.7E+13	7.0E+11	1.6E+13	Te-131	1.4E+07	1.4E+07	5.4E+03
Kr-87	2.6E+12	1.2E+11	2.5E+12	Te-132	3.1E+08	3.1E+08	1.5E+05
Kr-88	8.0E+12	3.4E+11	7.7E+12	I-132	9.9E+08	9.9E+08	4.7E+05
Xe-131m	9.5E+12	7.0E+11	8.8E+12	I-133	5.5E+09	5.5E+09	2.7E+06
Xe-133m	5.8E+11	4.2E+10	5.4E+11	I-134	5.7E+08	5.7E+08	2.5E+05
Xe-133	6.2E+14	4.5E+13	5.7E+14	Cs-134	2.8E+10	2.8E+10	1.4E+07
Xe-135m	6.7E+11	7.0E+10	6.0E+11	I-135	3.1E+09	3.1E+09	1.5E+06
Xe-135	1.2E+13	9.2E+11	1.1E+13	Cs-136	3.8E+09	3.8E+09	1.9E+06
Xe-137	7.1E+10	1.3E+10	5.8E+10	Cs-137	3.2E+10	3.2E+10	1.6E+07
Xe-138	5.5E+11	6.0E+10	4.9E+11	Ba-140	1.3E+07	1.3E+07	6.4E+03
Br-84	2.6E+07	2.6E+07	1.0E+04	La-140	4.3E+06	4.3E+06	2.1E+03
Rb-88	1.4E+11	1.4E+11	4.8E+07	Ce-141	4.8E+05	4.8E+05	2.4E+02
Sr-89	1.0E+07	1.0E+07	5.1E+03	Ce-143	1.3E+06	1.3E+06	6.3E+02
Sr-90	6.9E+05	6.9E+05	3.4E+02	Ce-144	1.4E+06	1.4E+06	7.0E+02
Sr-91	1.5E+07	1.5E+07	7.4E+03	Na-24	5.6E+08	5.6E+08	2.8E+05
Y-91m	3.9E+08	3.9E+08	1.7E+05	Cr-51	1.7E+08	1.7E+08	8.6E+04
Y-91	7.6E+07	7.6E+07	3.8E+04	Mn-54	2.0E+07	2.0E+07	1.0E+04
Y-93	1.8E+07	1.8E+07	8.8E+03	Fe-55	1.5E+07	1.5E+07	7.5E+03
Zr-95	4.8E+06	4.8E+06	2.4E+03	Fe-59	3.7E+06	3.7E+06	1.9E+03
Nb-95	1.6E+06	1.6E+06	8.1E+02	Co-58	5.7E+07	5.7E+07	2.9E+04
Tc-99m	5.0E+08	5.0E+08	2.5E+05	Co-60	6.6E+06	6.6E+06	3.3E+03
Mo-99	8.8E+08	8.8E+08	4.4E+05	Zn-65	6.4E+06	6.3E+06	3.2E+03
Ru-103	5.5E+05	5.5E+05	2.7E+02	Ba-137m	3.2E+10	3.2E+10	1.6E+07
Ru-106	2.3E+05	2.3E+05	1.2E+02	W-187	3.0E+07	3.0E+07	1.5E+04
Ag-110m	1.6E+07	1.6E+07	8.1E+03	Np-239	2.7E+07	2.7E+07	1.3E+04
Te-129m	9.3E+06	9.3E+06	4.6E+03				

Table 5. Contact Dose Rates for the Two Cases

CVCS Tanks	Case 1			Case 2		
	Source Phase	Volume Fraction (%)	Contact Dose Rate (mSv/hr)	Source Phase	Volume Fraction (%)	Contact Dose Rate (mSv/hr)
RDT	Liquid	79	3.15E+03	Liquid	73	5.04E+03
	Vapor	60		Vapor	27	
EDT	Liquid	37	8.86E+00	Liquid	50	5.21E+01
	Vapor	92		Vapor	50	
VCT	Liquid	62	9.29E+03	Liquid	40	1.09E+04
	Vapor	69		Vapor	60	
HUT	Liquid	20	1.90E-03	Liquid	12.5	2.13E-03
	Vapor	95		Vapor	87.5	
RMWT	Liquid	95	1.68E-04	Liquid	80	2.82E-04
	Vapor	35		Vapor	20	
BAST	Liquid	95	5.25E-04	Liquid	50	9.97E-04
	Vapor	60		Vapor	50	

3. The SHIELD-APR code was used to calculate the CVCS inventories. The SHIELD-APR code was modified to incorporate the design change (such as IRWST) from the SHIELD code which was developed by CE in the 1970s. The methods, models, and assumptions are included in the SHIELD user's manual and SVVR of SHIELD-APR. The calculation methods are described briefly below;

   a. Heat Exchanger

   The radioactivity inventory for the CVCS heat exchanger is calculated using the following equations:

   $A_{HX,i} = \frac{Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t_R}),$ for N-16

   $A_{HX,i} = a_i * V_{HX},$ for the other nuclides

   Where,

   $A_{HX,i}$ = activity in heat exchanger, Bq

   Q_i = influent flowrate, cm^3/sec

   a_i = influent specific activity, Bq/cm^3

λ_i = decay constant of a nuclide, sec^{-1}

t_R = transit time through heat exchanger, sec

V_{HX} = volume of heat exchanger, cm^3

b. Ion Exchanger

The radioactivity inventory for the CVCS ion exchangers is calculated using the following equations:

$$A_{IX,i} = \frac{\eta Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t}) \qquad \text{for DF}\neq 1.0$$

$$A_{IX,i} = a_i \times V_{IX,water} \qquad \text{for DF}=1.0$$

$$A_{IX,i} = \frac{Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t_R}) \qquad \text{for N-16}$$

Where,

$A_{IX,i}$ = activity in ion exchanger, Bq

Q_i = influent flowrate, cm^3/sec

a_i = influent specific activity, Bq/cm^3

η = removal efficiency of resin bed (=1-1/DF)

DF = decontamination factor

λ_i = decay constant of a nuclide, sec^{-1}

t = replacement period of ion exchanger resin, sec

t_R = transit time through ion exchanger, sec

$V_{IX,water}$ = water volume in ion exchanger, cm^3

It is assumed that the porosity of resin is 0.5.

c. Filter

The radioactivity inventory for the CVCS filters is calculated using the following equations:

$$A_{FL,i} = \frac{\eta Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t}) \qquad \text{for DF}\neq 1.0$$

$A_{FL,i} = a_i \times V_{FL}$ for DF=1.0

$A_{FL,i} = \frac{Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t_R})$, for N-16

Where,

$A_{FL,i}$ = activity in filter element, Bq

Q_i = influent flowrate, cm^3/sec

a_i = influent specific activity, Bq/cm^3

η = removal efficiency of filter element (=1-1/DF)

DF = decontamination factor of filter element

λ_i = decay constant of a nuclide, sec^{-1}

t = replacement period of filter element, sec

t_R = transit time through filter, sec

V_{FL} = filter volume, cm^3

d. Tank

The radioactivity inventory for the CVCS tanks is calculated using the following equations:

For Liquid activity,

$$A_{L,i} = \frac{Q_i a_i}{\lambda_i + \frac{Q_i}{V_L}}\left(1 - e^{-\left(\lambda_i + \frac{Q_i}{V_L}\right)t}\right)$$

