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Questions in Response to RAI 8089, Question 03.11-11

1. In the response, KHNP proposes adding a new Appendix 3A to APR1400-E-X-NR-14001-P, however, currently the DCD references the September 2014 version of APR1400-E-X-NR-14001-P, which does not include this newly added appendix. The applicant must ensure that the modifications to APR1400-E-X-NR-14001-P are appropriately referenced in the DCD.

   (KHNP Response) After incorporating the modifications into the next revision of technical report APR1400-E-X-NR-14001-P, the DCD will be reviewed to ensure that all references to the contained material in the revised technical report are appropriately referenced in the DCD.

2. In several places in the response, the applicant mentions a revised DCD Table 3.11-3 and revised Table 3 of APR1400-E-X-NR-14001-P, however, these revised tables were not included in the response. Please indicate when they will be provided.

   (KHNP Response) The revised DCD, Table 3.11-2 (Old Table 3.11-3) and the revised APR1400-E-X-NR-14001-P, Table 2 (old Table 3) have been provided in response to RAI 8089, Question 03.11-09, which was submitted on July 8, 2016 (ref. MKD/NW-16-0718L). These tables are enclosed with this response as Attachments 1 and 2, respectively for your information.

3. In the response to Question 5.b, the applicant indicates that TIDs from filter loading in the CRE ACUs are not specifically analyzed because they are bounded by the ABCAEEACUs. However, these filters are in different parts of the building than the ABCAEEACUs. Are the CRE ACUs considered to have the same loading as the ABCAEEACUs? If not, the ABCAEEACUs appear to be in a radiologically harsh environment during accident conditions for EQ purposes, meaning that it is radiologically significant for EQ purposes. Therefore, it doesn't appear to make sense to ignore the CRE ACUs simply because the ABCAEEACUs have a higher dose rate. Please provide better justification in the response for why the TIDs from filter loadings in the CRE ACUs are not specifically analyzed.

   (KHNP Response) The CRE ACUs are assumed to have the same TIDs for the ABCAEEACUs for conservatism, and therefore it is not necessary that the TIDs resulting from filter loadings in the CRE ACUs be specifically analyzed.

<u>The remaining questions are all regarding the proposed markup to APR1400-E-X-NR-14001-P (Attachment 2 in the response).</u>

4. In Section 3A.1.1, the first paragraph indicates that the components inside containment within the scope of the EQ program are the CS/SC and SI systems. However, this does

not include the safety-related radiation monitors inside containment or any other safety-related components inside containment. Please update the statement appropriately and include the radiation monitors in the updates DCD Table 3.11-3 and Table 3 of APR1400-E-X-NR-14001-P.

(KHNP Response) All safety-related components including the accidental radiation monitors inside the containment were considered for the TIDs calculation. To calculate the TIDs of all safety-related components inside the containment, the following rooms and areas containing safety-related components were taken into consideration for the TIDs, as follows:

- TENDON GALLERY
- ICI CAVITY
- REACTOR CAVITY
- HOLD-UP VOLUME TANK
- IRWST
- CORE DEBRIS CHAMBER
- REACTOR CAVITY ACCESS AREA
- CONTAINMENT ANNULUS AREA
- STEAM GENERATOR CAVITY
- REACTOR DRAIN TANK RM
- LETDOWN HX RM
- ELEV. HOISTWAY
- UGS LAYDOWN AREA
- CSB LAYDOWN AREA
- VALVE RM
- REGENERATIVE HX RM
- REFUELING POOL AREA
- CONTAINMENT ANNULUS AREA
- PRESSURIZER CAVITY
- OPERATING AREA
- ELEV. MACHINE RM

The associated description in Section 3A.1.1 will be revised, and the new Table 2 of the revised APR1400-E-X-NR-14001-P was be provided with the TIDs for the operating area where the safety-related radiation monitors in containment are situated.

