11 - RADIOACTIVE WASTE MANAGEMENT

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CHAPTER 11 - RADIOACTIVE WASTE MANAGEMENT

11.1 SOURCE TERMS

Radioactive source terms are discussed in this section. Radioactive source terms are used in: shielding design; ensuring adequacy of ventilation; design of radioactive systems; calculation of expected gaseous and liquid releases from the plant; and accident analyses. Source terms are dependent on a number of assumptions. The assumptions depend on the particular application under consideration. To avoid confusion, clear distinction is made between the design basis source term, the expected source term, shielding source term, and the accident source term. Operating limits are given in Operational Technical Specification.

Definition of Radioactive Source Terms 110

a. Design Basis Source Terms

Design basis source terms or conservative source terms are those used for the design of the radioactive waste management system and for determining 40-year integrated doses for the specifications of plant equipment.

b. Expected Source Terms

Expected or operating basis source terms are those used for describing releases from the plant to the environment on an annual average basis. Site boundary doses due to releases from the plant ventilation exhausts, liquid discharges, and offsite shipment of solid radioactive material are examples of calculations which use these source terms. Expected source terms are based on realistic models for reactor coolant activity as represented in Table 11.1-1. Calculations pertaining to releases described in Appendix I of 10 CFR 50 follow the assumptions of Regulatory Guide 1.112, Revision 1, April 1985.

c. Shielding Source Terms

Shielding source terms are described in Chapter 12.

d. Accident Source Terms

These source terms are defined and described in Chapter 15.

11.1.1 Design Basis Source Terms

11.1.1.1 Maximum Fission Product Activities in Reactor Coolant

Maximum fission product activities are used as design basis source terms for facilities design and for calculating the consequences of postulated accidents. The isotopes considered in the maximum case are those which are significant for design purposes by reason of a combination of energy, half-life, or abundance.

The mathematical model used to determine the concentration of nuclides in the 110
reactor coolant system involves a group of linear, first order differential equations. These equations are obtained by applying a mass balance for production and removal for the fuel pellet region and the coolant region. In the fuel pellet region, the mass balance includes fission product production by: direct fission yield, parent fission product decay and neutron activation, while the removal includes decay, neutron activation and escape to the coolant. In the coolant region the analysis includes the fission product production by: escape from the fuel through defective fuel rod cladding, parent decay in the coolant, and neutron activation of coolant and corrosion products. Removal is by: decay; coolant purification; feed and bleed operations (to accommodate fuel burnup); leakage and other feed and bleed operations such as startups, shutdowns, and load follow operations; and neutron activation.

The expression to determine the fission product inventory in the fuel pellet region is:

(11.1-1)

The expression to determine the fission product inventory in the reactor coolant region is:

[redacted] (11.1-2)

where the variables are identified as:

N = Population, atoms
F = Average fission rate, fissions/MWt - sec
Y = Core averaged fission yield of nuclide, fraction (Reference 1)
F = Core power, MWt
λ = Decay constant, sec^{-1} (Reference 2)
σ = Microscopic capture cross section, cm^2 (Reference 3)
ϕ = Thermal neutron flux, neutrons/cm^2-sec 110
ν = Escape rate coefficient, sec^{-1}
j = Branching fraction
t = Time, seconds
D = Defective fuel cladding, fraction
CVR = Core coolant volume to reactor coolant volume ratio
$\dot{Q}$ = CVCS purification mass flow rate during power operation, lbm/sec (kg/sec)
W = Reactor coolant system mass during power operation, lbm (kg)
η = Resin efficiency of CVCS ion exchanger and gas stripper efficiency (subscripted for a particular nuclide)
C_o = Beginning of core life boron concentration, ppm
$\dot{C}$ = Boron concentration reduction rate due to feed and bleed, ppm/sec
L = Leakage or other feed and bleed from the reactor coolant, lbm/sec (kg/sec)

and where the subscripts are identified as:

i = i^{th} nuclide
i-1 = precursor to i^{th} nuclide for decay
j = precursor to i^{th} nuclide for neutron activation

p = pellet region
c = coolant region

It should be noted that this model does not involve the fuel plenum and gap region. Instead, escape rate coefficients are used to represent the overall release from the fuel pellets to the coolant. The escape rate coefficient is an empirical value which was derived from experiments initiated by Bettis and run in the NRX and MTR reactors (Reference 4). The escape rate coefficients were obtained from test rods which were operated at high linear heat rates. The linear heat rates were uniform over the test sections of 10.25 inches (26.035 cm) in length. The exact linear heat rates were not precisely known but post-irradiation inspection showed that some test specimens had experienced centerline melting. Later tests were done in Canada to determine the effect of rod length on the release of fission gases and iodines from defective fuel rods (Reference 5). A byproduct of these experiments was the relationship between linear heat rate and escape rate coefficient. The escape rate coefficients are shown for noble gases and halogens in Table 11.1-1. Since the average heat rate for a fuel rod is well below the values that correspond to the selected escape rate coefficients for halogens and noble gases shown in Table 11.1-1, the presently used escape rate coefficients are conservative. These escape rate coefficients are based on a linear heat rate coefficient of 18 kW/ft (590.5 W/cm) rather than the design maximum linear heat rate of 12 kW/ft (394 W/cm). 110
Shown in Table 11.1-1 are the values of parameters that are used to calculate the reactor coolant fission product activities. Maximum reactor coolant activities, used for design, are presented in Table 11.1-2.

11.1.1.2 Spent Fuel Pool and Refueling Pool Activities

Spent fuel pool and refueling pool maximum and expected fission and corrosion product specific activities are given in Tables 11.1-3 and 11.1-7, respectively, for the start of the refueling period. It is assumed that upon shutdown for refueling, the reactor coolant system is cooled down for 2 days. During this period, the primary coolant is letdown through the purification filter, purification ion exchanger, gas stripper, and volume control tank. This serves two purposes: (1) removing the noble gases in the gas stripper avoids large activity releases to the containment following reactor vessel head removal and (2) the ion exchange and filtration reduce dissolved fission and corrosion products in the coolant which would otherwise enter the spent fuel pool and refueling pool. At the end of this period, the coolant above the reactor vessel flange is partially drained. The reactor vessel head is unbolted and the refueling pool is filled with approximately [redacted] of water from the refueling water tank. The remaining reactor coolant containing radioactivity is then mixed with the water in the refueling pool and [redacted] of water in the spent fuel pool. After refueling, the spent fuel pool is isolated and the water in the refueling pool is returned to the refueling water tank. This series of events determines the total activity in the spent fuel pool.

The spent fuel pool water is cooled and cleaned of radioactivity via the spent fuel pool cooling and cleanup systems. The refueling pool water is cooled and cleaned via the shutdown cooling and reactor cavity filtration systems, respectively.

Leakage of radionuclides into the spent fuel pool from damaged fuel stored in the pool is not considered to be a significant contributor to the radionuclidic 110
concentration in the spent fuel pool water. This is due to the extremely low fuel gap activity escape rate coefficients for the spent fuel located in the spent fuel pool. The low escape rate coefficients are due in part to the low spent fuel pool temperature. Most of the activity escapes from the defective fuel elements during shutdown and cooldown of the reactor prior to removal of the reactor vessel head. If significant releases from failed fuel are detected, the defective fuel elements are isolated in a separate container so that the released activity does not contribute to the specific activity in the spent fuel pool water. The primary source of radioactivity in the spent fuel pool water, after refueling operations have been completed, is due to displaced activation products (i.e., crud) from the surfaces of the spent fuel assemblies.

11.1.1.3 Secondary System Activity

If there are steam generator tube leaks, radionuclides will be introduced into the secondary system from the primary system. In determining design basis and expected sources in the secondary system, total steam generator tube leakage is assumed to be 75 lb/day (34 kg/day).
Radionuclides can be removed from the secondary system by any of the following mechanisms:

a. steam generator blowdown demineralizer treatment,

b. condensate polishing demineralizer treatment,

c. radioactive decay,

d. exhaust through the main condenser vacuum pumps,

e. exhaust through the turbine steam seal system,

f. main steam leakage,

g. condensate leakage to sumps, and

Primary coolant activities used to determine the secondary system design basis sources are discussed in Subsection 11.1.1.1. Assumptions used in determining the secondary system activities are listed in Table 11.1-4. Design-basis secondary system equilibrium radionuclidic concentrations are determined as described below. 110

The following expression determines the concentration of nuclides in the steam generator liquid (i.e., blowdown source):

(11.1-3)

The variables are identified as follows:

N = nuclide concentration, μCi/kg
R = primary-to-secondary leakage rate, kg/sec
T = main steam flow rate, kg/sec
F = fraction of radionuclide in the main steam reaching main condenser
M = liquid mass in steam generator, kg
B = steam generator blowdown rate, kg/sec
a = steam generator partition coefficient (concentration in steam/concentration in liquid)

DF = decontamination factor
λ = decay constant, sec-1
0.25 = Fraction of condensate water processed in condensate polishing system

The subscripts are identified as follows:

s refers to steam generator
W refers to reactor coolant
C refers to condenser evacuation system
D refers to condensate demineralizers
B refers to blowdown purification system
i refers to nuclide index.

The equilibrium concentration of nuclides in the steam generator liquid is given by:

(11.1-4) 110

The design basis radionuclidic concentrations in the steam generator liquid are listed in Table 11.1-24.

To obtain the peak noble gas concentration in the main steam leaving the steam generators, it is assumed that the noble gasses which enter the steam generator via primary coolant leakage leave entirely with the steam (i.e., none are contained within the steam generator secondary liquid). The noble gas activity concentration in the steam exiting the steam generator is therefore equal to the leakage rate of primary coolant into the steam generator multiplied by the radionuclidic concentration in the primary coolant and divided by the steam flow rate out of the steam generator. This can be expressed as

(11.1-5)

The equilibrium concentration of non-noble gas radionuclides in the steam exiting the steam generator is simply the equilibrium concentration of the radionuclide in the steam generator liquid multiplied by the steam generator partition coefficient (i.e., concentration in steam generator steam to concentration in steam generator water).

This can be expressed as

(11.1-6)

The design basis radionuclidic concentrations in the main steam are listed in Table 11.1-24.

About once per week, a high capacity blowdown through one of the four nozzles is performed to remove accumulated crud in the steam generator. As discussed in Subsection 10.4.8.2.3, this blowdown is performed at a flowrate of 146.6 lb/sec (66.57 kg/sec) or 294.8 lb/sec (133.70 kg/sec) for 2 minutes from one of the two steam generators. For conservatism, the flow rate of 146.7 lb/sec (66.54 kg/sec) is used for the calculation of radionuclidic crud concentrations in the high-capacity blowdown liquid. To obtain the radionuclidic crud activity in the high-capacity blowdown liquid, it is assumed that the crud radionuclides (i.e., Mn, Co, Fe, and Cr) due to leakage from the primary to the secondary coolant 110
remain within the steam generators between high-capacity blowdowns. This accumulated radionuclidic crud is diluted by and exhausted with the 1.76×10^4 lb (7.99×10^3 kg) of high-capacity blowdown. Specifically:

(11.1-7)

where:

A = radionuclidic concentration of crud within the high-capacity blowdown water, μCi/kg

t = time of 1 week in units to agree with λ , sec

λ = decay constant, sec^{-1}

K = constant to obtain the desired units of concentration

The remaining radionuclidic concentrations in the high-capacity blowdown liquid (i.e., nonnoble gas and noncrud radionuclides) are determined using the equation which determines the equilibrium radionuclide concentration in steam generator liquid (i.e., Equation 11.1-4).

Radionuclidic crud concentrations in the high capacity blowdown liquid are listed in Table 11.1-23.

11.1.1.4 Radwaste Management Systems Activities

Liquid waste management systems are addressed in Section 11.2. Gaseous waste management systems are addressed in Section 11.3.

Detailed information, including references to P&IDs, pressures, temperatures, flow rates, and expected volumes of waste input to each of the radwaste management systems is provided in Table 11.1-5.

11.1.1.5 Pressurizer Activity

Specific activities of the various nuclides in the pressurizer are expected to be less than or equal to the corresponding RCS specific activities (Table 11.1-2).

11.1.1.6 Reactor Drain Tank Activity 110

The total curie inventory in the RDT is based on an expected maximum water volume of 2,138 gallons (8,092 L) and an expected maximum vapor volume of 183 ft^3 (5,182 L).

11.1.1.7 Gas Stripper Activity

The total curie inventory in the Gas Stripper is based on the summation activity of aftercooler, heat recovery exchanger, overhead condenser, reboiler, stripper column, and feed preheater in the Gas Stripper package.

11.1.2 Radioactivity in Systems and Components, Realistic Basis

11.1.2.1 Reactor Coolant Activity

The data in Table 11.1-6 represent the expected normal fission product activities for the plant with no gas stripping. The activities for this case are based on ANSI/ANS-18.1, 1984 (Reference 6) and are intended for use in evaluating only normal operations including anticipated operational occurrences.

11.1.2.2 Spent Fuel Pool and Refueling Pool Activities

The model used to determine the spent fuel pool and refueling pool radionuclidic activities is discussed in Subsection 11.1.1.2. The realistic analysis model is the same with the exception that the primary coolant realistic source terms are used. Peak radionuclidic activity concentrations for the refueling pool and spent fuel pool waters for the realistic analysis are shown in Table 11.1-7.

11.1.2.3 Secondary Activity

Equilibrium normal operation radionuclide concentrations in the steam generator liquid and in the main steam are determined using the method discussed in Subsection 11.1.1.3. The steam generator tube leak rate from the primary to the secondary system is assumed to be 75 lb per day. The expected parameters of Table 11.1-4 are used.

Secondary system radionuclidic concentrations based on realistic sources are provided in Table 11.1-25. 110

11.1.3 Deposited Crud Activities

The activity of radioactive crud and its thickness on primary system surfaces have been evaluated using measured data from various operating pressurized water reactors.

Even though these reactors have different water chemistries and different materials in contact with the primary coolant, their crud activities (dpm/mg-crud), crud film thicknesses and dose rates due to this crud are remarkably similar. The half-lives, reactions and gamma decay energies for each of the long-lived isotopes in the radioactive crud are as shown in Table 11.1-8. The long-lived isotopes are those significant isotopes remaining after 48 hours decay.

The radioactive crud originates on incore and out-of-core surfaces. The crud plates out on the incore surfaces and re-erodes after a short irradiation period. This irradiation period or core residence time (tres) for each isotope is determined by the following equations (see Appendix 11.1A for the derivation of these equations):

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Circulating Crud:

[redacted] (11.1-8)

Deposited Crud:

[redacted] (11.1-9)

Where:

- A_i, A_j are the crud activities for each isotope (dpm/mg-crud),
- S_t is the total primary system area (cm^2),
- $\Sigma_i \phi$ is the activation rate (reaction/g-sec), and
- S_c is the core surface area (cm^2),
- λ is the decay constant (sec^{-1})
- 16.67 converts dpm/mg-crud to dps/g-crud.

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The activation cross-section (Σ_i) is as follows:

[redacted] (11.1-10)

Where:

- $(a/o)_i$ is the isotopic abundance,
- $(w/o)_i$ is the elemental abundance in the crud or the elemental abundance in the base metal
- N_o is Avogadro's number (0.6023×10^{24} atoms/g-mole), 375
- $[A]_i$ is the atomic weight of isotope (i), and
- σ_i is the microscopic cross-section (cm^2)

Circulating crud is taken to be all crud in the reactor coolant. Deposited crud is taken to be all crud which plates out on incore surfaces.

The measured average and maximum crud activities (dpm/mg-crud) as taken from References 7 through 20 for those reactors considered in determination of the core residence times are as shown in Table 11.1-9. The average and maximum core residence times are shown in Table 11.1-12. These are determined by the above expressions, the activities in Table 11.1-10, and the system parameters in Table 11.1-11. As all the Fe-59 residence times are long, its activity (A_j) is assumed saturated. The averages (t_{res}) of the maximum residence times are also given in Table 11.1-12.

The calculated crud activities(A_i) are determined utilizing the averages (t_{res}) of the maximum core residence times, the system parameters in Table 11.1-13 and the following equation:

(11.1-11)

As the averages (t_{res}) of the maximum residence times are used and in general these (t_{res}) are a factor of 2 to 4 higher than a straight average residence time, the resulting calculated crud activities are conservative. These calculated crud activities of the long-lived isotopes are as shown in Table 11.1-14. These calculated crud activities are applied to both the circulating crud and out of core deposited crud. Using the average crud level in the reactor coolant (75 ppb) of those operating reactors shown in Table 11.1-9 and the calculated crud activities (dpm/mg-crud) as shown in Table 11.1-14, the average isotopic activities in the primary coolant are determined by the following expression: 110

(11.1-12)

where ρ is the density of water (g/cm^3) and 1000 is for conversion i.e., mg/g.

The average calculated activities in the primary coolant using the above expression are shown in Table 11.1-15. The maximum coolant activities can be higher due to "crud bursts" during shutdowns or changes in power. However, these "bursts" occur over short periods of time, and therefore, the average values are more reasonable to use for long-term operation.

The equilibrium thickness of radioactive crud film (mg-crud/cm^2) has been determined by two methods:

a. The direct measurement of the film during maintenance and/or tests in operating reactors.

b. Calculating crud film thickness from measured dose rates and specific activities (dpm/mg-crud) of deposited crud.

The equilibrium crud film thicknesses for various reactor coolant system areas are as shown in Table 11.1-16.

The calculated crud activities in this section are reasonable values and together with measured plateout thicknesses, match measured shutdown dose rates around various equipment associated with operating reactors. Typical crud levels and plateout thicknesses are shown in Tables 11.1-9 and 11.1-16 for operating reactors.

The conservative evaluation of the above operating data yields circulating crud concentrations (Table 11.1-15) which are lower for Mn-54 and Fe-59 than the concentrations given in ANSI/ANS 18.1 (Reference 6). ANSI/ANS 18.1 is intended for use in evaluating only normal operations, including anticipated operational occurrences. However, the ANSI/ANS 18.1 values for circulating crud Mn-54 and Fe-59 are used as design source terms as well as for normal operations, since they 110
yield a design that is more conservative than that resulting from the derived values based on operating experience. The circulating corrosion product activity concentrations in the reactor coolant are listed in Tables 11.1-2 and 11.1-6.

11.1.4 Tritium Production in Reactor Coolant

The principal sources of tritium production in a pressurized water reactor (PWR) are from ternary fission and neutron-induced reactions in boron, lithium and deuterium that are present in the coolant and control element assemblies (CEA). The tritium produced in the coolant contributes immediately to the overall tritium activity, while the tritium produced by fission and neutron capture in the CEAs contributes to the overall tritium activity via release through the cladding.

11.1.4.1 Activation Sources of Tritium

The activation reactions producing tritium are as shown in Table 11.1-17. The tritium production from reactions 5) and 6) (B-11 and N-14 sources) is insignificant due to low cross section and/or abundance and can be neglected.

Reactions 1) through 4) (from B-10, lithium, and deuterium) are the major sources of tritium in the coolant and CEAs.

The tritium production from the above sources is determined by the following expressions:

(11.1-13)

Where:

$\Sigma a \phi$	is the production rate (atoms/cm^3-sec), 110
λ	is decay constant (sec-1),
t	is the reactor operating period of interest (sec),
V	is the effective core volume or CEA volume (cm3), and
2.7×10^{-11}	converts disintegrations/sec to curies.

The appropriate parameters used in the calculation are shown in Table 11.1-18. Based on these parameters, the tritium produced from activation sources in the reactor coolant for one equilibrium fuel cycle are included in Table 11.1-19.

11.1.4.2 Tritium from Fission

The ternary fission production of tritium in the core is expressed simply by:

(11.1-14)

Where:

- Y is the tritium fission yield,
- F is the fission rate (f/sec),
- λ is decay constant (sec-1),
- t is the reactor operating period of interest (sec), and
- 2.7×10^{-11} converts disintegrations/sec to curies.

Tritium as a product of fission is calculated using the ORIGEN-2 computer code. Based on the release rate data (References 21 and 22), an average tritium release from the fuel of 1% and a maximum design value of 2% are used to estimate the annual tritium production in Table 11.1-19.

11.1.4.3 Secondary System Tritium Concentrations

In determining the secondary system tritium activity concentrations, it is assumed that the tritium which enters the secondary system from the primary system via steam generator tube leakage is uniformly mixed in the secondary system steam and liquid masses. For the equilibrium condition, the decay and leakage losses of tritium from the secondary system is equal to the primary to secondary system tritium leakage. 110

11.1.5 Neutron Activation Products

11.1.5.1 Nitrogen-16 Activity

Nitrogen-16 is produced by the $O^{16}(n, p) N^{16}$ reaction. The gamma energies are 6.13 MeV (73% of the time) and 7.10 MeV (5% of the time). The N16 half life is 7.13 seconds. The threshold energy for the reaction is 10.2 MeV.

The N^{16} activity at the pressure vessel outlet nozzle is 5.50×10^{6} disintegrations/cm3-sec. This activity is based on the following expression and reactor parameters.

[redacted] (11.1-15)

Where:

$\Sigma\phi$ is the reaction rate (5.15×10^7 d/cm^3-sec),

t_c is the core transit time (0.74 sec),

t_t is the total primary loop time (9.74 sec),

t_r is the time from the active core outlet to the point of interest (0.59 sec to outlet nozzle), and

λ is the decay constant (0.097 sec^{-1})

11.1.5.2 Carbon-14 Production

Carbon-14 is produced in the RCS by activation of O^{17} and N^{14} isotopes. The greatest amount of C^{14} is produced by the O^{17} (n, α) C^{14} reaction, a lesser amount of C^{14} is produced by the N^{14} (n, p) C^{14} reaction. The production of C^{14} from both sources can be calculated by using the following equation:

(11.1-16)

Where: 110

N_o = atom concentration in the RCS water (atoms/kg H_2O)

σ = effective thermal cross section (cm^2)

ϕ = thermal neutron flux, 6.62×10^{13} n/cm^2-s

m = mass of core water, 1.6×10^4 kg

t = conversion factor, 4.7304×10^7 s/cycle

p = plant capacity factor, 0.87

s = 1.037×10^{-22} Ci/atom

$\dot{A}$ = production rate, ci/cycle

For C^{14} production from O^{17} activation, $N_o = 1.27 \times 10^{22}$ atoms O^{17}/kg (H_2O) and $\sigma_o = 2.35 \times 10^{-25}$ cm^2 (effective thermal cross section $\sigma = 1.48 \times 10^{-25}$ cm^2) are used in the above equation. The production rate is 8.49 curies/cycle. For C^{14} production from N^{14} activation $N_o = 1.28 \times 10^{20}$ atoms N^{14}/kg (H_2O) and $\sigma o = 1.81 \times 10^{-24}$ cm^2 (effective thermal cross section $\sigma = 1.14 \times 10^{-24}$cm^2) are used in the above equation. The production rate is 0.66 curies/cycle

The production of C^{14} from these sources during the fuel cycle is 9.15 curies.

11.1.6 Operation Experience

Operation experience is discussed in Subsection 4.2.3.2.10. On the basis of accumulated experience, it is expected that the failed fuel fraction during normal operation will be less than 0.12%.

11.1.7 Leakage Sources

Systems containing radioactive liquids and gases are potential sources of leakage and discharge to the environment. Liquid leakage is from potential sources such as pump seals and valve packings. Expected leakage of primary coolant into the containment building is at a rate which would result in the release of [redacted] of the primary coolant noble gas inventory and [redacted] of the primary coolant iodine inventory into the containment building atmosphere. The expected primary coolant leak rate into the auxiliary building is [redacted] and the expected leakage rate of steam into the turbine building is [redacted] Expected primary-to-secondary leak rate across the steam generator tubes is [redacted]. Table 11.1-20 provides maximum anticipated leak rates 110
from NSSS supplied valves and pumps.

Liquid radioactive releases are further discussed in Subsection 11.2.3. Gaseous radioactive releases are further discussed in Subsection 11.3.3. Concentrations of airborne radioactive nuclides in cubicles are discussed in Subsection 12.2.3.1.2.

11.1.8 Spent Resin Volumes

The spent demineralizers resin volumes and annual CVCS spent resin activities supplied to the solid waste management system from demineralizers are presented in Table 11.1-21 and Table 11.1-22, respectively.

