GE Nuclear Energy

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ABWR Design Control Document

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11.0 Radioactive Waste Management

11.1 Source Terms

The information provided in this section defines the radioactive source terms in the reactor water and steam which serve as design bases for the gaseous, liquid and solid radioactive waste management systems.

Radioactive source term data for boiling water reactors has been incorporated in American National Standard ANSI/ANS-18.1 (Reference 11.1-1). The Standard provides bases for estimating typical concentrations of the principal radionuclides which may be anticipated over the lifetime of a BWR plant. The source term data is based on the cumulative industry experience at operating BWR plants, including measurements at several stations through 1981. It therefore reflects the influence of a number of observations made during the transition period from operation with fuel of older designs to operation with fuel of current improved designs. The source terms specified in this section were obtained by applying the procedures of Reference 11.1-1 for estimation of typical source terms and adjusting the results upward as appropriate to assure conservative bases for design.

The various radionuclides included in the design basis term have been categorized as fission products or activation products and tabulated in the subsections which follow. The lists do not necessarily include all radionuclides which may be detectable or theoretically predicated to be present. Those which have been included are considered to be potentially significant with respect to one or more of the following criteria:

(1) Plant equipment design

(2) Shielding design

(3) Understanding system operation and performance

(4) Measurement practicability

(5) Evaluation of radioactivity in effluents to the environment

11.1.1 Fission Products

11.1.1.1 Noble Radiogas Fission Products

Typical concentrations of the 13 principal noble gas fission products as observed in steam flowing from the reactor vessel are provided in the Source Term Standard ANSI/ANS-18.1 (Reference 11.1-1). Concentrations in the reactor water are considered negligible because all of the gases released to the coolant are assumed to be rapidly transported out of the vessel with the steam and removed from the system with the other non-condensables in the main condenser. As a consequence of the immediate removal of all the gases, the expected relative mix of gases does not depend on the reactor design.

The design basis noble gas source term for ABWR is selected such that the mix is that of Reference 11.1-1 and the total of the release rates of the 13 noble gases from the vessel is 3700 MBq/s as evaluated at 30-minute decay. The noble radiogas source term rate after 30-minute decay has been used as a conventional measure of the fuel leakage rate, since it is conveniently measurable and was consistent with the nominal 30-minute offgas holdup system used on a number of early plants. A design basis noble gas release rate of 3700 MBq/s at 30-minute decay has historically been used for the design of the gaseous waste treatment systems in BWR plants (Reference 11.1-2) with satisfactory results. It was selected on the basis of operating experience with consideration given to several judgmental factors, including the implications to environmental releases, system contamination, and building air contamination. The design basis value is considered to represent a long-term average value. Operation at higher release rates can be tolerated for reasonable periods of time. Normal operational noble gas release rates for the ABWR are expected to be approximately 555 MBq/s as evaluated at 30-minute decay. This may be compared with normal release rates on the order of 1850 MBq/s based on fuel experience through the mid 1970’s (Reference 11.1-3). Consequently, continued application of the same design basis of 3700 MBq/s provides increased margin relative to expected release rates when operating with fuel of modern design. The design basis noble radiogas source terms are presented in Table 11.1-1.

11.1.1.2 Radioiodine Fission Products

For many years, design basis radioiodine source terms for BWRs have been specified to be consistent with an I-131 leak rate of 25.9 MBq/s from the fuel (Reference 11.1-2). Experience indicated that I-131 leakage rates this high would be approached only during operation with substantial fuel cladding defects. It would not be anticipated that full power operation would continue for any significant period of time with fuel cladding defects as severe as might be indicated by I-131 leakage in excess of 25.9 MBq/s.

The design basis reactor water radioiodine concentrations for the ABWR have been based on the relative mix of radioiodines in reactor water predicted by the data of Reference 11.1-1 with magnitudes increased such that the I-131 concentration is consistent with a release rate of 25.9 MBq/s from the fuel. This provides a substantial margin relative to the expected I-131 release rate of approximately 3.7 MBq/s. Reference 11.1-1 specifies expected concentrations of the five principal radioiodines in reactor water for a reference BWR design and provides the bases for adjusting the concentrations for plants with relevant plant parameters which do not match those of the reference plant. The concentration adjustment factors were calculated as described in Subsection 11.1.3 using the plant parameters in Table 11.1-6 and removal parameters from Table 11.1-7. The scale factor required to increase the I-131 concentration from that calculated using Reference 11.1-1 to the design basis value was approximately 6.7. The design basis concentrations are presented in Table 11.1-2.

The ratio of concentration in reactor steam to concentration in reactor water (carryover ratio) is taken to be 0.015 for radioiodines (Reference 11.1-1). Consequently, the design basis concentrations of radioiodines in steam are defined by multiplying the values of Table 11.1-2 by the factor 0.015.

11.1.1.3 Other Fission Products

This category includes all fission products other than noble gases and iodines and also includes transuranic nuclides. Some of the fission products are noble gas daughter products which are produced in the steam and condensate system. The only transuranic nuclide which is detectable in significant concentrations is Np-239. Concentrations of those radionuclides which are typically observable in the coolant are provided in Reference 11.1-1 for a Reference BWR plant. The Reference Plant concentrations were adjusted to obtain estimates for the ABWR plant by using the procedure described in Subsection 11.1.3 and appropriate data from Tables 11.1-6 and 11.1-7. In order to assure conservative design basis concentrations for the ABWR the results were increased by the same factor used to obtain design basis radioiodine concentrations (6.7). The design basis reactor water concentrations are presented in Table 11.1-3. The ratio of concentration in steam to concentration in water (carryover) for these nuclides is expected to be less than 0.001. The design basis concentrations in steam are obtained by multiplying the values in Table 11.1-3 by 0.001.

11.1.2 Activation Products

11.1.2.1 Coolant Activation Products

The coolant activation product of primary importance in BWRs is N-16. ANSI-18.1 (Reference 11.1-1) specifies a concentration of 1.85 MBq/g in steam leaving the reactor vessel. This is treated as essentially independent of reactor design because both the production rate of N-16 and the steam flow rate from the vessel are assumed to vary in direct proportion to reactor thermal power. The design basis N-16 concentration in steam for the ABWR is designated to be 1.85/g. This value has, in fact, been used as the design basis concentration for GE BWRs since the early 1970’s, and operating experience indicates that it is adequately conservative. It should be noted that a portion of the source term traditionally identified as “N-16” actually represents C-15, which is present to the extent of no more than about 0.555MBq/g. Historically, gross gamma dose rate measurements made to confirm the magnitude of the N-16 concentration have included responses to gamma-rays from C-15. Use of the combined “N-16” source term in the shielding design introduces additional conservatism because the C-15 component has a 2.45-s half-life and therefore decays more rapidly with transport time through the system than does N-16, which has a 7.1-s half-life.

The design basis N-16 concentrations in steam and reactor water are shown in Table 11.1-4. Reference 11.1-1 gives the reactor water concentration at the recirculation system nozzle as 2.2 MBq/g. Since the ABWR does not have an external recirculation loop, the reactor water concentration has been decay-corrected to the reactor core exit to obtain an estimated value of 7.03 MBq/g.

It has been observed that during operation with intentional introduction of hydrogen to the feedwater for the purpose of controlling feedwater oxygen concentrations (i.e., with hydrogen water chemistry), the N-16 concentration in the steam is significantly elevated. Under these circumstances, conditions for production of volatile nitrogen chemical species are more favorable so that a greater portion of the N-16 produced is carried with the steam. The C-15 concentration remains approximately the same. For operation with hydrogen water chemistry, the recommended design basis N-16 concentration in steam is six times (11.1 MBq/g) the value for natural water chemistry.

11.1.2.2 Noncoolant Activation Products

Radionuclides are produced in the coolant by neutron activation of circulating impurities and by corrosion of irradiated system materials. Typical reactor water concentrations for the principal activation products are contained in Reference 11.1-1. The values of Reference 11.1-1 were adjusted to ABWR conditions by using the procedure described in Subsection 11.1-3 and appropriate data from Tables 11.1-6 and 11.1-7. These results were arbitrarily increased by the same factor used for the design basis radioiodine concentrations (6.7) to obtain the conservative design basis reactor water concentrations shown in Table 11.1-5. The steam carryover ratio for these isotopes is estimated to be less than 0.001. A factor of 0.001 is applied to the Table 11.1-5 values to obtain the design basis concentrations in steam.

11.1.2.3 Tritium

Tritium is produced by activation of naturally occurring deuterium in the primary coolant and, to a lesser extent, as a fission product in the fuel (Reference 11.1-2). The tritium is primarily present as tritiated oxide (HTO). Since tritium has a long half-life (12 years) and will not be affected by cleanup processes in the system, the concentration will be controlled by the rate of loss of water from the system by evaporation or leakage. All plant process water and steam will have a common tritium concentration. The concentration reached will depend on the actual water loss rate; however, References 11.1-1 and 11.1-3 both specify a typical concentration of3.7E-04 MBq/g, which is stated in Reference 11.1-3 to be based on BWR experience adjusted to account for liquid recycle. This value is taken to be applicable for the ABWR.

11.1.2.4 Argon-41

Argon-41 is produced in the reactor coolant as a consequence of neutron activation of naturally occurring Argon-40 in air which is entrained in the feedwater. The Argon-41 gas is carried out of the vessel with the steam and stripped from the system with the non-condensables in the main condenser. Observed Argon-41 levels are highly variable due to the variability in air in-leakage rates into the system.

Reference 11.1-3 specifies an Argon-41 release rate from the vessel of 1.48 MBq/s for a 3400 MW Reference BWR. This value bounded the available experimental database. Based on adjusting to the ABWR thermal power, a design basis Argon-41 release rate of 1.70 MBq/s is specified for the ABWR.

11.1.3 Radionuclide Concentration Adjustment

In order to determine the estimated concentrations of radionuclides in the groups classified as iodines, other non-volatile fission products, and non-coolant activation products using the ANSI/ANS-18.1 Source Term Standard (Reference 11.1-1), it is necessary to apply appropriate adjustment factors to the Reference Plant concentrations provided in the Standard.

Equilibrium concentrations in reactor water are assumed to satisfy the relationship:

$$C = \frac{s}{M(\lambda + R)} \qquad (11.1\text{-}1)$$

where:

C	=	Radionuclide concentration
s	=	Radionuclide input rate to coolant
M	=	Reactor water mass
λ	=	Radionuclide decay constant
R	=	Sum of removal rates of the radionuclide from the system.

Consequently, if the radionuclide input rate is taken to depend primarily on the reactor thermal power, the adjustment factors to be applied to the Reference Plant reactor water concentrations are given by:

$$\text{Adjustment Factor} = \frac{P \cdot M_r \cdot (\lambda + R_r)}{P_r \cdot M \cdot (\lambda + R)} \quad (11.1\text{-}2)$$

where the subscript “r” refers to the Reference Plant, P is the reactor thermal power and M, λ, and R are as defined above. The removal rate from the system is the sum of the removal rates due to the Reactor Water Cleanup (CUW) System and the condensate demineralizer and is given by:

$$R = \frac{F_c \cdot E_c + (F_s \cdot A \cdot B \cdot E_s)}{M} \quad (11.1\text{-}3)$$

where:

F_c = Cleanup system flow rate

E_c = Fraction of radionuclide removed in cleanup demineralizer

F_s = Steam flow rate

A = Ratio of radionuclide concentration in steam to concentration in water (carryover ratio)

B = Fraction of radionuclide in steam which is circulated through the condensate demineralizer

E_s = Fraction of radionuclide removed in condensate demineralizer

The Reference Plant and ABWR plant parameters are shown in Table 11.1-6 and the nuclide-dependent removal rate parameters used for the ABWR are shown in Table 11.1-7. The nuclide-dependent parameters are the same as those used for the Reference Plant except for the fraction circulated through the condensate demineralizer. The Reference Plant data is given for a plant without pumped-forward heater drains so that the fraction of condensate treated by the demineralizer is 1.0. In the ABWR, which has pumped-forward drains, the radionuclides are assumed to preferentially go with the pumped-forward flow (Reference 11.1-3). The effective treatment fractions are 0.18 for iodines and 0.01 for other fission products and non-coolant activation products (Reference 11.1-3).

11.1.4 Fuel Fission Production Inventory

Fuel fission product inventory information is used in establishing fission product source terms for accident analysis and is discussed in Chapter 15.

11.1.5 Process Leakage Sources

Process leakage results in potential release of noble gases and other volatile fission products via ventilation systems. Liquid from process leaks is collected and routed to the liquid-solid radwaste system. With the effective process offgas treatment systems now in use, the ventilation releases are relatively significant contributions to total plant releases.

Leakage of fluids from the process system results in the release of radionuclides into plant buildings. In general, the noble radiogases will remain airborne and will be released to the atmosphere with little delay via the building ventilation exhaust ducts. Other radionuclides will partition between air and water and may plate-out on metal surfaces, concrete, and paint. Radioiodines are found in ventilation air as methyl iodide and as inorganic iodine (particulate, elemental, and hypoiodous acid forms).

As a consequence of normal steam and water leakage in to the drywell, equilibrium drywell concentrations will exist during normal operation. Purging of this activity from the drywell to the environment will occur via the Standby Gas Treatment System and will make minor contributions to total plant releases.

Airborne release data from BWR building ventilation systems and the main condenser mechanical vacuum pump have been compiled and evaluated in Reference 11.1-4, which contains data obtained by utility personnel and from special in-plant studies of operating BWR plants by independent organizations and the General Electric Company. Releases due to process leakage are reflected in the airborne release estimates discussed in Section 11.3.

11.1.6 References

11.1-1 American National Standard Radioactive Source Term for Normal Operation of Light Water Reactors, ANSI/ANS-18.1.

11.1-2 Skarpelos, J.M. and R.S. Gilbert, “Technical Derivation of BWR 1971 Design Basis Radioactive Material Source Terms”, March 1973 (NEDO-10871).

11.1-3 Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors, NUREG-0016, Revision 1, January 1979.

11.1-4 Marrero, T.R., “Airborne Releases From BWRs for Environmental Impact Evaluations”, March 1976 (NEDO-21159).

Table 11.1-1 Noble Radiogas Source Terms in Steam

Isotope	Decay Constant 1/hours	Source Term t = 30 min (MBq/s)
Kr-83m	3.73 E-01	1.1E+02
Kr-85m	1.55 E-01	2.0E+02
Kr-85	7.37 E-06	8.9E-01
Kr-87	5.47 E-01	5.6E+02
Kr-88	2.48 E-01	6.3E+02
Kr-89	1.32 E+01	6.3E+00
Xe-131m	2.41 E-03	7.4E-01
Xe-133m	1.30 E-02	1.1E+01
Xe-133	5.46 E-03	3.1E+02
Xe-135m	2.72 E+00	2.5E+02
Xe-135	7.56 E-02	8.1E+02
Xe-137	1.08 E+01	2.6E+01
Xe-138	2.93 E+00	7.8E+02
TOTAL		3.7E+03

Table 11.1-2 Iodine Radioisotopes in Reactor Water

Isotope	Decay Constant 1/hours	Concentration (MBq/g)
I-131	3.59 E-03	5.9E-04
I-132	3.03 E-01	5.2E-03
I-133	3.33 E-02	4.1E-03
I-134	7.91 E-01	8.9E-03
I-135	1.05 E-01	5.6E-03

Table 11.1-3 Non-Volatile Fission Products in Reactor Water

Isotope	Decay Constant (1/hours)	Concentration (MBq/g)
Rb-89	2.74 E+00	7.8E-04
Sr-89	5.55 E-04	1.2E-05
Sr-90/Y-90	2.81 E-06	8.5E-07
Sr-91	7.31 E-02	5.2E-04
Sr-92	2.56 E-01	1.4E-03
Y-91	4.93 E-04	4.8E-06
Y-92	1.96 E-01	8.1E-04
Y-93	6.80 E-02	5.2E-04
Zr-95/Nb-95	4.41 E-04	9.6E-07
Mo-99/Tc-99m	1.05 E-02	2.4E-04
Ru-103/Rh-103m	7.29 E-04	2.4E-06
Ru-106/Rh-106	7.83 E-05	3.7E-07
Te-129m	8.65 E-04	4.8E-06
Te-131m	2.31 E-02	1.2E-05
Te-132	8.89 E-03	1.2E-06
Cs-134	3.84 E-05	3.3E-06
Cs-136	2.22 E-03	2.2E-06
Cs-137	2.63 E-06	8.9E-06
Cs-138	1.29 E+00	1.5E-03
Ba-140/La-140	2.26 E-03	4.8E-05
Ce-141	8.88 E-04	3.7E-06
Ce-144/Pr-144	1.02 E-04	3.7E-07
Np-239	1.24 E-02	1.0E-03

NOTE:

Nuclides shown as pairs are assumed to be in secular equilibrium. The parent decay constant and concentration are shown.

Table 11.1-4 Coolant Activation Products in Reactor Water and Steam

Isotope	Half-Life	Steam Concentration (MBq/g)	Reactor Water Concentration (MBq/g)
N-16	7.13 s	1.9E+00*	3.6E+00†

* Use 11.1 MBq/g for operation with hydrogen water chemistry.

† Valid at core exit.

Table 11.1-5 Non-coolant Activation Products in Reactor Water

Isotope	Decay Constant (1/hours)	Concentration (MBq/g)
Na-24	4.63 E-2	1.3E-03
P-32	2.02 E-3	2.4E-05
Cr-51	1.04 E-3	7.4E-04
Mn-54	9.53 E-5	8.5E-06
Mn-56	2.69 E-1	6.7E-03
Co-58	4.05 E-4	2.4E-05
Co-60	1.50 E-5	4.8E-05
Fe-55	3.04 E-5	1.2E-04
Fe-59	6.33 E-4	3.7E-06
Ni-63	7.90 E-7	1.2E-04
Cu-64	5.42 E-2	3.7E-03
Zn-65	1.18 E-4	2.4E-05
Ag-110m	1.16 E-4	1.2E-07
W-187	2.90 E-2	3.7E-05

Table 11.1-6 Plant Parameters for Source Term Adjustment

Parameter	Reference Plant	ABWR
Thermal Power, MW	3400	3926
Reactor Water Mass, kg	1.73 E+05	3.06 E+05
Cleanup System Flow Rate, kg/h	5.9 E+04	1.52 E+05
Steam Flow Rate kg/h	6.81 E+06	7.63 E+06
Ratio of Condensate Demineralizer Flow Rate to Steam Flow Rate	1.0	*
The above values are expressed in the units required by the procedure in ANSI/ANS-18.1.		

* See Table 11.1-7.

Table 11.1-7 Removal Parameters for Source Term Adjustment

Parameter	Iodines	Other Radionuclides*	Rb, Cs
Fraction removed by cleanup system	0.90	0.90	0.50
Fraction removed by condensate demineralizers	0.90	0.90	0.50
Ratio of concentrations in steam and reactor water	0.015	0.001	0.001
Fraction of radionuclides in steam treated by condensate demineralizer	0.18	0.01	0.01

* Including all non-coolant activation products and all non-volatile fission products except Rb and Cs.

11.2 Liquid Waste Management System

Additional Liquid Radwaste System information is provided in Section 11A.2.

11.2.1 Design Basis

11.2.1.1 Design Objective

The Liquid Radwaste System is designed to segregate, collect, store, and process potentially radioactive liquids generated during various modes of typical plant operation: startup, normal operation, hot standby, shutdown, and refueling. The system is designed such that it may be operated to maximize the recycling of water within the plant, which would minimize the releases of liquid to the environment. Maximizing recycling serves to minimize the potential for exposure of persons in unrestricted areas from the liquid release pathway.

11.2.1.2 Design Criteria

The criteria considered in the design of this system include (1) minimization of solid waste shipped for burial, (2) reduction in personnel exposure, (3) minimization of offsite releases, and (4) maximizing the quality of water returned to the primary system.