For Noble Gases at equilibrium condition,

$$A_V = \frac{(18)(H)(V_V)(A_L)}{(V_L)(R)(T)}$$

For Noble Gases at non-equilibrium condition,

$$A_{V,i} = \left(\frac{PF}{PF+1}\right)\left(\frac{Q_i a_i}{\lambda_i}\right)(1 - e^{-\lambda_i t})$$

For Particulates,

$$A_V = \left(\frac{PF}{PF+1}\right)A_L$$

For new liquid activity (particulates and noble gases at non-equilibrium condition)

$$A_L = (\frac{1}{PF+1})A_L$$

Where,

A_L, A_V = Liquid and Vapor activity, respectively, Bq

V_L, V_V = Liquid and Vapor volume, respectively, cm^3

Q_i = influent flowrate, cm^3/sec

a_i = influent specific activity, Bq/ cm^3

λ_i = decay constant of a nuclide, sec^{-1}

PF = partition factor

t = transit time through tank, sec

18 = molecular weight of water, gram/mol

H = Henry's constant, atm

R = ideal gas constant, 82.06 cm^3-atm/°K-mol

T = temperature, °K

The liquid and vapor volumes are obtained from the low water level to maximize the VCT vapor source terms. The liquid source terms in VCT are additionally considered for the water volume from low water level to high water level. This maximizes the vapor and the liquid source terms in VCT.

The activity of the vapor space is determined initially by using Henry's law. For a non-equilibrium condition, partition factors are used to re-evaluate the vapor space activity. In the case of particulates and non-equilibrium noble gases, a new liquid activity is calculated after accounting for partitioning.

e. Boric Acid Concentrator (BAC) Package

The radioactivity inventory for the CVCS boric acid concentrator is calculated using the following equations. The influent specific activities of the concentrate heater are assumed to be equal to the specific activities of the holdup pump.

(1) Concentrate Heater

$a_{heater,i} = a_i(\frac{1}{1+PF})$ for noble gas

$a_{heater,i} = a_i \times CF_{BAC}$, for all nuclides except noble gas and N-16

$A_{heater,i} = a_{heater,i} \times V_{heater}$

Where,

$a_{heater,i}$ = specific activity of concentrate heater, Bq/cm^3

PF = partition factor for BAC heater (=10)

CF_{BAC} = BAC concentration factor (=100)

V_{heater} = BAC heater volume, cm^3

$A_{heater,i}$ = concentrate heater activity, Bq

(2) Concentrate Cooler

$A_{cooler,i} = a_{heater,i} \times V_{cooler}$

where,

V_{cooler} = concentrate cooler volume, cm^3

$A_{cooler,i}$ = concentrate heater activity, Bq

(3) Flash Tank

The influent vapor specific activities of flash tank are assumed to be equal to the specific activities of the holdup pump. The specific activities of the BAC heater are used to the influent liquid specific activities of BAC flash tank.

$A_{flash\ tank,i} = a_i \times V_{V,flash\ tank}$ for noble gas

$A_{flash\ tank,i} = a_{heater,i} \times V_{L,flash\ tank}$ for all nuclides except noble gas

Where,

$V_{V\ flash\ tank}$, $V_{L\ flash\ tank}$ = vapor and liquid volume in flash tank, respectively, cm^3

$A_{flash\ tank,i}$ = flash tank activity, Bq

(4) Vapor Separator

$a_{separator,i} = a_i \left(\frac{PF}{1+PF}\right)$ for noble gas

$a_{separator,i} = a_i$ for all nuclides except noble gas

$A_{separator,i} = a_{separator,i} \times V_{V,separator}$ for noble gas

$A_{separator,i} = a_{separator,i} \times V_{L,separator}$ for all nuclides except noble gas

Where,

$a_{separator,i}$ = specific activity of vapor separator, Bq/cm^3

PF = partition factor for BAC vapor separator (=10)

$V_{V\ separator}$, $V_{L\ separator}$ = vapor and liquid volume in vapor separator, respectively, cm^3

$A_{separator,i}$ = vapor separator activity, Bq

(5) Concentrate Pump,

$A_{conc\ pump,i} = a_{heater,i} \times V_{conc\ pump}$

Where,

$V_{conc\ pump,}$= concentrate pump volume, cm^3

$A_{conc\ pump,i}$ = concentrate pump activity, Bq

(6) Concentrate Transfer Pump

$A_{trans\ pump,i} = a_{heater,i} \times V_{trans\ pump}$

Where,

$V_{trans\ pump,}$= concentrate transfer pump volume, cm^3

$A_{trans\ pump,i}$ = concentrate transfer pump activity, Bq

Impact on DCD

DCD section 12.2 will be updated as indicated in the Attachments 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.

Table 12.2-6 lists the average expected activities due to crud deposits on SG tubing and reactor system piping. The deposited crud activity is calculated using measured data from various operating PWRs and Equation 11.1-11 (refer to Subsection 11.1.3.1).

The activation product, N-16, is the predominant activity source in the RCPs, SGs, and reactor coolant piping. The N-16 activity in each of the components depends on the transit time from the reactor core outlet to the component.

N-16 is produced by the $O^{16}(n, p)N^{16}$ reaction. The threshold energy for the reaction is 10.2 MeV. N-16 decays by beta emission with subsequent high-energy gamma emission 74 percent of the time. The gamma energies are 6.13 MeV, 69 percent of the time and 7.12 MeV, 5 percent of the time. The half-life of N-16 is 7.13 seconds.

The N-16 activity at the RV outlet nozzle is 5.53×10^6 disintegrations/cm^3-sec. This activity, after considering the volume expansion of coolant at the vessel outlet nozzle, is calculated by the following expression and the reactor parameters. Table 12.2-7 lists typical N-16 activities at various locations in the primary coolant loop.

$$\text{Activity (disintegrations/cm}^3\text{-sec)} = \frac{\Sigma\Phi(1 - e^{-\lambda t_c})e^{-\lambda t_r}}{(1 - e^{-\lambda t_t})}$$

Where:

$\Sigma\Phi$ = reaction rate (5.02×10^7 reactions/cm^3-sec)

t_c = core transit time (0.81 sec)

t_t = total primary loop time (10.6 sec)

t_r = time from the active core outlet to the point of interest

λ = decay constant (0.097 sec^{-1})

Insert Next Page

12.2.1.1.3 Secondary-Side Systems

The rate of SG tube leakage is assumed to be 3,270 L/day (0.6 gal/min). This is assumed to be concurrent with 0.25 percent fuel cladding defects for the shielding design basis source term calculations. A blowdown rate of 0.2 percent of maximum steaming rate is

The parameters and vapor activities in the pressurizer are listed in Table 12.2-27. The liquid activities in the pressurizer are assumed to be equal to the design basis reactor coolant activities in Table 12.2-5. The vapor activities of the pressurizer steam space are determined from the noble gases in Table 12.2-5. The vapor activities in the pressurizer are calculated using the following equation:

$$a_g = \frac{V_l}{V_g} \times \frac{m_g}{m_l} \times \left[\frac{M_{water} \times v_{steam}}{R \times T} \times H_{Xe\ or\ Kr}\right]^2 \times a_l$$

Where:

a_g, a_l = vapor and liquid activities, respectively, Bq

V_g, V_l = vapor and liquid volume, respectively, cm^3

m_g, m_l = vapor and liquid mass, respectively, gram

M_{water} = molecular weight of water, 18 gram/mol

v_{steam} = specific volume of steam, cm^3/gram

R = ideal gas constant, 82.06 cm^3-atm/°K-mol

T = temperature, °K

$H_{Xe\ or\ Kr}$ = Henry's law constant for Xenon or Krypton, atm assumed. No credit is taken for the operation of the condensate polisher demineralizers. Assumptions for calculation of main steam system (MSS) radiation sources are presented in Table 11.1-5, and results of the calculation are given in Table 12.2-18.

