NuScale US460 Plant
Standard Design Approval Application

Chapter Eleven

Radioactive Waste Management

Final Safety Analysis Report

Revision 1

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CHAPTER 11 RADIOACTIVE WASTE MANAGEMENT

11.1 Source Terms

Sources of radioactivity in the primary coolant are created by fission and activation processes in the reactor. The NuScale Power Plant US460 standard design uses a shared systems source term for systems that receive input from all six modules, such as radwaste systems. The shared systems source term is calculated as one module running at a design basis failed fuel fraction and five modules running at a realistic failed fuel fraction. The secondary coolant may become contaminated by primary-to-secondary leakage through the steam generator. This section discusses two source terms for the primary and secondary coolants: a design basis source term and a realistic source term. The design basis source term provides a basis for design capacities of waste management components, performance of the waste management systems and design of radiological monitoring equipment. The design basis source term is also used for the evaluation of shielding (General Design Criterion 61). The coolant source terms used for dose consequences of design basis events are found in Section 15.0. Equipment qualification is discussed in Section 3.11.

A realistic source term is used to calculate the quantity of radioactive materials released annually in liquid and gaseous effluents during normal plant operations, including anticipated operational occurrences, to demonstrate compliance with effluent limits of 10 CFR 20 Appendix B, Table 2, and the “as low as reasonably achievable” objectives of 10 CFR 50 Appendix I. The methodology used to develop the primary and secondary coolant realistic source terms is described in TR-123242, (Reference 11.1-1).

The plant is designed with up to six NuScale Power Modules (NPMs) partially immersed in a pool of water, called the reactor pool. Because of this design, there is a potential for neutron activation of the reactor pool water. Additionally, given the relative proximity of the secondary coolant to the reactor core, there is the potential for neutron activation of the secondary coolant. However, the production of radionuclides in the secondary coolant is several orders of magnitude less than that in the primary coolant and is considered negligible. The production of radionuclides in the reactor pool water is discussed in Section 12.2.1.

11.1.1 Design Basis Reactor Coolant Activity

The design basis source term uses the same methodology described in TR-123242, except it assumes that fuel defects are an order-of-magnitude greater than the realistic coolant source term (Table 11.1-2). These defects are assumed to be uniformly distributed throughout the reactor core. The primary coolant design basis source term is provided in Table 11.1-4.

11.1.1.1 Fission Products

The isotopic inventory is developed for a single fuel assembly irradiated to the value presented in Table A-1 in TR-123242 (Reference 11.1-1). The quantity of each nuclide is calculated by ORIGEN-S. The resultant bounding reactor core isotopic inventory is provided in Table 11.1-1.

The parameters used in the calculation of the coolant source terms, including values for the fission product escape rate coefficients, coolant cleanup rate, and demineralizer effectiveness, are listed in Table 11.1-2. The quantity of fission products in the fuel pins and the release to the primary coolant are calculated using the methodology in TR-123242 (Reference 11.1-1).

11.1.1.2 Activation Products

The permeation of tritium from the fuel to the primary coolant is modeled using the Electric Power Research Institute (EPRI) Tritium Management Model (Reference 11.1-3). The tritium permeation rate is linearly scaled from 4100 MWt to 250 MWt, and adjusted for a 95 percent capacity factor, as shown in Table 11.1-2.

In the primary coolant system, neutron activation of various constituents in the water forms activation products. These activation products are independent of the failed fuel fraction. The neutron activation products include N-16, H-3, Ar-41, and C-14.

Because of its short half-life, N-16 is not of concern for offsite dose considerations. Table 12.2-4 lists the N-16 concentration at various locations in the primary coolant loop.

The predominant tritium production reactions are high-energy neutron interactions with lithium and boron isotopes.

The concentrations of tritium in the coolant streams vary depending on whether the primary coolant letdown to liquid radioactive waste system is recycled to the reactor pool, recycled back to chemical and volume control system (CVCS) makeup, or discharged through liquid radioactive waste system. The various tritium concentrations are presented in Table 11.1-8.

In the absence of significant N-16 in the primary coolant near the steam generators, natural argon can be injected into the primary coolant to improve the sensitivity of primary-to-secondary leak rate calculations. When the injected argon is activated in the reactor core, Ar-41 is produced, which can be used to detect leakage from the primary system.

The C-14 primary coolant equilibrium activity is calculated using the following equation:

$$A_{C14} = P_{C14} \times f \qquad \text{Eq. 11.1-1}$$

where,

A_{C14} = The equilibrium activity of C-14 in the primary coolant (Ci),

P_{C14} = The total production rate of C-14 from N-14 and O-17 reactions (Ci/s), and

f = The fraction of C-14 retained in the primary coolant.

11.1.1.3 Corrosion Products

The concentration values of radioactive corrosion and wear products in the reactor coolant are developed using guidance from ANSI/ANS 18.1-1999 (Reference 11.1-2). The specific parameters for adjusting the ANSI/ANS 18.1-1999 reference values are listed in Table 11.1-3.

11.1.2 Design Basis Secondary Coolant Activity

The design basis secondary coolant activity is determined from an assumed primary-to-secondary leak rate (Table 11.1-2) assuming a design basis primary coolant activity concentration (Table 11.1-4). The secondary coolant design basis source term is listed in Table 11.1-5.

11.1.2.1 Steam Generator Leakage

For the radionuclides that enter the secondary coolant, various removal mechanisms are also incorporated that affect the equilibrium concentration in the secondary coolant. The removal mechanisms include steam leaks in the Turbine Building, condensate polishers, and radioactive decay.

11.1.2.2 Noble Gases in Secondary Coolant Activity Source Term

Noble gases are removed in the secondary coolant by the condenser air removal system. Therefore, only pass-through concentrations of noble gases are assumed to be present in the steam generators. The concentration of noble gases in the secondary coolant is calculated by multiplying the concentration of the noble gas in the primary coolant by the primary-to-secondary leak rate, and dividing by the sum of the secondary flow rate and primary-to-secondary leak rate. The secondary coolant noble gas concentration after passing through the condenser is negligible.

11.1.2.3 Other Isotopes in Secondary Coolant Activity Source Term

For radioisotopes other than tritium, it is assumed there are no steam leaks. The modeling process for secondary coolant concentrations is described in Section 4.2 of Reference 11.1-1. The condensate system is designed such that 100 percent of the secondary coolant flow passes through the condensate demineralizers. The parameters used to calculate the secondary design basis source term are listed in Table 11.1-2 and Table 11.1-4.

11.1.3 Realistic Reactor Coolant and Secondary Coolant Activity Source Terms

A realistic source term is used to evaluate normal expected effluent releases as described in Section 11.2 and Section 11.3.

Parameters used in the model are included in Table 11.1-2. The realistic source term values for the primary and secondary coolant are provided in Table 11.1-6 and Table 11.1-7.

Details of the release modeling are presented in Section 11.2 and Section 11.3.

The resultant airborne concentrations are presented in Section 12.2.

11.1.4 References

11.1-1 NuScale Power, LLC, “Effluent Release (GALE Replacement) Methodology and Results,” TR-123242-P, Revision 1.

11.1-2 American National Standards Institute/American Nuclear Society, "Radioactive Source Term for Normal Operation of Light Water Reactors," ANSI/ANS 18.1-1999, LaGrange Park, IL.

11.1-3 Electric Power Research Institute, Inc., "EPRI Tritium Management Model," EPRI #1009903, EPRI, Palo Alto, CA, 2005.

Table 11.1-1: Maximum Core Isotopic Inventory

Nuclide	Core Inventory (Ci)	Nuclide	Core Inventory (Ci)
Noble Gases		Other Fission Products	
Kr83m	7.3E+05	Y91	7.0E+06
Kr85m	1.5E+06	Y92	7.6E+06
Kr85	1.5E+05	Y93	8.9E+06
Kr87	2.8E+06	Zr97	1.1E+07
Kr88	3.7E+06	Nb95	1.1E+07
Kr89	4.6E+06	Mo99	1.3E+07
Xe131m	1.0E+05	Mo101	1.2E+07
Xe133m	4.5E+05	Tc99m	1.1E+07
Xe133	1.4E+07	Tc99	2.2E+02
Xe135m	3.3E+06	Ru103	1.4E+07
Xe135	4.1E+06	Ru105	1.1E+07
Xe137	1.2E+07	Ru106	8.6E+06
Xe138	1.1E+07	Rh103m	1.4E+07
Halogens		Rh105	1.0E+07
Br82	4.0E+04	Rh106	9.6E+06
Br83	7.1E+05	Ag110	3.6E+06
Br84	1.2E+06	Sb124	2.1E+04
Br85	1.5E+06	Sb125	1.5E+05
I129	5.5E-01	Sb127	8.3E+05
I130	4.2E+05	Sb129	2.4E+06
I131	7.2E+06	Te125m	3.6E+04
I132	1.0E+07	Te127m	1.3E+05
I133	1.4E+07	Te127	8.2E+05
I134	1.5E+07	Te129m	3.9E+05
I135	1.3E+07	Te129	2.3E+06
Rubidium, Cesium		Te131m	1.5E+06
Rb86m	3.1E+03	Te131	6.1E+06
Rb86	2.5E+04	Te132	1.0E+07
Rb88	3.8E+06	Te133m	6.4E+06
Rb89	5.0E+06	Te134	1.2E+07
Cs132	5.2E+02	Ba137m	1.7E+06
Cs134	3.4E+06	Ba139	1.2E+07
Cs135m	4.4E+04	Ba140	1.2E+07
Cs136	7.8E+05	La140	1.2E+07
Cs137	1.8E+06	La141	1.1E+07
Cs138	1.3E+07	La142	1.0E+07
Other Fission Products		Ce141	1.1E+07
P32	1.1E+03	Ce143	9.9E+06
Co57	8.1E+00	Ce144	9.2E+06
Sr89	5.2E+06	Pr143	9.6E+06
Sr90	1.2E+06	Pr144	9.3E+06
Sr91	6.8E+06	Np239	1.9E+08
Sr92	7.5E+06	C14	2.2E+01
Y90	1.2E+06	H3	2.1E+04
Y91m	4.0E+06		

Table 11.1-2: Parameters Used to Calculate Coolant Source Terms

Parameter	Value
Reactor core thermal power	250 + 5 = 255 MWt (102%)
Number of fuel assemblies in one core	37
Range of U-235 fuel enrichment	1.5% - 4.95%
Uranium mass in one fuel assembly	250.6 kg
Maximum fuel assembly burnup	62,GWD/MTU
Failed fuel fractions:	
NPM Realistic source term	0.0066%
NPM Design basis source term	0.066%
Escape rate coefficients:	
Xe, Kr gases	6.5E-08 s^{-1}
I, Br, Cs, Rb	1.3E-08 s^{-1}
Mo, Tc, Ag	2.0E-09 s^{-1}
Te	1.0E-09 s^{-1}
Sr, Ba	1.0E-11 s^{-1}
Others	1.6E-12 s^{-1}
Average density of reactor coolant	0.71 gram/cm^3
RCS mass	1.0E+05 lb
Argon injection concentration:	
Design basis	0.15 μCi/cm^3
Realistic	0.10 μCi/cm^3
CVCS flow rate (purification)	180 lb/min
Secondary coolant mass	5.0E+04 lb
Secondary steam leak rate:	
Design Basis	1700 lb/hr/NPM
Realistic	125 lb/hr/NPM
Secondary coolant flow rate	6.5E+05 lb/hr
Decontamination factors for CVCS mixed bed demineralizers:	
Halogens	100
Cs, Rb	2
Other	50
Decontamination factors for condensate demineralizers:	
Halogens	100
Cs, Rb	10
Other	100
Primary-to-secondary leak rate:	
Design basis	75 lb/day/NPM
Realistic	5.5 lb/day/NPM
Tritium permeation rate	9 Ci/yr
Carbon-14 primary coolant retention rate	0.01
Carbon-14 removal rate by CVCS demineralizers	0

Table 11.1-3: Specific Parameters for CRUD

Parameter	Symbol	Units	Value
Thermal power	P	MWt	250
Weight of water in RCS	WP	kg	4.7E+04
Letdown flow rate for purification	FD	kg/s	1.4
Letdown flow rate for boron control	FB	kg/s	3.9E-03
Flow through cation demineralizer	FA	kg/s	0
Fraction of material removed by cation demineralizer	NA	---	0.9
Fraction of material removed by purification demineralizer	NB	---	0.98

Table 11.1-4: Primary Coolant Design Basis Source Term

Nuclide	Primary Coolant Concentrations (Ci/g)	Nuclide	Primary Coolant Concentrations (Ci/g)
Noble Gases		Other FPs (continued)	
Kr83m	7.7E-09	Mo101	4.3E-10
Kr85m	3.2E-08	Tc99m	1.1E-08
Kr85	5.9E-06	Tc99	2.1E-13
Kr87	1.8E-08	Ru103	1.1E-11
Kr88	5.1E-08	Ru105	3.6E-12
Kr89	1.2E-09	Ru106	6.8E-12
Xe131m	1.4E-07	Rh103m	1.1E-11
Xe133m	1.2E-07	Rh105	7.4E-12
Xe133	8.6E-06	Rh106	6.8E-12
Xe135m	1.1E-08	Ag110	8.1E-12
Xe135	2.3E-07	Sb124	1.6E-14
Xe137	3.9E-09	Sb125	1.2E-13
Xe138	1.3E-08	Sb127	6.1E-13
Halogens		Sb129	7.6E-13
Br82	2.1E-10	Te125m	1.8E-11
Br83	1.2E-09	Te127m	6.7E-11
Br84	5.7E-10	Te127	2.6E-10
Br85	6.9E-11	Te129m	1.9E-10
I129	3.5E-15	Te129	2.7E-10
I130	1.7E-09	Te131m	6.2E-10
I131	4.4E-08	Te131	3.1E-10
I132	2.1E-08	Te132	4.6E-09
I133	6.7E-08	Te133m	3.9E-10
I134	1.2E-08	Te134	5.6E-10
I135	4.3E-08	Ba137m	2.1E-08
Rubidium, Cesium		Ba139	1.0E-11
Rb86m	5.2E-14	Ba140	5.6E-11
Rb86	3.0E-10	La140	1.6E-11
Rb88	5.1E-08	La141	3.2E-12
Rb89	2.4E-09	La142	1.5E-12
Cs132	6.0E-12	Ce141	8.6E-12
Cs134	4.3E-08	Ce143	6.5E-12
Cs135m	3.6E-11	Ce144	7.3E-12
Cs136	9.4E-09	Pr143	7.6E-12
Cs137	2.2E-08	Pr144	7.2E-12
Cs138	1.9E-08	Np239	1.4E-10
Other FPs		Corrosion/Activation Products - CRUD	
P32	8.4E-16	Na24	1.4E-08
Co57	6.4E-18	Cr51	7.7E-10
Sr89	3.8E-11	Mn54	4.0E-10
Sr90	6.0E-12	Fe55	3.0E-10
Sr91	2.0E-11	Fe59	7.5E-11
Sr92	1.1E-11	Co58	1.1E-09
Y90	1.5E-12	Co60	1.3E-10
Y91m	1.1E-11	Ni63	6.6E-11
Y91	5.6E-12	Zn65	1.3E-10
Y92	9.1E-12	Zr95	9.7E-11
Y93	4.3E-12	Ag110m	3.2E-10

Table 11.1-4: Primary Coolant Design Basis Source Term (Continued)

Nuclide	Primary Coolant Concentrations (Ci/g)	Nuclide	Primary Coolant Concentrations (Ci/g)
Zr97	6.3E-12	W187	7.0E-10
Nb95	9.1E-12	Water Activation Products	
Mo99	1.1E-08	C14	2.6E-10
		Ar41	2.1E-07

Table 11.1-5: Secondary Coolant Design Basis Source Term

Nuclide	Secondary Coolant Concentrations (Ci/g)	Nuclide	Secondary Coolant Concentrations (Ci/g)
Noble Gases		Other FPs (continued)	
Kr83m	3.7E-14	Mo101	1.7E-15
Kr85m	1.6E-13	Tc99m	5.1E-14
Kr85	2.8E-11	Tc99	1.0E-18
Kr87	8.5E-14	Ru103	5.3E-17
Kr88	2.5E-13	Ru105	1.7E-17
Kr89	5.6E-15	Ru106	3.3E-17
Xe131m	6.6E-13	Rh103m	4.9E-17
Xe133m	5.6E-13	Rh105	3.6E-17
Xe133	4.2E-11	Rh106	4.4E-18
Xe135m	5.3E-14	Ag110	4.4E-18
Xe135	1.1E-12	Sb124	7.9E-20
Xe137	1.9E-14	Sb125	5.9E-19
Xe138	6.3E-14	Sb127	3.0E-18
Halogens		Sb129	3.6E-18
Br82	1.0E-15	Te125m	8.5E-17
Br83	5.8E-15	Te127m	3.2E-16
Br84	2.5E-15	Te127	1.3E-15
Br85	1.6E-16	Te129m	9.3E-16
I129	1.7E-20	Te129	1.3E-15
I130	8.4E-15	Te131m	3.0E-15
I131	2.2E-13	Te131	1.3E-15
I132	9.8E-14	Te132	2.2E-14
I133	3.3E-13	Te133m	1.8E-15
I134	5.5E-14	Te134	2.5E-15
I135	2.1E-13	Ba137m	4.5E-14
Rubidium, Cesium		Ba139	4.8E-17
Rb86m	6.1E-20	Ba140	2.7E-16
Rb86	1.6E-15	La140	7.9E-17
Rb88	2.3E-13	La141	1.5E-17
Rb89	1.0E-14	La142	7.2E-18
Cs132	3.2E-17	Ce141	4.2E-17
Cs134	2.3E-13	Ce143	3.2E-17
Cs135m	1.8E-16	Ce144	3.5E-17
Cs136	5.0E-14	Pr143	3.7E-17
Cs137	1.2E-13	Pr144	3.0E-17
Cs138	9.3E-14	Np239	6.6E-16
Other FPs		Corrosion/Activation Products - CRUD	
P32	4.1E-21	Na24	6.7E-14
Co57	3.1E-23	Cr51	3.8E-15
Sr89	1.9E-16	Mn54	1.9E-15
Sr90	2.9E-17	Fe55	1.4E-15
Sr91	9.6E-17	Fe59	3.6E-16
Sr92	5.1E-17	Co58	5.6E-15
Y90	7.0E-18	Co60	6.4E-16
Y91m	4.9E-17	Ni63	3.2E-16
Y91	2.7E-17	Zn65	6.1E-16
Y92	4.3E-17	Zr95	4.7E-16
Y93	2.1E-17	Ag110m	1.6E-15

Table 11.1-5: Secondary Coolant Design Basis Source Term (Continued)

Nuclide	Secondary Coolant Concentrations (Ci/g)	Nuclide	Secondary Coolant Concentrations (Ci/g)
Zr97	3.1E-17	W187	3.4E-15
Nb95	4.4E-17	Water Activation Products	
Mo99	5.5E-14	C14	1.3E-15
		Ar41	1.0E-12

Table 11.1-6: Primary Coolant Realistic Source Term

Nuclide	Primary Coolant Concentrations (Ci/g)	Nuclide	Primary Coolant Concentrations (Ci/g)
Noble Gases		Other FPs (continued)	
Kr83m	7.7E-10	Mo101	4.3E-11
Kr85m	3.2E-09	Tc99m	1.0E-09
Kr85	1.6E-07	Tc99	2.1E-14
Kr87	1.8E-09	Ru103	1.1E-12
Kr88	5.1E-09	Ru105	3.6E-13
Kr89	1.2E-10	Ru106	6.8E-13
Xe131m	1.3E-08	Rh103m	1.1E-12
Xe133m	1.1E-08	Rh105	7.3E-13
Xe133	8.3E-07	Rh106	6.8E-13
Xe135m	1.1E-09	Ag110	4.8E-12
Xe135	2.3E-08	Sb124	1.6E-15
Xe137	3.9E-10	Sb125	1.2E-14
Xe138	1.3E-09	Sb127	6.1E-14
Halogens		Sb129	7.6E-14
Br82	2.1E-11	Te125m	1.7E-12
Br83	1.2E-10	Te127m	6.6E-12
Br84	5.7E-11	Te127	2.6E-11
Br85	6.9E-12	Te129m	1.9E-11
I129	3.5E-16	Te129	2.7E-11
I130	1.7E-10	Te131m	6.2E-11
I131	4.4E-09	Te131	3.1E-11
I132	2.1E-09	Te132	4.6E-10
I133	6.7E-09	Te133m	3.9E-11
I134	1.2E-09	Te134	5.6E-11
I135	4.3E-09	Ba137m	2.1E-09
Rubidium, Cesium		Ba139	1.0E-12
Rb86m	5.2E-15	Ba140	5.6E-12
Rb86	3.0E-11	La140	1.6E-12
Rb88	5.1E-09	La141	3.2E-13
Rb89	2.4E-10	La142	1.5E-13
Cs132	6.0E-13	Ce141	8.6E-13
Cs134	4.3E-09	Ce143	6.5E-13
Cs135m	3.6E-12	Ce144	7.3E-13
Cs136	9.4E-10	Pr143	7.6E-13
Cs137	2.2E-09	Pr144	7.2E-13
Cs138	1.9E-09	Np239	1.4E-11
Other FPs		Corrosion/Activation Products - CRUD	
P32	8.4E-17	Na24	1.4E-08
Co57	6.4E-19	Cr51	7.7E-10
Sr89	3.8E-12	Mn54	4.0E-10
Sr90	5.9E-13	Fe55	3.0E-10
Sr91	2.0E-12	Fe59	7.5E-11
Sr92	1.1E-12	Co58	1.1E-09
Y90	1.4E-13	Co60	1.3E-10
Y91m	1.1E-12	Ni63	6.6E-11
Y91	5.6E-13	Zn65	1.3E-10
Y92	9.0E-13	Zr95	9.7E-11
Y93	4.3E-13	Ag110m	3.2E-10

Table 11.1-6: Primary Coolant Realistic Source Term (Continued)

Nuclide	Primary Coolant Concentrations (Ci/g)	Nuclide	Primary Coolant Concentrations (Ci/g)
Zr97	6.3E-13	W187	7.0E-10
Nb95	1.6E-12	Water Activation Products	
Mo99	1.1E-09	C14	2.6E-10
		Ar41	1.4E-07

Table 11.1-7: Secondary Coolant Realistic Source Term

Nuclide	Secondary Coolant Concentrations (Ci/g)	Nuclide	Secondary Coolant Concentrations (Ci/g)
Noble Gases		Other FPs (continued)	
Kr83m	2.7E-16	Mo101	1.3E-17
Kr85m	1.1E-15	Tc99m	3.7E-16
Kr85	5.7E-14	Tc99	7.6E-21
Kr87	6.2E-16	Ru103	3.9E-19
Kr88	1.8E-15	Ru105	1.3E-19
Kr89	4.2E-17	Ru106	2.4E-19
Xe131m	4.5E-15	Rh103m	3.6E-19
Xe133m	4.0E-15	Rh105	2.6E-19
Xe133	2.9E-13	Rh106	3.2E-20
Xe135m	3.9E-16	Ag110	1.9E-19
Xe135	8.1E-15	Sb124	5.8E-22
Xe137	1.4E-16	Sb125	4.3E-21
Xe138	4.7E-16	Sb127	2.2E-20
Halogens		Sb129	2.7E-20
Br82	7.6E-18	Te125m	6.2E-19
Br83	4.3E-17	Te127m	2.4E-18
Br84	1.8E-17	Te127	9.4E-18
Br85	1.2E-18	Te129m	6.8E-18
I129	1.3E-22	Te129	9.3E-18
I130	6.2E-17	Te131m	2.2E-17
I131	1.6E-15	Te131	9.8E-18
I132	7.2E-16	Te132	1.6E-16
I133	2.4E-15	Te133m	1.3E-17
I134	4.1E-16	Te134	1.8E-17
I135	1.5E-15	Ba137m	3.3E-16
Rubidium, Cesium		Ba139	3.6E-19
Rb86m	4.5E-22	Ba140	2.0E-18
Rb86	1.2E-17	La140	5.8E-19
Rb88	1.7E-15	La141	1.1E-19
Rb89	7.5E-17	La142	5.3E-20
Cs132	2.3E-19	Ce141	3.1E-19
Cs134	1.7E-15	Ce143	2.3E-19
Cs135m	1.3E-18	Ce144	2.6E-19
Cs136	3.7E-16	Pr143	2.7E-19
Cs137	8.7E-16	Pr144	2.2E-19
Cs138	6.8E-16	Np239	4.9E-18
Other FPs		Corrosion/Activation Products - CRUD	
P32	3.0E-23	Na24	4.9E-15
Co57	2.3E-25	Cr51	2.8E-16
Sr89	1.4E-18	Mn54	1.4E-16
Sr90	2.1E-19	Fe55	1.1E-16
Sr91	7.1E-19	Fe59	2.7E-17
Sr92	3.7E-19	Co58	4.1E-16
Y90	5.2E-20	Co60	4.7E-17
Y91m	3.6E-19	Ni63	2.3E-17
Y91	2.0E-19	Zn65	4.5E-17
Y92	3.2E-19	Zr95	3.5E-17
Y93	1.5E-19	Ag110m	1.2E-16

Table 11.1-7: Secondary Coolant Realistic Source Term (Continued)

Nuclide	Secondary Coolant Concentrations (Ci/g)	Nuclide	Secondary Coolant Concentrations (Ci/g)
Zr97	2.2E-19	W187	2.5E-16
Nb95	5.6E-19	Water Activation Products	
Mo99	4.0E-16	C14	9.4E-17
		Ar41	5.0E-14

Table 11.1-8: Tritium Concentration versus Primary Coolant Recycling Modes

Recycle Mode	Primary Coolant Average Concentration (Ci/g)	Reactor Coolant System Letdown / CVCS Outlet (Ci/g)	Realistic Secondary Coolant Concentration (Ci/g)	Design Basis Secondary Coolant Concentration (Ci/g)
No recycle (discharge)	1.3E-06	1.0E-06	2.4E-09	---
Recycle to reactor pool makeup	1.3E-06	1.0E-06	2.5E-09	---
Recycle back to CVCS makeup	2.6E-06	2.6E-06	---	4.7E-09

Note: The maximum calculated peak primary coolant tritium concentration is 3.3 μCi/g.

11.2 Liquid Waste Management System

The liquid waste management system is called the liquid radioactive waste system (LRWS). The LRWS is designed to collect, hold, and process liquid radioactive waste generated from normal operations and anticipated operational occurrences (AOOs). After processing and satisfactory sampling, liquids may be recycled or discharged. The LRWS is operated in a batch mode by an operator located in the waste management control room (WMCR).

The LRWS receives radioactive fluids from the chemical and volume control system (CVCS), the solid radioactive waste system (SRWS), the containment evacuation system (CES), the reactor component cooling water system (RCCWS), mixtures from the boron addition system, waste water from pool cooling and cleanup system (PCWS), contaminated liquids from the balance-of-plant drain system, and the radioactive waste drain system (RWDS). The LRWS components are located in the Reactor Building (RXB) and in the Radioactive Waste Building (RWB).

11.2.1 Design Bases

The LRWS has no safety-related function and is not risk significant. A failure of the LRWS does not adversely affect safety-related systems or components. Table 11.2-8 identifies SSC classifications for LRWS. The LRWS is not credited for mitigation of design basis accidents and has no safe shutdown functions. General Design Criteria (GDC) 2, 3, 60, and 61 are considered in the design of the LRWS. Section 11.2.2.6 contains further detail.

The LRWS is designed to comply with the as low as reasonably achievable (ALARA) philosophy of 10 CFR 20.1101(b) and the dose limits of 10 CFR 20.1301, 10 CFR 20.1302, and 10 CFR 50 Appendix I ALARA design objectives, including the effluent concentration limits of 10 CFR 20 Appendix B, Table 2 and 40 CFR 190 as implemented under 10 CFR 20.1301(e). A design objective of the LRWS is to provide the capability for sampling to ensure that liquid releases of radioactive material in liquid effluents are ALARA. Section 12.1 contains more detail about ways ALARA is implemented into the design.

11.2.2 System Description

The LRWS includes tanks, pumps, filters, and ion exchangers to receive, store, process, and monitor liquid radioactive waste to be recycled or released to the environment in accordance with regulations.

The LRWS collects, processes, and releases radioactive and potentially radioactive liquid wastes produced by the plant during the plant lifecycle. Separate collection tanks are provided for low-conductivity waste subsystem (LCW), high-conductivity waste subsystem (HCW), and detergent wastes. Oily waste is removed by an oil separator, collected in drums and sent to the SRWS for eventual shipment offsite. The remaining fluid in the separator is sent to the HCW Collection Tanks. Chemical wastes are collected as a part of the RWDS. Mixed wastes are collected locally in drums and sent offsite. The LRWS processing equipment flow path consists of two preconditioning filter vessels, a solids collection filter, three accumulator vessels, five ion exchange vessels, a reverse osmosis skid, and four polisher vessels.

