RAIO-0818-61306

August 08, 2018

Docket No. 52-048

U.S. Nuclear Regulatory Commission
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SUBJECT: NuScale Power, LLC Response to NRC Request for Additional Information No. 327 (eRAI No. 9257) on the NuScale Design Certification Application

REFERENCE: U.S. Nuclear Regulatory Commission, "Request for Additional Information No. 327 (eRAI No. 9257)," dated January 08, 2018

The purpose of this letter is to provide the NuScale Power, LLC (NuScale) response to the referenced NRC Request for Additional Information (RAI).

The Enclosure to this letter contains NuScale's response to the following RAI Question from NRC eRAI No. 9257:

- 12.02-14

This letter and the enclosed response make no new regulatory commitments and no revisions to any existing regulatory commitments.

If you have any questions on this response, please contact Carrie Fosaaen at 541-452-7126 or at cfosaaen@nuscalepower.com.

Sincerely,

Zackary W. Rad
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Enclosure 1: NuScale Response to NRC Request for Additional Information eRAI No. 9257

Enclosure 1:

NuScale Response to NRC Request for Additional Information eRAI No. 9257

Response to Request for Additional Information
Docket No. 52-048

eRAI No.: 9257
Date of RAI Issue: 01/08/2018

NRC Question No.: 12.02-14

Regulatory Basis

10 CFR 52.47(a)(5) requires applicants to identify the kinds and quantities of radioactive materials expected to be produced in the operation and the means for controlling and limiting radiation exposures within the limits set forth in part 20 of this chapter. 10 CFR 20.1101(b) and 10 CFR 20.1003, require the use of engineering controls to maintain exposures to radiation as far below the dose limits in 10 CFR Part 20 as is practical. 10 CFR Part 50 Appendix A, criterion 4 requires applicants to identify the environmental conditions, including radiation, associated with normal operation. The DSRS Acceptance Criteria section of NuScale DSRS section 12.2 “Radiation Sources,’ states that the applications should contain the methods, models and assumptions used as the bases for all sources described in DCD Section 12.2. The DSRS Acceptance Criteria 12.3-12.4, “Radiation Protection Design Features,” states that the areas inside the plant structures, as well as in the general plant yard, should be subdivided into radiation zones, with maximum design dose rate zones and the criteria used in selecting maximum dose rates identified.

Background

NuScale DCD Tier 2, Revision 0 Section 12.2.1.3, “Chemical and Volume Control System,” states that at the end of the fuel cycle, a crud burst is assumed, with the mixed-bed demineralizers being loaded with the entire radionuclide inventory increased due to the crud burst. This increase in radionuclide concentration in the primary coolant is determined by a review of industry data of increased radionuclide concentrations during crud bursts. The resulting crud burst peaking factors are listed in DCD Table 12.2-6, “Chemical and Volume Control System Component Source Term Inputs and Assumptions.” This table lists the peaking factors to be applied to the normal reactor coolant system (RCS) activity expected to be contained in Chemical and Volume Control System (CVCS) liquid following a crud burst during an outage. DCD Section 12.2.3, “References,” references Electric Power Research Institute (EPRI), "Pressurized Water Reactor Primary Water Chemistry Guidelines," Volumes 1 and 2, EPRI 3002000505, Palo Alto, CA, Revision 7, April 2014. NuScale Technical Specification Section 5.5.4, “Steam Generator (SG) Program,” states the requirement for a Steam Generator program. DCD Table 1.8-2: “Combined License Information Items,” COL Item 5.4-1: states that the Steam Generator Program will be based on NEI 97-06, “Steam Generator Program

Guidelines," Revision 3 and applicable EPRI steam generator guidelines. One of the elements of the program is to include primary water chemistry controls. EPRI TR-3002000505 states that crud-related phenomena have occurred which have negatively impacted plant operations and core performance, such as anomalous crud releases and elevated radiation fields during refueling outages, crud induced power shift (CIPS, formerly called axial offset anomaly, AOA), and crud induced fuel failures. A frequently used expression to separate some PWRs with more aggressive core designs from others is to refer to these units as "high duty cores," which can give rise to enhanced corrosion product deposition in the core. The "high duty core index," (HDCI) methodology was developed and incorporated into the PWR Axial Offset Anomaly (AOA) Guidelines. This index serves as a screening tool for the susceptibility to enhanced crud deposition in the core. Because corrosion and wear products that spend longer periods in high neutron fluxes, such as material deposited on fuel surfaces, will have much higher specific radioactivity. Therefore plants with high HDCIs are subject to higher than normal specific activity crud bursts. Higher activity crud burst challenge the ability of plant systems to control airborne radioactive material, minimize surface contamination, reduce effluent releases and to control occupational radiation exposure.

Key Issue:

Using the methodology described in EPRI TR-1008102, "PWR Axial Offset Anomaly (AOA) Guidelines, Revision 1," appendix F "Definition of High Duty Core (A Means for Evaluating the Propensity to Deposit Crud on Fuel Assemblies)," the staff determined that based, on the core power density, heat flux, coolant flow rates etc. described in the relevant sections of the DCD, that the NuScale plant could also be classified as a High Duty Plant. The crud burst peaking factors listed in DCD Table 12.2-6 are based on operational data from plants without HDCI, and may understate the estimated crud burst.

Question

To facilitate staff understanding of the application information sufficient to make appropriate regulatory conclusions with respect to radiation exposures, the staff requests that the applicant:

- Describe how outage RCS activity estimates factor into the potential for increased material deposition on core surfaces due to the operating parameters of the NuScale design,
- As necessary revise DCD Table 12.2-6, to include increased crud deposition and activation,
- As necessary revise the radiation zone maps to account for any increased dose rates due increased crud deposition and activation,
- As necessary revise Table 12.2-33: "Reactor Building Airborne Concentrations," to account for any increased dose rates due increased crud deposition and activation,
- As necessary revise Table 12.2-7: "Chemical and Volume Control System Component Source Terms - Radionuclide Content" to account for any increased dose rates due increased crud deposition and activation,
- Provide information on design features provided to reduce crud buildup in the core,

OR

Provide the specific alternative approaches used and the associated justification.

NuScale Response:

During the development of the NuScale design and license application, radionuclide activity from an assumed end of cycle crud burst was included in addition to the crud radionuclide activity assumed using the methodology presented in ANSI/ANS 18.1-1999. This was done to be conservative in the facility's shielding design for worker protection. This crud burst model was developed using relevant industry operating information from EPRI Technical Report 1011106, "Proceedings of the June 2004 EPRI PWR Primary Shutdown Workshop." This EPRI report utilized data from several large PWRs, including some with high duty core indexes, from which NuScale selected the highest reported values on which to base its model.

Based on this RAI and other related NRC interactions, NuScale has decided to remove the additional radionuclide activity from an assumed crud burst transient condition from the CVCS design basis evaluation as this addition is unnecessarily conservative. NuScale will utilize the guidance of ANSI/ANS 18.1-1999 for crud isotopes, as recommended in NuScale DSRS Section 11.1. Therefore, the CVCS mixed bed demineralizers are assumed to collect radionuclide activity from the primary coolant during the operating cycle and for a short post-shutdown period, but with no additional radionuclide inventory from an assumed additional crud burst. The FSAR has been updated to reflect the removal of this crud burst model, including FSAR Section 11.2.3.1, Section 12.2.1.3, Section 12.2.1.8, Table 12.2-6, Table 12.2-7, Table 12.2-8, Section 12.3.1.3.1, and Section 12.3.2.3.

Impact on DCA:

FSAR Section 11.2.3.1, Section 12.2.1.3, Section 12.2.1.8, Section 12.3.1.3.1, Section 12.3.2.3, Table 12.2-6. Table 12.2-7 and Table 12.2-8 have been been revised as described in the response above and as shown in the markup provided in this response.

The calculation of liquid effluent releases is consistent with RG 1.112, as modified by Technical Report TR-1116-52065 (Reference 11.2-2). The calculation of off-site dose consequences from normal liquid effluents is consistent with RG 1.109.