Per General Design Criterion 60 of 10CFR50 Appendix A, the Radwaste System design includes means to suitably control the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. These operational occurrences include condenser leakage, maintenance activities, and process equipment downtime. The Liquid Radwaste System provides one discharge line to the canal. Radiation monitoring equipment is placed on this line to measure the activity discharged and to assure that specified limits are not exceeded. A high radiation signal from this monitor will close the discharge valve. The single discharge line is fed by the hot shower drain (HSD) sample tanks (a very low level radioactivity source) or one of the two sample tanks which usually contain condensate quality water.

In addition to providing a means for a controlled (i.e., batch) discharge, the sample tanks also function as surge tanks to minimize or delay the offsite discharge of liquid volume for which there is no immediate room available in condensate storage. By adminisrative control, the discharge from this single discharge line to the canal is adjusted so that it can be shown that the discharge will meet the requirements of 10CFR20 on concentration limit and Appendix I of 10CFR50.

Means are provided for monitoring effluent discharge paths that may be released from normal operations, including anticipated operational occurrences and from postulated accidents. The monitoring of liquid release as required by GDC 64 is accomplished in two steps. First, the sources of release are only from either the HSD sample tank or the LCW sample tanks. These tanks have the necessary connections to the sampling system to allow analysis prior to discharge.

The Liquid Radwaste System is designed to treat process liquids with radionuclide concentrations associated with the design basis fuel leakage and produce water suitable for recycle to condensate storage. Plant water balance considerations may require the discharge of processed liquids to the environs, in which case concentrations of radionuclides in the effluent will meet the requirements of 10CFR20. Radiation exposure to persons in unrestricted areas resulting from liquid waste discharged during normal operation and anticipated operational occurrences will be less than the values specified in 10CFR50, Appendix I. Liquid discharge to the canal may be initiated from only one sample tank at a time. The discharge sequence is initiated manually. No single error or failure will result in discharge. The design will maintain occupational exposure as low as practicable in accordance with NRC Regulatory Guide 8.8 while operating with the design basis fuel leakage.

The low conductivity waste (LCW) filters, mixed-bed demineralizers and concentrators are pressure vessels. The collection and sample tanks operate at atmospheric pressure.

The Liquid Radwaste System is essentially a manual-start and automatic-stop process. Process and radiation instruments are described in Section 11.5. The instrumentation allows for the initiation of processing from the shielded control room area. To ensure that the system performs its intended function in the event of failure of key components, redundancy is provided.

Input to parallel tankage is a feature of the design. Upon high level signals, inputs are automatically routed to a parallel tank. If input should continue, high-high level results in annunciation in the radwaste control room. The state of system operation such as water level of tanks, position of valves and pump operating condition are continuously shown on the radwaste system control panels. The operator will be able to see the changes in the system when the automatic transfer has occurred. Where practical, individual tanks and process equipment are located in separately shielded rooms. Pumps and valves in general are located in dedicated operating galleries. Piping to and from these pumps and valves penetrate shield walls only to the extent necessary to connect to the process equipment. Runs of piping between process equipment are contained either within the shielded areas or shielded pipe runs so that operating personnel exposure is kept to a minimum.

The Condensate storage tank, which is located outdoors, has liquid level monitoring with alarms in the control room. The tank overflows, drains and sample lines are routed to the radwaste system. A dike is provided around the tank to prevent runoff in the event of a tank overflow. A drain within the dike is routed to the radwaste system.

All tanks located outside reactor containment and containing radioactive liquids are indoors and are provided with liquid level monitoring and high liquid level conditions are alarmed locally and in the main control room. All Tank overflows, drains and sample lines are sent to the radwaste system. All tanks have curbs or elevated thresholds with floor drains routed to the radwaste system. Leakage is prevented from entering unmonitored and nonradioactive systems and ductwork in the area.

Radiation exposures are minimized according to Regulatory Guide 8.8 as described in Subsection 12.1.1.3.1.

The liquid radwaste system vessels, piping, welding and testing meet the quality assurance provisions as described in Subsection 11.2.1.2.1.

11.2.1.2.1 Quality Classification, Construction, and Testing Requirements

Equipment and piping are designed and constructed in accordance with the applicable codes listed in Table 11.2-1. The equipment and piping will comply with the requirements of Regulatory Guide 1.143.

Regulatory position C.1.2.1 of Regulatory Guide 1.143 requires that high level in the condensate storage tank be alarmed. Activities which send water to the condensate storage tank are controlled either in the radwaste building control room or the main control room. The location of alarms is interpreted to be in the radwaste building control room and the main control room.

11.2.1.2.2 Seismic Design

The buildings housing the liquid radwaste processing equipment are designed in accordance with the Uniform Building Codes. These buildings are not designated as Seismic Category I. Per regulatory position 1.1.3 of Regulatory Guide 1.43, the base mat and outside walls are Seismic Category I to a height necessary to retain spilled liquids within the building.

11.2.1.3 Occupational Exposure

Design features to minimize occupational exposure include:

(1) Design of equipment to minimize service time

(2) Location of instruments requiring calibration in a central station outside of equipment cells

(3) Arrangement of shield wall penetrations to avoid direct exposure to normally occupied areas

(4) Piping design to minimize crud traps and plateout (there are no socket welds in contaminated piping systems)

(5) Provision for remote pipe and equipment flushing

(6) Utilization of remote viewing and handling equipment as appropriate

(7) A centralized sampling station to minimize exposure time

(8) Controlled tank vents

Design of the building ventilation system includes provision for removal of radiohalogens if the actual dose pathways in the environs indicate the potential of exceeding the annual dose objectives of 10CFR50 Appendix I.

11.2.2 System Description

The Liquid Radwaste System is composed of three subsystems designed to collect, treat, and recycle or discharge different categories of waste water. The three subsystems are the Low Conductivity Subsystem, High Conductivity Subsystem, and Detergent Waste Subsystem.

11.2.2.1 Low Conductivity Subsystem

This subsystem collects and processes clean radwaste (i.e., water of relatively low conductivity). Equipment drains and backwash transfer water are typical of wastes found in this subsystem. These wastes are collected, filtered for removal of insolubles, demineralized on a mixed resin, deep-bed demineralizers for removal of solubles, processed through a second polishing demineralizer, and then routed to condensate storage unless high conductivity requires recycling for further treatment. A second LCW filter, arranged in parallel with the first, is also provided.

11.2.2.2 High Conductivity Subsystem

This subsystem collects and processes dirty radwaste (i.e., water of relatively high conductivity and solids content). Floor drains are typical of wastes found in this subsystem. These wastes are collected, chemically adjusted to a suitable pH for evaporation, and concentrated in a forced-circulation concentrator with a submerged, steam-heated element to reduce the volume of water containing contaminants and to decontaminate the distillate. The distillate is demineralized to remove any soluble contaminants that could potentially be carried over from the concentrator.

11.2.2.3 Detergent Waste Subsystem

This subsystem collects and processes detergent wastes from personnel showers and laundry operations. Normally, detergent wastes are collected in one of two detergent drain tanks and processed through a detergent filter and discharged.

Decontamination factors used for evaluations of the system are within those values in Table 1.5 of NUREG-0016.

Detergent wastes will be discharged after filtration. However, during periods of high laundry use, such as during outages, excess laundry above the capacity of the plant laundry will be sent offsite for processing by a licensed vendor. By administrative control, the amount of activity from both detergent wastes and from the LCW sample tasks will be limited so that the total annual liquid releases will not exceed 3700 MBq/year, excluding tritium.

11.2.3 Estimated Releases

The Liquid Radwaste System is designed with adequate margin so that liquid waste should not be discharged except as needed to maintain the plant water balance. Radwaste operational flexibility is required to assure continued plant operation. Under these conditions, discharge of excess water processed through the High Conductivity Subsystem may be desirable.

The various stream flow rates and the different combinations of events that supply water to the radwaste system for the treatment have been tabulated. The radwaste system is conservatively designed to handle the largest volume expected to be produced. The liquid radwaste subsystems have ample capacity to process the maximum daily generation rate of liquid wastes as shown in Table 11.2-2.

Regeneration of the condensate demineralizers will not be performed. NUREG-0016, Rev. 1, recommended complete resin regeneration, which produced a large volume of waste, every three to five days. The resin will be replaced when necessary. Titanium-tubed condensers have been virtually leak-free. Also, the use of condensate high efficiency filters before the condensate demineralizers have reduced the amount of insoluble solids which come into contact with the resin. As a result, it is expected that resin replacement will be less than once per year.

Decanting of the CUW phase separator is an infrequent event. It is expected to occur once each six months with an expected volume of 68 m^3. The LCW Subsystem can process this volume in addition to the other wastes.

The components of the Liquid Radwaste System are sized based on processing the maximum daily volume within 24 hours. The criteria is more conservative than basing the sizing upon normal expected waste volumes.

11.2.3.1 Release Points

The release point for liquid discharge to the environment is the discharge of the effluent from the LCW sample tank or the hot shower drain sample tank as indicated on the process diagram (Figure 11.2-1).

11.2.3.2 Dilution Factors

Dilution factors used in evaluating the release of liquid effluents are site dependent; however, for the purpose of evaluating the radwaste system against design objectives stated in Subsection 11.2.1, it is conservatively assumed that the expected 3700 MBq/yr is released to a discharge canal having a flow of 340 m^3/h. Also, it is assumed that a dilution factor of ten exists between the discharge canal and subsequent consumption or recreational activity involving liquid effluent. These assumptions are considered very conservative and are expected bound conditions found at any actual site.

If it assumed that 10% of the treated waste from the high conductivity subsystem is discharged, then the annual activity release of fission and activation products would be 74 MBq (excluding tritium), based on operating with the design basis radioactivity concentrations with an 80% plant capacity factor. The annual average liquid releases and the liquid pathway dose analyses are shown in Tables 12.2-22 and 12.2-23. They were calculated assuming release of up to 1850 MBq/y of detergent waste and 1850 MBq/y of treated HCW. A dilution flow of 340 m^3/h for evaluation of compliance with 10CFR20 and an additional dilution by a factor of ten in the discharge canal for dose evaluations were used. Table 12.2-22 and Table 12.2-23 discharges are in compliance with 10CFR50, Part 50, Appendix I.

The reactor coolant activity (RCA) fraction for each substream of the LCW and HCW are shown in Table 11.2-3.

The capabilities of the tank, pumps and other components of the liquid radwaste subsystems are in Table 11.2-4.

11.2.4 Tank Resistance to Vacuum Collapse

Several low pressure tanks in the liquid waste management system and in other systems that could contain reactor water were evaluated for potential vacuum collapse. The only tanks in the liquid waste management system that can contain reactor water, diluted with other wastes, are the LCW and HCW collector tanks. These tanks are vented to preclude vacuum collapse. Vessels coded for internal pressure in excess of 0.343 MPaG have, in general, been demonstrated to sustain full vacuum.

11.2.5 COL License Information

11.2.5.1 Plant-Specific Liquid Radwaste Information

The COL applicant shall provide the following which apply on a plant-specific basis.

(1) Compliance with Appendix I to 10CFR50 and the guidelines given in ANSI Std. N13.1, “Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities”, Regulatory Guide (RG) 1.21, “Measuring and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants”, and RG 4.15, “Quality Assurance for Radiological Monitoring Programs (Normal Operation)—Effluent Streams and the Environment” shall be provided.

(2) A radiation monitor in the discharge line that will automatically terminate liquid waste discharges from the LCW, HCW or detergent waste subsystem if radiation measurements exceed a predetermined level set by the COL applicant to meet 10CFR20, Sections 1001 - 2402, Appendix B, Table 2, Column 2 for the applicable subsystem shall be provided.

(3) Specific administrative controls and liquid effluent source terms to limit the liquid wastes to 3700 MBq/yr (excluding tritium) shall be provided.

(4) Procedures for demonstration of compliance with 10CFR50 (Appendix I) Sections II and III shall be provided.

(5) Administrative controls to limit the instantaneous discharge concentrations of the radionuclides in liquid effluents to an unrestricted area to within 10 times the limits in 10CFR20, Appendix B, Table 2, Column 2 shall be provided.

(6) Quality assurance (operations) provisions of the liquid radwaste systems shall be provided.

Table 11.2-1 Equipment Codes for Radwaste Equipment (from Table 1, RG 1.143)*

Equipment	Design and Fabrication	Materials	Vender Qualification and Procedures	Inspection and Testing
Pressure Vessels	ASME Code Section VIII, Div. 1	ASME Code Section II	ASME Code Section IX	ASME Code Section VIII, Div. 1
Atmospheric Tanks	ASME Code† Section III, Class 3,or API 650,or AWWA D-100†	ASME Code† Section II	ASME Code Section IX	ASME Code‡ Section III, Class 3, or API 650, or AWWA D-100†
0-15 psig Tanks	ASME Code‡ Section III, Class 3, or API 620†	ASME Code† Section II	ASME Code Section IX	ASME Code‡ Section III, Class 3, or API 620†
Heat Exchangers	ASME Code Section III, Div. 1 and TEMA	ASME Code Section II	ASME Code Section IX	ASME Code Section VIII, Div. 1
Piping and Valves	ANSI B31.1	ASTM and ASME Code Section II	ASME Code Section IX	ANSI B31.1
Pumps	Manufacturer's Standards*ƒ*	ASME Code Section II or Manufacturer's Standard	ASME Code Section IX (as required)	ASME Code‡ Section III, Class 3; or Hydraulic Institute

* Manufacturer's material certificates of compliance with material specifications may be provided in lieu of certified material.

† Fiberglass-reinforced plastic tanks may be used in accordance with appropriate articles of Section 10 of the ASME Boiler and Pressure Vessel Code for applications at ambient temperature.

‡ ASME Code stamp, material traceability, and the quality assurance criteria of Appendix B to 10CFR50 are not required. Therefore, these components are not classified as ASME Code Class 3.

ƒ Manufacturer's standard for the intended service. Hydrotesting should be 1.5 times the design pressure.

Table 11.2-2 Capability of Liquid Radwaste Subsystems to Process Expected Wastes

Subsystem	Capacity of Limiting Processing Equipment		Normal Waste Generation Rate	Maximum Daily Generation Rate	Hours to Process Max. Daily Rate
LCW	30 m^3/h	720 m^3/day	55m^3/day	615 m^3/day	20.5 h
HCW	6 m^3/h	144 m^3/day	15 m^3/day	65 m^3/day	10.8 h
DW	12 m^3/h	288 m^3/day	31.3 m^3/day	79 m^3/day	6.7 h

Table 11.2-3 Reactor Coolant Activity (RCA) Fraction

Area	Drain Source	Activity*	Drain Volume m^3/day
		LCW Activity	
Drywell	Steam valve seal leakage	R	1.5
	D/W cooler drain	R	2.9
Reactor Building	Steam valve seal leakage	R x 0.1	1.5
	Sampling drain	R x 0.1	4.3
	CRD pump seal drain	R x 0.1	0.2
	Others	R x 0.1	9.0
Turbine Building	Sampling Drain	R x 0.001	2.7
	Others	R x 0.001	12.3
Radwaste Building	Sampling Drain	R x 0.1	0.05
	Others	R x 0.1	4.95
Others		R x 0.1	10.0
		HCW Activity	
Reactor Building	Floor Drain	R x 0.01	5
Turbine Building	Floor Drain	R x 0.01	5
Service Building	Floor Drain	R x 0.01	2
Radwaste Building	Floor Drain	R x 0.01	3

* R = specific activity of reactor water

Concentrated Wastes from the evaporator are expected as follows:

Floor Drain	0.065 m^3/day
Laboratory drain	0.01 m^3/day
Condensate from solidification sys	0.026 m^3/day
Total	0.101 m^3/day

Table 11.2-4 Capacities of Tanks, Pumps, and Other Components

Component	Volume or Process Flow Rate
LCW System	
LCW Collector Tanks (two)	430 m^3/tank
LCW Filter (two)	15 m^3/h/unit
LCW Demineralizer (one)	30 m^3/h
LCW Backup Demineralizer (one)	36 m^3/h
LCW Sample Tanks (two)(3)	430 m^3/tank
RW/B LCW Sump	4 m^3
RW/B LCW Sump Pumps (two)	10 m^3/h/unit
LCW Collector Pumps (two)	220 m^3/h/unit
LCW Sample Pumps (two)	220 m^3/h/unit
HCW System	
HCW Collector Tank (two)	45 m^3/tank
HCW Evaporators (two)	3.0 m^3/h/unit
HCW Demineralizer	6.0 m^3/h
HCW Distillate Tank	16 m^3
HCW Collector Pumps (two)	60 m^3/h/unit
HCW Distillate Pumps (two)	3 m^3/h/unit
HCW Evaporator Recirculation Pumps (two)	600 m^3/h/unit
RW/B HCW Sump	4 m^3
RW/B Sump Pump (two)	10 m^3/h/unit
Waste Sludge System	
CUW Backwash Receiver Tank	60 m^3
CF Backwash Receiving Tank	60 m^3
CUW Phase Separator (two)	100 m^3/unit
Spent Resin Storage Tank	50 m^3
CUW Backwash Transfer Pump (two)	120 m^3/h/unit
CF Backwash Transfer Pump (two)	120 m^3/h/unit
Decant Pump (two)	10 m^3/h/unit
Slurry Recirculation Pump (two)	200 m^3/h/unit
Sludge Pump (two)	10 m^3/h/unit

Table 11.2-4 Capacities of Tanks, Pumps, and Other Components

Component	Volume or Process Flow Rate
Spent Resin Slurry Pump (two)	100 m^3/h/unit
Concentrated Waste System	
CONW Liquid Waste Tank (two)	16 m^3/tank
CONW Liquid Waste Pump (two)	32 m^3/h/unit
Detergent Waste System	
HSD Receiver Tank (one)(1)	33 m^3
HSD Sample Tanks (two)(2)	210 m^3/each
HSD Receiver Pumps (two)	25 m^3/h/each
HSD Sample Pumps (two)	80 m^3/h/each
HSD Filters (two)	6 m^3/h/each

Notes:

(1) Each HSD receiver tank is capable of collecting the normal volume of wastes, 31.3 m^3/day. This subsystem collects waste liquids from systems that are normally nonradioactive but may, under certain conditions, come into contact with radioactive liquids. The storm drains are sent to the HSD sample tanks from which it is discharged if desired. If needed, the storm drain water may be treated by the HSD filters prior to discharge.

(2) Water is discharged from this system from the HSD sample tanks.

(3) The LCW sample tanks are shared by both the LCW and HCW systems.

The following figures are located in Chapter 21:

Figure 11.2-1 Radwaste System (Sheet 1)

11.3 Gaseous Waste Management System

11.3.1 General

The objective of the Gaseous Waste Management (GWM) or Offgas System is to process and control the release of gaseous radioactive effluents to the site environs so as to maintain the exposure of persons in unrestricted areas to radioactive gaseous effluents as low as reasonably achievable (10CFR50 Appendix I). This shall be accomplished while maintaining occupational exposure as low as reasonably achievable and without limiting plant operation or availability.

The Offgas System provides for holdup and decay of radioactive gases in the offgas from the air ejector system of a nuclear reactor and consists of process equipment along with monitoring instrumentation and control components.

The purpose of the Offgas System is to minimize and control the release of radioactive material into the atmosphere by delaying and filtering the offgas process stream containing the radioactive isotopes of krypton, xenon, iodine, nitrogen, and oxygen sufficiently to achieve adequate decay before discharge from the plant.

The Offgas System design minimizes the explosion potential in the Offgas System through recombination of radiolytic hydrogen and oxygen under controlled conditions.

11.3.2 Design Criteria

The Offgas System is designed to limit the dose to offsite persons from routine station releases to significantly less than the limits specified in 10CFR20 and to operate within the relevant limits specified in the technical specifications.

As a conservative design basis for the Offgas System, an average annual noble radiogas source term (based on 30-minute decay) of 3700 MBq/s of the 1971 mixture will be assumed. Table 11.3-1 provides the design basis noble gas source terms referenced to 30-minute decay. The system is mechanically capable of processing three times the source term without affecting delay time of the noble gases. Also listed is the isotopic distribution at t=0. With an air in-leakage of 51 sm^3/h, this treatment system results in a delay of 46 hours for krypton and 42 days for xenon.