Commented [MS1]: Does this mean that we need to revise the tables that we just submitted or that they include the correct TIDs for the rad monitors?
This means that they include the TIDs for the rad. monitors. More accurately, the new Table 2 of the revised APR1400-E-X-NR-14001-P indicate not TIDs for the rad. monitor but TIDs for operating area where rad. monitor is located.

5. In Section 3A.1.1, under the definition of "Release Source Term," it states that the core inventory release fractions for each radionuclide group at the gap release and early in-vessel release phases for the LOCA are listed in DCD Table 15A-2." However, DCD Table 15A-2 only lists the gap phase. Please include the correct table(s) in this sentence.

(KHNP Response) To provide both the gap release and early in vessel release fraction, the referenced DCD Table 15A-2 in Section 3A.1.1 will be changed to Table 15.6.5-13.

6. In Section 3A.1.1 under IRWST Source term and in the DCD markup of Section 15.6.5.5.1.2, it states that the initial source term in the IRWST consists of 40% halogens in the core inventory, 30% of alkali metal, and small fractions of other fission products. Isn't this source term the same source term provided in Table 12.2-24, in the response to RAI 8247, Question 12.02-16? If so, why not include a reference to this table with this information or at a minimum, at least specify the fractions of the "other fission products," because a "small fraction" is too vague. If this is not the same source term as the proposed Table 12.2-24, please explain why a different IRWST source term is being used.

   (KHNP Response) The initial source term in the IRWST is the same source term as the proposed Table 12.2-24. For clarity, the corresponding description in Section 3A.1.1 will be updated as follows:

   > *"The initial source term in the IRWST except for noble gases consists of 40% of halogens in the core inventory, 30% of alkali metal, and fractions of other fission products which are addressed in detail in Table 15.6.5-13."*

7. In Section 3A.1, the applicant indicates that the dose rate was calculated at the containment atmosphere, containment wall surface, bottom of containment, and in the center of the containment IRWST sump. However, the markup does not specify why these locations were chosen and how the doses from these four locations were used to come up with the TID for components in containment (for example, were all four doses added to come up with a TID value to be used for all components in containment, or how were the individual dose rates assigned to specific equipment).

   (KHNP Response) As shown in Figure 1, the four locations evaluated were determined taking into account the installation locations of the components and equipment inside the containment.

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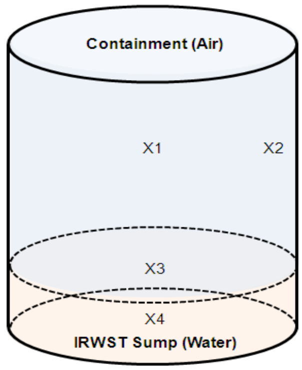

Figure 1. Locations of Dose Points for TID calculation inside Containment

The TIDs for each of the components/equipment at these locations, which are calculated using the RUNT-G code, are as follows:

Table 1. TIDs at Different Locations inside Containment

Location	TID [Sv]		
	Gamma	Beta	Total
X1 (Center of Containment)	1.3E5	9.4E5	1.1E6
X2 (Containment Wall)	8.9E4	9.4E5	1.0E6
X3 (Containment Bottom)	3.1E5	9.4E5	1.2E6
X4 (Center of IRWST Sump)	3.2E5	8.0E4	4.0E5

Depending on the location, the resultant TIDs assigned to specific components or equipment were determined for the bounding analysis as follows:

- Components located Above Elevation 100' = TIDs at X4 location
- Components located Below Elevation 100' = Maximum gamma TID + Maximum beta TID at any location (i.e., Gamma TID at X3 location + Beta TID at X2 location)

8. Section 3A.2.1, under "ESF Components Leakage," it states that the maximum anticipated leakage rate through all ESF system components containing the IRWST water source term (i.e., SI/SC/CS components) is calculated to be 0.285 ft^3/hour and that the value of 0.285 ft^3/hour (2.13 gal/hour) was doubled, in accordance with RG 1.183 to a value of 0.57 ft^3/hour (4.26 gal/hour). This value was also stated in Section 3A.2.2.2. However, the value of 2.13 gal/hour in DCD Table 15.6.5-13, was updated to 10 gal/hour in the response to RAI 8213, Question 15.00.03-29 (ML15301A901). Therefore, in accordance with RG 1.183 and the response to Question 15.00.03-29, the correct

assumption for ESF Component Leakage would be 2.674 ft^3/hour (20 gal/hour). Please update the ESF Component Leakage rate in Section 3A.2.1 and the associated calculations accordingly. Also, please ensure that other information referenced in the response is based on current information.