The radioisotopes that are assumed to be that become available for offsite release originate in the reactor core and the primary coolant. These radioisotopes are assumed to propagate through plant systems by various pathways and processes, and eventually are released. The calculation of this propagation through pathways and processes is performed using appropriate flow rates, decontamination factors and radioactive decay characteristics.

Normal liquid effluents are routed through the LRWS using three pathways: low-conductivity waste, high-conductivity waste, and detergent waste. The influent quantities for these are tabulated in Table 11.2-3. The expected activity of the influent streams is based on the realistic coolant activities from Section 11.1.3. For the purposes of calculating liquid effluents, liquid waste processing is assumed to be confined to a single pathway. Therefore, the liquid waste that is input into the LCW collection tank will be processed only by the LCW processing equipment, the HCW collection tank contents will be processed only by the HCW processing equipment and the detergent collection tank contents are expected to be low enough to release without treatment. The input assumptions related to decontamination factors for the LRWS processing equipment are listed in Table 12.2-12.

The influent streams to the LCW and HCW collection tanks include liquid waste that contains expected activity levels as indicated in Table 11.2-3. The activity concentrations listed in Table 11.2-3 that are based on primary coolant activity (PCA) are the indicated fraction of the radionuclide concentrations listed in Table 11.1-6. The activity concentrations that are labeled as 'CVCS outlet' has a radionuclide concentration based on primary coolant that has been processed by the CVCS processing equipment assuming the input values and decontamination factors listed in Table 11.2-4.

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The activity indicated as the pool source term in Table 11.2-3 is a time weighted average of the reactor pool water activity concentration based on radionuclides being added to the pool water during NPM disassembly and being removed by the PCUS demineralizers. Prior to NPM disassembly during a refueling outage, ~~an assumed crud burst is performed with a post-crud burst cleanup~~the primary coolant is cleaned up by the CVCS demineralizers. Afterwards, the NPM is disconnected, relocated to the refueling pool and disassembled. Between refueling outages, the reactor pool water is cleaned by the PCUS demineralizers and filters.

The activity indicated as CES liquid in Table 11.2-3 is primary coolant that leaves the primary system, either through leaks into the containment vessel or pressurizer venting for degasification. In either case, the associated partition fractions are listed in Table 11.2-4. These decontamination factors credit the evaporation process within the pressurizer and containment, resulting in the majority of radioactivity remaining behind. The radioactivity that does get out is divided between gaseous and liquid streams in the CES condenser.

The contribution of gamma radiation from the primary coolant is comprised of two components: a long-lived isotope (half-life >10 seconds) primary coolant source term, as described in Section 11.1, and a near core primary coolant source term that includes short-lived isotopes (half-life <10 seconds). Because of the low flow velocity of the primary coolant, the short-lived isotopes decay away quickly and are not considered to be present in the steam generator region or the reactor down comer region. The short lived isotope coolant source term was distributed on a coolant mass basis in the core, upper core plate, lower riser, and upper riser region (see Figure 12.3-3). This represents a conservative model because much of the short-lived isotope activity will decay away before reaching the upper riser region. By uniformly distributing the short-lived isotopic activity, the photon intensity in the upper portions of the NPM is conservatively modeled. The primary coolant gamma spectra are provided in Table 12.2-3 and Table 12.2-4.

Nitrogen-16 is one of the short-lived isotopes produced in the reactor core and circulated in the primary coolant loop. Although nitrogen-16 is present throughout the primary coolant loop, the modeling simplification described above is conservative from a bioshield radiation shielding perspective. Table 12.2-5 tabulates the nitrogen-16 concentration at several locations in the primary coolant system.

12.2.1.3 Chemical and Volume Control System

RAI 12.02-14

The chemical and volume control system (CVCS) takes a portion of the RCS and processes the water through heat exchangers, demineralizers, and filters. The treated primary coolant water is then returned to the RCS (Section 9.3.4). During this treatment process, components of the CVCS can become radiation sources due to soluble and non-soluble radionuclides in the primary coolant. The CVCS contained sources are determined using the design basis coolant source term from Section 11.1 (Table 11.1-4). ~~In addition to this steady-state primary coolant source term, a crud burst is assumed at the end of the fuel cycle. A list of inputs and assumptions are listed in Table 12.2-6.~~

Mixed-Bed and Cation Bed Demineralizers

RAI 12.02-14

The CVCS mixed-bed demineralizers are assumed to be in continuous operation during the entire fuel cycle. The decontamination factors assumed are listed in Table 11.1-2. ~~At the end of the fuel cycle, a crud burst is also assumed, with the mixed-bed demineralizers being loaded with the entire radionuclide inventory increase due to the crud burst. This increase in radionuclide concentration in the primary coolant is determined by a review of industry data of increased radionuclide concentrations during crud bursts. The resulting crud burst peaking factors are listed in Table 12.2-6.~~

RAI 12.02-14

The CVCS cation bed demineralizers are assumed to be in operation for one-half of the fuel cycle because they are operated intermittently during the operating cycle for lithium removal. The decontamination factors assumed are listed in Table 12.2-6. ~~The cation beds are assumed not to be in operation during a crud burst cleanup period.~~

The CVCS demineralizer radionuclide inventories and source strengths are tabulated for zero decay and 3.65 day (0.01 year) decay to demonstrate that maintenance activities during outages can be managed to allow the short-lived isotopes to decay away.

The CVCS demineralizer beds are located in the Reactor Building (RXB) on the 24' elevation inside the CVCS cubicles. The mixed-bed source terms and source strengths are listed in Table 12.2-7 and Table 12.2-8, respectively.

Regenerative and Non-Regenerative Heat Exchangers

The regenerative heat exchanger is used to cool the primary coolant as it enters the CVCS using the CVCS water returning back to the RCS. The non-regenerative heat exchanger further cools the primary coolant, using reactor component cooling water, to protect the demineralizer resins. The heat exchangers are tube and shell type, as described in Section 9.3.4. To calculate the radiological source term, the heat exchangers are assumed to be completely filled with primary coolant. The major source term model assumptions are listed in Table 12.2-6. The source term for the RCS water is found in Table 11.1-4.

The heat exchangers are located in the RXB on the 50' elevation inside the heat exchanger rooms.

Module Heating System Heat Exchangers

The module heating system heat exchanger radiological source term is assumed to be the same as the CVCS regenerative and non-regenerative heat exchanger source term. This is conservative because a module heatup system heat exchanger contains about one-third the source term used to model the CVCS heat exchangers.

Resin Transfer Pipe

RAI 12.02-29

~~The theoretical maximum for randomly 'jammed' spherical matter is a packing density of 63.4% (Reference 12.2-4). At somewhere below this point, the resin beads would no longer flow through a pipe. The 'jammed' sphere packing with the lowest density is a diluted ('tunneled') packing density of 49.365% (Reference 12.2-5). Therefore, to prevent resin beads from clogging, a packing density of less than 49.365% is needed.~~ A generic resin transfer line is modeled assuming it is 100% obstructed by spherical resin beads from the CVCS mixed bed demineralizer, which has been modeled using a bulk dry resin density ~~results in approximately 50% of the pipe's internal volume consisting of resin bead material and the other 50% consisting of water~~. The generic resin transfer line is modeled with the parameters listed in Table 12.2-6. The source term used for the spent resin transfer line is the CVCS mixed bed demineralizer decayed for 48 hours, as provided in Table 12.2-7 and Table 12.2-8, with a spent resin volume of 8.8 ft^3.

The estimated input flows from various sources to the high-conductivity waste (HCW) collection tanks, the low-conductivity waste (LCW) collection tanks, and the detergent collection tank are listed in Table 11.2-3. These inputs are processed in batches by the liquid radioactive waste processing skids and sent to the HCW and LCW sample tanks for final disposition. The assumed values for the LRW processing equipment radionuclide collection efficiencies are listed in Table 12.2-13. The LRWS component source terms are provided in Table 12.2-14a and Table 12.2-14b, and source strengths are provided in Table 12.2-15a and Table 12.2-15b. To establish the shielding design downstream of the GAC filter, the radionuclide concentration in the outlet stream from the GAC filter is assumed to not be reduced by the GAC filter.