12.2.1.1.4 Spent Fuel Handling and Transfer

The spent fuel assemblies are the predominant source of radiation in the reactor containment building (RCB) after plant shutdown for refueling. A reactor operating time to reach a near-equilibrium buildup level of fission products based on the rated power operation is used in determining the source strengths. The parameters used in the spent fuel decay gamma source calculation, such as fuel enrichment, specific core power, and discharge burnup, are given in Table 12.2-8. The spent fuel decay gamma source is given in Table 12.2-9. Fuel assembly dose rates as a function of distance in the refueling pool water and time after shutdown are shown in Figures 12.2-1 and 12.2-2.

12.2.1.1.5 Processing Systems

12.2.1.1.5.1 Chemical and Volume Control System

Insert Next Page A

The shielding design for chemical and volume control system (CVCS) components is based on the maximum expected radioactivity in each of the components. The component source terms are given in Tables 12.2-10 through 12.2-14.

a. Heat exchangers

Insert Next Page B

The maximum values for the CVCS heat exchanger (HX) radionuclide inventories are presented in Table 12.2-10.

The total radioactivity inventory for the CVCS heat exchangers is based on the tube-side water volume (including the shell-side water volume for regenerative heat exchangers).

A

The source term calculation is performed using SHIELD-APR (Reference 9) computer program. Parameters of the source term calculation in CVCS are listed in Table 12.2-28.

B

The radioactivity inventory for the CVCS heat exchanger is calculated using the following equations:

$$A_{HX,i} = \frac{Q_i a_i}{\lambda_i}\left(1 - e^{-\lambda_i t_R}\right), \qquad \text{for N-16}$$

$$A_{HX,i} = a_i * V_{HX}, \qquad \text{for the other nuclides}$$

Where :

$A_{HX,i}$ = activity in heat exchanger, Bq
Q_i = influent flowrate, cm^3/sec
a_i = influent specific activity, Bq/cm^3
λ_i = decay constant of a nuclide, sec^{-1}
t_R = transit time through heat exchanger, sec
V_{HX} = volume of heat exchanger, cm^3

b. Ion exchangers

Insert Next Page

The maximum values for CVCS ion exchanger (IX) radionuclide inventories are presented in Table 12.2-11.

1) Purification ion exchanger

The total radioactivity inventory is based on resin buildup for the duration of 120 percent of one cycle of effective full-power days (EFPDs). This ion exchanger is used for removing lithium and purifying coolant water from RCS letdown. It is used for lithium removal for the first part of one-cycle EFPDs, which spans an average of 20 percent, and then it is put into service as a purification ion exchanger. The decontamination factor (DF) for anions is 100 with an efficiency of 99 percent. The DF for crud is 50 with an efficiency of 98 percent. The DF for all remaining nuclides except Xe, Kr, Y, Rb, and Cs is 50 with an efficiency of 98 percent. The DF for Xe, Kr, and Y is 1 with an efficiency of 0 percent. The DF for Rb and Cs is 2 with an efficiency of 50 percent. The radioactivity inventory in processed liquid is based on a normal letdown flow rate.

2) Deborating ion exchanger

The total radioactivity inventory is based on resin buildup during the end-of-cycle (EOC) deborating operation. This ion exchanger is used to reduce reactor coolant boron concentration at the EOC. Boron control in the CVCS is described in detail in Subsection 9.3.4. The DF for nuclides except anions and crud is 1 with an efficiency of 0 percent. The DF for anions and cruds is 10 with an efficiency of 90 percent. The radioactivity inventory in processed liquid is based on a normal letdown flow rate.

3) Pre-holdup ion exchanger

The total radioactivity inventory is based on resin buildup for the duration of one-cycle EFPDs. The DF for all nuclides except Xe, Kr, Y, Rb, and Cs is 10 with an efficiency of 90 percent. The DF for Rb and Cs is 100 with an

The radioactivity inventory for the CVCS ion exchangers is calculated using the following equations:

$$A_{IX,i} = \frac{\eta Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t})$$ for DF≠1.0

$$A_{IX,i} = a_i \times V_{IX,water}$$ for DF=1.0

$$A_{IX,i} = \frac{Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t_R})$$ for N-16

Where :

$A_{IX,i}$ = activity in ion exchanger, Bq
Q_i = influent flowrate, cm^3/sec
a_i = influent specific activity, Bq/cm^3
η = removal efficiency of resin bed (=1-1/DF)
DF = decontamination factor
λ_i = decay constant of a nuclide, sec^{-1}
t = replacement period of ion exchanger resin, sec
t_R = transit time through ion exchanger, sec
$V_{IX,water}$ = water volume in ion exchanger, cm^3

It is assumed that the porosity of resin is 0.5.

efficiency of 99 percent. The DF for Xe, Kr, and Y is 1 with an efficiency of 0 percent. Liquid inputs processed by the pre-holdup ion exchanger include the letdown processed through the purification ion exchanger and the purification filter, and the inflow from the reactor drain tank (RDT) and the equipment drain tank (EDT).

4) Boric acid condensate ion exchanger

The total radioactivity inventory is based on resin buildup for the duration of one-cycle EFPDs. The DF for anions is 10 with an efficiency of 90 percent. The DF for other nuclides including crud is 1 with an efficiency of 0 percent. The radioactivity inventory is based on input from the letdown processed through the purification ion exchanger and the purification filter, the inflow from the RDT and the EDT, and the inflow from the boric acid concentrator (BAC) in consideration of the average condensation rate.

c. Filters

Insert Next Page A

The maximum values for CVCS filter radionuclide inventories are presented in Table 12.2-12.

The total radioactivity inventories in the CVCS filters are based on crud buildup for the duration of one-cycle EFPDs. The DF assumed for crud buildup in the filter is 10 with an efficiency of 90 percent.

d. Tanks

Insert Next Page B (2 pages)

The maximum values for CVCS tank radionuclide inventories are presented in Table 12.2-13.

The total radioactivity inventories in the CVCS tanks are based on buildup for the duration of one-cycle EFPDs.