Using the given isotopic activities at the discharge of the Offgas System, the decontamination factor for each noble gas isotope can be determined. Subsection 11.1.1.1 presents source terms for normal operational and anticipated occurrence releases to the primary coolant. Tables in this section, if not designated otherwise, are based upon a design basis offgas release rate of 3700 MBq/s of noble gases and 25.9 MBq/s of I-131. For normal expected condition, the leak rates and doses are expected to be less than one quarter of the design basis numbers.

The average annual exposure at the site boundary during normal operation from all gaseous sources is not expected to exceed the dose objectives of 10CFR50 Appendix I in terms of actual doses to actual persons (Subsection 12.2.2.4). The radiation dose design basis for the treated offgas is to provide sufficient holdup until the required fraction of the radionuclides has decayed with the daughter products retained by the charcoal and the High Efficiency Particulate Air (HEPA) filter.

The Offgas System equipment is selected, arranged, and shielded to maintain occupational exposure as low as reasonably achievable in accordance with NRC Regulatory Guide 8.8.

The Offgas System is designed to the requirements of the General Design Criteria described in Subsection 11.2.1.2.

A list of the Offgas System major equipment items, including materials, rates, process conditions, number of units supplied, and relevant design codes is provided in Table 11.3-2.

The Offgas System is also designed to the following codes and standards:

(1) U.S. Nuclear Regulatory Commission, Code of Federal Regulations, 10CFR20, Standards for Protection Against Radiation; and 10CFR50 Appendix I, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the “As Low As Is Reasonably Achievable” for Radioactive Material in Light-Water Cooled Nuclear Power Reactor Effluents.

(2) Nuclear Regulatory Commission (NRC), Regulatory Guide 1.143, Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants.

(3) American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII—Division 1.

(4) American Institute of Steel Construction (AISC), Manual of Steel Construction, 7th Edition.

(5) American National Standards Institute ANSI/ANS-55.4, Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants.

11.3.3 Process Description

11.3.3.1 Process Functions

Major process functions of the Offgas System include the following:

(1) Dilution of air ejector offgas with steam to less than 4% hydrogen by volume

(2) Recombination of radiolytic hydrogen and oxygen into water to reduce the gas volume to be treated and the explosion potential in downstream process components

(3) Two-stage condensation of bulk water vapor first using condensate and then chilled water as the coolant reducing the gaseous waste stream temperature to 18°C or less

(4) Dynamic adsorption of krypton and xenon isotopes on charcoal at about 38°C

(5) Filtration of offgas

(6) Monitoring of offgas radioactivity levels and hydrogen gas concentration

(7) Release of processed offgas to the atmosphere

(8) Discharge of liquids to the main condenser and radwaste systems

Major process functions of the ventilation systems are described in Section 9.4.

11.3.3.2 Process Equipment

Major process equipment of the Offgas System consists of the following:

(1) Process piping starting from the final steam dilution jets (SJAE) of the main condenser evacuation system(not a part of the Offgas System)

(2) Integral recombiners, including a Preheater section, a Recombiner section, and a Condenser section

(3) Cooler-condensers

(4) Activated charcoal adsorbers

(5) High efficiency particulate air (HEPA) filter

(6) Monitoring instrumentation

(7) Process instrumentation and controls

Major process equipment of the ventilation systems are described in Section 9.4.

11.3.3.3 Process Facility

The Offgas System process equipment is housed in a reinforced-concrete structure to provide adequate shielding. Charcoal adsorbers are installed in a temperature monitored and controlled vault. The facility is located in the Turbine Building to minimize piping.

Reactor condensate is used as the coolant for the offgas condensers. In this capacity:

(1) The temperature of condensate supplied to the offgas condenser should not exceed 56.6°C during periods of normal operation nor 43°C during periods of startup (main condenser evacuation) operation.

(2) The pressure of condensate supplied to the offgas condenser should not exceed the design pressure of the condenser.

(3) Reactor condensate isolation valves should be normally open to both recombiner condensers.

If any of these conditions cannot be met with reactor condensate, the coolant should be supplied by a closed cooling water system of reliability and quality equal to that of reactor condensate.

The gaseous waste stream is then cooled to 18°C or less in the cooler condenser. Chilled water (7°C) is used from the HNCW System (Subsection 9.2.12). The cooler condenser is located immediately above the offgas condenser and is designed to remove any condensed moisture from the gaseous waste stream. The condensed moisture drains into the offgas condenser where it is sent to the main condenser.

The gaseous waste stream is heated to approximately 38°C by ambient heating in the charcoal vault.

Chapter 12 provides the radioactivity inventories of the major Offgas System components during normal plant operation. Radiation shielding design provides adequate protection of instrumentation and plant personnel required to monitor and operate the system.

11.3.4 Offgas System Description

11.3.4.1 Releases

The significant gaseous wastes discharged to the Offgas System during normal plant operation are radiolytic hydrogen and oxygen, main condenser air inleakage, and radioactive isotopes of krypton, xenon, nitrogen and oxygen. The radiation dose from gaseous discharge is primarily external rather than ingestion or inhalation. When releasing gases from the plant, the plume or cloud is the source of radiation to the ground. The maximum radiation corresponds to the zone of maximum ground concentration. This, in turn, is a function of wind velocity and direction, the presence of building obstructions in the wake and other meteorological conditions in the area.

From the foregoing considerations, a maximum release rate from the plant stack or vent can be established such that the maximum radiation dose to any area in the environs is not exceeded.

Radioactive particles are present as a result of radioactive decay from the noble gas parents. These particulates are removed from the offgas stream by the condensation, adsorption, and filtration equipment. Therefore, effectively no radioactive particulates are released from the Offgas System to the plant stack or vent.

Radioiodines (notably I-131) may be present in significant quantities in the reactor steam and to some extent carried over through the condensation stages of the Offgas System. Removal of iodine takes place in the passage of process gas through the activated charcoal adsorbers, so that essentially no iodine is released from the Offgas System to the plant stack or vent.

The criterion for release of gaseous wastes to the atmosphere, excluding accident sequences, is that maximum external radiation dosage to the environment be maintained below the maximum dose objectives of Appendix I to 10CFR50 in terms of actual doses to actual offsite persons. An instantaneous release rate, established by 10CFR20, of several times the annual average permissible release rate limit may be permitted as long as the annual average is not exceeded. Every reasonable effort has been made to keep radiation exposures and release of radioactive materials as low as reasonably achievable (ALARA). The Offgas System discharge is routed to the plant stack.

11.3.4.2 Process Design

Primary design requirements and the process data for startup and normal operating conditions are shown on the process flow diagram (PFD) (Figure 11.3-1) and the piping and instrument diagram (P&ID) (Figure 11.3-2). The Offgas System instrument setpoints are given in Table 11.3-4.

The SJAE suction valving is constrained to incorporate a minimum time period in bringing the recombiner units from zero to full offgas flow in order to limit transient stresses. The minimum time period is 60 seconds, equivalent to linear valve characteristics. The SJAE suction valving and steam supply valving is operable from the main control room.

11.3.4.2.1 Dilution Steam

The last stage SJAE is:

(1) Noncondensing

(2) Always supplied with sufficient steam to maintain the hydrogen concentration downstream at less than 4% by volume

(3) Located in close proximity to the previous condensing stage in order to minimize the length of line carrying a detonable mixture

(4) Provided a backpressure capability as shown on the Process Flow Diagram (PFD)

There is no Offgas System valve operation or failure mode which could cause the loss of dilution steam while the first-stage Steam Jet Air Ejectors (SJAE) are operating. The air ejectors are capable of maintaining required main condenser vacuum concurrent with maximum ejector backpressure. Steam flow to the last-stage ejector is constant during all operating modes of the Offgas System and is not modulated with reactor power level.

A flow meter is provided to measure the dilution steam flow to the last-stage air ejectors. If the dilution steam flow falls below a specified value, the process offgas line suction valve between the main condenser and SJAE closes automatically. The event is alarmed in the main control room. The valve will remain closed until proper steam flow has been established. A high dilution steam flow above a specified value also alarms in the main control room.

The SJAE provides superheated steam at the inlet to the preheaters. The driving steam (dilution steam) to the SJAEs is nuclear steam or steam of nuclear quality. Nuclear quality steam is defined as steam having impurities in concentrations not exceeding that of nuclear steam.

Recombiner preheaters preheat gases to about 177°C for efficient catalytic recombiner operation and to ensure the absence of liquid water, which suppresses the activity of the recombiner catalyst. Maximum preheater temperature does not exceed 210°C should gas flow be reduced or stopped. This is accomplished by using a maximum steam pressure of 1.72 MPa, saturated. At startup, steam at this pressure is available before the process offgas is routed through the preheater to the recombiner catalyst. Electrical preheaters directly exposed to the offgas are not allowed. Each preheater connects to an independent final stage air ejector to permit separate steam heating of both recombiners during startup or drying one recombiner while the other is in operation. Preheater steam flow quantities are shown on the PFD. Preheater steam is nuclear steam for reliability. The preheater is sized to handle a dilution steam load of 115% of that shown on the PFD in addition to allowing for 5% plugged tubes.

11.3.4.2.2 Hydrogen/Oxygen Recombination

Minimum performance criteria for the catalytic recombiners are as follows:

(1) In normal full power operation, the hydrogen in the recombiner effluent does not exceed 0.1% by volume on a moisture-free basis, at the defined, 10 m^3/h, minimum air flow.

(2) During startup or other reduced power operations (between 1 and 50% of reactor rated power), the hydrogen in the recombiner effluent does not exceed 1.0% by volume on a moisture free basis at the defined, 10 m^3/h, minimum air flow.

(3) An intentional air bleed equal to minimum air flow is introduced into the system upstream of the operating recombiner when the main condenser air inleakage falls below the defined minimum air flow of 10 m^3/h. The out-of-service recombiner catalyst is heated to at least 121°C by diluted steam injection before admitting process gas (containing hydrogen) to the recombiner. Three temperature sensing elements are provided in each catalyst bed and are located to record the temperature profile from inlet to outlet.

11.3.4.2.3 Condensing

The offgas condensers cool the recombiner effluent gas to a maximum temperature of 68°C for normal operation and 57°C for startup operation. The condenser includes baffles to reduce moisture entrainment in the offgas. The unit is sized to handle a dilution steam load of 115% of that shown on the PFD, in addition to allowing for 5% plugged tubes. The drain is capable of draining the entire process condensate, including the 15% excess plus 9 m^3/h, from the unit at both startup and normal operating conditions, taking into account the possibility of condensate flashing in the return line to the main condenser. The drain also incorporates a flow element so that higher flows due to tube leakage can be easily identified. The drain is a passive loop seal with a block valve operable from the main control room.

The gaseous waste stream is then cooled to 18°C or less in the cooler condenser. The cooler condenser is designed to remove any condensed moisture by draining it to the offgas condenser.

11.3.4.2.4 Adsorption

The activated charcoal uses “arbitrary” adsorption coefficient Karb values for krypton and xenon at 25°C of at least 60 and 1170 cm^3/g, respectively (cm^3 defined at 0°C and 1.0 atmosphere). Separate Karb laboratory determinations of krypton and xenon are made for each manufacturer’s lot unless the manufacturer can supply proof convincing to the purchaser that other lots of the same production run immediately adjacent to the lot rested are equivalent to the lot tested with respect to krypton and xenon adsorption. Other adsorption tests (e.g., dynamic coefficients) may be acceptable, provided their equivalence to Karb tests for this purpose can be demonstrated. Charcoal particle size is 8-16 mesh (USS) with less than 0.5% under 20 mesh. Moisture content is less than 2% by weight. Ignition temperature will be above 150°C in air. Properties of activated charcoal used in the adsorber vessels are an optimization of the following:

(1) High adsorption for krypton and xenon

(2) High physical stability

(3) High surface area

(4) Low pressure drop

(5) Low moisture content

(6) High ignition temperature

(7) Dust-free structure

The krypton and xenon holdup time is closely approximated by the following equation:

$$T = \frac{K_d M}{V} \tag{11.3-1}$$

where

T = Holdup time of a given gas

K_d = Dynamic adsorption coefficient for the given gas

M = Weight of charcoal

V = Flow rate of the carrier gas in consistent units

Dynamic adsorption coefficient values for xenon and krypton were reported by Browning (Reference 11.3-1). General Electric has performed pilot plant tests at the Vallecitos Nuclear Center and the results were reported at the 12th AEC Air Cleaning Conference (Reference 11.3-2).

11.3.4.2.5 Filtration

The filter assembly contains a single high efficiency water-resistant filter element capable of removing at least 99.97% of 0.3 micrometer particles, as tested at the factory with mono-dispersed dioctylphthalate (DOP) smoke. The initial flow resistance of the filter does not exceed 2.54 cm water gauge (WG) at a water saturated air flow of 425 m^3/h. An upstream demister pad is not required in the filter assembly. The filter is capable of operating under 100% relative humidity conditions.

11.3.4.2.6 Noble Gas Mixture

The fission product noble gas composition used as the nominal design basis is 3700 MBq/s(after 30-minute decay) as defined in Section 11.1. During normal operation with no fuel leaks, a release rate of noble gases of about 3.7 MBq/s (after 30-minute decay) may occur due to minute quantities of uranium contamination. The system is also capable of safe mechanical operation at release rates of up to 14800 MBq/s (after 30-minute decay). However, the limits of Subsection 11.3.4.1 are calculated based upon the design basis activity releases shown on the PFD.

11.3.4.2.7 Air Supply

Carrier gas is the air leakage from the main condenser after the radiolytic hydrogen and oxygen are removed by the recombiner. The air inleakage design basis is conservatively assumed to be 48.2 m^3/h total. The Sixth Edition of Heat Exchange Institute Standards for Steam Surface condensers (Reference 11.3-3), Paragraph S1 (c) (2), indicates that with certain conditions of stable operation and suitable construction, noncondensibles (not including radiological decomposition products) should not exceed 10 m^3/h for large condensers.

An air bleed supply is provided for:

(1) Dilution of residual hydrogen at air inleakages below 10 m^3/h

(2) Valve stem sealing

(3) Recombiner startup

(4) Blocking during maintenance

(5) Instrument operation

(6) Providing an air flow through the standby recombiner when processing offgas

(7) Purging gas mixtures from process and instrument lines prior to maintenance

For dilution, at operating flows below 10 m^3/h, the air bleed is 10 m^3/h. Air flow rates for system purging are specified as normal flow on the PFD. These normal air purge flow rates are not used while the system processes reactor offgas. The air is supplied from a compressor which does not use oil for lubrication of the compressor cylinder, as oil compromises the performance of the catalytic recombiners and charcoal adsorbers.

All sources of air capable of entering the process downstream of the cooler condenser (i.e., valve double stem seals) have a dew point of less than –1°C. During both startup and normal operation, 1.7 m^3/h of air is bled to the standby recombiner train just downstream of the final SJAE suction valve for train purging after switchover. Flow indicators are provided on all air bleed lines to assure that proper air flow is being delivered to the process line or equipment. The air supply is protected from back flow of process gas by two check valves in series or a check valve and a pressure control valve in series.

11.3.4.2.8 Charcoal Vault Temperature

The charcoal adsorber vault air conditioning system is controlled at any selected temperature within a range of 29°C to 41°C. The temperature of the vault is maintained as indicated in Subsection 11.3.4.3.13.

11.3.4.2.9 Rangeability

The process can accommodate reactor operation from 0 to 100% of full power (full power is defined as the Normal Operating Case shown on the PFD). In normal operation, radiolytic gas production varies linearly with thermal power. The process can accommodate an air flow at 10 to 425 m^3/h for the full range of reactor power operation.

In addition, the process can mechanically accommodate a startup high air flow as shown on the Process Data Sheet upon initiation of the steam jet air ejectors. This startup air flow results from evacuation of the turbine condensing equipment while the reactor is in the range of about 3 to 7% of rated power.

Pressure drops through the entire system are as shown on the PFD.

11.3.4.2.10 Redundancy

All active equipment (e.g., valves and instrumentation) whose operation is necessary to maintain operability of the Offgas System is redundant. Passive equipment (e.g., charcoal adsorber) is not redundant. Instrumentation that performs an information function and is backed up by design considerations or other instrumentation need not be redundant. Instrumentation used to record hydrogen concentration or activity release (e.g., flow measurement, hydrogen analyzers) is also redundant.

Design provisions are incorporated which preclude the uncontrolled release of radioactivity to the environment as a result of any single equipment failure short of the equipment failure accident described in Chapter 15. An analysis of single equipment piece malfunctions is provided in Table 11.3-3.

Design precautions taken to prevent uncontrolled releases of activity include the following:

(1) The system design minimizes ignition sources so that a hydrogen detonation is highly unlikely even in the event of a recombiner failure.

(2) The system pressure boundary is detonation-resistant in addition to the measures taken to avoid a possible detonation. Detonation resistance is achieved by specifying a design pressure for the process stream equipment which is approximately seventeen times the design operating pressure of the system.

(3) All discharge paths to the environment are monitored—the normal effluent path by the Process Radiation Monitoring System and the equipment areas by the Area Radiation Monitoring System.

(4) Dilution steam flow to the SJAE is monitored and alarmed, and the valving is required to be such that loss of dilution steam cannot occur without coincident loss of motive steam so that the process gas is sufficiently diluted if it is flowing at all.

11.3.4.2.11 Charcoal Adsorber Bypass

A piping and valving arrangement is provided which allows isolation and bypass of the charcoal adsorber vessel most likely to catch fire or become wetted with water, while continuing to process the offgas flow through the remaining adsorber vessels. This bypass valve arrangement is such that no single valve failure or valve mis-operation would allow total charcoal bypass. A nitrogen purge can be injected upstream of the vault entrance so that further combustion is prevented and the charcoal is cooled below its ignition temperature. Capability is provided to employ all or a portion of the charcoal adsorber vessels to treat the offgas flow during normal or off-standard process operating conditions.

Complete bypass of all charcoal adsorber vessels is also possible, where the main purpose of this bypass is to protect the charcoal during preoperational and startup testing when gas activity is zero or very low and when moisture is most likely to enter the charcoal beds. The bypass modes of charcoal operation is not normal for power operation. However, it may be used if the resulting activity release is acceptable.

11.3.4.2.12 Valves

All valves with operators located on the gas process stream are operable from the main control room. Where radiation levels permit, valves handling process fluids are installed in service areas where maintenance can be performed if needed during operation.

11.3.4.2.13 System Insulation

The Offgas System is adequately insulated, where needed, to insure that the criteria on the PFD are satisfied. Non-sweating type insulation is used to minimize moisture condensation on external side of piping. Insulation requirements are discussed in Subsection 11.3.4.3.8.

11.3.4.2.14 Nitrogen and Air Purge

A nitrogen purge and air supply line is connected to the offgas process just upstream of the first inline charcoal adsorber vessel (guard bed). This arrangement is to allow the vessel to be nitrogen purged after a possible fire is detected or dried with heated air if the charcoal is wetted, while the offgas flow is bypassed around it and through the remaining charcoal vessels. Another nitrogen purge line is also provided just upstream of the remaining charcoal adsorber vessels, which will allow them to be purged, if required, without interrupting the processing of offgas through the first inline charcoal vessel. The isolation valves in the nitrogen and air purge lines and the connection for the gas supply are accessible from outside the charcoal vault.

11.3.4.2.15 Identification of Combustion Hazard

All offgas equipment, piping and instrument lines that could contain a combustible mixture of offgas are color coded or marked in some other suitable manner to identify them. Tags are attached to the lines, and adjacent notices are provided to warn of the hazards of welding in these areas.

11.3.4.3 Mechanical Design

Portions of the system potentially contain a highly explosive mixture. Safety considerations require that ignition sources be minimized and that the system has the integrity to sustain an explosion.

Calculation methods for translation of detonation pressures into wall thickness are summarized in the ANSI-55.4 standard referenced in Subsection 11.3.2. Equipment and piping will be designed and constructed in accordance with the requirements of Table 11.2-1.