11.1.9 References

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TABLE 11.1-1 (sh. 1 of 2)

BASIS FOR ANALYSIS OF REACTOR COOLANT FISSION PRODUCT ACTIVITIES

TABLE 11.1-1 (sh. 2 of 2)

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TABLE 11.1-2 (sh. 1 of 2)

MAXIMUM SPECIFIC ACTIVITIES IN THE REACTOR COOLANT DUE TO CONTINUOUS OPERATION AT MAXIMUM POWER WITH 1% FAILED FUEL AND CONTINUOUS GAS STRIPPING

Nuclide	Specific Activity* (μCi/cm^3 @ 70 °F (21.1 ℃))
Kr-85M	7.70 (-01)
Kr-85	1.50 (-02)
Kr-87	8.00 (-01)
Kr-88	1.90 (+00)
Xe-131M	1.60 (-01)
Xe-133M	4.20 (-02)
Xe-133	2.10 (+01)
Xe-135M	6.50 (-01)
Xe-135	3.10 (+00)
Xe-137	1.50 (-01)
Xe-138	5.50 (-01)
Br-84	2.20 (-02)
I-131	2.10 (+00)
I-132	6.70 (-01)
I-133	3.30 (+00)
I-134	4.60 (-01)
I-135	2.00 (+00)
Rb-88	2.00 (+00)
Cs-134	2.40 (-01)
Cs-136	4.00 (-02)
Cs-137	3.00 (-01)
N-16	2.12 (+02)**
Cr-51	1.02 (-02)
Mn-54	1.34 (-03)
Fe-59	2.52 (-04)
Co-58	6.22 (-03)
Co-60	6.89 (-04)

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* Numbers in parentheses denote power of ten.

** This is the specific activity of N-16 at the reactor vessel outlet nozzle.

TABLE 11.1-2 (sh. 2 of 2)

MAXIMUM SPECIFIC ACTIVITIES IN THE REACTOR COOLANT DUE TO CONTINUOUS OPERATION AT MAXIMUM POWER WITH 1% FAILED FUEL AND CONTINUOUS GAS STRIPPING

Nuclide	Specific Activity* ($\mu Ci/cm^3$ @ 70 °F (21.1 ℃))	
Sr-89	2.80 (-03)	
Sr-90	1.40 (-04)	
Sr-91	4.70 (-03)	
Y-91M	2.70 (-03)	
Y-91	3.90 (-04)	
Y-93	1.10 (-04)	
Zr-95	5.66 (-04)	
Nb-95	4.30 (-04)	110
Mo-99	2.50 (-01)	
Tc-99M	1.30 (-01)	
Ru-103	1.50 (-04)	
Ru-106	5.90 (-05)	
Te-129M	5.10 (-03)	
Te-129	6.00 (-03)	
Te-131M	2.60 (-02)	
Te-131	1.10 (-02)	
Te-132	1.70 (-01)	
Ba-137M	2.80 (-01)	
Ba-140	3.40 (-03)	
La-140	1.00 (-03)	
Ce-141	1.30 (-04)	
Ce-143	3.80 (-04)	
Ce-144	3.40 (-04)	

* Numbers in parentheses denote power of ten

TABLE 11.1-3 (sh. 1 of 2)

MAXIMUM FISSION AND CORROSION PRODUCT SPECIFIC ACTIVITIES IN THE SPENT FUEL AND REFUELING POOL

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TABLE 11.1-3 (sh. 2 of 2) 110

TABLE 11.1-4 (Sh. 1 of 1)

ASSUMPTIONS USED IN DETERMINING SECONDARY SYSTEM ACTIVITIES

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TABLE 11.1-5 (sh. 1 of 6)

DESIGN INPUTS OF THE RADWASTE SYSTEMS

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TABLE 11.1-5 (sh. 2 of 6)

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TABLE 11.1-5 (sh. 3 of 6)

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TABLE 11.1-5 (sh. 4 of 6)

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TABLE 11.1-5 (sh. 5 of 6)

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TABLE 11.1-5 (sh. 6 of 6)

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TABLE 11.1-6 (sh. 1 of 2)

REACTOR COOLANT SPECIFIC ACTIVITIES DURING NORMAL OPERATIONS, INCLUDING ANTICIPATED OPERATIONAL OCCURRENCES

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TABLE 11.1-6 (sh. 2 of 2)

REACTOR COOLANT SPECIFIC ACTIVITIES DURING NORMAL OPERATIONS,
INCLUDING ANTICIPATED OPERATIONAL OCCURRENCES

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TABLE 11.1-7 (sh. 1 of 2)

FISSION AND CORROSION PRDUCT SPECIFIC ACTIVITIES IN THE SPENT FUEL AND REFUELING POOL UNDER NORMAL CONDITIONS INCLUDING ANTICIPATED OPERATIONAL OCCURRENCES

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TABLE 11.1-7 (sh. 2 of 2)

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TABLE 11.1-8

LONG-LIVED ISOTOPES IN CRUD

Isotope	Half Life	λ, d^{-1}	Parent	Reaction	#/dis	E(MeV)	
^{60}Co	5.27y	3.60(-4)*	^{59}Co	n, γ	2.00	1.25	
^{58}Co	70.9d	9.78(3)	^{58}Ni	n, p	1.00	0.81	110
^{54}Mn	312.2d	2.22(3)	^{54}Fe	n, p	1.00	0.84	
^{51}Cr	27.7d	2.50(2)	^{50}Cr	n, γ	0.10	0.32	
^{59}Fe	44.5d	1.56(2)	^{58}Fe	n, γ	1.00	1.18	
^{95}Zr	64.0d	1.08(2)	^{94}Zr	n, γ	2.00	0.75	

* Numbers in parentheses denote powers of ten.

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TABLE 11.1-9(sh. 1 of 2)

MEASURED RADIOACTIVE CRUD ACTIVITY (dpm/mg-crud)

Reactor		^{60}Co	^{58}Co	^{54}Mn	^{51}Cr	^{59}Fe	^{181}Hf	^{95}Zr	^{64}Cu	Crud (ppb)	Ref
Conn. Yankee*	Ave.	9.1(+6)***	9.9(+7)	2.3(+6)	1.3(+7)	2.8(+6)	-	-	-	85	7
	Max.	2.5(+7)	4.0(+8)	1.2(+7)	3.6(+7)	1.5(+7)	-	-	-	4000	
San Onofre*	Ave.	2.0(+6)	2.2(+7)	1.4(+6)	3.1(+6)	6.7(+5)	-	-	-	90	8
	Max.	2.0(+7)	1.2(+8)	4.2(+6)	2.0(+7)	3.8(+6)	-	-	-	400	
Yankee Rowe*	Ave.	6.7(+6)	3.3(+7)	4.5(+6)	1.7(+7)	5.5(+6)	-	6.6(+5)	-	70	9 ,13
	Max.	2.1(+7)	1.2(+8)	1.9(+7)	1.4(+8)	1.8(+7)	-	1.8(+6)	-	-	
Saxtonl**	Ave.	4.3(+6)	2.7(+7)	3.9(+6)	9.0(+7)	1.2(+6)	-	-	-	55	10, 11
	Max.	2.2(+7)	1.5(+8)	1.4(+7)	1.1(+8)	6.0(+6)	-	-	-	250	12, 13
Shippingport*	Ave.	2.3(+7)	2.8(+6)	1.3(+6)	2.2(+6)	1.8(+6)	5.2(+6)	7.0(+5)	-	75	14,15
	Max.	4.8(+7)	3.2(+6)	1.7(+6)	2.2(+6)	1.8(+6)	7.6(+5)	9.7(+5)	-	-	
Indian Point I*	Ave.	1.8(+6)	4.6(+6)	7.7(+5)	5.7(+6)	2.2(+6)	1.5(+5)	2.3(+5)	3.1(+9)	77	16
	Max.	2.9(+6)	9.1(+6)	2.0(+6)	8.2(+6)	3.3(+6)	-	4.2(+5)	1.2(+10)	-	
Maine-Yankee*	Ave.	-	-	-	-	-	-	1.29(+6)	-		
	Max.	2.22(+6)	4.53(+7)	9.70(+5)	4.24(+7)	2.03(+6)	-	7.26(+6)	-	41	17

TABLE 11.1-9(sh. 2 of 2)

MEASURED RADIOACTIVE CRUD ACTIVITY (dpm/mg-crud)

Reactor	^{60}Co	^{58}Co	^{54}Mn	^{51}Cr	^{59}Fe	^{181}Hf	^{95}Zr	^{64}Cu	Crud (ppb)	Ref
Oconee*										
Ave.	2.8(+6)	5.1(+7)	5.5(+5)	2.9(+7)	2.4(+5)	-	5.6(+6)	-	25	18
Max.	2.3(+7)	1.9(+8)	1.1(+7)	1.5(+8)	1.7(+6)	-	8.7(+6)	-	100	19,20
Average crud									68	
(ppb)									75+	

* Circulating crud.

** Deposited crud on fuel rods with exception of Cr-51 (ave, max) and Fe-59 (ave), which are circulating.

*** Numbers in parentheses denotes power of ten(10).

\+ Does not include Oconee data.

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TABLE 11.1-10

ACTIVATION PRODUCTS IN PRIMARY COOLANT

Activation Rates, $\Sigma_i \varphi$(d/g-sec)

Reactor	^{60}Co	^{58}Co	^{54}Mn	^{51}Cr	^{59}Fe	^{95}Zr	A_t/A_c
Conn. Yankee**	1.90(+10)*	7.00(+10)	1.40(+9)	2.90(+10)	1.90(+8)	-	4.10
San Onofre**	1.90(+10)	7.00(+10)	1.40(+9)	2.90(+10)	1.90(+8)	-	4.10
Yankee Rowe	1.70(+10)	1.50(+10)	4.34(+9)	1.90(+10)	3.50(+8)	7.50(+8)	3.13
Saxton	8.00(+9)	1.00(+10)	2.95(+9)	1.30(+10)	2.40(+8)	-	5.26
Shippingport	2.30(+10)	9.90(+9)	2.90(+9)	2.90(+10)	5.20(+8)	6.80(+8)	2.44
Indian Point 1	6.6(+9)	1.3(+10)	3.7(+9)	1.1(+10)	2.0(+9)	1.4(+8)	4.53
Maine-Yankee	6.5(+9)	6.1(+10)	5.2(+8)	1.9(+10)	6.3(+7)	3.8(+8)	5.44
Oconee	1.3(+10)	1.00(11)	3.1(+9)	9.8(+10)	9.5(+8)	3.1(+9)	4.00

* Numbers in parentheses denote power of ten.

** Conn. Yankee and San Onofre fluxes and area ratios assumed the same.

TABLE 11.1-11

SYSTEM PARAMETERS

Reactor	Stm. Gen Tubing	Core Cladding	Thermal Flux (n/cm^2-sec)	Fast Flux(n/cm^2-sec)	A_t/A_c
Conn. Yankee	Inconel	S. steel	4.0(+13)*	1.8(+14)	4.10
San Onofre**	Inconel	S. steel	4.4(+13)	1.8(+14)	4.10
Yankee Rowe	S. steel	Zircaloy	3.9(+13)	2.6(+14)	3.13
Saxton	S. steel	S. steel	1.8(+13)	1.2(+14)	5.26
Shippingport	S. steel	Zircaloy	5.1(+13)	1.5(+14)	2.44
Indian Point I	S. steel	S. steel***	1.5(+13)	1.5(+14)	4.53
Maine-Yankee	Inconel	Zircaloy	3.6(+13)	1.6(+14)	5.44
Oconee	Inconel	Zircaloy	3.6(+13)	1.5(+14)	4.00

* Numbers in parentheses denote power of ten.
** San onofre fluxes and area ration assumed same as Conn. Yankee.
*** Zircaloy box around each fuel assembly.

TABLE 11.1-12 (sh. 1 of 2)

AVERAGE AND MAXIMUM RESIDENCE TIMES.
(day)

Reactor	^{60}Co	^{58}Co	^{54}Mn	^{51}Cr	^{59}Fe	^{95}Zr
Conn. Yankee						
Ave.	92	10	54	1	Sat.*	-
Max.	262	51	390	4	Sat.	-
San Onofre						
Ave.	20	2	32	1	18	-
Max.	207	13	104	2	Sat.	-
Yankee Rowe						
Ave.	58	13	25	2	111	6
Max.	185	56	116	19	Sat.	17
Saxton						
Ave.	25	5	10	38	38	-
Max.	136	30	38	54	Sat.	-
Shippingport						
Ave.	115	1	8	1	10	2
Max.	246	1	11	1	10	3
Indian Point I						
Ave.	58	3	7	2	115	13
Max.	94	6	19	2	Sat.	24
Maine-Yankee						
Ave.	-	-	-	-	-	34**
Max.	87	7	84	9	Sat.	

TABLE 11.1-12 (sh. 2 of 2)

Reactor	^{60}Co	^{58}Co	^{54}Mn	^{51}Cr	^{59}Fe	^{95}Zr
Oconee						
Ave.	41	3	5	1	1	12
Max.	356	13	118	4	8	66
Ave. of Max. (T_{res})	197	22	110	12	Sat.	29
	174***	23	109	13	Sat.	30

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* ^{59}Fe isotope reaches saturation before erosion from core surfaces.

** Included in Ar-95 ave. of Max. (t_{res}).

*** Lover values do not include Oconee data.

TABLE 11.1-13

ASSUMED SYSTEM PARAMETERS

Parameter	Value*
Maximum thermal flux (n/cm^2-sec)	6.62 (+13)
Maximum fast flux (n/cm^2-sec)	3.05 (+14)
A_t/A_c	4.39

Assumed Activation Rates 2815 MWt Plant

Isotope	Activation Rate, $\Sigma_i \phi$ (d/g sec)*
^{60}Co	2.18(+10)
^{58}Co	6.77(+10)
^{54}Mn	6.20(+8)
^{51}Cr	8.51(+10)
^{59}Fe	1.86(+8)
^{95}Zr	1.09(+9)

* Numbers in parentheses denote power of ten.

TABLE 11.1-14

LONG-LIVED CRUD ACTIVITY FOR YGN 3 & 4

Isotope	Residence Time	Half Life	Activity (dpm/mg)*
^{60}Co	197 d	5.27 y	2.04(+7)
^{58}Co	23 d	70.9 d	1.86(+8)
^{54}Mn	110 d	312.2 d	1.84(+6)
^{51}Cr	12 d	27.7 d	3.02(+8)
^{59}Fe	Sat.	44.5 d	2.55(+6)
^{95}Zr	29 d	64.0 d	4.02(+6)

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* Numbers in parentheses denote powers of ten.

TABLE 11.1-15

AVERAGE CALCULATED REACTOR COOLANT CRUD ACTIVITY*

Isotope	Activity ($\mu Ci/cm^3$)
^{60}Co	6.89(-4)**
^{58}Co	6.27(-3)
^{54}Mn	6.19(-5)***
^{51}Cr	1.02(-2)
^{59}Fe	8.60(-5)***
^{95}Zr	1.36(-4)***

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* Reactor coolant temperature is 70 F (21.1℃). Crud level is 75 ppb.

** Numbers in parentheses denote powers of ten.

*** Lower than expected values based on ANSI/ANS-18.1-1984

TABLE 11.1-16

EQUILIBRIUM CRUD FILM THICKNESS

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TABLE 11.1-17

TRITIUM ACTIVATION REACTIONS

	Reaction	Threshold Energy (MeV)*	Cross Section (cm^2)**
1)	^{10}B (n, 2α)T	1.4	1.15(-26)***
2)	^{7}Li (n, nα)T	3.9	9.5 (-27)
3)	^{6}Li (n, α)T	Thermal	9.45(-22)
4)	D (n, γ)T	Thermal	5.50(-28)
5)	^{11}B (n, T)^{9}Be	10.4	7.3 (-30)
6)	^{14}N (n, T)^{12}C	4.3	3.00(-28)

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* Threshold energy and cross sections are from References 3.

** Spectrum averaged value for neutrons of energy greater than 0.625 eV.

*** Numbers in parentheses denote power of ten.

TABLE 11.1-18

PARAMETERS USED IN TRITIUM PRODUCTION DETERMINATION

Active core water volume, cm^3	2.29 (+7)*
Maximum thermal neutron flux, n / cm^2-se	6.62 (+13)
Maximum fast neutron flux, n / cm^2-sec	3.05 (+14)
Lithium concentration, ppm	
Average	1.1
Maximum	2.3
Lithium-6 Abundance, %	0.1
Boron concentration, ppm	
Average	685
Maximum	760
Power level, MWt	2872
Tritium release from fuel, %	
Average	1
Maximum	2
Tritium release from(EA, %)	50

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* Numbers in parentheses denote powers of ten.

TABLE 11.1-19

TRITIUM PRODUCTION IN REACTOR COOLANT (Bq/cycle)

Reaction	Maximum	Expected
H^2 (n, γ)T	2.58E+11	2.58E+11
Li^6 (n, α)T	8.80E+12	4.21E+12
Li^7 (n, nα)T	6.49E+11	3.10E+11
B^{10} (n, 2α)T	3.36E+13	3.02E+13
CEA	9.30E+12	1.67E+12
Fission	1.65E+13	8.26E+12
Total	6.91E+13	4.49E+13

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TABLE 11.1-20

MAXIMUM ANTICIPATED LEAKAGE RATES
FROM NSSS COMPONENTS
TO BUILDING ENVIRONMENT

Component	Leakage Assumptions
Valves	
Disk Leakage	10 cc/hr/inch seat diameter
Stem Leakage	10 cc/hr/inch seat diameter
Pumps	
Centrifugal (mechanical seal)	50 cc/hr per seal during normal operating conditions with availability of seal cooling water
	100 cc/hour per seal during loss of externally supplied cooling water
Positive Displacement	1 gallon/hr (3.785 L/hr)
HPSI & LPSI Pumps	1000 cc/hr per seal
Flanges	30 cc/hr

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Table 11.1-21

EXPECTED SPENT RESIN VOLUME (2 Units)

	Number	Volume (ft^3)	No. of Changes-Beds per Year	Total Waste Volume (ft^3)
CVCS				
Purification Ion Exchanger	4	36	4	144
Deborating Ion Exchanger	2	36	2	72
Preholdup Ion Exchanger	2	36	2	72
Boric Acid Condensate Ion Exchanger	2	34	2	68
Spent Fuel Pool Cleanup Demineralizers	4	108.0	4	432.0
Steam Generator Blowdown Demineralizers	4	155.0	4	620.0
LRS				
Radwaste Demineralizers	2	49.0	2	98.0
Chemical Waste	2	49.0	2	98.0
Demineralizer	2	49.0	2	98.0
Polishing Demineralizers	2	49.0	2	98.0
Oil Adsorber				

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TABLE 11.1-22 (sh. 1 of 2)

ANNUAL EXPECTED SPENT RESIN ACTIVITY INPUT TO SWMS

(Curies)

Nuclide	PURIFICATION IX	DEBORATING IX	PREHOLDUP IX	BORIC ACID CONDENSATE IX
N-16	1.6E-06	.0E+00	.0E+00	.0E+00
KR-85M	2.2E-01	2.2E-01	2.0E-01	1.8E-09
KR-85	1.5E+00	1.5E+00	1.5E+00	1.1E-07
KR-87	2.0E-01	2.0E-01	1.8E-01	4.9E-10
KR-88	3.8E-01	3.8E-01	3.4E-01	2.0E-09
XE-131M	1.2E+00	1.2E+00	1.1E+00	3.6E-08
XE-133M	9.8E-02	9.8E-02	9.1E-02	9.1E-09
XE-133	3.8E+00	3.8E+00	3.6E+00	7.2E-07
XE-135M	1.8E-01	1.8E-01	1.6E-01	8.7E-11
XE-135	1.2E+00	1.2E+00	1.0E+00	2.0E-08
XE-137	4.6E-02	4.6E-02	4.1E-02	5.5E-12
XE-138	1.6E-01	1.6E-01	1.5E-01	7.2E-11
BR-84	2.1E-01	1.9E-03	3.5E-05	4.3E-12
RB-88	7.2E-01	1.3E-01	1.5E-02	7.8E-10
SR-89	3.4E+00	3.0E-06	6.6E-03	9.0E-10
SR-90	1.9E+00	2.6E-07	4.0E-03	1.1E-10
SR-91	2.1E-01	2.3E-05	1.0E-04	5.7E-11
Y-91M	6.1E-04	6.1E-04	5.5E-04	1.1E-09
Y-91	5.6E-06	5.6E-06	5.4E-06	3.8E-09
ZR-95	1.2E+01	8.4E-06	2.4E-02	2.7E-09
NB-95	4.8E+00	6.0E-06	8.8E-03	1.6E-09
TC-99M	6.6E-01	1.2E-04	3.0E-04	1.7E-10
MO-99	8.9E+00	1.4E-04	8.1E-03	3.9E-09
RU-103	1.4E+02	1.6E-04	2.7E-01	4.4E-08
RU-106	9.5E+03	1.9E-03	2.0E+01	8.0E-07
TE-129M	3.2E+00	5.0E-03	5.1E-03	3.1E-07
TE-129	6.8E-01	6.2E-03	1.2E-04	3.1E-11
I-131	1.9E+02	9.4E-01	2.1E-01	6.2E-06
TE-131M	9.7E-01	8.7E-03	4.2E-04	2.7E-09
TE-131	8.1E-02	7.4E-04	1.3E-05	1.3E-12
TE-132	2.8E+00	2.2E-02	2.0E-03	3.1E-08
I-132	1.2E+01	1.1E-01	2.2E-03	1.1E-09

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TABLE 11.1-22 (sh. 2 of 2)

(Curies)

Nuclide	PURIFICATION IX	DEBORATING IX	PREHOLDUP IX	BORIC ACID CONDENSATE IX
I-133	6.6E+01	6.0E-01	2.4E-02	1.1E-07
I-134	7.5E+00	6.8E-02	1.3E-03	2.5E-10
CS-134	5.1E+02	4.1E-03	1.3E+01	3.9E-08
I-135	4.1E+01	3.7E-01	9.5E-03	1.5E-08
CS-136	3.1E+00	5.1E-04	7.2E-02	2.1E-09
CS-137	8.2E+02	5.5E-03	2.0E+01	5.2E-08
BA-140	8.1E+01	2.8E-04	1.3E-01	4.0E-08
LA-140	2.1E+01	5.6E-04	1.6E-02	8.2E-09
CE-141	2.4E+00	3.2E-06	4.3E-03	8.2E-10
CE-143	2.0E+00	6.3E-05	1.4E-03	7.1E-10
CE-144	3.8E+02	8.6E-05	7.9E-01	3.5E-08
CR-51	4.2E+00	1.6E-02	7.2E-03	1.5E-09
MN-54	1.6E+01	9.2E-03	3.2E-02	1.4E-09
FE-59	6.6E-01	1.6E-03	1.2E-03	1.8E-10
CO-58	1.6E+01	2.6E-02	3.0E-02	3.2E-09
CO-60	7.8E+00	3.1E-03	1.6E-02	4.8E-10
AG-110M	1.2E+02	2.8E-05	2.4E-01	1.1E-08
NA-24	1.6E+01	1.1E-03	8.5E-03	4.6E-09
FE-55	1.6E+01	6.9E-03	3.3E-02	1.1E-09
W-187	1.3E+00	5.7E-05	8.0E-04	4.3E-10
NP-239	2.6E+00	4.9E-05	2.2E-03	1.1E-09
ZN-65	4.5E+00	2.9E-03	9.0E-03	4.3E-10

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TABLE 11.1-23

RADIONUCLIDIC CRUD CONCENTRATIONS IN THE HIGH CAPACITY BLOWDOWN LIQUID
(μCi/gm)

Nuclide	Design-Basis Sources	Realistic Sources
Cr-51	4.71E-05	1.20E-05
Mn-54	6.70E-06	6.70E-06
Fe-55	0.00E+00	5.02E-06
Fe-59	1.19E-06	1.20E-06
Co-58	3.03E-05	1.88E-05
Co-60	3.47E-06	2.23E-06
Zn-65	0.00E+00	9.35E-07

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Table 11.1-24 (sh. 1 of 2)