The liquid wastes from the various sources are temporarily stored in collection tanks located in the RWB. System equipment and components are located in stainless-steel-lined, shielded cubicles as necessary to contain leaks and for radiation shielding. Other equipment areas, located outside of steel-lined cubicles, have concrete surfaces that are sealed with a qualified coating. The system operates on a batch basis, using skid-based processing equipment that includes filters, ion exchangers, and reverse osmosis components. Subsequent to processing, the liquid is routed to sample tanks to monitor the quality of the liquid before recycling or release. If the water quality is not acceptable, the water is returned to a collection tank for further treatment.

The LRWS is designed with sufficient capacity to process liquid wastes during periods of equipment maintenance or failures and during periods of abnormal waste generation. To meet these processing demands, interconnections between LRWS components, redundant equipment, skid-based equipment, liquid holdup storage, and treatment capacity are provided in the design.

The LRWS is designed to control leakage and facilitate access, operation, inspection, testing, and maintenance to maintain radiation exposures to operating and maintenance personnel as low as is reasonably achievable and to minimize contamination of the facility.

The LRWS design includes the following maintenance considerations:

- location of redundant permanent plant equipment in separate shielded cubicles
- clean-in-place provisions to reduce the radiation source term before maintenance
- redundant components allow uninterrupted waste operation and flexibility in maintenance scheduling

When the sample results of the LRWS meet discharge limits, the utility water system (UWS) discharges the treated effluent to the environment. The UWS dilutes the liquid effluent further before discharge.

11.2.2.1 Low Conductivity Waste Subsystem

The LCW consists of coolant-grade boron and hydrogen-containing wastes with high radioactivity concentrations. The CVCS letdown during normal operation and reactor heatup, along with the pressurizer vent letdown before and during reactor shutdown, are routed to the LRWS degasifiers for hydrogen and fission gas removal. The stripped gases are sent to the gaseous radioactive waste system (GRWS) for holdup and radioactive decay. The liquid waste is routed to the LCW collection tanks. The LCW collection tank fluid can be sent back to the degasifiers for additional gas removal if sample results determine it necessary. The LCW collection tanks have connections to be purged with nitrogen for inerting, as required.

The LCW collection tanks also receive RXB and RWB equipment drains from the RWDS, liquid from the SRWS spent resin storage tanks, liquid from the SRWS phase separator tanks, liquid from the SRWS dewatering process, and pool water from the PCWS and out-of-specification boric acid batches from the boron addition system.

The LCW collection tanks provide for sampling of the waste on a batch basis before sending to the LCW processing equipment. The LCW processing equipment is designed to handle filtering and removal of radioactive waste. The treated liquid waste is routed to the LCW sample tanks for sampling. The treated effluent is either recycled for use within the plant or discharged to the environment through the UWS. The UWS dilutes the liquid effluent further before discharge to the environment. If the LCW sample tank sample results do not meet specified requirements, the waste can be returned to the collection tanks for reprocessing. Reactor coolant letdown may be sent from the LCW collection tanks to the LCW sample tanks and then back to CVCS, bypassing the LCW processing equipment. Treated liquid waste may also be routed to the HCW sample tanks or the drum dryer skid.

11.2.2.2 High Conductivity Waste Subsystem

The HCW consists of liquid radioactive waste containing a varying degree of suspended solids and low radioactivity concentration. The HCW collection tanks collect waste from the following sources:

- The RXB floor drains through RWDS
- The RWB floor drains through RWDS
- The balance-of-plant drain system chemical waste collection tank
- The PCWS pool surge control tank overflow
- The RWDS Reactor Building reactor component cooling water system drain tank
- The RWDS Reactor Building chemical drain tank

The HCW collection tank contents can be sampled before sending to the HCW processing equipment. The HCW processing equipment contains two carbon filter vessels. The HCW may be routed through the HCW processing equipment to the LCW processing equipment for additional treatment. Treated effluent is routed to the HCW sample tanks for sampling. When the sample result meets discharge limits, the treated effluent is discharged to the environment via UWS, or it is recycled for use within the plant. If needed, the waste can be returned to the HCW or LCW collection tanks for reprocessing.

11.2.2.3 Chemical Waste Processing

Chemical waste is collected in the RWDS. If it is contaminated, operators send it to the HCW collection tanks. The RCCWS drains are collected separately in the RWDS to prevent the introduction of nitrite into resins that may be used in the LCW processing equipment to avoid the potential for exothermic reactions. The

RCCWS drains are collected and either returned to the RCCWS as makeup, routed to the HCW processing equipment, or discharged.

11.2.2.4 Detergent Waste Subsystem

Detergent wastes from personnel decontamination showers and small component decontamination sinks are collected in a dedicated collection tank and sampled. Wastes are then discharged through a cartridge filter if the sample results indicate that the specified requirements are satisfied. If the detergent sample result is not within the discharge limits, the contents go to the drum dryer skid. Detergent wastes are collected and processed separately to prevent degradation of the HCW and LCW processing equipment. There is a single train of detergent waste due to the low volume of waste generation expected, as there is no on-site laundry for the design.

11.2.2.5 Off-Normal Operations

The LRWS is designed to be tolerant of failures and abnormal conditions as summarized in Table 11.2-2.

11.2.2.6 Safety Evaluation

The LRWS complies with the following GDC:

- GDC 2 as it relates to structures and components of the LRWS, by using the guidance of RG 1.143 for the seismic, safety and quality classifications.
- GDC 3 as it relates to protecting the LRWS from the effects of fires or explosions by avoiding the generation of explosive gas mixtures and exothermic reactions with ion exchange resins.
- GDC 60 as it relates to the design of the LRWS to control releases of radioactive liquid effluents generated during normal reactor operations, including AOOs (Section 11.2.3).
- GDC 61 as it relates to radioactive waste systems being designed to provide for adequate safety under normal and postulated accident conditions, and designed with suitable shielding for radiation protection and with appropriate containment, confinement, and filtering systems.

The LRWS components are evaluated and classified as RW-IIa, RW-IIb or RW-IIc, as described in RG 1.143, by comparing the radioisotopic content of the component with the A_1 and A_2 quantities listed in Appendix A of 10 CFR 71. The safety classification for the LRWS components applies to components up to and including the nearest isolation device. The resulting safety classifications for LRWS components are listed in Table 11.2-1. The applicable standards from RG 1.143 Table 1 are used in the design, construction, and testing of the LRWS components. The applicable design criteria from RG 1.143 Table 2, Table 3, and Table 4 are used in the design analysis of the LRWS components.

Features are designed in accordance with the requirements of 10 CFR 20.1406, following the guidance of RG 4.21 to the extent practicable, to reduce contamination of the facility and the environment, facilitate eventual decommissioning, and reduce the generation of radioactive waste. Additional details are provided in Section 12.3.

The design of the principle components, piping, and valves that contain radioactive fluids comply with the seismic and quality requirements of RG 1.143. The design of the LRWS utilizes and conforms to the guidance provided in RG 1.143, including Branch Technical Position 11-6.

The RWB safety classification is described in Section 3.2 and presented in Table 3.2-1.

11.2.3 Radioactive Effluent Releases

11.2.3.1 Radioactive Releases

The system design reduces liquid effluent discharges from the LRWS to the environment by adequately processing liquid wastes and monitoring releases. The design employs the use of a single point of discharge for liquid effluents to the environment through the LRWS discharge header, which is sent to the UWS discharge basin.

The calculation of liquid effluent releases is consistent with RG 1.112, as modified by Technical Report TR-123242 (Reference 11.2-1). The calculation of off-site dose consequences from normal liquid effluents is consistent with RG 1.109.

The total resultant liquid release concentrations are provided in Table 11.2-9, and demonstrate compliance with 10 CFR 20 Appendix B, Table 2.

The maximum individual doses are calculated using the LADTAP II Code, using the input parameters listed in Table 11.2-6. The resultant doses are presented in Table 11.2-7 and demonstrate compliance with the limits of 10 CFR 50 Appendix I.

COL Item 11.2-1: An applicant that references the NuScale Power Plant US460 standard design will calculate doses to members of the public using the site-specific parameters, compare those liquid effluent doses to the numerical design objectives of 10 CFR 50, Appendix I, and comply with the requirements of 10 CFR 20.1302 and 40 CFR 190.

11.2.3.2 Compliance with Branch Technical Position 11-6

The only outdoor tank expected to contain radioactive liquids is the PCWS pool surge control storage tank, described in FSAR Section 9.1. The PCWS pool surge control storage tank secondary containment tank has sufficient volume to store the contents of the PCWS pool surge control storage tank plus the contents of related piping. The radionuclide concentration water of the PCWS pool surge control storage tank is provided in Table 12.2-9 with Table 12.2-8 providing the water mass.

COL Item 11.2-2: An applicant that references the NuScale Power Plant US460 standard design will perform a site-specific evaluation of the consequences of an accidental release of radioactive liquid from the pool surge control storage tank in accordance with NRC Branch Technical Position 11-6.

11.2.3.3 Dilution Factors

The utility water discharge flow rate is credited in the calculation of the discharge concentrations, as described in Reference 11.2-1. The design ensures that the discharge concentrations are within 10 CFR 20 Appendix B, Table 2, limits. The unrestricted area doses are calculated using a dilution factor as shown in Table 11.2-6, which results in the unrestricted area doses being within 10 CFR 50, Appendix I limits.

COL Item 11.2-3: An applicant that references the NuScale Power Plant US460 standard design will perform a site-specific evaluation using the site-specific source term and dilution flow for liquid effluent releases, and confirm that the discharge concentrations do not exceed the limits specified by 10 CFR 20, Appendix B, Table 2.

11.2.3.4 Site-Specific Cost-Benefit Analysis

COL Item 11.2-4: An applicant that references the NuScale Power Plant US460 standard design will perform a cost-benefit analysis as required by 10 CFR 50.34a and 10 CFR 50, Appendix I, to demonstrate conformance with regulatory requirements. This cost-benefit analysis is to be performed using the guidance of Regulatory Guide 1.110.

11.2.4 Testing and Inspection Requirements

Section 14.2 describes the LRWS preoperational tests and includes the applicable testing and inspection requirements from RG 1.143.

The design incorporates inspection and testing provisions to enable periodic evaluation of the operability and requires functional performance of active components of the system.

11.2.5 Instrumentation and Controls

The plant controls and indications for filling waste collection tanks are automatic and are controlled by the plant control system with indication in the WMCR. The atmospheric tanks in LRWS include high-level alarms and controls to prevent overflow. If a collection tank high-level alarm is received, system valves automatically realign to direct the incoming waste flows toward the collection tank that is in the standby mode.

The liquid radioactive waste effluent discharge line is a double-walled pipe that has dual radiation monitors, dual automated isolation valves, a flow-indicating transmitter with totalizer, and leak detection that monitors the pipe's annulus. The double-walled pipe's annulus is pressurized to be greater than the process or groundwater pressure and is alarmed to stop the discharge flow upon an indication of low pressure.

A liquid radioactive waste discharge automatically isolates upon an alarm due to a low dilution flow indication, a low pressure indication in the discharge pipe annulus, or a high-radiation alarm in a discharge line radiation monitor.

11.2.6 Reference

11.2-1 NuScale Power, LLC, "Effluent Release (GALE Replacement) Methodology and Results," TR-123242, Revision 1.

Table 11.2-1: Major Component Design Parameters

Component (Quantity)	RG 1.143 Safety Classification	Type	Capacity	Design Pressure (psig)	Design Temperature (°F)	Material	Table for Assumed Radioactive Content
Degasifier (2)	RW-IIa	Vertical	12,500 gallons	150	550	Stainless Steel	Table 12.2-15a
Degasifier Liquid Transfer Pumps (2)	RW-IIc	Sealless Centrifugal	28 gpm	150	210	Stainless Steel	-
LCW collection tank (2)	RW-IIc	Vertical, conical	16,000 gallons	15	240	Stainless Steel	Table 12.2-12a
LCW collection tank transfer pump (2)	RW-IIc	Sealless Centrifugal	39 gpm	290	155	Stainless Steel	-
HCW collection tank (2)	RW-IIc	Vertical Conical	16,000 gallons	15	200	Stainless Steel	Table 12.2-12a
HCW collection tank transfer pump (2)	RW-IIc	Sealless Centrifugal	39 gpm	230	155	Stainless Steel	-
LCW sample tank (2)	RW-IIc	Vertical conical	16,000 gallons	15	155	Stainless Steel	Table 12.2-12b
LCW sample tank transfer pump (2)	RW-IIc	Sealless Centrifugal	28 gpm	150	155	Stainless Steel	-
HCW sample tank (2)	RW-IIc	Vertical conical	16,000 gallons	15	155	Stainless Steel	Table 12.2-12b
HCW sample tank transfer pump (2)	RW-IIc	Sealless Centrifugal	28 gpm	150	155	Stainless Steel	-
Oil separator (1)	RW-IIc	-	240 gpm	150	155	Stainless Steel	Table 12.2-12a
Detergent waste collection tank (1)	RW-IIc	Vertical conical	500 gallons	15	200	Stainless Steel	-
Detergent waste drain filter (1)	RW-IIc	Cartridge	20 micron	150	155	Stainless Steel	-
Demineralized water break tank (1)	RW-IIc	Vertical	10,000 gallons	15	155	Stainless Steel	-
HCW Processing charcoal filter (2)	RW-IIb	Vertical Vessel	35 gpm	230	155	Stainless Steel	LCW-Table 12.2-12a HCW- Table 12.2-12b
LCW Reverse Osmosis Skid (1)	RW-IIc	Vertical	35 gpm	290	155	Stainless Steel	LCW-Table 12.2-12a HCW- Table 12.2-12b
Clean-In-Place Skid (1)	RW-IIc	-	55 gallons	150	155	Stainless Steel	-
Drum Dryer Skids (1)	RW-IIc	-	55 gpd	15	155	Stainless Steel	-
LCW Pre-conditioning filter vessels (2)	RW-IIa	-	35 gpm	290	155	Stainless Steel	
LCW accumulator vessels (3)	RW-IIa	-	35 gpm	290	155	Stainless Steel	
LCW Ion Exchange vessel (5)	RW-IIa	-	35 gpm	290	155	Stainless Steel	Table 12.2-12a
LCW solids collection filter (1)	RW-IIc	-	35 gpm	290	155	Stainless Steel	
LCW Polishing Ion Exchange Vessel (4)	RW-IIc	-	35 gpm	290	155	Stainless Steel	Table 12.2-12a
Demineralized water break tank transfer pump (1)	RW-IIc	Sealless centrifugal	220 gpm	150	155	Stainless Steel	-

Table 11.2-2: Off-Normal Operation and Anticipated Operational Occurrence Consequences

Off Normal Operation/AOO		Consequences	
Event	**Indication**	**System Response**	**Corrective Action**
High level or loss of vacuum in Degasifier when in use	Automatic	Switch to standby degasifier	Corrective maintenance of idle equipment
Degasifier transfer pump trips	Automatic	Switch to standby degasifier	Corrective maintenance of idle equipment
Collection Tank Transfer Pump failure	Automatic	Switch to standby Collection Tank Transfer Pump	Corrective maintenance of idle equipment
High-high level in Collection or Sample Tanks	Operator surveillance	Discharge valves automatically close and runnning pump stops	Investigate cause and procedures to prevent challenges to control system
One train of processing equipment inoperable	Operator surveillance	Based on sample results, use one train to alternately process LCW and HCW	Repair or replace components and restore operability
Sample Tank shows sample of high radioactivity	Review of sample results	Pump to Collection Tank for reprocessing	Diagnose cause and repair or replace as necessary
High radiation on single point LRW discharge	Automatic	Discharge valves automatically close and runnning pump stops	Diagnose cause, reprocess remaining sample tank contents
Low guard pipe pressure on buried LRW discharge pipe	Automatic	Discharge valves automatically close and running	Diagnose cause, repair buried LRW discharge pipe
Area radiation alarm	Local and MCR alarm	pump stops	Investigate cause and initiate cleanup and corrective maintenance
Leaks or spills	Operator surveillance (or leak detection alarm or area radiation alarm)	Suspend processing, prevent the spread of contamination	Investigate cause and initiate cleanup and corrective maintenance
Loss of Nitrogen pressure to Degasifiers	Indication from vendor control system	Vendor control system isolates degasifier skid	Investigate, restore Nitrogen pressure and resume operation

Table 11.2-3: Expected Liquid Waste Inputs

LRWS Input Source	Expected Input Rate (6 NPMs) (gpy)	Expected Activity
LCW collection tank		
RXB/RWB equipment drains	2.9E+04	0.001 primary coolant activity (PCA)
Other equipment drains	1.1E+04	0.093 PCA
Normal letdown (six operating units)	1.9E+05	CVCS outlet
Degasification prior to shutdown (six events per year)	3.0E+03	primary coolant through evaporator
Additional CVCS letdown streams	3.8E+04	CVCS outlet
LCW Total	**2.7E+05**	
HCW collection tank		
RXB/RWB floor drains (via oil separator)	7.3E+04	0.1 PCA
RXB RCCW drain tank (via oil separator)	3.6E+01	0.001 PCA
Hot machine shop, decontamination room sump (via oil separator)	9.0E+04	0.01 PCA
RXB chemical drain tank (Hot lab sink) (via oil separator)	4.4E+03	0.05 PCA
RXB chemical drain tank (CES sample tank) (via oil separator)	2.2E+04	primary coolant through evaporator
Pump seal leaks (via oil separator)	8.1E+03	0.1 PCA
Valve packing leaks (via oil separator)	4.8E+03	0.1 PCA
Groundwater / Condensation (via oil separator)	2.5E+05	0.001 PCA
Equipment area decontamination (outside hot machine shop) (via oil separator)	1.5E+04	0.01 PCA
Secondary coolant sampling drains	4.2E+03	Secondary coolant
Condensate polisher rinse and transfer	3.6E+04	Secondary coolant
Condensate polisher regeneration solutions	1.0E+04	Secondary coolant
Turbine Generator Building floor drains	2.2E+04	Secondary coolant
Pool water source streams	2.9E+05	Pool water source term
CVCS outlet sources	3.5E+04	CVCS outlet
HCW Total	**8.6E+05**	

Note: Assumes six NPMs operating on an 18-month refueling cycle.

Table 11.2-4: Liquid Effluent Release Calculation Inputs

NuScale Effluent Source Term Model Assumption	Value	Units
Primary coolant source term	Table 11.1-6	
CVCS demineralizer decontamination factors-		
- Halogens	100	--
- Cs, Rb	2	--
- Others	50	--
Pool water source	Table 12.2-9	
CES liquid partition fractions-and PCA through Evaporator		
- Noble gases	1	--
- Halogens	100	--
- Others	1000	--
Secondary coolant source term	Table 11.1-7	
AOO adjustment	0.07	Ci/year
UWS dilution factor for 10 CFR 20 Appendix B	700	gpm

Table 11.2-5: Estimated Annual Releases to Liquid Radioactive Waste System Discharge Header

Nuclide	LRWS LCW Sample Tank Release (Ci/yr)	LRWS HCW Sample Tank Release (Ci/yr)	Plant Liquid Release without AOO Adjustment (Ci/yr)	Total Liquid Release with AOO Adjustment (Ci/yr)
Br82	1.4E-12	2.3E-09	2.3E-09	4.9E-08
Br83	-	2.5E-30	2.5E-30	5.3E-29
I129	4.9E-13	1.4E-12	1.9E-12	4.2E-11
I130	1.2E-19	2.1E-11	2.1E-11	4.6E-10
I131	1.0E-06	1.6E-05	1.7E-05	3.7E-04
I132	1.6E-08	3.6E-07	3.8E-07	8.2E-06
I133	4.5E-13	5.8E-08	5.8E-08	1.3E-06
I135	4.1E-29	5.3E-14	5.3E-14	1.1E-12
Rb86	3.6E-06	1.4E-06	5.0E-06	1.1E-04
Cs132	1.6E-08	1.6E-08	3.3E-08	7.1E-07
Cs134	1.1E-03	2.7E-04	1.4E-03	3.0E-02
Cs136	8.1E-05	3.9E-05	1.2E-04	2.6E-03
Cs137	5.8E-04	1.4E-04	7.2E-04	1.6E-02
P32	9.8E-14	2.4E-13	3.4E-13	7.3E-12
Co57	2.0E-15	2.6E-15	4.5E-15	9.9E-14
Sr89	1.9E-08	1.7E-08	3.6E-08	7.8E-07
Sr90	1.9E-09	2.5E-09	4.4E-09	9.5E-08
Sr91	1.0E-24	1.3E-14	1.3E-14	2.8E-13
Sr92	-	4.1E-30	4.1E-30	9.0E-29
Y90	1.9E-09	2.2E-09	4.1E-09	9.0E-08
Y91m	6.5E-25	8.1E-15	8.1E-15	1.8E-13
Y91	1.4E-09	2.1E-09	3.5E-09	7.7E-08
Y92	-	2.7E-24	2.7E-24	5.8E-23
Y93	1.6E-24	5.6E-15	5.6E-15	1.2E-13
Zr97	1.7E-18	1.2E-12	1.2E-12	2.6E-11
Nb95	9.7E-08	6.7E-07	7.7E-07	1.7E-05
Mo99	1.8E-08	6.6E-07	6.8E-07	1.5E-05
Tc99m	1.7E-08	6.4E-07	6.6E-07	1.4E-05
Tc99	6.9E-11	8.9E-11	1.6E-10	3.4E-09
Ru103	2.4E-09	3.9E-09	6.3E-09	1.4E-07
Ru105	-	3.7E-22	3.7E-22	8.1E-21
Ru106	2.1E-09	2.8E-09	4.9E-09	1.1E-07
Rh103m	2.4E-09	3.9E-09	6.3E-09	1.4E-07
Rh105	1.3E-13	8.5E-11	8.5E-11	1.8E-09
Rh106	2.1E-09	2.8E-09	4.9E-09	1.1E-07
Ag110	1.3E-08	1.8E-07	1.9E-07	4.2E-06
Sb124	4.1E-12	6.1E-12	1.0E-11	2.2E-10
Sb125	3.9E-11	5.0E-11	8.8E-11	1.9E-09
Sb127	4.4E-12	6.2E-11	6.7E-11	1.5E-09
Sb129	-	6.0E-23	6.0E-23	1.3E-21
Te125m	4.4E-09	6.6E-09	1.1E-08	2.4E-07
Te127m	1.9E-08	2.6E-08	4.5E-08	9.8E-07
Te127	1.8E-08	2.6E-08	4.4E-08	9.6E-07
Te129m	4.0E-08	6.7E-08	1.1E-07	2.3E-06

Table 11.2-5: Estimated Annual Releases to Liquid Radioactive Waste System Discharge Header (Continued)

Nuclide	LRWS LCW Sample Tank Release (Ci/yr)	LRWS HCW Sample Tank Release (Ci/yr)	Plant Liquid Release without AOO Adjustment (Ci/yr)	Total Liquid Release with AOO Adjustment (Ci/yr)
Te129	2.5E-08	4.2E-08	6.8E-08	1.5E-06
Te131m	1.7E-12	3.5E-09	3.5E-09	7.6E-08
Te131	3.9E-13	7.9E-10	7.9E-10	1.7E-08
Te132	1.5E-08	3.5E-07	3.7E-07	8.0E-06
Ba137m	5.5E-04	1.3E-04	6.8E-04	1.5E-02
Ba140	5.8E-09	1.5E-08	2.1E-08	4.5E-07
La140	6.6E-09	1.7E-08	2.3E-08	5.1E-07
La141	-	7.1E-24	7.1E-24	1.5E-22
Ce141	1.8E-09	3.0E-09	4.8E-09	1.0E-07
Ce143	5.2E-14	5.4E-11	5.4E-11	1.2E-09
Ce144	2.2E-09	2.9E-09	5.2E-09	1.1E-07
Pr143	9.2E-10	2.3E-09	3.2E-09	7.0E-08
Pr144	2.2E-09	2.9E-09	5.1E-09	1.1E-07
Np239	9.0E-11	5.8E-09	5.8E-09	1.3E-07
Na24	3.0E-15	1.0E-08	1.0E-08	2.2E-07
Cr51	1.5E-06	2.5E-05	2.7E-05	5.8E-04
Mn54	1.2E-06	1.6E-05	1.7E-05	3.8E-04
Fe55	9.5E-07	1.2E-05	1.3E-05	2.9E-04
Fe59	1.7E-07	2.7E-06	2.9E-06	6.2E-05
Co58	3.0E-06	3.9E-04	4.0E-04	8.7E-03
Co60	4.2E-07	5.5E-06	5.9E-06	1.3E-04
Ni63	2.1E-07	2.7E-06	3.0E-06	6.4E-05
Zn65	3.9E-07	5.1E-06	5.5E-06	1.2E-04
Zr95	2.5E-07	3.6E-06	3.9E-06	8.5E-05
Ag110m	9.9E-07	1.3E-05	1.4E-05	3.1E-04
W187	8.7E-13	3.6E-08	3.6E-08	7.8E-07
H3	8.6E+02	3.0E+02	1.2E+03	1.2E+03
Total	**8.6E+02**	**3.0E+02**	**1.2E+03**	**1.2E+03**

Table 11.2-6: LADTAP II Inputs

Parameter	Value	Units
Source term	Table 11.2-5	--
Shore-width factor	1.0	--
Discharge flow rate	605	gpm
Impoundment reconcentration model	None	--
Irrigation rate	100	liters/m^2-month
Dilution factor for aquatic food, boating, shoreline, swimming and drinking water	1	--
Dilution factor for irrigation water usage location	1	--
Site type	Freshwater	--
Exposure Pathway-		--
• Transit time - aquatic food	0	--
• Transit time - boating	0	--
• Transit time - swimming	0	--
• Transit time - shoreline	0	--
• Transit time - drinking water	0	--
• Transit time - irrigated crops	0	--
• Transit time - milk/meat animal water usage	0	--
Fraction of crops irrigated using non-contaminated water	0	--
Fraction of milk/meat animal feed irrigated using non-contaminated water	0	--
Fraction of milk/meat animal drinking water from non-contaminated water	0	--
Minimum dilution flow rate	141	cfs

Table 11.2-7: Liquid Effluent Dose Results for 10 CFR 50 Appendix I

Type of Dose	Calculated Dose (mrem/yr)	10 CFR 50, Appendix I ALARA Design Objective (mrem/yr)
Total Body	2.9	3
Individual Organ	4.5	10

Table 11.2-8: Classification of Structures, Systems, and Components

SSC (Note 1)	Location	SSC Classification (A1, A2, B1, B2)	Augmented Design Requirements (Note 2)	Quality Group/Safety Classification (Ref RG 1.26 or RG 1.143) (Note 3)	Seismic Classification (Ref. RG 1.29 or RG 1.143) (Note 4)
LRWS, Liquid Radioactive Waste System					
All components (except those listed below):	RWB/RXB	B2	RG 1.143	RW-IIc	III
• Degasifier (including condensers & vacuum pumps) • LCW accumulator, ion exchanger & pre-condition filter vessels	RWB/RXB	B2	RG 1.143	RW-IIa	RW-IIa
HCW processing equipment	RWB	B2	RG 1.143	RW-IIb	III

Note 1: Acronyms used in this table are listed in Table 1.1-1

Note 2: Additional augmented design requirements, such as the application of a Quality Group, Radwaste safety, or seismic classification, to nonsafety-related SSC are reflected in the columns Quality Group / Safety Classification and Seismic Classification, where applicable. Environmental Qualifications of SSC are identified in Table 3.11-1.

Note 3: Section 3.2.2.1 through Section 3.2.2.4 provides the applicable codes and standards for each RG 1.26 Quality Group designation (A, B, C, and D). A Quality Group classification per RG 1.26 is not applicable to supports or instrumentation. Section 3.2.1.4 provides a description of RG 1.143 classification for RW-IIa, RW-IIb, and RW-IIc.

Note 4: Where SSC (or portions thereof) as determined in the as-built plant that are identified as Seismic Category III in this table could, as the result of a seismic event, adversely affect Seismic Category I SSC or result in incapacitating injury to occupants of the control room, they are categorized as Seismic Category II consistent with Section 3.2.1.2 and analyzed as described in Section 3.7.3.8.