A

The radioactivity inventory for the CVCS filters is calculated using the following equations:

$$A_{FL,i} = \frac{\eta Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t})$$ for DF≠1.0

$$A_{FL,i} = a_i \times V_{FL}$$ for DF=1.0

$$A_{FL,i} = \frac{Q_i a_i}{\lambda_i}(1 - e^{-\lambda_i t_R}),$$ for N-16

Where:

$A_{FL,i}$ = activity in filter element, Bq
Q_i = influent flowrate, cm^3/sec
a_i = influent specific activity, Bq/cm^3
η = removal efficiency of filter element (=1-1/DF)
DF = decontamination factor of filter element
λ_i = decay constant of a nuclide, sec^{-1}
t = replacement period of filter element, sec
t_R = transit time through filter, sec
V_{FL} = filter volume, cm^3

B

The radioactivity inventory for the CVCS tanks is calculated using the following equations:

For Liquid activity,

$$A_{L,i} = \frac{Q_i a_i}{\lambda_i + \frac{Q_i}{V_L}}(1 - e^{-\left(\lambda_i + \frac{Q_i}{V_L}\right)t})$$

For Noble Gases at equilibrium condition,

$$A_V = \frac{(18)(H)(V_V)(A_L)}{(V_L)(R)(T)}$$

For Noble Gases at non-equilibrium condition,

$$A_{V,i} = \left(\frac{PF}{PF+1}\right)\left(\frac{Q_i a_i}{\lambda_i}\right)(1 - e^{-\lambda_i t})$$

For Particulates,

$$A_V = \left(\frac{PF}{PF+1}\right)A_L$$

For new liquid activity (particulates and noble gases at non-equilibrium condition)

$$A_L = \left(\frac{1}{PF+1}\right)A_L$$

Where:

- A_L, A_V = Liquid and Vapor activity, respectively, Bq
- V_L, V_V = Liquid and Vapor volume, respectively, cm^3
- Q_i = influent flowrate, cm^3/sec
- a_i = influent specific activity, Bq/ cm^3
- λ_i = decay constant of a nuclide, sec^{-1}
- PF = partition factor
- t = transit time through tank, sec
- 18 = molecular weight of water, gram/mol
- H = Henry's constant, atm
- R = ideal gas constant, 82.06 cm^3-atm/°K-mol
- T = temperature, °K

The liquid and vapor volumes are obtained from the low water level to maximize the VCT vapor source terms. The liquid source terms in VCT are additionally considered for the water volume from low water level to high water level. This maximizes the vapor and the liquid source terms in VCT.

The activity of the vapor space is determined initially by using Henry's law. For non-equilibrium condition, partition factors are used to re-evaluate the vapor space activity. In the case of particulates and non-equilibrium noble gases, a new liquid activity is calculated after accounting for partitioning.

e. Boric acid concentrator

Insert Next Page B (2 pages)

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 radioactivity inventory for the CVCS boric acid concentrator is calculated using the following equations. The influent specific activities of concentrate heater are assumed to be equal to the specific activities of holdup pump.

(1) Concentrate Heater

$a_{heater,i} = a_i(\frac{1}{1+PF})$ for noble gas

$a_{heater,i} = a_i \times CF_{BAC},$ for all nuclides except noble gas and N-16

$A_{heater,i} = a_{heater,i} \times V_{heater}$

Where:

$a_{heater,i}$ = specific activity of concentrate heater, Bq/cm^3
PF = partition factor for BAC heater (=10)
CF_{BAC} = BAC concentration factor (=100)
V_{heater} = BAC heater volume, cm^3
$A_{heater,i}$ = concentrate heater activity, Bq

(2) Concentrate Cooler

$A_{cooler,i} = a_{heater,i} \times V_{cooler}$

Where:

V_{cooler} = concentrate cooler volume, cm^3
$A_{cooler,i}$ = concentrate heater activity, Bq

(3) Flash Tank

The influent vapor specific activities of flash tank are assumed to be equal to the specific activities of holdup pump. The specific activities of BAC heater used to the influent liquid specific activities of BAC flash tank.

$A_{flash\ tank,i} = a_i \times V_{V,flash\ tank}$ for noble gas
$A_{flash\ tank,i} = a_{heater,i} \times V_{L,flash\ tank}$ for all nuclides except noble gas

Where:

$V_{V\ flash\ tank}$, $V_{L\ flash\ tank}$ = vapor and liquid volume in flash tank, respectively, cm^3
$A_{flash\ tank,i}$ = flash tank activity, Bq

(4) Vapor Separator

$a_{separator,i} = a_i\left(\frac{PF}{1+PF}\right)$ for noble gas
$a_{separator,i} = a_i$ for all nuclides except noble gas
$A_{separator,i} = a_{separator,i} \times V_{V,separator}$ for noble gas
$A_{separator,i} = a_{separator,i} \times V_{L,separator}$ for all nuclides except noble gas

Where:

$a_{separator,i}$ = specific activity of vapor separator, Bq/cm^3

PF = partition factor for BAC vapor separator (=10)

$V_{V\ separator}$, $V_{L\ separator}$ = vapor and liquid volume in vapor separator, respectively, cm^3

$A_{separator,i}$ = vapor separator activity, Bq

(5) Concentrate Pump,

$$A_{conc\ pump,i} = a_{heater,i} \times V_{conc\ pump}$$

Where:

$V_{conc\ pump,}$= concentrate pump volume, cm^3

$A_{conc\ pump,i}$ = concentrate pump activity, Bq

(6) Concentrate Transfer Pump

$$A_{trans\ pump,i} = a_{heater,i} \times V_{trans\ pump}$$

Where:

$V_{trans\ pump,}$= concentrate transfer pump volume, cm^3

$A_{trans\ pump,i}$ = concentrate transfer pump activity, Bq

12.2.5 References

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9. 00000-CV-VV-002, Rev.00, "Software Verification and Validation Report for SHIELD-APR," KEPCO E&C, October 2002.

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Table 12.2-13 (1 of 2)

CVCS Tank Inventories, Maximum Values (Bq)

Nuclide	Reactor Drain	Equipment Drain	Volume Control	Holdup	Reactor Makeup Water	Boric Acid Storage
H-3	1.6E+12	1.7E+11	2.0E+12	1.9E+14	1.8E+14	4.1E+13
N-16	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	1.4E+11	2.3E+10	3.8E+12	8.4E+09	3.8E+03	0.0E+00
Kr-85	9.1E+12	4.0E+11	1.7E+13	1.9E+11	1.3E+08	1.3E+09
Kr-87	6.7E+10	1.1E+10	2.6E+12	1.9E+09	2.5E+02	0.0E+00
Kr-88	2.5E+11	4.1E+10	8.0E+12	1.2E+10	3.3E+03	0.0E+00
Xe-131m	3.8E+12	6.0E+10	9.5E+12	1.5E+10	1.3E+07	4.6E+07
Xe-133m	1.2E+11	2.1E+10	5.8E+11	9.0E+09	7.2E+04	3.1E+03
Xe-133	1.9E+14	3.4E+12	6.2E+14	5.7E+11	2.3E+08	2.0E+08
Xe-135m	3.7E+10	6.4E+09	6.7E+11	1.3E+08	4.3E+00	0.0E+00
Xe-135	8.6E+11	1.4E+11	1.2E+13	4.4E+10	4.9E+04	5.8E-09
Xe-137	8.2E+09	1.4E+09	7.1E+10	9.0E+05	6.9E-02	0.0E+00
Xe-138	3.2E+10	5.6E+09	5.5E+11	1.0E+08	3.0E+00	0.0E+00
Br-84	1.2E+09	2.0E+08	2.6E+07	1.1E+06	1.2E-01	0.0E+00
Rb-88	1.4E+11	2.4E+10	1.4E+11	1.0E+08	3.2E+01	0.0E+00
Sr-89	3.7E+08	4.2E+07	1.0E+07	1.6E+08	2.2E+05	1.6E+09
Sr-90	2.6E+07	2.9E+06	6.9E+05	1.3E+07	3.4E+04	8.1E+08
Sr-91	3.1E+08	5.1E+07	1.5E+07	1.3E+07	1.2E+02	4.8E-08
Y-91m	1.7E+08	2.9E+07	3.9E+08	1.5E+08	7.2E+01	0.0E+00
Y-91	5.5E+07	6.2E+06	7.6E+07	2.5E+09	3.2E+06	2.5E+10
Y-93	7.4E+06	1.2E+06	1.8E+07	7.6E+07	4.1E+02	4.6E-07
Zr-95	1.8E+08	2.0E+07	4.8E+06	7.7E+07	1.2E+05	1.0E+09
Nb-95	5.8E+07	6.5E+06	1.6E+06	2.4E+07	2.7E+04	1.5E+08
Tc-99m	1.0E+10	1.7E+09	5.0E+08	2.3E+08	1.5E+03	5.8E-15
Mo-99	2.3E+10	3.1E+09	8.8E+08	5.0E+09	3.3E+05	2.3E+07
Ru-103	2.0E+07	2.2E+06	5.5E+05	8.2E+06	9.8E+03	5.9E+07
Ru-106	8.8E+06	9.8E+05	2.3E+05	4.1E+06	1.0E+04	1.8E+08
Ag-110m	6.1E+08	6.8E+07	1.6E+07	2.8E+08	6.5E+05	1.1E+10