DESIGN BASIS RADIONUCLIDIC CONCENTRATION
IN THE SECONDARY SYSTEM
(μCi/gm)

Nuclide	Steam Generator Liquid	Main Steam	
Kr-85m	0.00E+00	1.89E-07	
Kr-85	0.00E+00	3.69E-09	
Kr-87	0.00E+00	1.97E-07	
Kr-88	0.00E+00	4.67E-07	
Xe-131m	0.00E+00	3.93E-08	
Xe-133m	0.00E+00	1.03E-08	
Xe-133	0.00E+00	5.16E-06	
Xe-135m	0.00E+00	1.60E-07	
Xe-135	0.00E+00	7.62E-07	110
Xe-137	0.00E+00	3.69E-08	
Xe-138	0.00E+00	1.35E-07	
Br-84	1.31E-07	1.31E-09	
I-131	4.35E-05	4.35E-07	
I-132	8.88E-06	8.88E-08	
I-133	6.47E-05	6.47E-07	
I-134	3.83E-06	3.83E-08	
I-135	3.47E-05	3.47E-07	
Rb-88	7.86E-06	3.93E-08	
Cs-134	5.81E-06	2.90E-08	
Cs-136	9.64E-07	4.82E-09	
Cs-137	7.26E-06	3.63E-08	
Cr-51	2.39E-07	1.20E-09	
Mn-54	3.15E-08	1.58E-10	
Fe-55	0.00E+00	0.00E+00	
Fe-59	5.87E-09	2.94E-11	
Co-58	1.46E-07	7.31E-10	

Table 11.1-24 (sh. 2 of 2)

Nuclide	Steam Generator Liquid	Steam Generator Main Steam
Co-60	1.62E-08	8.11E-11
Zn-65	0.00E+00	0.00E+00
Sr-89	6.58E-08	3.29E-10
Sr-90	3.29E-09	1.65E-11
Sr-91	9.56E-08	4.78E-10
Y-91m	4.34E-08	2.17E-10
Y-91	9.17E-09	4.58E-11
Y-93	2.26E-09	1.13E-11
Zr-95	1.33E-08	6.65E-11
Nb-95	1.01E-08	5.05E-11
Mo-99	5.75E-06	2.88E-08
Tc-99m	2.45E-06	1.23E-08
Ru-103	3.52E-09	1.76E-11
Ru-106	1.39E-09	6.94E-12
Ag-110m	0.00E+00	0.00E+00
Te-129m	1.20E-07	5.99E-10
Te-129	6.19E-08	3.09E-10
Te-131m	5.83E-07	2.91E-09
Te-131	5.68E-08	2.84E-10
Te-132	3.93E-06	1.96E-08
Ba-137m	6.85E-06	3.42E-08
Ba-140	7.96E-08	3.98E-10
La-140	2.27E-08	1.13E-10
Ce-141	3.05E-09	1.53E-11
Ce-143	8.56E-09	4.28E-11
Ce-144	8.00E-09	4.00E-11
H-3	1.84E-03	1.84E-03

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TABLE 11.1-25 (sh. 1 of 2)

EXPECTED RADIONUCLIDIC CONCENTRATIONS IN THE SECONDARY SYSTEM
(μCi/gm)

Nuclide	Steam Generator Liquid	Main Steam
Kr-85m	0.00E+00	4.15E-08
Kr-85	0.00E+00	2.46E-07
Kr-87	0.00E+00	3.88E-08
Kr-88	0.00E+00	7.25E-08
Xe-131m	0.00E+00	2.27E-07
Xe-133m	0.00E+00	1.88E-08
Xe-133	0.00E+00	7.37E-07
Xe-135m	0.00E+00	3.37E-08
Xe-135	0.00E+00	2.21E-07
Xe-137	0.00E+00	8.77E-09
Xe-138	0.00E+00	3.10E-08
Br-84	9.92E-08	9.92E-10
I-131	8.21E-07	8.21E-09
I-132	2.82E-06	2.82E-08
I-133	2.55E-06	2.55E-08
I-134	2.93E-06	2.93E-08
I-135	4.40E-06	4.40E-08
Rb-88	7.82E-07	3.91E-09
Cs-134	1.56E-07	7.81E-10
Cs-136	1.92E-08	9.59E-11
Cs-137	2.07E-07	1.03E-09
Cr-51	6.10E-08	3.05E-10
Mn-54	3.15E-08	1.58E-10
Fe-55	2.35E-08	1.18E-10
Fe-59	5.92E-09	2.96E-11
Co-58	9.08E-08	4.54E-10
Co-60	1.04E-08	5.22E-11

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TABLE 11.1-25 (sh. 2 of 2)

EXPECTED RADIONUCLIDIC CONCENTRATIONS IN
THE SECONDARY SYSTEM
(μCi/gm)

Nuclide	Steam Generator Liquid	Main Steam
Zn-65	9.80E-09	4.90E-11
Sr-89	2.75E-09	1.37E-11
Sr-90	2.35E-10	1.18E-12
Sr-91	1.83E-08	9.17E-11
Y-91m	7.63E-09	3.81E-11
Y-91	1.02E-10	5.12E-13
Y-93	8.04E-08	4.02E-10
Zr-95	7.69E-09	3.84E-11
Nb-95	5.52E-09	2.76E-11
Mo-99	1.27E-07	6.35E-10
Tc-99m	8.53E-08	4.27E-10
Ru-103	1.48E-07	7.39E-10
Ru-106	1.77E-06	8.87E-09
Ag-110m	2.56E-08	1.28E-10
Te-129m	3.76E-09	1.88E-11
Te-129	2.54E-07	1.27E-09
Te-131m	2.96E-08	1.48E-10
Te-131	4.14E-08	2.07E-10
Te-132	3.37E-08	1.69E-10
Ba-137m	1.95E-07	9.75E-10
Ba-140	2.58E-07	1.29E-09
La-140	4.97E-07	2.49E-09
Ce-141	2.96E-09	1.48E-11
Ce-143	5.56E-08	2.78E-10
Ce-144	7.88E-08	3.94E-10
W-187	4.94E-08	2.47E-10
Np-239	4.36E-08	2.18E-10
H-3	1.84E-03	1.84E-03

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APPENDIX 11.1A

CORE RESIDENCE TIMES

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11.2 LIQUID WASTE MANAGEMENT SYSTEM

Liquid waste management is provided by the following systems:

a. Secondary chemistry control system(SCCS) comprised of the condensate polishing and steam generator blowdown processing subsystems

b. Spent fuel pool cooling and cleanup system (SFPCCS)

c. Radioactive drain system (RDS)

d. Radioactive laundry system (RLS)

e. Liquid radwaste system (LRS). Also, if necessary, the liquid radwastes which are collected and transported from YGN maintenance working shop can be treated by the liquid radwaste system (LRS) 425

The SCCS is discussed in Section 10.4, while the SFPCCS and RDS are discussed in Sections 9.1 and 9.3, respectively. The RLS and LRS are both discussed in this chapter under Subsection 11.2.2.

The LRS is common to both reactor units and is located in a separate building (e.g., the radwaste building). The other four systems are not shared between reactor units.

The boric acid recycle system is not part of the liquid waste management system. It is part of the chemical and volume control system (CVCS) and is discussed in Subsection 9.3.4.

11.2.1 Design Bases

11.2.1.1 Design Objectives

The function of the liquid radwaste management systems is to collect radioactive or potentially radioactive liquid wastes generated during plant operation, to process the liquid waste in order to remove radioactive isotopes; to accumulate radioactive isotopes for storage or disposal; and to recycle or discharge the treated liquid to the environment.

The principal design objectives of the liquid waste management systems are as follows:

a. To collect liquid waste generated during plant operation which may contain radioactive material.

b. To provide sufficient processing capacity, redundancy, and flexibility to treat the liquid radwaste in a manner to reduce the radionuclide concentrations to levels that do not exceed the concentration limits of the NSSC Notice 2014-34(방사선방호 등에 관한 기준) during normal operation, during periods of equipment downtime, and during operation with design basis fuel leakage. 735

c. To control releases of radioactive materials within the numerical design objectives of Appendix I to 10 CFR 50 in addition to maintaining releases "as low as reasonably achievable."

d. To purify the radioactive liquid wastes to enable reclaimed water to be reused in the plant to the extent practical.

A discussion of the ability of the liquid waste management systems to provide sufficient capacity, redundancy, and flexibility to control wastes in order to prevent radioactive liquid releases and minimize solidified waste is given in Subsection 11.2.2.

11.2.1.2 System Design

The major components of the LRS are listed in Table 11.2-1. Included are equipment sizes and/or capacities, process flow rates, storage capabilities, materials of construction, design temperatures and pressures and other relevant parameters. Applicable codes and standards of process equipment are listed in Table 11.2-2. The ability of the liquid waste management systems to process surge waste volumes is discussed in Subsection 11.2.2.

The layout of LRS components is indicated in the general arrangement drawings of Figures 1.2-42 through 1.2-46.

The seismic and quality group classifications for the LRS components and piping are provided in Table 3.2-3.

Compliance with General Design Criteria 60 and 64 of Appendix A to 10 CFR 50 is described in Section 3.1.

As required in Appendix I to 10 CFR 50, the liquid radwaste system is designed to meet the "as low as reasonably achievable" guidelines for population dose within 80 km of the site.

Equipment design provisions have been incorporated to reduce maintenance radiation exposure, equipment downtime, liquid leakage, and gaseous releases of radioactive materials to the building atmosphere. Where practical, welded connections are used in lieu of flanged ones. Butt welds and plug valves are used in high solids service in the liquid waste systems to reduce crud trap formation. Redundant or backup pumps are provided for all appropriate services. Process lines have connections that allow for flushing and maintenance of mechanical components without restricting system operation. The pumps are provided with mechanical seals to minimize leakage. The design life of the equipment is extended by utilizing corrosion-resistant materials. Provisions have also been incorporated to control the release of radioactive materials due to overflows or leakage from tanks containing potentially radioactive liquids. The principal method is to provide adequate tank capacity to accommodate anticipated volumes. Overflow of atmospheric tanks is minimized by the installation of level indicating instrumentation and high level alarms that are annunciated in radwaste control rooms to alert operators of potential overflow situations; a high-high level alarm is actuated by a separate level sensor. Overflow lines from the tanks are routed to the building sump whose contents are returned to the appropriate tanks in the LRS for processing. Table 11.2-3 provides a list of the potentially radioactive LRS atmospheric tanks and the design provisions incorporated to prevent releases by the control of tank overflow. Control of liquid releases due to tank leakage is provided for by plant design. Indoor tank rooms have entrance curbs to contain any leakage. Radioactive leakage is directed to the same sump as the tank overflow indicated in Table 11.2-3.

Liquid releases from the liquid waste management systems to the environment are through the circulating water channel for YGN 3&4.

Liquid leakage from the waste systems is collected by gravity drainage in respective sumps. The contents of these sumps are pumped to either the LRS high solids waste tanks or LRS low solids waste tanks. Liquid radioactive wastes are treated by filtration, oil removal processes, evaporation, and ion exchange for recycle or discharge. Radioactive wastes unsuited for plant recycle are discharged or solidified for offsite shipment.

Evaporative losses from the liquid waste management systems are filtered and monitored by the plant ventilation systems prior to discharge to the plant vent.

11.2.1.3 Codes and Standards

Codes and standards applicable to the LRS are listed in Table 3.2-1. The LRS is designed and constructed in accordance with the requirements of Regulatory Guide 1.143 as indicated in the Table 11.2-2.

11.2.2 System Description

11.2.2.1 Secondary Chemistry Control System (SCCS)

The SCCS is described in Section 10.4. High-conductivity regenerant solutions are produced as a result of condensate polishing demineralizer regeneration. | 204
These wastes are normally treated through the non-radioactive chemical waste treatment system. If a significant event occurs which necessitates that the regenerants be processed by the LRS (eg. steam generator tube leaks coincident with failed fuel), the wastes are transferred to the high or low solids waste collection tanks, depending on the conductivity. Based on the assumptions given is Table 11.2-4, the design basis radionuclide activity inventories on the SCCS components are listed in Table 11.2-5.

11.2.2.2 Spent Fuel Pool Cooling and Cleanup System (SFPCCS)

The SFPCCS is described in Subsection 9.1.3. Design-basis and expected fuel pool specific activities are listed in Table 11.1-3 and Table 11.1-7, respectively. Radionuclide activity inventories on the spent fuel pool cleanup system filters and demineralizers for design-basis and expected sources are presented in Table 11.2-7, based on assumptions in Table 11.2-6. No liquid releases from the SFPCCS are anticipated.

11.2.2.3 Radioactive Drain System (RDS)

The RDS is described in Subsection 9.3.3. The expected flows (for 2 operating units) and activities as a fraction of primary coolant activity are presented in Table 11.2-8, along with other waste inputs to the LRS.

The turbine building floor drain system is designed to collect and transfer liquid waste water from the turbine building sump (see Subsection 9.3.3.2) to the appropriate treatment/disposal area. The turbine building waste water is normally discharged to the discharge canal where it is monitored via the liquid discharge effluent monitor. If radioactivity is detected, the waste water will be diverted to the high total dissolved solids (TDS) collection tanks of the LRS.

11.2.2.4 Radioactive Laundry System (RLS)

Radioactively contaminated laundry is handled by laundry facilities located in each unit's access control building. The RLS consists of two compartment collection tank, filter, and adsorption bed. The process flow diagram for the RLS is included in Figure 11.2-1, and the piping and instrumentation diagram (P&ID) of the RLS is shown in Figure 11.2-2. The inputs to the collection tank include laundry waste water, access control building floor drains from potentially contaminated areas, and floor drains from the low level laboratory. The collected waste water is filtered and transfered to the LRS release tank. Following sampling, the laundry waste water may be directed to the chemical waste drain tank. The expected flows and activities as a fraction of primary coolant activity are presented in Table 11.2-8, along with other waste inputs to the LRS.

11.2.2.5 Liquid Radwaste System (LRS)

YGN 3&4 is equipped with an LRS that is housed in a separate radwaste building and is shared by both units. The principal functions of the LRS are as follows:

a. To collect for processing radioactive and potentially radioactive liquid wastes from the plant.

b. To process liquid wastes to the degree of purity necessary for recycle in the plant.

c. To minimize the quantity of solid waste transferred to the solid radwaste system for solidification and ultimate disposal.

d. to process liquid wastes to reduce the radionuclide concentration to values that will permit releases to the environment to satisfy plant tritium inventory and plant water balance requirements.

The process flow diagram of the LRS is shown in Figure 11.2-1. The piping and instrumentation drawing (P&ID) of the LRS is shown in Figure 11.2-3.

Flow rates of input waste streams to the LRS are identified in Table 11.2-8. This table includes design basis input flow rates and specific activities of the input streams as a fraction of primary coolant activity.

High TDS wastes are pumped from the collection tanks through a filter and oil removal equipment to the LRS evaporators for processing. The evaporators concentrate the waste up to 25 wt.% total dissolved solids excluding neutralized boric acid, which is concentrated up to 17 wt.%. The evaporator 65
concentrate is pumped to the concentrate tanks and ultimately to the solid radwaste system. The distillate from the evaporators is collected in demineralizer feed tanks and then pumped through a radwaste demineralizer train and the demineralizer effluent is sent to monitor tanks from which the liquid may be released, recycled, or routed back to the low total dissolved

solids (TDS) collection tank should further processing be desired. If released, the liquid is thoroughly mixed and sampled and metered to the circulating water discharge channel where the liquid is continuously monitored for radioactivity. If recycled, the liquid is thoroughly mixed and sampled and then routed to each unit's condensate storage or reactor makeup water tank.

Low TDS wastes are pumped from the collection tanks through a filter and to the demineralizer feed tanks. After passing through the demineralizer train to the monitor tanks, the flow paths are the same as high TDS waste.

Chemical drain wastes are pumped from the collection tanks through a filter. From here the waste may be routed to a chemical waste demineralizer train for handling unusual chemical contaminants, or to the evaporator, or the radwaste demineralizers. The eventual flow paths have been described earlier for each path except for the chemical waste demineralizer train. If the liquid in the chemical waste collection tank is routed to the special demineralizer train, it will flow through demineralizers that may be selectively loaded with activated charcoal, anion, cation, or mixed resin to achieve specific contaminant removal. The effluent is sent to the monitor tank from which the liquid may be returned to the chemical waste collection tank for further processing or released.

Concentrated boric acid from the CVCS boric acid concentrator, may be transferred to the radwaste processing system, should it be desired to dispose of the boric acid. In this case, concentrator bottoms are sent to the concentrate waste tank and ultimately to the solidification system. Refer to Section 11.4 for further discussion.

The design basis liquid radwaste system process point specific activities and the expected and design-basis component inventories, based on the assumptions given in Table 11.2-9, are listed in Table 11.2-10.

11.2.2.6 Operating Procedures

Operation of the liquid waste management systems consists of a series of automatic and manual batch operations. Collection is generally accomplished automatically, and processing paths are selected by the operator.

Besides the normal processing paths, certain other paths are incorporated for the changeout of specified equipment and the switching to redundant equipment.

A filter remains on line until the pressure drop across it reaches the design limit. When the limit is reached, the process flow is either stopped or diverted to a redundant filter. The filter cartridge is then replaced by the method described in Subsection 11.4.2.

A demineralizer remains on line until the pressure drop across the vessel reaches the design limit, the resin bed is exhausted based on effluent conductivity and decontaimination factor (DF), or when the unit radwaste 1
supervisor determines it necessary to place the demineralizer off line. When the demineralizer is to be changed out, the process flow is terminated, the vessel isolated, and spent resin sluiced to the low activity spent resin tank. New resin is manually loaded into the vessel and processing continues.

The evaporators are operated on either a batch or semicontinuous basis, depending upon the system load. In the event of evaporator outage, liquid can be held in collection tanks, processed by the remaining evaporator, or processed via demineralizers.

11.2.2.6.1 LRS Operation

The LRS is normally utilized to process floor and equipment drains from the containment, fuel, radwaste, and auxiliary buildings. During periods of primary-to-secondary leakage, however, the LRS may also receive and process wastes generated in the turbine building, such as equipment drains, floor drains, and condensate polisher regenerants. Design inputs to the LRS are tabulated in Table 11.2-8. Typically, the LRS is divided into three process trains; those liquids containing a low degree of total dissolved solids, those containing a high degree of total dissolved solids, and those containing chemicals. The LRS is designed so that the three trains may operate simultaneously.

11.2.2.6.1.1 Low Total Dissolved Solids (TDS) Wastes

The low TDS collection tanks normally receive waste water from equipment drains in the various buildings. Decant from spent resin tanks and resin sluice water are also inputs to the low TDS collection tanks. Infrequent inputs to the low TDS collection tanks are the recycle streams from the radwaste monitor tanks, and turbine building equipment drains, if radioactive.

When a low TDS collection tank has been filled (as indicated by a high-level alarm in the radwaste control room) or reaches some predetermined level, the contents are prepared for processing. First, any settled sludge is discharged from the bottom of the collection tank with a short sludge blow to the radwaste sludge tank. Then the remaining contents are sampled for radiological and chemical analysis. To ensure a representative sample, each collection tank is provided with a mechanical mixer which is run before sampling and during transfer operations. Based upon the results of the analysis, acid, caustic, or other conditioning chemicals are added, as needed. Following the conditioning step, the tank contents are ready for treatment by filtration and then demineralization or evaporation. It is expected that the low TDS waste would be treated with demineralizers. Only if the chemical analysis indicated an unusually high concentration of dissolved solids would evaporation be elected for the treatment. The collection tank contents are mixed continuously for uniformity of composition while the discharge flow is pumped through a filter and to the demineralizer feed tanks. In the demineralizer feed tanks the low TDS waste is mixed with evaporator distillate and both are processed through a demineralizer train, postfilter, and finally sent to monitor tanks. The prefilter removes particulate matter in the low TDS waste stream, the demineralizer train removes ionic species, and the postfilter assures no carryover of resin fines from the demineralizer train. Demineralized water collected in the monitor tanks is sampled, analyzed, and then returned to the low TDS collection tanks for further processing, if needed, or sent for plant release or recycle. If released, the demineralized water can only be sent to the circulating water discharge canal. If the demineralized water is recycled, the water can be sent to condensate storage or reactor makeup. The choice of release or recycle is used to maintain overall plant water balance. It is also used to maintain tritium concentrations in plant water at acceptably low levels by releasing tritiated water as needed and replacing the released water with non-tritiated makeup water.

11.2.2.6.1.2 High Total Dissolved Solids (TDS) Wastes

The high TDS collection tanks normally collect waste water from floor and equipment drains in the fuel building, the primary and secondary auxiliary buildings, the radwaste building and from floor drains in the containment. Regeneration wastes and decant from sludge tanks are also inputs to the high TDS collection tanks. Infrequent inputs to the high TDS collection tanks are the high solid drains from the radwaste sludge, concentrate, and resin tank cubicles.

When steam generator tube leaks exist coincident with failed fuel, the secondary water from the turbine and condenser will contain radioactivity. At these times provisions are made to treat waste water from the turbine building as radioactive waste. To achieve this the turbine building floor drains and condensate polisher regenerant chemicals are pumped into the high TDS collection tanks.

When a high TDS collection tank has been filled (as indicated by a high-level alarm in the radwaste control room) or reaches some predetermined level, the contents are prepared for processing. First, any settled sludge is discharged from the bottom of the collection tank with a short sludge blow to the radwaste sludge tank. Then the remaining contents are sampled for radiological and chemical analysis. To ensure a representative sample each collection tank is provided with a mechanical mixer which is run before sampling and during transfer operations. Based upon the results of the analysis, acid, caustic, or other conditioning chemicals are added, as needed. Following the conditioning step, the tank contents are ready for treatment by filtration, oil removal, and then evaporation. The collection tank contents are mixed continuously for uniformity of composition while the discharge flow is pumped through a filter, oil coalescer, oil adsorbers, and into the evaporator feed tank. When the evaporator feed tank has been filled (as indicated by a high-level alarm in the radwaste control room) or reaches some predetermined level, the contents are prepared for processing. A mechanical mixer is run to thoroughly mix the tank contents prior to drawing a sample and performing a chemical analysis. Based upon the results of the analysis, acid, caustic, or anti-foam agents are added, as needed. Following the chemical addition step, the tank contents are metered into the evaporator system. The evaporator is designed to operate on a batch or semicontinuous basis and the process flow is concentrated up to 50 wt.% total solids excluding neutralized boric acid which is concentrated to 25 wt.%. When the desired concentration is achieved, as indicated by density instrumentation, the evaporator concentrate is pumped to the concentrate waste tanks and ultimately to the solid radwaste system for solidification and shipment offsite. Distillate from the evaporation system is collected in the demineralizer feed tanks where it mixes with low TDS waste before being processed through a demineralizer train.

From the demineralizer feed tanks to final release from the plant or recycle, the high TDS operating procedures are identical to the low TDS procedures described in Subsection 11.2.2.6.1.1.

The entire sequence of steps for high TDS waste processing provides particulate matter removal by prefiltration, oil removal by coalescing and adsorption, purification by evaporation, residual ionic species removal by demineralization, and final resin fines removal by post filtration.

11.2.2.6.1.3 Chemical Wastes

The chemical waste tanks receive waste streams from the laundry, radiochemistry laboratories in the secondary auxiliary and radwaste buildings and waste streams from the decontamination facilities. When the tank has been filled (as indicated by a high-level alarm in the radwaste control room) or reaches some predetermined level, the contents are prepared for processing. First, any settled sludge is discharged from the bottom of the collection tank with a short sludge blow to the waste sludge tank. Then the remaining contents are sampled for radiological and chemical analysis. To ensure a representative sample the collection tank is provided with a mechanical mixer which is run before sampling and during transfer operations. Based upon the results of the analysis, acid, caustic, or other conditioning chemicals are added, as needed. Following the conditioning step, the tank contents are ready for treatment by filtration. The collection tank contents are mixed continuously for uniformity of composition while the discharge flow is pumped through a filter and to further treatment that includes special demineralization, processing as low TDS, or processing as high TDS.

