RP-CQ-201506-Ch12_#2 Response (Rev. 1)

Revised Response - DCD Tier 2, SECTION Chapter 12 #2

There are various issues with source terms, including:

a. Page 12.2-4 of the DCD indicates that the CVCS ion exchangers have 0 efficiency for collecting noble gases (which makes sense). However, in the source term information for the ion exchangers, the source term for some of the ion exchangers have an increased noble gas source term concentration beyond what is in the RCS. If the efficiency is 0 should the ion exchangers be concentrating noble gases?

b. The dimensions for several sources in Table 12.2-25 for some components are grossly inconsistent with the information in other chapters, for example the Volume control tank and several ion exchanger dimensions provided in Table 12.2-25 are inconsistent with volumes provided in Chapter 9.

c. Staff confirmatory calculations provide results inconsistent with the applicant's source term for some isotopes. For example, for the purification ion exchanger, the Cesium values appear reasonable, but Strontium 90 and Cobalt 60 values appear lower than what they should be for the assumptions provided.

d. A review of FSAR Tables 12.2-19 (0.25% failed fuel GRS source term) and 11.3-11 (1% failed fuel GRS source term) reveals that for certain isotopes the values in Table 12.2-19 are higher than the values in Table 11.3-11. Staff sees no apparent reason why for some isotopes the 1% failed fuel values would be lower than the 0.25% failed fuel values.

Response

a. The letdown flow passes through the regenerative heat exchanger, the letdown heat exchanger, the purification filter and the purification ion exchanger, and the deborating ion exchanger.

   Since the CVCS ion exchangers have 0 efficiency, there is no removal of noble gases for these components. So the influent specific activities of these components are assumed to be the same as the RCS specific activities. The source terms of noble gases in the ion exchanger are equal to or less than the RCS activities.

   The inventories for CVCS ion exchanger in DCD Table 12.2-11 have units in Bq and the RCS equilibrium concentration in DCD Table 12.2-5 has units in Bq/g.A comparison of the noble gas source terms from Tables 12.2-11 and 12.2-5 are provided in Table 1.

Table 1 Comparison of source terms for noble gases

Nuclide	CVCS Purification IX Inventories (Bq) (Table 12.2-11)	RCS Specific Activities (Bq/g) (Table 12.2-5)	Calculated CVCS Purification IX Inventories (Bq)
Kr-85m	1.2E+10	1.04E+04	1.17E+10
Kr-85	5.0E+10	4.44E+04	5.00E+10

Kr-87	9.2E+09	8.14E+03	9.16E+09
Kr-88	2.5E+10	2.26E+04	2.54E+10
Xe-131m	5.0E+10	4.44E+04	5.00E+10
Xe-133m	3.0E+09	2.70E+03	3.04E+09
Xe-133	3.3E+12	2.89E+06	3.25E+12
Xe-135m	6.7E+09	5.92E+03	6.66E+09
Xe-135	6.7E+10	5.92E+04	6.66E+10
Xe-137	1.5E+09	1.37E+03	1.54E+09
Xe-138	5.8E+09	5.18E+03	5.83E+09

For Kr-85m, the RCS specific activity is 1.04E+04 Bq/g.

The vessel volume (V_{IX}) for the purification ion exchanger is 417 gal (1,578,524 cc) and the resin volume (V_R) is 32 ft^3 (906,144 cc).

The water volume in the resin region is assumed to be 50% (porosity of resin is 0.5). It is also assumed only 50% of the resin bed volume is used as it is assumed that the other 50% is void space, due to the physical shape of resin, which will be filled with water. Therefore, the volume used is $V_L = V_{IX} - (0.5)\ V_R$. So the water volume is 1,125,452 cc [=1,578,524 – 0.5 * 906,144].

The Kr-85m inventory of the purification ion exchanger is calculated at 1.17E+10 Bq [=1.04E+04×1,125,452]. The water density is assumed to be 1 g/cc. The value of 1.2E+10 in DCD Table 12.2-11 is the rounded off value of 1.17E+10.

b. As indicated in the question, several dimensions in Table 12.2-25 were mistyped. The diameter of the Pre-Holdup and Purification ion exchangers should be 105.28 cm. The value of 52.54 cm corresponds to the radius of the ion exchangers, not the diameter. The height of the Volume Control Tank (VCT) should also be corrected to 553.95 cm. The value of 218.09 cm is the expected height of the water portion of the VCT during normal operation.

DCD Table 12.2-25 will be revised to correct the typing errors as indicated above. Refer to the attached “RP-CQ-201506-Ch12_#2 Markup” for the DCD markups.

c. The Co-60, Sr-90 and Cs-137 activities are calculated as follows;
1) The specific activities of influent flow at the purification ion exchanger,
a(Co-60) = 2.10E+01 Bq/cc (same as RCS activity, Table 12.2-5)
a(Sr-90) = 2.18E+00 Bq/cc (same as RCS activity, Table 12.2-5)
a(Cs-137) = 4.07E+03 Bq/cc (same as RCS activity, Table 12.2-5)
The water density is assumed to be 1 g/cc.