12.2.1.6 Gaseous Radioactive Waste System

Radioactive fission gases are produced in the reactor core and assumed to be released to the primary coolant, as discussed in Section 11.1. The radionuclide input to the gaseous radioactive waste system (GRWS) comes primarily from the LRWS degasifier, which strips the dissolved gases from the primary coolant that enters the degasifier from the CVCS. The gases from the degasifier are sent to the GRWS for conditioning and processing. Table 12.2-16 lists the assumed values pertaining to the GRWS source geometries and Table 11.3-1 describes the GRWS processing parameters. The GRWS component source terms are provided in Table 12.2-17 and the source strengths are provided in Table 12.2-18.

12.2.1.7 Solid Radioactive Waste System

RAI 12.02-2

The solid radioactive waste system (SRWS) handles solid radioactive waste from various waste streams, as described in Section 11.4. The waste inputs to the SRWS components are collected, resulting in a radionuclide source term for the SRWS components. The assumed values used to develop the SRWS component source terms are listed in Table 12.2-19. Table 12.2-20 lists the radionuclide inventory of the major SRWS components and Table 12.2-21 lists the SRWS component source strengths. As described in Section 11.4, there is storage space provided in the Radioactive Waste Building for processed waste packages that contain spent filters, dewatered resins, and other solid wastes. For shielding design purposes, it is assumed that the Class A/B/C high integrity container storage area contains five high integrity containers loaded with Class B/C dewatered spent resins from the spent resin storage tank, which has been decayed for approximately two years (one fuel cycle). Storage areas are shielded to limit the radiation level to be compliant with the designated radiation zone.

12.2.1.8 Reactor Pool Water

RAI 12.02-6, RAI 12.02-14

The reactor pool is housed within the RXB and contains up to 12 NPMs, which are partially immersed in the reactor pool water. Because the spent fuel pool communicates with the reactor pool through the weir wall, radionuclides are mixed with the spent fuel pool water volume. There are two sources of radioactive material considered for the reactor pool water: primary coolant released during refueling outages and direct neutron activation. Because of the low power and low temperatures in the spent fuel pool, the radionuclide contribution to the pool water from defective fuel assemblies in the storage racks is considered negligible. The primary source of radionuclides in the reactor pool comes from the primary coolant system when an NPM is disassembled in the reactor pool during outages. During refueling outages, after the primary coolant ~~crud burst~~ is cleaned by the CVCS, the small remaining quantities of radionuclides are released into the pool water during NPM disassembly. The post-crud burst cleanup of the primary coolant in the NPM by CVCS will operate until the projected dose rate (after NPM disassembly) at one meter above the ultimate heat sink water is less than 5 mR/hr, consistent with Reference 12.2-3. The other major input assumptions for the pool water source term are provided in Table 12.2-9.

RAI 12.02-23

The radionuclide contribution resulting from neutron activation of the reactor pool water contents is not significant due to the reduced neutron flux in the reactor pool water. The neutron flux at the outside edge of the containment vessel ~~was calculated~~is many ~~to be approximately six~~ orders of magnitude less than the average neutron flux in the core, and continues to quickly decrease in the reactor pool's borated water. The small amount of neutron activation products in the reactor pool water was calculated to be insignificant compared to the amount of primary coolant radionuclides released to the reactor pool water during refueling outages. The reactor pool and RCS water chemistry limits (when the temperature of the RCS is less than 250 degrees F) are in conformance with the Electric Power Research Institute primary water chemistry guidelines (Reference 12.2-3). The reactor pool water volume dilutes inadvertently introduced impurities that could result from component failures and, because the chemistry limits in both the reactor pool and each NPM are monitored, impurities in either of the two water sources are minimized.

Between refueling outages, the radionuclides in the reactor pool water are treated by the PCUS demineralizers and filters to reduce the radionuclide content. The pool water has a negligible neutron activation source term. The major input assumptions are listed in Table 12.2-9.

The pool surge control system (PSCS) storage tank is designed to temporarily store pool water that is displaced during drydock operations. The PSCS storage tank is modeled as a vertical cylindrical tank with the characteristics listed in Table 12.2-9.

The source terms and the source strengths for the pool water and the PSCS storage tank are provided in Table 12.2-11 and Table 12.2-12, respectively.

12.2.1.9 Spent Fuel

Spent fuel stored in the spent fuel racks presents a radiation source that is shielded by the water in the spent fuel pool as well as by the pool's concrete walls. The same methodology used to determine the maximum core isotopic source term in Section 11.1 is used to develop the spent fuel source term, resulting in the bounding assumption that the spent fuel racks are filled with freshly-discharged, irradiated fuel assemblies. Spent fuel gamma ray and neutron source strengths are considered in the evaluation of radiation levels for fuel handling and spent fuel storage.

RAI 12.02-14

Table 12.2-6: Chemical and Volume Control System Component Source Term Inputs and Assumptions

Model Parameter	Value
CVCS mixed bed:	
CVCS mixed bed operation time	100% of fuel cycle
Decontamination ~~f~~Factors	Table 11.1-2
Geometry	vertical cylinder
Source dimensions of vessel	diameter=24”; height=96”
Shielding thickness of steel shell	1.5”
Volume of resin	8.8 ft^3
~~Crud burst activity buildup on CVCS mixed bed~~	~~100%~~
CVCS ~~c~~Cation bed:	
CVCS ~~c~~Cation ~~b~~Bed ~~o~~Operation ~~t~~Time	50% of fuel cycle
CVCS ~~c~~Cation ~~b~~Bed ~~d~~Decontamination ~~f~~Factors:	
Halogens	1
Cs, Rb	10
Others	10
Geometry	vertical cylinder
Source dimensions of vessel	diameter=24”; height=96”
Shielding thickness of steel shell	1.5”
Regenerative, ~~heat exchanger and~~ Non-~~r~~Regenerative and Module ~~h~~Heating System Heat ~~e~~Exchangers:	
Contents	100% primary coolant (see Table 11.1-4)
Geometry	vertical stack of 5 horizontal cylinders
Source dimensions of each cylinder	diameter=12”; length=11.5’
Shielding thickness of steel shell	0.5”
CVCS flowrate	22 gpm
~~Peaking factor due to crud burst:~~	~~-~~
• ~~Co-58~~	~~10,000~~
• ~~Other radionuclides~~	~~1,000~~
CVCS filter efficiency	9.1% (DF = 1.1)
CVCS resin transfer line:	
Pipe internal diameter	2"
Pipe wall thickness	0.154"
Pipe length	20’
Pipe material	Stainless steel
Resin source term	CVCS mixed bed resin (~~no~~48-hr decay)
CVCS pipe inside vertical pipe chase	
Contents	~~225% p~~Primary coolant (see ~~Table 11.1-4~~Table 12.2-8)
Geometry	vertical cylinder
Source length of pipe	20’
Shielding dimensions of pipe	inside diameter=2.5”; thickness=0.375~~1~~”

RAI 12.02-14

Table 12.2-7: Chemical and Volume Control System Component Source Terms - Radionuclide Content