(KHNP Response)

1) Response to RAI 8213, Question 15.00.03-29 (Refer to Attachment 3)

RAI 8213, Question 15.00.03-29 was about resolving the discrepancy between the assumed ESF leakage rates addressed in DCD Table 15.6.5-13 (2 of 3) and in DCD Section 15.6.5.5.1.2, which was found to be an editorial error. As discussed in the response to this question, the value of 8.08 L/hr (2.13 gal/hr) in Table 15.6.5-13 (2 of 3) was updated to be consistent with the description (i.e., 37.8 L/hr (10 gal/hr)) in DCD Subsection 15.6.5.5.1.2. The ESF leakage rate of 10 gal/hr was a result of increasing the 5 gal/hr by a factor of 2 and is in compliance with the RG 1.183 guidance.

2) Applicability of 0.57 ft^3/hour (4.26 gal/hour).

Based on the leak rates from valves and pumps of all ESF systems (i.e., SI and CS) during the emergency operation, the resultant total leak rate is calculated to be 8,080 cm^3/hr (2.13 gal/hr). In accordance with RG 1.183 guidance, the ESF leakage of 2.13 gal/hr is doubled to the modeled value of 4.26 gal/hr for the EQ TID calculations. In performing the radiological consequence analysis, the calculated leak rate of 8,080 cm^3/hr (2.13 gal/hr) is conservatively assumed to be increased to 5 gal/hr, which is then doubled to 10 gal/hr.

Therefore, it can be concluded that the assumed leak rates for the radiological consequence analysis are more conservative, and that the EQ TIDs due to the ESF component leakages were calculated in compliance with the RG 1.183 guidance.

9. In Section 3A.2.1, under “Partition Coefficient,” the applicant assumes that the partition factor is 10% for halogens, while RG 1.183, Appendix A, Section 5.4, indicates that if the leakage exceeds 212 degrees Fahrenheit, that the equation in Section 5.4 should be used to calculate the partition coefficient. It is only assumed to be 10% if the fluid is less than 212 degrees Fahrenheit or if the value calculated is less than 10%. However, DCD Table 15.6.5-13 shows that containment sump fluid, post-LOCA, is above 212 degrees Fahrenheit. Therefore, please justify the use of the 10% value for halogens or update the partition coefficient accordingly.

(KHNP Response) The flashing fraction (FF) is calculated based on the enthalpy difference under the circumstance of coolant leakage by assuming the leakage to be in a constant enthalpy process, of which the equation is given below. Based on this equation, the use of the maximum IRWST water temperature of 235.50°F yields an iodine FF of 2.39%, resulting in a smaller FF than 10%. However, in the analysis of EQ TIDs, 0.1 of the partition factor for halogens was conservatively used instead of the FF of 0.024 in addition to using 0.1 of the partition factor at a temperature of the leakage less than 212 °F.

$$\text{Flashing Fraction (FF)} = \frac{h_{f_1} - h_{f_2}}{h_{fg}} = \frac{203.90 - 180.17}{970.3} = 0.024$$

where,

- h_{f_1}: Enthalpy at system temperature and pressure before leaking from a component
- h_{f_2} : Enthalpy at saturation condition after leaking from a component / equipment
- h_{fg} : Enthalpy of steam at saturation condition after leaking from a component

10. Also under "Partition Coefficient" in Section 3A.2.1, it reads as if the partition coefficients are only used for calculating the amount that goes into the ABCAEES. Please verify that the partition coefficients are also used for calculating airborne activity inside the Auxiliary Building. If so, specify this under "Partition Coefficient," if not, please indicate what partition coefficients were used for calculating the airborne activity source term.