11.3.4.3.1 Materials

Per Regulatory Guide 1.143, regulatory position 1.1.2, materials for pressure-retaining components of process systems* are selected from those covered by the material specifications listed in Section II, Part A of the ASME Boiler and Pressure Vessel Code, except that malleable, wrought or cast-iron materials and plastic pipe are not allowed in this application. The components satisfy all of the mandatory requirements of the

* “Process system” refers to that portion of the Offgas System that normally processes SJAE offgas.

material specifications with regard to manufacture, examination, repair, testing, identification and certification.

Brittle fracture control required of carbon steels used for equipment in the Offgas System is as follows:

(1) For equipment, piping, and valves with operating temperatures 93°C or greater, there are no special requirements.

(2) For equipment, piping, and valves with operating temperatures in the range 0 to 93°C inclusive, there are no special requirements, except that high quality material is used (e.g., SA 106 pipe is used instead of A-53 material).

11.3.4.3.2 Pressure Relief

Adequate pressure relief is provided at all locations where it is possible to isolate a portion of the system containing a potential heat source. Adequate pressure relief is also provided downstream of pressure-reducing valves to protect equipment from overpressure.

11.3.4.3.3 Equipment Room Ventilation Control

The equipment rooms are under positive ventilation control. Environmental conditions are maintained within the following ranges:

Area	Pressure (static cm water gauge)	Temp (°C)	Relative Humidity (%)	Air Turnover Rate (room air changes)
Offgas Bldg. Area, except Equipment Cells	0.0 to - 0.63	4.4 Min 21 normal 40 Max	20 Min 40 normal 90 Max	3/h
Charcoal Vault	- 0.63 to -1.26	4.4 Min 35 normal 65.6 Max	20 Min 40 normal 70 Max	3/h
Other offgas Equipment Cells	- 0.63 to -1.26	4.4 Min 21 normal 48.9 Max	20 Min 40 normal 90 Max	3/h

Differential pressure between general areas and equipment cells is at least –6 mm W.G., so as to maintain a flow of air from clean areas into potentially contaminated areas. In addition, the general area air ventilation system is capable of removing sufficient heat from the process piping, equipment, motors, and instrumentation so as to maintain the environmental temperatures in the ranges cited above. All equipment cell and charcoal vault ventilation air is discharged without passing through occupied areas.

11.3.4.3.4 Maintenance Access

Equipment will not normally be accessible for maintenance during system operation. All equipment is available during the annual plant outage. The following are exceptions:

(1) The redundant offgas recombiner trains are located in separate rooms to allow maintenance access to the standby train when processing offgas in the operable train.

(2) Control valving and hydrogen analyzers are accessible for maintenance during the out-of-service portion of their cycle.

(3) Charcoal vault air conditioning and ventilation equipment are accessible for maintenance during plant operation.

Maintenance valving and a 1.7 m^3/h air bleed on the process side of each valve are provided for items (1) through (3) above. Each air line incorporates a flow indicator, isolation valve, and appropriate check valve(s).

The Offgas System is designed, constructed and tested to be as leaktight as practicable. The allowable leakage is a function of the system specific activity, the ventilation rate of the equipment cells, and the maximum permissible concentration (MPC) of the specific activity. Field testing of Offgas System leakage has demonstrated a practical limit of detectability of $1x10^{-6}$ cm^3/s at standard atmosphere. The major offgas activities have an MPC of 0.185 Bq/cm^3. This requires isotope identification, which for an offgas system consists of kryptons and xenons (10CFR20, Appendix B, Table 1, Column 1).

Design features which reduce or ease required maintenance or which reduce personnel exposure during maintenance include the following:

(1) Redundant components for all active, in-process equipment pieces located in separate shielded cells

(2) No rotating equipment in the radioactive process stream but located either where maintenance can be performed while the system is in operation or in non-radioactive streams

(3) Block valves with air bleed pressurization for maintenance which is required during plant operation

(4) Shielding of non-radioactive auxiliary subsystems from the radioactive process stream

Design features which reduce leakage and releases of radioactive material include the following:

(1) Extremely stringent leak rate requirements placed upon all equipment, piping and instruments and enforced by requiring as-installed helium leak tests of the entire process system

(2) Use of welded joints wherever practicable

(3) Specification of valve types with extremely low leak rate characteristics (i.e., bellows seal, double stem seal, or equal)

(4) Routing of drains through steam traps to the main condenser

(5) Specification of stringent seat-leak characteristics for valves and lines discharging to the environment via other systems

11.3.4.3.5 Leakage

The leakage criteria apply from the SJAE through the discharge isolation valve of the Offgas System, including all process equipment and piping in between as shown on the P&ID. Leakage from the process through purge or tap lines to external atmospheric pressure should be less than 10^{-5} cm^3/s at standard atmosphere and is not to be detectable by "soap bubble" test. This requirement does not apply to inline process valves. Leakage to a normally occupied area should not exceed 10^{-5} cm^3/s at standard atmosphere. Leakage from the process side of the equipment to the atmosphere at a differential pressure of 0.0353 MPa is limited to the following maximums:

Equipment Piece	Leak Rate (cm^3/s at standardatmosphere) Zone	Zone Total
Instrument panels	10^{-5}	
All process valves	10^{-5}	
SJAE to recombiner exit	10^{-1}	10^{-1}
Recombiner exit to exit of first charcoal tank	10^{-3}	5×10^{-2}

Equipment Piece	Leak Rate (cm^3/s at standardatmosphere) Zone	Zone Total
Exit of first charcoal tank to exit of last bed	10^{-2}	10^{-1}
Exit of last bed to exit of the system	10°	10

Instrument panels (e.g., hydrogen analyzers) connected to process gas are enclosed, the enclosure maintained under a negative pressure, and vented to an equipment vault or to building ventilation. To reduce instrument line leakage, welded rather than threaded connections are used wherever possible.

11.3.4.3.6 Vents and Drains

Offgas System drains, depending on source, should be routed to either the condenser hotwell or to the Radwaste System. All piping is provided with high point vents and low point drains to permit system drainage following the hydrostatic test. These vents and drains are seal-welded closed prior to the final leak test. All piping is pitched to allow draining to the nearest line or equipment drain shown on the system P&ID. A water drain is provided on the process line just upstream of the charcoal tanks. The process line to and from the charcoal adsorbers is sloped so that there are no intervening low spots to act as water traps.

11.3.4.3.7 Valves

No valves controlling the flow of process gas are located in the charcoal adsorber vault. Gate valves are rising-stem, wedge type. Valve operators may be chosen for operating pressure service (about 0.0343 MPa) rather than for the ASA rating required of the valve body for explosion resistance. For all valves exposed to process offgas, valve seats (trim) are all metal and spark resistant; that is, at least one surface should be fabricated from one of the following materials or equivalent: American Brass Co. Everdur, Beryllium Corp. of America-Berylco, or Allegheny Ludlum-Nitanol.

All valves exposed to process gas have bellows stem seals, double stem seals or equivalent. Bellows design pressure may be the system operating pressure, provided the bellows seal is backed up by a packing seal. Acceptable alternates to bellows seal design are as follows:

(1) A valve having a metal diaphragm backed up by a packing gland using Grafoil (Union Carbide Corp.) or equivalent packing.

(2) A valve having a double stem seal and lantern ring type bonnet, with Grafoil or equivalent packing with the lantern ring leakoff connection pressurized with nitrogen or air form an oil-free compressor to a pressure exceeding the normal system operating pressure. The pressurization line includes a flow indicating device mounted on the valve (such as a purge gas rotameter Schutte and Koerting Type 1875-V or equivalent) with a scale in the 0.5 to 1.0 cm^3/s (at standard atmosphere) range, direct reading.

All valves exposed to process gas, except those specifically designated as control valves on the P&ID, incorporate a backseating feature to minimize potential leakage. The bonnet seal of all valves exposed to process gas are all metal or Grafoil type. It is recommended that the bonnets of valves in inhabited areas such as instrument panels be seal welded. All main process line valves are of bolted or welded bonnet design. Pressure seal bonnets are not used.

Valve external leakage is measured using an approved helium leak test procedure. In the case of double stem seal valves, the lantern ring may be pressurized during testing to the pressure it will see in service, and the valve shall exhibit neither external leakage in excess of the specified maximum nor inward leakage of pressurizing air in excess of 1.0 cm^3/s at standard atmosphere.

11.3.4.3.8 Insulation Materials

Pipe insulating materials for offgas systems shall be from one of the following types or equivalent: S Glass, Refrasil, Cerafelt, Cerafiber, Marinite, Nextil, Fibrefax, Kaowool, or Nukon. Charcoal adsorber vault thermal insulation, if required, is resistant to vault radiation levels and is protected against moisture by a vapor barrier appropriate to the service. Chlorides are not permitted in the insulating material applied to stainless steel equipment.

11.3.4.3.9 Gaskets

It is unacceptable to use gasket sorting techniques to pass the equipment leak test. The required gasket design must have a 95% probability of sealing each time the flanged joint is closed. Process piping and vessels use a metal or spiral wound gasket, incorporating a compression limiting ring.

11.3.4.3.10 Flange Surface Finish

Flanges used in the process stream have a maximum surface roughness of 3 µm rms in a circular lay.

11.3.4.3.11 Recombiners

The recombiners are mounted with the gas inlet at the bottom. The inlet piping has sufficient drains, traps and moisture separators to prevent liquid water from entering the recombiner vessel during startup. The recombiners are catalytic type with a non-dusting catalyst supported on metallic screens or ribbons. The catalyst is replaceable without requiring replacement of the external pressure vessel.

Fabrication procedures will take cognizance of catalyst poisons. Freons, oil, halogens, and welding fumes are to be excluded from the catalyst bed at all times.

Because the possibility exists for all types of catalysts to dust to some degree and then migrate to non-steam-diluted portions of the system downstream of the recombiner, no flow paths exist whereby unrecombined offgas can bypass the recombiners and ignite due to migrated catalyst.

11.3.4.3.12 Charcoal Adsorber Vessels

The charcoal adsorber beds are to be installed vertically. Bed settling could result in gas channeling. Bed settling in horizontal beds could result in excessive gas channeling.

Charcoal adsorber vessel packed heights, diameters, and flow arrangements are shown on the PFD and the P&ID. Channeling in the charcoal adsorbers is prevented by supplying an effective flow distributor on the inlet, which has long columns and a high bed-to-particle diameter ratio of approximately 500. Underhill (Reference 11A.3-4) has stated that channeling or wall effects may reduce efficiency of the holdup bed if this ratio is not greater than 12. During transfer of the charcoal into the charcoal adsorber vessels, radial sizing of the charcoal will be minimized by pouring the charcoal (by gravity or pneumatically) over a cone or other instrument to spread the granules over the surface. Three temperature elements are installed within the first charcoal adsorber vessel to monitor the temperature profile with the flow path during operation. The remaining adsorber vessels each have a temperature element in the charcoal and one in the piping immediately downstream of the vessel.

11.3.4.3.13 Charcoal Adsorber Vault

The temperature within the charcoal adsorber vault is maintained and controlled by appropriate connection(s) to the Turbine Building HVAC System. The flow rate and temperature of the air supplied to the vault has the capacity to cool the vault and equipment within from 66°C to 27°C in 48 hours. The decay heat is sufficiently small that, even in the no-flow condition, there is no significant loss of adsorbed noble gases due to temperature rise in the adsorbers. The HVAC design is capable of controlling the vault temperature within 3°C over the range of 27 to 38°C.

The charcoal adsorber vault temperature is controlled in the range 27°C to 38°C. If it becomes necessary to heat a vessel or the vault to 66°C to facilitate drying the charcoal, portable heaters can be used. A smoke detector is installed in the exhaust ventilation duct from the charcoal adsorber vault to detect and provide alarm to the operator, as a charcoal fire within the vessel(s) usually results in the burning of the exterior painted surface.

11.3.4.3.14 Filter Cartridges

The offgas filter cartridge is designed to be readily removable from the filter vessel and replaceable.

11.3.4.3.15 Weld Inserts

Weld inserts, other than consumable ones, are prohibited from being in contact with the process or process discharges, unless they are ground out after the weld is completed.

11.3.4.3.16 Construction of Process Systems

Pressure-retaining components of process systems employ welded construction to the maximum practicable extent. Process piping systems include the first root valve on sample and instrument lines. Process lines are not less than 50A. Sample and instrument lines are not considered as portions of the process systems. Flanged joints or suitable rapid disconnect fittings are not used except where maintenance requirements clearly indicate that such construction is preferable. Screwed connections in which threads provide the only seal are not used. Screwed connections backed up by seal welding or mechanical joints are used only on lines of 20A. In lines 20A or greater, but less than 65 A nominal pipe size, socket type welds are to be used. In lines 65A and larger, pipe welds are of the butt joint type.

All welding constituting the pressure boundary of pressure-retaining components will be performed by qualified welders employing qualified welding procedures.

11.3.4.3.17 Process-Piping Nozzles

The pipe-to-shell connections are fabricated with integral reinforcing. Nozzle reinforcing pads are not utilized and are not acceptable.

11.3.4.3.18 Traps

All traps incorporate a strainer upstream, in a reasonably accessible location for maintenance, to minimize the chance of debris plugging the trap. Trap designs are not used which, like the inverted-bucket design, incorporate a small, easily plugged orifice. The strainer blowdown line and trap bypass line used for trap maintenance is routed back to the main drain line downstream of the trap to minimize the possibility of escaping process gas.

11.3.4.3.19 Moisture Separator

A moisture separator should be incorporated into the cooler-condenser heat exchanger.

11.3.5 Other Radioactive Gas Sources

Radioactive gases are present in the power plant buildings as a result of process leakage and steam discharges. The process leakage is the source of the radioactive gases in the air discharged through the ventilation system. The design of the ventilation system is described in Section 9.4, the radiation activity levels from the ventilation systems in Section 12.3, and the ventilation flow rates in Section 9.4.

11.3.6 Instrumentation and Control

Control and monitoring of the offgas process equipment is performed both locally and remotely from the main control room, as shown on the P&ID. Indication, recording and alarm functions are shown on the P&ID. Generally, system control is from the main control room. Instrument components are installed, wherever possible, in accessible areas to facilitate operation and maintenance. Only instrument sensing elements are permitted behind shield walls.

The temperature of the gaseous waste stream is measured in the preheater and at various locations in the recombiner to assure that recombination is occurring. The gaseous waste stream temperature is also measured after both the offgas condenser and the cooler condenser to assure the stream is cooled sufficiently to remove undesired moisture. All of these temperatures are alarmed in the main control room.

The flow rate of the air ejector offgases downstream of the recombiner is continuously recorded. This flow rate, in conjunction with activity concentrations in Bq/cc, as measured by the monitor downstream of the recombiners and the monitor downstream of the charcoal adsorbers, will permit monitoring fission gases from the reactor, calculation of offgas discharge to the vent in MBq and will permit calculation of the charcoal adsorber system performance. Activity release that would exceed the maximum permitted instantaneous value is alarmed, and causes closure of the final process gas release valve.

Instrumentation and control of the ventilation systems are described in Section 9.4.

11.3.7 Quality Control

The following, exerpted from ANS-55.4 (Section 11.3.2), provides quality control features to be established for the design, construction, and testing of the Offgas System.

System Designer and Procurer

(1) Design and Procurement Document Control: Design and procurement documents shall be independently verified for conformance to the requirements of this standard by individual(s) within the design organization who are not the originators of the document. Changes to these documents shall be verified or controlled to maintain conformance to this standard.

(2) Control of Purchased Material, Equipment and Services: Measures shall be established to ensure that suppliers of material, equipment and construction services are capable of supplying these items to the quality specified in the procurement documents. This may be done by an evaluation or a survey of the suppliers' products and facilities.

(3) Handling, Storage and Shipping: Instructions shall be provided in procurement documents to control the handling, storage, shipping and preservation of material and equipment to prevent damage, deterioration and reduction of cleanness.

System Constructor

(1) Inspection: In addition to required code inspections, a program for inspection of activities affecting quality shall be established and executed by, or for, the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity. This shall include the visual inspection of components prior to installation for conformance with procurement documents and the visual inspection of items and systems following installation, cleaning and passivation (where applied).

(2) Inspection, Test and Operating Status: Measures shall be established to provide for the identification of items which have satisfactorily passed required inspections and tests.

(3) Identification and Corrective Action for Items of Nonconformance: Measures shall be established to identify items of nonconformance with regard to the requirements of the procurement documents or applicable codes and standards and to identify the action taken to correct such items.

Quality control for the ventilation systems is described in Section 9.4.

11.3.8 Seismic Design

Offgas System equipment and piping are classified non-Seismic Category I. The support elements of the charcoal adsorbers, including legs or skirts, lateral supports (if required) and anchor bolting, are designed such that the fundamental frequency of the vessels including all support elements, is greater than 33 Hz. The charcoal adsorbers, including support elements, are designed to static seismic coefficients of 0.2g horizontal and 0.0g vertical. Stress levels in the charcoal adsorber support elements do not exceed 1.33 times the allowable stress levels permitted by the AISC Manual of Steel Construction, 7th Edition (Section 11.3.2).

Seismic design for the ventilation systems is described in Section 9.4.

11.3.9 Testing

Shop fabricated equipment and the piping system will pass the required tests for integrity as specified in the pressure integrity design specification. In all cases, pressure-containing butt welds exposed to radioactive gas will have 100% radiography and all other pressure-containing welds will have liquid penetrant or magnetic particle surface inspection.

Completed process systems are pressure tested to the maximum practicable extent. Piping systems are hydrostatically tested in their entirety, utilizing available valves or temporary plugs at atmospheric tank connections. Hydrostatic testing of piping systems is performed at a pressure of 3.62 MPaG, which is 1.5 times 2.41 MPa, the design pressure of the lowest pressure rated part of the system. The test pressure will be held for a minimum of 30 minutes with no leakage indicated. Hydrostatic testing will not be performed with the recombiner catalyst, the activated carbon or the filter element in place in the system. Pneumatic testing may be substituted for hydrostatic testing in accordance with the applicable Code of Construction. However, any pressure testing performed after the activated carbon is in place in the vessels would utilize vaporized liquid nitrogen (not compressed air) to avoid contamination or combustion of the carbon.

The installed Offgas System will be leak tested to verify that the leak criteria of Subsection 11.3.4.3.5 are met. A helium leak test is used. Testing is completed prior to application of thermal insulation or corrosion protective coating. Surfaces of the Offgas System to be leak tested will be clean and free of water, oil, grease, paint and other contaminants which would interfere with the leak test.

The object of the preoperation tests is to test installed equipment and piping configurations. Preoperation tests are intended to verify that the equipment was built and installed correctly. The preoperation tests are not complete design tests nor full range calibrations.

The coolant input temperature and flow rate for the offgas condenser and cooler-condenser will be verified to be in compliance with the design basis given on the PFD. The offgas filter cartridge is tested for proper sealing and filtration.

The hydrogen analyzers are tested for proper functioning. During operation, the analyzer will be calibrated on the manufacturer's recommended interval as a minimum.

The equipment operation will be verified at about 10 and 100% of the normal flow case of the PFD.

During reactor startup, after air ejector cut-in and Offgas System startup, the following will be verified:

(1) Air ejector function, through offgas pressure and flow

(2) Preheater operation, through recombiner inlet temperature

(3) Catalyst temperature and H_2 effluent concentration

(4) Offgas condenser operation

The pressure drops of the Offgas System will be verified for both startup and normal operation.

In-place testing facilities are provided for testing the integrity of the filter and filter seal after installation. Such facilities include a polydisperse dioctylphthalate (DOP) smoke generator, means for smoke injection and dispersion upstream of the filter, and analytical instrumentation for determining DOP smoke concentration upstream and downstream of the filter.

Means should be provided for testing the leaktightness of the installed filter when filters are initially installed or when they are replaced. Tests should include the following:

(1) New filters should be factory tested for efficiency.

(2) Immediately prior to installation, new filters should be visually inspected for damage using strong backlighting.

(3) After installation and prior to use, the filter should be DOP tested to ensure that it is sealed and that no unseen filter damage exists.