It is expected that the chemical waste will be contaminated with unusual organic compounds. Chemical waste demineralizers are provided to remove the organics or other chemical species by demineralizer vessels that may be loaded with anion, cation, or mixed bed resin, activated charcoal, or other adsorption media. With several vessels in the train the operator and chemist will have the flexibility to tailor the media loaded into each vessel to address specific contaminant problems.

If the chemical analysis indicates no unusual chemical compounds are present, the chemical drain waste may be processed as low TDS waste or high TDS waste as described in Subsections 11.2.2.6.1.1 and 11.2.2.6.1.2.

Chemical wastes that are processed through the special demineralizer train are discharged into the LRS monitor tank.

11.2.2.6.1.4 LRS Abnormal Operation

The LRS abnormal design basis inputs are listed in Table 11.2-8 and the design assumptions are listed in Table 11.2-9. Inputs in excess of those tabulated for the design basis operation can be caused by a single isolated occurrence, such as back-to-back refueling or equipment outages. The LRS collection tanks have sufficient capacity to accommodate one condensate polishing demineralizer regeneration per day with accumulation of normal daily input from both units.

LRS process equipment is backed up by redundant equipment within the LRS itself. LRS collection tanks, feed tanks, monitor tanks, filters, pumps, demineralizers, and evaporators are all redundant. The capability of further processing is provided by the option to recirculate flow through the demineralizers or evaporators as many times as necessary. During equipment outages, the redundant equipment ensures that the liquid waste can be processed for recycle to the plant or released.

11.2.3 Radioactive Releases

"Delete"

Liquid wastes are released to 440

the circulating water discharge canal if the condensate or reactor makeup water system cannot accept additional water or if a discharge is necessary to prevent build-up of tritium levels in the plant water systems. Liquid releases are determined in the release tank and the recycle tank. The 369
release tank contents and the recycle tank contents are recirculated, sampled, and analyzed for chemical contaminants and radioactivity before it is routed to the release points. The radioactivity measurement must be below the limits listed in ITS, before a release is permitted. 349

This section describes the estimated liquid release from the plant for normal operation, including anticipated operational occurrences. Expected annual average releases of radionuclides in the liquid effluents are shown in Tables 11.2-11 "Delete" . These releases are determined by using the PWR-GALE 440
(Rev.1) computer program. Parameters describing the normal operation are listed in Tables 11.2-13 and 14. These values are used as input to the computer code.

11.2.3.1 Release Points

The only release point of liquid radwaste is the circulating water discharge canal. Prior to any discharges, activity levels are measured from samples 369
taken from the release tank and the recycle tank. A description of the effluent monitoring system is contained in Section 11.5.

11.2.3.2 Dilution Factors

Expected liquid effluent concentrations and comparison of concentrations in liquid effluents to the NSSC Notice 2014-34(방사선방호 등에 관한 기준). 735 Concentration Limits (for unrestricted areas) are presented in Table 11.2-15.

11.2.3.3 Estimated Doses

Results for the effective and organ doses to a maximum individual, and collective organ and effective doses to an individual, and thyroid and total body doses to the exposed population have been tabulated in Tables 11.2-16 and 11.2-17. Table 11.2-18 presents a comparison of these doses and the dose limits specified in the NSSC Notice 2014-34(방사선방호 등에 관한 기준). Assumptions and potential paths used in determining doses to the general public are given tin Table 11.2-19. 440 735

11.2.4 Safety Evaluation

The LRS serves no safety-related function.

11.2.5 Tests and Inspections

Preoperational testing is discussed in Chapter 14. Before installation, the LRS evaporators are functionally tested to verify that they perform properly. The system control panels are shop tested. The remainder of the system components are tested and inspected prior to shipment.

After installation, but before initial plant startup, the liquid waste system components are tested to verify pressure integrity, design condition flow characteristics, and proper valve, instrumentation, and control operation.

Upon plant startup and initial power operation, samples are taken o a batch basis to verify the particulated load and decontamination efficiencies of the filters, ion-exchangers, and evaporators. Instrumentation is recalibrated periodically.

High or potentially high activity streams, to and from or within the radwaste building, are routed through the hot pipe chases in which there are no valves or active components located. Spare lines will be provided with the hot pipe chases.

Design of the chase drainage and ventilation ensures efficient collection and detection of any leakage into the chase. Valves at the end of pipe chases permit hydrotesting for verification of leaktightness and for isolation of any line, if required.

11.2.6 Instrumentation

The instrumentation readout is located mainly on the control panel in the radwaste building control room, though some instruments are read locally. All alarms are shown separately on the radwaste building control room. Differential pressure indicators with local readout are provided for filters, strainers, and demineralizers.

The radiation monitoring instrumentation is described in Section 11.5.

11.2.7 References

1. Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants, U.S NRC Regulatory Guide 1.143, Rev.1, Oct. 1979.

2. Standard Review Plan 11.2, Liquid Waste Management System, NUREG-0800.

3. Liquid Radioactive Waste Processing System for Light Water Reactor Plant, ANSI/ANS-55.6, 1979.

TABLE 11.2-1 (Sh. 1 of 16)

LIQUID RADWASTE SYSTEM (LRS) EQUIPMENT DESCRIPTIONS

TABLE 11.2-1 (Sh. 2 of 16)

TABLE 11.2-1 (Sh. 3 of 16)

TABLE 11.2-1 (Sh. 4 of 16)

TABLE 11.2-1 (Sh. 5 of 16)

TABLE 11.2-1 (Sh. 6 of 16)

TABLE 11.2-1 (Sh. 7 of 16)

TABLE 11.2-1 (Sh. 8 of 16)

TABLE 11.2-1 (Sh. 9 of 16)

TABLE 11.2-1 (Sh. 10 of 16)

TABLE 11.2-1 (Sh. 11 of 16)

TABLE 11.2-1 (Sh. 12 of 16)

TABLE 11.2-1 (Sh. 13 of 16)

TABLE 11.2-1 (Sh. 14 of 16)

TABLE 11.2-1 (Sh. 15 of 16)

TABLE 11.2-1 (Sh. 16 of 16)

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TABLE 11.2-2

LIQUID RADWASTE SYSTEM EQUIPMENT CODES

TABLE 11.2-3

RADWASTE ATMOSPHERIC RADIOACTIVE TANK OVERFLOW PROTECTION

TABLE 11.2-4 (Sh. 1 of 2)

ASSUMPTIONS USED IN DETERMINING DESIGN BASIS SCCS ACTIVITIES

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TABLE 11.2-4 (Sh. 2 of 2)

TABLE 11.2-5 (Sh. 1 of 2)

DESGN-BASIS ACTIVITIES FOR SCCS COMPONENTS AND FLOW STREAMS

TABLE 11.2-5 (Sh. 2 of 2)

TABLE 11.2-6

ASSUMPTIONS USED IN DETERMINING SFPCCS ACTIVITIES

Item	Assumption
1.	Refueling pool activity listed in Table 11.1-3 for design-basis sources and Table 11.1-7 for expected sources are the activity when the dose rate from the source is maximum cycle, taken just after reactor vessel head removal.
2.	SFP activity listed in Table 11.1-3 for design-basis sources and Table 11.1-7 for expected sources are the peak for the cycle.
5.	No credit is taken for removal of activity by the SFPCCS filters in determining process point activities. In determining filter inventories, crud activity is assumed deposited on the filter element with the decontamination factor of 10.

TABLE 11.2-7 (sh. 1 of 2)

SFPCCS DESIGN BASIS AND EXPECTED ACTIVITIES (Ci)

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TABLE 11.2-7 (sh. 2 of 2)

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TABLE 11.2-8 (Sh. 1 of 2)

LRS INPUT

TABLE 11.2-8 (Sh. 2 of 2)

TABLE 11.2-9 (Sh. 1 of 3)

ASSUMPTIONS USED IN DETERMINING LRS ACTIVITIES

TABLE 11.2-9 (Sh. 2 of 3)

TABLE 11.2-9 (Sh. 3 of 3)

TABLE 11.2-10 (sh. 1 of 9)

LIQUID RADWASTE SYSTEM SOURCE TERMS

A. Liquid Radwaste System Expected Process Stream Concentration (μCi/㎤)

Radionuclide	Radwaste Evaporator Distilates	Radwaste Evaporator Concentrates	1st Radwaste Demineralizer Output Stream	2nd Radwaste Demineralizer Output Stream	1st Chemical Demineralizer Output Stream	2nd Chemical Demineralizer Output Stream
H 3	1.035E-01	0.000E-00	1.000E-01	1.000E-01	1.000E-02	1.000E-02
Na 24	4.000E-03	1.821E-00	4.000E-02	4.000E-03	4.000E-03	4.000E-04
Cr 51	2.600E-07	2.483E-04	2.600E-06	2.600E-07	2.600E-07	2.600E-08
Mn 54	1.340E-07	1.303E-04	1.340E-06	1.340E-07	1.340E-07	1.340E-08
Fe 55	1.000E-07	9.736E-05	1.000E-06	1.000E-07	1.000E-07	1.000E-08
Co 58	3.860E-07	3.731E-04	3.860E-06	3.860E-07	3.860E-07	3.860E-08
Fe 59	2.520E-08	2.425E-05	2.520E-07	2.520E-08	2.520E-08	2.520E-09
Co 60	4.440E-08	4.324E-05	4.440E-07	4.440E-08	4.440E-08	4.440E-09
Zn 65	4.270E-08	4.150E-05	4.270E-07	4.270E-08	4.270E-08	4.270E-09
Br 84	1.660E-06	3.234E-05	1.660E-05	1.660E-06	1.660E-06	1.660E-07
Rb 88	1.990E-05	2.169E-04	9.950E-03	9.950E-04	9.950E-04	9.950E-05
Sr 89	1.170E-08	1.128E-05	1.170E-07	1.170E-08	1.170E-08	1.170E-09
Y 89m	0.000E+00	1.128E-09	0.000E+00	0.000E+00	0.000E-00	0.000E+00
Sr 90	1.000E-09	9.741E-07	1.000E-08	1.000E-09	1.000E-09	1.000E-10
Y 90m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 90	0.000E+00	1.783E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 91	9.010E-08	2.977E-05	9.010E-07	9.010E-08	9.010E-08	9.010E-09
Y 91m	4.750E-08	1.881E-05	4.750E-07	4.750E-08	4.750E-08	4.750E-09
Y 91	4.360E-10	8.317E-07	4.360E-09	4.360E-10	4.360E-10	4.360E-11
Y 93	3.920E-07	1.353E-04	3.920E-06	3.920E-07	3.920E-07	3.920E-08
Zr 93	0.000E-00	1.916E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb 93m	0.000E+00	1.609E-17	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Zr 95	3.270E-08	3.158E-05	3.270E-07	3.270E-08	3.270E-08	3.270E-09
Nb 95m	0.000E+00	8.560E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb 95	2.350E-08	2.302E-05	2.350E-07	2.350E-08	2.350E-08	2.350E-09

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TABLE 11.2-10 (sh. 2 of 9)

A. Liquid Radwaste System Expected Process Stream Concentration (μCi/㎤) (Cont'd)

Radionuclide	Radwaste Evaporator Distilates	Radwaste Evaporator Concentrates	1st Radwaste Demineralizer Output Stream	2nd Radwaste Demineralizer Output Stream	1st Chemical Demineralizer Output Stream	2nd Chemical Demineralizer Output Stream
Mo 99	5.520E-07	4.432E-04	5.520E-06	5.520E-07	5.520E-07	5.520E-08
Tc 99m	4.520E-07	4.086E-04	4.520E-06	4.520E-07	4.520E-07	4.520E-08
Tc 99	0.000E-00	3.523E-12	0.000E+00	0.000E+00	0.000E+00	0.000E-00
Ru103	6.290E-07	6.042E-04	6.290E-06	6.290E-07	6.290E-07	6.290E-08
Rh103m	0.000E-00	0.000E-00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Ru106	7.540E-06	7.334E-03	7.540E-05	7.540E-06	7.540E-06	7.540E-07
Rh106m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rh106	0.000E+00	0.000E+00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Ag110m	1.090E-07	1.059E-04	1.090E-06	1.090E-07	1.090E-07	1.090E-08
Ag110	0.000E+00	1.377E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te129m	1.600E-08	1.533E-05	1.600E-07	1.600E-08	1.600E-08	1.600E-09
Te129	2.460E-06	1.132E-04	2.460E-05	2.460E-06	2.460E-06	2.460E-07
I 129	0.000E-00	1.897E-14	0.000E-00	0.000E+00	0.000E-00	0.000E-00
Te131m	1.320E-07	8.505E-05	1.320E-06	1.320E-07	1.320E-07	1.320E-08
Te131	8.010E-07	2.742E-05	8.010E-06	8.010E-07	8.010E-07	8.010E-08
I 131	3.970E-05	3.588E-03	3.970E-05	3.970E-06	3.970E-06	3.970E-07
Xe131m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te132	1.460E-07	1.204E-04	1.460E-06	1.460E-07	1.460E-07	1.460E-08
I 132	2.130E-04	1.891E-03	2.130E-04	2.130E-05	2.130E-05	2.130E-06
I 133	1.300E-04	7.099E-03	1.300E-04	1.300E-05	1.300E-05	1.300E-06
Xe133m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133	0.000E-00	0.000E+00	0.000E+00	0.000E-00	0.000E-00	0.000E+00
I 134	3.520E-04	1.111E-03	3.520E-04	3.520E-05	3.520E-05	3.520E-06
Cs134	6.450E-07	6.279E-04	3.225E-04	3.225E-05	3.225E-05	3.225E-06
I 135	2.530E-04	6.026E-03	2.530E-04	2.530E-05	2.530E-05	2.530E-06
Xe135m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E-00	0.000E+00
Xe135	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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TABLE 11.2-10 (sh. 3 of 9)

A. Liquid Radwaste System Expected Process Stream Concentration (μCi/㎤) (Cont'd)

Radionuclide	Radwaste Evaporator Distilates	Radwaste Evaporator Concentrates	1st Radwaste Demineralizer Output Stream	2nd Radwaste Demineralizer Output Stream	1st Chemical Demineralizer Output Stream	2nd Chemical Demineralizer Output Stream
Cs135	0.000E+00	0.000E+00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Cs136	7.960E-08	7.430E-05	3.980E-05	3.980E-06	3.980E-06	3.980E-07
Cs137	8.540E-07	8.319E-04	4.270E-04	4.270E-05	4.270E-05	4.270E-06
Ba137m	0.000E+00	7.766E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba140	1.100E-06	1.026E-03	1.100E-05	1.100E-06	1.100E-06	1.100E-07
La140	2.190E-06	1.838E-03	2.190E-05	2.190E-06	2.190E-06	2.190E-07
Ce141	1.260E-08	1.207E-05	1.260E-07	1.260E-08	1.260E-08	1.260E-09
Ce143	2.470E-07	1.648E-04	2.470E-06	2.470E-07	2.470E-07	2.470E-08
Pr143	0.000E+00	0.000E+00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Ce144	3.350E-07	3.257E-04	3.350E-06	3.350E-07	3.350E-07	3.350E-08
Pr144	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
W 187	2.230E-07	1.306E-04	2.230E-06	2.230E-07	2.230E-07	2.230E-08
Np239	1.900E-07	1.474E-04	1.900E-06	1.900E-07	1.900E-07	1.900E-08
Totals	1.085E-01	1.857E+00	1.519E-01	1.052E-01	1.519E-02	1.052E-02

TABLE 11.2-10 (sh. 4 of 9)

B. Liquid Radwaste System Expected Inventories (Curies) (Based on Average Daily Flows for 1 Unit)

Radionuclide	Radwaste Evaporator	Radwaste Demineralizer	Chemical Waste Dmineralizer	Chemical Waste Filter	Laundry Drains Fiiter	TDS Filter	Radwaste Demins After Filter	Chem.Waste Demins.After Filter
H 3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Na 24	1.931E+01	2.323E+01	5.428E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cr 51	2.632E-03	6.639E-02	1.565E-03	1.272E-03	3.403E-06	3.850E-02	6.088E-05	1.422E-06
Mn 54	1.381E-03	1.326E-01	4.976E-03	1.487E-03	2.073E-06	2.996E-02	1.936E-04	4.524E-06
Fe 55	1.032E-03	1.140E-01	4.808E-03	1.188E-03	1.565E-06	2.306E-02	1.871E-04	4.371E-06
Co 58	3.955E-03	2.145E-01	5.774E-03	3.156E-03	5.641E-06	7.479E-02	2.247E-04	5.249E-06
Fe 59	2.571E-04	9.945E-03	2.446E-04	1.674E-04	3.531E-07	4.402E-03	9.518E-06	2.224E-07
Co 60	4.584E-04	5.237E-02	2.278E-03	5.364E-04	6.965E-07	1.031E-02	8.866E-05	2.071E-06
Zn 65	4.400E-04	4.033E-02	1.459E-03	0.000E+00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Br 84	3.429E-04	3.400E-04	7.942E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rb 88	2.300E-03	1.151E-03	2.690E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 89	1.195E-04	5.192E-03	1.308E-04	0.000E+00	0.000E+00	0 000E+00	0.000E-00	0.000E-00
Y 89m	1.195E-08	5.193E-07	1.308E-08	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.00DE+00
Sr 90	1.033E-05	1.213E-03	5.410E-05	0.000E+00	0.000E-00	0.000E+00	0.000E+00	0.000E+00
Y 90m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.00QE+00
Y 90	1.890E-06	1.188E-03	5.354E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 91	3.156E-04	3.366E-04	7.864E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 91m	1.994E-04	2.129E-04	4.973E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 91	8.818E-06	5.264E-04	1.358E-05	0.000E+00	0.000E+00	0.000E-00	0.000E+00	0.000E+00
Y 93	1.434E-03	1.546E-03	3.612E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr 93	2.032E-12	3.706E-10	1.666E-11	0.000E+00	0.000E+00	0 000E+00	0.000E+00	0.000E+00
Nb 93m	1.706E-16	0.000E+00	8.866E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr 95	3.348E-04	1.709E-02	4.505E-04	2.580E-04	4.743E-07	6.228E-03	1.753E-05	4.096E-07
Nb 95m	9.075E-07	3.387E-04	8.999E-06	4.965E-06	0.000E+00	1.102E-04	3.502E-07	8.181E-09
Nb 95	2.441E-04	2.204E-02	6.180E-04	2.877E-04	3.192E-07	5.834E-03	2.405E-05	5.618E-07
Mo 99	4.699E-03	1.428E-02	3.336E-04	3.033E-04	2.217E-06	1.300E-02	1.298E-05	3.033E-07
Tc 99m	4.332E-03	1.353E-02	3.160E-04	2.650E-04	0.000E+00	1.136E-02	1.135E-05	2.650E-07
Tc 99	3.735E-11	2.561E-08	1.161E-09	2.334E-10	0.000E+00	4.166E-09	4.207E-11	9.828E-13
Ru103	6.405E-03	2.221E-01	5.373E-03	3.883E-03	8.680E-06	1.058E-01	2.091E-04	4.884E-06
Rh103m	0.000E+00	2.221E-01	5.373E-03	3.882E-03	0.000E+00	1.057E-01	2.091E-04	4.884E-06
Ru106	7.775E-02	7.733E+00	2.984E-01	8.514E-02	1.169E-04	1.699E+00	1.161E-02	2.713E-04
Rh106m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rh106	0.000E+00	7.733E+00	2.984E-01	8.514E-02	0.000E+00	1.699E+00	1.161E-02	2.713E-04
Ag110m	1.123E-03	1.037E-01	3.774E-03	1.186E-03	0.000E+00	2.416E-02	1.469E-04	3.431E-06

TABLE 11.2-10 (sh. 5 of 9)

B. Liquid Radwaste System Expected Inventories (Curies) (Based on Average Daily Flows for 1 Unit) (Cont'd)

Radionuclide	Radwaste Evaporator	Radwaste Demineralizer	Chemical Waste Dmineralizer	Chemical Waste Filter	Laundry Drains Fiiter	TDS Filter	Radwaste Demins After Filter	Chem. Waste Demins. After Filter
Ag110	1.460E-05	1.348E-03	4.907E-05	1.542E-05	0.000E+00	3.140E-04	1.909E-06	4.461E-08
Te129m	1.626E-04	4.936E-03	1.177E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te129	1.200E-03	4.251E-03	1.008E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 129	2.01IE-13	1.028E-10	5.184E-12	0.000Et00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te131m	9.017E-04	1.529E-03	3.571E-05	0.000Et00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te131	2.907E-04	4.040E-04	9.439E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 131	3.804E-02	2.983E-01	6.969E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe131m	0.000E+00	1.790E-03	4.181E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te132	1.276E-03	4.403E-03	1.029E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 132	2.005E-02	2.332E-02	5.449E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 133	7.527E-02	1.055E-01	2.465E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133m	0.000E+00	2.532E-03	5.916E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133	0.000E+00	1.055E-01	2.465E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 134	1.178E-02	1.179E-02	2.754E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs134	6.657E-03	3.646E-01	1.514E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 135	6.389E-02	6.554E-02	1.531E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe135m	0.000E+00	1.966E-02	4.593E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe135	0.000E+00	6.554E-02	1.531E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs135	0.000E+00	7.836E-09	3.525E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs136	7.877E-04	4.836E-03	1.130E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs137	8.820E-03	5.232E-01	2.335E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba137m	8.233E-03	4.892E-01	2.184E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba140	1.088E-02	1.304E-01	3.047E-03	0.000E+00	0.000E-00	0.000E-00	0.000E+00	0.000E+00
La140	1.949E-02	1.644E-01	3.841E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce141	1.280E-04	3.784E-03	9.001E-05	6.950E-05	1.693E-07	1.995E-03	3.503E-06	8.183E-08
Ce143	1.748E-03	3.150E-03	7.358E-05	6.689E-05	5.067E-07	2.868E-03	2.863E-06	6.689E-08
Pr143	0.000E+00	3.150E-03	7.358E-05	6.614E-05	0.000E+00	2.453E-03	2.863E-06	6.689E-08
Ce144	3.453E-03	3.272E-01	1.215E-02	3.693E-03	5.173E-06	7.468E-02	4.726E-04	1.104E-05
Pr144	0.000E+00	3.271E-01	1.215E-02	3.692E-03	0.000E+00	7.465E-02	4.726E-04	1.104E-05
W 187	1.385E-03	2.057E-03	4.805E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Np239	1.562E-03	4.142E-03	9.677E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total =	1.969E+01	4.302E+01	1.286E+00	1.958E-01	1.482E-04	4.008E+00	2.558E-02	5.976E-04

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TABLE 11.2-10 (sh. 6 of 9)

C. Liquid Radwaste System Design Basis Process Stream Concentrations (μCi/㎤)

Radionuclide	Radwaste Evaporator Distilates	Radwaste Evaporator Concentrates	1st Radwaste Demineralizer Output Stream	2nd Radwaste Demineralizer Output Stream	1st Chemical Demineralizer Output Stream	2nd Chemical Demineralizer Output Stream
H 3	1.034E-01	0.000E+00	1.000E-01	1.000E-01	1.000E-02	1.000E-02
Cr 51	1.020E-06	1.698E-02	1.020E-05	1.020E-06	1.020E-06	1.020E-07
Mn 54	1.340E-07	2.267E-03	1.340E-06	1.340E-07	1.340E-07	1.340E-08
Co 58	6.220E-07	1.047E-02	6.220E-06	6.220E-07	6.220E-07	6.220E-08
Fe 59	2.520E-08	4.224E-04	2.520E-07	2.520E-08	2.520E-08	2.520E-09
Co 60	6.890E-08	1.167E-03	6.890E-07	6.890E-08	6.890E-08	6.890E-09
Br 84	2.200E-06	1.064E-03	2.200E-05	2.200E-06	2.200E-06	2.200E-07
Rb 88	2.000E-04	5.448E-02	1.000E-01	1.000E-02	1.000E-02	1.000E-03
Sr 89	2.800E-07	4.700E-03	2.800E-06	2.800E-07	2.800E-07	2.800E-08
Y 89m	0.000E+00	4.700E-07	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 90	1.400E-08	2.372E-04	1.400E-07	1.400E-08	1.400E-08	1.400E-09
Y 90m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 90	0.000E+00	3.802E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 91	4.700E-07	3.156E-03	4.700E-06	4.700E-07	4.700E-07	4.700E-08
Y 91m	2.700E-07	2.003E-03	2.700E-06	2.700E-07	2.700E-07	2.700E-08
Y 91	3.900E-08	6.896E-04	3.900E-07	3.900E-08	3.900E-08	3.900E-09
Y 93	1.100E-08	7.666E-05	1.100E-07	1.100E-08	1.100E-08	1.100E-09
Zr 93	0.000E+00	8.527E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb 93m	0.000E+00	6.475E-18	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr 95	5.660E-08	9.519E-04	5.660E-07	5.660E-08	5.660E-08	5.660E-09
Nb 95m	0.000E+00	2.252E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb 95	4.300E-08	7.314E-04	4.300E-07	4.300E-08	4.300E-08	4.300E-09
Mo 99	2.500E-05	3.584E-01	2.500E-04	2.500E-05	2.500E-05	2.500E-06
Tc 99m	1.300E-05	2.927E-01	1.300E-04	1.300E-05	1.300E-05	1.300E-06
Tc 99	0.000E+00	2.124E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ru103	1.500E-08	2.511E-04	1.500E-07	1.500E-08	1.500E-08	1.500E-09
Rh103m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ru106	5.900E-09	9.983E-05	5.900E-08	5.900E-09	5.900E-09	5.900E-10
Rh106m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rh106	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te129m	5.100E-07	8.519E-03	5.100E-06	5.100E-07	5.100E-07	5.100E-08
Te129	6.000E-07	5.741E-03	6.000E-06	6.000E-07	6.000E-07	6.000E-08
I 129	0.000E+00	7.003E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00