~~Isotope~~	~~CVCS Mixed Bed Demineralizer (Ci)~~	~~CVCS Cation Bed Demineralizer (Ci)~~	~~CVCS Reactor Coolant Filter (Ci)~~	~~Resin Transfer Pipe in Pipechase (Ci)~~
Isotope	CVCS Mixed Bed Ci	CVCS Cation Bed Ci	CVCS Particulate Filter Ci	CVCS Mixed Bed Transfer - 48-hour decay Ci
~~Br82~~	~~1.58E-02~~	-	-	~~8.03E-05~~
~~Br83~~	~~5.29E-03~~	-	-	~~6.57E-11~~
~~Br84~~	~~5.19E-04~~	-	-	-
~~Br85~~	~~5.63E-06~~	-	-	-
~~I129~~	~~1.37E-04~~	-	-	~~1.78E-06~~
~~I130~~	~~4.26E-02~~	-	-	~~3.76E-05~~
~~I131~~	~~1.86E+01~~	-	-	~~2.03E-01~~
~~I132~~	~~8.39E-01~~	-	-	~~5.53E-09~~
~~I133~~	~~2.85E+00~~	-	-	~~7.49E-03~~
~~I134~~	~~1.90E-02~~	-	-	-
~~I135~~	~~5.28E-01~~	-	-	~~4.34E-05~~
~~Rb86m~~	~~7.39E-10~~	~~6.65E-10~~	-	-
~~Rb86~~	~~1.48E-01~~	~~1.33E-01~~	-	~~1.79E-03~~
~~Rb88~~	~~2.64E-01~~	~~2.62E-01~~	-	-
~~Rb89~~	~~6.19E-04~~	~~5.68E-04~~	-	-
~~Cs132~~	~~9.79E-04~~	~~8.81E-04~~	-	~~1.03E-05~~
~~Cs134~~	~~5.01E+02~~	~~2.62E+02~~	-	~~6.51E+00~~
~~Cs135m~~	~~3.03E-05~~	~~2.73E-05~~	-	-
~~Cs136~~	~~3.82E+00~~	~~3.43E+00~~	-	~~4.47E-02~~
~~Cs137~~	~~4.09E+02~~	~~1.86E+02~~	-	~~5.33E+00~~
~~Cs138~~	~~1.43E-02~~	~~1.34E-02~~	-	-
~~P32~~	~~3.98E-06~~	~~7.31E-08~~	-	~~4.70E-08~~
~~Co57~~	~~4.76E-07~~	~~6.23E-09~~	-	~~6.17E-09~~
~~Ni63~~	~~6.93E+00~~	~~3.86E-02~~	~~1.28E-02~~	~~9.02E-02~~
~~Sr89~~	~~1.02E-01~~	~~2.35E-03~~	-	~~1.29E-03~~
~~Sr90~~	~~2.17E-01~~	~~2.02E-03~~	-	~~2.83E-03~~
~~Sr91~~	~~3.73E-04~~	~~6.85E-06~~	-	~~1.53E-07~~
~~Sr92~~	~~5.27E-05~~	~~9.68E-07~~	-	~~3.19E-12~~
~~Y90~~	~~2.21E-01~~	~~2.22E-03~~	-	~~1.71E-03~~
~~Y91m~~	~~2.39E-04~~	~~4.75E-06~~	-	-
~~Y91~~	~~1.72E-02~~	~~3.12E-04~~	-	~~2.19E-04~~
~~Y92~~	~~1.16E-04~~	~~2.22E-06~~	-	~~1.25E-10~~
~~Y93~~	~~9.07E-05~~	~~1.67E-06~~	-	~~4.50E-08~~
~~Zr95~~	~~4.90E+00~~	~~1.51E-02~~	~~9.07E-03~~	~~6.24E-02~~
~~Zr97~~	~~2.13E-04~~	~~3.92E-06~~	-	~~3.88E-07~~
~~Nb95~~	~~8.65E-01~~	~~1.65E-02~~	-	~~1.08E-02~~
~~Mo99~~	~~1.57E+00~~	~~2.89E-02~~	-	~~1.24E-02~~
~~Mo101~~	~~1.75E-04~~	~~3.22E-06~~	-	-

Table 12.2-7: Chemical and Volume Control System Component Source Terms - Radionuclide Content (Continued)

~~Isotope~~	~~CVCS Mixed Bed Demineralizer (Ci)~~	~~CVCS Cation Bed Demineralizer (Ci)~~	~~CVCS Reactor Coolant Filter (Ci)~~	~~Resin Transfer Pipe in Pipechase (Ci)~~
Isotope	CVCS Mixed Bed Ci	CVCS Cation Bed Ci	CVCS Particulate Filter Ci	CVCS Mixed Bed Transfer - 48-hour decay Ci
~~Tc99m~~	~~1.54E+00~~	~~3.06E-02~~	~~-~~	~~7.90E-05~~
~~Ru103~~	~~2.20E-02~~	~~4.03E-04~~	~~-~~	~~2.76E-04~~
~~Ru105~~	~~1.07E-03~~	~~1.97E-05~~	~~-~~	~~7.75E-09~~
~~Ru106~~	~~9.96E-02~~	~~1.21E-03~~	~~-~~	~~1.29E-03~~
~~Rh103m~~	~~2.22E-02~~	~~4.43E-04~~	~~-~~	~~1.03E-19~~
~~Rh105~~	~~3.16E-03~~	~~5.97E-05~~	~~-~~	~~1.60E-05~~
~~Rh106~~	~~1.02E-01~~	~~1.34E-03~~	~~-~~	~~-~~
~~Ag110m~~	~~2.37E+01~~	~~1.36E-01~~	~~4.38E-02~~	~~3.06E-01~~
~~Sb124~~	~~4.97E-05~~	~~8.98E-07~~	~~-~~	~~6.33E-07~~
~~Sb125~~	~~2.84E-03~~	~~2.93E-05~~	~~-~~	~~3.70E-05~~
~~Sb127~~	~~1.19E-04~~	~~2.19E-06~~	~~-~~	~~1.08E-06~~
~~Sb129~~	~~6.05E-06~~	~~1.11E-07~~	~~-~~	~~4.10E-11~~
~~Te125m~~	~~6.13E-02~~	~~1.11E-03~~	~~-~~	~~7.80E-04~~
~~Te127m~~	~~3.71E-01~~	~~6.18E-03~~	~~-~~	~~4.77E-03~~
~~Te127~~	~~3.75E-01~~	~~6.78E-03~~	~~-~~	~~1.39E-04~~
~~Te129m~~	~~3.31E-01~~	~~6.08E-03~~	~~-~~	~~4.14E-03~~
~~Te129~~	~~2.13E-01~~	~~4.26E-03~~	~~-~~	~~9.72E-16~~
~~Te131m~~	~~3.83E-02~~	~~7.04E-04~~	~~-~~	~~1.65E-04~~
~~Te131~~	~~8.92E-03~~	~~1.78E-04~~	~~-~~	~~-~~
~~Te132~~	~~7.36E-01~~	~~1.35E-02~~	~~-~~	~~6.22E-03~~
~~Te133m~~	~~6.13E-04~~	~~1.13E-05~~	~~-~~	~~-~~
~~Te134~~	~~6.55E-04~~	~~1.20E-05~~	~~-~~	~~-~~
~~Ba137m~~	~~7.73E+02~~	~~1.95E+02~~	~~-~~	~~-~~
~~Ba139~~	~~3.93E-03~~	~~2.92E-04~~	~~-~~	~~1.87E-15~~
~~Ba140~~	~~3.90E-02~~	~~7.19E-04~~	~~-~~	~~4.55E-04~~
~~La140~~	~~4.14E-02~~	~~8.25E-04~~	~~-~~	~~2.36E-04~~
~~La141~~	~~3.45E-05~~	~~6.36E-07~~	~~-~~	~~9.25E-11~~
~~La142~~	~~7.16E-06~~	~~1.32E-07~~	~~-~~	~~2.84E-17~~
~~Ce141~~	~~1.45E-02~~	~~2.66E-04~~	~~-~~	~~1.81E-04~~
~~Ce143~~	~~4.46E-04~~	~~8.19E-06~~	~~-~~	~~2.12E-06~~
~~Ce144~~	~~8.78E-02~~	~~1.13E-03~~	~~-~~	~~1.14E-03~~
~~Pr143~~	~~5.83E-03~~	~~1.08E-04~~	~~-~~	~~6.85E-05~~
~~Pr144~~	~~8.87E-02~~	~~1.25E-03~~	~~-~~	~~-~~
~~Np239~~	~~1.63E-02~~	~~3.00E-04~~	~~-~~	~~1.18E-04~~
~~Na24~~	~~6.56E+02~~	~~2.97E-02~~	~~1.21E+00~~	~~9.23E-01~~
~~Cr51~~	~~3.52E+01~~	~~5.17E-02~~	~~6.53E-02~~	~~4.36E-01~~
~~Mn54~~	~~2.94E+01~~	~~1.62E-01~~	~~5.45E-02~~	~~3.81E-01~~
~~Fe55~~	~~2.75E+01~~	~~1.55E-01~~	~~5.09E-02~~	~~3.57E-01~~
~~Fe59~~	~~3.56E+00~~	~~7.95E-03~~	~~6.59E-03~~	~~4.49E-02~~
~~Co58~~	~~4.89E+02~~	~~1.88E-01~~	~~9.05E-01~~	~~6.24E+00~~
~~Co60~~	~~1.29E+01~~	~~7.28E-02~~	~~2.40E-02~~	~~1.68E-01~~