The test at the time of filter installation or replacement uses DOP (dioctylphthalate) aerosol to determine whether the installed filter meets the minimum in-place efficiency of 99.97% retention. The DOP test consists of injecting cold (polydisperse) DOP in a 16.5 to 33 cubic meters per hour air stream so that it is well mixed when it reaches the filter. The DOP and air enter the offgas pipe at least eight offgas pipe diameters upstream of the filter and inlet sampling point. The outlet sampling point is located at least eight pipe diameters downstream of the outlet of the filter, and the return line from the DOP sampler must be located at least four pipe diameters beyond the outlet sampling point. Sampling connection from the inlet and outlet sampling line should be made through a DOP measuring instrument to a vacuum pump of 1.3 to 2 cubic meters per hour capacity. The DOP measuring instrument is used to measure individual DOP concentrations at the filter inlet and outlet, thereby measuring filter efficiency by comparing these concentrations. At the end of the test, the process lines are purged with bleed air.

The DOP from filter testing is not allowed into the activated carbon.

Performance tests during plant operation should consist only of taking filter inlet and outlet samples by drawing them through Millipore filters for laboratory measurement of radioactive particles collected.

Filter test equipment used with the Offgas System should have the following characteristics:

(1) The smoke injection and sample piping should have the same pressure rating as the offgas line through the first valve.

(2) The smoke generator and measuring instrumentation, including the vacuum pump, can be made portable for common use on the Standby Gas Treatment System.

(3) The DOP connections should be installed so that representative inlet and outlet samples can be obtained.

Testing requirements for the ventilation systems are listed in Section 9.4.

11.3.10 Radioactive Releases

11.3.10.1 Release Points

The primary release point for the ABWR plant is the Reactor Building plant stack. This stack serves as the release point for the Reactor Building, Turbine Building, and Radwaste Building. Other exhaust points for clean releases are the roof top vents for the Control and Service Buildings and the Service Building health physics room roof vent. The Reactor Building stack is a roof-mounted steel shell in a steel framework extending to a height of 76m above ground level. The closest plant buildings are the Reactor Building to a height of 37.7m and the Turbine Building to a height of 43m. A sketch of the layout for the plant is shown in Figure 1.2-1 and a sketch of the stack with perspective to the local buildings is shown in Figure 15.6-4.

11.3.10.2 Ventilation Releases

Ventilation releases are given in Section 12.2 and assume releases from the plant stack with a total flow rate of at least 566,000 m^3/h through a 2.4m diameter circular stack at

76m above ground level. Ventilation releases are assumed to be less than 40°C. The ABWR is licensed for a generic site for which no specific site parameters have been stipulated by the NRC; therefore, an ambient temperature of 38°C is assumed based upon Table 2.0-1.

11.3.10.3 Dilution Factors

Since the ABWR certification stipulates a generic site and in lieu of NRC guidance on meteorological parameters for generic sites, recourse was made to the determination of the annual average dilution factors (χ/Q and D/Q) for multiple sites. Using data described in Reference 11.3-5 for 26 sites around the U.S. including New York City (derived from Reference 11.3-6) and the above parameters, a determination of χ/Q and D/Q variability using code XOQDOQ (Reference 11.3-7) was made. From this, a minimum χ/Q of 2.0×10^{-6} and a minimum D/Q of 4×10^{-8} was used.

11.3.10.4 Estimated Doses

The calculated exposures are discussed in Section 12.2.

11.3.11 COL License Information

11.3.11.1 Compliance with Appendix I to 10CFR50

The COL applicant shall demonstrate compliance with Appendix I to 10CFR50 numerical guidelines for offsite radiation doses as a result of gaseous or airborne radioactive effluents during normal plant operations, including anticipated operational occurrences shall be provided.

11.3.12 References

11A.3-1 Browning, W.E., et al., “Removal of Fission Product Gases from Reactor Offgas Streams by Adsorption”, June 11, 1959 (ORNL) CF59-6-47.

11A.3-2 Seigwarth, D.P., “Measurement of Dynamic Adsorption Coefficients for Noble Gases on Activated Carbon”, 12th AEC Air Cleaning Conference.

11A.3-3 Standards for Steam Surface Condensers, Sixth Edition, Heat Exchange Institute, New York, NY (1970).

11A.3-4 Underhill, Dwight, et al., “Design of Fission Gas Holdup Systems”, Proceedings of the Eleventh AEC Air Cleaning Conference, 1970, p. 217.

11A.3-5 Hall, Irving, et al, “Generations of Typical Meteorological Years for 26 SOLMET Stations”, Sandia National Laboratory, SAND78-1601.

11A.3-6 Ritchie, Lynn T, et al, “Calculations of Reactor Accident Consequences Version 2 CRAC2: Computer Code”, NUREG/CR-2326, February 1983.

11A.3-7 Sagendorf, J.F., et al, “XOQDOQ: Computer Program for the Meteorolgical Evaluation of Routine Effluent Releases at Nuclear Power Stations”, NUREG/CR-2919, September 1982.

Table 11.3-1Estimated Air Ejector Offgas Release Rates Per Unit ($51\ sm^3/h$ Inleakage)

Isotope	Half-Life	MBq/s	T = 30 Minutes MBq/s	Discharge from Charcoal Adsorber MBq/s	MBq/y*
Kr-83m	1.86 h	1.3E+02	1.1E+02	7.0E-09	2.0E-01
Kr-85m	4.4 h	2.3E+02	2.1E+02	1.3E-02	3.6E+05
Kr-85†	10.74 y	0.37 to .74	0.37 to .74	7.4E-01	2.1E+07
Kr-87	76 min	7.4E+02	5.5E+02	--	
Kr-88	2.79 h	7.4E+02	6.7E+02	1.1E-04	3.2E+03
Kr-89	3.18 min	4.8E+03	6.7E+00	--	
Kr-90	32.3 s	1.0E+04	--	--	
Kr-91	8.6 s	1.2E+04	--	--	
Kr-92	1.84 s	1.2E+04	--	--	
Kr-93	1.29 s	3.7E+03	--	--	
Kr-94	1.0 s	8.5E+02	--	--	
Kr-95	0.5 s	7.8E+01	--	--	
Kr-97	1 s	5.2E-01	--	--	
Xe-131m	11.96 day	5.5E-01	5.5E-01	6.7E-02	1.9E+06
Xe-133m	2.26 day	1.1E+01	1.0E+01	1.1E-04	3.1E+03
Xe-133	5.27 day	3.0E+02	3.0E+02	2.4E+00	6.7E+07
Xe-135m	15.7 min	9.6E+02	2.6E+02	--	--
Xe-135	9.16 h	8.1E+02	8.1E+02		
Xe-137	3.82 min	5.5E+03	2.5E+01		
Xe-138	14.2 min	3.3E+03	7.8E+02	--	
Xe-139	40 s	1.0E+04	--	--	
Xe-140	13.6 s	1.1E+04	--	--	
Xe-141	1.72 s	8.9E+03	--	--	
Xe-142	1.22 s	2.7E+03	--	--	
Xe-143	0.96 s	4.4E+02	--	--	
Xe-144	9 s	2.1E+01	--	--	
TOTALS		9.0E+04	3.7E+03	3.2E+00	9.0E+07

* This is based on the activity present at time of release. No decay in environment is included.
† Estimated from experimental observations.

Table 11.3-2 Offgas System Major Equipment Items

Recombiner (Item D005, 2 required, contains preheater, catalyst, and condenser sections)
Carbon steel shell
Shell length: approximately 70m
Shell OD: approximately 1.3m
Total unit height: approximately 2.95m
Design pressure: 2.41 MPa
Design temperature: 232°C
Code of construction: ASME Section VIII, Division 1
Preheater section
Shell and tube heat exchanger
Tubes: stainless steel, rolled into stainless steel tube sheet
Tube-side design pressure: 2.41 MPa
Design temperature: 232°C
Catalyst section
Catalyst support: stainless steel
Design temperature: 482°C
Catalyst: precious metal on ceramic or metal base
Offgas condenser section
Shell and tube heat exchanger
Tubes: stainless steel, rolled into stainless steel tube sheet
Tube-side design pressure: 2.41 MPa
Design temperature: 482°C
Cooler condenser (Item B010, 2 required)
Shell and tube heat exchanger, carbon steel vessel
Shell length: 3.05m
Shell-side design pressure: 2.41 MPa
Shell-side design temperature: 0 to 121°C
Tubes: stainless steel, welded into stainless tube sheet
Tube-side design pressure: 0.69 MPa
Tube-side design temperature: 0 to 65.6°C
Code of construction: TEMA Class C
Charcoal adsorbers (Items D012A and D012B-J)
Carbon steel vessels filled with activated charcoal: 4500 kg D012A, 13,600 kg D012B-J

Table 11.3-2 Offgas System Major Equipment Items (Continued)

Height: approximately 10.4m
Outside diameter: approximately 1.2m D012A, 2.1m D012B-J
Design pressure: 2.41 MPa
Design temperature: 4.4 to 121°C
Code of construction: ASME Section VIII, Division 1
Filter (Item D016, 1 required)
Carbon steel vessel with removable HEPA filter
Height (includes legs): approximately 1.8m
Outside diameter: approximately 0.61m
Flow: 425 m^3/h at 2.54 cm H_2O gauge
Design pressure: 2.41 MPa
Design temperature: 4.4 to 65.6°C
Code of construction: ASME Section VIII, Division 1

Table 11.3-3 Equipment Malfunction Analysis

Equipment Item	Malfunction	Consequences	Design Precautions
Steam jet air ejectors	Low flow of motive high pressure steam	When the hydrogen and oxygen concentrations exceed 4 and 5 volume percent, respectively, the process gas becomes flammable.	Automatic system isolation on low steam flow.
		Inadequate steam flow will cause overheating and deterioration of the catalyst.	Steam flow to be held at constant maximum flow regardless of plant power level.
	Wear of steam supply nozzle of ejector	Increased steam flow to recombiner could reduce degree of recombination at low power levels. High discharge temperature from the recombiner condenser could result due to inadequate condenser capacity.	Low-temperature alarms on preheater exit (catalyst inlet). Downstream H_2 analyzer. High-temperature alarm on exit from recombiner.
Recombiner preheater	Steam leak	Would further dilute offgas. Steam consumption would increase.	Spare recombiner.
	Low-pressure steam supply	Recombiner performance would fall off at low-power level, and hydrogen content of recombiner gas discharge would increase eventually to a combustible mixture.	Low-temperature alarms on preheater exit (catalyst inlet). Downstream H_2 analyzer.
Recombiner catalyst	Catalyst gradually deactivates	Temperature profile changes through catalyst. Eventually, excess H_2 would be detected by H_2 analyzer or by gas flow meter. Eventually, the gas could become combustible.	Temperature probes in catalyst bed and H_2 analyzer provided. Spare recombiner.
	Catalyst gets wet at start	H_2 recombination fails. Eventually, the gas could become combustible.	Condensate drains, temperature probes in recombiner. Air bleed system at startup. Spare recombiner. Hydrogen analyzer.

Table 11.3-3 Equipment Malfunction Analysis (Continued)

Equipment Item	Malfunction	Consequences	Design Precautions
Recombiner condenser	Cooling water leak	The coolant (reactor condensate) would leak to the process gas (shell) side. This would be detected if drain well liquid level increases. Moderate leakage would be of no concern from a process standpoint. (The process condensate drains to the hotwell.)	Drain well high level alarm. Redundant recombiner.
	Liquid level Instruments fail	If drain valve fails to open, water will build up in the condenser and pressure drop will increase. The high ΔP, if not detected by instrumentation, could cause pressure buildup in the main condenser and eventually initiate a reactor scram. If a drain valve fails to close, gas will recycle to the main condenser, increase the load on the SJAE, and cause a slight backpressure on the main condenser.	High- and low-level alarms on drain well level. Redundant recombiner.
Cooler condenser	Corrosion of tubes	Water would leak into process (shell) side and be discharged to clean radwaste.	Stainless-steel tubes specified.
Moisture separator in cooler condenser	Corrosion of wire mesh element	Increased moisture would be retained in process gas routed to gas dryers. Over a long period, the desiccant dryer cycle period would deteriorate as a result of moisture pickup.	Stainless steel mesh specified. Spare cooler condenser provided. Moisture detector provided downstream of gas dryer.
Charcoal adsorbers	Charcoal gets wet	Charcoal performance will deteriorate gradually as moisture deposits. Holdup times for krypton and xenon would decrease, and plant emissions would increase. Provisions made for drying charcoal as required during annual outage.	High instrumented, mechanically simple gas dehumidification system.

Table 11.3-3 Equipment Malfunction Analysis (Continued)

Equipment Item	Malfunction	Consequences	Design Precautions
After filter	Hole in filter media	Probable of no real consequence. The charcoal itself will retain virtually all solid daughters. Particulates released would be the negligible amount formed in the pipe run after the exit of the last charcoal adsorber.	ΔP instrumentation provided.
System	Internal detonation	Release of radioactivity if pressure boundary fails.	Main process equipment and piping are designed to contain a detonation.
		Internal damage to the recombiner and its heat exchanger.	Redundant recombiner, damaged internals can be repaired.
		Damage to instrumentation sensors.	Redundant, damaged sensors can be replaced.
		Filter media blown out.	The inventory of this filter is trivial. The filter can be replaced at first outage.
System	Earthquake damage	Release of radioactivity.	Dose consequences are within the design guidance of BTP ETSB 11-5.

Table 11.3-4 Offgas System Instrument Setpoints

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
1	Steam Flow	N070	100–105%	75–115%	Superheated	0–120%	L 75% Trip
	to Final	R625			Steam	± 113 kg/h	AH 110%
	SJAE				10–315.6°C		AL 95%
Based on full power flow of 3383.2 kg/hr steam					0-7.24 MPa		
2	Final SJAE	N011	121–143°C	115–150°C	Superheated	90°–150°C	N/A
	Temperature	R045		Steam	± 3°C	AL 115°C	
					10–200°C		
					0-7.24 MPa		
3	Preheater Inlet	N001	0.003-0.03 MPa		Offgas and	0-0.055 MPa	N/A
	Pressure	R600	0.02-0.041 MPa		Steam 10–315°C	± 0.001 MPa	AH 0.046 MPa
					0-7.24 MPa		
4	Air Bleed	R039	0.062 to 0.076	0.046 to 0.076	Air	0-1.03 MPa	N/A
	Pressure		MPa	MPa	10–65°C	± 0.005 MPa	N/A
					0–1.03 MPa		
5	Air Bleed (Standard Atmosphere)	R040	1.7 or 11.9 m^3/h	1.7 to 105	Air	0–110 m^3/h	N/A
	Total Flow (Standard Atmosphere)		1.7 or 104 m^3/h	m^3/h	10–65°C	± 3.7 m^3/h	N/A

Table 11.3-4 Offgas System Instrument Setpoints (Continued)

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
					0-1.03 MPa		
6	Air Bleed (Standard Atmosphere)	R041	1.7 or 2.4 m^3/h	1.7 m^3/h	Air	0–3.7 m^3/h	N/A
	Normal (Standard Atmosphere)				10–65°C	± 0.17m^3/h	N/A
					0-1.03 MPa		
7	Recombiner	N002	163–190.6°C	115–399°C	Offgas and	20–399°C	N/A
	Inlet Temp.	R604			Steam	± 5.6°C	AL 149°C
		N003			10–454°C		
					0-2.40 MPa		
8	Pressure	N006	0–0.009 MPa		Superheated	0-0.021 MPa	N/A
	Drop from	R603	0.013 MPa		Steam	± 0.0014 MPa	AH 0.015 MPaD
	Preheater				10–121°C		
	to Cooler				0-7.24 MPa		
	Cond. Exit						
9	Temperature	N004	190.6–443°C	121–482°C*	Offgas and Steam	10–538°C	N/A
	Profile of	R602			10–565.5°C	± 6.7°C	AH 443°C
	Recombiner	N005			0–2.41 MPa		AL 149°C

Table 11.3-4 Offgas System Instrument Setpoints (Continued)

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
10	Offgas Cond. Loop Level	N007 R621	0m	0 ± 0.3m	Water 10–100°C 0–7.24 MPa	± 0.1m	AL – 0.3m
11	Offgas Cond. Water Level	N014 R622	L.T. 0.5m	L.T. 0.5m	Water 10–100°C 7.24 MPa	± 0.1m	AH + 1.0m
12	Offgas Cond. Loop Seal Water Flow	N041 R617	L.T. 75.7m	L.T. 227m	Water 10–93.3°C 2.41 MPa	0–227m ± 3.8m	N/A N/A
13	Offgas Cond. Cool and Exit Water Temp.	N063 R004	L.T. 62.6°C L.T. 57.2°C	10–62.6°C	Water 10–93.3°C 3.45 MPa	10–93.3°C ± 3°C	N/A AH 65.6°C
14	Offgas Cond. Exit Temp.	N009 R006	L.T. 71°C L.T. 57.2°C	10–71°C	Offgas 10–93.3°C 7.24 MPa	10–93.3°C ± 2°C	N/A AH 71.0°C
15	Hydrogen Analyzer	N012 R605	0–0.1% By V. 0–1.0% By V.	0–4% By V.	Offgas 10–93.3°C 7.24 MPa	0–5% By V. ± 0.15% By V.	N/A AH 2% By V.

Table 11.3-4 Offgas System Instrument Setpoints (Continued)

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
16	Air Bleed (Standard Atmosphere)	R042	0–1.7 m^3/h	0–3.4 m^3/h	Air	0–3.4 m^3/h	N/A
	Inlet at (Standard Atmosphere)				10–65.5°C	± 0.3 m^3/h	
	Cooler Cond.				1.03 MPa		
17	Cooler	N020	15.6–21.1°C	10–23.9°C	Offgas	-1–37.9°C	N/A
	Cond. Exit	N600			10–65.5°C	± 1°C	AH 21.7°C
	Temp.	R610			7.24 MPa		
18	Charcoal	N035	0.007–0.02 MPa	0.027 MPa	Offgas	0.055 MPa	N/A
	Adsorber	R609			-1–65.5°C	± 0.002 MPa	N/A
	Inlet Press.				7.24 MPa		
19	Charcoal	N022	0.002-0.02 MPa	0.027 MPa	Offgas	0.027 MPa	N/A
	Adsorber	R612			4.4–121°C	± 0.0001 MPa	AH 0.02 MPa
	Diff. Press.				7.24 MPa		
20	Charcoal	N023-26	35–40.6°C	32.2–41.6°C	Offgas	4.4–121°C	N/A
	Adsorber	R606-8			4.4–121°C	± 1.1°C	AH 43.3°C
	Vessel				2.41 MPa		
	Temperature						

Table 11.3-4 Offgas System Instrument Setpoints (Continued)

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
21	Charcoal Adsorber Vault Temp. Control	N031 R037	35–40.6°C	32.2–43.3°C	Ambient Air 21.1–121°C	21.1–121°C ± 2.2°C	N 40.6°C L 26.7°C
22	Charcoal Vault Inlet Water Level	N008	0–1m	0.05–1.5m	4–100°C 7.24 MPa	0.0–1.5m ± 0.01m	AH 1.2m AL 0.1m
23	Charcoal Vault Exit Temperature	N029 R610	N/A	4.4–43.3°C	Ambient Air 4.4–121°C	4.4–121°C ± 2.2°C	AH 43.3°C AL 26.7°C
24	After Filter Differential Pressure	N034 R619	0.5–2.5 cm WC 1.27–10 cm WC	0–20 cm WC	Offgas 10–121°C 7.24 MPa	0–30.5 cm WC ± 0.9 cm WC	N/A AH 12 cm WC
25	Process Flow	N010 N061 R620	10.2–51 m^3/h L.T. 425 m^3/h	0–510 m^3/h	Offgas 0–121°C 7.24 MPa	Narrow Range 5–51 m^3/h ± 3 m^3/h Wide Range 5–510 m^3/h	AL 10 m^3/h AH 68 m^3/h AHH 425 m^3/h

Table 11.3-4 Offgas System Instrument Setpoints (Continued)

Item	Function	MPL	Normal Range Startup Range	Operational Limits	Sensor Qualifications	Scale Range Tolerance	Setpoint Alarm
						50–100 m^3/h	
						± 5 m^3/h	
						100–510 m^3/h	
						± 40 m^3/h	

* Operational limit for standby recombiner is 71 - 210°C.