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TABLE 11.2-10 (sh. 7 of 9)

C. Liquid Radwaste System Design Basis Process Stream Concentrations ($\mu Ci/cm^3$) (cont'd)

Radionuclide	Radwaste Evaporator Distilates	Radwaste Evaporator Concentrates	1st Radwaste Demineralizer Output Stream	2nd Radwaste Demineralizer Output Stream	1st Chemical Demineralizer Output Stream	2nd Chemical Demineralizer Output Stream
Te131m	2.600E-06	3.085E-02	2.600E-05	2.600E-06	2.600E-06	2.600E-07
Te131	1.100E-06	5.871E-03	1.100E-05	1.100E-06	1.100E-06	1.100E-07
I 131	2.100E-03	3.326E+00	2.100E-03	2.100E-04	2.100E-04	2.100E-05
Xe131m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te132	1.700E-05	2.494E-01	1.700E-04	1.700E-05	1.700E-05	1.700E-06
I 132	6.700E-04	3.543E-01	6.700E-04	6.700E-05	6.700E-05	6.700E-06
I 133	3.300E-03	3.396E+00	3.300E-03	3.300E-04	3.300E-04	3.300E-05
Xe133m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 134	4.600E-04	3.569E-02	4.600E-04	4.600E-05	4.600E-05	4.600E-06
Cs134	2.400E-05	4.064E-01	1.200E-02	1.200E-03	1.200E-03	1.200E-04
I 135	2.000E-03	1.013E+00	2.000E-03	2.000E-04	2.000E-04	2.000E-05
Xe135m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe135	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs135	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs136	4.000E-06	6.531E-02	2.000E-03	2.000E-04	2.000E-04	2.000E-05
Cs137	3.000E-05	5.083E-01	1.500E-02	1.500E-03	1.500E-03	1.500E-04
Ba137m	2.800E-05	4.752E-01	2.800E-04	2.800E-05	2.800E-05	2.800E-06
Ba140	3.400E-07	5.548E-03	3.400E-06	3.400E-07	3.400E-07	3.400E-08
La140	1.000E-07	2.623E-03	1.000E-06	1.000E-07	1.000E-07	1.000E-08
Ce141	1.300E-08	2.171E-04	1.300E-07	1.300E-08	1.300E-08	1.300E-09
Ce143	3.800E-08	4.648E-04	3.800E-07	3.800E-08	3.800E-08	3.800E-09
Pr143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce144	3.400E-08	5.751E-04	3.400E-07	3.400E-08	3.400E-08	3.400E-09
Pr144	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	1.123E-01	1.064E+01	2.385E-01	1.138E-01	2.385E-02	1.138E-02

TABLE 11.2-10 (sh. 8 of 9)

D. Liquid Radwaste System Design Basis Inventories (Curies)

Radionuclide	Radwaste Evaporator	Radwaste Demineralizer	Chemical Waste Dmineralizer	Chemical Waste Filter	Laundry Drains Filter	TDS Filter	Radwaste Demins After Filter	Chem. Waste Demins. After Filter
H 3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cr 51	1.801E-01	9.649E-01	7.062E-02	1.229E-02	2.276E-05	3.811E-01	1.682E-03	8.692E-05
Mn 54	2.403E-02	1.590E-01	1.547E-02	3.664E-03	3.534E-06	7.561E-02	4.013E-04	3.648E-05
Co 58	1.110E-01	6.835E-01	5.996E-02	1.253E-02	1.550E-05	3.041E-01	1.505E-03	1.060E-04
Fe 59	4.478E-03	2.616E-02	2.135E-03	4.124E-04	5.971E-07	1.111E-02	5.243E-05	3.197E-06
Co 60	1.237E-02	8.341E-02	8.352E-03	2.051E-03	1.843E-06	4.039E-02	2.187E-04	2.151E-05
Br 84	1.128E-02	4.059E-03	1.683E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rb 88	5.776E-01	1.042E-01	4.321E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 89	4.983E-02	2.968E-01	2.486E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 89m	4.983E-06	2.968E-05	2.486E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 90	2.515E-03	1.700E-02	1.710E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 90m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 90	4.030E-04	1.390E-02	1.581E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr 91	3.346E-02	1.582E-02	6.557E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 91m	2.124E-02	1.007E-02	4.174E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 91	7.311E-03	4.553E-02	3.894E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Y 93	8.128E-04	3.908E-04	1.620E-05	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr 93	9.040E-13	1.008E-11	1.033E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb 93m	6.864E-17	9.294E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Zr 95	1.009E-02	6.162E-02	5.340E-03	1.101E-03	1.399E-06	2.720E-02	1.335E-04	9.157E-06
Nb 95m	2.388E-05	9.396E-04	9.776E-05	2.117E-05	0.000E+00	4.815E-04	2.492E-06	1.802E-07
Nb 95	7.754E-03	5.426E-02	5.433E-03	1.260E-03	9.959E-07	2.643E-02	1.408E-04	1.155E-05
Mo 99	3.800E+00	5.794E+00	2.415E-01	3.384E-02	1.711E-04	1.486E+00	5.296E-03	2.196E-04
Tc 99m	3.104E+00	5.333E+00	2.223E-01	2.958E-02	0.000E+00	1.299E+00	4.629E-03	1.919E-04
Tc 99	2.252E-08	9.236E-07	1.064E-07	2.605E-08	0.000E+00	4.762E-07	2.696E-09	2.814E-10
Ru103	2.662E-03	1.525E-02	1.213E-03	2.282E-04	3.529E-07	6.365E-03	2.956E-05	1.723E-06
Rh103m	0.000E+00	1.521E-02	1.212E-03	2.281E-04	0.000E+00	6.359E-03	2.954E-05	1.723E-06
Ru106	1.058E-03	7.029E-03	6.881E-04	1.642E-04	1.560E-07	3.355E-03	1.788E-05	1.652E-06
Rh106m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Rh106	0.000E+00	7.029E-03	6.881E-04	1.641E-04	0.000E+00	3.355E-03	1.788E-05	1.652E-06

TABLE 11.2-10 (sh. 9 of 9)

D. Liquid Radwaste System Design Basis Inventories (Curies) (Cont'd)

Radionuclide	Radwaste Evaporator	Radwaste Demineralizer	Chemical Waste Dmineralizer	Chemical Waste Filter	Laundry Drains Filter	TDS Filter	Radwaste Demins After Filter	Chem. Waste Demins. After Filter
Te129m	9.032E-02	5.041E-01	3.879E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te129	6.086E-02	3.242E-01	2.491E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 129	7.424E-12	6.351E-10	1.294E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te131m	3.271E-01	2.712E-01	1.124E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te131	6.224E-02	5.042E-02	2.090E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 131	3.526E+01	1.183E+02	5.798E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe131m	0.000E+00	3.694E-01	3.060E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te132	2.644E+00	4.566E+00	1.915E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 132	3.756E+00	5.101E+00	2.137E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 133	3.600E+01	2.413E+01	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133m	0.000E+00	5.776E-01	2.401E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe133	0.000E+00	2.226E+01	9.987E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 134	3.783E-01	1.388E-01	5.753E-03	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs134	4.308E+00	1.459E+01	1.448E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I 135	1.074E+01	4.667E+00	1.935E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe135m	0.000E+00	1.400E+00	5.804E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe135	0.000E+00	4.667E+00	1.935E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs135	0.000E+00	5.915E-08	6.123E-09	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs136	6.924E-01	1.476E+00	8.480E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs137	5.389E+00	1.840E+01	1.851E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba137m	5.038E+00	1.721E+01	1.730E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba140	5.882E-02	2.467E-01	1.411E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
La140	2.781E-02	2.432E-01	1.454E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce141	2.301E-03	1.277E-02	9.762E-04	1.767E-04	2.977E-07	5.193E-03	2.352E-05	1.289E-06
Ce143	4.927E-03	4.365E-03	1.810E-04	2.536E-05	1.329E-07	1.114E-03	3.968E-06	1.645E-07
Pr143	0.000E+00	2.700E-03	1.660E-04	2.507E-05	0.000E+00	9.523E-04	3.771E-06	1.644E-07
Ce144	6.097E-03	4.027E-02	3.911E-03	9.234E-04	8.950E-07	1.913E-02	1.014E-04	9.158E-06
Pr144	0.000E+00	4.024E-02	3.910E-03	9.233E-04	0.000E+00	1.912E-02	1.013E-04	9.157E-06
Total =	1.128E+02	2.533E+02	1.461E+01	9.961E-02	2.196E-04	3.716E+00	1.439E-02	7.131E-04

Table 11.2-11 (1 of 2)

Expected Releases of Radionuclides in Liquid Effluents(One-Unit Operation)

Table 11.2-11 (2 of 2)

TABLE 11.2-12

"Delete" 440

TABLE 11.2-13

DESIGN-BASIS PROCESS DECONTAMINATION FACTORS (DF)

Filters

For process stream decontamination: DF = 1
For filters buildup determination: DF = 10 for crud isotopes

Demineralizer*	Anion	Cs, Rb	Other Nuclides
Mixed Bed			
Primary coolant letdown (CVCS)	100	2	50
Radwaste (H^+OH^-)	100(10)	2(10)	100(10)
Evaporator condensate polishing	5	1	10
Boron recycle	10	2	10
Steam generator blowdown	100(10)	10(10)	100(10)
Cation bed (any system)	1(1)	10(10)	10(10)
Anion bed (any system)	100(10)	1(1)	1(1)
Powdex (any system)	10(10)	2(10)	10(10)

Evaporators	All Nuclides Except Iodine	Iodine
Miscellaneous radwaste	1000	100
Boric acid recovery	1000	100

NOTE : $DF = \frac{\text{concentration entering component}}{\text{concentration leaving component}}$

* For two demineralizers in series, the DF of the second is given in parentheses.

The DF value of the demineralizer unit for the BRS distillate is taken from NUREG-0017, April 1985 (Rev. 1).

DF = 1 for noble gases, ^3H, and ^{16}N.

TABLE 11.2-14 (Sh. 1 of 3)

PARAMETERS USED IN THE PWR-GALE COMPUTER PROGRAM

TABLE 11.2-14 (Sh. 2 of 3)

TABLE 11.2-14 (Sh. 3 of 3)

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TABLE 11.2-15 (Sh. 1 of 2)

COMPARISON OF EXPECTED LIQUID EFFLUENT CONCENTRATIONS
TO NSSC Notice LIMITS FOR YGN 1, 2, 3 & 4 582

440

TABLE 11.2-15 (Sh. 2 of 2)

COMPARISON OF EXPECTED LIQUID EFFLUENT CONCENTRATIONS
TO NSSC Notice LIMITS FOR YGN 1, 2, 3 & 4

582

440

Table 11.2-16 (Sh. 1 of 2)

MAXIMUM OFFSITE DOSES TO INDIVIDUAL RESULTING FROM NORMAL PLANT LIQUID RELEASE

(One Unit Operating, Values in mSv/yr)

Table 11.2-16 (Sh. 2 of 2)

Table 11.2-17

OFFSITE DOSES TO EXPOSED POPULATION RESULTING FROM NORMAL PLANT LIQUID RELEASE

(One Unit Operating, Values in person-mSv/yr)

Table 11.2-18

SUMMARY OF MAXIMUM, OFFSITE INDIVIDUAL DOSE

RESULTING FROM NORMAL PLANT LIQUID RELEASE

TABLE 11.2-19 (Sh. 1 of 2)

ASSUMPTIONS USED IN NORMAL RELEASE DOSE ANALYSIS

440

TABLE 11.2-19 (Sh. 2 of 2)

KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4 FSAR

LIQUID RADWASTE SYSTEM
FLOW DIAGRAM

Figure 11.2-1

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

RADIOACTIVE LAUNDRY SYSTEM P&ID

Figure 11.2-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 1 of 12)

Figure 11.2-3

KOREA HYDRO & NUCLEAR POWER CO.,LTD
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 2 of 12)

Figure 11 . 2 - 3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 3 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 4 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 5 of 12)
Figure 11.2-3

KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4 FSAR

LIQUID RADWASTE SYSTEM P&ID
(Sheet 6 of 12)

Figure 11.2-3

KOREA HYDRO & NUCLEAR POWER COMPANY
YGN 3 & 4 FSAR

LIQUID RADWASTE SYSTEM P&ID
(Sheet 7 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 8 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 9 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 10 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 11 of 12)

Figure 11.2-3

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

LIQUID RADWASTE SYSTEM P & ID
(Sheet 12 of 12)

Figure 11.2-3

11.3 GASEOUS WASTE MANAGEMENT SYSTEM

A common gaseous radwaste system and separate low-activity waste gas systems for each unit are provided for YGN 3&4.

The gaseous radwaste system (GRS) collects and delays the high-activity gases that are vented from nonaerated processing equipment.

Low-activity waste gases are filtered in the HVAC system prior to release to the atmosphere. The low-activity waste gas systems are the building ventilation exhaust systems, the main condenser evacuation system, and the turbine gland sealing system. The main condenser evacuation system and the turbine gland sealing system are described in Subsections 10.4.2 and 10.4.3, respectively. The building ventilation systems are described in Section 9.4. The design of the low-activity waste gas systems is not discussed in this section, except for those portions of the systems relating to gaseous waste management.

11.3.1 Design Bases

11.3.1.1 System Design Bases

The GRS collects and processes radioactive or potentially radioactive waste gas. This gas, containing primarily hydrogen and nitrogen, is delayed in a low pressure, ambient temperature, charcoal delay bed. The GRS has been sized to provide the capability of delaying krypton and xenon for not less than 45 days for xenon and 2.6 days for krypton.

After leaving the delay bed, the gases are discharged through a high-energy particulate air (HEPA) filter and past a radiation monitor to the radwaste building vent stack. Control and monitoring of radioactive releases is consistent with General Design Criteria 60 and 64 of Appendix A to 10 CFR 50.

The waste gas is diluted in common duct downstream of the radwaste building exhaust air cleaning unit prior to release to the atmosphere. The GRS is designed to maintain a positive pressure to prevent air in-leakage. The gaseous radwaste process lines are connected to an oxygen/hydrogen analyzer to preclude the formation of explosive gas mixtures by controlling a nitrogen injection system. The GRS limits the release of gaseous activity so that personnel exposure and activity releases in restricted and unrestricted areas are as low as is reasonably achievable within the guidelines set forth in Appendix I to 10 CFR 50.

Low-activity waste gases are routed to building vents through HEPA filters. Personnel exposures and activity releases from these wastes in restricted and unrestricted areas are within the "as low as reasonably achievable" guidelines set forth in Appendix I to 10 CFR 50 when combined with the releases from the GRS.

11.3.1.2 Power Generation Design Bases

[redacted]

During this mode of operation, the Waste Gas Dryer does not have to operate effectively. The expected activity inputs to the GRS are listed in Table 11.3-3. These inputs are based on reactor coolant gaseous activities shown in Table 11.1-6.

The maximum and expected GRS component radionuclide inventories are listed in Table 11.3-4. Sizing of the GRS is based on the anticipated operational occurrences that could occur during normal operation as described in Table 11.3-1. The activity of gas to be processed is determined by calculating the gas generated in the most restrictive 30-day time period in the core cycle.

During this 30-day interval, it is assumed that the gas stripper operates continuously, the volume control tank is vented twice, the reactor drain tank is vented continuously and one RCS degassing occurs. Based on these assumptions, the GRS has capacity for a minimum of 45 days delay for xenon and 2.6 days delay for krypton, including anticipated operational occurrences. Calculated radioactive releases (see Subsection 11.3.3) assume a 45-day delay for xenon and a 2.6-day delay for krypton even though the average delay time may be far greater.

11.3.1.3 Codes and Standards

Codes and standards applicable to the gaseous waste management system are listed in Table 3.2-1. The GRS is located in the radwaste building.

The GRS equipment and piping are designated as Seismic Category II or III (with the exception of the containment isolation portion of the reactor drain tank (RDT) vent line which is Seismic Category I), non-Class 1E, Quality Group D and designed, fabricated, and tested in accordance with the requirements of Regulatory Guide 1.143 as indicated in the Table 11.3-5.

11.3.2 System Description

11.3.2.1 General Description

The gaseous radwaste system (GRS) has two 100% capacity parallel trains between prefilters and charcoal delay beds, that are extensively crosstied.

It is comprised of two collection headers (one from each unit), two prefilters, two waste gas dryers, two guard beds, four charcoal delay beds, one HEPA filter and one waste gas analyzer with automatic nitrogen dilution capability. The waste gas charcoal delay beds adsorb the radioactive krypton and xenon atoms and retain them for radioactive decay. After passing through the charcoal delay beds, the gas is discharged through a HEPA filter and a radiation monitor to the Radwaste Building HVAC System. The gas is diluted with nitrogen thereby precluding air migration in the system during low or no flow period. Radiation monitoring is provided on the discharge line from the charcoal delay beds and on the radwaste building vent as described in Section 11.5. The radwaste building exhaust radiation monitor is interlocked to shut the discharge line isolation valves on high radiation level. The radwaste building ventilation exhaust systems are described in Sections 9.4 and 12.3.

11.3.2.2 Component Description

Components of the GRS are listed in Table 11.3-6. The description includes equipment flow rates and/or capacity, material of construction, and the design temperatures and pressures. The process flow diagram of the GRS is shown in Figure 11.3-1 and the piping and instrumentation diagram of the GRS is shown in Figure 11.3-2.

The GRS includes the following major components:

a. Two waste gas headers, one from Unit 3 and one from Unit 4.

b. One header drain tank with relief valve

c. Two waste gas dryers to reduce the waste gas dew point to between 34°F (1.1°C) and 38°F (3.3°C). The dryers use ethylene glycol as a heat transfer medium. The refrigeration units are in a separate shielded area.

d. Two inlet skids.

e. Two particulate prefilters.

f. Two charcoal guard beds to delay the short-lived radionuclides and to protect the charcoal delay beds from moisture.

g. Four charcoal delay beds to delay the xenon at least 45 days and the krypton at least 2.6 days.

h. One HEPA filter to remove particulates and charcoal fines from the waste gas stream.

i. One nitrogen injection unit to dilute the waste gas below the flammability limit.

j. One H_2/O_2 analyzer to continuously monitor the gas in the header drain tank and inlet line of the prefilter.

The equipment layout of the GRS is presented as part of the radwaste building equipment layout in Figures 1.2-42 through 1.2-46. The layout provides design features consistent with the recommendations of NRC Regulatory Guide 8.8 to minimize occupational radiation exposure to plant personnel. Waste gas dryers, guard beds and charcoal delay beds are segregated and shielded in separate compartments. In addition, provisions are included for nitrogen purging to remove radioactive gases from components requiring maintenance or to remove the moisture from charcoal guard and delay beds requiring drying. This aids in reducing radiation exposure to the operator.

Piping runs are located in shielded pipe tunnels and hot piping areas. Line routing prevents accumulation of water inside the piping. Local samples are drawn into the Gaseous Radwaste Sample Panel, which is provided with a nitrogen purge and sample piping shielding to minimize radiation exposure to the operator.

Manual, remotely operated, and automatic valves used in the GRS are designed to minimize gas leakage. Engineering features such as diaphragms with all-metal seats are employed in the system to prevent or minimize leakage. Each valve in the GRS is designed to meet the chemical, temperature, pressure, and code requirements for the specific application for which it is used.

The GRS instrumentation is shown in Figure 11.3-2. The GRS radiation monitors are discussed in Section 11.5. Instrumentation necessary for GRS operation is located at the radwaste control panel including remote indications and alarms.

The automatic isolation valve on the charcoal delay bed discharge line is interlocked to close on high radiation signals from the Radwaste Building HVAC exhaust radiation monitor and low flow signal from the fans of the radwaste building exhaust air cleaning unit. Temperature sensors (with recorders and alarms) are installed in the lines upstream and downstream of the charcoal beds to detect moisture adsorption and thermal upsets.

11.3.2.3 System Operation

The major sources of hydrogen in the GRS are the off-gases from the gas stripper. The major gas flows to the GRS are as follows:

a. CVCS reactor drain tank

b. CVCS volume control tank

c. CVCS gas stripper

These sources will produce a gas consisting primarily of hydrogen and nitrogen with trace quantities of oxygen and fission gases. Each source is piped to the GRS inlet surge header.

The GRS and its input sources are initially purged with nitrogen at plant startup to remove the air from the system. The input sources, GRS headers, and various points within the GRS system are monitored for oxygen and hydrogen as described in Subsection 9.3.2. The hydrogen and oxygen analyzer in the Gaseous Radwaste Sample Panel sequentially samples the points within the system. A high oxygen (2%) alarm from any of these sources is annunciated in the radwaste control room. Operating personnel can be dispatched to mitigate the situation by closing the source of oxygen or via nitrogen dilution, purge, etc. An alarm on high-high oxygen (4%) from any of these sources is annunciated in the main control room and in the radwaste control room. Under these conditions, nitrogen will be automatically injected into the GRS system to mitigate the situation.

The waste gas flows from the various waste gas sources to the waste gas headers. The waste gas headers are maintained at a pressure of 0.5 - 5.0 psig (0.035 - 0.35 kg/cm^2). A primary off-gas hydrogen and an oxygen analyzer in the Normal primary Sample Sink (NPSS) is monitoring this line and provides a continuous signal to a recorder and alarm. Each unit's header has a designed low point to which the header drain tank is connected. Most of the condensing liquid in the GRS inlet piping is drained to the header drain tank and further processed in the liquid radwaste system.

The waste gas flows into the waste gas dryer where the dew point is reduced to between 34°F (1.1°C) and 38°F (3.3°C). The water that condenses is drained to the radwaste building sump. The gas is reheated to 120°F (49°C), and the moisture content of the waste gas is measured, and the flow is routed through the charcoal guard bed.

The waste gas flows through the guard bed where the short lived gaseous radionuclides are delayed and iodine is held for decay. The guard bed also protects the main charcoal delay bed from moisture. When the charcoal absorbs moisture, the temperature rises significantly, and the temperature sensors in the guard beds and charcoal delay beds are used to detect the presence of moisture in the beds.

The waste gas flows through four(4) charcoal delay beds in series where the krypton and xenon are delayed using a dynamic adsorption process. The system is designed to delay xenon for at least 45 days and krypton at least 2.6 days considering the average flow rates. 1

After passing through the charcoal delay beds, the waste gas flows through a HEPA filter where particulates, including charcoal fines, are removed. The filter has test ports for in-place testing. From the HEPA filter, the waste gas flows through a check valve to the radwaste building HVAC to prevent air inleakage into the system. Small flow of nitrogen can be driven automatically to prevent diffusion of air into the system during low or no flow periods, and to dilute the oxygen content in the waste gas to less than 4% by volume.