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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	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

Table 12.2-13 (1 of 5)

CVCS Tank Inventories, Maximum Values (Bq)

Nuclide	Reactor Drain		Equipment Drain		Volume Control	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
H-3	1.6E+12	7.9E+08	1.7E+11	3.7E+06	2.0E+12	1.0E+09
N-16	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	6.4E+10	7.9E+10	1.1E+10	1.2E+10	1.6E+11	3.6E+12
Kr-85	5.3E+11	8.5E+12	4.7E+10	3.5E+11	7.0E+11	1.6E+13
Kr-87	4.9E+10	1.8E+10	8.5E+09	2.8E+09	1.2E+11	2.5E+12
Kr-88	1.4E+11	1.1E+11	2.4E+10	1.7E+10	3.4E+11	7.7E+12
Xe-131m	4.6E+11	3.3E+12	4.7E+10	1.3E+10	7.0E+11	8.8E+12
Xe-133m	2.2E+10	9.5E+10	3.0E+09	1.8E+10	4.2E+10	5.4E+11
Xe-133	2.7E+13	1.6E+14	3.0E+12	3.8E+11	4.5E+13	5.7E+14
Xe-135m	3.5E+10	1.5E+09	6.2E+09	2.3E+08	7.0E+10	6.0E+11
Xe-135	3.8E+11	4.9E+11	6.2E+10	7.8E+10	9.2E+11	1.1E+13
Xe-137	8.1E+09	9.3E+07	1.4E+09	1.4E+07	1.3E+10	5.8E+10
Xe-138	3.1E+10	1.2E+09	5.4E+09	1.8E+08	6.0E+10	4.9E+11
Br-84	1.2E+09	5.9E+03	2.0E+08	1.2E+01	2.6E+07	1.0E+04
Rb-88	1.4E+11	3.8E+05	2.4E+10	7.7E+02	1.4E+11	4.8E+07
Sr-89	3.7E+08	1.8E+05	4.2E+07	7.8E+02	1.0E+07	5.1E+03
Sr-90	2.6E+07	1.3E+04	2.9E+06	6.3E+01	6.9E+05	3.4E+02
Sr-91	3.1E+08	2.4E+04	5.1E+07	5.1E+01	1.5E+07	7.4E+03
Y-91m	1.7E+08	1.3E+03	2.9E+07	2.7E+00	3.9E+08	1.7E+05
Y-91	5.5E+07	2.7E+04	6.2E+06	1.2E+02	7.6E+07	3.8E+04
Y-93	7.4E+06	6.0E+02	1.2E+06	1.3E+00	1.8E+07	8.8E+03
Zr-95	1.8E+08	8.7E+04	2.0E+07	3.8E+02	4.8E+06	2.4E+03
Nb-95	5.8E+07	2.8E+04	6.5E+06	1.1E+02	1.6E+06	8.1E+02
Tc-99m	1.0E+10	5.3E+05	1.7E+09	1.1E+03	5.0E+08	2.5E+05
Mo-99	2.3E+10	6.5E+06	3.1E+09	1.7E+04	8.8E+08	4.4E+05
Ru-103	2.0E+07	9.5E+03	2.2E+06	4.0E+01	5.5E+05	2.7E+02
Ru-106	8.8E+06	4.4E+03	9.8E+05	2.1E+01	2.3E+05	1.2E+02
Ag-110m	6.1E+08	3.1E+05	6.8E+07	1.4E+03	1.6E+07	8.1E+03

Table 12.2-13 (2 of 5)

Nuclide	Reactor Drain		Equipment Drain		Volume Control	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
Te-129m	6.7E+08	3.2E+05	7.5E+07	1.3E+03	9.3E+06	4.6E+03
Te-129	3.8E+08	4.0E+03	6.6E+07	8.1E+00	9.0E+06	4.0E+03
I-131	2.4E+11	9.7E+07	2.9E+10	3.1E+05	3.9E+09	1.9E+06
Te-131m	2.0E+09	3.6E+05	3.0E+08	8.3E+02	4.4E+07	2.2E+04
Te-131	6.6E+08	2.6E+03	1.2E+08	5.3E+00	1.4E+07	5.4E+03
Te-132	1.7E+10	5.0E+06	2.2E+09	1.3E+04	3.1E+08	1.5E+05
I-132	4.0E+10	8.5E+05	7.0E+09	1.7E+03	9.9E+08	4.7E+05
I-133	2.4E+11	3.5E+07	3.7E+10	7.7E+04	5.5E+09	2.7E+06
I-134	2.4E+10	2.0E+05	4.2E+09	4.0E+02	5.7E+08	2.5E+05
Cs-134	4.2E+10	2.1E+07	4.7E+09	1.0E+05	2.8E+10	1.4E+07
I-135	1.3E+11	7.2E+06	2.1E+10	1.5E+04	3.1E+09	1.5E+06
Cs-136	5.0E+09	2.2E+06	5.8E+08	7.6E+03	3.8E+09	1.9E+06
Cs-137	4.9E+10	2.5E+07	5.4E+09	1.2E+05	3.2E+10	1.6E+07
Ba-140	4.2E+08	1.8E+05	4.9E+07	6.4E+02	1.3E+07	6.4E+03
La-140	1.0E+08	2.3E+04	1.5E+07	5.4E+01	4.3E+06	2.1E+03
Ce-141	1.7E+07	8.1E+03	1.9E+06	3.3E+01	4.8E+05	2.4E+02
Ce-143	3.0E+07	5.8E+03	4.4E+06	1.4E+01	1.3E+06	6.3E+02
Ce-144	5.3E+07	2.6E+04	5.9E+06	1.2E+02	1.4E+06	7.0E+02
Na-24	1.2E+10	1.4E+06	1.9E+09	2.9E+03	5.6E+08	2.8E+05
Cr-51	6.1E+09	2.9E+06	6.9E+08	1.1E+04	1.7E+08	8.6E+04
Mn-54	7.5E+08	3.8E+05	8.4E+07	1.8E+03	2.0E+07	1.0E+04
Fe-55	5.7E+08	2.9E+05	6.3E+07	1.4E+03	1.5E+07	7.5E+03
Fe-59	1.4E+08	6.6E+04	1.5E+07	2.8E+02	3.7E+06	1.9E+03
Co-58	2.1E+09	1.0E+06	2.4E+08	4.6E+03	5.7E+07	2.9E+04
Co-60	2.5E+08	1.3E+05	2.8E+07	6.0E+02	6.6E+06	3.3E+03
Zn-65	2.4E+08	1.2E+05	2.7E+07	5.6E+02	6.3E+06	3.2E+03
Ba-137m	4.9E+10	2.5E+07	5.4E+09	1.2E+05	3.2E+10	1.6E+07
W-187	6.8E+08	1.1E+05	1.0E+08	2.4E+02	3.0E+07	1.5E+04
Np-239	6.9E+08	1.8E+05	9.4E+07	4.5E+02	2.7E+07	1.3E+04