    (KHNP Response) As addressed in Section 3A.2.2.2 and as can be seen in Figure 3A-7, the airborne activity inside the Auxiliary Building should be evaluated first with the partition coefficient corresponding to each isotope group in order to calculate the amount of radioactivity that goes into the ABCAEES, and then the loading of radioactivity in the filter is calculated. Therefore, both airborne activities inside the Auxiliary Building or from the filter loading are calculated with the one partition coefficient. For clarity, the associated description in the "Partition Coefficient" part of Section 3A.2.1 will be updated as follows:

    "**Partition Coefficient**: *When some radionuclides that leak from SI/SC/CS equipment* become airborne in the auxiliary building and subsequently *enter into the ABCAEES, the assumed partition coefficient of each isotope group is as follows, based on the RG 1.183 guidance:"*

11. In Section 3A.2.1, under "SI/SC/CS Piping geometry", it indicates that Schedule 40S steel pipe and nominal pipe size of 16-inch are assumed for conservatism. However, DCD Table 6.8-4 indicates that there is SI piping as large as 24-inches. 24 inch pipe would result in a larger dose rate, that 16 inch pipe. Therefore, please explain why 16 inches is considered conservative.

(KHNP Response) All the pipes in each cubicle containing the SI/SC/CS components are taken into account for the EQ TIDs calculations, not just the one nominal pipe size of 16-inches, where schedule 40S steel pipe is typically used. Therefore, the associated description in SI/SC/CS Piping Geometry" part of Section 3A.2.1 will be updated as follows:

> "**SI/SC/CS Piping Geometry**: *All the pipes in each cubicle containing* the SI/SC/CS components where *Schedule 40S steel pipe is assumed* are taken into account."

12. In Section 3A.2.2.1, on the very last line of Page (7/30), it specifies that the relative concentration of the plume is 6.725×10^{-4} sec/m^3. Please specify how this value was derived.

    (KHNP Response) As addressed in Section 3A.2.1, the relative concentration of the plume is calculated by using the following equation, which is from USAEC, "Meteorology and Atomic Energy."

$$\chi/Q = (UCA)^{-1}$$

where,

U: wind speed (1 m/sec)
C: building wake factor (= 0.5)
A: cross section area of containment (=2973.9m^2)

Therefore, $\chi/Q = (1 \times 0.5 \times 2973.9)^{-1} = 6.725 \times 10^{-4}$ sec/m^3

13. Editorial error, on the very first line of page 8/30, it states that the ABCAEES intake flow rate is 1.02×10^4 m^{3}hr. The units should be m^3/hr.

    (KHNP Response) The units will be corrected.

14. In Section 3A.2.2.2 (titled Airborne Activity and Filter Loading Dose due to SI/SC/CS Leakage), regarding SI/SC/CS leakage, it states that the airborne Iodine radioactivity in cubicles of the Auxiliary Building is released to the environment via the ABCAEES filter. In addition, Figure 3A-7 indicates that radioactivity being released to the environment is accounted for in the calculation. However, for determining the doses for equipment qualification purposes, RG 1.183, Appendix I, Paragraph 13 specifies that the filter media should be assumed to be 100% efficient for iodine and particulates, meaning that there would be no radioactivity release, outside of containment, for the purposes of calculating equipment qualification dose. Therefore, for Auxiliary Building leakage, please clarify what efficiency is being assumed for the filters and what amount of

radioactivity is being released (not accumulated in the filters). If the efficiency for Iodine and particulates are different than 100%, please justify the values used.

(KHNP Response) In compliance with the RG 1.183 guidance, all airborne radioactivity inside the Auxiliary Building is assumed to be removed with 100% filter efficiency of the ABCAEES, thereby resulting in no radioactivity release to the environment. This assumption is addressed in the “ABCAEES Envelope Areas” part of Section 3A.2.1.