2) The source terms for Co-60, Sr-90 and Cs-137 are calculated by the following equation.

$$\frac{A_{IX(Pu)}}{dt} = \eta Q_i a_i - \lambda A_{IX(Pu)}$$

$$A_{IX(Pu)} = \frac{\eta Q_i a_i}{\lambda}(1 - e^{-\lambda t})$$

$A_{IX(Pu)}$: activity in ion exchanger [Bq]

η : removal efficiency of ion exchanger resin bed (=1-1/DF)
DF : decontamination factor of ion exchanger, DF=50 for Co-60 and Sr-90, DF=2 for Cs-137
Q_i : influent flowrate [cc/sec], letdown flow rate = 5047.2 cc/sec (80 gpm)
a_i : influent specific activity [Bq/cc]
λ : decay constant of a nuclide [sec^{-1}], λ(Co-60)=4.17E-09, λ(Sr-90)=7.80E-10, λ(Cs-137)=7.32E-10
t : replacement period of ion exchanger resin [sec], t=4.15E+7 sec (480 days)

$A_{IX(Pu)}$ (Co-60) = 3.96E+12 Bq
$A_{IX(Pu)}$ (Sr-90) = 4.40E+11 Bq
$A_{IX(Pu)}$ (Cs-137) = 4.20E+14 Bq

The purification ion exchanger is used to remove lithium from the RCS which is produced by interactions between boron and neutrons. To consider this lithium removal operation, the following terms are added to the results calculated above.

$$A_{IX(Li)} = \frac{\eta_{Li} \times (0.2 \times Q_i a_i)}{\lambda \times DF_{IX}} (1 - e^{-\lambda t})$$

η_{Li} : removal efficiency of ion exchanger resin bed for lithium removal (=1-1/DF_{Li})
DF_{Li} : decontamination factor of lithium removal ion exchanger, DF_{Li}=10 for Co-60, Sr-90 and Cs-137
DF_{IX} : decontamination factor of ion exchanger, DF_{IX}=50 for Co-60 and Sr-90, DF_{IX}=2 for Cs-137
0.2 : fraction of lithium removal operation time during one cycle operation
Q_i : influent flowrate [cc/sec], letdown flow rate = 5047.2 cc/sec (80 gpm)
a_i : influent specific activity [Bq/cc]
λ : decay constant of a nuclide [sec^{-1}], λ(Co-60)=4.17E-09, λ(Sr-90)=7.80E-10, λ(Cs-137)=7.32E-10
t : replacement period of ion exchanger resin [sec], t=4.15E+7 sec (480 days)

$A_{IX(Li)}$ (Co-60) = 1.45E+10 Bq
$A_{IX(Li)}$ (Sr-90) = 1.62E+09 Bq
$A_{IX(Li)}$ (Cs-137) = 7.55E+13 Bq

Therefore, the results are

A_{IX} (Co-60) = $A_{IX(Pu)}$(Co-60)+$A_{IX(Li)}$(Co-60)
= 3.96E+12 +1.45E+10= 3.97E+12 Bq
A_{IX} (Sr-90) = 4.40E+11 + 1.62E+09 = 4.42E+11 Bq
A_{IX} (Cs-137) = 4.20E+14 + 7.55E+13 = 4.95E+14 Bq

The above results for Co-60, Sr-90, and Cs-137 are consistent with the values provided in DCD Table 12.2-11.

While in reality separate purification ion exchangers will be used for lithium removal and radionuclide removal, for conservatism the source term for each purification ion exchanger assumes that one ion exchanger is doing both within a change out period (480 days).

d. FSAR Tables 11.3-11 and 12.2-19 are based on FSAR Table 11.1-2 (1% fuel failure, gas stripping) and 12.2-5 (0.25% fuel failure, no gas stripping).

RP-CQ-201506-Ch12_#2 Response (Rev. 1)

For Kr-85, Xe-131m, Xe-133m, and Xe-133, the values in Table 11.1-2 are lower than the values in Table 12.2-5. The reason for this difference is that the fuel failure rate and the operation of the gas stripper have effects on the noble gas concentrations.