Table 11.2-9: Liquid Release Concentrations Compared to 10 CFR 20 Appendix B Limits

Nuclide	Discharge Concentration (μCi/ml)	Concentration Limit (μCi/ml)	Fraction of Limit
Br82	3.5E-14	4.0E-05	8.8E-10
I129	3.0E-17	2.0E-07	1.5E-10
I130	3.3E-16	2.0E-05	1.6E-11
I131	2.7E-10	1.0E-06	2.7E-04
I132	5.9E-12	1.0E-04	5.9E-08
I133	9.1E-13	7.0E-06	1.3E-07
I135	8.2E-19	3.0E-05	2.7E-14
Rb86	7.8E-11	7.0E-06	1.1E-05
Cs132	5.1E-13	4.0E-05	1.3E-08
Cs134	2.1E-08	9.0E-07	2.4E-02
Cs136	1.9E-09	6.0E-06	3.1E-04
Cs137	1.1E-08	1.0E-06	1.1E-02
Co57	7.1E-20	6.0E-05	1.2E-15
Sr89	5.6E-13	8.0E-06	7.0E-08
Sr90	6.8E-14	5.0E-07	1.4E-07
Sr91	2.0E-19	2.0E-05	9.9E-15
Y90	6.4E-14	7.0E-06	9.2E-09
Y91m	1.3E-19	2.0E-03	6.3E-17
Y91	5.5E-14	8.0E-06	6.9E-09
Y92	4.2E-29	4.0E-05	1.0E-24
Y93	8.7E-20	2.0E-05	4.4E-15
Zr97	1.8E-17	9.0E-06	2.1E-12
Nb95	1.2E-11	3.0E-05	4.0E-07
Mo99	1.1E-11	2.0E-05	5.3E-07
Tc99m	1.0E-11	1.0E-03	1.0E-08
Tc99	2.5E-15	6.0E-05	4.1E-11
Ru103	9.9E-14	3.0E-05	3.3E-09
Ru105	5.8E-27	7.0E-05	8.3E-23
Ru106	7.6E-14	3.0E-06	2.5E-08
Rh103m	9.8E-14	6.0E-03	1.6E-11
Rh105	1.3E-15	5.0E-05	2.6E-11
Sb124	1.6E-16	7.0E-06	2.3E-11
Sb125	1.4E-15	3.0E-05	4.6E-11
Sb127	1.0E-15	1.0E-05	1.0E-10
Sb129	9.4E-28	4.0E-05	2.3E-23
Te125m	1.7E-13	2.0E-05	8.6E-09
Te127m	7.0E-13	9.0E-06	7.8E-08
Te127	6.9E-13	1.0E-04	6.9E-09
Te129m	1.7E-12	7.0E-06	2.4E-07
Te129	1.1E-12	4.0E-04	2.6E-09
Te131m	5.5E-14	8.0E-06	6.8E-09
Te131	1.2E-14	8.0E-05	1.5E-10
Te132	5.7E-12	9.0E-06	6.4E-07
Ba140	3.3E-13	8.0E-06	4.1E-08
La140	3.6E-13	9.0E-06	4.0E-08

Table 11.2-9: Liquid Release Concentrations Compared to 10 CFR 20 Appendix B Limits (Continued)

Nuclide	Discharge Concentration (μCi/ml)	Concentration Limit (μCi/ml)	Fraction of Limit
La141	1.1E-28	5.0E-05	2.2E-24
Ce141	7.5E-14	3.0E-05	2.5E-09
Ce143	8.5E-16	2.0E-05	4.2E-11
Ce144	8.1E-14	3.0E-06	2.7E-08
Pr143	5.0E-14	2.0E-05	2.5E-09
Pr144	8.0E-14	6.0E-04	1.3E-10
Np239	9.1E-14	2.0E-05	4.6E-09
Na24	1.6E-13	5.0E-05	3.2E-09
Cr51	4.2E-10	5.0E-04	8.4E-07
Mn54	2.7E-10	3.0E-05	9.1E-06
Fe55	2.1E-10	1.0E-04	2.1E-06
Fe59	4.5E-11	1.0E-05	4.5E-06
Co58	6.2E-09	2.0E-05	3.1E-04
Co60	9.2E-11	3.0E-06	3.1E-05
Ni63	4.6E-11	1.0E-04	4.6E-07
Zn65	8.6E-11	5.0E-06	1.7E-05
Zr95	6.1E-11	2.0E-05	3.0E-06
Ag110m	2.2E-10	6.0E-06	3.7E-05
W187	5.6E-13	3.0E-05	1.9E-08
H3	8.3E-04	1.0E-03	8.3E-01
Total	**8.3E-04**	**1.3E-02**	**8.6E-01**