15. In Section 3A.3.1, under “Fuel Handling Area,” the applicant indicates that the removal efficiency of the carbon absorbers is assumed to be 100%. Are the HEPA filters also assumed to be 100%, consistent with RG 1.183? If so, please state this in this section. If not, please indicate what value is assumed for the HEPA filters and justify the value used.

    (KHNP Response) According to RG 1.183, Appendix B “Assumption for evaluating the radiological consequences of a fuel handling accident,” all particulate radionuclides are assumed to be retained by the water in the fuel pool or reactor cavity (i.e., infinite decontamination factor). Therefore no airborne activity due to particulates exists above the spent fuel pool that goes into the fuel handing area HVAC system. Thus, it is not required that the filter efficiency of HEPA be taken into consideration. However, as with the carbon absorber, in this analysis, the HEPA filter was also conservatively assumed to have a 100% filter efficiency in compliance with the RG 1.183 guidance.

    The associated description in the ”Fuel Handing Area” part of Section 3A.3.1 will be updated as follows:

    “The removal efficiencies of the carbon absorbers and HEPA filter are assumed to be 100%.”

16. Section 3A.4 specifies that the main steam valve house source term for equipment qualification purposes is based on a main steam line break. Please indicate if a steam generator tube rupture was considered for this analysis and specify why a main steam line break was chosen.

    (KHNP Response) The EQ TIDs for components/equipment should consider the expected worst-case environment condition (i.e., bounding) taking into account all post-accident conditions. Therefore, the main steam line break (MSLB) accident that would occur in the main steam valve room (MSVR) is determined to maximize the EQ TIDs of components.

    After initiation of a steam generator tube rupture (SGTR) accident, the steam produced in the SGs for plant cooldown, which contains radioactivity, is released to the environment via the MSSVs or ADVs in the Auxiliary Building. However, as illustrated in

Figure 2, since the pipes of the MSSVs and ADVs are routed through the MSVR, and the release points of MSSVs and ADVs are located outside the MSVR, the TID for components/equipment inside the MSVR due to the SGTR accident would be affected only by directed radiation from the pipes of the MSSVs and ADVs. The impact of the SGTR accident is, therefore, expected to be insignificant compared to the MSLB accident, which would occur inside the MSVR, because of the shielding effect of pipe wall. In addition, the results of radiological consequences of these accidents, which are given in Table 2, have shown that the TEDE at the EAB due to a MSLB accident was higher than a SGTR accident, which means that the amount of radioactivity released from the MSLB accident would be higher than the SGTR accident.

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Figure 2. Release Points of MSSVs and ADVs and piping inside MSVR

Table 2. Summary of Radiological Consequences of MSLB and SGTR accidents

Accident	TEDE (mSv) @ EAB
MSLB	4.91E+01
SGTR	8.07E+00

17. On page 5/30, it states that the containment inner diameter is 75 feet. However, in Table 3A-1, for ISOSHLD inputs, it indicates in multiple places that a radius of 2290 centimeters (75 feet) was used. Please make sure the response is accurate and consistent regarding whether the radius or diameter of the inside of containment is 75 feet and ensure that all calculations were performed using the correct value.

(KHNP Response) The inner diameter of 75 feet on page 5/30 is an editorial error, which will be updated to correct “inner diameter” to “inner radius”. All the inputs and parameters used in this analysis were reviewed and confirmed to ensure that all calculations were performed using the correct values.