Table 12.2-7: Chemical and Volume Control System Component Source Terms - Radionuclide Content (Continued)

~~Isotope~~	~~CVCS Mixed Bed Demineralizer (Ci)~~	~~CVCS Cation Bed Demineralizer (Ci)~~	~~CVCS Reactor Coolant Filter (Ci)~~	~~Resin Transfer Pipe in Pipechase (Ci)~~
Isotope	CVCS Mixed Bed Ci	CVCS Cation Bed Ci	CVCS Particulate Filter Ci	CVCS Mixed Bed Transfer - 48-hour decay Ci
~~W187~~	~~3.21E+01~~	~~2.11E-03~~	~~5.95E-02~~	~~1.03E-01~~
~~Zn65~~	~~8.78E+00~~	~~4.70E-02~~	~~1.63E-02~~	~~1.14E-01~~
~~C14~~	~~3.86E+01~~	~~3.55E-01~~	~~-~~	~~5.03E-01~~
Br82	3.40E-02	-	-	1.33E-02
Br83	1.32E-02	-	-	1.26E-08
Br84	1.36E-03	-	-	7.42E-31
Br85	1.50E-05	-	-	-
I129	2.82E-04	8.69E-11	-	2.82E-04
I130	9.62E-02	-	-	6.52E-03
I131	3.74E+01	5.99E-04	-	3.15E+01
I132	1.76E+00	1.43E-02	-	1.04E+00
I133	4.62E+00	1.20E-05	-	9.33E-01
I134	4.87E-02	1.57E-05	-	1.70E-18
I135	1.25E+00	-	-	7.88E-03
Rb86m	1.97E-09	8.85E-10	-	-
Rb86	3.08E-01	1.39E-01	-	2.86E-01
Rb88	3.48E-02	1.57E-02	-	6.03E-51
Rb89	1.36E-03	6.12E-04	-	8.10E-61
Cs132	2.06E-03	9.29E-04	-	1.67E-03
Cs134	1.03E+03	2.70E+02	-	1.03E+03
Cs135m	7.95E-05	3.58E-05	-	3.49E-21
Cs136	7.96E+00	3.58E+00	-	7.16E+00
Cs137	8.43E+02	1.92E+02	-	8.43E+02
Cs138	2.40E-02	1.08E-02	-	2.70E-28
P32	1.32E-06	1.21E-08	-	1.20E-06
Co57	1.57E-07	1.03E-09	-	1.56E-07
Sr89	2.10E-01	2.51E-03	-	2.04E-01
Sr90	4.47E-01	2.08E-03	-	4.47E-01
Sr91	8.61E-04	7.90E-06	-	2.72E-05
Sr92	1.27E-04	1.17E-06	-	4.70E-10
Y90	4.45E-01	2.06E-03	-	4.46E-01
Y91m	5.41E-04	4.97E-06	-	1.73E-05
Y91	3.55E-02	3.21E-04	-	3.46E-02
Y92	2.71E-04	2.49E-06	-	5.28E-08
Y93	1.94E-04	1.78E-06	-	7.39E-06
Zr97	4.70E-04	4.32E-06	-	6.44E-05
Nb95	7.27E-01	6.39E-03	-	7.25E-01
Mo99	3.32E+00	3.05E-02	-	2.01E+00
Mo101	4.63E-04	4.25E-06	-	2.11E-63
Tc99m	3.20E+00	2.94E-02	-	1.94E+00
Tc99	1.71E-02	7.84E-05	-	1.71E-02

Table 12.2-7: Chemical and Volume Control System Component Source Terms - Radionuclide Content (Continued)

~~Isotope~~	~~CVCS Mixed Bed Demineralizer (Ci)~~	~~CVCS Cation Bed Demineralizer (Ci)~~	~~CVCS Reactor Coolant Filter (Ci)~~	~~Resin Transfer Pipe in Pipechase (Ci)~~
Isotope	**CVCS Mixed Bed Ci**	**CVCS Cation Bed Ci**	**CVCS Particulate Filter Ci**	**CVCS Mixed Bed Transfer - 48-hour decay Ci**
Ru103	4.54E-02	4.16E-04	-	4.38E-02
Ru105	7.03E-05	6.46E-07	-	3.91E-08
Ru106	2.05E-01	1.24E-03	-	2.05E-01
Rh103m	4.49E-02	4.12E-04	-	4.33E-02
Rh105	1.26E-03	1.16E-05	-	4.96E-04
Rh106	2.05E-01	1.24E-03	-	2.05E-01
Ag110	1.07E-01	7.14E-04	-	1.06E-01
Sb124	1.03E-04	9.27E-07	-	1.00E-04
Sb125	5.86E-03	3.02E-05	-	5.85E-03
Sb127	2.51E-04	2.30E-06	-	1.75E-04
Sb129	1.47E-05	1.35E-07	-	7.63E-09
Te125m	1.28E-01	1.15E-03	-	1.25E-01
Te127m	7.66E-01	6.37E-03	-	7.56E-01
Te127	7.58E-01	6.32E-03	-	7.41E-01
Te129m	6.84E-01	6.28E-03	-	6.56E-01
Te129	4.32E-01	3.97E-03	-	4.14E-01
Te131m	8.32E-02	7.64E-04	-	2.74E-02
Te131	1.90E-02	1.75E-04	-	6.18E-03
Te132	1.55E+00	1.43E-02	-	1.01E+00
Te133m	1.59E-03	1.46E-05	-	3.56E-19
Te134	1.71E-03	1.57E-05	-	3.10E-24
Ba137m	7.96E+02	1.81E+02	-	7.96E+02
Ba139	6.31E-05	5.79E-07	-	2.30E-15
Ba140	7.60E-02	6.98E-04	-	6.82E-02
La140	7.90E-02	7.25E-04	-	7.48E-02
La141	5.54E-05	5.09E-07	-	1.14E-08
La142	1.03E-05	9.41E-08	-	3.12E-15
Ce141	2.99E-02	2.75E-04	-	2.87E-02
Ce143	9.57E-04	8.79E-06	-	3.50E-04
Ce144	1.81E-01	1.17E-03	-	1.80E-01
Pr143	1.21E-02	1.11E-04	-	1.09E-02
Pr144	1.79E-01	1.16E-03	-	1.78E-01
Np239	3.44E-02	3.16E-04	-	1.91E-02
Na24	6.17E-01	8.77E-03	1.77E-03	6.67E-02
Cr51	2.39E+00	2.22E-02	4.48E-03	2.28E+00
Mn54	1.11E+01	7.03E-02	1.42E-02	1.11E+01
Fe55	1.31E+01	6.75E-02	1.36E-02	1.31E+01
Fe59	3.72E-01	3.43E-03	6.92E-04	3.61E-01
Co58	9.10E+00	8.14E-02	1.65E-02	8.93E+00
Co60	6.46E+00	3.16E-02	6.37E-03	6.45E+00
Ni63	3.63E+00	1.67E-02	3.38E-03	3.63E+00

Table 12.2-7: Chemical and Volume Control System Component Source Terms - Radionuclide Content (Continued)