Figure 11.2-1a: Liquid Radioactive Waste System Diagram

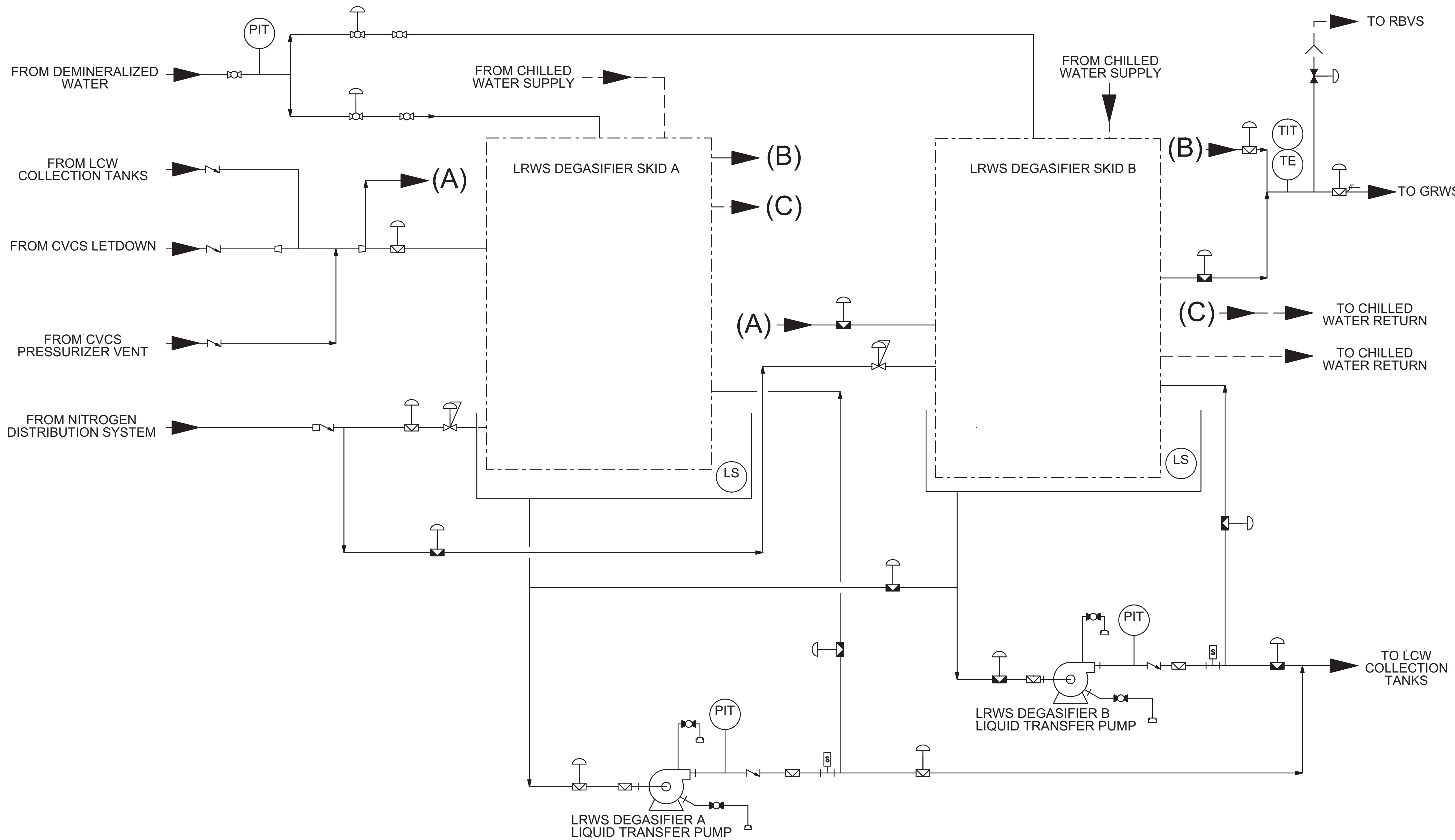


Figure 11.2-1b: Liquid Radioactive Waste System Diagram

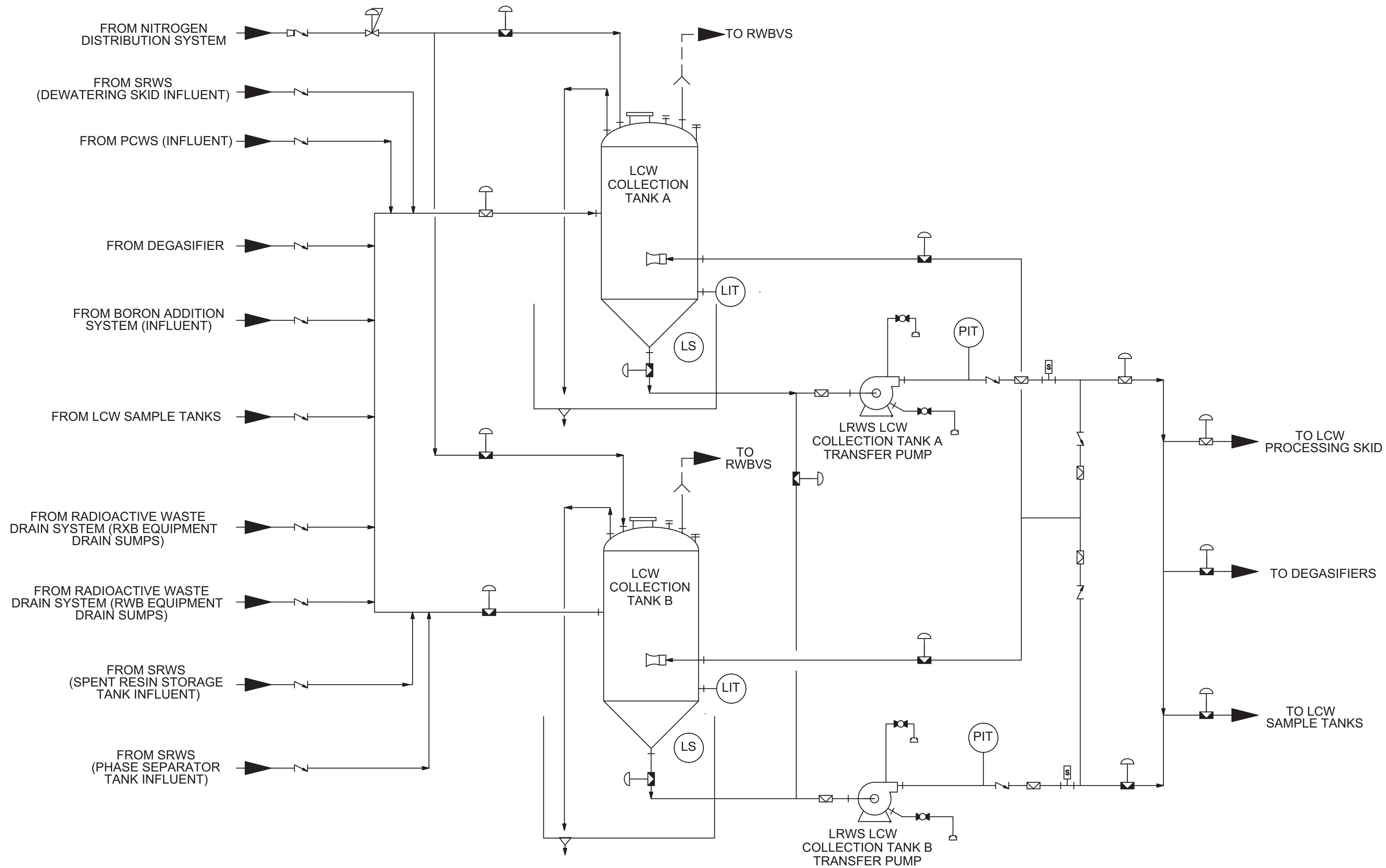


Figure 11.2-1c: Liquid Radioactive Waste System Diagram

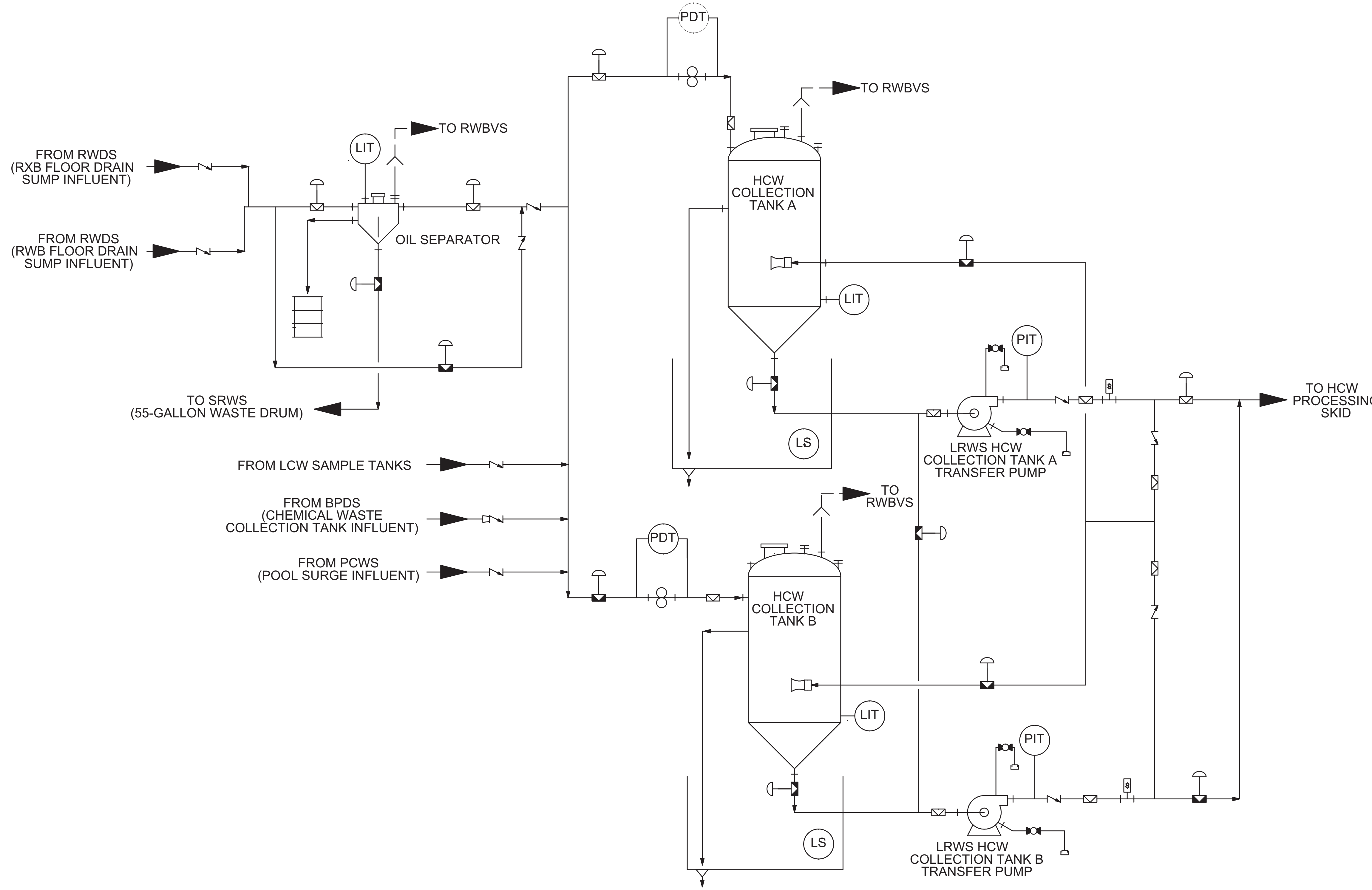


Figure 11.2-1d: Liquid Radioactive Waste System Diagram

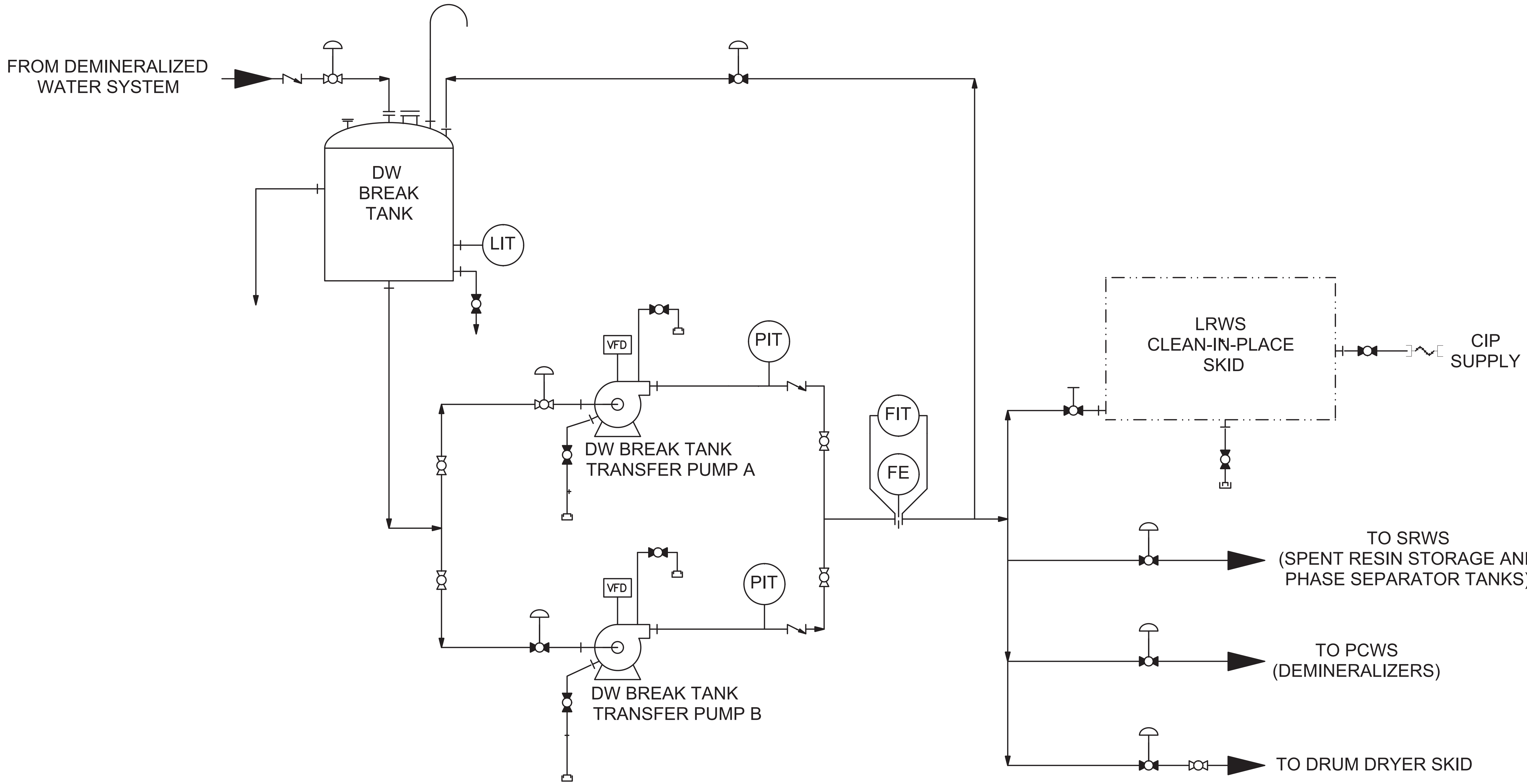


Figure 11.2-1e: Liquid Radioactive Waste System Diagram

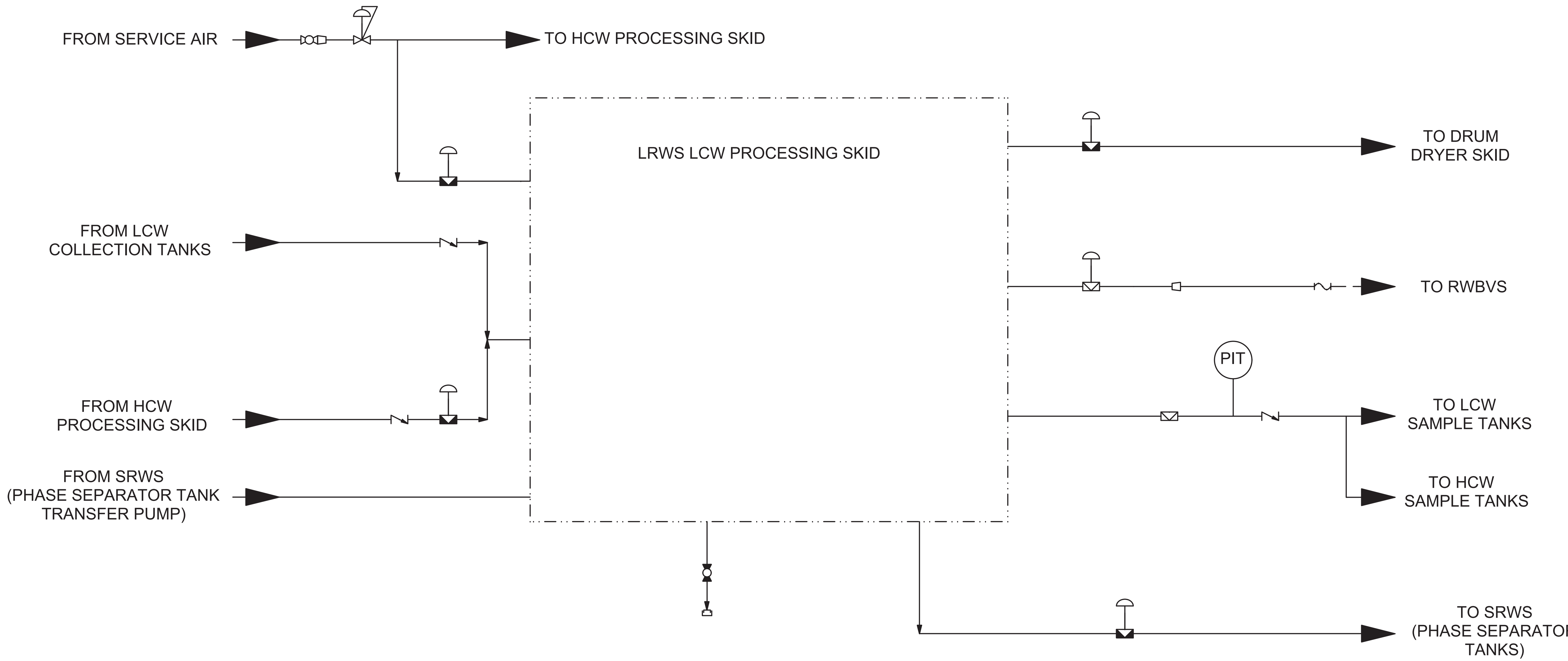


Figure 11.2-1f: Liquid Radioactive Waste System Diagram

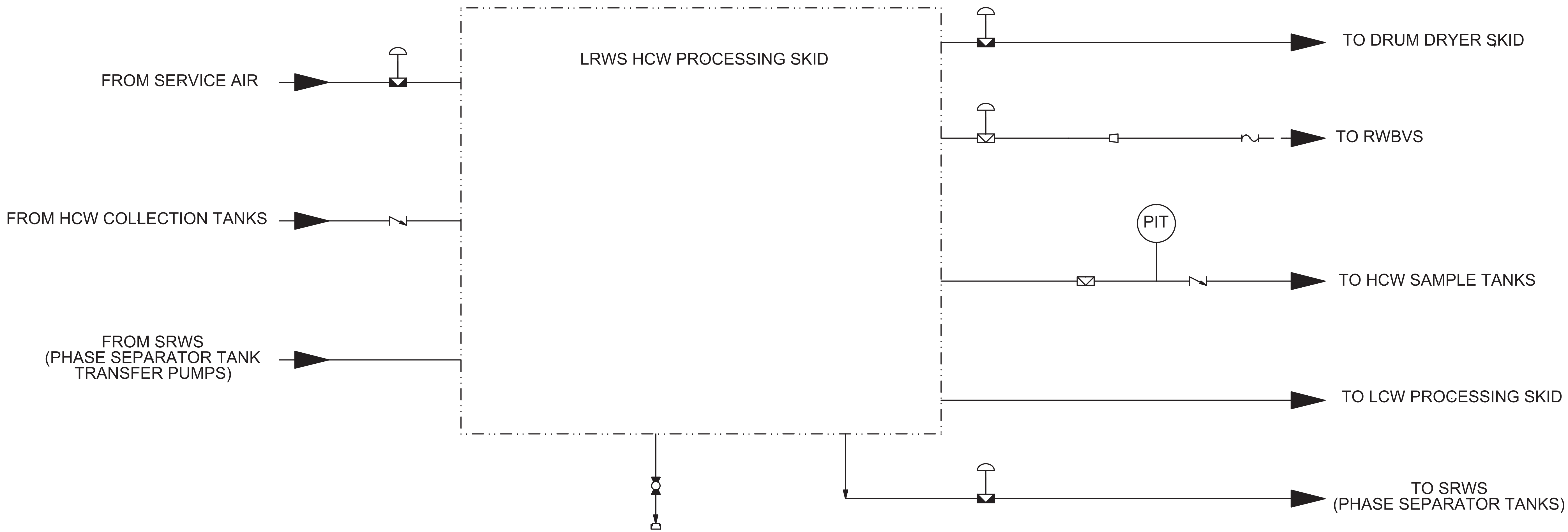


Figure 11.2-1g: Liquid Radioactive Waste System Diagram

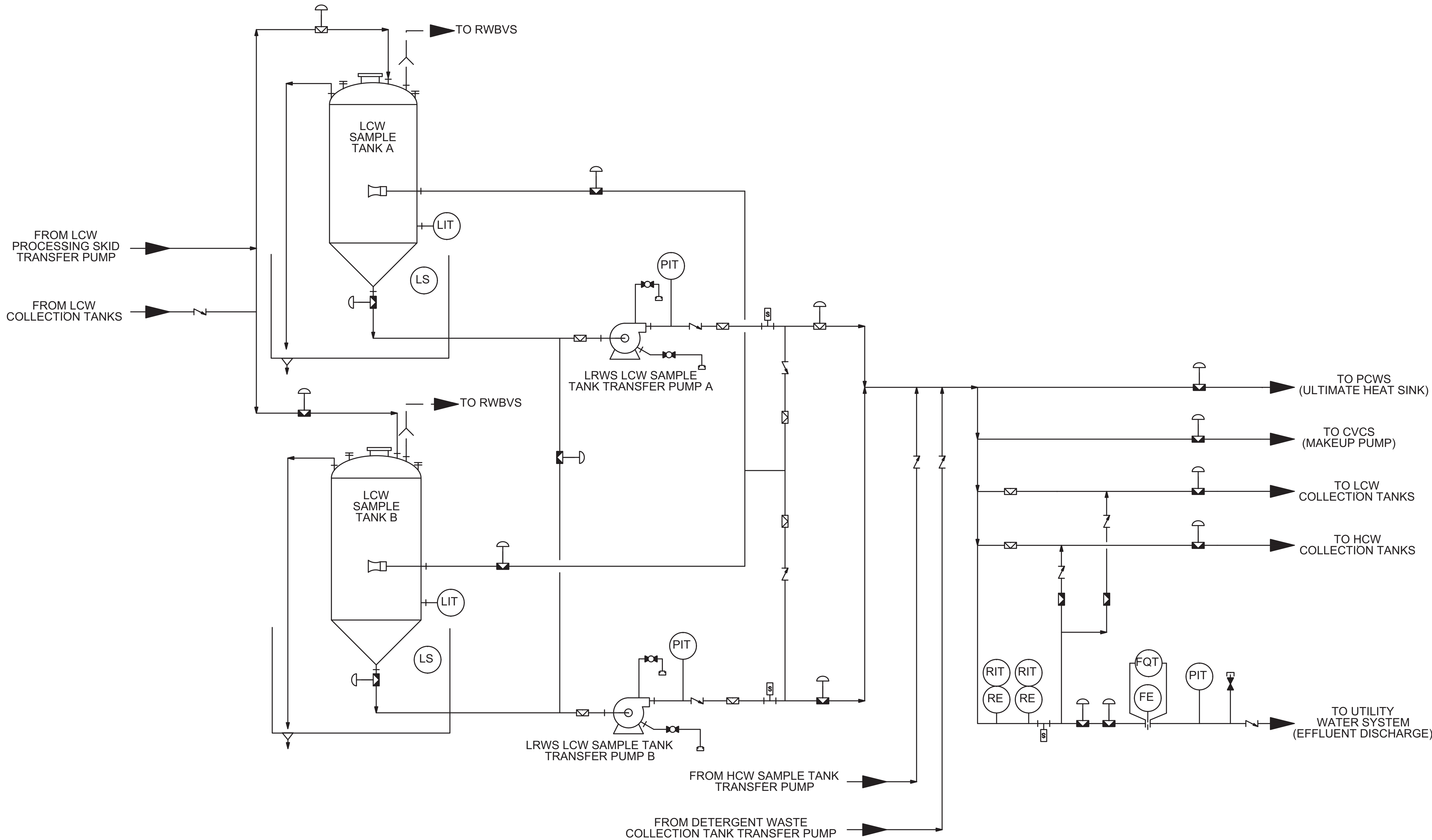


Figure 11.2-1h: Liquid Radioactive Waste System Diagram

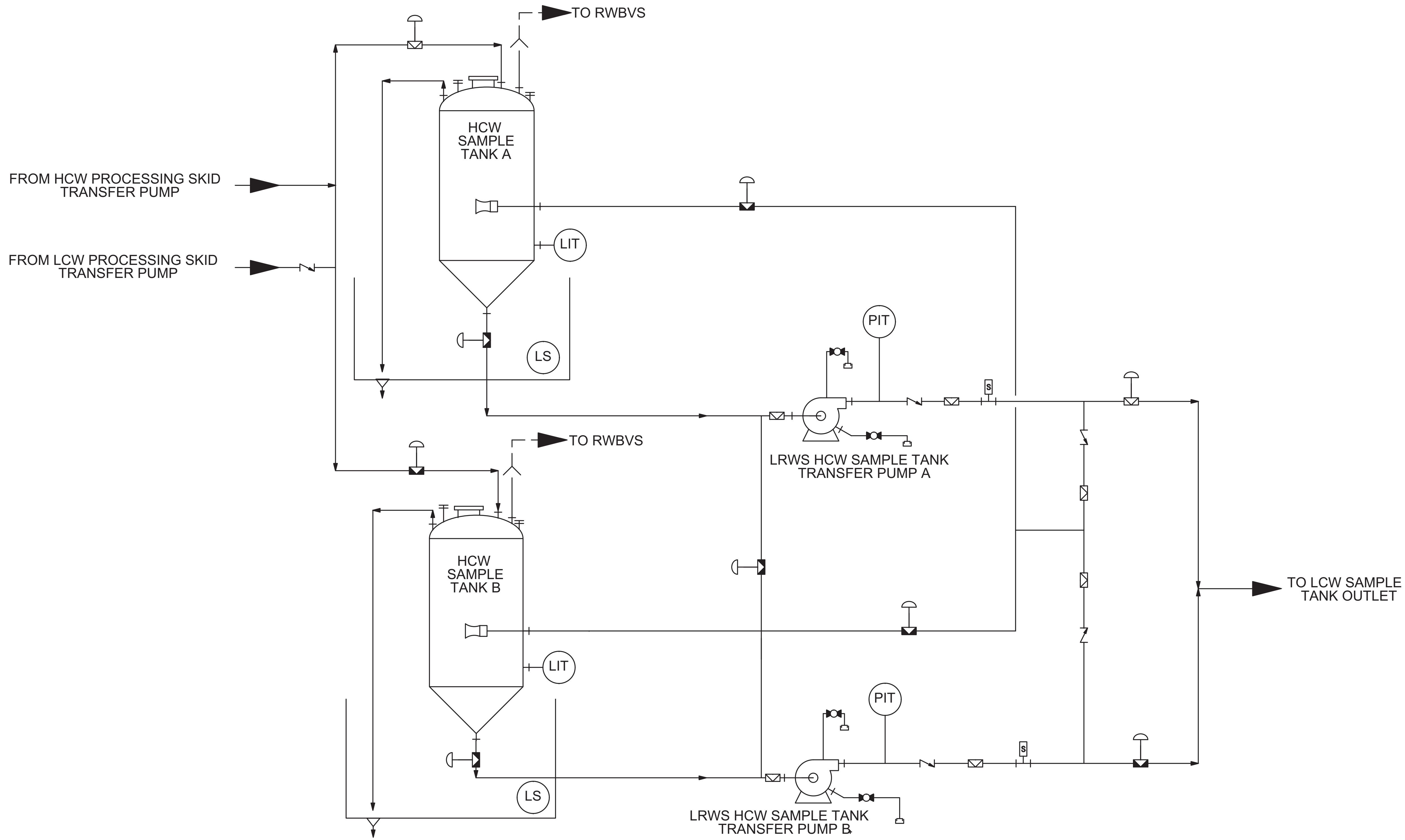


Figure 11.2-1i: Liquid Radioactive Waste System Diagram

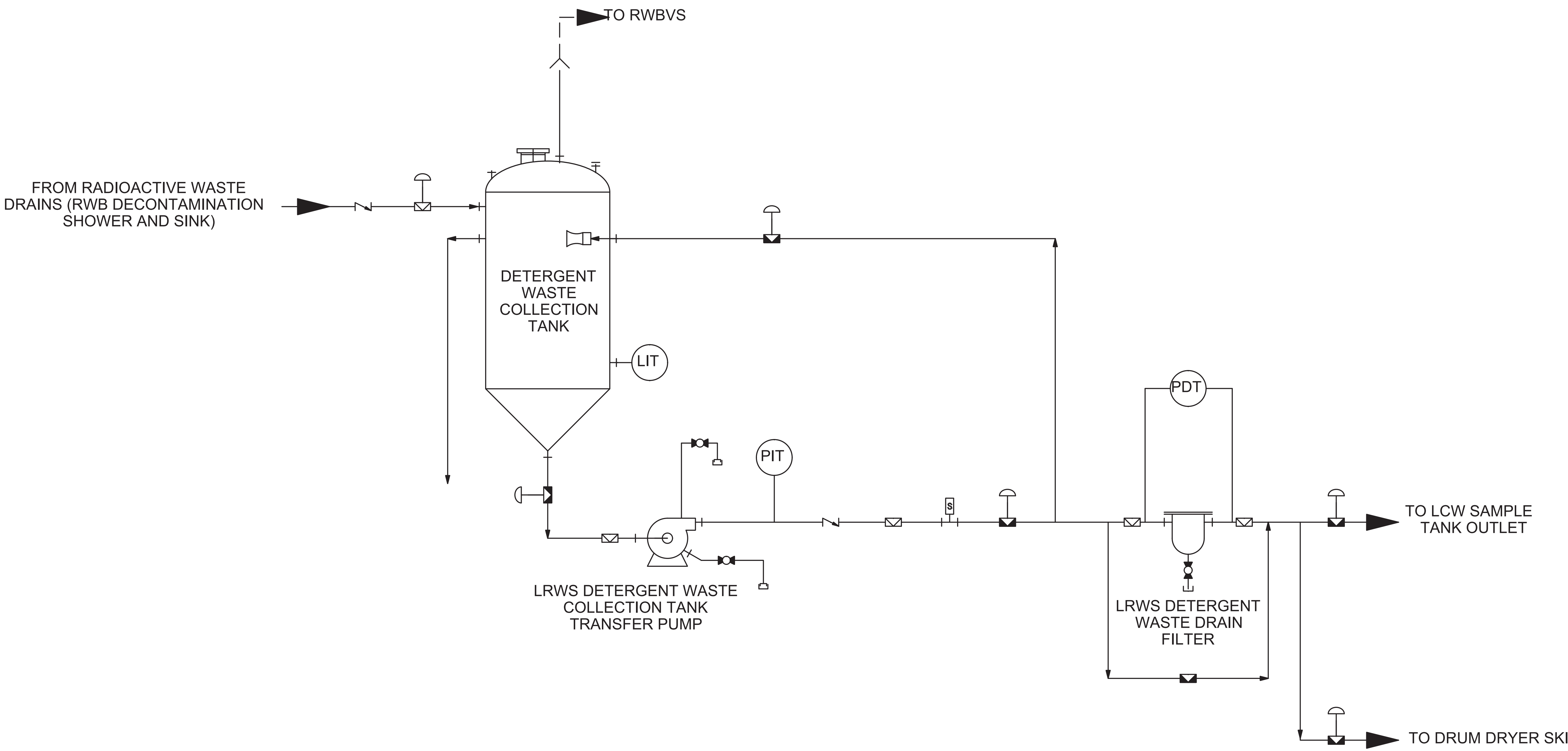
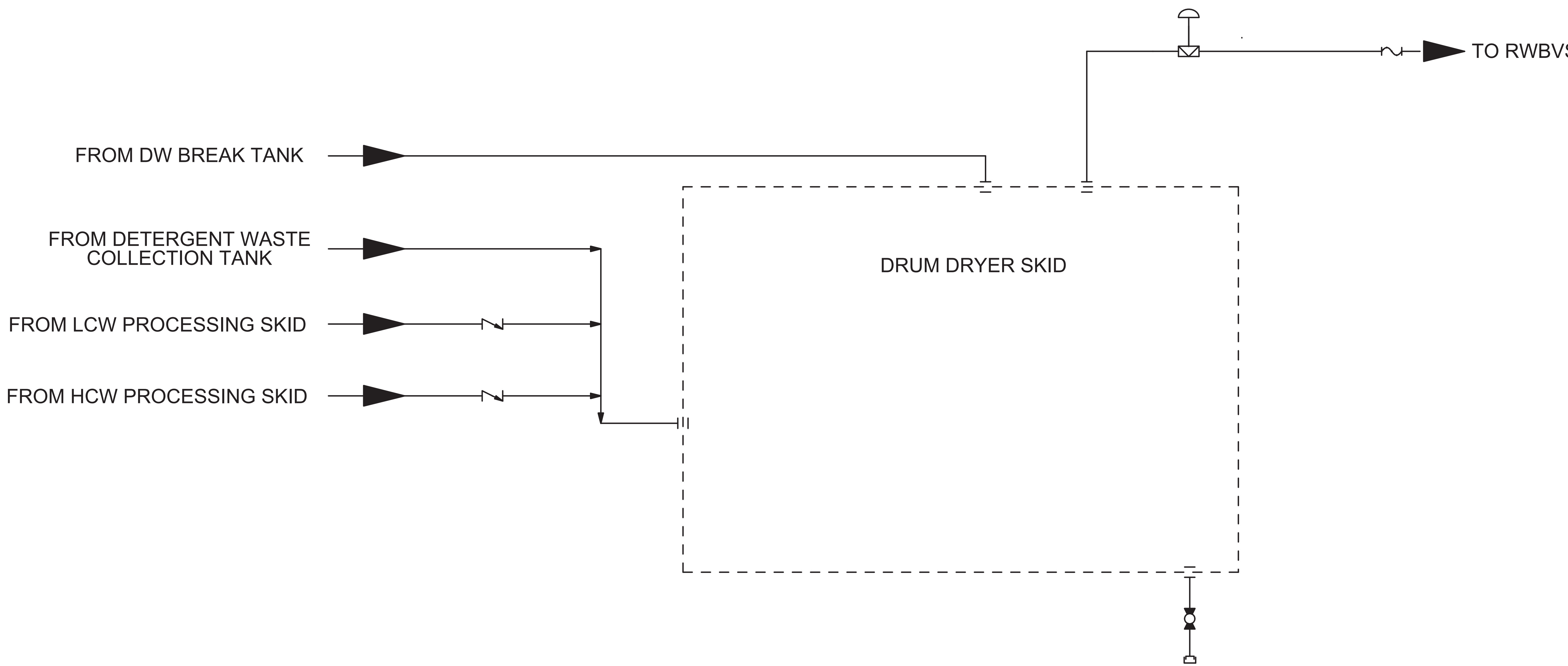


Figure 11.2-1j: Liquid Radioactive Waste System Diagram



11.3 Gaseous Waste Management System

The gaseous radioactive waste system (GRWS) design processes the gaseous waste stream from the liquid radioactive waste system (LRWS) degasifier and the containment evacuation system (CES), provide holdup for radioactive decay of xenon and krypton, and convey the gaseous effluent to the Radioactive Waste Building heating ventilation and air conditioning (HVAC) system (RWBVS), which transports the effluent to the Reactor Building HVAC system (RBVS) for monitoring and release. The GRWS filters out particulate carryover and delays the noble gases through activated charcoal beds until they have decayed sufficiently to allow release to the environment. Design and performance of the charcoal delay system is in accordance with NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)," April 1985, as modified by TR-123242 (Reference 11.3-1).

Exhaust flow from the RWBVS and RBVS are combined and monitored by the RBVS exhaust stack radiation effluent monitor before release to the environment (Section 11.5). Primary gaseous effluent sources, besides gaseous radioactive waste, include the CES (Section 9.3.6), RWBVS (Section 9.4.3) and other sources exhausted by the RBVS (Section 9.4.2). In addition, small releases that occur in the Turbine Generator Building from the condenser air removal system (CARS) (Section 10.4.2) and turbine gland sealing system (Section 10.4.3) are monitored, but directly released to the environment.

11.3.1 Design Bases

The GRWS serves no safety function and is not risk-significant. Table 11.3-10 identifies SSC classifications for GWMS. The GRWS does not mitigate design basis accidents and has no safe shutdown functions. General Design Criteria (GDC) 2, 3, 60, and 61 were considered in the design of the GRWS.

11.3.2 System Description

The GRWS is in the RWB and is a passive, once-through, ambient temperature charcoal delay system that receives hydrogen-bearing gas containing fission gases from the LRWS degasifier. The GRWS also receives gaseous waste inputs from the individual NuScale Power Modules (NPMs) via the CES, if high radiation is detected in the CES exhaust. The GRWS filters particulate carryover, removes moisture, delays the gas to allow radioactive decay, and conveys it to the RBVS via the RWBVS for release to the environment through the plant exhaust stack as a monitored release (Section 11.5).

Nitrogen from the nitrogen distribution system dilutes the waste gas input from the liquid radioactive waste degasifier (and potentially CES) to maintain a hydrogen concentration of less than 4 percent. Because the waste gas input flow is not constant, the nitrogen supply maintains a positive GRWS pressure and a constant flow. The waste gas input into the GRWS passes through a vapor condenser package assembly that contains a waste gas cooler (cooled by chilled water) and a moisture separator. The moisture separator includes level control drain valves piped to the equipment drain sump in the radioactive waste drain system (RWDS). The drain line passes through a drain trap to prevent radioactive gas from passing to the RWDS in the event of a system failure. After the vapor condenser, the waste gas stream passes through two redundant oxygen analyzers, two hydrogen analyzers, and a manual sample port. If high oxygen levels are detected, the inlet stream to the GRWS automatically isolates and a nitrogen purge flushes the GRWS. Operators manually initiate termination of nitrogen flushing and restart of normal operations.

The waste gas passes through a charcoal guard bed located in an ambient temperature-controlled shielded cubicle. Because the guard bed is at ambient room temperature, the guard bed warms the gas from the gas cooler (lowering its relative humidity) to improve fission gas capture efficiency in the decay beds. The guard bed also acts as a backup moisture-removal device. The guard bed contains a safety relief valve, differential pressure instrumentation, and a means to dry or replace charcoal. Operators manually initiate charcoal drying using remotely-operated valves and a normally deenergized charcoal drying heater, which provide a heated nitrogen flow to the guard bed. The heated, moisture-laden nitrogen recycles back to the inlet of the vapor condenser. The guard bed also contains a fire detector that automatically activates a nitrogen purge upon detecting a fire.

The conditioned waste gas then flows into either one of two charcoal decay beds, each decay bed consisting of four charcoal vessels connected in series. Entrance into the first vessel and exit from the last vessel is through the top of the vessel to minimize the potential of charcoal loss. Each decay bed contains activated charcoal optimized for xenon and krypton retention. Like the guard bed, the decay beds contain differential pressure instrumentation, fire detection instrumentation, safety relief valves, and the ability to either dry or replace charcoal. In addition, the decay beds contain radiation monitors that automatically isolate flow in the event of a high radiation indication.

The processed waste gas goes to the RWBVS, which interfaces with the RBVS that monitors the effluent path to the environment. The GRWS outlet also has an offline radiation monitor with the capability to take samples before being sent to the ventilation systems.

The gaseous radioactive waste process design is illustrated in Figure 11.3-1. Table 11.3-1 provides the GRWS design parameters.

11.3.2.1 Component Description

This section describes the key GRWS equipment. Table 11.3-2 summarizes specific component design parameters. Design codes, standards, and materials for construction of these components are consistent with RG 1.143, Table 1.

11.3.2.1.1 Waste Gas Cooler

The waste gas cooler is a stainless steel, double-pipe heat exchanger that cools the incoming waste gas stream from the LRWS and CES. Chilled water (shell side) cools the waste gas stream (tube side) to condense water vapor from the gas stream to protect the charcoal beds from moisture.

11.3.2.1.2 Moisture Separator

The stainless steel moisture separator collects condensed water from the waste gas cooler. Level instrumentation controls the outlet drain valve. The condensate goes to the equipment drain waste sump in the RWDS. The drain line passes through a drain trap to prevent radioactive gases from passing to the RWDS.

11.3.2.1.3 Charcoal Guard Bed

The charcoal guard bed is an American Society of Mechanical Engineers (ASME) Section VIII stainless steel vessel located in an ambient temperature-controlled cubicle that warms the waste gas stream, thus reducing its relative humidity. The guard bed also removes additional moisture in the waste gas stream to improve fission gas capture efficiency and protect the charcoal decay beds. The charcoal guard bed includes a safety relief valve, differential pressure instrumentation, a fire detector, and a means to dry with a charcoal drying heater or replace the charcoal, if needed.

11.3.2.1.4 Charcoal Decay Beds

The two charcoal decay beds each consist of four ASME Section VIII stainless steel decay vessels connected in series. The vessels contain activated charcoal to allow the waste gas radionuclides to decay sufficiently before being released. Each decay bed train has a pressure relief valve, differential pressure instrumentation, and a fire detector that upon sensing a fire automatically activates a nitrogen purge. The exit of each of the two decay beds has a radiation monitor that automatically isolates the bed in the event of a high radiation signal.

11.3.2.1.5 Charcoal Drying Heater

If needed, the charcoal drying heater is a manually initiated, stainless steel electric heater that heats nitrogen gas from the nitrogen distribution system to flow through the charcoal guard bed to dry the charcoal. Operators can also send heated nitrogen to the charcoal decay beds. After exiting the guard bed or decay beds, the nitrogen is routed back to the inlet of the waste gas cooler to remove the moisture. The charcoal drying heater has a temperature controller with a high temperature cutoff. If a fire is detected in a charcoal bed, the heater is automatically deenergized.

11.3.2.1.6 Oxygen and Hydrogen Analyzers

There are a total of three independent oxygen analyzers and two hydrogen analyzers that continuously monitor the GRWS. Two redundant oxygen analyzers and two redundant hydrogen analyzers are downstream of the moisture separator, upstream of the charcoal guard bed, and indicate and annunciate locally, in the main control room (MCR), and in the WMCR. In the event that high oxygen levels exceed 1 percent, the system initiates an alarm locally and in both the WMCR and MCR. If the oxygen level reaches

2 percent, the inlet stream to the GRWS automatically isolates and a nitrogen purge valve automatically opens to purge the GRWS with nitrogen. The hydrogen monitor ensures detection of a maximum concentration of 4 percent with notification of a high-high alarm. The high alarm at approximately one-half of the maximum oxygen concentration includes a local, WMCR and MCR notification.

The design of the gas analyzer instruments is to be non-sparking. Gas analyzers have sensor checks, functional checks, and calibrations performed in accordance with vendor recommendations.

11.3.2.2 Malfunction Analysis

Table 11.3-3 provides a summary of a malfunction analysis of the GRWS.

11.3.2.3 Design Safety Evaluation

The GRWS complies with the following GDC found in 10 CFR Part 50, Appendix A:

- GDC 2 as it relates to structures and components of the GRWS using the guidance of RG 1.143 for the seismic, safety, and quality classifications
- GDC 3 as it relates to protecting the GRWS from the effects of a detonation of a hydrogen-oxygen mixture by preventing such mixtures from occurring
- GDC 60 as it relates to the design of the GRWS to control releases of radioactive gaseous effluents generated during normal reactor operations, including AOOs
- GDC 61 as it relates to radioactive waste systems being designed to provide for adequate safety under normal and postulated accident conditions, and designed with suitable shielding for radiation protection and with appropriate containment, confinement, and filtering systems

There are design features that comply with the requirements of 10 CFR 20.1406 following the guidance of RG 4.21, to minimize contamination of the facility and the environment, facilitate eventual decommissioning, and minimize the generation of radioactive waste. Section 12.3.6 provides additional details.

The gaseous radioactive waste structures, systems, and components design complies with the codes and standards provided in RG 1.143, Table 1 through 4. The applicable design criteria from RG1.143, Table 2, Table 3 and Table 4 are used in the design analysis of the GRWS components. The safety classification for the GRWS components applies to components, up to and including the nearest isolation device. Table 11.3-2 provides the design parameters of major components, including safety classification and operating conditions.

11.3.2.4 Site-Specific Cost-Benefit Analysis

COL Item 11.3-1: An applicant that references the NuScale Power Plant US460 standard design will perform a site-specific cost-benefit analysis using the guidance in Regulatory Guide 1.110.

11.3.2.5 Seismic Design

The gaseous radioactive waste equipment and piping classification complies with RG 1.143. Section 3.7 describes the RWB seismic design.

11.3.3 Radioactive Effluent Releases

Technical Report TR-123242 (Reference 11.3-1) describes the gaseous radioactive effluent release methodology, inputs, and results.

Table 11.3-5 tabulates the results of the radioactive effluent calculation and demonstrate compliance with the limits from 10 CFR 20, Appendix B, Table 2. Table 11.3-4 provides the inputs. The comparison demonstrates that the overall expected gaseous releases are within the release limits.

The GASPAR II Code is used to calculate the maximum individual doses at the exclusion area boundary. Table 11.3-6 tabulates the input parameters. Table 11.3-7 tabulates the resultant doses and demonstrates compliance with the limits of 10 CFR 50 Appendix I.

COL Item 11.3-2: An applicant that references the NuScale Power Plant US460 standard design will calculate doses to members of the public using the site-specific parameters, compare those gaseous effluent doses to the numerical design objectives of 10 CFR 50, Appendix I, and comply with the requirements of 10 CFR 20.1302 and 40 CFR 190.

11.3.3.1 Radioactive Effluent Releases and Dose Calculation due to Gaseous Radioactive Waste System Leak or Failure

The analysis of a GRWS leak or failure follows the guidance of Branch Technical Position 11-5 and demonstrates compliance with regulatory limits. The dose consequence analysis evaluates a postulated event in which the GRWS fails. The analysis used in determining the radionuclide content of the effluents assumes that 1 percent of the operating fission product inventory in the core is released to the primary coolant. Table 11.3-8 tabulates the release source term. The dose consequences are calculated using the Radionuclide Transport and Removal and Dose (RADTRAD) code using the two-hour exclusion area boundary atmospheric dispersion factor from Table 2.0-1. Table 11.3-8 presents the resultant offsite doses.

COL Item 11.3-3: An applicant that references the NuScale Power Plant US460 standard design will perform an analysis in accordance with Branch Technical Position 11-5 using the site-specific parameters.

11.3.4 Ventilation Systems

The design of the ventilation systems for normal operation is in accordance with RG 1.140, and is described in Section 9.4.

11.3.5 Instrumentation and Controls

The instruments that provide automated functions in the GRWS include the following:

11.3.5.1 Waste Gas Cooler Moisture Separator Level

The waste gas cooler moisture separator level instrument monitors the water level in the drain tank and opens the tank's drain valve to route the water to the RWDS.

11.3.5.2 Hydrogen and Oxygen Gas Analyzers

Section 11.3.2.1.6 describes the hydrogen and oxygen gas analyzers.

11.3.5.3 Fire Detectors

Each of the charcoal beds has fire detectors to indicate the presence of a fire. If a fire is detected in a guard or decay bed, the GRWS waste gas inlet valve automatically closes and the nitrogen supply valve automatically opens to the associated charcoal bed.

11.3.5.4 Waste Gas Flow Instrument

The waste gas flow instrument is downstream of the moisture separator and downstream of the decay beds in the outlet line. Nitrogen flow maintains maintain a minimum flow through the charcoal beds.

11.3.5.5 Moisture Instrument

The waste gas stream contains a moisture level instrument at the outlet of the guard bed. If high moisture is detected, the waste gas inlet valve to the GRWS closes to stop the system flow.

11.3.5.6 Charcoal Bed Process Radiation Monitors

The outlet of each of the two charcoal decay beds has process radiation monitors. If high radiation is detected, the charcoal bed outlet valve closes.

11.3.5.7 Gaseous Radioactive Waste System Outlet Process Radiation Monitor

The outlet of the GRWS also has a radiation monitor. If high radiation is detected, the GRWS outlet valve closes to stop system flow to the RWBVS.

11.3.5.8 Cubicle Area Airborne Radiation Detectors

Each of the charcoal bed cubicles has area airborne radiation detectors. If high radiation is detected, the waste gas inlet valve to the GRWS closes and the nitrogen purge valve opens.

11.3.6 Reference

11.3-1 NuScale Power, LLC, "Effluent Release (GALE Replacement) Methodology and Results," TR-123242, Revision 1.

Table 11.3-1: Gaseous Radioactive Waste System Design Parameters

Parameter	Nominal Value
Xenon delay	69 days (normal)
Krypton delay	2.9 days (normal)
Dynamic adsorption coefficient (Kd) for xenon	1400 cm3/g
Dynamic adsorption coefficient (Kd) for krypton	60 cm3/g
Maximum gas waste stream temperature	200 °F
Activated carbon operating temperature	50-105 °F
Gas flow rate	1.03 scfm (normal)
Charcoal particle size	0.132 inch

Table 11.3-2: Major Equipment Design Parameters

Equipment / Parameter	Description / Value
Vapor Condenser Package Assembly	
Quantity	2
Design pressure	150 psig
Design temperature	250 °F
Max gas design flow rate	3.5 scfm
Max gas inlet temperature	200 °F
Max chilled water inlet temperature	40.5 °F
Material	Stainless Steel
RG 1.143 safety classification	RW-IIc
Table for Assumed Radioactive Content	Table 11.3-9
Charcoal Drying Heater	
Quantity	1
Type	Electric
Flow	2.28 scfm
Minimum Temperature Inlet	-10 °F
Temperature outlet	140 °F
Charcoal Guard Bed	
Quantity	1
Type	cylindrical pressure vessel
Nominal volume	10 ft^3
Design pressure	125 psig
Design temperature	250 °F
Design flow rate	3.5 scfm
Material	Stainless Steel
RG 1.143 safety classification	RW-IIa
Table for Assumed Radioactive Content	Table 12.2-15
Charcoal Decay Bed Vessel	
Quantity	2
Type	cylindrical pressure vessel
Nominal volume	147.5 ft^3/sec
Design pressure	125 psig
Design temperature	250 °F
Material	Stainless Steel
RG 1.143 safety classification	RW-IIa
Table for Assumed Radioactive Content	Table 12.2-15

Table 11.3-3: Gaseous Radioactive Waste System Equipment Malfunction Analysis

<table>
<tr><th>Equipment Item</th><th>Malfunction</th><th>Results (Consequences)</th><th>Mitigating or Alternate Action</th></tr>
<tr><td>Vapor Condenser Package Assembly</td><td>Skid Failure</td><td>Failure of the gas cooler causes ineffective removal of moisture in the gas.</td><td>If one of the condenser package assemblies fail, the influent gas stream can be diverted to the other vapor condenser package. This allows processing to continue.</td></tr>
<tr><td>Charcoal Drying Heater</td><td>Heater Failure</td><td>The purpose of the heater is to heat nitrogen used to periodically dry the charcoal in the charcoal guard bed by allowing hot nitrogen to flow through the charcoal. There is no immediate impact to the GRW operation if the heater fails. The downstream charcoal decay bed efficiency may be lowered.</td><td>The charcoal decay bed skids may be aligned in series to improve the decontamination factor if the guard bed is saturated with moisture.</td></tr>
<tr><td rowspan="4">Charcoal Guard Bed</td><td rowspan="4">Guard Bed Failure</td><td rowspan="4">There is only one charcoal guard be in the system. If the guard bed fails, the fission gas removal efficiency may be lowered.</td><td>Operation may continue by sending the gas to be treated in one of the two charcoal decay beds, which is located downstream of the bed.</td></tr>
<tr><td>Pressure differential transmitter monitors different pressures across the guard bed.</td></tr>
<tr><td>Detect moisture content of the gaseous stream through the moisture monitor located downstream of the guard bed.</td></tr>
<tr><td>The charcoal decay bed skids may be aligned in series to improve the decontamination factor if the guard bed is saturated with moisture.</td></tr>
<tr><td rowspan="2">Charcoal Decay Bed Skids</td><td rowspan="2">Decay Bed Failure</td><td rowspan="2">There is one set of redundant charcoal decay bed skids. Failure of one decay bed skid decreases removal efficiency of radioactive noble gases.</td><td>If one decay bed skid fails, the gas can be switched to the redundant decay bed skid for continued operation.</td></tr>
<tr><td>Radiation monitors downstream of the charcoal decay beds alarm when high radiation level is detected in the effluent gas. A high radiation alarm also triggers automatic closure of the isolation valves to the RWBV. Operators should review indications and determine whether to isolate influent streams to the GRW as well.</td></tr>
<tr><td rowspan="2">Pressure Boundary</td><td rowspan="2">Gas Leaks</td><td rowspan="2">Waste gas is released to the RWB.</td><td>Very small gas leaks in the GRW Charcoal Beds room can be detected by the area airborne radiation monitors.</td></tr>
<tr><td>The system can be purged with nitrogen before repair of replacement of the leaking component.</td></tr>
<tr><td rowspan="3">Oxygen Monitor</td><td rowspan="3">Fail to monitor</td><td rowspan="3">Monitoring capability is lost in detecting oxygen concentration.</td><td>The redundant oxygen analyzer monitors the oxygen concentration downstream of the vapor condensers. A single oxygen analyzer is placed just before the discharge to RWBV.</td></tr>
<tr><td>The oxygen analyzers are set to alarm at 1% and 2%.</td></tr>
<tr><td>The high-high oxygen alarm with a set point of 2% isolates the input streams from CE and LRW. Operators allow the continuous nitrogen flow to purge the system.</td></tr>
</table>

Table 11.3-3: Gaseous Radioactive Waste System Equipment Malfunction Analysis (Continued)

Equipment Item	Malfunction	Results (Consequences)	Mitigating or Alternate Action
Hydrogen Monitor	Fail to monitor	Monitoring capability is lost in detecting hydrogen concentration.	The redundant hydrogen analyzer monitors the hydrogen concentration downstream of the vapor condensers.
			Hydrogen analyzers are set to alarm at 2% and 4%.
Radiation Monitor	Fail to monitor/Loss of power	There are two types of radiation monitors: one is an area airborne monitor and the other is an in-line process radiation monitor. In both cases, monitoring capability is lost in detecting leakage to the GRW rooms housing the equipment and system and any waste gas released through the doors to the RWB.	In-line process radiation is monitored at each of the decay skid outlets and at the system discharge providing redundancy for the process. Therefore, failure of one does not impact operation of the other unless there is a loss of power.
			Upon loss of power to the radiation monitors the inlet and outlet valves are closed to isolate the GRW.

