11.3 Gaseous Waste Management System

The gaseous waste management system (GWMS) is designed to monitor, control, collect, process, handle, store, ventilate, and dispose of gaseous radioactive waste generated as a result of normal operation, including anticipated operational occurrences AOOs, following the applicable guidance of NUREG-0017 (Reference 1) and NRC RG 1.143 (Reference 2).

The GWMS consists of two subsystems: the process vent subsystem and the process gas subsystem. The process vent subsystem is designed as part of building HVAC systems and is described in Subsection 11.3.4. Further information about building HVAC systems is provided in Section 9.4. The process gas subsystem, referred to as the gaseous radwaste system (GRS), is described in Subsection 11.3.2. The radionuclide concentration of gaseous effluent releases at the site during normal operation including AOOs are below the radionuclide concentration limit in 10 CFR 20, Appendix B (Reference 3), and comply with the ALARA criteria of 10 CFR 50, Appendix I (Reference 4), based on the use of industry-proven technologies incorporated into the design.

The lessons learned program provides guidance on the integration of industry, operating, and construction experience into the APR1400 design. Under this program, NRC generic communications, and industry operating and construction experience are maintained in a database that is reviewed, assessed, and integrated into the design as appropriate. The construction and operating experience of nuclear power plants has been incorporated into the database for design improvement.

The GWMS manages the radioactive gases collected from the off-gas system and other tank vents containing radioactive materials. Gaseous waste from the above sources is treated to reduce the quantity of radioactive material prior to release to the environment.

The radiation level in the processed gases is verified by radiation monitors prior to release to the environment. Process and effluent radiation monitoring and sampling systems are described in Section 11.5.

11.3.1 Design Bases

11.3.1.1 Design Objectives

The design objectives of the GWMS are as follows:

a. Provide the capability to monitor, control, collect, process, handle, store, and dispose of radioactive gaseous waste generated as the result of normal operation including AOOs to meet release radionuclide concentration limits in accordance with 10 CFR 20, Appendix B (Reference 3), prior to discharge to the environment.

b. Provide reasonable assurance that the release of radioactive material in gaseous effluents is kept ALARA.

c. Remove and reduce radioactive materials to the environment to meet the requirements of 10 CFR 50, Appendix I (Reference 4).

The GWMS is designed for individual unit operation, and no subsystems or components are shared with radwaste systems or other systems.

11.3.1.2 Design Criteria

The GWMS is designed in accordance with the acceptance criteria in the NRC Standard Review Plan, Section 11.3 (Reference 5). The design criteria are as follows:

a. Effluents normally released to unrestricted areas meet the concentration limits of 10 CFR 20, Appendix B (Reference 3), during normal operation, including AOOs.

   The GWMS discharges effluent continuously. Table 11.3-1 provides an estimate of the annual airborne effluent releases using PWR-GALE Code based on NRC RG 1.112 (Reference 6), NUREG-0017 (Reference 1), and ANSI/ANS 18.1 (Reference 7) methodology. Assumptions used to calculate the annual release rate are addressed in Subsection 11.3.3.1, and the results are listed in Table 11.3-6. The analysis provides reasonable assurance that effluents from normal operation and AOOs meet the concentration limits of 10 CFR 20, Appendix B (Reference 3).

The GWMS is designed to provide reasonable assurance that normal releases, including releases from AOOs to unrestricted areas, comply with the effluent concentration limits of 10 CFR 20, Appendix B (Reference 3), based on the design basis source term. Subsection 11.3.3 provides a detailed description of the methodology used to calculate the concentration of the effluent in unrestricted areas. The results of these analyses provide reasonable assurance that the maximum concentrations of the effluent at the site boundary comply with the concentration limits of 10 CFR 20, Appendix B (Reference 3).

b. The system meets the design objectives of performance without interference with normal operation, including AOOs.

The GWMS is a non-nuclear, non-safety-related system with the exception of the containment penetration isolation valves and piping (which are safety related) and has no accident mitigation function. The GWMS is designed in accordance with ANSI/ANS 55.4 (Reference 8) and conforms to NRC RGs 1.52 (Reference 9), 1.140 (Reference 10), and 1.143 (Reference 2).