The following figures are located in Chapter 21:

Figure 11.3-1Offgas System PFD (Sheets 1-2)

Figure 11.3-2Offgas System P&ID (Sheets 1-3)

11.4 Solid Waste Management System

The Solid Waste System is designed to provide solidification and packaging for radioactive wastes produced during shutdown, startup, and normal operation and to store these wastes, as required, in the Radwaste Building. Additional Solid Waste System information is provided in Section 11A.4.

11.4.1 Design Bases

11.4.1.1 Design Objective

The Solid Waste System provides the capability for solidifying and packaging wastes from the Reactor Water Cleanup (CUW) System, the Fuel Pool Cooling and Cleanup System, the Suppression Pool Cleanup System, the Condensate Polishing System, and the Radwaste System itself. Wastes from these systems will consist of spent resin, concentrator bottoms and backwash slurries.

The Solid Waste System also provides a means of:

(1) Incinerating and packaging combustible dry radioactive materials, such as paper, rags, contaminated clothing, gloves, and shoe coverings

(2) Compacting and packaging non-combustible and compressible materials, such as HVAC filters and non-flammable organic materials

(3) Packaging contaminated metallic materials and incompressible solid objects such as small tools and equipment components

The Solid Waste System is designed so that the failure or maintenance of any frequently used component does not impair system or plant operation. Storage is provided ahead of the process equipment to allow holdup for radioactive decay and as required in case of a delay in processing due to maintenance.

Drum capping and sample retrieval are performed locally. The operating philosophy of the solid radwaste control system is manual start and automatic stop with all functions interlocked to provide a fail-safe mode of Solid Waste System operation.

11.4.1.2 Design Criteria

Collection, solidification incineration, packaging, and storage of radioactive wastes will be performed to maintain any potential radiation exposure to plant personnel as low as is reasonably achievable (ALARA) in accordance with Regulatory Guide 8.8 and within the limits of 10CFR20.

Proportional amounts of wastes and fixative are incorporated into the solid radwaste matrix to assure that no free water accumulates in the waste container in compliance with the Branch Technical Position ETSB 11-3.

Packaging and transporting radioactive wastes will be in conformance with 10CFR61. Packaged wastes will be shipped in conformance with 49CFR173, Subpart I, limits. Sufficient onsite storage is provided to hold at least six months production of radwaste. The radiation monitoring of the solid product generated for shipment offsite (GDC 64) is accomplished by providing monitoring devices at the solids container so that, as the container is filled, the waste accumulation is measured to prevent the container from exceeding acceptable radiation levels.

Other criteria that are also applicable to the solid waste portion of the Radwaste System have been discussed previously in Section 11.2.1.2.

11.4.2 System Description

11.4.2.1 General Description

The major Solid Waste System equipment consists of the following:

(1) Thin-film dryer

(2) A waste supply tank and a waste supply pump

(3) A moisture separator, a condenser and a vent blower

(4) A pelletizer

(5) A powder hopper and a binder measuring hopper

(6) A pellet filling machine

(7) A particle filter, HEPA filter and a filter blower

(8) A mixing tank

(9) A solidification agent measuring hopper and an additive water tank

(10) A drum conveyor assembly

(11) A capping machine

(12) A cleaning water tank and a cleaning water pump

(13) A cleaning water receiving tank and a decant pump

(14) An incinerator

(15) Primary and secondary ceramic filters

(16) A HEPA filter

(17) A dry active waste compactor

(18) Connections and auxiliaries for mobile systems

Some of the above components may be changed if a solidification agent other than cement-glass is used.

See Table 11.4-2 for an estimate of expected annual "dry" solid wastes and curie content.

These storage tanks are sized to meet the storage requirements of BTP ETSB 11.3, Part B.III.

Four weight elements are installed to monitor the amount of waste in the container. Standard 208 liter drums are used in this system. Additionally, the pellet-filling machine and a solidification paste pouring station provides a tight fit over the only opening in the solids container so that splashing is essentially precluded. Pellet filling operations are controlled by interlock with the weight sensors. Solidification agent pouring operations are controlled by interlock with the level sensors.

The following design features identified under "Additional Design Features" in BTP ETSB 11.3, Part B.V. are incorporated into the Solid Waste System:

(1) All evaporator concentrate piping and tanks are heat traced to prevent the concentrates from solidifying.

(2) All components and piping which contain slurries have flushing connections.

(3) The storage facilities for solidification agents are in low radiation areas, generally less than 25 μGy/hr, and have provisions for sampling.

(4) All tanks and equipment which use compressed gases for transport or drying of resins or filter sludges are vented to the plant ventilation exhaust system. The vents are designed to prevent liquids and solids from entering the plant ventilation system.

11.4.2.2 System Operation

11.4.2.2.1 General Requirements

The solid waste management system processes both wet and dry solid wastes in compliance with the following:

(1) The releases of radioactive materials to an unrestricted area are within the concentration limits of 10CFR20, Appendix B, Table II. All solid wastes are monitored for radiation before either processing or disposal as nonradioactive waste. It is expected that some dry solid waste will be disposable as nonradioactive. All liquids and gases from solid waste processing are treated by the liquid waste system or by the Radwaste Building ventilation system.

(2) The Solid Waste System has sufficient storage of both unprocessed and processed wastes to deal with both normal and anticipated operational occurrences. These storage facilities have been designed with adequate shielding to protect the operators from excessive radiation.

Wastes will be solidified separately by type and source.

11.4.2.2.2 Spent Resins and Sludges

The wastes are spent resins, sludges from powdered resins and filter backwashing and concentrated liquids from the evaporators. The spent resins and sludges may be treated either by sending them to the thin film dryer for evaporation or they can be sent to vendor-supplied mobile dewatering systems. The concentrated liquids from the evaporators are sent to the thin film dryer.

See Table 11.4-1 for “Expected Waste Volumes Generated Annually by Each “Wet” Solid Waste Source and Tank Capacities”.

To process the wastes, the operator assures that he has pellets and solidification agents. An empty drum is placed on the drum conveyor. Position switches acknowledge the correct placement of the drums under the pellet-filling station and the solidification paste pouring station so that perfect mating is accomplished to avoid spillage while filling and pouring.

To prevent overfilling the drums, weight elements are placed at the pellet-filling station and a level sensor is placed at the solidification paste pouring station. Additionally, radiation monitors are positioned at the end of drum conveyors so that the radiation resulting from mixture in the drums and surface contamination of the drums may be monitored.

11.4.2.2.3 Dry Active Waste (DAW)

The combustible dry wastes are burned by the incinerator and periodically discharged to an ash storage drum. The incombustible and compressible dry wastes in drums are reduced in volume by using a compactor.

The DAW drums are individually handled with no solidification agent added and can be shipped for burial either separately or with other drums containing solidified liquid wastes, as required to meet shipping limitations.

11.4.2.2.4 Environmental and Exposure Control

During the operation of the wet waste solidification equipment, incinerator, and compactor, the individual component vent systems assure that dust or contaminated air are not released to the work spaces.

11.4.2.2.5 Malfunction Analysis

The process system is protected from component failure and operator error through a series of safety interlocks. These assure that the system will operate to solidify waste only if all of the following conditions are met:

(1) A waste container is in place.

(2) The mix/fill assembly is covering the container.

(3) The container is not full.

(4) The container is not overweight.

(5) One source of waste is available.

(6) An adequate supply of solidification agent is available and the mixer is operable.

Failure to meet any of the above conditions will stop the operation in progress. Interruption may occur at any phase and the process is designed so that restart may occur without adverse consequences. Restart may be undertaken at the same point in the process after the failed condition has been remedied.

11.4.2.2.6 Shipment

Containers normally can be shipped immediately after solidification, provided the proper shielding is available, without exceeding U.S. Department of Transportation radiation limits. If 49CFR173 dose limitations cannot be met, the containers are stored until the appropriate shielding is available.

Normally, high integrity containers will be shipped promptly after they are filled. If shipment is not prompt, the high integrity containers will be stored with shielding in the truck area shown in Figure 1.2-23c.

A barrier to restrict access shall be placed around the shielding. The radiation dose rate at the barrier shall be 50 MGy/yr or less.

There are three additional storage areas for radioactive waste awaiting shipment. These wastes will be stored either in drums or boxes. There is space for six drums in the filled drum stock area (FDSA) (Figure 1.2-23c). Also, there is space for drums in the MSW rooms. Finally, there is space for either boxes or pallets in the solid waste storage area (SWSA) (Figure 1.2-23b).

All contaminated shipping containers and vehicles used for solid waste handling will be stored in the Radwaste Building. Uncontaminated shipping containers and vehicles may be stored outside. The expected annual volumes of solid radwaste to be shipped offsite are estimated in Table 11.4-3.

11.4.3 COL License Information

11.4.3.1 Plant-Specific Solid Radwaste Information

The COL applicant shall provide the following which apply on a plant-specific basis:

(1) A description of the incinerator complete with the source of incinerator heat, heat source storage facility and specific fire protection features to prevent any undue fire hazard shall be provided.

(2) Demonstration that the wet waste solidification process and the spent resin and sludge dewatering process will result in products that comply with 10CFR61.56 shall be provided.

(3) Establishment and implementation of a process control program (PCP) for solidifying the evaporator concentrates, using an approved solidification agent, and the dewatering processing of the spent resins and filter sludges shall be provided.

(4) A discussion of onsite storage of low-level waste beyond that discussed in Tier 2 shall be provided.

(5) Demonstration that all radioactive waste shipping packages meet the requirements in 10CFR71 shall be provided.

(6) Based on the as-built design, establish set points for the liquid discharge radiation monitor.

Table 11.4-1 Expected Waste Volume Generated Annually by Each “Wet” Solid Waste Source and Tank Capacities

Wet Waste Source	Volume Generated(m^3/yr)	Specific Activity (MBq/g)
CUW F/D sludge	4.7	2.72E+03
FPC F/C sludge	1.8	7.18E+01
Condensate Filter sludge	4.6	8.88E+00
LCW Filter sludge	0.2	5.55E+01
Condensate Demineralizer resin	18.0	2.11E+00
LCW Demineralizer resin	5.0	4.37E+00
HCW Demineralizer resin	2.7	3.11E-04
Concentrated Liquid Waste	27.4	1.73E-01

The first four items in the table above are stored in either of two CUW phase separators which have a capacity of 4m^3 each. During a normal period these four wastes are generated at a rate of about 2m^3 in 60 days.
The waste resins are stored in the spent resin tank which has a capacity of 50m^3. During a normal period spent resin is generated at a rate of about 2m^3 in 30 days.
The concentrated liquid wastes are stored in two storage tanks which have a capacity of 16m^3 each. Thus, at lease six months storage capacity is provided.
Thus, the storage requirements in BTP ETSB 11.3, Part B.III.1 are met.

Table 11.4-2 Estimate of Expected Annual “Dry” Solid Wastes and Becquerel Content

Dry Waste Source	Volume Generated(m^3/yr)	Total Megabecquerels
Combustible waste	225	5.92E+04
Compactible waste	38	1.11E+04
Other waste	100	2.59E+05

Table 11.4-3 Calculated Shipped Solid Waste Volumes and Becquerel Count

Waste Type	Shipped Volume Cubic Meters/Year	Total Megabecquerels
Concentrated Waste	4.4	4.81E+04
Combustible Waste	5.6	5.92E+04
Compressible Waste	15	1.11E+04
Resins and Sludges	40	2.48E+07
Other Waste	100	2.59E+05

11.5 Process and Effluent Radiological Monitoring and Sampling Systems

The Process and Effluent Radiological Monitoring and Sampling Systems are provided to allow determination of the content of radioactive material in various gaseous and liquid process and effluent streams. The design objective and criteria are based on the following requirements:

(1) Radiation instrumentation required for safety and protection.

(2) Radiation instrumentation required for monitor and plant operation.

All critical radioactive release points/paths within the plant are indentified and monitored by this system. All other release points/paths of the plant are located in clean areas where radiological monitoring is not required.

This system provides continuous monitoring and display of the radiation measurements during normal, abnormal and accident conditions. Most measurements are continuously logged in by the process computer and recorded.

For gaseous discharge from the SGTS and from the main plant stack, extended range effluent monitors are provided to measure post-accident levels of noble gases. Additionally, these subsystems have filters that are capable of extracting high levels of radioactive iodines and particulates in the gaseous effluent streams during and following and accident.

Refer to Subsection 11.5.6 for COL license information.

11.5.1 Design Bases

11.5.1.1 Design Objectives

11.5.1.1.1 Radiation Monitors Required for Safety and Protection

The main objective of this radiation monitoring is to initiate appropriate protective action to limit the potential release of radioactive materials from the reactor vessel and primary and secondary containment if predetermined radiation levels are exceeded in major process/effluent streams. Another objective is to provide control room personnel with an indication of the radiation levels in the major process/effluent streams plus alarm annunciation if high radiation levels are detected.

The Process Radiation Monitoring System provides the following design objectives:

(1) Main steamline tunnel area radiation monitoring

(2) Reactor building heating, ventilating, and air conditioning (HVAC) exhaust air radiation monitoring

(3) Fuel handling area HVAC exhaust air radiation monitoring

(4) Control building HVAC air intake supply radiation monitoring

(5) Drywell sump discharge radiation monitoring

11.5.1.1.2 Radiation Monitors Required for Plant Operation

The main objective of this radiation monitoring is to provide operating personnel with measurements of the content of radioactive material in all effluent and important process streams. This demonstrates compliance with plant normal operational technical specifications by providing gross radiation level monitoring and by collection of halogens and particulates on filters (gaseous effluents) as required by Regulatory Guide 1.21. Additional objectives are to initiate discharge valve isolation on the offgas or liquid radwaste systems if predetermined release rates are exceeded, and to provide for sampling at certain radiation monitor locations to allow determination of specific radionuclide content.

The Process Radiation Monitoring System also provides the following design objectives:

(1) Monitors Gaseous Effluent Streams

  (a) Plant stack discharge

  (b) Turbine Building ventilation exhaust

  (c) Radwaste Building ventilation exhaust

  (d) Turbine gland seal condenser exhaust

  (e) Standby gas treatment offgas discharge

  (f) Incinerator stack discharge

(2) Monitors Liquid Effluent Streams

  (a) Radwaste liquid discharge

(3) Monitors Gaseous Process Streams

  (a) Offgas pre-treatment sampling

  (b) Offgas post-treatment sampling

  (c) Charcoal vault ventilation exhaust

(4) Monitors Liquid Process Streams

(a) Reactor Building closed cooling water intersystem radiation leakage

11.5.1.2 Design Criteria

Design criteria of this system are based on meeting the relevant requirements of General Design Criteria (GDC) 19, 60, 63, and 64 of 10CFR50 Appendix A in accordance with SRP 11.5 of NUREG-0800. These GDCs are in addition to those GDCs specified in Subsection 7.6.2.2 for system instrumentation.

Also, the system is designed to meet the applicable provisions of 10CFR20.1302, RG 1.21 and RG 1.97 and TMI NUREG-0737, Item II.F.1, Attachments 1 and 2.

The safety-related process radiation monitoring subsystems are classified Safety Class 2, Seismic Category I. These subsystems conform to the quality assurance requirements of 10CFR50 Appendix B.

11.5.1.2.1 Radiation Monitors Required for Safety

The design criteria for the safety-related monitors include the following functional requirements:

(1) Withstand the effect of natural phenomena (e.g., earthquakes) without loss of capability to perform their functions.

(2) Perform the intended safety functions in the environment resulting from normal and abnormal conditions (e.g., loss of HVAC and isolation events).

(3) Meet the reliability, testability, independence, and failure mode requirements of engineered safety features.

(4) Provide continuous output of radiation levels in the main control room.

(5) Permit checking of the operational availability of each channel during reactor operation with provisions for calibration function and instrument checks.

(6) Assure an extremely high probability of accomplishing safety functions in the event of anticipated operational occurrences.

(7) Initiate protective action when operational limits are exceeded.

(8) Warn and annunciate the high radiation levels indicative of abnormal conditions.

(9) Insofar as practical, provide self-monitoring of components to the extent that power failure or component malfunction causes annunciation and channel trip.

(10) Register full-scale output if radiation detection exceeds full scale.

(11) Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions (RG 1.97).

(12) Each safety-related monitoring channel is powered from its respective Class 1E power source.

11.5.1.2.2 Radiation Monitors Required for Plant Operation

The design criteria for operational radiation monitoring shall include the following functional requirements:

(1) Provide continuous indication of radiation levels in the main control room.

(2) Warn and annunciate the high radiation levels indicative of abnormal conditions.

(3) Insofar as practical, provide self-monitoring of components to the extent that power failure or component malfunction causes annunciation and discharge valve isolation channel trip.

(4) Monitor a sample representative of the bulk stream or volume.

(5) Incorporate provisions for calibration and functional checks.

(6) Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions (RG 1.97).

(7) Register full-scale output if radiation detection exceeds full scale.

The radiation subsystem that monitors liquid discharges from the radwaste treatment system shall have provisions to alarm and initiate automatic closure of the waste discharge valve on the affected treatment system prior to exceeding the normal operation limits specified in technical specifications as required by Regulatory Guide 1.21.

11.5.2 System Description

11.5.2.1 Radiation Monitors Required for Safety

Information on these monitors is presented in Table 11.5-1 and the arrangements are shown in Subsection 7.6.1.2. Each potential radioactive path/stream is monitored by an independent PRM subsystem.

11.5.2.1.1 Main Steamline (MSL) Radiation Monitoring

This subsystem monitors the gamma radiation level of the steam transported by the main steamlines in the MSL tunnel. The normal radiation level is produced primarily by coolant activation gases plus smaller quantities of fission gases being transported with the steam. In the event of a gross release of fission products from the core, the monitoring channels provide trip signals to the Leak Detection and Isolation System.

The MSL radiation monitors consist of four redundant instrument channels. Each channel consists of a local detector (ion chamber) and a control room radiation monitor. Power for channels A, B, C, and D monitors is supplied from vital 120 VAC divisions 1, 2, 3 and 4, respectively. All four channels are physically and electrically independent of each other.

The detectors are physically located near the main steamlines (MSL) just downstream of the outboard MSIVs in the steam tunnel. The detectors are geometrically arranged and are capable of detecting significant increases in radiation level with any number of main steamlines in operation. Table 11.5-1 lists the location and range of the detectors.

Each radiation monitor has four trip circuits: two upscale (high-high and high), one downscale (low), and one inoperative. Each trip is visually displayed on the affected radiation monitor. A high-high or inoperative trip in the radiation monitor results in a channel trip which is provided to the Reactor Protection System (RPS) and to the Leak Detection and Isolation System (LDS). Any two-out-of-four channel trip results in initiation of MSIV closure, reactor scram, main condenser mechanical vacuum pump (MVP) shutdown, and MVP line discharge valve closure. High and low trips do not result in a channel trip. Each radiation monitor displays the measured radiation level in mGy/h. All channel trips are annunciated in the main control room.

11.5.2.1.2 Reactor Building HVAC Radiation Monitoring

This subsystem monitors the radiation level in the secondary containment of the Reactor Building ventilation system exhaust duct. A high activity level in the ductwork could be due to fission gases from a leak or an accident.

The system consists of four redundant instrument channels. Each channel consists of a digital gamma-sensitive GM detector and a control room radiation monitor. Power is supplied to channels A, B, C, and D monitors from vital 120 VAC Divisions 1, 2, 3 and

4, respectively. A two-pen recorder powered from the 120 VAC instrument bus allows the output of any two channels to be recorded by the use of selection switches.

The detectors are located adjacent to the exhaust ducting upstream of the ventilating system isolation valves and monitor the HVAC vent exhausts from the primary containment during purging and from the secondary containment. These detectors have sufficient sensitivity to detect high radiation levels during primary containment purge to alert the operator for corrective action and to initiate the appropriate measures.

Each radiation monitor has four trip circuits: two upscale, one downscale and one inoperative similar to MSL radiation monitors.

