Response to SDAA Audit Question

Question Number: A-12.2-5

Receipt Date: 07/03/2023

Question:

This is a follow-up to audit item 12.2-1. The SDA should be updated to better describe N-16 concentrations in the CVCS system, including the N-16 concentrations in each heat exchanger, a description of when N-16 decays in the CVCS line to no longer be significant, and a discussion of when the SDA Table 12.2-7, source term with N-16 is used versus when the "CVCS Letdown – 71.3 second decay" with no N-16 is used.

Response:

Updates to SDAA Section 12.2.1.2, Table 12.2-7, and Table 12.2-11 provide additional description of the nitrogen-16 concentrations in the chemical volume control system (CVCS).

Markups of the affected changes, as described in the response, are provided below:

12.2 Radiation Sources

This section describes the sources of both contained and airborne radiation that provide input to:

- radiation shielding design calculations.
- ventilation systems design.
- radwaste systems design, including the classification of structures, systems, and components per Regulatory Guide (RG) 1.143.
- radiation protection assessment, including personnel protection.

12.2.1 Contained Sources

The contained radiation sources are developed for normal operation and shutdown conditions. The design basis primary coolant activity concentrations (Section 11.1) are the basis for the contained radiation sources. They are determined by propagating this radionuclide activity through various plant systems using the parameters and assumptions provided in this section. In order for the radiological source terms to be used in shielding calculations, the isotopic inventory is used to calculate the intensity and energy spectrum of the total emitted radiation. The ORIGEN-S code is used to bin the particle emissions into default energy bins based on the activity of each individual isotope. This section describes the radiation sources that provide part of the basis for the design of radiation shielding features. The radiation zone maps in Section 12.3 include drawings showing locations of contained sources.

12.2.1.1 Reactor Core

During normal reactor operations, neutron and gamma radiation are released from the reactor core and from the primary coolant. This radiation is attenuated by the reactor internals, the reactor vessel, the containment vessel, the water surrounding the NuScale Power Module (NPM), the reactor pool concrete walls, and by the bioshield. Table 12.2-1 provides the fission neutron source strength as well as neutron energy spectrum information. The n-gamma and fission gamma source strength is internally generated by MCNP6 using the neutron source strength as an input. The fission neutron source utilizes the Watt spectrum for U-235.

12.2.1.2 Reactor Coolant System

Radionuclides present in the reactor coolant system (RCS) are generated from the release of radioactive materials from postulated fuel clad defects and neutron activation of the primary coolant and impurities in the primary coolant.

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The contribution of gamma radiation from the primary coolant is comprised of two components: the primary coolant at the steam generator entrance and at the core exit. The nitrogen-16 concentration is calculated at the core exit, the top of the upper riser/steam generator entrance, and at various points along the chemical and volume control system (CVCS) letdown line. Because of the low flow velocity of the primary coolant, the short half-life of nitrogen-16 causes it to decay by about one order of magnitude by the time it reaches the steam generator entrance. The corrosion and wear activation products (commonly referred to as CRUD) are uniformly modeled on a primary coolant mass basis. Tables 12.2-2 and 12.2-3 provide the primary coolant gamma spectra. Table 12.2-4 tabulates the nitrogen-16 concentration at several locations. prior to the LRWS degasifier. Table 12.2-7 tabulates the source term at the LRWS degasifier vessels based on a decay (transit) time of 71.3 seconds (ten nitrogen-16 half-lives) to represent reduction of nitrogen-16 down to insignificant levels.

12.2.1.3 Chemical and Volume Control System

The CVCS processes a portion of the RCS through heat exchangers, demineralizers, and filters. The treated primary coolant 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).

Mixed-Bed and Cation Bed Demineralizers

The CVCS mixed-bed demineralizers are modeled in continuous operation during the entire fuel cycle. The decontamination factors assumed are listed in Table 11.1-2.

The CVCS cation bed demineralizers are modeled in operation for one-half of the fuel cycle because they are operated intermittently during the operating cycle for lithium removal. Table 12.2-5 lists the assumed decontamination factors.

Tables 12.2-6 and 12.2-7 list the mixed-bed source terms and source strengths, respectively. These source terms and the associated analyses do not include short-term transients such as CRUD bursts associated with refueling outages. This results in the estimates of activity within some plant structures, systems, and components to not reflect the CRUD-burst related activity, including the CVCS mixed-bed demineralizer values (both columns) in Table 12.2-6 and Table 12.2-7. It is estimated that a CRUD burst could add up to 680 curies of CRUD isotopes to the CVCS mixed-bed demineralizer.

Regenerative and Non-Regenerative Heat Exchangers

The CVCS regenerative and non-regenerative heat exchangers are shell and tube 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 12.2-5. The source term for the RCS water is found in Table 11.1-4.