The gaseous discharge isolation valve is interlocked with a radiation monitor at the radwaste building HVAC exhaust, which isolates the discharge line in the event that the specific activity is excessive. This valve is also interlocked with the fans of the radwaste building exhaust air cleaning unit such that the valve can be opened only after the air cleaning unit fan is running.

The airflow rate through the radwaste building exhaust vent will be such that the hydrogen concentration is much less than 1%, well below the combustion limit of hydrogen in air. The waste gas is continuously analyzed for radioactivity and the H_2 and O_2 concentration. Pressure, flow rate, and total radioactivity released are recorded. Isotopic content of the waste gases is determined and recorded as specified in the station specific procedures.

The maximum rates and quantities of radionuclides released from the GRS will be in accordance with the limits imposed by ~~Chapter 16, Technical~~ ITS

The rate of flow through the charcoal delay beds into the radwaste building HAVC exhaust is controlled so as not to exceed the release limits of the NSSC Notice 2014-34(방사선방호 등에 관한 기준). Releases are conducted to meet the "as low as reasonably achievable"(ALARA) objectives of Appendix I to 10 CFR 50. 735

Potential buildup of hydrogen in the ventilation exhaust systems could come from the storage tanks that contain liquids previously processed through the gas stripper. The maximum hydrogen concentration that can exist in the gas space above a liquid surface downstream of the gas stripper is 4 vol. %, well below the combustion limit of hydrogen in air.

Another potential source of hydrogen is liquids collected in the high TDS collection tanks and chemical waste tanks, but these will contain only small quantities of dissolved hydrogen. The sources of dissolved hydrogen in these tanks are reactor coolant system leakage and reactor coolant system samples. These liquid sources release most of their dissolved hydrogen while being depressurized from system pressure to atmospheric pressure. This liquid is then diluted with other drains that contain no dissolved hydrogen. Thus, the contents of the high TDS collection tanks and chemical waste tanks contain a low concentration of dissolved hydrogen at atmospheric pressure, precluding a hydrogen buildup in the gas space over the liquid surface of these tanks.

Main Condenser Evacuation System

The mechanical operation and description of the main condenser evacuation system are discussed in Subsection 10.4.2

Turbine Gland Seal System

The mechanical operation and description of the turbine gland seal system are discussed in Subsection 10.4.3.

Building Ventilation Systems

The plant building ventilation systems discharge radioactive gaseous waste resulting from equipment leakage and are discussed in Subsection 9.4. The radioactive sources are discussed in Section 11.1.

11.3.3 Gaseous Radioactive Releases

This section describes the estimated gaseous release from a unit for normal operation and anticipated operational occurrences.

11.3.3.1 Release Points

Gaseous releases are directed through the auxiliary building vent, turbine building ventilation exhaust, containment minipurge discharge, fuel building ventilation exhaust, and radwaste building ventilation exhaust.

The release points of the GRS and low-activity aerated vent system are through the radwaste building exhaust plenums.

11.3.3.2 Estimated Releases

Gaseous wastes consist primarily of hydrogen stripped from coolant discharged to CVCS holdup tanks during boron dilution, nitrogen and hydrogen gases purged from the chemical and volume control system volume control tank when degassing the reactor coolant, and nitrogen from the nitrogen cover gas.

The charcoal delay system capacity guarantees at least 45 days decay for xenon gas.

Estimated annual total releases of radioactive noble gases and particulates from the YGN 3&4 units are determined by using the computer program PWR-GALE

(Rev.1). Parameters describing the normal operation of one unit are listed in Table 11.2-14. These values are used as input to the computer code. Releases from routine and shutdown degassing of the primary coolant and from the building ventilation systems are shown in Table 11.3-7.

11.3.3.3 Dispersion Factors

Section 2.3 describes the meteorological data of the YGN 3&4 site. But, the annual average X/Q calculated using meteorogical data obtained from 1994 to 1997 is higher than the annual average X/Q provided in subsection 2.3.5. So, the offsite concentrations and estimated doses at Exclusion Area Boundary (EAB) are obtained by applying X/Q (from 1994 to 1997) for concervatism. 440

11.3.3.4 Estimated Doses

For the sources identified in Table 11.3-7, estimates of the following are given in Tables 11.3-11, 11.3-12, and 11.3-13:

a. Internal, external equivalent and effective doses to a maximum individual at the site boundary.

b. Air absorbed doses from gamma and beta ray at the site boundary. 440

c. Expected collective thyroid, skin equivalent and collective effective doses to the population.

The estimated doses at the site boundary are obtained by applying the annual average site boundary X/Q to the applicable emission spectra and exposure assumptions listed in Table 11.3-10.

The annual person-Sv estimate is obtained by summing the products of the annual average dose multiplied by the population in each distance interval. Person-Sv estimates are obtained for the projected population distribution in 2031. See Subsection 2.1.3 for a discussion of the present and anticipated population distribution in the vicinity of the facility. 440

Tables 11.3-11 and 11.3-12 list estimated individual dose at the site boundary and population dose during expected operation from the sources identified in Table 11.3-7.

Tables 11.3-8, 11.3-9, and 11.3-13 demonstrate that the design objectives, outlined in Subsection 11.3.1, are met.

11.3.4 Safety Evaluation

The GRS serves no safety-related function.

11.3.5 Tests and Inspection

Preoperational testing is described in chapter 14.

After installation, but prior to initial system operation, the GRS is tested to verify that pressure integrity, design flow conditions, instrumentation, and control operation are functional. Periodically during operation, tests of GRS automatic functions and alarms are performed, and control instrumentation is checked for alignment. Applicable instrumentation are calibrated at proper time intervals. Particular attention is given to the oxygen/hydrogen analyzer to assure that potentially explosive concentrations are detected and eliminated before hazardous conditions develop.

Normal operation and efficiency of GRS components can be observed during system operation. Adequate delay of noble gases is the best measure of system performance. Intermediate point gas samples may be collected to monitor the performance of specific equipment items.

11.3.6 Instrumentation Application

Instrumentation is provided to monitor oxygen/hydrogen concentration, gas flow rate, humidity, and temperature at critical points in the system. The GRS instrumentation is shown on figure 11.3-1 and the radiation monitor is discussed in section 11.5. All instrumentation can be read locally, and remote indication and all alarms are provided in the radwaste building control room. The control building control room of each unit will have a general alarm alerting the operators to any alarmed condition in the radwaste building.

TABLE 11.3-1

GASEOUS RADWASTE SYSTEM DESIGN ASSUMPTIONS

TABLE 11.3-2

MAJOR SOURCES, VOLUMES, AND FLOW RATES OF

GASES TO THE GASEOUS RADWASTE SYSTEM

TABLE 11.3-3

EXPECTED SPECIFIC ACTIVITIES OF SOURCES TO THE GRS
DURING NORMAL OPERATION
(μCi/cc)

110

TABLE 11.3-4

RADIONUCLIDE INVENTORIES: IN GASEOUS RESEASTE SYSTEM COMPONENTS
(CHARCOAL, DELAY BEDS)
(ACTIVITIES IN CURIES)

TABLE 11.3-5

EQUIPMENT CODES, GASEOUS RADWASTE SYSTEM

TABLE 11.3-6

GASEOUS RADWASTE SYSTEM PROCESS EQUIPMENT DATA

Table 11.3-7 (Sh. 1 of 2)

Expected Releases of Radionuclides in Gaseous Effluents(One-Unit Operation, TBq/yr)

Table 11.3-7 (Sh. 2 of 2)

Table 11.3-8 (Sh. 1 of 2)

Comparison of Design Base Gaseous Effluent Concentrations at Exclusion Area
Boundary to NSSC Notice Limits(One-Unit Operation) 735

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Table 11.3-8 (Sh. 2 of 2)

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Table 11.3-9 (Sh. 1 of 2)

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Table 11.3-8 (Sh. 2 of 2)

440

Table 11.3-10 (Sh. 1 of 2)

ASSUMPTIONS USED IN NORMAL RELEASE DOSE ANALYSIS

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Table 11.3-10 (Sh. 2 of 2)

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Table 11.3-11 (Sh. 1 of 2)

INDIVIDUAL DOSES RESULTING FROM NORMAL PLANT GRASEOUS RELEASE
(One Unit Operating, Values in mSv/yr)

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Table 11.3-11 (Sh. 2 of 2)

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Table 11.3-12

POPULATION DOSE RESULTING FROM NORMAL PLANT GASEOUS RELEASE
(One Unit Operating, Values in person-mSv/yr)

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Table 11.3-13

SUMMARY OF MAXIMUM OFFSITE INDIVIDUAL DOSE
RESULTING FROM NORMAL PLANT GASEOUS RELEASE

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KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM
FLOW DIAGRAM

Figure 11.3-1

KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P&ID
(Sheet 1 of 7)

Figure 11.3-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P & ID
(Sheet 2 of 7)

Figure 11.3-2

KOREA HYDRO & NUCLEAR POWER COMPANY
YGN 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P&ID
(Sheet 3 of 7)

Figure 11.3-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P & ID
(Sheet 4 of 7)

Figure 11.3-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P & ID
(Sheet 5 of 7)

Figure 11.3-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P & ID
(Sheet 6 of 7)

Figure 11.3-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

GASEOUS RADWASTE SYSTEM P & ID
(Sheet 7 of 7)

Figure 11.3-2

11.4 SOLID WASTE MANAGEMENT SYSTEM

Solid waste management is provided by the solid radwaste system (SRS) which is designed to holdup, treat, and package radioactive wastes generated by 148 plant operation, handle the packaged solid radioactive waste, and store these wastes until they are transferred to the onsite storage area or shipped offsite 204 for disposal. The system is located in the radwaste building, which is designed to withstand an operating basis earthquake.

11.4.1 Design Bases

The design bases of the solid radwaste system are as follows:

a. The SRS provides the capability of solidifying/drying, packaging, storing, 148 and disposing of the concentrated waste solutions from the LRS evaporators and CVCS boric acid concentrator, spent resins from radioactive ion exchangers, and the sludge wastes from the LRS radwaste tanks.

b. The SRS provides for handling and packaging of spent radioactive cartridge filters from the CVCS, spent fuel pool cooling and cleanup system, steam generator blowdown system, and LRS for storage and disposal.

c. The SRS provides for compacting and packaging of miscellaneous dry radioactive materials, such as paper, rags, contaminated clothing, gloves, and shoe covers, and for packaging of contaminated metallic materials and noncompactible solid radwaste, such as small tools and equipment parts.

d. The SRS provides solidifying/drying, packaging, storage and disposal of blowdown demineralizer resin and condensate polishing resin, in the event that they become contaminated. 148

e. The SRS provides the capability of reducing the waste volumes of the concentrate waste solutions and dry active wastes for storage and disposal. 1

11.4.1.1 Safety Design Bases

The SRS performs no function related to the safe shutdown of the plant, and its failure does not adversely affect any safety-related system or component. Therefore, the SRS has no safety design bases.

Collection, solidification/drying, packaging, and storage of radioactive wastes are 148
performed to maintain radiation exposure to plant personnel "as low as is reasonably achievable" (ALARA), consistent with the recommendations of Regulatory Guide 8.8 and within the dose limits of the Korean AEA. Design features incorporate ALARA criteria such as remote system operation, remotely actuated flushing, quick disconnect, equipment layout permitting the shielding of components containing radioactive materials, and remote handling of packaged solid radwaste. Additional ALARA provisions applicable to the SRS are described in Section 12.5.

Packaging and transportation of radioactive wastes are in conformance with 10 CFR 71 Collection, solidification/drying, packaging, and storage of radioactive 148
wastes are performed in conformance with 10 CFR 50.

11.4.1.2 Power Generation Design Bases

The maximum and expected input and discharge volumes to the SRS from each source of solid waste material are presented in Table 11.4-1. The SRS input activities associated with the expected input volumes are presented in Table 11.4-2.

Laundry is cleaned by washing machines in the access control building for each unit. The laundry waste processing system is also located in the access control building for each unit. Solid wastes are manually transferred to the SRS for packaging.

11.4.1.3 Codes and Standards

The solid radwaste system is designed and constructed in accordance with the applicable requirements of Regulatory Guide 1.143, as indicated in the Table 11.4-3. Codes and standards applicable to the solid radwaste system are listed in Table 3.2-1.

11.4.2 System Description

11.4.2.1 General Description

The SRS is subdivided into the following subsystems.

a. Radwaste solidification subsystem
b. Dry active waste sorting and segregation subsystem | 1
c. Filter handling subsystem
d. Resin transfer subsystem
e. Concentrated waste subsystem
f. Sludge waste subsystem
g. Concentrate waste drying subsystem | 1
h. Mobile spent resin drying subsystem | 148

Plant layout drawings illustrating the processing, packaging, storage, and handling areas of the radwaste building are presented in Figures 1.2-42 through 1.2-46. A SRS process flow diagram is presented as Figure 11.4-1, which includes process routes and flow rates. The equipment capacities of the SRS are presented in Table 11.4-4. The SRS piping and instrumentation diagram is provided in Figure 11.4-2.

11.4.2.2 Component Description

A description of the SRS components is given in Table 11.4-4 and equipment codes are given in Table 11.4-3. The following is a functional description of the major system components:

a. Sludge Tanks

Sludge tanks receive the tank bottom sludge from the radwaste tanks in the LRS. 1

The sludge is removed through a nozzle at the bottom of the tank and the liquid is decanted through strainers at various levels on the side of the tanks. The sludge tanks are equipped with mechanical mixers with the drive on the floor above.

b. Concentrate Tanks

The concentrate tanks receive concentrated waste from the LRS evaporators and CVCS boric acid concentrators, and hold it until it is transferred to the CWDS blender/dryer. These tanks are heat traced 204
and insulated. A vent condenser is provided to reduce the moisture loading on the ventilation system. The concentrated waste enters through the top of the tanks. The concentrate tanks are equipped with mechanical mixers with the drive on the floor above.

c. Spent Resin Tanks

Separate high-activity and low-activity spent resin tanks are provided for storage and decay of the spent resins from the demineralizers in the CVCS, spent fuel pool cooling and cleanup system, steam generator blowdown system, and LRS prior to processing by the radwaste solidification system or the spent resin drying system. Resin removal from the tanks is through a line located at the bottom of the tank. Resin flow into the tanks is via the inlet nozzle located on the top head. The capacity of the spent resin tanks is large enough to allow the simultaneous changeout of all the high-activity ion exchangers in one tank, and one of each of the low-activity ion exchangers in the other. 148

Service air connections are provided as a backup method for fluidizing the spent resin tank. The spent resin tanks have provisions for dewatering the resin in the tank.

d. Sludge Decant Pumps

The sludge decant pumps are centrifugal type pumps that are used to remove excess water from the sludge tank through decant lines. The excess water is pumped back to the LRS radwaste tanks for processing.

e. Sludge and Concentrates Pumps

Centrifugal-type pumps transfer sludge and concentrates to the RSS or CWDS. 204

f. Resin Sluice Pumps

Pogressive-cavity-type pumps delivers the spent resin from the spent resin tanks to the waste feed tank. Sizing of these resin sluice pumps are based on the minimum slurry velocity needed to transport resin in suspension.

g. Waste Feed Tank

Radwaste in the form of spent resin is collected for solidification in the waste feed tank. A adjustable decanting arm is used to decant water to the desired liquid and radwaste interface level. Two ultrasonic sensors located at the inlet nozzle are used to detect arm position and interface level. 204
Mechanical limit switches prevent over travel of the decanting arm. The waste feed tank is mixed prior to sampling or processing. The overflow is connected to plant drain system. The vent line is provided for air displaced during filling of the tank to the HVAC system. 1

h. Decanting Pump

A positive displacement rotary-type pump is used to transfer decanted water to the LRS radwaste tank.

i. Circulation and Transfer

The circulation and transfer pump is a centrifugal-type pump with variable-speed controls. Radwaste from the waste feed tank is mixed and recirculated prior to pH determination. Chemical additions may be made to the waste feed tank before the radwaste is pumped to the cement drumming station.

j. Cement Drumming Station

The cement drumming station mixes cement with a predetermined quantity of waste pumped from the waste feed tank into 55-gallon drums. The drum is tumbled for proper mixing of the contents and to complete the solidification process.

A metering pump measures the quantity of liquid wastes delivered to the drum fill nozzle in the drum processing enclosure. It may also be used to flush radioactive pipelines with water.

k. Cement Filling Station

The cement filling station provides dry cement storage and accurately fills empty storage drums with a specific quantity of cement.

l. Cement Storage Silo

This silo provides dry cement storage.

m. Travelling Bridge Crane

This crane is provided with a drum grab and rotating block to carry containers from the processing areas to the waste drum storage area and from the waste drum storage area to the shipping area. It is equipped with television cameras to facilitate remote-handling operations from the radwaste control room.

Motorized conveyors are used to transfer drums within the solid radwaste system.

n. Spent-Filter Cartridge Handling Systems

There are spent-filter cartridge handling systems. 204

The filters in the plant are used in top-loading filter vessels. The spent cartridges are lifted from the filter vessels, placed into the filter cask in the secondary auxiliary building, and transferred to the radwaste building through the personnel and filter transfer tunnel. Finally the filter cartridges are lowered into a waste container.

The spent filters in the radwaste building are lifted into the filter handling cask and transferred to the solidification area using a monorail hoist.

The cask is shielded with 6.5 inch thick lead, and the dose rate on
the cask surface was evaluated to be 20 mrem/hr and at 1m apart from
the cask surface 2.5 mrem/hr during the changeout and transfer 1
operation of letdown purification filter which has the highest
radioactive inventory.

o. Waste Containers

The SRS is designed to package waste in 55-gallon drums or High Integrity
Containers(HICs) for storage and offsite shipment. The drums or HICs are filled with 148
a concrete mixture, spent filter cartridges and other suitable waste materials.

p. Solid Waste Compactor

The solid waste compactor is used to package solid, compressible, low-level radioactive wastes into standard 55-gallon drums. The primary function of the compactor is to reduce the volume of wastes that often contain a large percentage of void space. Potentially radioactive air that escapes from the drum during compaction is exhausted by the compactor exhaust fan through a HEPA filter to the radwaste building ventilation exhaust. The drums of compacted waste are moved by a forklift to the low-activity storage area.

"Delete" 447

r. Waste Shredder

This is an electric powered, low-speed, rotary shear shredding unit, which shreds to change geometry of clean items that passed survey on the waste sorting table.

"Delete" 447

t. Supercompactor

The mobile supercompactor is a common unit for all plants, which is a single stroke compactor to deliver a compaction force of 2,000 metric tons to the dry low level radioactive waste package of a 55-gallon drum for offsite disposal. The supercompacted 55-gallon drums are packaged in the 80-gallon overpack drums. The mobile supercompactor consists of the following major components:

- Semi-trailer
- Hydraulic power unit
- Off-gas treatment unit
- Overpack filling system
- 2,000 MT supercompactor
- Control unit
- Conveyor system
- Drum piercing unit

u. Overpack Drums

The 80-gallon overpack drums are provided to contain supercompacted 55-gallon dry active waste drums during storage and shipment offsite. 1

v. CWDS Enclosure Skid

The enclosure skid consists of two parts, that is, blender/dryer and enclosure. A blender/dryer is used to dry precipitates. The agitator scraper is driven by an electric motor. Jacket heating is provided by plant auxiliary steam. A discharge valve is located at the bottom center of the shell. The agitator helix moves the material to the valve for gravity discharge.

The enclosure is the air-tight housing for the drum filling operation. The enclosure is equipped with the remote drum capping and ventilation system. The ventilation system draws a slight negative pressure on the housing to prevent any uncontrolled release of contaminated particles. Ventilation outlet ducting is routed to the radwaste building HVAC system. A fullwidth door allows accesses to the drum.

w. Steam Skid

This unit introduces the auxiliary steam to process components, collects the auxiliary steam condensates from these components, and returns condensates to auxiliary steam system.

x. Condensate Skid

This unit provides a heat transfer medium for exhausted water vapor that is drawn from the blender/dryer and collected in condensate reservoir. This heat transfer occurs across a primary heat exchanger, which is supplied with chilled water from the plant chilled water system. The condensate skid returns the collected condensates to liquid radwaste system, and/or provides motive water for the jet pump. 1

y. SRDS Dewatering Fillhead

The dewatering fillhead provides the connections between the dewatering equipment and the HIC. The lower portion of the fillhead has a set of doors, which allows easy access for connecting to and disconnecting from the HIC internal. The fillhead seals to the upper portion of the neck of the HIC and is held in place by gravity. The upper portion of the dewatering fillhead is divided into piping section and an enclosed electronic section. 148

z. SRDS Piping Skid

The piping skid contains hose connections for processing spent resins, an entrainment separator tank to collect the removed water, and air driven diaphragm pump to remove the collected water from the entrainment separator tank. It is the interface among the dewatering fillhead, the pump skid, and the plant.

aa. SRDS Blower Skid

The blower skid contains an air blower to recirculate air through the drying system components. In the skid, fluid flow and temperature are controlled to facilitate drying of the resin and is operated after the bulk of the water has been removed. It is equipped with temperature instrumentation interlocked such that will shut down automatically on high temperature.

ab. SRDS Control Panel

The control panel provides a central location to start and stop the system equipment and indicator for container level, system temperatures, valve positions, fillhead position indication, and system alarm indicators.

ac. Mobile Spent Oil and Sludge Solidification Equipment

This equipment is used to provide the solidification of sludge and spent oil. Spent oil is collected from radioactive areas and sludge is collected from radioactive sumps. The equipment use solidification material and additives agent to enhance the solidification. 381

11.4.2.3 System Operation

a. Radwaste Solidification Subsystem (RSS)

The RSS operates on a batch basis to solidify concentrated wastes, sludge, and spent resins, if necessary. It is also used to encapsulate spent radioactive cartridge filters and other miscellaneous contaminated objects. The system uses a cement solidification agent to solidify spent blowdown demineralize resin and spent condensate-polishing resin, if required. To ensure a solid matrix and proper waste form characteristics, all liquid and wet wastes are solidified in accordance with a process control program prior to shipment offsite. Sufficient capacity is provided to solidify radioactive wastes resulting from normal plant operations.

Liquid inputs from spent resin tank is transferred to the waste feed tank for holdup and chemical treatment prior to solidification.

After mixing with the agitator to homogenize tank contents, the circulation and transfer pump recirculates the waste feed tank for sampling and chemical adjustment. In the waste feed tank, the solid-to-water ratio is also adjusted to provide the water content necessary to ensure complete solidification. After the required adjustments are made, the waste is pumped to the cement drumming station.

The waste feed tank is used as a batch tank for each specific waste stream. Waste streams are not to be mixed. Each waste stream is to be processed independently of the others.

The cement drumming station allows drums to be filled with sludge, concentrated waste, and spent resin from the waste feed tank, if necessary. 148

The remotely-operated traveling bridge crane is used for transporting drums, which have been filled with dry cement (and possibly sodium metasilicate additions) from the cement filling station, to the loading platform located in the drum processing enclosure. Once drumming operations are initiated, the crane drum grab is used to lower the drum through the hatch opening onto a positioning cradle inside the processing enclosure. After the drum has been loaded, the grab is raised out of the enclosure. This allows the operator to remotely actuate closure of the hatch, thereby isolating the drum from the station's environment during processing.

With the metering pumps and the appropriate feed controls set up for the correct quantity of waste, drum processing can then be initiated. The movement of the drum through the cement drumming station cycle is automatic once the drum has been loaded into the drum processing enclosure and the hatch has been closed. The drum is uncapped, filled, recapped, clamped, tumbled, and unclamped. This operational sequence may be repeated in the automatic cycle to permit the drum to be filled twice. This double-filling technique, repeating the filling and mixing operation twice, allows for the solidification of the maximum amount of waste in each drum.

Filter cartridges can be disposed of by solidification in waste containers. Encasement and immobilization is achieved by surrounding the filter cartridge in the waste container with the solidification agent.