A high-high, inoperative or a downscale trip in the radiation monitor results in a channel trip which is provided to LDS. Any two-out-of-four channel trips will result in the initiation by LDS of the Standby Gas Treatment System (SGTS) and in the isolation of the secondary containment (including closure of the containment purge and vent valves and closure of the Reactor Building ventilating exhaust isolation valves).

All trip circuits will initiate their respective alarms in the main control room.

A downscale or an inoperative trip is displayed on the radiation monitor and actuates a control room annunciator common to all four channels.

Each radiation monitor will display the measured radiation level in mGy/h.

11.5.2.1.3 Fuel Handling Area Ventilation Exhaust Radiation

This subsystem monitors the radiation level in the fuel handling area ventilation exhaust duct. The system consists of four channels which are physically and electrically independent of each other. Each channel consists of a digital gamma-sensitive GM detector and a control room radiation monitor. Power for channels A, B, C, and D is supplied from the vital 120 VAC Divisions 1, 2, 3 and 4, respectively.

Each radiation monitor has four trip circuits: two upscale, one downscale and one inoperative similar to the MSL radiation monitors. This subsystem performs the same trip functions as those described in Subsection 11.5.2.1.2 for the Reactor Building HVAC exhaust radiation monitoring.

11.5.2.1.4 Control Building HVAC Radiation Monitoring

The Control Building HVAC Radiation Monitoring Subsystem is provided to detect the radiation level in the normal outdoor air supply, automatically closes the outdoor air intake and the exhaust dampers, and initiates automatically the emergency air filtration system. The emergency air filtration system fans shall be started and area exhaust fans stopped on high radiation.

The Control Building HVAC consists of two redundant but independent subsystems.

The radiation monitors for each of the control building HVAC subsystems consist of four redundant channels to monitor the air intake to the building. Each radiation monitor is physically separated and powered from separate vital 120 VAC divisional power. Failure of one channel will not cause isolation of the HVAC System.

The monitors meet the requirements for Class 1E components to provide appropriate reliability. The system will warn of the presence of significant air contamination in inlet air, from any source, and will provide isolation of intake air ducts from accident radiation sources escaping from other plant buildings.

Each radiation channel consists of a digital gamma-sensitive GM detector and a radiation monitor which is located in the control room.

Each radiation monitor has four trip circuits: two upscale, one inoperative and one downscale. All trips are displayed on the appropriate radiation monitor and each actuates a control room annunciator.

11.5.2.1.5 Drywell Sumps Discharge Radiation Monitoring

This subsystem monitors the radiation level in the liquid waste transferred in the drain line from the drywell LCW and HCW sumps to the Radwaste System. One monitoring channel is provided in each sump drain line. Each channel uses an ionization chamber which is located on the drain line from the sump just downstream from the outboard isolation valve. The output from each sensor is fed to a radiation monitor in the control room for display, recording and annunciation.

The radiation monitor provides three trip circuits: two upscale (radiation high-high and high), one downscale/inoperative. The high-high signal is used to close the outboard isolation valve in its respective drain line. All trips are annunciated in the main control room.

11.5.2.2 Radiation Monitors Required for Plant Operation

Each radioactive path/stream is monitored by an independent PRM subsystem.

Information on these monitors is presented in Table 11.5-1

11.5.2.2.1 Offgas Pre-Treatment Radiation Monitoring

This subsystem monitors radioactivity in the condenser offgas at the discharge of the delay pipe after it has passed through the offgas condenser and moisture separator. The monitor detects the radiation level which is attributable to the fission gases produced in the reactor and transported with stream though the turbine to the condenser.

A continuous sample is extracted from the offgas pipe via a stainless steel sample line. It is then passed through a sample chamber and a sample panel before being returned to the suction side of the steam jet air ejector (SJAE). The sample chamber is a stainless steel pipe which is internally polished to minimize plateout. It can be purged with room air to check detector response to background radiation by using a three-way solenoid-operated valve. The valve is controlled by a switch located in the main control room. The sample panel measures and indicates sample line flow. A digital gamma-sensitive GM detector is positioned adjacent to the vertical sample chamber and is connected to radiation monitors in the main control room.

Power is supplied from 120 VAC vital non-1E bus for the radiation monitor and from the 120 VAC instrument bus for the local sample and vital sampler panel.

The radiation monitor has four trip circuits: two upscale (high-high and high), one downscale and one inoperative.

The trip outputs are used for alarm function only. Each trip is visually displayed on the radiation monitor and actuates a control room annunciator: offgas high-high, offgas high, and offgas downscale/inoperative. High or low sample line flow measured at the sample panel actuates a main control room offgas sample high-low flow annunciator.

The radiation level output level by the monitor can be directly correlated to the concentration of the noble gases by using a semiautomatic vital sampler to obtain a grab sample. To draw a sample, a serum bottle is inserted into a sampler holder, the sample lines are evacuated, and a solenoid-operated sample valve is opened to allow offgas to enter the bottle. The bottle is then removed and the sample is analyzed in the counting room with a multichannel gamma pulse height analyzer to determine the concentration of the various noble gas radionuclides. A correlation between the observed activity and the monitor reading permits calibration of the monitor.

11.5.2.2.2 Offgas Post-Treatment Radiation Monitoring

This subsystem monitors radioactivity in the offgas piping downstream of the offgas system charcoal adsorbers and upstream of the offgas system discharge valve. A continuous sample is extracted from the Offgas System piping, passed through the offgas post-treatment sample panel for monitoring and sampling, and returned to the Offgas System piping. The sample panel has a pair of filters (one for particulate collection and one for halogen collection) in parallel (with respect to flow) with two identical GM detectors. Two radiation monitors in the main control room analyze and visually display the measured gross radiation level.

The sample panel shielded chambers can be purged with room air to check detector response to background radiation by using solenoid valves operated from the control room. The sample panel measures and indicates sample line flow. A remotely-operated check source for each detector assembly is used to check operability of the gross radiation channel.

Power is supplied from a 120 VAC vital non-1E bus to the radiation monitors and to the local sample panel. A 120 VAC local bus supplies the vital sample to panel.

Each radiation monitor has trip circuits that indicate high-high-high, high-high, high, and downscale/inoperative. Each trip is visually displayed on the radiation monitor. The trips actuate corresponding main control room annunciators: offgas post-treatment high-high-high radiation, offgas post-treatment high-high radiation, and offgas post-treatment high and downscale/inoperative monitor.

High or low flow measured at the sample panel actuates an annunciator in the control room to indicate abnormal flow.

The high-high-high and downscale trip/inoperative outputs initiate closure of the offgas system discharge and bypass valves. The high-high-high trip setpoint is determined so that valve closure is initiated prior to exceeding technical specification limit. Any one high-high channel trip initiates alignment of the Offgas System flow valves to achieve treatment through the charcoal vault.

A vial sampler panel similar to the pre-treatment sampler panel is provided for grab sample collection to allow isotopic analysis and gross monitor calibration.

11.5.2.2.3 Charcoal Vault Radiation Monitoring

The charcoal vault is monitored for gross gamma radiation level with a single instrument channel. The channel includes a digital sensor and converter, and a radiation monitor. The sensor is located outside the vault on the HVAC exhaust line from the vault. The radiation monitor is located in the main control room. The channel provides for sensing and readout of gross gamma radiation over a range of six logarithmic decades (0.01 to 10^4 mGy/h).

The monitor has one adjustable upscale trip circuit for alarm and one downscale trip for instrument trouble. Power to the monitor is supplied from 120 VAC vital non-1E bus.

11.5.2.2.4 Plant Stack Discharge Radiation Monitoring

This subsystem monitors the stack discharge for gross radiation level during normal plant operation and collects halogen and particulate samples for laboratory analysis.

The discharge through this common plant vent includes HVAC exhausts* from the secondary containment, turbine building, radwaste building, and service building controlled area. Also, this system utilizes a high-range radiation monitor that measures fission products in plant gaseous effluents during and following an accident.

A representative sample is continuously extracted from the ventilation ducting through an isokinetic probe in accordance with ANSI N13.1 and passed through the stack ventilation sample panels for monitoring and sampling, and returned to the ventilation ducting. Each sample panel has a pair of filters (one for particulate collection and one for halogen collection) in parallel (with respect to flow) for continuous gaseous radiation sampling. The radiation detector assembly consists of a shielded gas chamber that houses a scintillation detector and a check source. The extended range detector assembly consists of an ionization chamber which measures radiation levels up to 3700 MBq/cm^3. A radiation monitor in the main control room analyzes and visually displays the measured radiation level. These sensors are qualified to operate under accident conditions.

The gas shielded chambers can be purged with room air from the control room. The gas chamber is equipped with a check source to test detector response to background radiation, thus checking operability of the radiation channel.

Power is supplied from 120 VAC vital non-1E bus for the radiation monitor and for the sample panel.

The radiation monitor initiates trips for alarm indications on high-high, high, and low radiation from each detector assembly. Also, the sampled line is monitored for high or low flow indications and alarming.

Table 11.5-2 presents the gaseous and airborne monitors for the Effluent Radiation Monitoring System.

* The Reactor Building essential electrical HVAC, diesel generator HVAC, main control room habitability HVAC, service building clean area exhaust, and the electrical building ventilation systems contain no radioactive systems. The only releases to the environs by these systems would first have to be brought into the buildings by their own supply fans. Hence, monitoring of these exhausts are not required or provided.

The control building essential electrical HVAC contain no radioactive system except for the reactor building cooling water system. The reactor building cooling water system is considered a clean system with monitoring to alarm at a radiation level above background from potential leakage sources. Such contamination would require dumping of the cooling water to radwaste and replacing the dumped water with clean water therefore maintaining the cleanliness of the system. In addition the system operates at temperatures below 35°C. At this temperature, potential for airborne contamination is negligible and any releases other than a vanishingly small fraction of 10CFR20 concentration limits are not expected.

11.5.2.2.5 Radwaste Liquid Discharge Radiation Monitoring

This subsystem continuously monitors the radioactivity in the radwaste liquid during its discharge to the environment and stops the discharge on high radiation level.

Liquid waste can be discharged from the sample tanks containing liquids that have been processed through one or more treatment systems such as evaporation, filtration, and ion exchange. During the discharge, the liquid is extracted from the liquid drain treatment process pipe, passed through a liquid sample panel which contains a detection assembly for gross radiation monitoring, and returned to the process pipe. The detection assembly consists of a scintillation detector mounted in a shielded sample chamber equipped with a check source. A radiation monitor in the control room analyzes and visually displays the measured gross radiation level.

The sample panel chamber and lines can be drained to allow assessment of background buildup. The panel measures and indicates sample line flow. A check source operated from the control room can be used to check operability of the channel.

Based on acceptable radiation levels, discharge is permitted at a specified release rate and dilution rate.

The radiation monitor has three trip circuits: Two upscale trips (high-high and high), and one downscale/inoperative trip. The high-high upscale trip and the downscale/inoperative trip are used to stop the discharge to the environment. Also, the two upscale trips and the low downscale/inoperative trip actuate annunciators in the main control room and in the Radwaste Building control room. Table 11.5-3 describes the liquid monitors used for process radiation monitoring.

11.5.2.2.6 Reactor Building Cooling Water Radiation Monitoring

This subsystem consists of three channels: one for each RCW A, B and C loop for monitoring intersystem radiation leakage into the Reactor Building Cooling Water System.

Each channel consists of a scintillation detector which is located in a well near the RCW heat exchanger exit pipe. Radiation detected from the three channels is multiplexed and fed into a common radiation monitor. This monitor provides individual channel trips on high radiation level and downscale/inoperative indication for annunciation in the control room. Power to the monitors is provided from the non-1E vital 120 VAC source.

11.5.2.2.7 Radwaste Building Ventilation Exhaust Monitoring

This subsystem monitors the Radwaste Building ventilation discharge to the stack, including the radwaste storage tank vents, for gross radiation. The single instrument channel consists of a local detector and a control room digital radiation monitor. Power is supplied to the channel by the 120 VAC vital non-1E bus.

The radiation monitor provides two trip circuits: one for upscale (high) radiation and one for downscale/inoperative trip.

The trip signals are annunciated in the Radwaste Building control room and in the main control room.

A remotely-operated gamma check source is provided for testing channel operability.

11.5.2.2.8 Turbine Building Ventilation Exhaust Monitoring

This subsystem monitors the vent discharge in the Turbine Building for gross radiation levels. This includes the discharge from the mechanical vacuum pump. The monitoring is provided by four channels (two redundant sets). Two redundant channels monitor radiation in the compartment area air exhaust duct and the other two redundant channels monitor the radiation in the ventilation system air exhaust from the clean area. Each channel uses a digital detector located adjacent to the monitored exhaust duct. The outputs from each set of detectors are multiplexed and then fed into two separate radiation monitors for display, recording and annunciation. Each monitor provides alarm trips on radiation high and on radiation low (downscale/inoperative).

11.5.2.2.9 Turbine Gland Seal Condenser Exhaust Discharge Monitoring

This subsystem monitors the offgas releases to the stack from the turbine gland seal system. The offgas releases are continuously sampled and monitored for noble gases by a scintillation detector. The output signal is multiplexed and then fed to a shared radiation monitor in the main control for display, recording and annunciation. This monitor provides two trip alarms, one on radiation high and one on radiation low (downscale/inoperative).

A grab sample of the offgas is provided for laboratory analysis. Also, samples of halogens and particulates are collected on filters for periodic analysis.

A remotely operated gamma check source is provided for testing channel operability.

11.5.2.2.10 Standby Gas Treatment System Radiation Monitoring

This subsystem monitors the offgas radiation level in the SGTS exhaust duct to the stack using four channels.

Two ionization chamber detectors are physically located downstream of the exhaust fans on the exhaust duct to the stack and are utilized to monitor the high levels of radioactivity expected under accident conditions. Two other scintillation detectors are used during offgas sampling of the gas exhaust to the stack to monitor the normal level of radioactivity expected during normal plant operation.

The sensors are qualified to operate under accident conditions at the installed location.

The subsystem consists of four instrumented channels. Each channel consists of a detector and a main control room radiation monitor.

Power for the channels is supplied from the non-Class 1E vital 120 VAC source.

Each radiation monitor has four trip circuits: two upscale, one inoperative and one downscale. All trips are displayed on the appropriate radiation monitor and each actuates a main control room annunciator for high-high, high and low/inoperative indications.

11.5.2.2.11 Incinerator Stack Discharge Radiation Monitoring

This subsystem monitors the radioactivity in the discharge from the incinerator stack during burning of low radioactive waste. A representative sample from the discharge path is drawn through an isokinetic probe and routed to a local sample panel in the Radwaste Building for monitoring and particle collection. The sample panel houses the radiation detector assembly, a pair of filters for collection of airborne particulates and halogens, the vacuum pumps and associated plumbing, and a gamma check source for testing operability of the radiation channel. Also, the sample panel includes provisions for purging from the Radwaste Building control room.

The local sample panel and the radiation monitor are powered from 120 VAC instrument power.

The radiation monitor initiates trips on high and high-high levels and on downscale/inoperative indication. These trips are alarmed in the Radwaste Building control room. On high-high trip, the incinerator exhaust fans are shutdown to terminate any further discharge from the stack.

11.5.3 Effluent Monitoring and Sampling

All potentially radioactive effluent materials are monitored for radioactivity releases in accordance with GDC 64 as follows:

(1) Liquid releases are monitored for gross gamma radioactivity.

(2) Gaseous releases are monitored for gross gamma radioactivity.

11.5.3.1 Basis for Monitor Location Selection

The detector locations are selected per Regulatory Guide 1.21 to monitor all the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences. Monitoring of each major path provides measurements that are representative of effluent releases to demonstrate compliance with 10CFR20 limits and/or the technical specifications limits.

11.5.3.2 Expected Radiation Levels

Expected radiation levels are within the ranges specified in Tables 11.5-2 and 11.5-3.

11.5.3.3 Instrumentation

The radiation detectors used to measure radioactivity are listed in Table 11.5-1.

Grab samples are analyzed to identify and quantify the specific radionuclides in effluents and wastes. The results from the sample analysis are used to establish relationships between the gross gamma monitor readings and concentrations or release rates of radionuclides in continuous effluent releases.

11.5.3.4 Setpoints

The trip setpoints that initiate automatic isolation functions are specified in the plant Technical Specifications as indicated in Table 11.5-1.

11.5.4 Process Monitoring and Sampling

11.5.4.1 Implementation of General Design Criterion 19

The control building is provided with radiation monitors that will detect radiation in the intake air supply to the control building and provide warning and adequate radiation protection to operating personnel to permit access and occupancy of the control room under accident conditions.

11.5.4.2 Implementation of General Design Criterion 60

All potentially significant radioactive discharge paths are equipped with a control system to automatically isolate the discharge on indication of a high radiation level. These include:

(1) Offgas post-treatment

(2) Reactor Building HVAC air exhaust

(3) Fuel handling area ventilation exhaust

(4) Drywell sump liquid waste discharge

(5) Radwaste liquid discharge

11.5.4.3 Implementation of General Design Criterion 64

Radiation levels in radioactive and potentially radioactive process streams are monitored for radioactivity releases. These include:

(1) Main steamline

(2) Offgas pre-treatment and post-treatment

(3) Carbon vault vent

(4) Intersystem leakage into Reactor Building cooling water

(5) Incinerator stack discharge

11.5.4.4 Basis for Monitor Location Selection

The detector locations are selected per Regulatory Guide 1.21 to monitor all the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences. Monitoring of each major path provides measurements that are representative of releases to demonstrate compliance with 10CFR20 limits and/or the technical specification limits.

11.5.4.5 Expected Radiation Levels

Expected radiation levels are listed in Tables 11.5-2 and 11.5-3.

11.5.4.6 Instrumentation

The radiation detectors used to measure radioactivity are listed in Table 11.5-1.

Grab samples are analyzed to identify and quantify the specific radionuclides in process streams. The results from the sample analysis are used to establish relationships between the gross gamma monitor readings and concentration and radionuclides in the process streams.

11.5.4.7 Setpoints

The radiation trip setpoints for the various monitors are listed in Table 11.5-1.

11.5.5 Calibration and Maintenance

11.5.5.1 Inspection and Tests

During reactor operation, daily checks of system operability are made by observing channel behavior. At periodic intervals during reactor operation, the detector response of each monitor provided with a remotely positioned check source will be recorded, together with the instrument background count rate, to ensure proper functioning of the monitors. Any detector whose response cannot be verified by observation during normal operation or by using the remotely positioned check source will have its response checked with a portable radiation source. A record will be maintained showing the background radiation level and the detector response.

The system incorporates self diagnostics and online calibration for its process radiation monitors that operate continuously to assure maximum availability and minimum down time. Also, each radiation channel is tested and calibrated periodically using a standard radiation source to validate channel operability.

The following monitors have alarm trip circuits which can be tested by using test signals or portable gamma sources:

(1) Main steamline

(2) Reactor Building vent exhaust

(3) Fuel handling area vent exhaust

(4) Control building air intake supply

(5) Reactor Building cooling water intersystem leakage

(6) SGTS offgas discharge

(7) Turbine Building ventilation exhaust

(8) Offgas pre-treatment

(9) Carbon vault vent exhaust

The following monitors include built-in check sources and purge systems which can be operated from the main control room:

(1) Offgas post-treatment

(2) Plant stack discharge

(3) Liquid waste discharge

(4) SGTS offgas discharge

(5) Radwaste building vent exhaust

(6) Gland seal condenser exhaust

(7) Incinerator stack discharge

11.5.5.2 Calibration

Calibration of radiation monitors is performed using certified commercial radionuclide sources traceable to the National Institute of Standards and Technology. The overall reproducibility of calibration is limited to ±15%. The source-detector geometry during primary calibration will be mechanically precise enough to ensure that positioning errors of either instruments or radiation sources do not affect the calibration accuracy by more than ±3%. Each continuous monitor is calibrated during plant operation or during the refueling outage if the detector is not readily accessible. Calibration can also be performed on the applicable instrument by using liquid or gaseous radionuclide standards or by analyzing particulate iodine or gaseous grab samples with laboratory instruments.