Table 11.3-4: Gaseous Effluent Release Calculation Inputs

NuScale Effluent Source Term Model Assumption	Value (1 NPM)	Value (6 NPMs)
Degasifier partition fractions:		
- Noble gases	1	1
- Halogens	0.5	0.5
Reactor pool evaporation rate	-	1300 lb/hour
Pool evaporation partition fractions:		
- Halogens (except iodine)	0.01	0.01
- Iodine	0.0005	0.0005
- Cs, Rb, particulates	0.005	0.005
- Gases and tritium	1	1
Steam generator partition coefficient	1	1
High-efficiency particulate air filter particulate efficiency	0	0
Primary coolant system leakrate	11.8 lb/day	70.6 lb/day
Primary coolant leak flashing fraction	0.4	0.4
Primary coolant leak partition fractions:		
- Halogens	0.01	0.01
- Cs, Rb, particulates	0.005	0.005
- Gases and tritium	1	1
Secondary coolant system steam leakrate	125 lb/day	750 lb/day
Condenser air removal normalized iodine release rate	125 Ci/yr/μCi/gm	750 Ci/yr/μCi/gm
Containment vessel design leakrate	0.2 weight%/day	0.2 weight%/day
Containment depressurization time	30 hours	30 hours

Table 11.3-5: Gaseous Estimated Discharge for Normal Effluents

Nuclide	GRWS (Ci/yr)	Pool Evaporation (Ci/yr)	AOO Gas Leakage (Ci/yr)	Primary Coolant Leaks (Ci/yr)	Plant Exhaust Stack Total (Ci/yr)	Secondary Steam Leaks (Ci/yr)	Condenser Air Removal System (Ci/yr)	Total TGB Releases (Ci/yr)	Total Gaseous Effluent Concentration at Site Boundary (µCi/ml)	10 CFR 20 Appendix B Limits (µCi/ml)	Fraction of Limit
Kr83m	6.5E-07	1.5E-07	8.8E-05	9.1E-03	9.1E-03	8.2E-07	4.2E-03	4.2E-03	4.2E-15	5.0E-05	8.5E-11
Kr85m	6.0E-05	-	3.7E-04	3.8E-02	3.8E-02	3.4E-06	1.8E-02	1.8E-02	1.8E-14	1.0E-07	1.8E-07
Kr85	1.4E+02	-	1.8E-02	1.9E+00	1.4E+02	1.7E-04	8.9E-01	8.9E-01	4.6E-11	7.0E-07	6.6E-05
Kr87	5.2E-17	-	2.0E-04	2.1E-02	2.1E-02	1.9E-06	9.7E-03	9.7E-03	9.7E-15	2.0E-08	4.8E-07
Kr88	1.9E-07	-	5.9E-04	6.0E-02	6.1E-02	5.4E-06	2.8E-02	2.8E-02	2.8E-14	9.0E-09	3.1E-06
Kr89	-	-	1.3E-05	1.4E-03	1.4E-03	1.2E-07	6.4E-04	6.4E-04	6.4E-16	-	-
Xe131m	2.0E-01	3.6E-01	1.4E-03	1.5E-01	7.0E-01	1.3E-05	6.9E-02	6.9E-02	2.4E-13	2.0E-06	1.2E-07
Xe133m	3.2E-07	4.2E-01	1.3E-03	1.3E-01	5.6E-01	1.2E-05	6.3E-02	6.3E-02	2.0E-13	6.0E-07	3.3E-07
Xe133	8.4E-02	6.0E+00	9.5E-02	9.7E+00	1.6E+01	8.8E-04	4.6E+00	4.6E+00	6.5E-12	5.0E-07	1.3E-05
Xe135m	7.3E-05	5.4E-02	1.3E-04	1.3E-02	6.7E-02	1.2E-06	6.1E-03	6.1E-03	2.3E-14	4.0E-08	5.8E-07
Xe135	3.2E-05	3.0E-02	2.6E-03	2.7E-01	3.0E-01	2.4E-05	1.3E-01	1.3E-01	1.4E-13	7.0E-08	1.9E-06
Xe137	-	-	4.4E-05	4.5E-03	4.6E-03	4.1E-07	2.1E-03	2.1E-03	2.1E-15	-	-
Xe138	-	-	1.5E-04	1.5E-02	1.6E-02	1.4E-06	7.2E-03	7.2E-03	7.2E-15	2.0E-08	3.6E-07
Br82	9.5E-09	6.4E-09	-	1.0E-06	1.0E-06	2.3E-08	5.7E-09	2.8E-08	3.3E-19	5.0E-09	6.6E-11
Br83	5.4E-08	1.1E-14	-	5.7E-06	5.8E-06	1.3E-07	3.2E-08	1.6E-07	1.9E-18	9.0E-08	2.1E-11
Br84	2.5E-08	-	-	2.7E-06	2.7E-06	5.5E-08	1.4E-08	6.9E-08	8.7E-19	8.0E-08	1.1E-11
Br85	3.1E-09	-	-	3.2E-07	3.2E-07	3.5E-09	8.7E-10	4.3E-09	1.0E-19	-	-
I129	1.6E-13	3.1E-13	-	1.6E-11	1.7E-11	3.7E-13	9.4E-14	4.7E-13	5.5E-24	4.0E-11	1.4E-13
I130	7.7E-08	6.8E-09	-	8.2E-06	8.2E-06	1.8E-07	4.7E-08	2.3E-07	2.7E-18	3.0E-09	8.9E-10
I131	2.0E-06	3.2E-04	-	2.1E-04	5.3E-04	4.7E-06	1.2E-06	5.9E-06	1.7E-16	2.0E-10	8.5E-07
I132	9.1E-07	7.9E-07	-	9.6E-05	9.8E-05	2.1E-06	5.4E-07	2.7E-06	3.2E-17	2.0E-08	1.6E-09
I133	3.0E-06	2.8E-05	-	3.2E-04	3.5E-04	7.2E-06	1.8E-06	9.0E-06	1.1E-16	1.0E-09	1.1E-07
I134	5.4E-07	8.5E-26	-	5.7E-05	5.7E-05	1.2E-06	3.1E-07	1.5E-06	1.9E-17	6.0E-08	3.1E-10
I135	1.9E-06	1.0E-08	-	2.0E-04	2.0E-04	4.5E-06	1.1E-06	5.6E-06	6.5E-17	6.0E-09	1.1E-08
Rb86m	-	-	-	1.2E-10	1.2E-10	1.3E-12	-	1.3E-12	3.9E-23	-	-
Rb86	-	8.3E-07	-	7.0E-07	1.5E-06	3.5E-08	-	3.5E-08	5.0E-19	1.0E-09	5.0E-10
Rb88	-	-	-	1.2E-04	1.2E-04	5.0E-06	-	5.0E-06	4.0E-17	9.0E-08	4.4E-10
Rb89	-	-	-	5.5E-06	5.5E-06	2.2E-07	-	2.2E-07	1.8E-18	2.0E-07	9.1E-12

Table 11.3-5: Gaseous Estimated Discharge for Normal Effluents (Continued)

Nuclide	GRWS (Ci/yr)	Pool Evaporation (Ci/yr)	AOO Gas Leakage (Ci/yr)	Primary Coolant Leaks (Ci/yr)	Plant Exhaust Stack Total (Ci/yr)	Secondary Steam Leaks (Ci/yr)	Condenser Air Removal System (Ci/yr)	Total TGB Releases (Ci/yr)	Total Gaseous Effluent Concentration at Site Boundary (µCi/ml)	10 CFR 20 Appendix B Limits (µCi/ml)	Fraction of Limit
Cs132	-	1.4E-08	-	1.4E-08	2.8E-08	7.0E-10	-	7.0E-10	9.1E-21	6.0E-09	1.5E-12
Cs134	-	1.3E-04	-	1.0E-04	2.3E-04	5.0E-06	-	5.0E-06	7.4E-17	2.0E-10	3.7E-07
Cs135m	-	1.1E-26	-	8.4E-08	8.4E-08	3.9E-09	-	3.9E-09	2.8E-20	3.0E-07	9.3E-14
Cs136	-	2.5E-05	-	2.2E-05	4.7E-05	1.1E-06	-	1.1E-06	1.5E-17	9.0E-10	1.7E-08
Cs137	-	6.6E-05	-	5.2E-05	1.2E-04	2.6E-06	-	2.6E-06	3.8E-17	2.0E-10	1.9E-07
Cs138	-	-	-	4.5E-05	4.5E-05	2.0E-06	-	2.0E-06	1.5E-17	8.0E-08	1.9E-10
P32	-	6.9E-13	-	2.0E-12	2.7E-12	8.9E-14	-	8.9E-14	8.7E-25	5.0E-10	1.7E-15
Co57	-	5.8E-15	-	1.5E-14	2.1E-14	6.8E-16	-	6.8E-16	6.8E-27	9.0E-10	7.5E-18
Sr89	-	3.4E-08	-	8.9E-08	1.2E-07	4.1E-09	-	4.1E-09	4.0E-20	2.0E-10	2.0E-10
Sr90	-	5.4E-09	-	1.4E-08	1.9E-08	6.3E-10	-	6.3E-10	6.3E-21	6.0E-12	1.1E-09
Sr91	-	3.2E-10	-	4.6E-08	4.7E-08	2.1E-09	-	2.1E-09	1.5E-20	5.0E-09	3.1E-12
Sr92	-	4.6E-15	-	2.5E-08	2.5E-08	1.1E-09	-	1.1E-09	8.3E-21	9.0E-09	9.2E-13
Y90	-	3.2E-09	-	3.4E-09	6.6E-09	1.5E-10	-	1.5E-10	2.1E-21	9.0E-10	2.4E-12
Y91m	-	2.1E-10	-	2.5E-08	2.5E-08	1.1E-09	-	1.1E-09	8.3E-21	2.0E-07	4.1E-14
Y91	-	5.0E-09	-	1.3E-08	1.8E-08	5.9E-10	-	5.9E-10	5.9E-21	2.0E-10	2.9E-11
Y92	-	6.5E-13	-	2.1E-08	2.1E-08	9.5E-10	-	9.5E-10	7.0E-21	1.0E-08	7.0E-13
Y93	-	8.6E-11	-	1.0E-08	1.0E-08	4.5E-10	-	4.5E-10	3.3E-21	3.0E-09	1.1E-12
Zr97	-	5.7E-10	-	1.5E-08	1.5E-08	6.7E-10	-	6.7E-10	5.1E-21	2.0E-09	2.5E-12
Nb95	-	3.9E-05	-	3.7E-08	3.9E-05	1.7E-09	-	1.7E-09	1.2E-17	2.0E-09	6.2E-09
Mo99	-	5.8E-06	-	2.7E-05	3.2E-05	1.2E-06	-	1.2E-06	1.1E-17	2.0E-09	5.3E-09
Mo101	-	-	-	1.0E-06	1.0E-06	3.8E-08	-	3.8E-08	3.3E-19	2.0E-07	1.7E-12
Tc99m	-	5.6E-06	-	2.5E-05	3.0E-05	1.1E-06	-	1.1E-06	9.9E-18	2.0E-07	4.9E-11
Tc99	-	2.0E-10	-	5.0E-10	7.0E-10	2.3E-11	-	2.3E-11	2.3E-22	8.0E-09	2.8E-14
Ru103	-	9.5E-09	-	2.5E-08	3.5E-08	1.2E-09	-	1.2E-09	1.1E-20	9.0E-10	1.3E-11
Ru105	-	5.3E-13	-	8.4E-09	8.4E-09	3.8E-10	-	3.8E-10	2.8E-21	2.0E-08	1.4E-13
Ru106	-	6.2E-09	-	1.6E-08	2.2E-08	7.2E-10	-	7.2E-10	7.2E-21	2.0E-11	3.6E-10
Rh103m	-	9.4E-09	-	2.5E-08	3.4E-08	1.1E-09	-	1.1E-09	1.1E-20	2.0E-06	5.6E-15
Rh105	-	2.4E-09	-	1.7E-08	2.0E-08	7.8E-10	-	7.8E-10	6.4E-21	8.0E-09	8.1E-13

Table 11.3-5: Gaseous Estimated Discharge for Normal Effluents (Continued)

Nuclide	GRWS (Ci/yr)	Pool Evaporation (Ci/yr)	AOO Gas Leakage (Ci/yr)	Primary Coolant Leaks (Ci/yr)	Plant Exhaust Stack Total (Ci/yr)	Secondary Steam Leaks (Ci/yr)	Condenser Air Removal System (Ci/yr)	Total TGB Releases (Ci/yr)	Total Gaseous Effluent Concentration at Site Boundary (μCi/ml)	10 CFR 20 Appendix B Limits (μCi/ml)	Fraction of Limit
Rh106	-	6.2E-09	-	1.6E-08	2.2E-08	9.7E-11	-	9.7E-11	7.0E-21	-	-
Ag110	-	4.0E-05	-	1.1E-07	4.0E-05	5.7E-10	-	5.7E-10	1.3E-17	-	-
Sb124	-	1.4E-11	-	3.8E-11	5.2E-11	1.7E-12	-	1.7E-12	1.7E-23	3.0E-10	5.7E-14
Sb125	-	1.1E-10	-	2.8E-10	3.9E-10	1.3E-11	-	1.3E-11	1.3E-22	7.0E-10	1.8E-13
Sb127	-	3.7E-10	-	1.4E-09	1.8E-09	6.5E-11	-	6.5E-11	5.9E-22	1.0E-09	5.9E-13
Sb129	-	1.0E-13	-	1.8E-09	1.8E-09	7.9E-11	-	7.9E-11	5.8E-22	1.0E-08	5.8E-14
Te125m	-	1.6E-08	-	4.1E-08	5.6E-08	1.9E-09	-	1.9E-09	1.8E-20	1.0E-09	1.8E-11
Te127m	-	6.0E-08	-	1.6E-07	2.2E-07	7.1E-09	-	7.1E-09	7.0E-20	4.0E-10	1.8E-10
Te127	-	6.2E-08	-	6.2E-07	6.8E-07	2.8E-08	-	2.8E-08	2.2E-19	2.0E-08	1.1E-11
Te129m	-	1.7E-07	-	4.5E-07	6.1E-07	2.0E-08	-	2.0E-08	2.0E-19	3.0E-10	6.7E-10
Te129	-	1.0E-07	-	6.3E-07	7.4E-07	2.8E-08	-	2.8E-08	2.4E-19	9.0E-08	2.7E-12
Te131m	-	1.6E-07	-	1.5E-06	1.6E-06	6.6E-08	-	6.6E-08	5.3E-19	1.0E-09	5.3E-10
Te131	-	3.5E-08	-	7.2E-07	7.6E-07	2.9E-08	-	2.9E-08	2.5E-19	2.0E-08	1.2E-11
Te132	-	2.5E-06	-	1.1E-05	1.3E-05	4.8E-07	-	4.8E-07	4.3E-18	9.0E-10	4.8E-09
Te133m	-	2.4E-25	-	9.2E-07	9.2E-07	3.9E-08	-	3.9E-08	3.0E-19	2.0E-08	1.5E-11
Te134	-	-	-	1.3E-06	1.3E-06	5.5E-08	-	5.5E-08	4.3E-19	7.0E-08	6.1E-12
Ba137m	-	6.2E-05	-	4.8E-05	1.1E-04	9.7E-07	-	9.7E-07	3.5E-17	-	-
Ba139	-	6.9E-21	-	2.4E-08	2.4E-08	1.1E-09	-	1.1E-09	8.0E-21	4.0E-08	2.0E-13
Ba140	-	4.5E-08	-	1.3E-07	1.8E-07	5.9E-09	-	5.9E-09	5.7E-20	2.0E-09	2.9E-11
La140	-	3.5E-08	-	3.8E-08	7.3E-08	1.7E-09	-	1.7E-09	2.4E-20	2.0E-09	1.2E-11
La141	-	1.5E-13	-	7.5E-09	7.5E-09	3.4E-10	-	3.4E-10	2.5E-21	1.0E-08	2.5E-13
La142	-	1.2E-20	-	3.6E-09	3.6E-09	1.6E-10	-	1.6E-10	1.2E-21	3.0E-08	3.9E-14
Ce141	-	7.5E-09	-	2.0E-08	2.8E-08	9.1E-10	-	9.1E-10	9.0E-21	8.0E-10	1.1E-11
Ce143	-	1.8E-09	-	1.5E-08	1.7E-08	6.9E-10	-	6.9E-10	5.6E-21	2.0E-09	2.8E-12
Ce144	-	6.6E-09	-	1.7E-08	2.4E-08	7.7E-10	-	7.7E-10	7.7E-21	2.0E-11	3.9E-10
Pr143	-	6.5E-09	-	1.8E-08	2.4E-08	8.1E-10	-	8.1E-10	7.9E-21	9.0E-10	8.8E-12
Pr144	-	6.5E-09	-	1.7E-08	2.3E-08	6.5E-10	-	6.5E-10	7.6E-21	2.0E-07	3.8E-14
Np239	-	6.3E-08	-	3.2E-07	3.8E-07	1.5E-08	-	1.5E-08	1.3E-19	3.0E-09	4.2E-11

Table 11.3-5: Gaseous Estimated Discharge for Normal Effluents (Continued)

Nuclide	GRWS (Ci/yr)	Pool Evaporation (Ci/yr)	AOO Gas Leakage (Ci/yr)	Primary Coolant Leaks (Ci/yr)	Plant Exhaust Stack Total (Ci/yr)	Secondary Steam Leaks (Ci/yr)	Condenser Air Removal System (Ci/yr)	Total TGB Releases (Ci/yr)	Total Gaseous Effluent Concentration at Site Boundary (µCi/ml)	10 CFR 20 Appendix B Limits (µCi/ml)	Fraction of Limit
Na24	-	9.4E-06	-	3.2E-04	3.3E-04	1.5E-05	-	1.5E-05	1.1E-16	7.0E-09	1.6E-08
Cr51	-	6.7E-03	-	1.8E-05	6.7E-03	8.2E-07	-	8.2E-07	2.1E-15	3.0E-08	7.1E-08
Mn54	-	3.6E-03	-	9.3E-06	3.6E-03	4.2E-07	-	4.2E-07	1.1E-15	1.0E-09	1.1E-06
Fe55	-	2.7E-03	-	7.0E-06	2.7E-03	3.2E-07	-	3.2E-07	8.6E-16	3.0E-09	2.9E-07
Fe59	-	6.6E-04	-	1.7E-06	6.6E-04	8.0E-08	-	8.0E-08	2.1E-16	5.0E-10	4.2E-07
Co58	-	1.0E-01	-	2.7E-05	1.0E-01	1.2E-06	-	1.2E-06	3.2E-14	1.0E-09	3.2E-05
Co60	-	1.2E-03	-	3.1E-06	1.2E-03	1.4E-07	-	1.4E-07	3.8E-16	5.0E-11	7.6E-06
Ni63	-	6.0E-04	-	1.5E-06	6.0E-04	7.0E-08	-	7.0E-08	1.9E-16	2.0E-09	9.5E-08
Zn65	-	1.2E-03	-	3.0E-06	1.2E-03	1.3E-07	-	1.3E-07	3.7E-16	4.0E-10	9.1E-07
Zr95	-	8.7E-04	-	2.3E-06	8.7E-04	1.0E-07	-	1.0E-07	2.7E-16	4.0E-10	6.9E-07
Ag110m	-	2.9E-03	-	7.5E-06	2.9E-03	3.4E-07	-	3.4E-07	9.3E-16	1.0E-10	9.3E-06
W187	-	1.2E-03	-	1.6E-05	1.3E-03	7.4E-07	-	7.4E-07	4.0E-16	1.0E-08	4.0E-08
H3	-	6.6E+02	-	6.3E+00	6.7E+02	7.4E+00	-	7.4E+00	2.1E-10	1.0E-07	2.1E-03
C14	2.3E-01	5.4E-03	-	1.2E-03	2.4E-01	2.8E-07	-	2.8E-07	7.5E-14	3.0E-09	2.5E-05
Ar41	2.3E+00	-	1.6E-02	1.6E+00	4.0E+00	1.5E-04	7.7E-01	7.7E-01	1.5E-12	1.0E-08	1.5E-04
Total	**1.5E+02**	**6.7E+02**	**1.4E-01**	**2.0E+01**	**8.4E+02**	**7.4E+00**	**6.5E+00**	**1.4E+01**	**2.7E-10**	**5.8E-05**	**2.5E-03**

Note- The X/Q used to calculate the site boundary concentrations is provided in Table 11.3-6

Table 11.3-6: GASPAR Code Input Parameter Values

Parameter	Value
Routine release X/Q (undepleted/no decay)	Table 2.0-1
Routine release D/Q	Table 2.0-1
Milk animal	Greater of goat or cow
Midpoint of plant life	20 yrs
Fraction of year that leafy vegetables are grown	1.0
Fraction of year that milk cows are in pasture	1.0
Fraction of the maximum individual's vegetable intake that is from his own garden	0.76
Fraction of milk-cow feed intake that is from pasture while on pasture	1.0
Average absolute humidity over the growing season	8.0 gram/m^3
Fraction of year that beef cattle are in pasture	1.0
Fraction of beef cattle feed intake that is from pasture while the cattle are on pasture	1.0
Source term	Table 11.3-5

Table 11.3-7: Gaseous Effluent Dose Results for 10 CFR 50 Appendix I

Type of Dose	Dose Estimate
Beta Dose Air (mrad/yr)	0.10
Gamma Dose Air (mrad/yr)	0.02

PATHWAY	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
Plume	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.3E-02	8.2E-02
Ground	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01	3.2E-01
VEGETABLE								
ADULT	3.4E-01	6.6E-01	1.0E-01	3.3E-01	3.0E-01	3.9E-01	3.0E-01	2.9E-01
TEEN	4.1E-01	7.1E-01	1.6E-01	4.0E-01	3.6E-01	4.6E-01	3.5E-01	3.4E-01
CHILD	6.7E-01	7.8E-01	3.9E-01	6.4E-01	5.7E-01	7.7E-01	5.6E-01	5.5E-01
MEAT								
ADULT	6.0E-02	1.8E-01	3.3E-02	5.8E-02	4.8E-02	4.9E-02	4.6E-02	4.5E-02
TEEN	4.0E-02	1.0E-01	2.7E-02	3.8E-02	3.0E-02	3.1E-02	2.9E-02	2.8E-02
CHILD	5.5E-02	7.3E-02	5.1E-02	4.9E-02	4.0E-02	4.2E-02	3.8E-02	3.7E-02
COW MILK								
ADULT	1.2E-01	3.1E-01	5.0E-02	1.3E-01	1.1E-01	2.2E-01	1.0E-01	1.0E-01
TEEN	1.6E-01	3.7E-01	8.9E-02	1.8E-01	1.6E-01	3.2E-01	1.4E-01	1.3E-01
CHILD	2.6E-01	3.8E-01	2.2E-01	3.0E-01	2.6E-01	5.8E-01	2.2E-01	2.2E-01
INFANT	4.0E-01	5.3E-01	3.7E-01	4.9E-01	4.0E-01	1.2E+00	3.5E-01	3.5E-01
GOAT MILK								
ADULT	2.3E-01	2.2E-01	4.7E-02	2.3E-01	2.1E-01	3.4E-01	2.0E-01	2.0E-01
TEEN	2.9E-01	2.9E-01	8.5E-02	3.2E-01	2.8E-01	4.8E-01	2.7E-01	2.6E-01
CHILD	4.5E-01	4.4E-01	2.0E-01	5.2E-01	4.6E-01	8.6E-01	4.3E-01	4.2E-01
INFANT	6.8E-01	6.8E-01	3.7E-01	8.4E-01	7.1E-01	1.7E+00	6.7E-01	6.5E-01
INHALATION								
ADULT	1.5E-01	1.6E-01	2.1E-04	1.5E-01	1.5E-01	1.6E-01	1.9E-01	1.5E-01
TEEN	1.6E-01	1.6E-01	2.8E-04	1.6E-01	1.6E-01	1.6E-01	2.1E-01	1.6E-01
CHILD	1.4E-01	1.4E-01	3.8E-04	1.4E-01	1.4E-01	1.4E-01	1.8E-01	1.4E-01
INFANT	7.9E-02	7.9E-02	1.9E-04	7.9E-02	7.9E-02	8.2E-02	1.1E-01	7.9E-02
TOTAL								
ADULT	2.8E-01	1.3E+00	1.9E-01	7.8E-01	7.2E-01	9.3E-01	7.4E-01	4.0E-01
TEEN	2.8E-01	1.3E+00	2.8E-01	9.2E-01	8.2E-01	1.1E+00	8.5E-01	4.0E-01
CHILD	2.8E-01	1.4E+00	6.6E-01	1.4E+00	1.2E+00	1.8E+00	1.2E+00	4.0E-01
INFANT	2.8E-01	7.6E-01	3.7E-01	9.2E-01	7.9E-01	1.8E+00	7.8E-01	4.0E-01

Table 11.3-8: Gaseous Effluent Dose Evaluation for Gaseous Radioactive Waste System Failure

Parameter	Value
Release Source Term:	
I-131	4.1E-04 Ci
I-132	1.9E-04 Ci
I-133	6.2E-04 Ci
I-134	1.1E-04 Ci
I-135	3.9E-04 Ci
Xe-133	5.3E-02 Ci
Xe-135	9.7E+00 Ci
Kr-85m	2.9E-02 Ci
Kr-85	8.4E-02 Ci
Kr-87	1.4E+01 Ci
Kr-88	3.8E-01 Ci
Dispersion factor (0-2 hour exclusion area boundary)	Table 2.0-1
Offsite dose consequence	< 10 mrem
Allowable dose limit	100 mrem

Table 11.3-9: Vapor Condenser Package Assembly Radiological Content

Isotope	Activity (Ci/cm^3)
Kr83m	1.2E-10
Kr85m	5.1E-10
Kr85	9.2E-08
Kr87	2.8E-10
Kr88	8.0E-10
Kr89	1.8E-11
Xe131m	2.1E-09
Xe133m	1.8E-09
Xe133	1.3E-07
Xe135m	1.7E-10
Xe135	3.6E-09
Xe137	6.0E-11
Xe138	2.1E-10
Br82	1.8E-14
Br83	1.0E-13
Br84	4.8E-14
Br85	5.8E-15
I129	3.0E-19
I130	1.5E-13
I131	3.8E-12
I132	1.7E-12
I133	5.7E-12
I134	1.0E-12
I135	3.6E-12
C14	1.6E-11
Ar41	1.3E-08

Table 11.3-10: Classification of Structures, Systems, and Components

SSC (Note 1)	Location	SSC Classification (A1, A2, B1, B2)	Augmented Design Requirements (Note 2)	Quality Group/Safety Classification (Ref RG 1.26 or RG 1.143) (Note 3)	Seismic Classification (Ref. RG 1.29 or RG 1.143) (Note 4)
GRWS, Gaseous Radioactive Waste System					
All components (except those listed below):	RWB	B2	RG 1.143	RW-IIc	III
• Charcoal decay bed skid & associated valves (except inlet & outlet root valves) • Charcoal guard bed & associated valves • Instrument root valves (RIT-1021A/B)	RWB	B2	RG 1.143	RW-IIa	RW-IIa
• Instrumentation • Gas sampler	RWB	B2	None	N/A	III

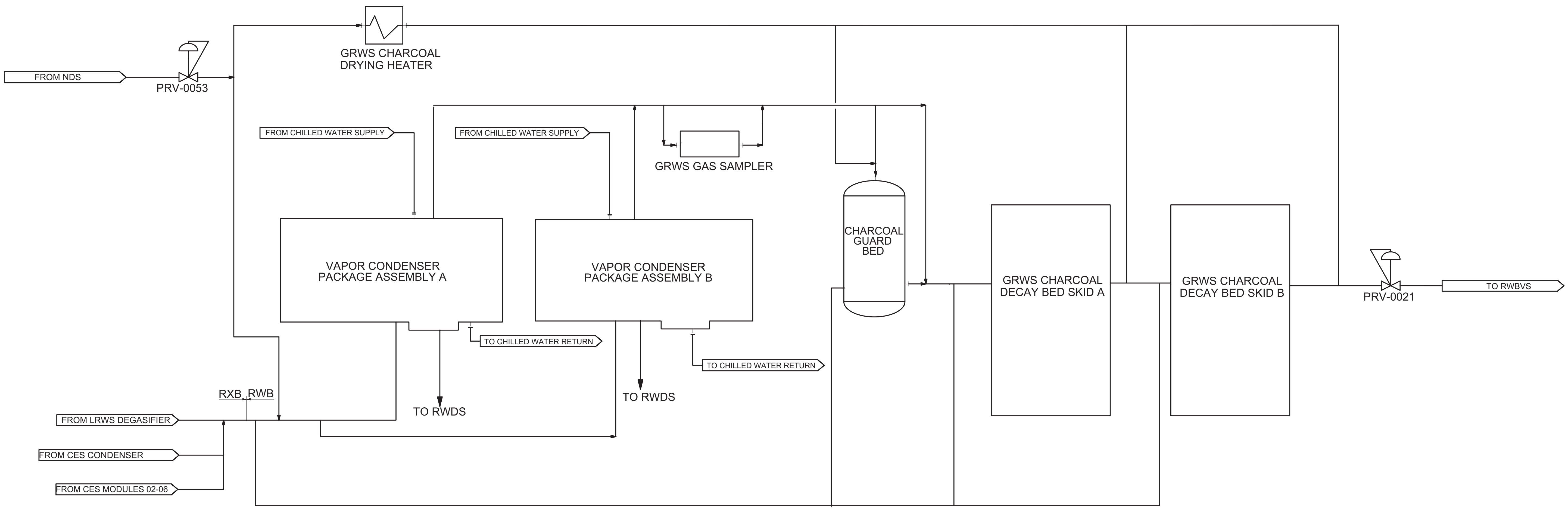
Note 1: Acronyms used in this table are listed in Table 1.1-1

Note 2: Additional augmented design requirements, such as the application of a Quality Group, Radwaste safety, or seismic classification, to nonsafety-related SSC are reflected in the columns Quality Group / Safety Classification and Seismic Classification, where applicable. Environmental Qualifications of SSC are identified in Table 3.11-1.