Table 12.2-13 (3 of 5)

Nuclide	Holdup		Reactor Makeup Water		Boric Acid Storage	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
H-3	2.3E+15	1.0E+09	1.8E+14	1.2E+10	9.7E+13	3.3E+09
N-16	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Kr-85m	3.3E+08	8.1E+09	6.6E+02	3.1E+03	0.0E+00	0.0E+00
Kr-85	1.4E+10	1.8E+11	1.6E+07	1.1E+08	1.6E+09	1.3E+09
Kr-87	7.9E+07	1.9E+09	4.3E+01	2.0E+02	0.0E+00	0.0E+00
Kr-88	5.2E+08	1.1E+10	5.8E+02	2.7E+03	0.0E+00	0.0E+00
Xe-131m	8.6E+09	6.6E+09	4.5E+06	8.9E+06	2.0E+07	1.1E+08
Xe-133m	2.9E+08	8.7E+09	2.4E+04	4.8E+04	1.3E+03	7.6E+03
Xe-133	3.9E+11	1.9E+11	7.7E+07	1.5E+08	8.7E+07	5.0E+08
Xe-135m	4.7E+06	1.3E+08	1.4E+00	2.9E+00	0.0E+00	0.0E+00
Xe-135	2.6E+09	4.1E+10	1.6E+04	3.3E+04	2.5E-09	1.4E-08
Xe-137	1.6E+05	7.7E+06	2.2E-02	4.6E-02	0.0E+00	0.0E+00
Xe-138	3.4E+06	9.9E+07	9.7E-01	2.0E+00	0.0E+00	0.0E+00
Br-84	1.1E+06	3.5E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Rb-88	1.0E+08	1.6E+03	3.2E+01	0.0E+00	0.0E+00	0.0E+00
Sr-89	1.8E+08	2.5E+03	2.2E+05	1.2E+01	3.2E+09	1.5E+05
Sr-90	2.4E+07	2.0E+02	3.4E+04	2.3E+00	1.9E+09	6.5E+04
Sr-91	1.3E+07	1.7E+02	1.2E+02	0.0E+00	9.6E-08	0.0E+00
Y-91m	1.5E+08	1.3E+03	7.2E+01	0.0E+00	0.0E+00	0.0E+00
Y-91	9.6E+09	3.4E+04	3.2E+06	1.8E+02	5.1E+10	2.3E+06
Y-93	7.6E+07	5.9E+02	4.1E+02	0.0E+00	9.2E-07	0.0E+00
Zr-95	8.9E+07	1.2E+03	1.2E+05	6.8E+00	2.1E+09	9.3E+04
Nb-95	2.6E+07	3.8E+02	2.7E+04	1.4E+00	3.0E+08	1.4E+04
Tc-99m	2.3E+08	3.7E+03	1.5E+03	0.0E+00	0.0E+00	0.0E+00
Mo-99	5.0E+09	6.1E+04	3.3E+05	1.6E+01	4.6E+07	2.3E+03
Ru-103	8.9E+06	1.3E+02	9.8E+03	0.0E+00	1.2E+08	5.6E+03
Ru-106	6.6E+06	6.5E+01	1.0E+04	0.0E+00	4.1E+08	1.5E+04
Ag-110m	4.3E+08	4.5E+03	6.5E+05	4.1E+01	2.4E+10	9.0E+05

Table 12.2-13 (4 of 5)

Nuclide	Holdup		Reactor Makeup Water		Boric Acid Storage	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
Te-129m	2.7E+08	4.0E+03	2.8E+04	1.4E+00	3.0E+09	1.4E+05
Te-129	9.6E+05	2.4E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00
I-131	7.0E+10	1.0E+06	2.0E+06	9.4E+01	5.0E+10	2.5E+06
Te-131m	2.5E+08	2.6E+03	5.5E+02	0.0E+00	2.4E+03	1.2E-01
Te-131	4.4E+05	1.5E+01	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Te-132	3.6E+09	4.4E+04	2.9E+04	1.4E+00	7.7E+07	3.8E+03
I-132	2.3E+08	5.1E+03	7.8E+01	0.0E+00	0.0E+00	0.0E+00
I-133	2.2E+10	2.4E+05	3.6E+04	1.8E+00	3.2E+03	1.6E-01
I-134	4.4E+07	1.2E+03	6.9E+00	0.0E+00	0.0E+00	0.0E+00
Cs-134	8.8E+09	1.3E+05	2.1E+07	1.4E+03	1.0E+12	3.6E+07
I-135	2.3E+09	4.5E+04	2.0E+03	0.0E+00	0.0E+00	0.0E+00
Cs-136	7.2E+08	1.2E+04	3.8E+05	1.8E+01	1.8E+09	8.8E+04
Cs-137	1.1E+10	1.5E+05	2.6E+07	1.8E+03	1.5E+12	5.0E+07
Ba-140	1.5E+08	2.3E+03	7.0E+04	3.4E+00	3.3E+08	1.6E+04
La-140	1.8E+07	1.9E+02	5.9E+02	0.0E+00	4.6E+03	2.3E-01
Ce-141	7.3E+06	1.1E+02	7.3E+03	0.0E+00	7.8E+07	3.7E+03
Ce-143	4.5E+06	4.8E+01	1.2E+02	0.0E+00	1.9E+02	9.3E-03
Ce-144	3.8E+07	3.9E+02	5.7E+04	3.7E+00	2.2E+09	8.2E+04
Na-24	8.8E+08	1.0E+04	1.1E+04	0.0E+00	3.9E-01	1.9E-05
Cr-51	2.5E+09	3.8E+04	2.3E+06	1.2E+02	2.2E+10	1.0E+06
Mn-54	5.5E+08	5.6E+03	8.3E+05	5.4E+01	3.3E+10	1.2E+06
Fe-55	4.9E+08	4.2E+03	7.1E+05	4.7E+01	3.5E+10	1.2E+06
Fe-59	6.3E+07	9.1E+02	7.3E+04	3.9E+00	9.9E+08	4.5E+04
Co-58	1.1E+09	1.5E+04	1.5E+06	8.5E+01	2.7E+10	1.2E+06
Co-60	2.3E+08	1.9E+03	3.2E+05	2.2E+01	1.7E+10	5.9E+05
Zn-65	1.7E+08	1.8E+03	2.5E+05	1.6E+01	9.1E+09	3.5E+05
Ba-137m	1.3E+06	5.9E+01	2.6E+07	1.8E+03	0.0E+00	0.0E+00
W-187	8.1E+07	8.4E+02	1.5E+03	0.0E+00	7.9E+01	4.0E-03
Np-239	1.4E+08	1.6E+03	7.3E+03	0.0E+00	4.6E+05	2.3E+01