During solidification of waste, the circulation and transfer pump, solidification agent feeder, and additive feeder are adjusted to provide the specific mixing ratios needed for the type of waste being solidified. The mixing ratios are chosen based on laboratory samples and operating experience.

b. Dry Active Waste Sorting and Segregation Subsystem 1

Potentially radioactive dry active waste (DAW) is collected at appropriate locations throughout the plant. As necessary, these wastes are taken to the radwaste building for sorting and packaging. 1
The DAW can be carried to the radwaste building outside at ground level or through the personnel and filter transfer tunnel. When the DAW is received, it is sorted for volume reduction. The waste, sorted to be clean, is shredded for uncontrolled disposal if 1
appropriate. The compactible waste is compressed in drums to minimize shipping volume. Additional compressible material is added, and the drum contents are recompacted until a drum is filled. The drums are then sealed and moved to the waste storage area until shipped off site. During compaction, the airflow in the vicinity of the compactor is directed by the compactor exhaust fan through a HEPA filter before it is discharged to the radwaste building ventilation exhaust. The precompacted DAW drums are supercompacted to reduce volumes and packaged into overpack drums for offsite 1
disposal.

Large or highly radioactive components and equipment that have been contaminated during reactor operation and that are not amenable to compaction or decontamination by plant personnel are packaged in shipping containers of an appropriate size and design.

c. Filter Handling Subsystem

The filters handling subsystem provides the capability to remove spent radioactive cartridge filters from their housing. Then the spent radioactive cartridge filters are transported to the radwaste solidification area in the radwaste building or transported to the temporary storage area in the auxiliary building for the decay of short-lived radionuclides. Long-handled tools are used to penetrate the shield plug to extract the spent cartridges. 381

In addition, the system operating procedures are employed to minimize radiation exposure to operating personnel and the spread of radioactive contamination.

For solidification of a spent filter, it is transferred in a shielded transfer cask to the solidification station. A monorail hoist is used to transport the transfer cask over a drum which is 381 partially filled with cement. After the spent filter cartridge is immobilized with cement mixture in the drum, the drum is then capped, wiped, decontaminated, and moved to the waste drum storage area in the radwaste building.

d. Resin Transfer Subsystem (RTS)

The RTS receives and stores radioactive spent resins and adds new resin to the adsorption and ion exchange vessels in the chemical and volume control system, spent fuel pool cooling and cleanup system, steam generator blowdown system, and liquid radwaste system. The chemical and volume control and spent fuel cooling and cleanup systems are served by the secondary auxiliary building resin transfer subsystem, and the steam generator blowdown and liquid radwaste systems are served by the radwaste building resin transfer subsystem.

These two subsystems are similar in design. Each subsystem consists of a spent resin tank, which stores radioactive spent resins to permit decay, and a resin sluice pump which pumps demineralized water to sluice spent resins from the vessels.

When removing high-level radioactive spent resin from a vessel in the secondary auxiliary building, the water from the reactor makeup water tank passes through a resin sluice supply header to the vessel, entrains the resin beads, and carries the resin slurry to the high-activity spent resin tank. When removing low-level radioactive spent resin from a vessel in the radwaste building, demineralized water from the sluice pump passes through a common header to the vessel, entrains the resin beads, and carries the resin slurry to the low-activity spent resin tank. Resin is removed from the high- and low-activity spent resin tanks using sluice pumps. It is then sent to the waste feed tank in the RSS for solidification/drying process.

Instrumentation is provided to determine when a vessel is empty of resin, measure the spent resin tank resin level, monitor the percent solids of the slurry, and adjust and alarm the performance of the RTS. A provision is made for sluicing new resin with a portable resin ejector into the vessels.

e. Concentrated Waste Subsystem

The concentrated waste subsystem provides the means to receive and store concentrated wastes from the LRS evaporators and CVCS boric acid concentrator. The system consists of two 100% paralleled loops, each loop having one concentrate tank which stores concentrated wastes to permit decay, and a pump to direct CWDS. | 204

The concentrated waste is directed to the concentrate tank in one loop. Once the tank in one loop is filled, the flow stream is directed to the concentrate tank in another loop. Contents of the filled tank are sampled, treated with chemicals to ensure compatibility with solidification agents, and transferred to the CWDS. All piping and tanks are heat traced to prevent boric acid | 204 salts from crystallizing and the subsequent component or system malfunction due to line plugging.

Instrumentation is provided to measure the concentrate tank waste level and to adjust and alarm the performance of the system.

f. Sludge Waste Subsystem

The sludge waste subsystem provides the means to receive and store tank bottom sludges from the LRS radwaste tanks. The system consists of two 100% paralleled loops. Each loop has one sludge tank which receives and stores sludge wastes to permit decay, one sludge pump which pumps sludge wastes to the waste feed tank in RSS, and one sludge decant pump which removes free-waters in the tank to the LRS radwaste tank. Once the tank is filled in one loop, the filled tank is isolated from the upstream line and the process stream is directed to the tank in the other loop. Instrumentation is provided to measure the sludge tank waste level and to adjust and alarm the performance of the system.

g. Concentrate Waste Drying System (CWDS)

This system is used to provide the greatest volume reduction of concentrate waste to a dry solid form. The dried powder of the concentrate waste is stored in the waste storage area by drumming after sealed until solidification process is determined, prior to shipment 591
from site. The major components and process capacity of the CWDS are listed in Table 11.4-4. The concentrate waste is transferred to the CWDS blender/dryer using the concentrate tank pump, the level instrument in the dryer is interlocked with the concentrate tank pump and waste supply isolation valve, thus, when the liquid level in the dryer reaches predetermined level, the concentrate tank pump stops, and the waste supply isolation valve is closed automatically. The concentrate waste in the dryer is heated by auxiliary steam and the vapor is pushed from the dryer to the CWDS condenser heat exchanger which is cooled by plant chilled water. The concentrate is routed to the CWDS condensate reservoir from which it can be reurned to the liquid radwaste system. After approximately three (3) hours(the time varys with waste characteristics), the dryer boils down to the low level. At this

time, the waste supply isolation is opened and the concentrate tank pump is started simultaneously, then, additional waste is added to the blender/dryer up to the dryer high level. Such three (3) transfers become one batch cycle. The dryout phase begins with the end of the third transfer. Upon verification of dryness, the dried waste is discharged into the 55 gallon drum with flame retardant plastic bag and sealed. Radiation level is surveyed after the drum is bolted. This drum is transferred to the waste storage area(100ft) in the radwaste building using monorail hoist, RSS cask/drum handling crane, drum conveyer, and remotely operated bridge crane. 591

h. Mobile Spent Resin Drying Subsystem

The Spent Resin Drying System(SRDS) processes ion exchange resins by removing the excess water from the resins, and provides the means of positively ensuring the waste container meets the free-standing water requirement of 10 CFR 61 section 56.

The HIC is filled with spent resin from the plant's waste tanks using excess water to keep the resin in a slurry. During this transfer, the HIC will be dewatered so that the available space in the HIC is filled with resin to the maximum extent practicable. 148

The excess water is pumped out of the HIC using a positive displacement diaphragm pump to the radioactive drain system.

When all of the pumpable water is removed, the blower is stared to recirculate air through the resin. The blower heats the air and as the warm air passes through the resin it entrains and vaporizes moisture in the resin bed. This moist air is pumped through the entrainment separator tank where refrigeration coils condense the water vapor in the air stream and any entrained water is remove. The water is pumped out of the tank using a diaphragm pump. The air is recirculated through the resin for a specified period of time. After this period of time, the percent relative humidity of the air stream should be at or below the required value indicating the resin bed is dry. The system then shut down, the fillhead removed and the HIC capped.

The HIC is considered to be dewatered when relative humidity in the recirculating drying air meet the acceptable criteria specified in the process control program. A relative humidity instrument and monitor are provided to remotely and continuously monitor the HIC outlet air. This instrument is used to establish positive end point to the dewatering process. The HIC is then transferred to the container storage area where further decay occurs to permanent disposals. 148

11.4.2.4 Packaging, Storage, and Shipment

All radioactive wastes are prepared for shipment in containers which meet the requirements of U.S. Department of Transportation (DOT) and NRC regulations. Wet wastes are solidified in 55-gallon, DOT-17C drums or dried in the HICs. Dry wastes and spent filter cartridges are compacted or solidified in 55-gallon, DOT-17H drums. 204

All drums and containers are capped prior to storage and offsite shipment. 148

The specific activity of the radioactive waste is determined before solidification/drying process and, if necessary, the disposable container is placed in a lead-shielded transportation cask. Shielded transportation casks are used when required. 148

Packaged solid radwaste is stored in a shielded waste storage area in the radwaste building or onsite storage area. Unused, uncontaminated shipping containers are stored in allocated storage areas on site. The solid radwaste storage areas are segregated into high-activity and low-activity waste storage areas. The 148 storage space provided in the radwaste building allows for a 30-to-90 day storage of high- and low-activity wastes at the expected generation rates.

Containers can normally be shipped 2 to 5 days after filling, to allow the cement to set adequately. Onsite storage for the decay of short-lived radionuclides is accomplished both prior to conditioning in liquid storage tanks and in the solid waste storage area. 148

The input and discharge annual volumes and estimated curie content of solid radwaste to be produced from YGN 3&4 are given in Tables 11.4-1 and 11.4-5, respectively. The solid radwaste is transferred to stored in the on-site temporary storage vaults from the radwaste building whenever accumulated volume or plant operation requires transfer of solid radwaste. The first storage vault can accumulate about 13,300 drums the second storage vault can accumulate about 10,000 drums. 95

Hanbit 3&4 Temporary Storage is located in the Hanbit site, and two old reactor vessel heads as well as four old steam generators can be stored. These old components are temporarily stored until these are transferred to the permanent storage. 766

Old Reactor storage Vessel Head(ORVH) storage area in YGN maintenance working shop only stores two(2) ORVHs of YGN units 3&4 689

The Radioactive Waste Assay System (RAS) is used to identify and measure activity of gamma emitting radionuclides, and the Scaling Factor(SF) given in Table 11.4-6 is applied in order to identify and measure activity of alpha, beta emitting radionuclides in radioactive drums stored in the on-site temporary storage vaults prior to shipping offsite to a licensed burial site. 642

11.4.2.4.1 <u>Radioactive Waste Assay System</u>

The function of the RAS is to identify and measure activity, specific activity of radionuclides in waste drums generated in all Yonggwang units using the NDA (Non-Destructive Assay) method, prior to shipping offsite to a licensed burial site. The RAS is commonly used for all YongGwang units and installed in the on-site temporary storage vaults. The system is composed of the following major components: 338

1. Radioactive Waste Assay System

   a. Detector Assembly

      The Detector Assembly is used to identify and measure gamma-emitting nuclides in radioactive drums. This assembly have scanning modes to support both Segmented Gamma Scanner (SGS) for high density drum and

Tomographic Gamma Scanner(TGS) for low density drums. This assembly is composed of an HPGe detector, a detector shield & collimator, an attenuator, and a detector drive.

b. Transmission Source Assembly

For high quality analysis of radionuclides in radioactive drums, the Transmission Source Assembly is used. The Transmission Source Assembly

uses a tungsten shutter and a lead storage shield. The storage shield and shutter can accommodate a source strength of up to 15 mCi Eu-152.

c. Drum Loading & Rotator Assembly

The Drum Loading & Rotator Assembly is used to move the radioactive drums to the detector and to rotate the drums. The assembly can accommodate drums of up to 1,000 kg to measure various waste drums. 338

d. Data Acquisition Hardware Assembly

The Data Acquisition Hardware Assembly consists of system operation and analysis software, a PC, and acquisition electronics. The assembly can assay the radioactive drums and create an image of the drum matrix. The assembly is installed in a shielded control room to protect the operator from the radiation.

e. Automatic Conveyor System

The Automatic Conveyor System can accommodate drums of up to 1,000 kg to handle the various waste drums. The system is integrated with the RAS and can be operated automatically to ensure proper operation of radioactive drums.

2. In-Situ Object Counting System

The In-Situ Object Counting System (ISOCS) is a portable Radioactive Waste Assay System. The ISOCS can be used to assay gamma-emitting nuclides in the special radioactive waste containers, such as High Integrated Containers (HIC), which cannot be measured by the RAS. This system is shared by all the other nuclear power plants

11.4.3 Safety Evaluation

The SRS serves no safety-related function

11.4.4 Tests and Inspection

The SRS is in use intermittently throughout normal reactor operation. Periodic visual inspection and preventative maintenance are conducted using normal industry practice.

11.4.5 Instrumentation Application

The solid radwaste system (SRS) area is monitored by area radiation monitors. In order to keep operator exposures "as low as is reasonably achievable" (ALARA), an area monitor is located in the truck loading area. Two area monitors are located in the drumming station to allow measurement of the

radiation external to a filled drum. An area monitor is also located in the SRS control station to warn the operator of abnormally high radiation levels. Two area monitors are located in the waste feed tank area and waste storage area to monitor the radiation level. An area monitor is also located in the dry active waste storage area to allow measurement of the radiation external to the dry active waste drum.

The area radiation monitoring instrumentation is described in Section 12.3.4.

TABLE 11.4-1
INPUT AND DISCHARGE VOLUMES FOR THE SRS (TWO UNITS)

Source	Annual volume (㎥)	
	Input[5)]	Output
Filters(Solidified)[1)]	25	27
Spent Resin[2)]	56	111[12)] (56)[13)]
Liquid Radwaste Concentrate[3)]	538	1076[6)] (108)[9)]
Miscellaneous[4)]	415	415[7)] (138)[10)]
Sludge	8.49	14.86[14)]
Spent oil(concentrated)[15)]	0.20	0.35[14)]
Total	1044.49	1616.9[8)] (343.86)[11)]

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1) Volumes based upon o.012 ㎥/MWe of shipped waste. Shipped volume includes solidification agent equal to 10% of input volume.
2) Volumes based upon 0.051 ㎥/MWe of shipped waste. Input volume based upon 50% of shipped volume comprised of solidification agent.
3) Volumes based upon 0.49 ㎥/MWe of shipped waste. Adjusted for 50% solidification agent in drummed waste.
4) Volumes based upon 0.19 ㎥/MWe.
5) Input volumes based on "On-Site Alternative for Low Level Radwaste Management," NUS Corporation, June 21, 1978.
6) Output volume based upon no operation of the concentrate waste drying system (100% radwaste solidification system operation).
7) Output volume based upon no operation of the sorting and segregation system.
8) Total output volume based upon no operation of the volume reduction system.
9) Output volume based upon 100% concentrate waste drying system operation.
10) Output volume based upon operation of the sorting and segregation system.
11) Total output volume based upon operation of the volume reduction system.
12) Output volumes based upon no operation of the spent resin drying system (100% radwaste solidification system operation) 148
13) Output volume based upon 100% spent resin drying system operation.
14) Output volume based upon 175% increase of input volume using the solidification material and additives agents.
15) The volume based upon 10% decrease of concentrated volume after decontamination of radioactive material from spent oil. 381

TABLE 11.4-2 (sh. 1 of 3)

SRS EXPPECTED INPUT ACTIVITIES (Ci/yr-unit)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Br 84	7.12E-04	2.12E-01	3.30E+02	6.43E-02	2.51E-04	0.00E+00	0.00E+00
I 129	2.04E-10	0.00E+00	0.00E+00	3.77E-11	0.00E+00	0.00E+00	0.00E+00
I 131	7.14E-01	1.95E+02	7.90E+02	7.14E+00	8.72E-04	0.00E+00	0.00E+00
I 132	5.13E-02	1.22E+01	4.24E+03	3.76E+00	3.25E-03	0.00E+00	0.00E+00
I 133	2.52E-01	6.67E+01	2.59E+03	1.41E+01	2.20E-03	0.00E+00	0.00E+00
I 134	2.53E-02	7.57E+00	7.00E+03	2.21E+00	5.34E-03	0.00E+00	0.00E+00
I 135	1.53E-01	4.14E+01	5.03E+03	1.20E+01	3.94E-03	0.00E+00	0.00E+00
Rb 88	4.43E-03	8.65E-01	3.96E+02	4.31E-01	3.20E-03	0.00E+00	0.00E+00
Cs134	1.43E+00	5.26E+02	1.28E+01	1.25E+00	1.91E-04	0.00E+00	0.00E+00
Cs135	1.55E-08	3.47E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E-00
Cs136	2.18E-02	3.34E+00	1.58E+00	1.48E-01	2.02E-05	0.00E+00	0.00E+00
Cs137	2.05E+00	8.44E+02	1.70E+01	1.65E+00	2.59E-04	0.00E+00	0.00E+00
Sr 89	1.13E-02	3.43E+00	2.33E+00	2.24E-02	3.11E-06	0.00E+00	0.00E+00
Sr 90	2.52E-03	1.91E+00	1.99E-01	1.94E-03	2.73E-07	0.00E+00	0.00E+00
Sr 91	8.10E-04	2.10E-01	1.79E+01	5.92E-02	1.47E-05	0.00E+00	0.00E+00
Y 89m	1.02E-06	4.22E-06	0.00E+00	2.24E-06	0.00E+00	0.00E+00	0.00E+00
Y 90	2.36E-03	2.95E-03	0.00E+00	3.55E-04	0.00E+00	0.00E+00	0.00E+00
Y 91	1.08E-03	1.42E-02	8.67E-02	1.65E-03	1.43E-07	0.00E+00	0.00E+00
Y 91m	4.38E-04	1.77E-03	9.45E+00	3.74E-02	8.63E-06	0.00E-00	0.00E+00
Y 93	3.73E-03	1.46E-02	7.80E+01	2.69E-01	7.80E-05	0.00E-00	0.00E+00

TABLE 11.4-2 (sh. 2 of 3)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Zr 93	7.35E-10	0.00E+00	0.00E+00	3.81E-10	0.00E+00	0.00E+00	0.00E+00
Zr 95	3.68E-02	1.21E+01	6.50E+00	6.28E-02	8.74E-06	1.13E-01	0.00E+00
Nb 93m	0.00E+00	0.00E+00	0.00E+00	3.20E-14	0.00E+00	0.00E+00	0.00E+00
Nb 95	4.53E-02	4.85E+00	4.67E+00	4.58E-02	6.02E-06	1.06E-01	0.00E+00
Nb 95m	6.65E-04	8.08E-04	0.00E+00	1.70E-04	0.00E+00	2.00E-03	0.00E+00
MO 99	3.52E-02	9.07E+00	1.10E+02	8.82E-01	1.05E-04	2.35E-01	0.00E+00
Tc 99	5.08E-08	1.58E-08	0.00E+00	7.01E-09	0.00E+00	7.60E-08	0.00E+00
Tc 99m	2.70E-02	8.23E-01	8.99E+01	8.13E-01	7.05E-05	2.06E-01	0.00E+00
Ag110	2.66E-03	6.32E+01	0.00E+00	2.74E-03	0.00E+00	5.72E-03	0.00E+00
Ag110m	2.17E-01	1.21E+02	2.17E+01	2.11E-01	3.02E-05	4.40E-01	0.00E+00
Te129	8.59E-03	7.13E-01	4.89E+02	2.25E-01	3.73E-04	0.00E+00	0.00E+00
Te129m	1.10E-02	3.24E+00	3.18E+00	3.05E-02	4.11E-06	0.00E+00	0.00E+00
Te131	8.07E-04	8.26E-02	1.59E+02	5.45E-02	1.20E-04	0.00E+00	0.00E+00
Te131m	3.76E-03	9.83E-01	2.63E+01	1.69E-01	2.28E-05	0.00E+00	0.00E+00
Te132	1.09E-02	2.88E+00	2.90E+01	2.39E-01	2.82E-05	0.00E+00	0.00E+00
Ba137m	1.91E+00	3.31E+00	0.00E+00	1.54E+00	0.00E+00	0.00E+00	0.00E+00
Ba140	3.13E-01	8.25E+01	2.19E+02	2.04E+00	2.61E-04	0.00E+00	0.00E+00
La140	3.40E-01	2.25E+01	4.36E+02	3.66E+00	3.88E-04	0.00E+00	0.00E+00
Ce141	8.46E-03	2.42E+00	2.51E+00	2.40E-02	3.21E-06	3.62E-02	0.00E+00
Ce143	7.76E-03	2.01E+00	4.91E+01	3.28E-01	4.26E-05	5.19E-02	0.00E+00
Ce144	6.84E-01	3.82E+02	6.66E+01	6.48E-01	9.27E-05	1.36E+00	0.00E+00
Pr143	6.18E-03	1.38E-02	0.00E+00	0.00E+00	0.00E+00	4.44E-02	0.00E+00
Pr144	6.46E-01	9.98E-01	0.00E+00	0.00E+00	0.00E+00	1.36E+00	0.00E+00

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TABLE 11.4-2 (sh. 3 of 3)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Ru103	4.91E-01	1.41E+02	1.25E+02	1.20E+00	1.63E-04	1.92E+00	0.00E+00
Ru106	1.61E+01	9.54E+03	1.50E+03	1.46E+01	2.04E-03	3.09E+01	0.00E+00
Rh103m	4.36E-01	1.07E+00	0.00E+00	0.00E+00	0.00E+00	1.92E+00	0 00E+00
Rh106	1.53E+01	2.37E+01	0.00E+00	0.00E+00	0.00E+00	3.09E+01	0.00E-00
W 187	5.04E-03	1.30E+00	4.44E+01	2.60E-01	3.79E-05	0.00E+00	0.00E+00
Np239	1.02E-02	2.64E+00	3.78E+01	2.93E-01	3.55E-05	0.00E+00	0.00E+00
Pu239	0.00E+00	4.18E-08	0.00E+00	0.00E+00	0.00E+00	0,00E+00	0.00E+00
Na 24	4.56E+01	1.60E+01	8.55E+02	3.62E+03	7.01E-04	0.00E+00	0.00E+00
Cr 51	1.51E-01	4.61E+00	5.17E+01	4.94E-01	3.61E+01	6.98E-01	2.68E-03
Mn 54	2.77E-01	1.63E+01	2.67E+01	2.59E-01	5.24E+01	5.45E-01	1.72E-03
Fe 55	2.28E-01	1.62E+01	1.99E+01	1.94E-01	4.24E+01	4.20E-01	1.36E-03
Fe 59	2.18E-02	7.01E-01	5.01E+00	4.82E-02	5.11E+00	7.99E-02	2.69E-04
Co 58	4.60E-01	1.67E+01	7,68E+01	7.42E-01	1.00E+02	1.36E+00	4.43E-03
Co 60	1.09E-01	7.91E+00	8.83E+00	8.60E-02	1.92E+01	1.88E-01	6.10E-03
Zn 65	8.01E-02	4.59E+00	8.49E+00	8,25E-02	1.61E+01	0.00E+00	0.00E+00

TABLE 11.4-3

EQUIPMENT CODES

TABLE 11.4-4 (Sh. 1 of 6) 338

SRS EQUIPMENT DESCRIPTIONS

375

TABLE 11.4-4 (Sh. 2 of 6) 338

1

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1

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1

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1

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TABLE 11.4-5 (sh. 1 of 3)

SRS EXPECTED OUTPUT ACTIVITIES (Ci/yr-unit)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Br 84	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I 129	2.04E-10	0.00E+00	0.00E+00	3.77E-11	0.00E+00	0.00E+00	0.00E+00
I 131	5.38E-02	1.47E+01	5.95E+01	5.38E-01	6.57E-05	0.00E+00	0.00E+00
I 132	3.89E-96	9.23E-94	3.21E-91	2.85E-94	2.46E-97	0.00E+00	0.00E+00
I 133	9.76E-12	2.58E-09	1.00E-07	5.46E-10	8.49E-14	0.00E+00	0.00E+00
I 134	0.00E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E-00	0.00E+00
I 135	2.25E-34	6.08E-32	7.40E-30	1.76E-32	5.79E-36	0.00E+00	0.00E-00
Rb 88	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs134	1.39E+00	5.11E+02	1.25E+01	1.21E+00	1.85E-04	0.00E+00	0.00E+00
Cs135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cs136	4.51E-03	6.91E-01	3.27E-01	3.05E-02	4.17E-06	0.00E+00	0.00E+00
Cs137	2.04E-00	8.42E+02	1.70E+01	1.65E+00	2.59E-04	0.00E+00	0.00E+00
Sr 89	7.48E-03	2.27E+00	1.54E+00	1.49E-02	2.06E-06	0.00E+00	0.00E+00
Sr 90	2.52E-03	1.90E+00	1.99E-01	1.93E-03	2.72E-07	0.00E+00	0.00E+00
Sr 91	1.21E-26	3.13E-24	2.67E-22	8.83E-25	2.20E-28	0 00E+00	0.00E+00
Y 89m	0.00E+00	0.00E+00	0.00E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y 90	9.63E-07	1.21E-06	0.00E+00	1.45E-07	0.00E+00	0.00E+00	0.00E+00
Y 91	7.54E-04	9.94E-03	6.08E-02	1.16E-03	1.00E-07	0.00E+00	0.00E+00
Y 91m	6.13E-72	2.48E-71	1.32E-67	5.23E-70	1.21E-73	0.00E+00	0.00E+00
Y 93	1.32E-24	5.18E-24	2.76E-20	9.53E-23	2.76E-26	0.00E+00	0.00E+00