Module Heatup System Heater

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

Energy Group	Energy (MeV)		Design Basis Primary Coolant at CVCS Pipe Chase Photon Spectra N-16	CVCS Mixed-Bed	CVCS Cation Bed	CVCS Particulate Filter	CVCS Mixed Bed Transfer - 48 hour decay	CVCS Letdown - 71.3 second decay
	Lower Bound	Upper Bound	(photon/sec/gram)	photons/sec	photons/sec	photons/sec	photons/sec	photons/sec/gram
1	1.00E-02	2.00E-02	7.0E+03	2.7E+11	5.7E+10	4.2E+06	6.5E+10	5.3E+02
2	2.00E-02	3.00E-02	7.5E+03	3.2E+11	3.1E+10	8.5E+06	7.4E+10	1.1E+03
3	3.00E-02	4.50E-02	1.4E+05	2.8E+12	6.0E+11	1.6E+06	6.8E+11	3.4E+04
4	4.50E-02	6.00E-02	2.4E+03	8.0E+10	1.5E+10	1.5E+06	1.9E+10	1.3E+02
5	6.00E-02	7.00E-02	1.2E+03	5.0E+10	1.5E+10	2.3E+06	1.2E+10	6.1E+01
6	7.00E-02	7.50E-02	5.0E+02	1.3E+10	2.9E+09	1.4E+06	3.3E+09	2.4E+01
7	7.50E-02	1.00E-01	1.2E+05	2.4E+11	1.9E+10	8.7E+05	5.5E+10	2.8E+04
8	1.00E-01	1.50E-01	3.2E+03	2.4E+11	1.1E+10	2.8E+06	4.2E+10	2.2E+02
9	1.50E-01	2.00E-01	3.1E+03	1.0E+11	3.2E+10	1.8E+06	2.3E+10	3.9E+02
10	2.00E-01	2.60E-01	1.0E+04	1.7E+11	6.5E+09	1.2E+06	2.1E+10	2.3E+03
11	2.60E-01	3.00E-01	8.0E+02	1.9E+11	2.0E+10	3.6E+05	4.0E+10	3.5E+01
12	3.00E-01	4.00E-01	3.2E+03	2.1E+12	7.6E+10	2.4E+07	4.5E+11	1.1E+02
13	4.00E-01	4.50E-01	1.1E+03	2.9E+10	3.1E+08	2.2E+07	1.7E+10	1.2E+02
14	4.50E-01	5.10E-01	8.7E+02	7.6E+11	1.9E+11	2.4E+06	1.9E+11	4.7E+01
15	5.10E-01	5.12E-01	5.4E+02	1.6E+11	1.4E+09	2.7E+08	1.5E+11	1.2E+02
16	5.12E-01	6.00E-01	4.0E+03	1.2E+13	3.2E+12	7.6E+05	3.0E+12	2.5E+02
17	6.00E-01	7.00E-01	4.1E+03	7.6E+13	1.9E+13	6.8E+08	1.9E+13	2.8E+02
18	7.00E-01	8.00E-01	2.8E+03	4.8E+13	1.3E+13	3.2E+08	1.2E+13	2.0E+02
19	8.00E-01	9.00E-01	2.3E+03	3.9E+12	7.0E+11	2.1E+09	2.0E+12	1.6E+02
20	9.00E-01	1.00E+00	6.4E+02	1.7E+11	1.2E+09	2.0E+08	1.5E+11	3.2E+01
21	1.00E+00	1.20E+00	1.7E+03	2.2E+12	4.9E+11	5.2E+08	8.9E+11	9.9E+01
22	1.20E+00	1.33E+00	8.9E+03	3.2E+11	3.5E+10	2.0E+08	2.2E+11	7.9E+03
23	1.33E+00	1.44E+00	1.4E+03	1.8E+12	3.9E+11	4.1E+08	6.6E+11	1.0E+02
24	1.44E+00	1.50E+00	2.2E+02	2.7E+10	1.4E+08	2.5E+07	1.8E+10	3.0E+00
25	1.50E+00	1.57E+00	3.4E+02	6.5E+10	6.3E+08	8.6E+07	6.3E+10	6.4E+01

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Table 12.2-11: Liquid Radioactive Waste System Component Source Term Inputs and Assumptions

Model Parameter	Value
LRWS degasifier	-
Contents	CVCS Letdown - 71.3 second decay
Geometry	Vertical Cylinder
Source dimensions	Diameter=138 in, Height=193 in
Shield thickness of steel shell	1.75 in
Volume	12500 Gallons
LCW and HCW collection tanks	-
Inputs	Table 11.2-3
Geometry	Vertical Cylinder
Source dimensions	Diameter=12 ft, Height=21 ft
Shield thickness of steel shell	0.25 in
Volume	14400 gallons
LRWS oil separator	-
Inputs	Table 11.2-3
Geometry	Horizontal Cylinder
Source dimensions	Diameter=51 in, Height=118 in
Shield thickness of steel shell	0.25 in
~~LCW and~~ HCW granulated activated charcoal (GAC) units	-
Decontamination Factors	-
Cr-51	256
Mn-54	107
Co-58	13.2
Co-60	6.7
Ag-110m	3250
Antimony	7.1
Nb-95	639
Geometry	Vertical Cylinder
Source dimensions of vessel	Diameter=71 in, Height=71 in
Shield thickness of steel shell	0.25 in
LCW reverse osmosis (RO) unit	-
Decontamination factors	-
All nuclides	10
Geometry	Horizontal Cylinder
Source dimensions	Diameter=59 in, Length=102 in
Shield thickness of steel shell	0.25 in
LCW and HCW sample tanks	-
Geometry	Vertical Cylinder
Source dimensions	Diameter=12 ft, Height=21 ft
Shield thickness of steel shell	0.25 in
Drum dryer and holdup tank	-
Inputs	RO Rejects
Geometry	Vertical Cylinder
Source dimensions	Diameter=65.0 in, Height=118 in
Shield thickness of steel shell	0.25 in
LCW processing skid	-