Table 12.2-13 (5 of 5)

Nuclide	In-containment Refueling Water Storage		Nuclide	In-containment Refueling Water Storage	
	Liquid	Vapor		Liquid	Vapor
H-3	1.7E+14	2.7E+10	Te-129m	1.6E+09	8.9E+04
N-16	0.0E+00	0.0E+00	Te-129	3.1E-03	0.0E+00
Kr-85m	5.1E+08	0.0E+00	I-131	3.6E+11	3.5E+05
Kr-85	1.3E+12	4.0E+09	Te-131m	1.6E+09	2.5E-03
Kr-87	2.2E+01	0.0E+00	Te-131	0.0E+00	0.0E+00
Kr-88	2.3E+07	0.0E+00	Te-132	2.2E+10	2.1E+02
Xe-131m	1.2E+12	3.6E+06	I-132	2.1E+05	0.0E+00
Xe-133m	5.0E+10	4.7E+01	I-133	1.4E+11	2.4E-03
Xe-133	7.0E+13	7.1E+06	I-134	7.0E-05	0.0E+00
Xe-135m	0.0E+00	0.0E+00	Cs-134	1.6E+12	2.3E+08
Xe-135	8.8E+10	0.0E+00	I-135	3.7E+09	0.0E+00
Xe-137	0.0E+00	0.0E+00	Cs-136	1.4E+10	2.0E+04
Xe-138	0.0E+00	0.0E+00	Cs-137	2.7E+12	4.1E+08
Br-84	0.0E+00	0.0E+00	Ba-140	6.6E+08	3.6E+03
Rb-88	0.0E+00	0.0E+00	La-140	1.1E+08	6.7E-03
Sr-89	1.5E+09	1.4E+05	Ce-141	4.1E+07	2.2E+03
Sr-90	3.3E+09	5.4E+05	Ce-143	2.7E+07	2.2E-04
Sr-91	3.6E+07	0.0E+00	Ce-144	2.4E+09	3.7E+05
Y-91m	4.0E-07	0.0E+00	Na-24	4.1E+09	2.1E-07
Y-91	2.0E+10	2.6E+06	Cr-51	1.3E+10	5.2E+05
Y-93	3.8E+06	0.0E+00	Mn-54	3.7E+10	5.8E+06
Zr-95	1.1E+09	1.2E+05	Fe-55	5.4E+10	8.6E+06
Nb-95	1.5E+08	9.0E+03	Fe-59	4.7E+08	3.8E+04
Tc-99m	1.8E+08	0.0E+00	Co-58	1.4E+10	1.7E+06
Mo-99	3.0E+10	1.1E+02	Co-60	2.8E+10	4.5E+06
Ru-103	5.9E+07	4.1E+03	Zn-65	9.3E+09	1.4E+06
Ru-106	5.0E+08	7.8E+04	Ba-137m	0.0E+00	0.0E+00
Ag-110m	2.4E+10	3.7E+06	W-187	4.6E+08	6.8E-05
			Np-239	8.5E+08	9.3E-01

Add New Table

Table 12.2-27 Vapor Activities in Pressurizer

Parameters Used in Pressurizer Vapor Activity Calculation

Parameter	Value
Liquid Volume (cm^3)	3.32E+07
Vapor Volume (cm^3)	3.57E+07
Liquid Mass (gram)	1.99E+07
Vapor Mass (gram)	3.52E+06
Temperature (°K)	619.44
Henry's Constant (Xe), atm	9.21E+03
Henry's Constant (Kr), atm	1.84E+03
Liquid specific volume, (cm^3/g)(1)	1.67
Vapor specific volume, (cm^3/g)(1)	10.16

Pressurizer Vapor Activities

Nuclide	Activity (Bq/g)
Kr-85m	7.5E+04
Kr-85	3.2E+05
Kr-87	5.9E+04
Kr-88	1.6E+05
Xe-131m	8.0E+06
Xe-133m	4.9E+05
Xe-133	5.2E+08
Xe-135m	1.1E+06
Xe-135	1.1E+07
Xe-137	2.5E+05
Xe-138	9.3E+05

(1) Saturation condition at 154.7 kg/cm^3A (2200 psia)

Add New Table (2 pages)

Table 12.2-28 Parameters Used in CVCS Inventory Calculations (1/2)

Components	Parameters	Value	Components	Parameters	Value
Letdown HX	Tube Volume (cm^3)	270658	Equipment Drain Tank	Tank Volume (cm^3)	3.596E+07
Regenerative HX	Tube Volume (cm^3)	27984	Equipment Drain Tank	Low Level Fraction	0.08
Regenerative HX	Shell Volume (cm^3)	174886	Equipment Drain Tank	High Level Fraction	0.37
CCP Mini Flow HX	Tube Volume	145738	Equipment Drain Tank	RCS Activity Fraction	0.1
Purification IX	Vessel Volume (cm^3)	1578517	Equipment Drain Tank	Flow rate (cm^3/sec)	2.19
Purification IX	Resin Volume (cm^3)	906138	Volume Control Tank	Tank Volume (cm^3)	2.536E+07
Deborating IX	Vessel Volume (cm^3)	1578517	Volume Control Tank	Low Level Fraction	0.31
Deborating IX	Resin Volume (cm^3)	906138	Volume Control Tank	High Level Fraction	0.62
Pre-holdup IX	Vessel Volume (cm^3)	1578517	Holdup Tank	Tank Volume (cm^3)	1.590E+09
Pre-holdup IX	Resin Volume (cm^3)	906138	Holdup Tank	Low Level Fraction	0.05
Boric Acid Condensate IX	Vessel Volume (cm^3)	1457384	Holdup Tank	High Level Fraction	0.20
Boric Acid Condensate IX	Resin Volume (cm^3)	906138	Reactor Makeup Water Tank	Tank Volume (cm^3)	1.495E+09
Seal Injection Filter	Vessel Volume (cm^3)	7570	Reactor Makeup Water Tank	Low Level Fraction	0.65
Reactor Drain Filter	Vessel Volume (cm^3)	15142	Reactor Makeup Water Tank	High Level Fraction	0.95
Boric Acid Filter	Vessel Volume (cm^3)	15142	Boric Acid Storage Tank	Tank Volume (cm^3)	9.464E+08
Purification Filter	Vessel Volume (cm^3)	15142	Boric Acid Storage Tank	Low Level Fraction	0.40
Reactor Makeup Water Filter	Vessel Volume (cm^3)	15142	Boric Acid Storage Tank	High Level Fraction	0.95
Reactor Drain Tank	Tank Volume (cm^3)	1.514E+07	In-containment Refueling Water Storage Tank	Tank Volume (cm^3)	2.961E+09
Reactor Drain Tank	Low Level Fraction	0.40	In-containment Refueling Water Storage Tank	Low Level Fraction	0.81
Reactor Drain Tank	High Level Fraction	0.79	In-containment Refueling Water Storage Tank	High Level Fraction	0.87
Reactor Drain Tank	Flow rate (cm^3/sec)	11			

Table 12.2-28 Parameters Used in CVCS Inventories (2/2)