18. The proposed markup is unclear and appears inconsistent regarding the assumptions used for airborne activity in the Auxiliary Building. First on page 3/30, it specifies that the RUNT-G and ISOSHLD codes run as one computer program. On page 6/30, under “ABCAEES Envelope Areas,” it states that for the RUNT-G model the Auxiliary Building controlled areas I and II are assumed to be one area having a volume of 497,000 ft^3 (which seems small for the entire Auxiliary Building Controlled Area). Then on note 2 of Table 3A-2 (ISOSHLD Input Parameters for Airborne Activity in Auxiliary Building), it states that the volume of 170,000 ft^3 is assumed as a conservative bounding volume, because ESF system rooms range from 7820 ft^3 to 32,300 ft^3. However, it is not just the ESF systems for which airborne activity needs to be considered (there is other safety-related equipment required to be qualified beside just ESF systems) and a higher volume should lower the airborne concentration because the activity would become more dispersed. Please clarify what is being modeled for calculating airborne activity in the Auxiliary Building and explain why what is being assumed is accurate or conservative. Also please ensure that the response and report are accurate.

(KHNP Response) The TID from the airborne activity in the Auxiliary Building is calculated considering two pathways: 1) from containment leakage and 2) from ESF leakage:

1) From Containment Leakage

Upon receipt of an ESFAS-SIAS after initiation of a LOCA, all of the auxiliary building controlled area emergency exhaust ACUs start. The mechanical penetration rooms and the safety-related mechanical equipment rooms are maintained under a minimum 6.35 mm (0.25 in) water gauge of negative pressure by exhausting air from the mechanical penetration rooms and the safety-related mechanical equipment rooms. Negative pressure would make the radioactivity released to the environment flow into those rooms. Such radioactivity is assumed to be uniformly dispersed within volumes of those rooms (i.e., 497,000 ft^3). The volume of 497,000 ft^3 is relatively small compared to the entire Auxiliary Building Controlled Area since it is only the rooms including the ESF components. Therefore, the TID for the component or equipment in a certain room will be increased as the volume of a room is increased, because all the rooms have the same airborne concentration.

The rooms considered include the following: SC/CS Heat Exchanger Room, CCW Pump Room, SI Pump Room, SC/CS Pump and Miniflow Heat Exchanger Room, Mechanical Penetration Room, Charging Pump Room, Aux. Charging Pump Room, where their volumes range from 7820 ft^3 to 32,300 ft^3.

It is therefore concluded that the application of volume of 170,000 ft^3 is very conservative; thereby, resulting in the bounding TID results, which are comparable to the TID due to the airborne activity, assuming a semi-infinite cloud geometry.

2) From ESF Leakage

Airborne activity in the Auxiliary Building, which comes from the ESF leakage, is calculated using the same method to calculate the airborne activity in the Auxiliary Building as the containment leakage. That is, although the airborne activity produced from the ESF leakage in a room would be restricted within the volume of that room, it is assumed that all the airborne activity leaked from all the ESF components are uniformly distributed over the ESF rooms for calculation convenience. This assumption does not have a significant impact on TID.

19. In Section 3A.1.2, it specifies that radioactive decay and sub-sequent daughter products were considered, however, this section is only applicable to inside containment. Please update the markup to clearly specify if radioactive decay and sub-sequent daughter products were considered for calculations outside containment, as well.

(KHNP Response) As with the inside of containment, the radioactive decay and subsequent daughter products are also considered in the outside containment calculations. For clarity, Sections 3A.2.1, 3A.3.1 and 3A.4.1 will be updated to include the following statement:

> *"**Radioactive Decay and subsequent daughters**: The effect of radioactive decay during holdup including subsequent daughter products is included for duration of 1 year.*

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06/27/2016 Additional Questions

1. It is unclear that the atmospheric dispersion (X/Q) estimates are appropriate. Therefore, please provide the following information:

   a. DCD Chapter 2, Table 2.3-3, provides X/Q values for the Auxiliary Building for accident analysis. However, in the response, the applicant calculates a separate X/Q value specifically for accident EQ purposes. Please discuss why a unique X/Q value was calculated for accident EQ doses and why the X/Q values from the response to RAI 7912, Question 02.03.04-1, Revision 2 (the revised DCD Table 2.3-3), were not used.