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TABLE 11.4-5 (sh. 2 of 3)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Zr 93	7.35E-10	0.00E+00	0.00E-00	3.81E-10	0.00E+00	0.00E+00	0.00E+00
Zr 95	2.66E-02	8.74E+00	4.70E+00	4.54E-02	6.31E-06	8.18E-02	0.00E+00
Nb 93m	0.00E+00	0.00E+00	0.00E+00	3.19E-14	0.00E+00	0.00E+00	0.00E+00
Nb 95	2.50E-02	2.68E+00	2.58E+00	2.53E-02	3.33E-06	5.87E-02	0.00E+00
Nb 95m	2.59E-06	3.15E-06	0.00E+00	6.64E-07	0.00E+00	7.81E-06	0.00E+00
Mo 99	1.83E-05	4.72E-03	5.72E-02	4.59E-04	5.49E-08	1.23E-04	0.00E+00
Tc 99	5.08E-08	1.58E-08	0.00E-00	7.01E-09	0.00E+00	7.60E-08	0.00E+00
Tc 99m	2.96E-38	9.03E-37	9.87E-35	8.92E-37	7.73E-41	2.26E-37	0.00E+00
Ag110	0.00E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ag110m	2.00E-01	1.11E+02	2.00E+01	1.94E-01	2.78E-05	4.05E-01	0.00E+00
Te129	0.00E+00	0.00E+00	0.00E+00	0.00E-00	0.00E-00	0.00E+00	0.00E+00
Te129m	5.93E-03	1.74E+00	1.71E+00	1.64E-02	2.21E-06	0.00E+00	0.00E+00
Te131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E-00	0.00E-00
Te131m	2.25E-10	5.88E-08	1.57E-06	1.01E-08	1.36E-12	0.00E+00	0.00E+00
Te132	1.85E-05	4.89E-03	4.93E-02	4.06E-04	4.78E-08	0.00E+00	0.00E+00
Ba137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ba140	6.16E-02	1.62E+01	4.30E+01	4.01E-01	5.13E-05	0.00E+00	0.00E+00
La140	1.42E-06	9.43E-05	1.82E-03	1.53E-05	1.62E-09	0.00E+00	0.00E+00
Ce141	4.46E-03	1.28E+00	1.32E+00	1.27E-02	1.69E-06	1.91E-02	0.00E+00
Ce143	2.10E-09	5.46E-07	1.33E-05	8.89E-08	1.16E-11	1.41E-08	0.00E+00
Ce144	6.36E-01	3.55E+02	6.19E+01	6.02E-01	8.61E-05	1.26E-00	0.00E+00
Pr143	1.34E-03	2.99E-03	0.00E-00	0.00E+00	0.00E-00	9.63E-03	0.00E+00
Pr144	0.00E-00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

TABLE 11.4-5 (sh. 3 of 3)

Radio-nuclide	Low-Activity Spent Resin	High-Activity Spent Resin	Boric Acid Evaporator Concentrates	Radwaste Evaporator Concentrate	CVCS Filters	Radwaste Filters	SFPCCS Filters
Ru103	2.89E-01	8.33E+01	7.38E+01	7.08E-01	9.59E-05	1.13E+00	0.00E+00
Ru106	1.53E-01	9.02E+03	1.42E+03	1.38E-01	1.92E-03	2.92E+01	0.00E-00
Rh103m	2.57E-01	6.35E-01	0.00E-00	0.00E+00	0.00E+00	1.13E+00	0.00E+00
Rh106	0.00E-00	0.00E-00	0.00E-00	0.00E-00	0.00E+00	0.00E+00	0.00E-00
W 187	4.01E-12	1.04E-09	3.53E-08	2.07E-10	3.01E-14	0.00E-00	0.00E-00
Np239	1.46E-06	3.77E-04	5.39E-03	4.18E-05	5.05E-09	0.00E+00	0.00E+00
Pu239	0.00E-00	4.18E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Na 24	7.87E-20	2.77E-20	1.48E-18	6.25E-18	1.21E-24	0.00E+00	0.00E+00
Cr 51	7.12E-02	2.18E+00	2.45E+01	2.34E-01	1.71E+01	3.30E-01	1.27E-03
Mn 54	2.59E-01	1.52E+01	2.49E+01	2.42E-01	4.90E+01	5.10E-01	1.61E-03
Fe 55	2.23E-01	1.59E+01	1.95E+01	1.90E-01	4.15E+01	4.11E-01	1.33E 03
Fe 59	1.37E-02	4.40E-01	3.15E+00	3.03E-02	3.21E+00	5.02E-02	1.69E-04
Co 58	3.43E-01	1.24E+01	5.72E+01	5.53E-01	7.48E+01	1.01E+00	3.30E-03
Co 60	1.08E-01	7.82E+00	8.74E+00	8.51E-02	1.90E+01	1.86E-01	6.03E-03
Zn 65	1.64E-05	9.38E-04	1.73E-03	1.69E-05	3.29E-03	0.00E+00	0.00E+00

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TABLE 11.4-6

The Scaling Factor of solid radioactive wastes in YGN 3&4

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM
FLOW DIAGRAM

Figure 11.4-1

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM
FLOW DIAGRAM
(Sheet 1 of 3)

Figure 11.4-1

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM
FLOW DIAGRAM
(Sheet 2 of 3)

Figure 11.4-1

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KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
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SOLID RADWASTE SYSTEM
FLOW DIAGRAM
(Sheet 3 of 3)

Figure 11.4-1

KOREA HYDRO & NUCLEAR POWER CO.,LTD.
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SOLID RADWASTE SYSTEM P & ID
(Sheet 1 of 3)

Figure 11.4-2

KOREA HYDRO & NUCLEAR POWER COMPANY
YGN 3 & 4 FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 2 of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM
FLOW DIAGRAM
(Sheet 3 of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3a of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3b of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3c of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
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SOLID RADWASTE SYSTEM P&ID
(Sheet 3d of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3e of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
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SOLID RADWASTE SYSTEM P&ID
(Sheet 3f of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3g of 3)

Figure 11.4-2

KOREA ELECTRIC POWER CORPORATION
YONGGWANG 3 & 4
FSAR

SOLID RADWASTE SYSTEM P&ID
(Sheet 3h of 3)

Figure 11.4-2

11.5 PROCESS AND EFFLUENT RADIOLOGICAL MONITORING AND SAMPLING SYSTEMS

The process and effluent radiological monitoring systems are designed to monitor, record, and/or control the release of radioactive materials that may be contained in the liquids and gases that are discharged from the site or contained in the process streams. One or more systems are capable of handling normal operation, anticipated operational occurrences, and postulated accidents. These systems monitor radioactivity levels or concentrations of radioactive contaminants in liquid process stream, airborne radioactivity in HVAC systems, as well as the effluent. Grab sampling and laboratory analysis can be utilized to satisfy the monitoring requirements, which are described in Subsection 9.3.2 in detail. Permanently installed continuous monitoring plus sampling and analysis are designed to satisfy the requirements of General Design Criteria 60, 63 and 64 of Appendix A to 10 CFR 50, and also to meet the intent of Regulatory Guide 1.21.

11.5.1 Design Bases

The process and effluent radiological monitoring and sampling systems are provided for measurement, indication, and/or control of radioactivity in liquid and gaseous process streams that could conceivably become contaminated by radioactive substances, of which uncontrolled discharge may adversely affect the environs outside the site boundary. In addition selected monitors perform plant protective functions.

11.5.1.1 Safety Design Bases

a. Among the monitors of the process and effluent radiological monitoring and sampling systems, the control room HVAC area intake process monitors are designed to generate the BOP ESF actuation signal control room emergency ventilation actuation signal (ESFAS CREVAS) in the event that airborne radioactivity exceeds allowable limits. The CREVAS actuates BOP ESF systems and equipment to maintain the habitability condition in the main control room during various postulated design basis earthquakes.

b. These monitors are safety-related and part of the plant protection system, designed in accordance with IEEE Standards 279, 323 and 344 to meet the single failure criteria, separation, isolation, environmental and seismic qualification requirements. These monitors together with selected area radiation monitoring system (ARMS) monitors described in section 12.3.4 form the BOP ESFAS. The ARMS monitors generate the BOP ESFAS CPIAS and CREVAS.

c. The safety evaluation of these monitors is discussed in Section 7.3.

d. The BOP ESFAS actuation setpoints of these monitors are established based on USNRC RG 1.105.

11.5.1.2 Power Generation Design Bases

a. The process liquid and gaseous monitors provide radiological information for early detection of radioactive leakage into normally nonradioactive systems during normal plant operation.

b. The process gaseous monitors provide continuous indication of air-borne radioactive contamination in the form of particulate and iodides in areas where personnel normally have access in order to follow the recommendations of USNRC RG 8.8 and 8.10 for control of occupational radiation exposure.

c. The liquid and gaseous effluent monitors continuously monitor every plant gaseous and liquid discharge regardless of whether the discharge is continuous or an intermittent batch release during normal plant operation. The monitors verify that the most restrictive anticipated radioactive nuclide concentrations are within the limits specified in 10 CFR 50, Appendix I, and the NSSC Notice 2014-34(방사선방호 등에 관한 기준) for unrestricted areas. 735

d. All effluent monitors are provided with a means of sampling, for routine and periodic collection of radioactive samples for laboratory analyses during normal plant operation.

e. When radioactive nuclide concentrations exceed the limits specified in 10 CFR 50, Appendix A, GDC 60 during normal plant operation, the effluent monitors generate alarm to alert the operator who can tank action to correct the situation or terminate the release. Certain monitors auto automatically terminate the effluent discharge or divert the effluent for further processing before discharge. 3

f. The gaseous effluent monitors provide radioactivity release data coupled with the metrological data from the metrological instrumentation to the offsite dose calculation (ODC) computer. This subsystem of the radiation monitoring system (RMS) prepares the monthly, quarterly, semiannual, and annual periodic reports required by USNRC RG 1.21 during normal plant operation.

g. The containment air process monitor continuously measures particulate and noble gas radioactivity to detect reactor coolant pressure boundary leakage in accordance with USNRC RG 1.45.

h. During the postulated design basis events, the selected process monitors provide signals for the generation of the BOP ESFAS actuation described in Section 11.5.1.1 to automatically mitigate the consequences of the accidents.

I. During the postulated design basis events and postaccident period, the selected monitors required by USNRC RG 1.97 and NUREG-0718, Item II.F.3 provide long term monitoring function.

j. Under postulated accident conditions, a means is provided within the RMS to monitor increasing iodine level in various building areas and HVAC process streams in accordance with USNRC NUREG-0718, Item III.D.3.3.

k. During the postaccident period, the process and effluent monitors provide various plant radiological data to the technical support center (TSC, Unit 3), satellite TSC (STSC, Unit 4) and EOF to aid the site emergency management activity in accordance with USNRC NUREG-0696 and NUREG-0737, Supplement 1.

11.5.1.3 Codes and Standards

The above codes and regulatory guides reference the industrial codes and standards that are applicable.

11.5.2 System Descriptions

11.5.2.1 General Description

Each gaseous process and effluent radiation monitor consists of multiple detector channels (usually particulate, iodine and noble gas channels) that continuously monitor radioactivity levels in various plant operating systems and effluent streams. The output from each detector is processed locally by a microprocessor and transmitted to the radiation monitoring system cabinet located in the computer room. In addition, each safety-related monitor provides radiological data directly via dedicated wiring to each redundant safety-related divisionalized cabinet (SRDC) in the auxiliary electrical equipment room.

The radiation monitoring system (RMS) is a digital system consisting of local unit microprocessors connected to a dual central computer located in the computer room. The system CRTs (located in the main control room, the health physics office, computer room, TSC and EOF) display all system data. The keybords at the health physics office and computer room are fully interactive and are able to enter changes to the channel parameter file. The other keyboards are capable of display control only, with no ability to enter changes to the channel parameter file.

The RMS also provides hardwired analog indicators in the radwaste control room for the display of all gaseous and liquid radiation monitors located in the radwaste building for the local operator.

All high radiation alarms are displayed in the main control room. Radwaste building gaseous and liquid radiation monitor alarms are displayed at the radwaste control room annunciator as well as in the main control room.

Strip chart recorders are provided on the SRDCs to record data associated with safety-related monitors.

Both Class 1E and non-Class 1E signals are generated by the RMS to provide control interlocks to various plant control circuits.

Each radiation monitoring local unit contains a completely integrated modular assembly including sample pump, filters, sensor(s), and necessary tubing. Radiological shielding is provided for each detector to shield out background radiation and maximize detector sensitivity.

The gaseous process and effluent monitor obtains representative samples from the HVAC process and effluent stream via a isokinetic probe in accordance with ANSI Standard N13.1, to the extent practicable.

The effluent monitoring system for Hanbit 3&4 Temporary Storage is designed in accordance with ANSI/HPS N13.1(1999) 766

11.5.2.2 Check Sources

Each monitor is provided with a check source, which can be operated locally from the main control room, which simulates a radioactive sample in the detector assembly for operational and gross calibration checks.

11.5.2.3 Power Supplies

All Class 1E monitors and the SRDCs are powered from Class 1E power sources. The power supplies for all of the monitors are listed in Table 11.5-1.

11.5.2.4 Calibration and Maintenance

The radiation monitors are calibrated by the manufacturer for the principal radionuclides listed in Table 11.5-1. The source detector geometry during this primary calibration is identical to the sample detector geometry. Secondary standards counted in reproducible geometry during the primary calibration are supplied with each continuous monitor. Each continuous monitor is calibrated annually, using the secondary radionuclide standards.

The count rate response for each continuous monitor to remotely positionable check sources is recorded by the manufacturer after the primary calibration, and is recorded together with the instrument background count rate at intervals during plant operation to ensure proper functioning of the monitors.

A control chart showing check source response and counter background is maintained for each monitor. Instrument responses falling outside the statistical limits imposed by counting statistics are investigated as to cause, and appropriate measures are taken to restore proper functioning. Following repairs or modifications, the monitors are recalibrated at the plant with the secondary radionuclide standards. Process and effluent monitors monitor low activity streams and decontamination is not anticipated to be required for routine maintenance. However, provisions are made to purge the monitors with filtered air or demineralized water, as appropriate without disconnecting the monitor's inlet or outlet tubing. If decontamination is required after flushing, the inlet and outlet tubing can be disconnected and the monitor decontaminated with appropriate solutions either at the equipment location or in the hot machine shop. Following flushing or decontamination, defective components of a monitor can be replaced.

Any effluent released to the environment is analyzed for radioactivity prior to release. If, at any time, a monitor requires maintenance or decontamination, the process flow is terminated. If termination of the process flow is not possible, the effluent monitoring can be accomplished by taking local samples of the process flow in conjunction with the use of portable monitors. This does not impair system integrity since the detector is off-line or can be bypassed.

11.5.2.5 Sensitives

Each effluent monitoring system is able to detect a minimum concentration within the release limits established in ITS.

Due to sensitivity considerations, monitors are located at the effluent release points. Dilution factors between the release point and the site boundary are considered when evaluating compliance with the limitations of the NSSC Notice 2014-34(방사선방호 등에 관한 기준) and Appendix I to 10 CFR 50. 735
Table 11.5-1 provides the detailed sensitivity requirements for the process and effluent monitors.

11.5.2.6 Monitor Locations

The monitors are located in low background areas near the systems being monitored, to minimize background interferences and to minimize the sample line length.

11.5.2.7 Ranges and Setpoints

The ranges of the various process monitors are based on the expected activity levels in the system being monitored. The bases for their setpoints are determined by the need for process control and to alert the operators to leakage of radioactivity into normally nonradioactive systems and areas.

The ranges of the various effluent monitors are based on the ability to detect radioactivity concentrations at the effluent release point which might result in site boundary doses in excess of 10 CFR 50, Appendix I levels, up to those which might result from postulated accidents. The warning setpoints are typically set to alert operators to releases which might exceed the 10 CFR 50, Appendix I annual averages. The alarm setpoints are typically established to alert operators to the occurrence of postulated releases which might exceed the NSSC Notice 2014-34(방사선방호 등에 관한 기준) limits or to automatically initiate ESF actuation in the case of safety-related effluent monitors. 735

The ranges and setpoints for the process and effluent monitors are provided in Table 11.5-1.

11.5.2.8 Expected System Parameters

The expected ranges of system parameters, such as flow composition, and concentrations, are summarized in Table 11.5-1. Detailed information on the individual systems can be found in other sections, principally Chapters 9 and 11.

11.5.2.9 Process and Effluent Radiation Monitoring

The following gaseous process and effluent radiation monitoring channels are provided (The associated P&IDs are shown in Figure 11.5-1.):

a. Primary auxiliary building HVAC effluent monitor
b. Primary auxiliary building HVAC ACU filter inlet monitors
c. Secondary auxiliary building HVAC effluent monitor
d. Secondary auxiliary building HVAC ACU filter inlet monitor
e. Fuel building HVAC effluent monitor
f. Containment purge effluent monitor

g. Main control room outside air intake monitor
h. Containment air monitor
i. Radwaste building HVAC effluent monitor
j. Condenser vacuum vent effluent monitor
k. Gaseous radwaste system exhaust monitor
l. TSC air intake monitor
m. Miscellaneous process monitors

11.5.2.9.1 Primary Auxiliary Building HVAC Effluent Monitor

A monitor is provided with air particulate and iodine samplers to monitor HVAC effluent from the YGN 3&4 primary auxiliary building HVAC air cleaning unit discharge.

11.5.2.9.2 Primary Auxiliary Building HVAC ACU Filter Inlet Monitor

Two monitors are provided with air particulate, gas and iodine channels, to monitor primary auxiliary building plant areas.

11.5.2.9.3 Secondary Auxiliary Building HVAC Effluent Monitor

A monitor is provided with air particulate and iodine samplers to monitor HVAC effluent from the YGN 3&4 secondary auxiliary building HVAC air cleaning unit discharge.

11.5.2.9.4 Secondary Auxiliary Building HVAC ACU Filter Inlet Monitor

A monitor is provided with air particulate, gas and iodine channels, to monitor secondary auxiliary building plant areas.

11.5.2.9.5 Fuel Building HVAC Effluent Monitor

A monitor is provided with air particulate, gas and iodine channels, to monitor HVAC effluent from the YGN 3&4 fuel building HVAC air cleaning unit discharge.

11.5.2.9.6 Containment Purge Effluent Monitor

A monitor is provided with air particulate, gas and iodine channels, to monitor YGN 3&4 containment effluent.

11.5.2.9.7 Main Control Room Air Intake Monitor

Two redundant safety-related monitors per division are provided with gas channel to monitor each of the main control room air intakes. The output signals from these monitors are provided to the BOP ESFAS for the generation of the CREVAS upon detection of high radiation level.

With the initiation of the CREVAS, the outside air intake redundant dampers, which are open for normal operation, are closed and the air is routed through the makeup air cleaning unit.

11.5.2.9.8 Containment Air Monitor

One monitor is provided with air particulate, gas, and iodine detectors, to monitor the YGN 3&4 containments.

The containment air monitors continuously measure, indicate, and record the particulate, iodine and noble gas radioactivity in sample air drawn from the containment. The particulate and noble gas radioactivity is also used to measure the reactor coolant pressure boundary leakage in accordance with USNRC RG 1.45.

11.5.2.9.9 Radwaste Building HVAC Effluent Monitor

One monitor is provided with air particulate, gas and iodine channels to monitor 3

HVAC effluent from the YGN 3&4 radwaste building air cleaning unit discharge.

11.5.2.9.10 Condenser Vacuum Vent Effluent Monitor

A monitor is provided with a gas channel, with a particulate and iodine sampler, to monitor the condenser vacuum system effluent. Upon detection of high radiation, the effluent is automatically directed to the containment building. 3

11.5.2.9.11 Steam Packing Exhaust Vent Effluent Monitor

A monitor is provided with a gas channel, with a particulate and iodine sampler, to monitor the steam packing exhaust vent effluent. 3

11.5.2.9.12 Gaseous Radwaste System Exhaust Monitor

A monitor is provided with gas channel to monitor radiation level of gaseous radwaste system exhaust to radwaste building vent stack.

11.5.2.9.13 TSC Air Intake Monitor

This monitor is used to monitor radiation levels in the TSC when it is occupied after an accident.

11.5.2.9.14 Miscellaneous Process Monitors

Miscellaneous other monitors shown in Table 11.5-1 are provided to monitor the process as indicated.

11.5.2.10 Process Liquid Radiation Monitors

The following process liquid radiation monitors are provided:

a. Liquid radwaste system effluent monitor
b. Component cooling water pump discharge header monitors
c. Steam generator blowdown monitors
d. Miscellaneous process liquid monitors

11.5.2.10.1 Liquid Radwaste System Effluent Monitor

Two monitors are provided to monitor liquid radwaste system effluent and are interlocked with the discharge valve.

The discharge valve is closed automatically if there is high radiation in the liquid radwaste system effluent.

11.5.2.10.2 Component Cooling Water Pump Discharge Header Monitor

Two monitors are provided to continuously monitor the component cooling system for leakage of reactor coolant from the reactor coolant system and/or the shutdown cooling system.

11.5.2.10.3 Steam Generator Blowdown Monitor

A monitor is provided to monitor downstream head flow after filter to the condenser hotwell. A monitor is also a provided to monitor sampling blowdown line flow from each steam generator.

Both of the blowdown line isolation valves and the secondary continuous sample line isolation valves are automatically closed when high radiation is detected.

11.5.2.10.4 Miscellaneous Process Liquid Monitors

Two monitors are provided to continuously monitor the radiation level of the letdown and gas stripper outlets. Detailed information for these monitors can be found in subsection 9.3.4.5.6. Potentially radioactive miscellaneous wastewater such as the condensate polishing demineralizer waste is monitored before discharge to the environment using the monitors listed in Table 11.5-1.

11.5.3 Effluent Monitoring and Sampling

All radioactive discharge paths are continuously monitored in accordance with the design bases stated in Subsection 11.5.1.2. Grab sampling and onsite laboratory analysis are included in the design so that the station is able to trace effluent radiation back to its source. This tracing process will aid the plant operator in fulfilling reporting requirements when required. The process sampling system is described further in Subsection 9.3.2.

Airborne effluents are monitored for gross beta and gross gamma radiation. Liquid effluents are monitored for gross gamma radiation. Isotopic analyses are performed by grab sampling from properly designed sampling taps which are included in the design of the effluent path.

11.5.4 Process Monitoring and Sampling

Process monitoring and sampling are designed to follow the design bases stated in Subsection 11.5.1.2. The identification of radioisotopic constituent is by analysis of samples in the lab. The other portion of the process sampling system is described further in Subsection 9.3.2.

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TABLE 11.5-1 (Sh. 1 of 4)

TABLE 11.5-1 (Sh. 2 of 4)

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TABLE 11.5-1 (Sh. 3 of 4)

440 110 599 599

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TABLE 11.5-1 (Sh. 4a of 4)

KOREA HYDRO & NUCLEAR POWER CO.,LTD
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RADIATION MONITORING SYSTEM P&ID
(Sheet 1 of 2)

Figure 11.5-1

KOREA HYDRO & NUCLEAR POWER COMPANY
YONGGWANG 3 & 4 FSAR

RADIATION MONITORING SYSTEM P&ID
(Sheet 2 of 3)

Figure 11.5-1

KOREA ELECTRIC POWER CORPORATION
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RADIATION MONITORING SYSTEM P&ID
(Sheet 3 of 3)

Figure 11.5-1