In the fuel pellet region, the fission product production considers the fission yield and the removal by decay and based on these assumptions DCD equation Eq. 11.1-1 is simplified as follow:

$$\frac{\mathrm{d}N^p}{\mathrm{dt}} = \mathrm{FYP} - \lambda N^p,\ N^p = \frac{\mathrm{FYP}}{\lambda}(1 - e^{-\lambda \mathrm{t}}) \qquad (1)$$

In the reactor coolant region, the fission product inventory considers the escape from fuel pellet through defective fuel rod cladding, the removal by decay, and the removal by gas stripping. Based on these assumptions DCD Eq. 11.1-2 is simplified as follows:

$$\frac{\mathrm{d}N^c}{\mathrm{dt}} = \nu \mathrm{D} N^p - (\lambda + \mathrm{k})N^c,\ N^c = \frac{\nu\mathrm{DFYP}}{\lambda(\lambda+\mathrm{k})}(1 - e^{-(\lambda+\mathrm{k})\mathrm{t}}) \qquad (2)$$

Where the variables in Eqs. (1) and (2) are defined as:
N = nuclide population, atoms
F = average fission rate, fissions/MWt-sec
Y = core averaged fission yield of nuclide, fraction
P = core power, MWt
λ = decay constant, sec^{-1}
ν = escape rate coefficient, sec^{-1}
t = time, seconds
D = defective fuel cladding, fraction
$\dot{Q}$ = chemical and volume control system (CVCS) purification mass flow rate during power operation, kg/sec
W = RCS mass during power operation, kg
η = efficiency of CVCS gas stripper
$\mathrm{k} = \frac{\dot{\mathrm{Q}}}{W} \cdot \eta$

The activity (Bq/g) in the reactor coolant is derived as follows:

$$A^c = \frac{\lambda N^c}{W}$$

Case i) Activity in case of 0.25% fuel failure and no gas stripping
From Eq. (2), since k=0 (η=0)

$$A^c_{No\ GS} = \frac{\nu\mathrm{DFYP}}{\lambda\mathrm{W}}\left(1 - e^{-\lambda\mathrm{t}}\right) \approx \frac{\nu(0.0025)\mathrm{FYP}}{\lambda\mathrm{W}} \qquad (3)$$

Case ii) Activity in case of 1% fuel failure and gas stripping
From Eq. (2)

RP-CQ-201506-Ch12_#2 Response (Rev. 1)

$$A_{GS}^{c} = \frac{\nu DFYP}{(\lambda+k)W}\left(1 - e^{-(\lambda+k)t}\right) + A_{GS}^{c}(0)e^{-(\lambda+k)t} \approx \frac{\nu(0.01)FYP}{(\lambda+k)W} \quad (4)$$

Table 2 shows the comparison results of cases i) and ii) using the parameters of FSAR Table 11.1.1-1.

Table 2 Comparison results

Nuclide	λ (sec^{-1})	λ+k (sec^{-1})	$\frac{Eq.(3)}{Eq.(4)}$	FSAR Table 12.2-5 ①	FSAR Table 11.1-2 ②	①/②
Kr-85m	4.30E-05	6.02E-05	0.35	1.04E+04	3.00E+04	0.34
Kr-85	2.05E-09	1.68E-05	2047	4.44E+04	7.40E+02	60.0
Kr-87	1.51E-04	1.68E-04	0.28	8.14E+03	2.92E+04	0.28
Kr-88	6.78E-05	8.50E-05	0.31	2.26E+04	7.40E+04	0.31
Xe-131m	6.74E-07	1.78E-05	6.62	4.44E+04	7.40E+03	6.00
Xe-133m	3.66E-06	2.08E-05	1.42	2.70E+03	1.92E+03	1.41
Xe-133	1.53E-06	1.87E-05	3.06	2.89E+06	9.62E+05	3.00
Xe-135m	7.56E-04	7.73E-04	0.26	5.92E+03	2.29E+04	0.26
Xe-135	2.11E-05	3.83E-05	0.45	5.92E+04	1.30E+05	0.46
Xe-137	3.03E-03	3.05E-03	0.25	1.37E+03	5.55E+03	0.25
Xe-138	8.20E-04	8.37E-04	0.26	5.18E+03	1.96E+04	0.26

Because the removal amount due to gas stripping is larger than the removal amount due to decay ($k > 3\lambda$), the activities for Kr-85, Xe-131m, Xe-133m, and Xe-133 noble gases in Table 11.1-2 are lower than the values in Table 12.2-5.

In particular, since the removal amount by decay is very small due to the long half-life of Kr-85 (10.73 y), the operation of the gas stripper has a greater effect on Kr-85 activity.

Impact on DCD

DCD Table 12.2-25 will be updated as indicated in "RP-CQ-201506-Ch12_#2 Markup".

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 and Environmental Reports.

Table 12.2-25 (2 of 3)

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	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	—	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	Cylinder	137.16	—	803.15	Water: 94 % Vapor: 6 %	0.942 0.453	Steel	1.27
	SFP Clean-up Demi.	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	134.16	198.28	Water: 67 % Steel: 33 %	0.67 2.63	Not considered	
	Volume Control Tank	Cylinder	120.72	—	~~218.09~~ 553.95	Water: 40 % Vapor: 60 %	1.00 0.001293	Not considered	
	SGBD Flash Tank	Cylinder	152.40	—	455.96	Water: 100 %	1.00	Not considered	
	SGBD HX	Cylinder	42.43	—	487.68	Water: 86 % Steel: 14 %	0.90 1.12	Steel	1.27