The GWMS design includes the following features:

1) The GWMS is designed to preclude buildup of an explosive mixture of hydrogen and oxygen, which could affect the operation of the plant.

2) The GWMS is designed with sufficient capacity and redundancy to accommodate an increase in demand during normal operation of the plant.

c. Releases of radioactive materials to the environment are controlled and monitored in accordance with 10 CFR 50, Appendix A, General Design Criteria (GDC) 60, 61, and 64 (References 11, 12, and 13, respectively).

The GWMS is provided with a radiation monitor at the discharge line from the charcoal delay beds to the compound building HVAC system. The discharge of the GWMS is automatically isolated if the preset trip setpoint is exceeded. Section 11.5 provides a detailed description of radiation monitoring for the GWMS.

d. Accidental releases of radioactive materials from a single component of the GWMS are not to result in offsite doses that exceed the guidelines of NRC Branch Technical Position (BTP) 11-5 (Reference 14).

   Subsection 11.3.3.2 provides a description of the analysis of a single component failure of the GWMS. The methodology used in this analysis is in accordance with BTP 11-5 (Reference 14) for the design basis source term. The results of these analyses confirm that the consequence of a single component failure of the GWMS is within the guideline dose limits of BTP 11-5 (Reference 14) (1 mSv total effective dose equivalent).

e. The system is designed to meet the design objective of the occupational exposure by keeping operation and maintenance exposure ALARA.

   The GWMS is designed in accordance with guidance provided in ANSI/ANS 55.4 (Reference 8) and conforms to NRC RGs 1.143, 1.52, 1.140, and 8.8 (References 2, 9, 10, and 15, respectively). Shielding is provided to the equipment cubicles for the equipment containing design basis source terms to keep doses to personnel ALARA. This guarantees that the GWMS satisfies the ALARA objectives.

f. The gaseous waste handling and treatment system is protected from the effects of an explosive mixture of hydrogen and oxygen in accordance with 10 CFR 50, Appendix A, GDC 3 (Reference 16).

g. Cubicles containing radioactive liquid are lined with an epoxy coating to minimize the potential contamination to the groundwater system and to facilitate maintenance and decontamination. Epoxy coatings in cubicles are Service Level II coatings as defined in NRC RG 1.54 (Reference 17). The COL applicant is to confirm the implementation milestones for the coating program in the GWMS (COL 11.3(1)).

h. Interconnections between the GWMS and other plant systems are designed so that contaminations of non-radioactive systems are precluded and the potential for uncontrolled and unmonitored releases of radiation to the environment from a

single failure is minimized. This feature meets the requirements of IE Bulletin 80-10 (Reference 18).

The GWMS is designed with hard piping between radioactive and non-radioactive systems in accordance with the IE Bulletin 80-10 (Reference 18). Nitrogen gas is used for purging pipe after each transfer of contaminated fluid. The connections are hard pipes and are equipped with double barriers to prevent unintended contamination in accordance with NRC RG 4.21 (Reference 19).

i. In accordance with ANSI/ANS-55.4 (Reference 8), GWMS is designed to withstand the effect of an OBE.

j. The GWMS equipment is designed, located, and shielded in accordance with NRC RG 8.8 (Reference 15).

The GWMS design includes two gas analyzers with automatic control functions to preclude the buildup of an explosive mixture of hydrogen and oxygen in accordance with the NRC Standard Review Plan, Section 11.3 (Reference 5). Gaseous waste is sampled from various process points for analyzing oxygen and hydrogen concentration within the GWMS. Two hydrogen analyzers and two oxygen analyzers are used to monitor hydrogen and oxygen gas concentrations within the GWMS. One hydrogen and one oxygen analyzer is provided to continuously monitor hydrogen and oxygen gas concentrations in the gas surge header of the GWMS. The other hydrogen and oxygen analyzer in the gaseous radwaste sample panel is used to analyze samples from process points within the GWMS package. Alarms are provided in the radwaste control room of the compound building and the main control room (MCR) and annunciate on high and high-high oxygen concentrations.