Note 3: Section 3.2.2.1 through Section 3.2.2.4 provides the applicable codes and standards for each RG 1.26 Quality Group designation (A, B, C, and D). A Quality Group classification per RG 1.26 is not applicable to supports or instrumentation. Section 3.2.1.4 provides a description of RG 1.143 classification for RW-IIa, RW-IIb, and RW-IIc.

Note 4: Where SSC (or portions thereof) as determined in the as-built plant that are identified as Seismic Category III in this table could, as the result of a seismic event, adversely affect Seismic Category I SSC or result in incapacitating injury to occupants of the control room, they are categorized as Seismic Category II consistent with Section 3.2.1.2 and analyzed as described in Section 3.7.3.8.

Figure 11.3-1: Gaseous Radioactive Waste System Diagram



11.4 Solid Waste Management System

The solid waste management system is called the solid radioactive waste system (SRWS). The SRWS is designed to process both wet solid waste (WSW) and dry solid waste (DSW) from various plant systems produced during normal operation and anticipated operational occurrences, including startup, shutdown, and refueling operations. The Radioactive Waste Building (RWB) has adequate space for onsite storage for various solid waste containers plus space for mobile processing equipment. The SRWS includes the WSW system, DSW system, mixed waste system, and an onsite storage area.

The design basis source term identified in Section 11.1 forms the basis for the shielding design. The shield wall thickness evaluation assumes that the spent filters and spent resins fully loaded using the design basis source term. Section 12.3 discusses additional details on the shielding design.

The wet and dry radioactive solid waste packaged for offsite shipment and disposal complies with the requirements of 10 CFR 61.55, 10 CFR 61.56, 10 CFR 71 and 49 CFR 171-180, as applicable.

Onsite storage allows for radioactive decay with adequate storage in case of processing, maintenance or transportation delays. Onsite storage is adequate to hold solid waste for at least 30 days in accordance with ANSI/ANS-55.1-1992 (Reference 11.4-1) and BTP 11-3. The SRWS meets the design recommendations of BTP 11-3.

The SRWS and associated handling areas have area radiation monitoring equipment to detect excessive radiation or airborne levels and initiate appropriate alarms and procedural actions to maintain radiation exposure as low as reasonably achievable (ALARA). Section 12.3 provides additional information on area radiation monitors.

11.4.1 System Description

The SRWS is a nonsafety-related system, serves no safety-related functions, and is not risk-significant. Table 11.4-5 identifies SSC classifications for the SRWS. The SRWS is designed to

- collect, process, sample, package, and store WSW generated from the chemical and volume control system (CVCS), pool cooling and cleanup system, and liquid radioactive waste system (LRWS), using both permanently installed and mobile equipment in the SRWS.
- collect, segregate, sample, package, and store compactible and non-compactible DSW.
- collect, sample, segregate, package, and ship mixed and oily wastes.
- provide sufficient storage space for packaged solid wastes.
- process and package waste into disposal containers that are approved by the Department of Transportation and are acceptable to licensed waste disposal facilities for offsite shipment and burial.

- meet federal regulations and protect the worker and the general public from radiation by maintaining dose levels ALARA.
- transfer liquid wastes to the RWDS or LRWS.

The SRWS design handles three types of generated wastes: WSWs, DSWs, and miscellaneous wastes.

The boundaries of the SRWS begin at the connection to a particular waste stream source and end at the packaged waste container offsite shipment. For WSW, these connections usually involve flanged joints, and boundary valves at the system inlets. For DSW, the boundaries are not always physical because much of DSW is collected from a variety of locations and transported through corridors to the solid radioactive waste sorting area.

For spent resins and granular activated charcoal, the SRWS starts downstream of the boundary valve from each demineralizer and carbon bed. Operators sluice spent resin into the SRSTs or PSTs for decay, and to waste containers.

For spent cartridge filters, the SRWS starts at the filter extraction point. Operators remove the spent filter from the filter housing and place it in a shielded spent filter transfer cask.

11.4.1.1 Dry Solid Waste

Dry solid waste includes heating ventilation and air conditioning filters, tools and equipment, used personnel protective equipment, rags, paper, wood and miscellaneous cleaning supplies. Figure 11.4-1 summarizes the DSW handling and storage operation.

During some anticipated operational occurrences, such as refueling, the rate of DSW generation is higher than during normal operations. Major equipment items, such as core components and containment vessel components, are not processed in the SRWS.

11.4.1.2 Wet Solid Waste

The WSW processing system receives and processes three major waste streams:

- radioactive spent resin and spent charcoal
- spent cartridge filters
- filter membranes and reverse osmosis

The WSW is homogenized, sampled, and analyzed to classify the waste in accordance with 10 CFR 61. Operators transfer spent resin and spent charcoal to high integrity containers (HICs) that are connected to a dewatering system located inside a confined enclosure.

Operators cap and seal containers after dewatering, and survey and decontaminate the containers, as necessary, to meet 49 CFR 173 requirements.

If operational conditions develop such that condensate polisher demineralizer resins require removal as contaminated waste, operators transfer resins to HICs or other suitable containers and transfer the containers to the SRWS area for processing and storage.

In accordance with BTP 11-3, components and piping that contain slurries have flushing capabilities via the LRW clean-in-place skid or directly from the demineralized water break tank. The spent resin storage and PSTs are ASME Section VIII tanks that can use compressed service air to pressurize the tanks and pneumatically transport resin to a HIC. The associated pressure relief valves on the spent resin storage and PSTs are vented to the tank's cubicle, which are vented to the RWBVS. The hooded vents on the SRWS PST and SRST consist of tank vent piping that terminates below a vent hood and directs air into the RWBVS. The vent piping exiting the storage tanks contains an internal screen designed to prevent solids (i.e., resin) from escaping. An air gap between the tank vent piping and the vent hood minimizes contamination from entering the RWBVS. Liquid overflow flows out of a vent pipe into shielded cubicles lined with stainless steel.

Figure 11.4-2a and Figure 11.4-2b are process flow diagrams of the spent resin handling system.

To avoid the generation of explosive gas mixtures and exothermic reactions, the upstream systems (LRWS, pool cooling and cleanup system, CVCS) that transfer resins to the SRST or phase separator tank (PST) do not use chemicals (e.g., nitrates, nitrites) that can generate exothermic reactions with resins.

The main source of oily waste is expected to come from floor drains. Operators direct the oil to the SRWS from the LRWS oil separators and manually collect it in drums. The drums of contaminated oil are sent to an offsite treatment facility.

11.4.1.3 Mixed Waste Handling

Mixed waste is a combination of radioactive waste mixed with Resource Conservation and Recovery Act-listed hazardous waste as defined in 40 CFR 261 Subpart D. The generation of mixed waste volume is expected to be low. Mixed waste can only be disposed of in a permitted mixed waste disposal facility. Operators collect mixed waste near the source and transfer in drums to a permitted facility.

11.4.1.4 Packaging, Storage, and Shipping

The Process Control Program (PCP) classifies waste as Class A, Class B, Class C, or greater than Class C in accordance with 10 CFR 61.55 and 10 CFR 61.56. Table 11.4-2 and Table 11.4-3 provide the expected annual volumes of solid waste and shipment offsite estimates. The packaging and shipment of radioactive solid waste for disposal complies with 10 CFR 20, Appendix G, 10 CFR 61.56, and 49 CFR 173, Subpart I.

The RWB provides space for both Class A and Class B/C waste storage. Solid waste is typically stored below grade on the lower level. There is a storage area on the upper level for Class A waste. At the expected waste generation rates, there is storage capacity for at least 30 days.

The design and construction of SRWS components are in compliance with the codes and standards provided in RG 1.143. Each component is classified as RW-IIa, RW-IIb or RW-IIc based on the radionuclide content compared against the A_1 and A_2 values tabulated in 10 CFR 71, Appendix A. The safety classification for the SRWS components applies to components, up to and including the nearest isolation device. Table 11.4-1 provides design parameters for each of the major components.

11.4.1.4.1 Piping and Valves

The SRWS piping material is stainless steel and is butt-welded to minimize crud traps. Backing rings are not allowed in SRWS piping. Slurry transport lines are sized to maintain a flow velocity to prevent the slurry from settling and utilize bends of five pipe diameter radius. Slurry lines are also sloped to promote complete drainage and are connected to the clean-in-place skid and directly to the demineralized water break tank to allow flushing and cleaning of SRWS piping and components after batch operations. Piping is also arranged to minimize tees, pipe branches, and dead legs. The SRWS valves are stainless steel, remote air-operated valves. Valves in slurry transfer lines are full-ported ball valves and liquid process valves are diaphragm valves.

11.4.1.4.2 Dewatering System

The dewatering system is a skid-based, vendor-supplied package that removes free-standing water from waste packages to meet transportation and disposal requirements. The fillhead portion of the dewatering system includes an exhaust vent with high-efficiency particulate air filtration routed to the Radioactive Waste Building HVAC system (RWBVS) to control airborne contamination. Liquid removed by the dewatering system is routed to the LRWS low-conductivity waste collection tank. The dewatering system and associated connections to permanent plant equipment, including non-contaminated utilities, complies with IE Bulletin 80-10, Regulatory Guide 1.143, ANSI/ANS-55.1-1992 (Reference 11.4-1), and ANSI/ANS-40.37-2009 (Reference 11.4-2).

11.4.1.5 Effluent Controls

The SRWS does not release effluents directly to the environment. Liquids removed from solid waste processing are transferred to the LRWS for further processing.

During the operation of the SRWS, such as processing and packaging solid waste, the expelled air is captured by the RWBVS to prevent unmonitored contamination being released to the environment.

11.4.1.6 Site-Specific Cost-Benefit Analysis

Because the SRWS does not release effluents to the environment, a cost-benefit analysis is not performed separately from the evaluations in Section 11.2 and Section 11.3.

11.4.1.7 Mobile or Temporary Equipment

The design of SRWS includes modular equipment (e.g., spent resin dewatering system) and options for additional mobile equipment (e.g., shredders, laundry unit). The purpose of modular and mobile equipment is to provide ease of equipment replacement due to either advances in treatment technologies or equipment problems.

11.4.2 Radioactive Effluent Releases

The SRWS sends liquid and gaseous effluents to the LRWS and RWBVS, respectively. As a result, other than solid waste shipments offsite, the SRWS does not release effluents directly to the environment. The contributions to the offsite dose consequences from SRWS are included in the evaluations for LRW and gaseous radioactive waste systems in Section 11.2 and Section 11.3.

The SRWS design complies with the requirements of 10 CFR 20.1406. Section 12.3 discusses the SRWS design features to prevent the spread of contamination, facilitate decommissioning, and reduce the generation of radioactive waste.

The PCP follows the guidance of Nuclear Energy Institute 07-10A (Reference 11.4-3). The PCP describes the administrative and operational controls used for the solidification of liquid or WSW and the dewatering of WSW.

11.4.3 Malfunction Analysis

To demonstrate the design's resistance to failures, a malfunction analysis is performed. Table 11.4-4 summarizes this malfunction analysis.

11.4.4 Testing and Inspection Requirements

The SRWS is tested during plant pre-operations to ensure operation of components and processes as discussed in Section 14.2. During plant operations, the periodic testing and inspection requirements of RG 1.143 are performed to support continued proper operation of components.

11.4.5 References

11.4-1 American National Standards Institute/American Nuclear Society, "Solid Radioactive Waste Processing System for Light-Water-Cooled Reactor Plants," ANSI/ANS-55.1-1992, LaGrange Park, IL.

11.4-2 American National Standards Institute/American Nuclear Society, "Mobile Low-Level Radioactive Waste Processing Systems," ANSI/ANS-40.37-2009, LaGrange Park, IL.

11.4-3 Nuclear Energy Institute, "Generic FSAR Template Guidance for Process Control Program," NEI 07-10A, Revision 0, March 2009.

Table 11.4-1: List of Systems, Structures, and Components Design Parameters

Component (Quantity)	RG 1.143 Safety Classification	Standards	Type	Capacity	Design Pressure (psig)	Design Temperature (°F)	Material	Table for Assumed Radioactive Content
Spent resin storage tank (2)	RW-IIa	ASME BVPC Section VIII	Vertical Conical	10,000 gal	175	155	Austenitic Stainless Steel	12.2-18
SRST transfer pump (2)	RW-IIc	API-685	Sealless, centrifugal	75 gpm & 200 gpm	238	180	Austenitic Stainless Steel	-
Phase separator tank (2)	RW-IIa	ASME BVPC Section VIII	Vertical Conical	12,500 gal	175	155	Austenitic Stainless Steel	12.2-18
PST transfer pump (2)	RW-IIc	API-685	Sealless, centrifugal	75 gpm	238	180	Stainless Steel	-
Dewatering skid (1)	RW-IIc	ANS-55.1	-	35 gpm	238	180	Stainless Steel	-
Compactor (1)	-	ANS-55.1	-	40 ft^3	238	130	Stainless Steel	-

Table 11.4-2: Estimated Annual Volumes of Dry Solid Waste

Waste Classification	Sources and Waste Classification (A or B/C)	Volume Generated (ft^3/yr)	Container Type	Container Volume (ft^3)	No. of Containers (rounded off)
Class A	Filters	194	B-25 box	90	3
Class A	PPE/rags	2500	B-25 box	90	28
Class A	Tools	9	drum	7.4	2
Total Class A		2700			
Class B/C	Failed equipment	14	drum	7.4	2

Table 11.4-3: Estimated Annual Volumes of Wet Solid Waste

Waste Classification	Sources	Volume Generated (ft^3/yr)	Container Type	Container Volume (ft^3)	No. of Containers (rounded off)
Class B/C	Resin	320	HIC	120	3
Class B/C	Cartridge Filters	26	HIC	120	1
Class B/C	Membrane Filters	4	Drum	7.4	1
Total Class B/C		350			
Class A	Resin/Activated Charcoal	940	HIC	120	9
Class A	Filters	4	Drum	7.4	1
Class A	self-contained filter	24	IP-1	24	1
Total Class A		970			

Table 11.4-4: Solid Radioactive Waste System Equipment Malfunction Analysis

Equipment Item	Malfunction	Results (Consequences)	Mitigating or Alternate Actions
Spent Resin Storage Tank	Tank failure	There are two Spent Resin Storage Tanks to collect Class B/C spent resins from the PCW and the CVC ion exchangers. The PCW/CVC demineralizers would not be able to send spent resins to the Spent Resin Storage Tanks for processing.	If one of the tanks fail, the other tank can receive the PCW and CVC resins. Alternate action includes direct sluicing to the Dewatering Skid.
Spent Resin Transfer Pump	Pump failure	There are two Spent Resin Transfer Pumps with one pump dedicated to each Spent Resin Storage Tank. The consequence would be that liquid waste could not be transferred to the LRW collection tanks and the pumps would not be able to transfer spent resin to the Spent Resin Storage Tanks or HICs.	The tank transfer line is cross-connected to the pump suction, allowing the process to continue using the redundant pump when one pump fails[1].
Phase Separator Tank	Tank failure	There are two Phase Separator Tanks to collect Class A spent media. The LRW processing equipment or CVC auxiliary ion exchangers would not be able to transfer spent media to the phase separator tanks or the HIC.	If one tank fails, the other tank would continue to receive spent media. Alternate action includes direct sluicing to the Dewatering Skid.
Phase Separator Transfer Pump	Pump failure	There are two pumps, with one pump dedicated to each tank. The consequence would be that liquid waste could not be transferred to the LRW collection tanks and the pumps would not be able to be used to transfer spent resin to the Phase Separator Tank or HICs.	The separator transfer line is cross connected to the pump suction. The other pump allows processing to continue when one pump fails[1].
Dewatering Skid	Skid component failure	The major components for the Dewatering Skid are not equipped with standby units. Excess liquid waste from the HIC cannot be extracted using the dewatering pump. If the level control valve on the dewatering skid fails, the HIC may be overflowed.	No impact on collection of WSW. The Phase Separator Tanks or the Spent Resin Storage Tanks can store the waste until dewatering skid components are repaired or replaced. The HICs are equipped with a camera on the fill head to monitor the HIC level. The video monitors external leaks associated with the HIC.
High Integrity Container	Container is dropped during transportation	HICs are transported between the fill station, storage area, and truck bay area. Dropping a HIC can cause local contamination. The floor drains in the area collect the liquid; however, the solid portion needs to be removed by a shop vacuum.	The grapple assembly has limit switches to ensure all the legs are engaged prior to lifting the HIC. In addition, the crane has its own safety brake system to ensure the HIC is not dropped during the power failure.
Spent Resin Storage Tanks and Phase Separator Tanks	Service Air Supply	The tanks cannot be pressurized to perform pneumatic sluicing. The Spent Resin Storage Tanks and Phase Separator Tanks would not be able to send spent resins to the HICs for shipping offsite.	If one service air compressor fails, the backup service air compressor is used to pressurize the tanks to complete the sluicing[2]. If service air fails during the resin transfer, the lines are flushed to the HIC and system is restored to standby position.

Table 11.4-4: Solid Radioactive Waste System Equipment Malfunction Analysis (Continued)

Equipment Item	Malfunction	Results (Consequences)	Mitigating or Alternate Actions
Dewatering Skid hoses	Hose ruptures or flange failure	The dewatering room is contaminated, and resin slurry enters the drainage system.	The video in the room shows the hoses connected to the HIC and dewatering operation. Operation is stopped manually, and affected hose is replaced after decontaminating the area.

Notes:

1. Pumps are provided with drain connections to the RWD to prevent the spread of contamination from leaks or from repairs.
2. Service air compressors are part of the service air system (SAS). Section 9.3 contains information on the SAS.

Table 11.4-5: Classification of Structures, Systems, and Components

SSC (Note 1)	Location	SSC Classification (A1, A2, B1, B2)	Augmented Design Requirements (Note 2)	Quality Group/Safety Classification (Ref RG 1.26 or RG 1.143) (Note 3)	Seismic Classification (Ref. RG 1.29 or RG 1.143) (Note 4)
SRWS, Solid Radioactive Waste System					
All components (except those listed below)	RWB/RXB	B2	RG 1.143	RW-IIc	III
Phase separator tank (including strainers and valves) Spent resin storage tank (including strainers and valves)	RWB	B2	RG 1.143	RW-IIa	RW-IIa
Instrumentation	RWB	B2	None	N/A	III

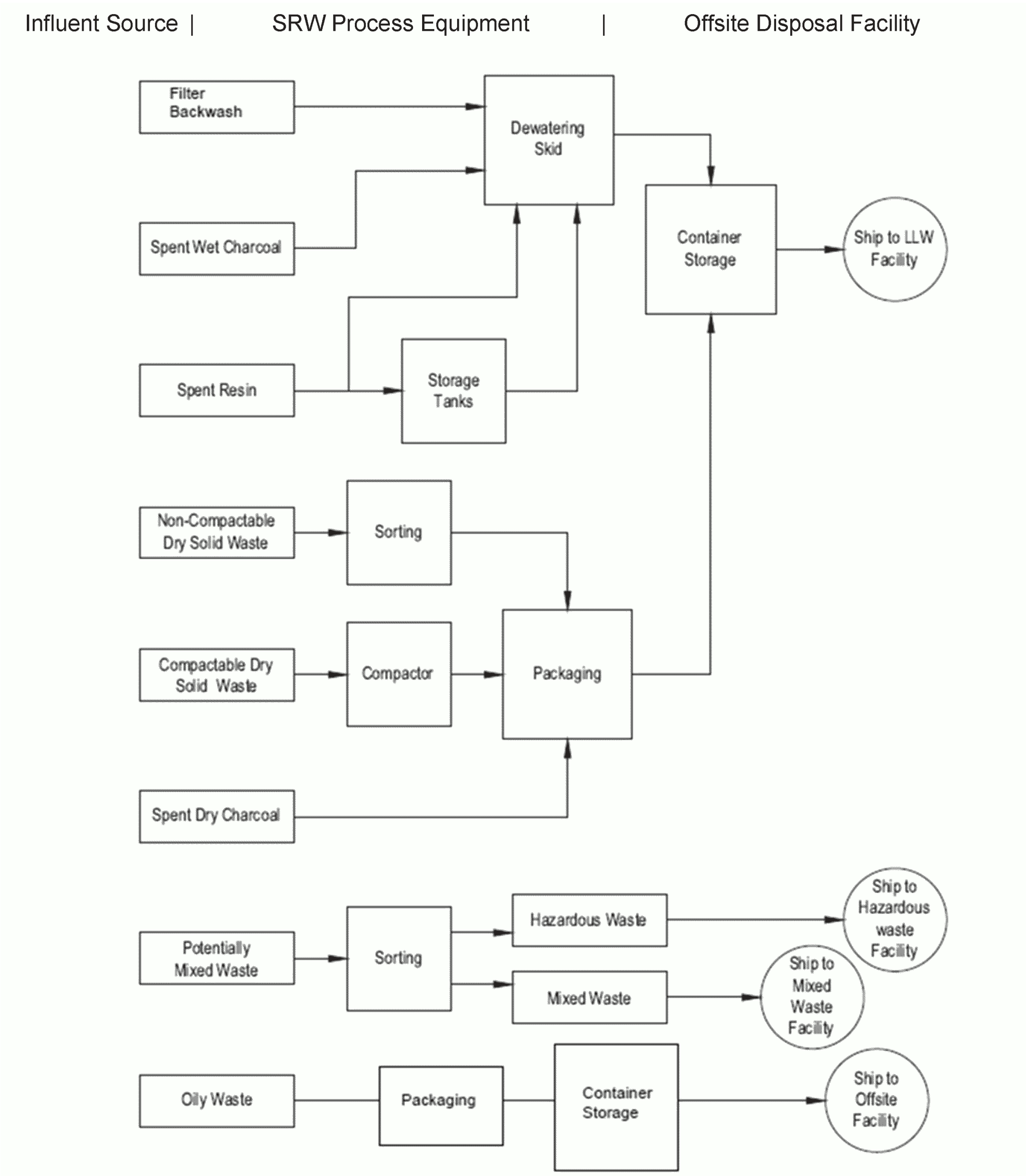
Note 1: Acronyms used in this table are listed in Table 1.1-1

Note 2: Additional augmented design requirements, such as the application of a Quality Group, Radwaste safety, or seismic classification, to nonsafety-related SSC are reflected in the columns Quality Group / Safety Classification and Seismic Classification, where applicable. Environmental Qualifications of SSC are identified in Table 3.11-1.

Note 3: Section 3.2.2.1 through Section 3.2.2.4 provides the applicable codes and standards for each RG 1.26 Quality Group designation (A, B, C, and D). A Quality Group classification per RG 1.26 is not applicable to supports or instrumentation. Section 3.2.1.4 provides a description of RG 1.143 classification for RW-IIa, RW-IIb, and RW-IIc.

Note 4: Where SSC (or portions thereof) as determined in the as-built plant that are identified as Seismic Category III in this table could, as the result of a seismic event, adversely affect Seismic Category I SSC or result in incapacitating injury to occupants of the control room, they are categorized as Seismic Category II consistent with Section 3.2.1.2 and analyzed as described in Section 3.7.3.8.

Figure 11.4-1: Block Diagram of the Solid Radioactive Waste System



Notes:

1) The Drum Dryer skid is part of the LRW. Filled, 55-gallon drums are transferred to the SRW for storage ("Container Storage") and eventual disposal.

2) Oily waste is part of the LRWS. Oily waste influent from the LRWS is packaged in 55-gallon drums in the RWB and then shipped offsite.