~~Isotope~~	~~CVCS Mixed Bed Demineralizer (Ci)~~	~~CVCS Cation Bed Demineralizer (Ci)~~	~~CVCS Reactor Coolant Filter (Ci)~~	~~Resin Transfer Pipe in Pipechase (Ci)~~
Isotope	**CVCS Mixed Bed Ci**	**CVCS Cation Bed Ci**	**CVCS Particulate Filter Ci**	**CVCS Mixed Bed Transfer - 48-hour decay Ci**
Zn65	3.02E+00	2.04E-02	4.11E-03	3.00E+00
Zr95	6.97E-01	6.30E-03	1.27E-03	6.82E-01
Ag110m	7.84E+00	5.25E-02	1.06E-02	7.79E+00
W187	5.87E-02	7.09E-04	1.43E-04	1.44E-02

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Table 12.2-8: Chemical and Volume Control System Component Source Terms - Source Strengths

Energy Group	Energy Boundary (MeV)	Design Basis Primary Coolant Photon Spectra (photon/s/gram)	CVCS Mixed Bed ~~Demineralizer~~ (photon/s)	CVCS Cation Bed ~~Demineralizer~~ (photon/s)	CVCS ~~Reactor Coolant~~Particulate Filter (photon/s)	~~Resin Transfer Pipe (photons/s)~~CVCS Mixed Bed Transfer - 48-hour decay (photon/s)
~~1~~	~~1.00E-02 - 2.00E-02~~	~~7.15E+02~~	~~3.86E+11~~	~~4.59E+10~~	~~5.84E+08~~	~~2.10E+09~~
~~2~~	~~2.00E-02 - 3.00E-02~~	~~1.19E+03~~	~~2.69E+11~~	~~2.44E+10~~	~~3.10E+08~~	~~1.77E+09~~
~~3~~	~~3.00E-02 - 4.50E-02~~	~~3.17E+04~~	~~2.14E+12~~	~~5.55E+11~~	~~2.31E+08~~	~~1.48E+10~~
~~4~~	~~4.50E-02 - 6.00E-02~~	~~1.87E+02~~	~~1.22E+11~~	~~1.23E+10~~	~~2.78E+08~~	~~6.21E+08~~
~~5~~	~~6.00E-02 - 7.00E-02~~	~~8.84E+01~~	~~6.22E+10~~	~~1.17E+10~~	~~5.80E+08~~	~~3.53E+08~~
~~6~~	~~7.00E-02 - 7.50E-02~~	~~3.46E+01~~	~~2.36E+10~~	~~2.29E+09~~	~~3.56E+08~~	~~1.14E+08~~
~~7~~	~~7.50E-02 - 1.00E-01~~	~~2.66E+04~~	~~1.15E+11~~	~~1.47E+10~~	~~1.39E+08~~	~~7.50E+08~~
~~8~~	~~1.00E-01 - 1.50E-01~~	~~3.89E+02~~	~~1.55E+11~~	~~8.66E+09~~	~~3.94E+08~~	~~9.24E+08~~
~~9~~	~~1.50E-01 - 2.00E-01~~	~~4.24E+02~~	~~9.07E+10~~	~~2.38E+10~~	~~1.03E+08~~	~~6.64E+08~~
~~10~~	~~2.00E-01 - 2.60E-01~~	~~2.74E+03~~	~~6.16E+10~~	~~4.89E+09~~	~~6.07E+07~~	~~4.27E+08~~
~~11~~	~~2.60E-01 - 3.00E-01~~	~~1.05E+02~~	~~7.49E+10~~	~~1.45E+10~~	~~2.44E+07~~	~~7.19E+08~~
~~12~~	~~3.00E-01 - 4.00E-01~~	~~6.03E+02~~	~~8.00E+11~~	~~5.53E+10~~	~~2.72E+08~~	~~8.76E+09~~
~~13~~	~~4.00E-01 - 4.50E-01~~	~~1.71E+02~~	~~4.43E+10~~	~~3.70E+08~~	~~7.52E+07~~	~~4.71E+08~~
~~14~~	~~4.50E-01 - 5.10E-01~~	~~1.02E+02~~	~~2.87E+11~~	~~1.44E+11~~	~~5.99E+08~~	~~3.63E+09~~
~~15~~	~~5.10E-01 - 5.12E-01~~	~~2.18E+02~~	~~5.40E+12~~	~~2.13E+09~~	~~1.00E+10~~	~~6.90E+10~~
~~16~~	~~5.12E-01 - 6.00E-01~~	~~1.13E+03~~	~~4.58E+12~~	~~2.34E+12~~	~~1.52E+08~~	~~5.86E+10~~
~~17~~	~~6.00E-01 - 7.00E-01~~	~~1.29E+03~~	~~4.41E+13~~	~~1.54E+13~~	~~2.85E+09~~	~~4.04E+11~~
~~18~~	~~7.00E-01 - 8.00E-01~~	~~8.35E+02~~	~~1.83E+13~~	~~9.24E+12~~	~~1.16E+09~~	~~2.38E+11~~
~~19~~	~~8.00E-01 - 9.00E-01~~	~~5.91E+02~~	~~2.00E+13~~	~~5.23E+11~~	~~3.53E+10~~	~~2.55E+11~~
~~20~~	~~9.00E-01 - 1.00E+00~~	~~1.16E+02~~	~~3.06E+11~~	~~2.40E+09~~	~~5.52E+08~~	~~3.89E+09~~
~~21~~	~~1.00E+00 - 1.20E+00~~	~~4.05E+02~~	~~1.38E+12~~	~~3.63E+11~~	~~1.40E+09~~	~~1.78E+10~~
~~22~~	~~1.20E+00 - 1.33E+00~~	~~7.72E+03~~	~~3.49E+11~~	~~2.65E+10~~	~~5.76E+08~~	~~4.36E+09~~
~~23~~	~~1.33E+00 - 1.44E+00~~	~~7.58E+02~~	~~2.50E+13~~	~~2.92E+11~~	~~4.51E+10~~	~~4.69E+10~~
~~24~~	~~1.44E+00 - 1.50E+00~~	~~4.87E+01~~	~~3.91E+10~~	~~2.19E+08~~	~~6.80E+07~~	~~4.80E+08~~
~~25~~	~~1.50E+00 - 1.57E+00~~	~~7.58E+01~~	~~1.29E+11~~	~~8.85E+08~~	~~2.37E+08~~	~~1.67E+09~~
~~26~~	~~1.57E+00 - 1.66E+00~~	~~1.15E+01~~	~~1.76E+09~~	~~3.56E+07~~	~~3.94E+05~~	~~2.07E+07~~
~~27~~	~~1.66E+00 - 1.80E+00~~	~~1.28E+02~~	~~9.51E+10~~	~~7.44E+07~~	~~1.68E+08~~	~~1.16E+09~~
~~28~~	~~1.80E+00 - 2.00E+00~~	~~1.21E+02~~	~~3.17E+09~~	~~2.14E+09~~	~~2.75E+05~~	~~6.72E+06~~
~~29~~	~~2.00E+00 - 2.15E+00~~	~~7.35E+01~~	~~5.26E+08~~	~~6.32E+07~~	~~1.64E+04~~	~~2.14E+06~~
~~30~~	~~2.15E+00 - 2.35E+00~~	~~1.13E+02~~	~~3.71E+08~~	~~7.90E+07~~	~~1.02E+04~~	~~1.37E+06~~
~~31~~	~~2.35E+00 - 2.50E+00~~	~~1.64E+02~~	~~2.85E+08~~	~~8.74E+06~~	~~3.33E+02~~	~~6.09E+05~~
~~32~~	~~2.50E+00 - 2.75E+00~~	~~3.48E+02~~	~~1.27E+13~~	~~8.58E+08~~	~~2.34E+10~~	~~1.80E+10~~
~~33~~	~~2.75E+00 - 3.00E+00~~	~~2.74E+02~~	~~1.16E+13~~	~~5.42E+08~~	~~2.14E+10~~	~~1.64E+10~~
~~34~~	~~3.00E+00 - 3.50E+00~~	~~5.63E+00~~	~~4.96E+07~~	~~4.67E+07~~	~~4.10E+01~~	~~6.03E+03~~
~~35~~	~~3.50E+00 - 4.00E+00~~	~~2.27E+00~~	~~1.85E+10~~	~~9.02E+06~~	~~3.42E+07~~	~~2.62E+07~~
~~36~~	~~4.00E+00 - 4.50E+00~~	~~6.57E-01~~	~~2.05E+08~~	~~1.68E+06~~	~~3.75E+05~~	~~2.88E+05~~
~~37~~	~~4.50E+00 - 5.00E+00~~	~~9.71E-01~~	~~1.86E+07~~	~~1.84E+07~~	~~-~~	~~7.88E-10~~
~~38~~	~~5.00E+00 - 5.50E+00~~	~~7.34E-02~~	~~4.46E+04~~	~~4.02E+04~~	~~-~~	~~8.79E-12~~
~~39~~	~~5.50E+00 - 6.00E+00~~	~~1.30E-02~~	~~1.57E+03~~	~~8.75E+01~~	~~-~~	~~3.68E-12~~