Components	Parameters	Value	Remarks
Reactor Drain Tank	Partition Factor	0.001	Particulates
		10	Noble Gas
Equipment Drain Tank	Partition Factor	0.0001	Particulates
		10	Noble Gas
Volume Control Tank	Partition Factor	0.001	Particulates
		10	Noble Gas
Holdup Tank	Partition Factor	0.0001	Particulates
		10	Noble Gas
Reactor Makeup Water Tank	Partition Factor	0.0001	Particulates
		10	Noble Gas
Boric Acid Storage Tank	Partition Factor	0.0001	Particulates
		10	Noble Gas
In-containment Refueling Water Storage Tank	Partition Factor	0.0001	Particulates
		10	Noble Gas
Yearly Generated Waste	Volume (cm^3)	4.164E+09	
Boration Waste	Volume (cm^3)	1.772E+08	
Dilution Waste	Volume (cm^3)	3.358E+08	
Drained Coolant	Volume (cm^3)	1.616E+08	
Contraction Addition	Volume (cm^3)	1.268E+08	
RCS Partial Refill Addition	Volume (cm^3)	4.823E+08	

Table 12.2-25 (1 of 3)

Radioactive Source Dimensions and Parameters Used in S

700.06	Water : 48%	0.59
747.71	Vapor : 52%	0.001293

Building	Component	Source Dimension				Source Characteristic		Housing	
		Shape	Diameter (or Width) (cm)	Length (cm)	Height (cm)	Material	Partial Density (g/cm3)	Material	Thickness (cm)
Reactor Containment Building	Pressurizer	Cylinder	244.48	-	~~700.66~~	~~Water: 100 %~~	~~0.59~~	Steel	12.38
	Reactor coolant pump	Cylinder	185.00	-	126.74	Water: 100 %	0.75	Steel	14.00
	Reactor drain tank	Cylinder	Liquid: 162.90 Vapor: 99.70	-	528.57	Water: ~~27 %~~ 62% Vapor: ~~73 %~~ 38%	1.00 0.001293	Not considered	
	Regenerative HX	Cylinder	24.69	-	400.69	Water: 85 % Steel: 15 %	0.85 1.18	Steel	2.22
	Letdown HX	Cylinder	45.72	-	341.36	Water: 88 % Steel: 12 %	0.88 0.95	Steel	2.54
	Steam generator	Annular cylinder	OD: 497.80 ID: 415.80	-	969.57	Water: 100 %	0.70	Steel	12.86
		Semisphere	472.60						
Auxiliary Building	SC HX	Cylinder	~~68.58~~ 137.16		803.15	Water: 94 % Steel: 6 %	0.94 0.54	Steel	1.27
	SC miniflow HX	Cylinder	33.66	-	173.43	Water: 93 % Steel: 7 %	0.93 0.59	Steel	0.95
	Charging pump miniflow HX	Cylinder	38.10	-	298.70	Water: 94 % Steel: 6 %	0.94 0.50	Steel	1.27
	CS HX	Cylinder	129.54	-	701.04	Water: 94 % Steel: 6 %	0.94 0.49	Steel	1.59

Table 12.2-25 (2 of 3)

Building	Component	Source Dimension: Shape	Source Dimension: Diameter (or Width) (cm)	Source Dimension: Length (cm)	Source Dimension: Height (cm)	Source Characteristic: Material	Source Characteristic: Partial Density (g/cm^3)	Housing: Material	Housing: Thickness (cm)
Auxiliary Building	CS miniflow HX	Cylinder	31.75	-	186.06	Water: 94 % Steel: 6 %	0.94 0.45	Steel	0.95
	Equipment drain tank	Cylinder	~~193.59~~ Liquid: 96.80 Vapor: 96.80	-	610.87	Water: 50 % Vapor: 50 %	1.00 0.001293	Not considered	
	Boric acid concentrator	Cylinder	Liquid: 193.53 Vapor: 206.58	-	180.52	Water: 47 % Vapor: 53 %	1.00 0.001293	Not considered	
	~~SC HX~~	[illegible] Delete this line	~~[illegible].16~~	-	~~803.15~~	~~Water: 94 %~~ ~~Vapor: 6 %~~	~~0.942~~ ~~0.453~~	~~Steel~~	~~1.27~~
	SFP cleanup demin.	Cylinder	145.70	-	144.17	Water: 100 %	1.00	Not considered	
	Boric acid condensate IX	Cylinder	74.60	-	206.17	Water: 100 %	1.00	Not considered	
	Deborating IX	Cylinder	105.08	-	104.49	Water: 100 %	1.00	Not considered	
	Pre-holdup IX	Cylinder	~~52.54~~ 105.08	-	104.49	Water: 100 %	1.00	Not considered	
	Purification IX	Cylinder	~~52.54~~ 105.08	-	104.49	Water: 100 %	1.00	Not considered	
	SFP cooling HX	Rectangular ~~parallelepiped~~	31.19 5	134.16 5	198.28	Water: 67 % Steel: 33 %	0.67 2.63	Not considered	
	Volume control tank	Cylinder	~~120.72~~ 241.44	-	~~218.09~~ Liquid: 223.23 Vapor: 330.72	Water: 40 % Vapor: 60 %	1.00 0.001293	Not considered	
	SGBD flash tank	Cylinder	~~152.40~~ 304.8	-	455.96	Water: 100 %	1.00	Not considered	
	SGBD HX	Cylinder	~~42.43~~ 84.86	-	487.68	Water: 86 % Steel: 14 %	0.90 1.12	Steel	1.27

IRWST	Annular Cylinder	O.D:4328 I.D:2987	-	365.76	Water: 75%	1.00	Not considered
				121.92	Vapor: 25%	0.001293	

Building	Component	Source Dimension				Source Characteristic		Housing	
		Shape	Diameter (or Width) (cm)	Length (cm)	Height (cm)	Material	Partial Density (g/cm^3)	Material	Thickness (cm)
Auxiliary Building	Spent fuel pool	Rectangular ~~parallelepiped~~	869.00	1,113.50	381.00	Water: 70% UO_2: 22% Zircaloy: 8%	0.70 1.98 0.56	Not considered	
	Cask loading pit	Rectangular parallelepiped	20.23	20.23	381.00	Water: 58% UO_2: 30% Zircaloy: 12%	0.58 2.76 0.79	Not considered	
	GRS header drain tank	Cylinder	45.72	-	172.48	Vapor: 100%	0.001293	Not considered	
Compound Building	Chemical waste tank	Cylinder	304.80	-	466.91	Water: 100%	1.00	Not considered	
	Floor drain tank	Cylinder	358.14	-	676.38	Water: 100%	1.00	Not considered	
	Equipment drain tank	Cylinder	358.14	-	676.38	Water: 100%	1.00	Not considered	
	Low-activity spent resin tank	Cylinder	274.32	-	383.33	Water: 100%	1.00	Not considered	
	Spent resin long-term storage tank	Cylinder	~~243.84~~ 487.68		482.92	Water: 100%	1.00	Not considered	
	LRS IX	Cylinder	120.17	-	124.83	Water: 100%	1.00	Not considered	
	Waste drum storage	Rectangular parallelepiped	601.98	782.57	262.89	Carbon: 100%	2.62	Not considered	

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.

The source terms for the SFP demineralizers and filters are provided in Table 12.2-17a.

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

This table will be added following Table 12.2-17.

Table 12.2-17a

SFP Demineralizer and Filter Source Terms

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