The following monitors display the gross gamma signal in counts/min:

(1) Offgas post-treatment

(2) Plant stack discharge (low to normal levels)

(3) Radwaste liquid discharge

(4) SGTS offgas discharge (low to normal levels)

(5) Reactor Building cooling water intersystem leakage

(6) Radwaste Building ventilation exhaust

(7) Main turbine gland seal condenser offgas exhaust

(8) Incinerator stack discharge

The following monitors are calibrated to provide measurements of the gross gamma dose rate in mGy/h:

(1) Main steamline tunnel area

(2) Reactor Building ventilation exhaust

(3) Fuel handling area ventilation exhaust

(4) Charcoal vault vent exhaust

(5) Control Building air intake supply

(6) Turbine Building ventilation exhaust

(7) SGTS offgas discharge (high level)

(8) Offgas pre-treatment

(9) Drywell sump liquid discharge

(10) Plant stack discharge (high level)

11.5.5.3 Maintenance

All channel detectors, electronics, and recorders are serviced and maintained on an annual basis or in accordance with manufacturers' recommendations to ensure reliable operations. Such maintenance includes cleaning, lubrication and assurance of free movement of the recorder in addition to the replacement or adjustment of any components required after performing a test or calibration check. If any work is performed which would affect the calibration, a recalibration is performed at the completion of the work.

11.5.5.4 Audits and Verifications

Audits and verification during normal plant operation are out-of-scope for the Standard ABWR Plant.

11.5.6 COL License Information

11.5.6.1 Calculation of Radiation Release Rates

The COL applicant shall provide and describe in the operation and maintenance manual the procedures and/or methods for the conversion of the radiation measurements into release rates of gaseous discharge from the main plant stack. (Section 11.5)

11.5.6.2 Compliance with the Regulatory Shielding Design Basis

The COL applicant shall describe in the operation and maintenance manual the sampling system design of the SGTS and of the main stack effluent monitoring subsystems and show compliance with the regulatory shielding requirements for low radiation exposure under accident conditions as stipulated in NUREG-0737, Item II.F.1, clarification 2 of Attachment 2. The requirement for the shielding design will be covered in the equipment design specifications. (Section 11.5)

11.5.6.3 Provisions for Isokinetic Sampling

The COL applicant shall describe in the operation and maintenance manual the sampling technique used for monitoring and sampling of effluent gasses to assure that a representative gas sample is extracted and that the sampling system is capable of maintaining isokinetic conditions within 20% of the flow rate during and following as accident as stipulated in NUREG-0737, Item II.F.1, clarification 3 of Attachment 2. (Section11.5)

11.5.6.4 Sampling of Radioactive Iodines and Particulates

The COL applicant shall describe in the operation and maintenance manual the collection technique used to extract representative samples of radioactive iodines and particulates during and following an accident. These measurements are used to determine the quantitative releases for dose calculations and assessment (as stipulated in NUREG-0737, Table II.F.1-2). (Section 11.5)

11.5.6.5 Calibration Frequencies and techniques

The COL applicant shall provide in the operation and maintenance manual for the system the calibration frequencies and techniques for the radiation sensors. This information shall be based on vendor data for the equipment. (Section 11.5)

Table 11.5-1 Process and Effluent Radiation Monitoring Systems

Monitored Process	No. of Channels	Detector Type	Sample Line or Detector Location	Channel Range[*]	Setpoint: Warning Alarm	Setpoint: ACF Trip	Scale
A. Safety-Related Monitors							
Main steamline tunnel area	4	IC	Immediately downstream of plant main steamline isolation valve	10^{-2} to 10^{4} mGy/h	Above full power background, below trip	Technical Specification	6 dec. log
Reactor Building vent exhaust	4	S/C	Exhaust duct upstream of exhaust ventilation isolation valve	10^{-4} to 1 mGy/h	Above background, below trip	Technical Specification	4 dec. log
Control Building air intake	8[†]	S/C	Intake duct upstream of intake ventilation isolation valve	10^{-4} to 1 mGy/h	Above background, below trip	Technical Specification	4 dec. log
Drywell sump discharge	2	IC	Drain line from LCW & HCW sumps	10^{-2} to 10^{4} mGy/h	Above background	Technical Specification	6 dec. log
Fuel handling area air vent exhaust	4	S/C	Locally above operating floor	10^{-3} to 10 mGy/h	Above background, below trip	Technical Specification	4 dec. log
B. Monitors Required for Plant Operation							
Radwaste liquid discharge	1	S/D	Sample line	10^{-1} to 10^{4} cpm	Above background, below trip	Technical Specification	5 dec. log
Reactor Building cooling water system	3	S/D	RCW Hx line exit	10^{-1} to 10^{4} cpm	Above background	None	5 dec. log
Offgas post-treatment	2	GM-B	Sample line	10 to 10^{6} cpm	Above background, below trip	Technical Specification	5 dec. log
Offgas pre-treatment	1	S/C	Sample line	10^{-2} to 10^{4} mGy/h	At Tech Spec report level	None	6 dec. log

ACF = Automatic Control Function; GM-B = Beta-Sensitive GM Detector; IC = Ion Chamber; S/C = Digital Gamma-Sensitive GM Detector; S/D = Scintillation Detector

Table 11.5-1 Process and Effluent Radiation Monitoring Systems (Continued)

Monitored Process	No. of Channels	Detector Type	Sample Line or Detector Location	Channel Range*	Setpoint: Warning Alarm	Setpoint: ACF Trip	Scale
B. Monitors Required for Plant Operation (Continued)							
Charcoal vault vent	1	S/C	On charcoal vault HVAC exhaust line	10^{-2} to 10^{4} mGy/h	Above background	None	6 dec. log
Plant stack discharge	2 Δ	S/D	Sample line	10 to 10^{6} cpm	At quarterly tech spec level	None	5 dec. log
		IC	Sample line	10^{-13} to 10^{-6} Amps (10^{-2} to 10^{4} mGy/h)	Above background, below trip	None	6 dec. log
Radwaste Building exhaust vent	1	GM-B	Exhaust ducts	10 to 10^{6} cpm	Above background, below trip	None	5 dec. log
Turbine Building vent exhaust	4	S/C	Exhaust duct	10^{-4} to 1 mGy/h	Above background	None	4 dec. log
Standby Gas Treatment System offgas	2 Δ	S/D	SGTS exhaust air duct downstream of exhaust fans	1 to 10^{6} cpm	Above background, below trip above background	None	6 dec. log
		IC		10^{-13} to 10^{-6} Amps (10^{-2} to 10^{4} mGy/h)		None	6 dec. log
Turbine gland seal condenser offgas	1	S/D	Sample line	1 to 10^{6} cpm	Above background	None	6 dec. log
Incinerator stack discharge	1	GM-B	Sample line	1 to 10^{6} cpm	Above background	Technical Specification	6 dec. log

ACF = Automatic Control Function; GM-B = Beta-Sensitive GM Detector; IC = Ion Chamber; S/C = Digital Gamma-Sensitive GM Detector; S/D = Scintillation Detector

* The channel range specified in this table is the equipment measuring or display range of the indicated parameter. Refer to Tables 11.5-2 and 11.5-3 for the dynamic detection range of the monitoring channel expressed as concentration in units of megabecquerels per cubic centimeter, referenced to a specific nuclide.

† 4 Channels for each air intake

Δ One each S/D and IC is required to cover the channel range.

Table 11.5-2 Process Radiation Monitoring System (Gaseous and Airborne Monitors)

Radiation Monitor	Configuration	Type	Sensitivity	Dynamic Detection Range	Principal Radionuclides Measured	Expected Activity[*]	Alarms and Trips
Offgas post-treatment	Offline	GM-B Filter-P Filter-I	2.7×10^5 cpm per MBq/cm^3	3.7×10^{-5} to 3.7 MBq/cm^3	Xe-133[†] Cs-137 I-131	1.1×10^{-3} MBq/cm^3	Flow H/L DNSC/INOP High High-High HIgh-High-High
Offgas pre-treatment	Adjacent to sample chamber	S/C	189 Gy/h per MBq/cm^3	3.7×10^{-5} to 3.7×10^2 MBq/cm^3	Noble gases fission products	~1.1×10^{-2} MBq/cm^3	High-High High DNSC/INOP Flow H/L
Main steamline tunnel area	Adjacent to steamlines	IC	3.7×10^{-8} Amp/Gy/h (Co-60)[†]	10^{-11}– 10^{-5} MGy/h	Coolant activation gases	~1 mGy/h	High-High High DNSC INOP
Charcoal vault	Inline	S/C	135 Gy/h per MBq/cm^3	3.7×10^{-5} to 37 MBq/cm^3	Noble gases	Negligible	High Low
T/B vent exhaust	Inline	S/C	135 Gy/h per MBq/cm^3	3.7×10^{-7} to 3.7×10^{-3} MBq/cm^3	Xe-133[†] Xe-135	~1.48 Bq/cm^3	High DNSC/INOP
Reactor Building vent exhaust	Inline	S/C	135 Gy/h per MBq/cm^3	3.7×10^{-7} to 3.7×10^{-3} MBq/cm^3	Noble gases Xe-133[†] Xe-135	~1.48 Bq/cm^3	High-High High DNSC/INOP
Plant stack discharge (normal range)	Offline	S/D Filter-P Filter-I	3.51×10^8 cpm per MBq/cm^3	3.7×10^{-9} to 3.7×10^{-3} MBq/cm^3	Xe-133[†] Cs-137 I-131	~1.85 Bq/cm^3	High-High High DNSC/INOP Flow H/L

P = Particulate Filter; I = Iodine or Charcoal Filter

Table 11.5-2 Process Radiation Monitoring System (Gaseous and Airborne Monitors) (Continued)

Radiation Monitor	Configuration	Type	Sensitivity	Dynamic Detection Range	Principal Radionuclides Measured	Expected Activity*	Alarms and Trips
Plant stack (high-range)	Offline	IC	4.32 x 10^{-9} Amp per MBq/cm^3	$3.7x10^{-4}$ to $3.7x10^{3}$ MBq/cm^{3}‡	Xe-133†	~1.85 Bq/cm^3	Flow H/L DNSC/INOP High High-High
Radwaste Building ventilation exhaust	Offline	GM-B Filter-P Filter-I	3.51 x 10^{8} cpm per MBq/cm^3	3.7 x 10^{-9} to 3.7 x 10^{-3} MBq/cm^3	Xe-133† Cs-137 I-131	~$3.7x10^{-7}$ MBq/cm^3	High-High High DNSC/INOP Flow H/L
Gland seal condenser exhaust discharge	Offline	S/D Filter-P Filter-I	1.33 x 10^{9} cpm per MBq/cm^3	$3.7x10^{-9}$ to $3.7x10^{-3}$ MBq/cm^3	Xe-133 Cs-137† I-131	~$3.7x10^{-8}$ MBq/cm^3	High DNSC/INOP Flow H/L
Control Bldg. HVAC air intake	Inline	S/C	135 mGy/h per MBq/cm^3	$3.7x10^{-7}$ to $3.7x10^{-3}$ MBq/cm^3	Xe-133†	Negligible	High-High High DNSC/INOP
Standby Gas Treatment System exhaust	Offline	S/D Filter-P Filter-I	1.33 x 10^{9} cpm per MBq/cm^3	$3.7x10^{-9}$ to $3.7x10^{-3}$ MBq/cm^3	Noble gases Cs-137† I-131	~$1.85x10^{-8}$ MBq/cm^3	High-High High DNSC/INOP Flow H/L
	Inline	IC	4.32 x 10^{-9} Amp per MBq/cm^3	$3.7x10^{-4}$ to $3.7x10^{3}$ MBq/cm^{3}‡	Noble gases	~$1.85x10^{-8}$ MBq/cm^3	High-High High DNSC/INOP
Fuel handling area exhaust	Inline	S/C	9.19 mGy/h per MBq/cm^3 (Xe-135)†	$3.7x10^{-5}$ to $3.7x10^{-1}$ MBq/cm^3	Noble gases	~$2.22x10^{-4}$ MBq/cm^3	High-High High DNSC/INOP

P = Particulate Filter; I = Iodine or Charcoal Filter

Table 11.5-2 Process Radiation Monitoring System (Gaseous and Airborne Monitors) (Continued)

Radiation Monitor	Configuration	Type	Sensitivity	Dynamic Detection Range	Principal Radionuclides Measured	Expected Activity*	Alarms and Trips
Incinerator stack discharge	Offline	GM-B Filter-P Filter-I	3.51 x 10^8 cpm per MBq/cm^3	3.7×10^{-9} to 3.7×10^{-3} MBq/cm^3	Xe-133 Cs-137† I-131	~2.22×10^{-7} MBq/cm^3	High-High High DNSC/INOP
P = Particulate Filter; I = Iodine or Charcoal Filter							

* Expected activities are estimated and are based on existing plants.

† Sensitivity based upon this radionuclide.

Table 11.5-3 Process Radiation Monitoring System (Liquid Monitors)

Radiation Monitor	Configuration	Sensitivity	Dynamic Detection Range	Principal Radionuclides Measured	Expected Activity*	Alarms & Trips
Radwaste liquid discharge	Offline	$3.6x10^6$ cpm per MBq/cm^3	$3.7x10^{-9}$ to $3.7x10^{-4}$ MBq/cm^3	Cs-137† Co-60	~$3.7x10^{-8}$ MBq/cm^3	High/High High DNSC/INOP
Reactor Building cooling water intersystem leakage	Inline	$3.2x10^6$ cpm per MBq/cm^3	$3.7x10^{-7}$ to $3.7x10^{-2}$ MBq/cm^3	Cs-137* Co-60	~$2.22x10^{-6}$ MBq/cm^3	High DNSC/INOP
Drywell sump drain liquid discharge	Inline	8.11 mGy/h per MBq/cm^3	$3.7x10^{-4}$ to $3.7x10^{2}$ MBq/cm^3	Gross Gamma Cs-137*	~$1.85x10^{-3}$ MBq/cm^3	High-High High DNSC/INOP

* Expected activities are estimated and are based on existing plants.

† Sensitivity based upon this radionuclide.

DNSC—Downscale Indication

INOP—Monitor Inoperative

Table 11.5-4 Radiological Analysis Summary of Liquid Process Samples

Sample Description	Grab Sample Frequency	Analysis	Sensitivity MBq/L	Purpose
1 Reactor Coolant				
Filtrate	Daily*	Gross gamma	3.7×10^{-5}	Evaluate reactor water activity
Crud	Daily*	Gross gamma	3.7×10^{-5}	Evaluate crud activity
Filtrate	Weekly†	I-131, I-133	3.7×10^{-6}	Evaluate fuel cladding integrity
Crud and filtrate	Weekly	Gamma spectrum	1.85×10^{-6}	Determine radionuclides present in system
2. Reactor water cleanup system	Biweekly	Gross gamma	3.7×10^{-5}	Evaluate cleanup efficiency
3. Condenser demineralizer				
Influent	Monthly	Gross gamma	3.7×10^{-5}	Evaluate leakage
Effluent	Monthly	Gross gamma	3.7×10^{-5}	Evaluate demineralizer performance
4. Condensate storage tank	Weekly	Gross β-γ	3.7×10^{-5}	Evaluate water radioactivity
5. Fuel pool filter—demineralizer				
Inlet and outlet	Periodically	Gross β-γ	3.7×10^{-5}	Evaluate system performance
6. LCW collector and sampling tanks (4)	Periodically	Gross β-γ	3.7×10^{-5}	Evaluate system performance
7. HCW collector tanks (2)	Periodically	Gross β-γ	3.7×10^{-5}	Evaluate system performance
8. HSD sample tanks (2)	Periodically	Gross β-γ	3.7×10^{-5}	Evaluate system performance
9. Solid waste supply tank (evaporator bottoms)	Periodically	Gross β-γ	3.7×10^{-5}	Compare activity with that determined by drum readings
10. HCW distillate tank (evaporator)	Periodically	Gross β-γ	3.7×10^{-5}	Evaluate evaporator performance
11. Reactor Building Cooling Water System	Weekly	Gross β-γ	3.7×10^{-5}	Evaluate intersystem leakage

* Daily means five times per week.
† Performed more frequently if increase noted on daily gamma count.

Table 11.5-5 Radiological Analysis Summary of Gaseous Process Samples

Sample Description	Sample Frequency	Analysis	Sensitivity MBq/L	Purpose
1. Containment atmosphere (drywell)	Periodically and prior to entry	Gross α&β Tritium	3.7×10^{-10} 3.7×10^{-5}	Determine need for respiratory equipment
2. Offgas monitor sample	Monthly	Gamma spectrum	3.7×10^{-9}	Determine offgas activity
3. Offgas vent sample	Weekly	Gross β^{*}	3.7×10^{-10}	Determine offgas system cleanup
		I-131†	3.7×10^{-9}	
		Gamma spectrum Tritium	3.7×10^{-9} 3.7×10^{-5}	

* On particulate filter

† On charcoal cartridge

Table 11.5-6 Radiological Analysis Summary of Liquid Effluent Samples

Sample Description	Sample Frequency	Analysis	Sensitivity MBq/L	Purpose
1. Detergent drain tanks	Batch[*]	Gross Gamma	$3.7\text{x}10^{-6}$	Effluent discharge record
2. Liquid radwaste effluent	Weekly[†]	Ba/La-140 and I-131	$1.85\text{x}10^{-6}$	Effluent discharge record
composite of all discharges	Monthly	Gamma Spectrum	$1.85\text{x}10^{-6}$	
		Tritium	$3.7\text{x}10^{-4}$	
		Gross alpha	$3.7\text{x}10^{-6}$	
		Dissolved gas[‡]	$3.7\text{x}10^{-4}$	
	Quarterly	Sr 89 and 90	$1.85\text{x}10^{-6}$	
3. Circulating water decant line	Weekly grab of continuously collected proportional sample	Gross Gamma	$3.7\text{x}10^{-6}$	Effluent discharge record (backup sample)
		Tritium	$3.7\text{x}10^{-4}$	
4. Reactor service water	Weekly	Gross Gamma	$3.7\text{x}10^{-6}$	Effluent discharge record
		Tritium	$3.7\text{x}10^{-4}$	

* If tank is to be discharged, analysis will be performed on each batch. If tank is not to be discharged, analysis will be performed periodically to evaluate equipment performance.

† Typical batch of average release. All other samples are proportional composites.

‡ If no discharge event occurs during the week, frequency shall be so adjusted.

Table 11.5-7 Radiological Analysis Summary of Gaseous Effluent Samples

Sample Description	Sample Frequency	Analysis	SensitivityMBq/L	Purpose
1 Plant stack discharge*	Weekly	Gross β †	3.7×10^{-10}	Effluent record
		I-131‡	3.7×10^{-9}	
		Ba/La-140†	3.7×10^{-8}	
	Monthly	Gamma spectrum†	3.7×10^{-9}	
		I-133 and 135‡	3.7×10^{-9}	
		Tritium	3.7×10^{-5}	
		Gross alpha+	3.7×10^{-10}	
	Quarterly	Sr-89 and 90†	3.7×10^{-10}	
2. Gland steam condenser exhaust discharge	As above	As above	As above	Effluent record
3. Incinerator stack discharge	As above	As above	As above	Effluent record

* This includes discharges from the Reactor Building, Turbine Building, Radwaste Building and Service Building.

† On particulate filter.

‡ On charcoal cartridge.

11.6 Offsite Radiological Monitoring Program

Out of ABWR Standard Plant scope.

Appendix 11A
Table of Contents

11A.0 Radioactive Waste Management - Additional Information

11A.1 Introduction

This appendix provides a proprietary version of Section 11.2 and 11.4. Included in this version are expanded text and tables. Also included in this proprietary version are the associated process flow diagrams and P&IDs.

11A.2 Liquid Waste Management

[Proprietary information not included in DCD (Refer to SSAR Section 11A.2, Amendment 34).]

11A.3 Not Used

11A.4 Solid Waste Management System

[Proprietary information not included in DCD (Refer to SSAR Section 11A.4, Amendment 34).]