Table 12.2-8: Chemical and Volume Control System Component Source Terms - Source Strengths (Continued)

Energy Group	Energy Boundary (MeV)	Design Basis Primary Coolant Photon Spectra (photon/s/gram)	CVCS Mixed Bed ~~Demineralizer~~ (photon/s)	CVCS Cation Bed ~~Demineralizer~~ (photon/s)	CVCS ~~Reactor Coolant~~Particulate Filter (photon/s)	~~Resin Transfer Pipe (photons/s)~~CVCS Mixed Bed Transfer - 48-hour decay (photon/s)
~~40~~	~~6.00E+00 - 6.50E+00~~	~~6.36E-03~~	~~9.31E+02~~	~~1.80E-01~~	-	~~1.85E-12~~
~~41~~	~~6.50E+00 - 7.00E+00~~	~~4.89E-04~~	~~4.50E+01~~	-	-	~~9.31E-13~~
~~42~~	~~7.00E+00 - 7.50E+00~~	~~1.02E-04~~	~~3.30E+00~~	-	-	~~4.69E-13~~
~~43~~	~~7.50E+00 - 8.00E+00~~	~~1.39E-09~~	~~4.52E-05~~	-	-	~~2.36E-13~~
~~44~~	~~8.00E+00 - 1.00E+01~~	~~1.20E-09~~	~~3.89E-05~~	-	-	~~2.15E-13~~
~~45~~	~~1.00E+01 - 1.20E+01~~	-	-	-	-	~~7.15E-15~~
~~46~~	~~1.20E+01 - 1.40E+01~~	-	-	-	-	-
~~47~~	~~1.40E+01 - 2.00E+01~~	-	-	-	-	-
~~**Total**~~		~~7.95E+04~~	~~1.49E+14~~	~~2.91E+13~~	~~1.46E+11~~	~~1.17E+12~~
1	1.00E-02 - 2.00E-02	2.09E+03	2.15E+11	4.69E+10	2.81E+06	2.06E+11
2	2.00E-02 - 3.00E-02	3.26E+03	2.27E+11	2.49E+10	5.68E+06	2.00E+11
3	3.00E-02 - 4.50E-02	8.54E+04	2.38E+12	5.25E+11	1.07E+06	2.36E+12
4	4.50E-02 - 6.00E-02	5.80E+02	6.18E+10	1.25E+10	1.03E+06	5.79E+10
5	6.00E-02 - 7.00E-02	2.79E+02	3.90E+10	1.21E+10	1.56E+06	3.68E+10
6	7.00E-02 - 7.50E-02	1.14E+02	1.03E+10	2.33E+09	9.24E+05	9.91E+09
7	7.50E-02 - 1.00E-01	7.16E+04	1.64E+11	1.51E+10	5.85E+05	1.45E+11
8	1.00E-01 - 1.50E-01	1.06E+03	1.63E+11	8.69E+09	1.87E+06	1.11E+11
9	1.50E-01 - 2.00E-01	1.19E+03	7.61E+10	2.47E+10	1.23E+06	6.66E+10
10	2.00E-01 - 2.60E-01	7.24E+03	1.09E+11	4.97E+09	7.87E+05	5.47E+10
11	2.60E-01 - 3.00E-01	2.69E+02	1.26E+11	1.51E+10	2.40E+05	1.06E+11
12	3.00E-01 - 4.00E-01	1.37E+03	1.33E+12	5.75E+10	1.61E+07	1.12E+12
13	4.00E-01 - 4.50E-01	4.71E+02	1.89E+10	2.28E+08	1.50E+07	1.37E+10
14	4.50E-01 - 5.10E-01	2.95E+02	5.76E+11	1.48E+11	1.58E+06	5.72E+11
15	5.10E-01 - 5.12E-01	5.37E+02	1.08E+11	9.29E+08	1.85E+08	1.04E+11
16	5.12E-01 - 6.00E-01	2.61E+03	9.38E+12	2.42E+12	5.09E+05	9.25E+12
17	6.00E-01 - 7.00E-01	2.84E+03	6.21E+13	1.52E+13	4.58E+08	6.20E+13
18	7.00E-01 - 8.00E-01	1.82E+03	3.66E+13	9.52E+12	2.16E+08	3.66E+13
19	8.00E-01 - 9.00E-01	1.37E+03	2.80E+12	5.30E+11	1.42E+09	2.75E+12
20	9.00E-01 - 1.00E+00	3.01E+02	1.14E+11	8.14E+08	1.33E+08	1.06E+11
21	1.00E+00 - 1.20E+00	9.71E+02	1.62E+12	3.72E+11	3.44E+08	1.58E+12
22	1.20E+00 - 1.33E+00	8.27E+03	2.14E+11	2.67E+10	1.36E+08	1.87E+11
23	1.33E+00 - 1.44E+00	8.41E+02	1.35E+12	2.99E+11	2.76E+08	1.33E+12
24	1.44E+00 - 1.50E+00	1.19E+02	1.76E+10	9.46E+07	1.64E+07	1.28E+10
25	1.50E+00 - 1.57E+00	1.98E+02	4.39E+10	4.39E+08	5.73E+07	4.24E+10
26	1.57E+00 - 1.66E+00	3.23E+01	3.05E+09	2.76E+07	9.52E+04	2.74E+09
27	1.66E+00 - 1.80E+00	3.20E+02	1.21E+10	2.28E+07	3.10E+06	2.02E+09
28	1.80E+00 - 2.00E+00	3.29E+02	2.21E+09	1.40E+08	6.65E+04	8.22E+08
29	2.00E+00 - 2.15E+00	1.97E+02	1.02E+09	1.01E+07	3.93E+03	3.29E+08
30	2.15E+00 - 2.35E+00	3.02E+02	7.67E+08	6.64E+07	2.71E+03	2.09E+08
31	2.35E+00 - 2.50E+00	4.47E+02	6.34E+08	2.16E+06	2.91E+00	9.77E+07
32	2.50E+00 - 2.75E+00	3.67E+02	1.22E+10	2.21E+08	3.43E+07	1.41E+09

Table 12.2-8: Chemical and Volume Control System Component Source Terms - Source Strengths (Continued)

Energy Group	Energy Boundary (MeV)	Design Basis Primary Coolant Photon Spectra (photon/s/gram)	CVCS Mixed Bed ~~Demineralizer~~ (photon/s)	CVCS Cation Bed ~~Demineralizer~~ (photon/s)	CVCS ~~Reactor Coolant~~Particulate Filter (photon/s)	~~Resin Transfer Pipe (photons/s)~~CVCS Mixed Bed Transfer - 48-hour decay (photon/s)
33	2.75E+00 - 3.00E+00	1.82E+02	1.09E+10	1.56E+08	3.13E+07	1.18E+09
34	3.00E+00 - 3.50E+00	1.65E+01	1.56E+07	4.82E+06	6.00E-02	8.98E+05
35	3.50E+00 - 4.00E+00	8.39E+00	2.28E+07	1.04E+06	5.00E+04	1.88E+06
36	4.00E+00 - 4.50E+00	2.09E+00	7.21E+05	1.80E+05	5.49E+02	2.07E+04
37	4.50E+00 - 5.00E+00	3.75E+00	2.45E+06	1.10E+06	-	-
38	5.00E+00 - 5.50E+00	1.28E+00	4.62E+03	2.07E+03	-	-
39	5.50E+00 - 6.00E+00	6.30E-01	-	-	-	-
40	6.00E+00 - 6.50E+00	4.16E+03	-	-	-	-
41	6.50E+00 - 7.00E+00	2.72E+00	-	-	-	-
42	7.00E+00 - 7.50E+00	3.04E+02	-	-	-	-
43	7.50E+00 - 8.00E+00	8.70E-02	-	-	-	-
44	8.00E+00 - 1.00E+01	4.85E+00	-	-	-	-
45	1.00E+01 - 1.20E+01	1.24E-03	-	-	-	-
46	1.20E+01 - 1.40E+01	-	-	-	-	-
47	1.40E+01 - 2.00E+01	-	-	-	-	-
Total		2.02E+05	1.20E+14	2.93E+13	3.36E+09	1.19E+14

12.3.1.2.3 Penetrations

Penetrations through shield walls are minimized as much as possible.