Figure 11.4-2a: Process Flow Diagram for Wet Solid Waste

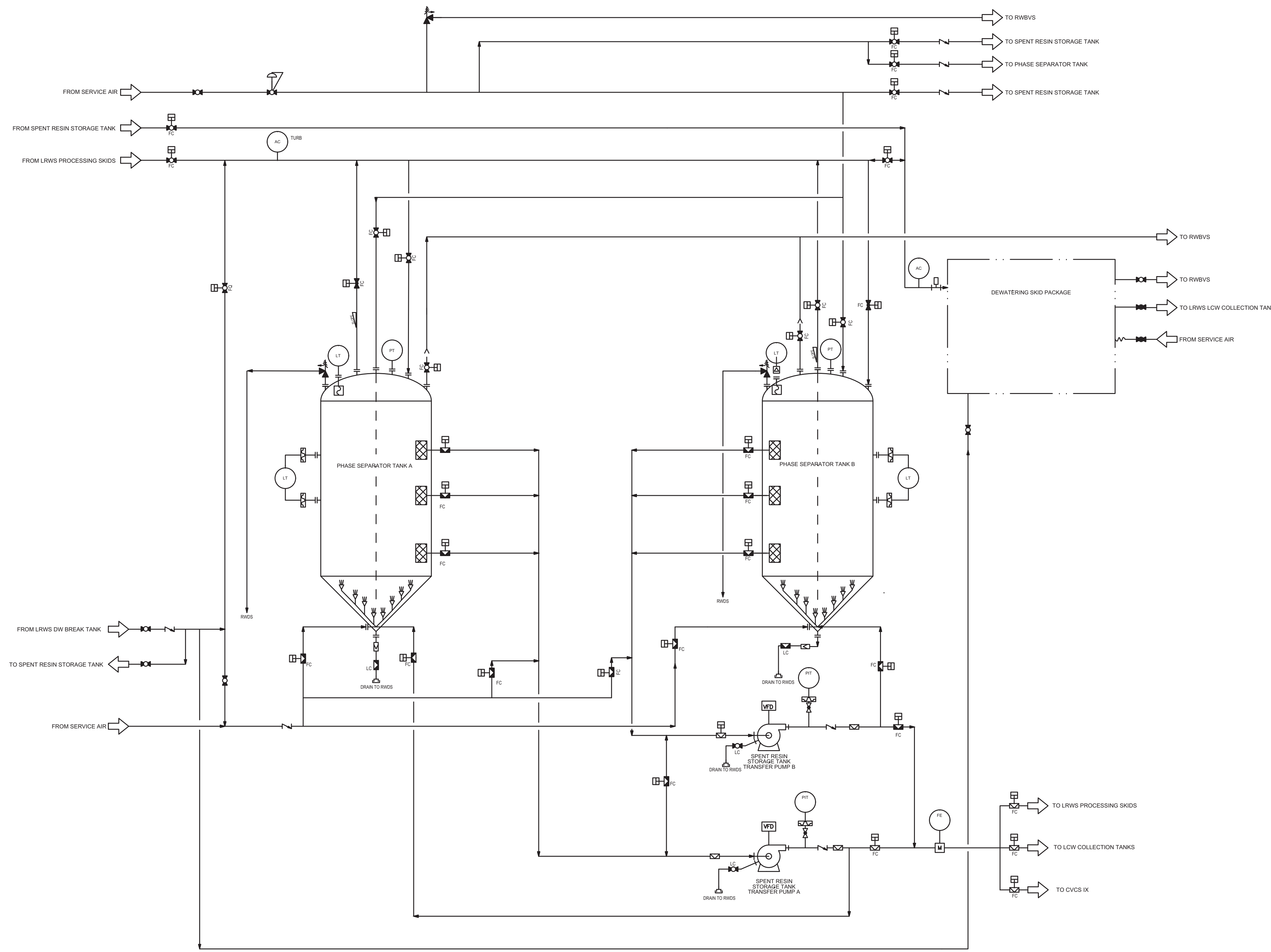
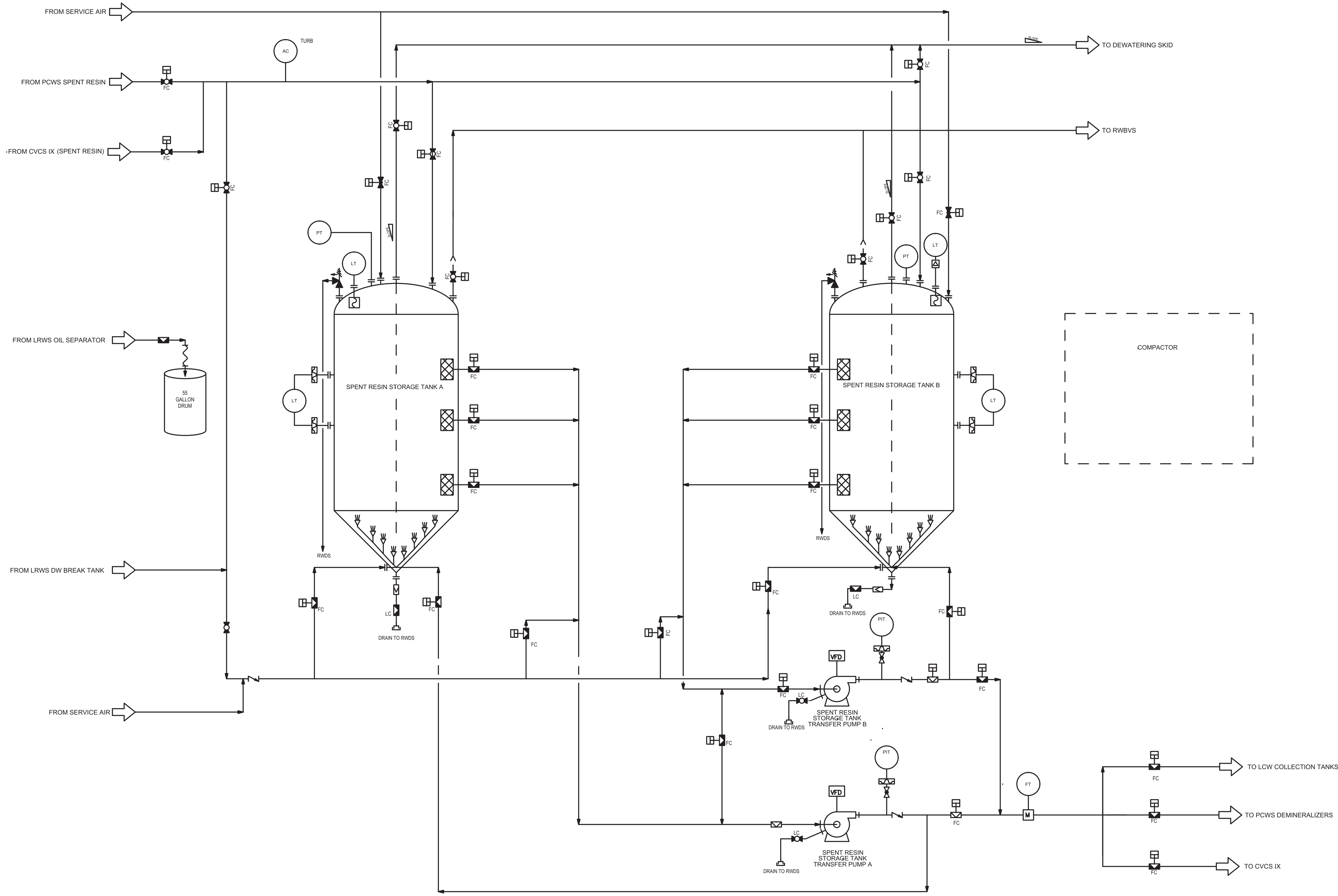


Figure 11.4-2b: Solid Radioactive Waste System Diagram



11.5 Process and Effluent Radiation Monitoring Instrumentation and Sampling System

The process and effluent radiological monitoring instrumentation and sampling design features provide the ability to detect and determine the content and, where required, the concentration and release rate of radioactive material in various gaseous and liquid process and effluent streams. The design features facilitate radiation monitoring and control, archiving, alarm functions and, where required, isolation and actuation functions to support the design objectives of the related system. The monitoring of in-plant radiation and airborne radioactivity is performed by the area radiation monitoring instrumentation described in Section 12.3.4.

11.5.1 System Description

Effluent Radiation Monitoring is provided for:

- Air cooled condenser system (ACCS) (Section 10.4.1)
- Liquid radioactive waste system (LRWS) (Section 11.2)
- Pool cooling and cleanup system (PCWS) (Section 9.1.3)
- Reactor Building HVAC system (RBVS) (Section 9.4.2)
- Site cooling water system (SCWS) (Section 9.2.7)
- Utility water system (UWS) (Section 9.2.9)

Process Radiation Monitoring is provided for:

- Auxiliary boiler system (ABS) (Section 10.4.7)
- Balance-of-plant drain system (BPDS) (Section 9.3.3)
- Chemical and volume control system (CVCS) (Section 9.3.4)
- Condensate polisher resin regeneration system (CPS) (Section 10.4.5)
- Containment evacuation system (CES) (Section 9.3.6)
- Containment flooding and drain system (CFDS) (Section 9.3.7)
- Normal control room HVAC system (CRVS) (Section 9.4.1)
- Demineralized water system (DWS) (Section 9.2.3)
- Gaseous radioactive waste system (GRWS) (Section 11.3)
- Main steam system (MSS) (Section 10.3)
- Reactor component cooling water system (RCCWS) (Section 9.2.2)
- Radioactive Waste Building HVAC system (RWBVS) (Section 9.4.3)
- Radioactive waste drain system (RWDS) (Section 9.3.3)
- Turbine generator system (TGS) (Section 10.2)

The following tables and figures provide a summary of radiological monitoring:

- Detector information including number, type, location, and measurement range is provided in Table 11.5-1.

- Provisions for sampling are described in Table 11.5-2 and Table 11.5-3 for gaseous and liquid process streams, respectively.
- Effluent and process monitoring off-normal radiation conditions are described in Table 11.5-4.
- Figure 11.5-1a and Figure 11.5-1b present an integrated plant radiological monitoring drawing.
- Figure 11.5-2 provides a logic block diagram for radiation monitoring.
- Figure 11.5-3 provides an off-line radiation detection drawing.
- Figure 11.5-4 provides a process radiation adjacent-to-line detection drawing.
- Figure 11.5-5 provides a process radiation in-line detection drawing.
- Figure 11.5-6 provides a plant exhaust stack effluent radiation detection drawing.

Monitoring and operator response for effluent and process radiation monitors is performed in accordance with site procedures. Controls ensure that gaseous effluent content meet the objectives of 10 CFR 50 Appendix I and 10 CFR 20 before being released into the environment, and ensures compliance with GDC 60, 63, and 64.

Setpoints for radiation alarms (Section 11.5.1.2) and automated function initiation (Section 11.5.1.3) are based on ensuring that the limitations of 10 CFR 20 and 10 CFR 50 are met for plant conditions. Additionally, the alarms and isolations ensure compliance with GDC 60, 61, 63 and 64, and the applicable 10 CFR 20 and 10 CFR 50 requirements and limitations.

The ability to isolate and sample potentially contaminated systems ensures compliance to the occupation exposure limits in accordance with 10 CFR 20.1201 and 10 CFR 20.1202, and limits the spread of contamination per 10 CFR 20.1406.

Stack flow measurement capability supports the consideration of atmospheric dispersion (χ/Q) and deposition (D/Q) factors when developing alarm setpoints.

The RBVS plant exhaust stack flow rate and noble gas, particulate, and halogen activity indications are post-accident monitoring system variables as described in Table 7.1-7.

11.5.1.1 Reliability and Quality Assurance

The quality assurance controls for digital computer software used in radiation monitoring and sampling equipment is described in Section 7.2.

Programs and procedures for the control of measuring and test equipment are administered per the quality assurance program described in Section 17.5.

11.5.1.2 Effluent Instrumentation Alarm Setpoints

Effluent alarm setpoints are determined in accordance with the guidance of NUREG-1301 and NUREG-0133 such that effluent releases to unrestricted areas do not exceed those in 10 CFR 20 Appendix B, Table 2. The bases for establishing the alarm and trip setpoints for the initiating actions are documented in the Offsite Dose Calculation Manual (ODCM), with consideration given to site-specific liquid effluent dilution factors and gaseous effluent atmospheric dispersion conditions.

11.5.1.3 Effluent Release Controls

The gaseous and liquid effluent control for the plant is described in the ODCM and includes a description of how effluent release rates are derived and parameters used in setting instrumentation alarm setpoints to control or terminate effluent releases in unrestricted areas that are above the effluent concentrations in Table 2 of Appendix B to 10 CFR Part 20.

11.5.1.4 Offsite Dose Calculation Manual and Radiological Environmental Monitoring Program

The ODCM contains a description of the methodology and parameters used for calculation of offsite doses for gaseous and liquid effluents. The ODCM also contains the planned effluent discharge flow rates and addresses the numerical requirements of 10 CFR 50, Appendix I.

The ODCM and Radiological Environmental Monitoring Program are developed and implemented in accordance with the recommendations and guidance of NEI 07-09A (Reference 11.5-2).

11.5.1.5 Process and Effluent Monitor Ranges

The process and effluent radiation monitor instrument ranges are based on 10 CFR 20, Appendix B, and Regulatory Guides 1.21, 1.45, and 1.97.

11.5.2 References

11.5-1 American National Standards Institute/Health Physics Society, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities," ANSI/HPS N13.1-2011, Washington, DC.

11.5-2 Nuclear Energy Institute, "Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM) Program Description," NEI 07-09A, Revision 0, March 2009.

Table 11.5-1: Process and Effluent Radiation Monitoring Instrumentation Characteristics

System	Quantity	Type	Service	Isotopes	Measurement Range	Location/Function	Safety-related	Media	Instrument type
ABS	1	γ	ABS Skid Vent ATM	Cs-137	3E-10 to 1E-6 μCi/cc	ABS Skid Vent to Atmosphere	No	Gas	Off-line (PING)
		γ		I-131	3E-10 to 5E-8 μCi/cc				
		β		Kr-85 Xe-133	3E-7 to 1E-2 μCi/cc				
		γ		Ar-41	1E-7 to 1E-1 μCi/cc				
ABS	1	γ	ABS/Superheater skid BPDS Outlet	Ar-41	1E-7 to 1E-1 μCi/cc	ABS/Superheater Skid BPDS Outlet	No	Gas	Adjacent-to-line
ABS	1	γ	ABS Skid to AB Superheater Skid Vent	Cs-137	3E-10 to 1E-6 μCi/cc	ABS/Superheater Skid BPDS Vent	No	Gas	Off-line (PING)
		γ		I-131	3E-10 to 5E-8 μCi/cc				
		β		Kr-85 Xe-133	3E-7 to 1E-2 μCi/cc				
		γ		Ar-41	1E-7 to 1E-1 μCi/cc				
ABS	1	γ	Auxiliary Steam to BPD	Ar-41	1E-7 to 1E-1 μCi/cc	Auxiliary Steam to BPDS	No	Gas	Adjacent-to-line
ABS	1	γ	TGB Auxiliary Steam Header	Ar-41	1E-7 to 1E-1 μCi/cc	TGB Auxiliary Steam Header	No	Gas	Adjacent-to-line
ACCS	6	γ	SJAE Gaseous Effluent	Ar-41	1E-6 to 1E-1 μCi/cc	SJAE Vent Air Evacuation Line	No	Gas	Adjacent-to-line
ACCS	1	γ	LRVP Gaseous Effluent	Ar-41	1E-6 to 1E-1 μCi/cc	LRVP Vent Air Evacuation Line	No	Gas	Adjacent-to-line
ACCS	1	β	CARS Common Vent Air Evacuation Line	Cs-137	3E-10 to 1E-6 μCi/cc	CARS Common Vent Air Evacuation Line	No	Gas	Off-line (PING)
		γ		I-131	3E-10 to 5E-8 μCi/cc				
		β		Kr-85 Xe-133	3E-7 to 1E-2 μCi/cc				
		γ		Ar-41	1E-6 to 1E-1 μCi/cc				
BPDS	1	γ	Turbine Building Floor Drains Radiation	Cs-137	1E-7 to 1E-2 μCi/ml	Turbine Building Floor Drains Radiation	No	Liquid	In-line
BPDS	1	γ	Condensate Regeneration Skid	Cs-137	1E-7 to 1E-2 μCi/ml	Condensate Regeneration Skid	No	Liquid	In-line
BPDS	1	γ	Aux Boiler Blowdown	Cs-137	1E-7 to 1E-2 μCi/ml	Aux Boiler Blowdown	No	Liquid	In-line
CES	6	γ	Sample Tank Liquid Radiation	Cs-137	1E-7 to 1E-1 μCi/ml	Sample Tank Liquid Radiation	No	Liquid	Adjacent-to-line

Table 11.5-1: Process and Effluent Radiation Monitoring Instrumentation Characteristics (Continued)

System	Quantity	Type	Service	Isotopes	Measurement Range	Location/Function	Safety-related	Media	Instrument type
CES	6	γ γ β	Gaseous Discharge Particulate, Noble Gas, Iodine Radiation	Cs-137 I-131 Kr-85 Xe-133	3E-10 to 1E-6 μCi /cc 3E-10 to 5E-8 μCi /cc 3E-7 to 3E-2 μCi /cc	Gaseous Discharge Particulate, Noble Gas, Iodine Radiation	No	Gas	Off-line (PING)
CES	6	γ	Gaseous Discharge Ar-41 Radiation	Ar-41	1E-7 to 1E-1 μCi /cc	Gaseous Discharge Ar-41 Radiation	No	Gas	Off-line
CFDS	1	β	CFDS Drain Separator Gas Discharge	Kr-85 Xe-133	3E-7 to 1E-2 μCi /cc	CFDS radiation flow to HEPA filter	No	Gas	Off-line
CPS	1	γ	Resin Transfer Radioisotope concentration	Cs-137	1E-7 to 1E-2 μCi /ml	Turbine Generator Building (TGB)/Condenser Polisher Resin Regen Skid Inlet	No	Liquid	Adjacent-to-line
CPS	1	γ	Regeneration Sump Radioisotope Concentration	Cs-137	1E-7 to 1E-2 μCi /ml	TGB/Regeneration Sump	No	Liquid	Adjacent-to-line
CRVS	2	γ	CRVS Outside Air Intake Radiation Monitor	Kr-85 Xe-133	1E-5 to 1E+1 Rad/hr	Outside Air Intake	No	Air	Off-line
CRVS	2	γ γ β	CRE Supply Air Radiation	Cs-137 I-131 Kr-85 Xe-133	3E-10 to 1E-4 μCi /cc 1E-9 to 1E+2 μCi /cc 4E-5 to 1E+4 μCi /cc	CRE Supply Duct	No	Gas	Off-line (PING)
CVCS	6	γ	RPV Supply to regenerative heat exchanger (RHX) Cooling Inlet Radiation	Cs-137	1E-7 to 1E-2 μCi /ml	RPV Supply to RHX Cooling Inlet Radiation	No	Liquid	Adjacent-to-line
DWS	1	γ	DW North Reactor Building (RXB) Contaminated Header Radiation	Cs-137	1E-7 to 1E-2 μCi /ml	DW North RXB Contaminated Header Radiation	No	Liquid	Off-line
DWS	1	γ	DW South RXB Contaminated Header Radiation	Cs-137	1E-7 to 1E-2 μCi /ml	DW South RXB Contaminated Header Radiation	No	Liquid	Off-line
GRWS	2	β	Charcoal Decay Bed Skid A/B Outlet Radiation	Kr-85 Xe-133	3.0E-7 to 1.0E-2 μCi/ml	GRW Charcoal Decay Bed Skid A/B Outlet Radiation	No	Gas	Off-line

Table 11.5-1: Process and Effluent Radiation Monitoring Instrumentation Characteristics (Continued)

System	Quantity	Type	Service	Isotopes	Measurement Range	Location/Function	Safety-related	Media	Instrument type
GRWS	1	β	GRW Outlet Radiation	Kr-85 Xe-133	3.0E-7 to 1.0E-2 µCi/ml	GRW Outlet Radiation	No	Gas	Off-line
LRWS	2	γ	LRWS LCW Processing to UW radiation	Cs-137	1.0E-7 to 1.0E-2 µCi/ml	LWR discharge path	No	Liquid	Adjacent to-line
MSS	6	γ	SG1 Main Steam Line Radiation	Ar-41	1.0E-7 to 1.0E-1 µCi/cc	Main Steam Line 2 per steam header in the RXB	No	Gas	Adjacent to-line
MSS	6	γ	SG2 Main Steam Line Radiation	Ar-41	1.0E-7 to 1.0E-1 µCi/cc	Main Steam Line 2 per steam header in the RXB	No	Gas	Adjacent to-line
PCWS	1	β	Surge Control Storage Tank Vent	Kr-85 Xe-133	3.0E-7 to 1.0E-2 µCi/ml	Monitor the PCWS surge control storage tank vent line on PCWS	No	Gas	Off-line
RBVS	1	γ γ β	Spent Fuel Pool (SFP) Exhaust Filter Upstream Radiation	Cs-137 I-131 Kr-85 Xe-133	3E-10 to 1E-6 µCi/cc 3E-10 to 5E-8 µCi/cc 3E-7 to 1E-2 µCi/cc	SFP Exhaust Filter Upstream	No	Gas	Off-line (PING)
RBVS	1	γ γ	Reactor Pool and Gallery Area Exhaust	Cs-137 I-131	3E-10 to 1E-6 µCi/cc 3E-10 to 5E-8 µCi/cc	Reactor Pool and Gallery Area Exhaust	No	Gas	Off-line (PI)
RBVS	1	γ γ β	RBVS Exhaust Stack	Cs-137 I-131 Kr-85 Xe-133	1E-7 to 1E-2 µCi/cc 3E-10 to 1E-6 µCi/cc 3E-7 to 1E+4 µCi/cc	RBVS Exhaust Stack	No	Gas	Off-line (PING)
RBVS	2	γ γ β	RBVS South and North Module Battery Rooms air-handling unit (AHU) Radiation	Cs-137 I-131 Kr-85 Xe-133	3E-10 to 1E-6 µCi/cc 3E-10 to 5E-8 µCi/cc 3E-7 to 1E-2 µCi/cc	RBVS North and South Module Battery Rooms AHU Radiation	No	Gas	Off-line (PING)
RBVS	1	γ γ β	SFP Exhaust Filter Upstream Radiation	Cs-137 I-131 Kr-85 Xe-133	3E-10 to 1E-6 µCi/cc 3E-10 to 5E-8 µCi/cc 3E-7 to 1E-2 µCi/cc	SFP Exhaust Filter Upstream	No	Gas	Off-line (PING)

Table 11.5-1: Process and Effluent Radiation Monitoring Instrumentation Characteristics (Continued)

System	Quantity	Type	Service	Isotopes	Measurement Range	Location/Function	Safety-related	Media	Instrument type
RCCWS	6	γ	RCCW CVCS Non-regenerative heat exchanger Outlet Radiation	CS-137	1E-7 to 1E-2 µCi/ml	Located in the RCCW-downstream of loads that have potential for a radioactive release to alert the control room when there is a leak in the RCCWS	No	Liquid	Adjacent-to-line
RCCWS	6	γ	RCCW CES Condenser and Vacuum Pumps Outlet Radiation	CS-137	1E-7 to 1E-2 µCi/ml	Located in the RCCWS downstream of loads that have potential for a radioactive release to alert the control room when there is a leak in the RCCWS	No	Liquid	Adjacent-to-line
RCCWS	1	γ	RCCW PSS Primary Sample Chiller Outlet Radiation	CS-137	1E-7 to 1E-2 µCi/ml	Located in the RCCWS downstream of all cooled components	No	Liquid	Adjacent-to-line
RWBVS	1	γ	RWBV Exhaust Radiation Monitoring Skid	CS-137	3E-10 to 1E-6 µCi/cc	Located in the RWBV main exhaust duct before connecting to the RBVS exhaust duct	No	Gas	Off-line (PI)
		γ		I-131	3E-10 to 5E-8 µCi/cc				
RWDS	1	γ	RXB RCCWS Drain Tank Radiation	Cs-137	1E-7 to 1E-2 µCi /ml	RCCWS drain tank	No	Liquid	Off-line
SCWS	3	γ	PCWS heat exchanger A/B/C Outlet Radiation	Cs-137	1E-7 to 1E-2 µCi /ml	Downstream of RXB Heat Exchangers/ PCWS outlet radiation	No	Liquid	In-line
SCWS	1	γ	CT Blowdown Radiation	C-137	1E-7 to 1E-2 µCi /ml	Cooling Tower Blowdown Line	No	Liquid	Off-line with Sampling
SCWS	2	γ	RCCW Heat Exchanger A/B Outlet Radiation	Cs-137	1E-7 to 1E-2 µCi /ml	Downstream of RXB Heat Exchangers/ RCCW outlet radiation	No	Liquid	In-line
TGS	6	γ	Gland Steam Outlet	Cs-137	3E-10 to 1E-6 µCi/cc	Turbine generator skid common exhaust vent point particulates	No	Gas	Off-line (PING)
		γ		I-131	3E-10 to 5E-8 µCi/cc				
		β		Kr-85 Xe-133	3E-7 to 1E-2 µCi/cc				
		γ		Ar-41	1E-6 to 1E-1 µCi/cc				

Table 11.5-1: Process and Effluent Radiation Monitoring Instrumentation Characteristics (Continued)

System	Quantity	Type	Service	Isotopes	Measurement Range	Location/Function	Safety-related	Media	Instrument type
UWS	1	γ	Letdown Line Radiation	Cs-137	1E-7 to 1E-2 μCi/ml	UWS effluent path	No	Liquid	Off-line
General Notes: (a) - Main control room monitoring available (b) - Waste management control room monitoring available (c) - Local Monitoring Available (d) - Designed to meet ANSI/HPS N13.1-2011 (Reference 11.5-1) PING - Particulate, Iodine, Noble Gas PI - Particulate, Iodine									

Table 11.5-2: Provisions for Sampling Gaseous Process and Effluent Streams

No.	Gaseous Process or Waste System	Sample Provisions[a]	
		Process	Effluent
1	Auxiliary Boiler System	I, S&A	
2	Air Cooled Condensing System	I, S&A	S&A
3	Containment Evacuation System	I, S&A	
4	Control Room HVAC System	I	
5	Containment Flooding Drain System	S&A	
6	Gaseous Radioactive Waste System	I	
7	Main Steam System	S&A	
8	Pool Cooling & Clean Up System	S&A	S&A, H3
9	Radioactive Waste Building HVAC System	I	-
10	Reactor Building HVAC System	I	NG, H3
11	Reactor Building HVAC System (Spent Fuel Area)	I	
12	Turbine Generator System	I, S&A	

(a) - Sample point is available to obtain grab samples for laboratory analyses.
NG - Noble gas radioactivity
I - Iodine radioactivity
H3 - Tritium
S&A - Sampling and analysis of radionuclides, including gross radioactivity, identification, and concentration of principal or significant radionuclides, and concentration of alpha emitters.

Table 11.5-3: Provisions for Sampling Liquid Process and Effluent Streams

No.	Liquid Process or Waste System	Sample Provisions[(a)]	
		Process	Effluent
1	Balance of Plant Drain System	S&A, H3	-
2	Containment Evacuation System[(c)]	S&A	-
3	Condensate Polisher Resin Regeneration System	S&A	-
4	Chemical and Volume Control System	S&A, H3	-
5	Demineralized Water System	S&A, H3	-
6	Liquid Radioactive Waste System[(b)]	S&A	S&A, H3
8	Reactor Component Coolant Water System	S&A	
9	Radioactive Waste Drain System[(b)]	S&A	-
10	Site Cooling Water System	S&A	S&A, H3
11	Utility Water System	S&A	S&A,H3

(a) - Sample point is available to obtain grab samples for laboratory analyses.
(b) - The provisions for sampling potentially contaminated system and the use of the RWDS and LRWS for waste collection in the Reactor Building ensure compliance to occupational exposure limits in accordance with 10 CFR 20.1201 and 10 CFR 20.1202, and limit contamination per 10 CFR20.1406.
(c) - An installed mechanical liquid grab sampler located downstream of the CES sample vessel allows for the samples to be taken and analyzed in the laboratory for a more finite definition of the radionuclide content of the condensate, and to serve as a redundant means of measuring process radiation level. The mechanical sampler is designed to conform with RGs 8.8 and 8.10 and enhance plant staff capability to meet ALARA goals and contamination control in accordance with 10 CFR 20.1406. Compliance with RG 1.45 requirements and the capabilities of the CES sample vessel are discussed in Section 5.2.5.
NG -Noble gas radioactivity
I - Iodine radioactivity
H3 - Tritium
S&A -Sampling and analysis of radionuclides, including gross radioactivity, identification and concentration of principal or significant radionuclides, and concentration of alpha emitters.

Table 11.5-4: Effluent and Process Monitoring Off Normal Radiation Conditions

System	Condition	System Response
ABS	Radiation Detected	If high radiation is detected in the auxiliary boiler system skid vents, skid drains, or steam header drains, then the auxiliary boiler superheater skid outlet valve closes, auxiliary boiler skid to superheater skid valve closes, the module-specific main steam to auxiliary boiler header valves close, and the MCR receives an alarm.
BPDS	High Radiation	Upon alarm, the wastewater collection tank pumps are shut down, the discharge isolation valves directing the disposition of the water are both closed, and manual intervention is initiated. The chemical waste collection tank is also monitored for radiation and upon radiation detection, the two affected chemical waste collection tank pumps are disabled and the two affected discharge isolation valves are closed. The radiation monitor alarms in the main control room for action and the RWBS control for information and an operator is dispatched to assess the situation.
CES	High Radiation	Upon detection, the Purge Gas Supply to the vacuum pumps are shut off and that discharge path is switched from the RBVS to the GRWS valve. The SA Connection valve receives a close signal.
CPS	Radiation Detection	Spent resin being sent to the condensate polisher resin regeneration skid and the regeneration sump are monitored for radiation. If radiation is detected, a local alarm and an alarm in the MCR alerts operations staff.
CRVS	High Radiation levels continue to degrade or Radiation monitor power loss	Upon detection of a "high" radiation level in the outside air intake, the system is realigned so that 100 percent of the outside air passes through the CRVS filter unit, containing HEPA and charcoal filters, to filter outside air and minimize radiation exposure to personnel with the CRB. If power is not available to either CRVS AHU or to any of the four EDS-C battery chargers (after a 10-minute time delay), or if levels of radiation greater than 10 times background in the CRE supply air duct or if toxic gas is detected in the CRE supply air duct, the PPS automatically isolates the CRE from the adjacent areas by closing the redundant CRE isolation dampers). The time delay is to allow operators time to restore power and start the stand-by AHU. The operating supply AHU and associated components, the general exhaust fan, and the battery exhaust fan are also turned off and the CRH is automatically initiated. The CRH provides a supply of breathable air for the CRE occupants and maintains the CRE at a positive pressure with respect to the surrounding areas. The heat sink capacity of surrounding structures of the CRE helps maintain the temperature in the CRE within acceptable tolerances.

Table 11.5-4: Effluent and Process Monitoring Off Normal Radiation Conditions (Continued)

System	Condition	System Response
CVCS	High Radiation or Radiation monitor power loss	Process sample line isolation
DWS	Radiation Alarm	PCS alarms and automatically close the associated upstream on-off valve.
GRWS	High radiation level in a decay bed skid outlet	Close the inlet valve and outlet valve from the affected decay bed skid as well as the outlet valves to RWBVS.
GRWS	High radiation level in the connection line to the RWBVS	Close the outlet valves to the RWBVS to stop the system flow.
GRWS	High radiation level in charcoal bed cubicle	Close the inlet valves to the GRWS to stop the system flow. Open the nitrogen purge valve.
LRWS	High Radiation on Sample Tank	Pump to Collection Tank for reprocessing (manual operator action)
LRWS	High Radiation on single Point LRW discharge	Table 11.2-2
MSS	High Radiation	If a high radiation condition is detected on the main steam line radiation monitors, an alarm in the MCR cues the operators to take actions to mitigate the event per applicable operating procedures. If required, the main steam lines can be manually isolated from the MCR. Additionally, the MSS drain pots automatically isolate during high radiation for both normal operation or when a MPS isolation signal is present in order to ensure that the MSS does not contribute to unmonitored release of high radioactivity to the environment in the event of an abnormal tube leak. High radiation detection provides an alarm in the control room. If the drain pots and/or isolation valves to the ACC CCT are open, they close. Operator action from the MCR can isolate the MS lines, if required.
PCWS	High Radiation	Alarm in MCR to initiate appropriate safety actions.
RBVS	High Radiation	Alarm in MCR but no automatic actions. Operating staff takes actions to determine the source of the contamination and isolate it.
RBVS (SFP Area)	High Radiation	SFP exhaust is diverted through both the HEPA filters and the charcoal absorbers. Isolation dampers of the RXB general exhaust fans reduce speed in response to the damper closures to maintain the design exhaust header setpoint.
RWBVS	High Radiation	Upon high limit detection of radiation in the RWBVS exhaust effluent to the RBVS system, action is taken by plant operators to locate the source of contamination, however RWBVS continues to operate.
RWDS	High Radiation	PCS alarms and interlock closes the valve back to the RCCW expansion tank.