   (KHNP Response) The X/Q values provided in Table 2.3-3 of DCD Chapter 2 are ones for release points - main control room intake points or auxiliary intake points. However, since the X/Q value used in the EQ TID calculation is one for containment surface release-auxiliary building, a unique X/Q value needs to be separately calculated. For a conservative analysis, the smallest building wake factor (0.5) was applied within the range from 0.5 to 2 ,which is provided as a usable number for concentration estimations in the absence of suitable experimental data, as stated in the reference USAEC, "Meteorology and Atomic Energy."(Refer to Attachment 4)

   b. In calculating the Auxiliary Building filter loading and airborne activity in the Auxiliary Building for EQ purposes, please discuss the percent contribution from containment leakage vs. ESF system leakage. If the contribution from containment leakage is very small compared to ESF system leakage, differences in X/Q values may result in negligible changes to the doses to equipment.

   (KHNP Response) The contribution from containment leakage vs. ESF system leakage is shown in Table 3 below.

Table 3. Contribution from Containment Leakage vs. ESF system Leakage

Pathways	TID Contribution (%)	
	Airborne Activity in Aux. Building	ABCAEES Filter in Aux. Building
Containment leakage	12%	0.2%
ESF system leakage	88%	99.8%

As can be seen in the above Table, for the Auxiliary Building filter loading, the TID contribution from ESF system leakage is very dominant so that differences in X/Q values would result in negligible changes to the TID.

For the airborne activity in the Auxiliary Building, it was found that the TID contribution from containment leakage would be not negligible compared to ESF system leakage. However, unlike the Auxiliary Building filter loading case where its TID contribution is divided into both containment leakage and ESF leakage, the resultant TID of components/equipment in an ESF room of the Auxiliary Building consists of four (4) contributors: 1) Containment leakage, 2) ESF leakage, 3) Direct dose from the containment, and 4) Direct dose from the ESF system components. As given in Table 4, the largest contributor to the TIDs to a component is due to the "Direct dose from ESF system components," which accounts for about 99.98%. Contribution of the airborne activity from containment and ESF leakages was estimated to be very small. Thus, the difference in X/Q values would have negligible impact on the total TID of the components/equipment in the ESF rooms of the Auxiliary Building.

Table 4. Contributions of TIDs for Components and Filter in Auxiliary Building by Pathways

Pathways	TID Contribution (%)	
	Components in Aux. Building	ABCAEES Filter in Aux. Building
Containment leakage	0.002%	0.2%
ESF system leakage	0.014%	99.8%
Direct Dose from CTMT	Negligible	Negligible
Direct Dose from SI/SC/CS Components	99.984%	N/A
Total	100.0	100.0

2. The applicant provides equations for calculating the effective diameter of heat exchangers in Attachment 2, page 9/30. These effective diameters are then used to perform simplified TID calculations from the heat exchangers. While the equations appear to be conservative for calculating the dose from the tube portion of the heat exchangers, they appear non-conservative for the plenum region of the heat exchanger (the space before the fluid enters the tubes and after it leaves the tubes), which would consist of radioactive fluid over the entire diameter of the heat exchanger, with no shielding from the tubes or the CCW fluid. Therefore, please provide justification for the use of these equations for these areas, or provide new or additional criteria for accurately or conservatively calculating the dose from these plenum areas of the heat exchangers.

   (KHNP Response) The justification for the use of the equations, which are specified in Section 3A.2.2.5, for both plenum and tube regions is as follows:

   1) Justification for Tube Region

   As addressed in Section 3A.2.2.5, complex components such as heat exchangers are modeled as a right circular cylinder (i.e., pipe geometry) by deriving the effective diameter of the heat exchanger from the number of the tubes and their inside diameter, which is called a "Simplified Model". This simplified model is expected to be conservative since the modeled pipe contains only the radioactive fluid without the internal steel materials (i.e., tube wall) and the cooling water (i.e., CCW); thereby, leading to the higher TID compared to the case that assumes the actual geometry of the heat exchanger. This could be supported and justified by comparison of TIDs for the shutdown cooling (SC) heat exchanger, which is selected as a representative case, with and without the shielding effect of the internal steel materials and cooling water (i.e., the Actual model vs. Simplified model). This analysis was performed using the MicroShield program.