If penetrations through shield walls are necessary, the penetrations are designed to minimize streaming (e.g., with an offset) from a radiation source to accessible areas. If penetration offsets are not practical, then penetrations are either shielded or elevated above floor level.

12.3.1.2.4 Equipment Layout

Radioactive system components are located separately from "clean" components as much as practical. Individual components of a radioactive system are typically located in separate shielded compartments with short piping runs between components Where appropriate, shielded valve galleries are employed to allow system operation while shielding operators from high radiation components.

12.3.1.2.5 Lighting

Adequate lighting is provided in radiation areas requiring access to facilitate surveillance and maintenance activities. Light fixtures are located in accessible areas to reduce replacement time. Multiple light fixtures are provided to reduce the need for immediate light bulb replacement. Emergency lighting fixtures reduce personnel exposures by permitting prompt egress from radiation areas if normal lighting fails.

12.3.1.2.6 Cubicles

Shielded cubicles are provided for components containing significant radioactive sources. Cubicles are lined with stainless steel to a height necessary to contain the contents of the residing component plus piping drainage. In the event of a leak or spill, cubicle floors slope toward floor drains that are connected to sump tanks.

12.3.1.3 Radiation Zoning and Access Control

12.3.1.3.1 Normal Conditions

The NuScale Power Plant is analyzed for expected radiation levels resulting from normal operation. Since potential airborne exposures are possible in portions of the Reactor Building (RXB), principally due to off-gassing from the reactor pool and possible leaks or spills, airborne radiation zones are also developed. Radiation levels are categorized along with anticipated personnel occupancy in Table 12.3-1, which tabulates the radiation zone categories and their access descriptions. Table 12.3-2 tabulates the airborne zone categories and their access descriptions.

RAI 12.02-14

Normal operation radiation zones for the RXB are provided in Figure 12.3-1a through Figure 12.3-1i. Areas that have the potential for airborne radiation in the RXB and the Radioactive Waste Building (RWB) are listed in Table 12.3-5a and

Table 12.3-5b, respectively. Normal operation radiation zones for the RWB are provided in Figure 12.3-2a and Figure 12.3-2b. These radiation zones are based on conservative assumptions related to source terms and are not intended to reflect the anticipated dose rates over the entire area. ~~The radiation zones in the RXB near the CVCS demineralizers are impacted by the post-crud burst cleanup.~~ Short-lived isotopes have a significant impact on the area dose rates for a short period of time. Therefore, these area dose rates were also evaluated after a short period of decay to demonstrate that maintenance activities can be managed to avoid these peaks.

Access to radiologically controlled areas (RCA) is controlled by the facility's radiation protection staff. Access control facilities are provided to control the entrance and exit of personnel and materials into and out of the RCA. Access is controlled through a portal located in the Annex Building. Radiological areas are posted with signage in compliance with 10 CFR 20.1901 and 20.1902.

RAI 12.03-21, RAI 12.03-22

High radiation areas either are locked or have alarmed barriers. For areas that are not within lockable enclosures or other barriers, the area will be barricaded and posted, and be provided with a visible warning light. Positive control is exercised over each individual entry when access to the area is required, and egress from the area is not impeded.

COL Item 12.3-1: A COL applicant that references the NuScale Power Plant design certification will develop the administrative controls regarding access to high radiation areas per the guidance of Regulatory Guide 8.38.

RAI 12.03-21, RAI 12.03-22

Very high-radiation areas are locked. Positive control is exercised over each individual entry when access to the area is required, and egress from the area is not impeded. Access to very high-radiation areas complies with guidance in RG 8.38. The locations of very high-radiation areas are listed on Table 12.3-3.

COL Item 12.3-2: A COL applicant that references the NuScale Power Plant design certification will develop the administrative controls regarding access to very high radiation areas per the guidance of Regulatory Guide 8.38.

COL Item 12.3-3: A COL applicant that references the NuScale Power Plant design certification will specify personnel exposure monitoring hardware, specify contamination identification and removal hardware, and establish administrative controls and procedures to control access into and exiting the radiologically controlled area.

12.3.1.3.2 Accident Conditions

A radiation and shielding design review has been performed of spaces around systems that may contain accident source term materials, consistent with 10 CFR 50.34(f)(2)(vii). Post-accident access is discussed in Section 12.4.1.8 and equipment qualification is addressed in Section 12.2.1.13 and Section 3.11. Area radiation monitors are provided to indicate the post-accident radiation levels, to monitor

Consistent with RG 8.8, shielding analysis employs accurate modeling techniques and conservative approaches in the determination of shielding thickness. Source terms, geometries, and field intensities are analyzed conservatively. In addition to normal and shutdown conditions, source terms include transient conditions such as resin transfers.

RAI 12.03-58

The material used for a significant portion of plant shielding is concrete. For most applications, concrete shielding is designed in accordance with ANSI/ANS 6.4-2006 (Reference 12.3-1). Table 12.3-6 and Table 12.3-7 show~~s~~ the ~~nominal~~ shielding thicknesses assumed in the shielding analyses~~for rooms~~ in plant buildings. In addition to concrete, other types of materials such as steel, water, tungsten, and polymer composites are considered for both permanent and temporary shielding. The use of lead is minimized.

For shield walls that contain a door, the door provides an equivalent radiation attenuation as the shield wall that contains the door. A listing of radiation shield doors is provided in Table 12.3-8 for the RXB and Table 12.3-9 for the RWB.

12.3.2.3 Calculation Methods

The primary computer program used to evaluate shielding is Monte Carlo N-Particle Transport Code (MCNP6) (Reference 12.3-2) which was developed by Los Alamos National Laboratory. The MCNP6 code is a Monte Carlo radiation transport code designed to track a variety of particles over a broad spectrum of energies. The MCNP6 code is used for shielding calculations and for dose rate determinations. ANSI/ANS 6.1.1-1977, "Gamma Flux to Dose Conversion Factors," (Reference 12.3-3) is used to convert gamma flux at each detector location to a corresponding dose rate.

RAI 12.02-14

Radioactive components in the RXB and RWB are modeled using MCNP6. The codes used to prepare source strength input data are described in Section 12.2. A three-dimensional shielding model is constructed for radioactive components using structure, location, and equipment data. Source geometries and source term distributions and intensities are conservatively determined. ~~Source terms associated with resin transfers and crud bursts are included.~~ In general, the component source geometries are modeled as cylindrical volumes which incorporate the full volume of the component.

Shielding credit and material selections for MCNP6 cells are conservatively applied. The material compositions for air, concrete, water, and stainless steel are taken from PNNL-25870 (Reference 12.3-4). Structural steel composition is in accordance with plant drawings and ASTM standards. Credit is not taken for reinforcing steel bars in the concrete.

The operating NuScale Power Module (NPM) dose rate at full power is also calculated using MCNP6. The reactor shielding calculations consider dose rates from fission neutrons, fission photons, and gamma output from buildup of radioisotopes in the reactor coolant. The NPM model is conservatively developed using methods similar to