Table 11.5-4: Effluent and Process Monitoring Off Normal Radiation Conditions (Continued)

System	Condition	System Response
SCWS	Radiation Detection	Upon alarm, operators are alerted to abnormal condition, prompting them to investigate and isolate leaks or terminate other conditions that contribute to the off-normal conditions, through valve closures.
UWS	High Radiation	Alarm in the MCR and locally

Figure 11.5-1a: Radioactive Effluent Flow Paths with Process and Effluent Radiation Monitors

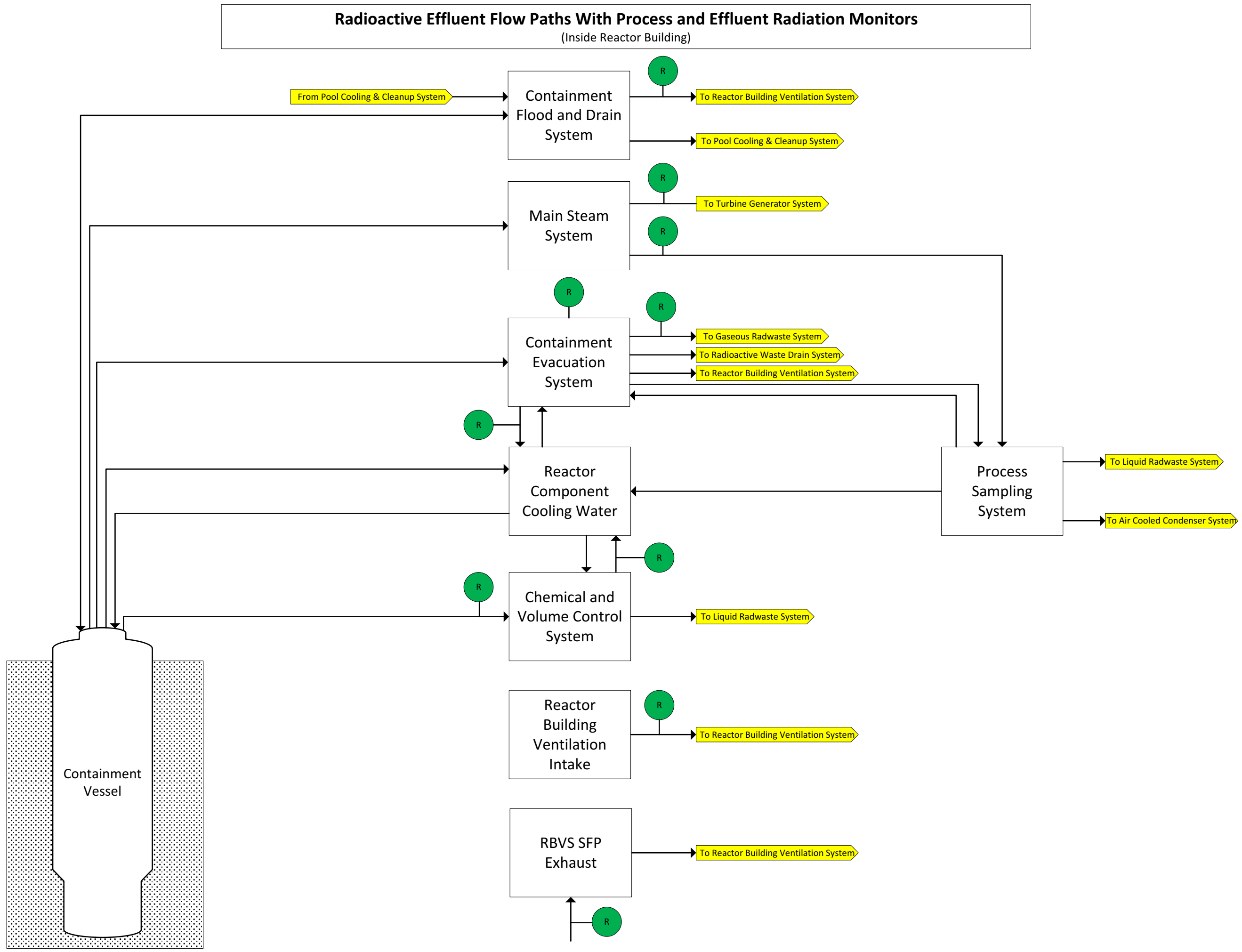


Figure 11.5-1b: Radioactive Effluent Flow Paths with Process and Effluent Radiation Monitors

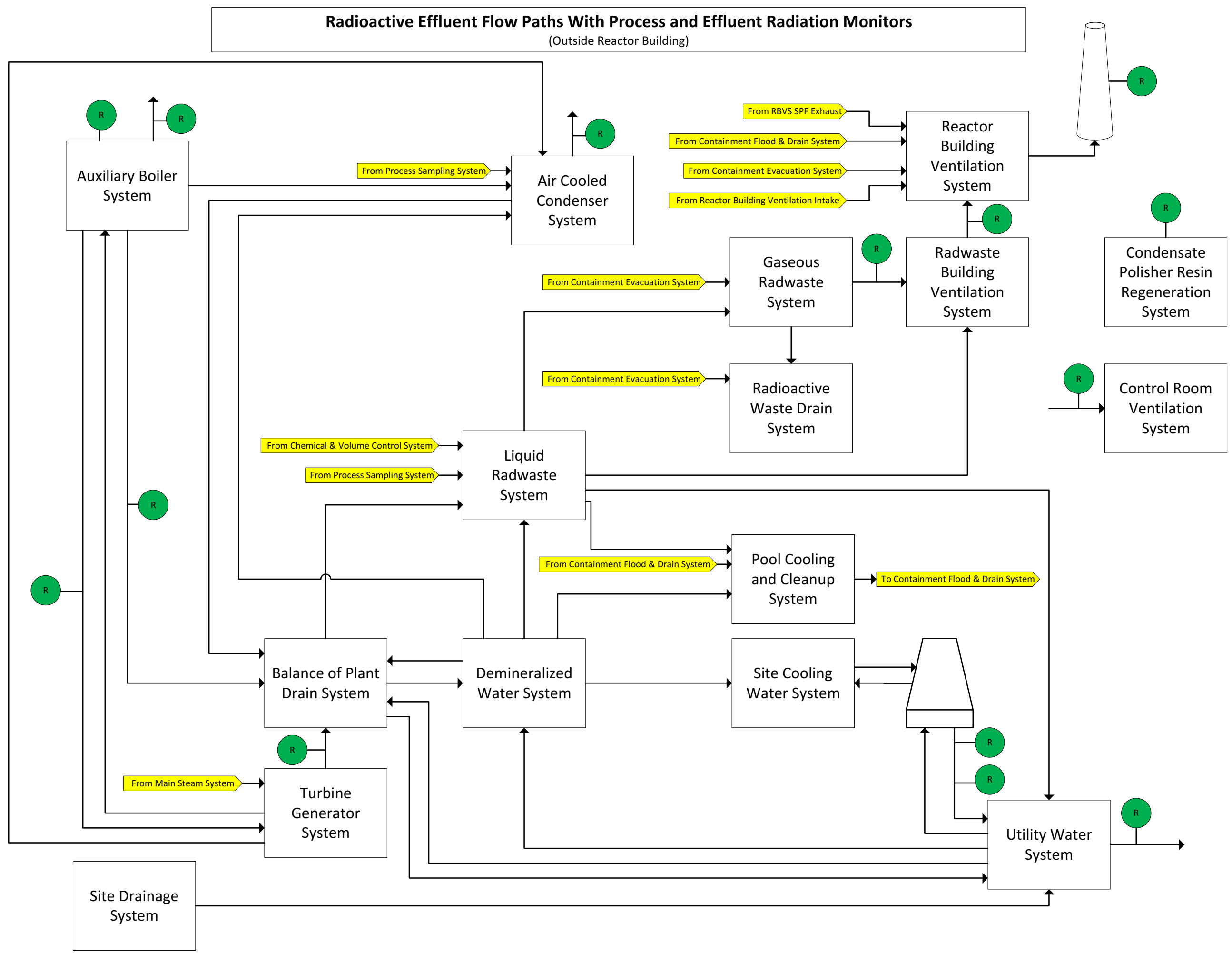


Figure 11.5-2: Process and Effluent Radiation Monitoring System Instrumentation and Control Configuration

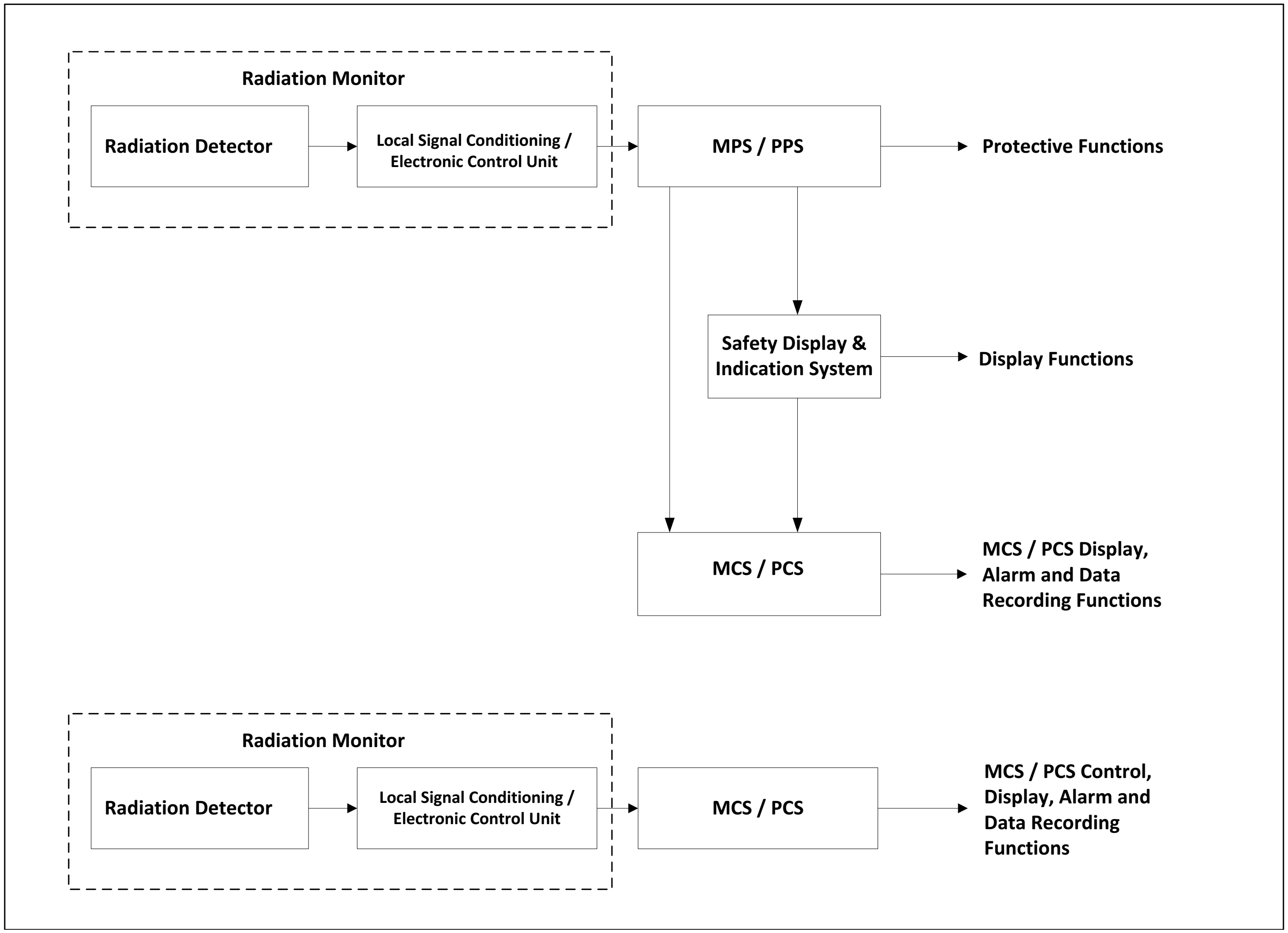


Figure 11.5-3: Off-Line Radiation Monitor

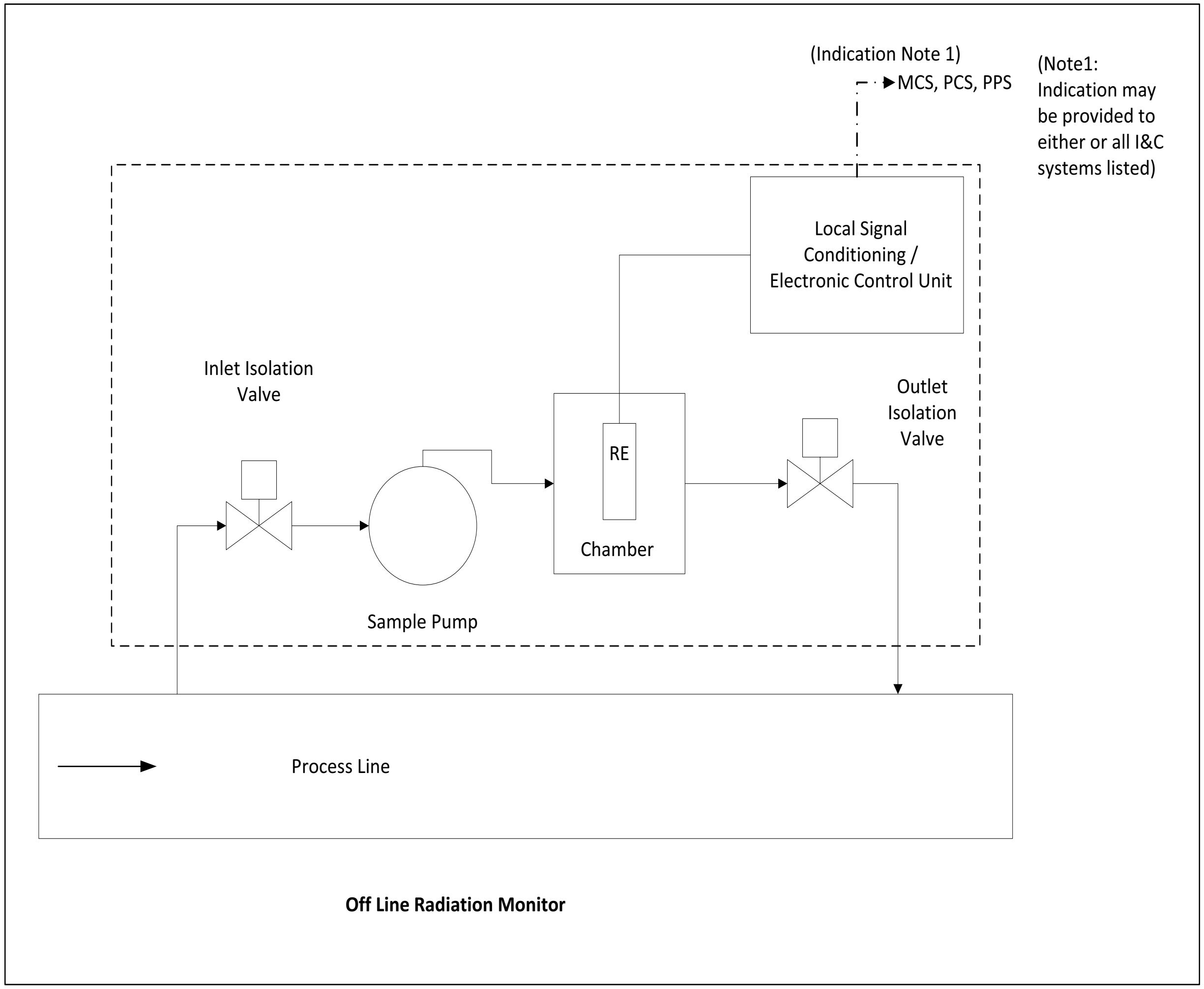


Figure 11.5-4: Adjacent-to-Line Radiation Monitor

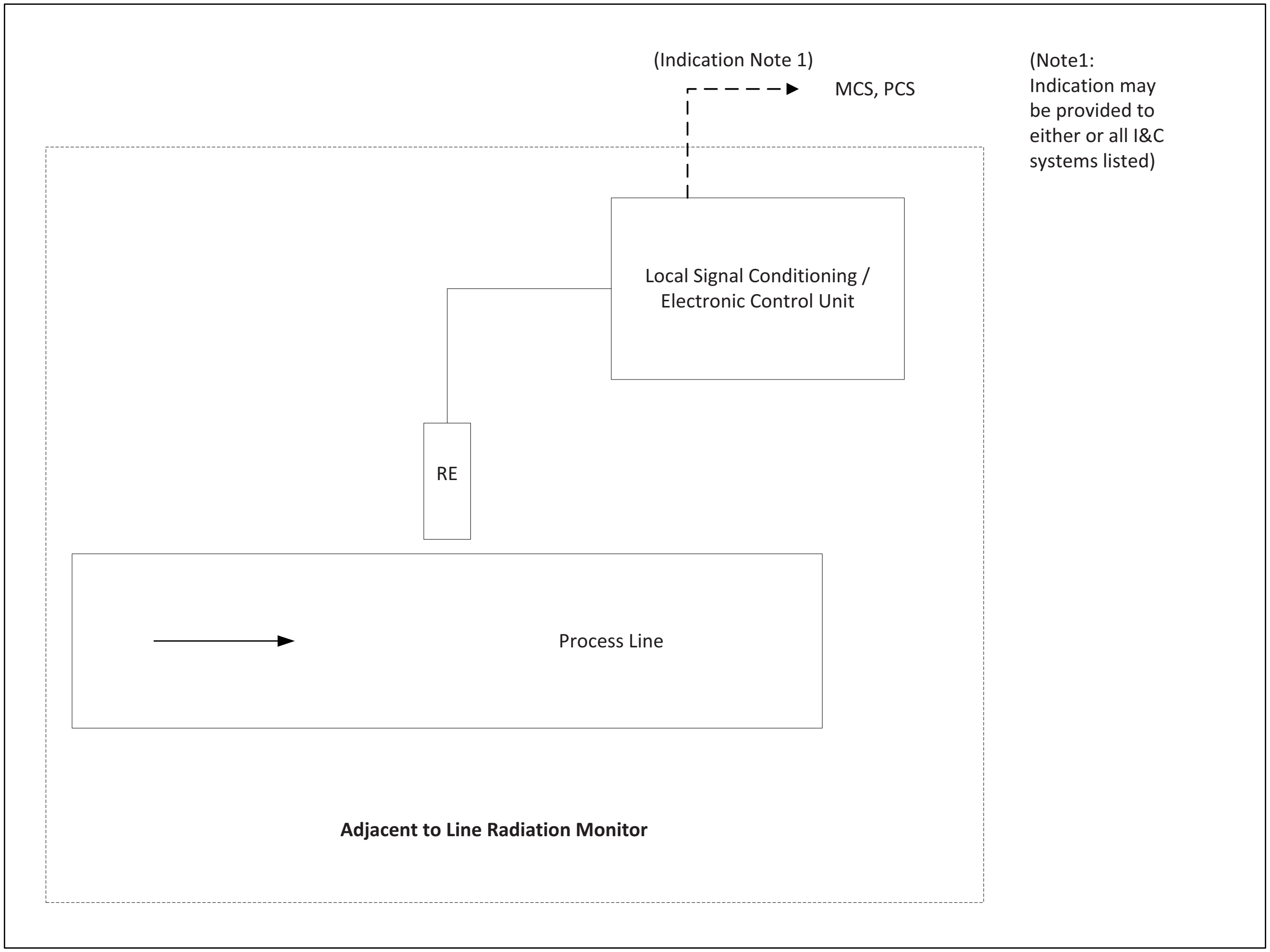


Figure 11.5-5: In-Line Radiation Monitor

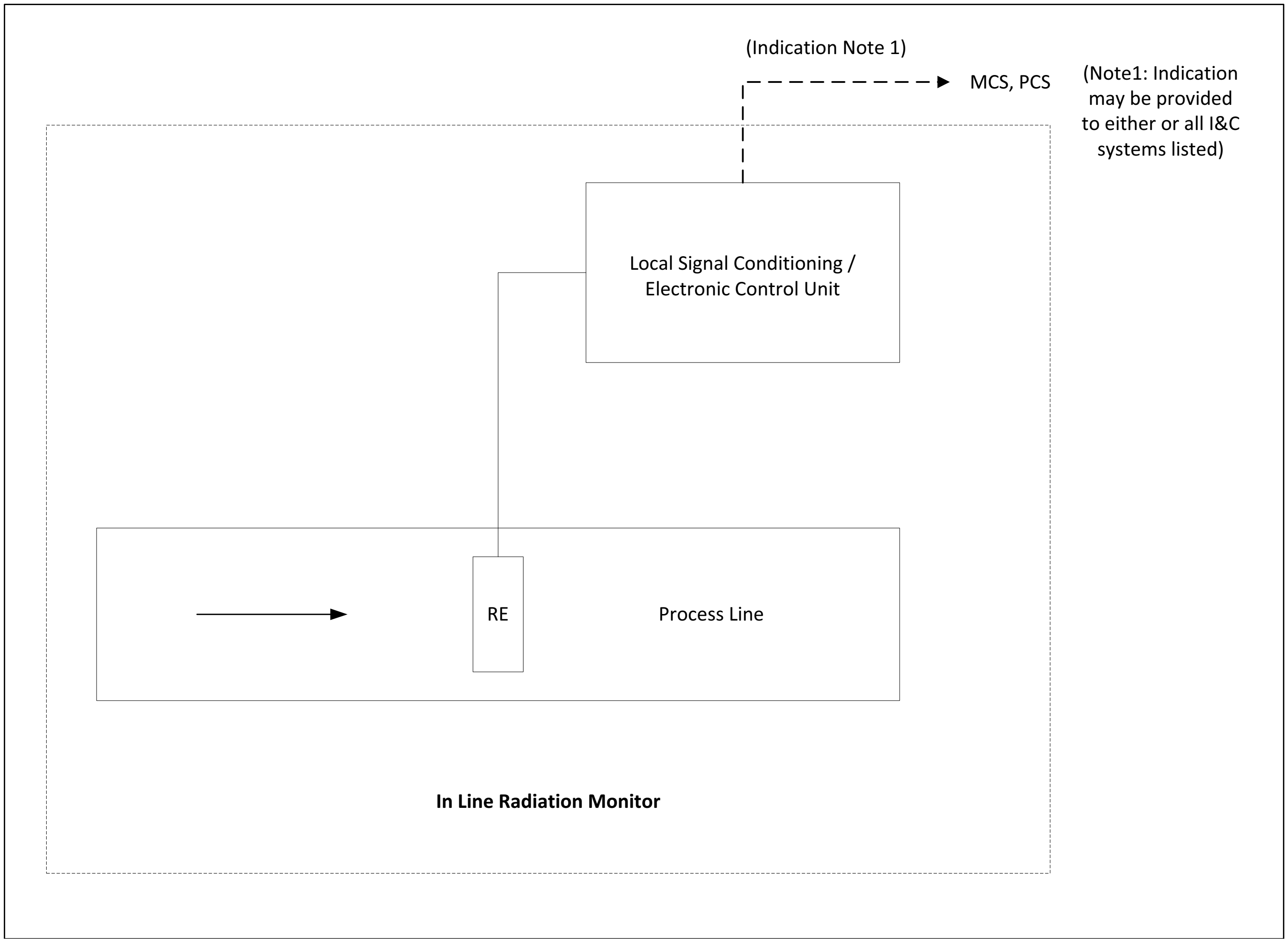
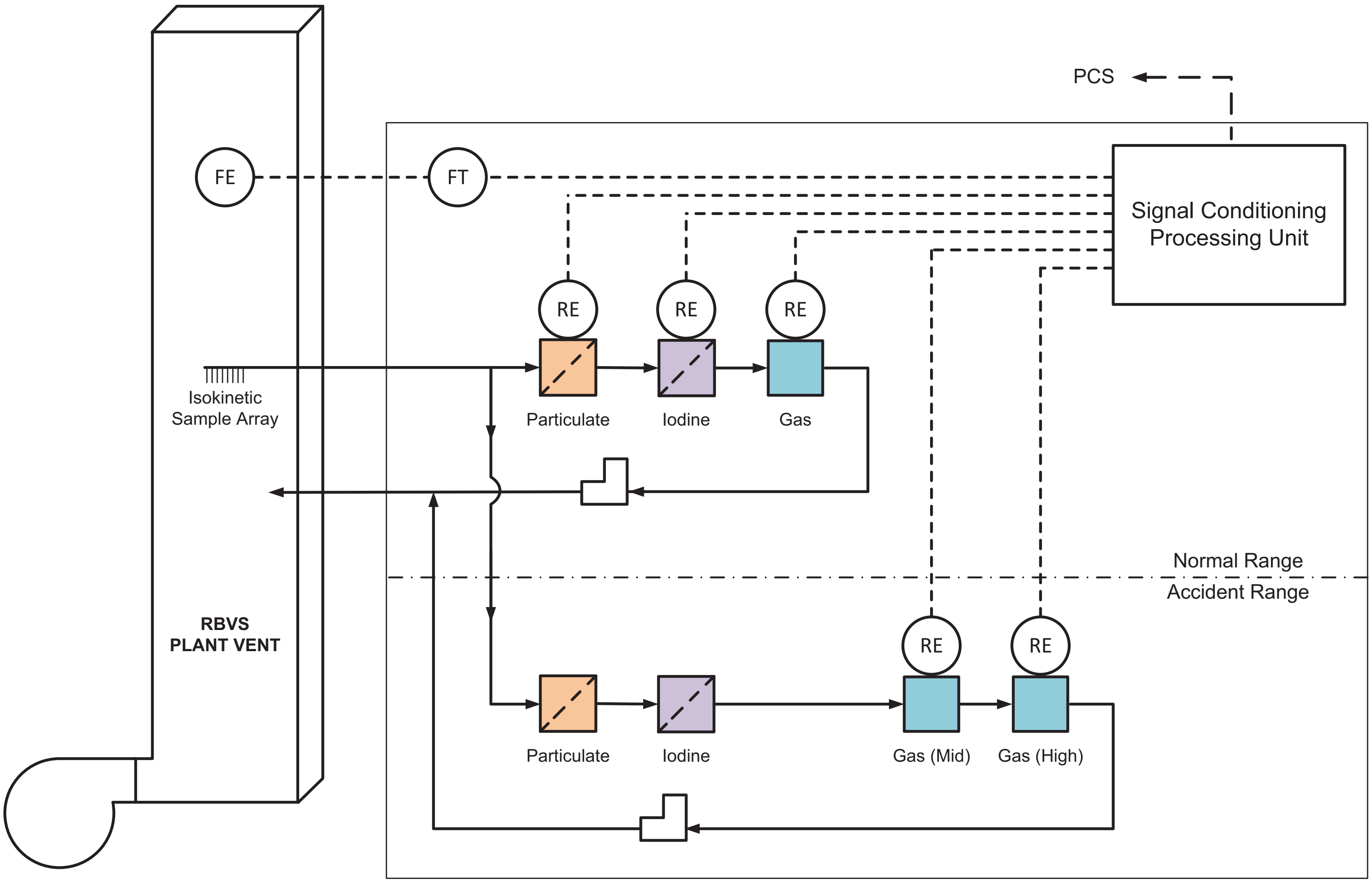


Figure 11.5-6: Reactor Building HVAC System Plant Exhaust Stack Effluent Radiation Monitor



11.6 Instrumentation and Control Design Features for Process and Effluent Radiological Monitoring, and Area Radiation and Airborne Radioactivity Monitoring

Section 11.5 discusses effluent and process radiation monitors. This discussion contains the radiation monitoring (RM) design functions, features, and bases for the plant systems containing effluent or process radiation monitors and includes a discussion of the compliance with associated regulatory requirements and guidance documents.

Section 11.5 discusses provisions for sampling in the systems containing effluent and process radiation monitors. For selected systems, these provisions include functions provided by the process sampling system, which is discussed in Section 9.3.2.

Section 12.3.4 discusses area radiation and airborne contamination monitors. This discussion contains the RM design functions, features, and bases for plant area radiation and airborne contamination monitors and includes a discussion of the compliance with associated regulatory requirements and guidance documents.

Section 7.2.13 describes effluent and area RM that provide input to the emergency response data system and the electronic data communication interface. Section 11.5 and Section 12.3.4 address effluent and area radiological monitoring parameters and equipment.

Applicable portions of the quality assurance program described in Section 17.5 administer the programs and procedures for the control of measuring and test equipment. Section 17.6 describes the program for monitoring the effectiveness of maintenance.