   As can be seen in Table 5, the results have presented that the Case 1 "Actual Model" yielded a lower TID than the Case 2 "Simplified Model." Therefore, it is concluded that the equation in Section 3A.2.2.5 would result in conservative TID values for the tube region of the heat exchangers.

Table 5. Comparison of TIDs from Actual Model and Simplified Model for Tube Region

Pipe Model	Dose Rate (mSv/hr) at 1 foot away from Component
Case 1: Actual Model 1)	1.45E+01
Case 2: Simplified Model 2)	3.69E+01

Note) Since the purpose of this response is to justify the use of the equation, the 0.25% fuel failure source term and evaluation model used for the shielding calculation in DCD Chapter 12 are used in this comparison analysis for the convenience. For Case 2, all the parameters except for source term are the same as those used for the TID calculation.

1) For the case where the internal steel materials and cooling water in heat exchanger is considered, the source region contains both the tube steel and cooling water as well as radioactive source, and is assumed to be homogenized for conservatism and calculation convenience.
2) For the case where the internal steel materials and cooling water in heat exchanger is not considered, the source region contains only the radioactive source (i.e., radioactive fluid).

2) Justification for Plenum Region

As discussed above, to calculate the TID for heat exchangers, the heat exchanger is modeled as pipe geometry having the effective diameter. Thus, the diameter of the plenum part of the heat exchanger will be larger than that of the pipe modeled for calculating the TID for the heat exchanger. For example, the plenum diameter of the SC heat exchanger (i.e., about 69 cm) is about 2 times larger than that of the simplified model pipe (i.e., about 39 cm). The larger diameter means the higher amount of radioactive source, which might lead to the higher TID values. However, the wall thickness of the plenum is typically thicker than the tube thickness, as shown in Figure 3(about 4 times thicker than the tubes).

Therefore, the evaluation of the impact of the trade-off between increased wall thickness and radioactive fluid (i.e., source term) was performed for the SC heat exchanger. As given in Table 6, it was found that the TID from the plenum (Case 1: Actual Model) was evaluated to be very small compared to TID from the simplified model used in this analysis (Case 2: Simplified Model). This result means that the relative impact of the increased wall thickness is higher than that of the source term increase. Therefore, although the plenum region contains radioactive fluid over the entire diameter of the heat exchanger with no shielding from the tubes or the CCW fluid, the impact of the plenum region of the heat exchanger is bounded by the results of the simplified model.

In addition, the length of the simplified model pipe is assumed to be 20 ft, which is considered conservative since no increase in dose rate from the pipe occurs when the length of the pipe exceeds 20 ft, according to the results of the sensitivity analysis for the length of pipe.

Therefore, it is concluded that use of the equation in Section B.2.2.5 is conservative.

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Figure 3. Outline Drawing for Shutdown Cooling Heat Exchanger

Table 6.

Comparison of TIDs from Actual Model and Simplified Model for Plenum Region

Pipe Model	Dose Rate (mSv/hr) at 1 feet away from Component
Case 1: Actual Model	2.42
Case 2: Simplified Model	13.1

Note) Since the purpose of this response is to justify the use of the equation, the 0.25% fuel failure source term and evaluation model used for the shielding calculation in DCD Chapter 12 was used in this comparison analysis for convenience.
For Case 1 and Case 2, the pipe is modeled with the same parameters except for the diameter and wall thickness. As shown in Figure 3, the diameter and wall thickness for Case 1 and Case 2 are 138 cm and 4.13 cm, and 78 cm (effective diameter) and 1.27 cm, respectively. Some of the tube regions are only considered by assuming the same length of the plenum in Figure 3 to compare the difference of TIDs between plenum and tubes under the identical conditions.