11.3.1.3 Other Design Considerations

The GWMS design conforms to NRC RG 1.143 (Reference 2) from the applicable Regulatory Positions (C.2, C.4, C.5, C.6, and C.7). The Regulatory Positions include the following:

a. The GWMS is designed and tested in accordance with Regulatory Position C.2 of NRC RG 1.143 (Reference 2).

1) The GWMS is designed and tested according to the codes and standards that are listed in Table 11.3-2, and conforms to Regulatory Positions C.2.2 and C.4 of NRC RG 1.143 (Reference 2).

2) Materials used for pressure retaining portions of components in the GWMS are designed in accordance with ASME Section II (Reference 20). Materials used in the GWMS are compatible with the chemical, physical, and radioactive environments during normal and AOO conditions. Malleable, wrought, or cast irons, and plastics cannot be used in the GWMS.

3) A high oxygen concentration alarm (for a concentration greater than 2 percent) from any incoming source is annunciated in the radwaste control room of the compound building. Operating personnel can mitigate the situation by closing the source of the oxygen or via nitrogen dilution or purge. A high-high oxygen concentration alarm (for a concentration greater than 4 percent) from any incoming sources is annunciated in the MCR and the radwaste control room of the compound building. Under this condition, nitrogen is automatically injected into the GWMS to reduce the oxygen concentration, and the incoming gaseous waste flow is terminated effectively by the nitrogen pressure.

b. The GWMS design and testing requirements conform to Regulatory Position C.4 of NRC RG 1.143 (Reference 2).

1) The GWMS is housed in the compound building and is designed to control leakage. In addition, sufficient space is provided to facilitate access, operation, inspection, testing, and maintenance to maintain personnel exposures ALARA in accordance with NRC RG 8.8 (Reference 15) guidelines.

2) The GWMS is constructed in accordance with Regulatory Position C.4.3 of NRC RG 1.143 (Reference 2).

3) The GWMS is pneumatically pressure tested in conformance with Regulatory Position C.4.4 of NRC RG 1.143 (Reference 2). Testing of piping systems during the operation phase is performed in accordance with applicable codes

and standards as described in Table 11.3-2. For the APR1400, repairs, replacements, and modifications of pipes less than 25 mm (1 in) are exempt from pressure testing provided the original system was pressure tested.

4) The GWMS is designed to permit periodic testing of active components to evaluate the operability in accordance with Regulatory Position C.4.5 of NRC RG 1.143 (Reference 2).

c. The GWMS and the structure housing the GWMS are classified as RW-IIa, RW-IIb, or RW-IIc as described in Regulatory Position C.5 and are designed to the natural phenomena and man-induced hazards criteria in Regulatory Position C.6 of NRC RG 1.143 (Reference 2). The compound building is designed as seismic Category II.

d. The quality assurance (QA) program for the design, installation, procurement, and fabrication of GWMS components complies with Regulatory Position C.7 of NRC RG 1.143 (Reference 2) and NRC RG 1.33 (Reference 21). Table 3.2-1 identifies seismic category, quality, and safety class for each of the respective components in the GWMS.

e. The GWMS equipment and piping are designed as seismic Category II or III, non-Class 1E, Quality Group D except for the containment isolation valve and line, and are designed, fabricated, and tested in accordance with NRC RG 1.143 (Reference 2) as specified in Table 11.3-2.

f. The GRS operates at slightly above atmospheric pressure and therefore limits system leakage. There is no effect of aging or positioning on charcoal by airborne contaminants.

g. The GWMS is designed to prevent wetting of the charcoal delay beds including controls and alarms in the waste gas dryer. Charcoal guard beds also remove the residual moisture. If moisture enters the charcoal delay beds, the operator bypasses gas stream and dries the charcoal delay bed with a nitrogen purge or replaces the charcoal.

11.3.1.4 Method of Treatment

The GWMS uses charcoal at ambient temperature to delay the passage of radioactive gases. When operating at design conditions, the mass of charcoal provided in the absorber beds is sufficient to provide a delay of 45 days for xenon and a delay of 3.5 days for krypton. The waste gas dryer controls the inlet gas moisture and temperature to achieve the desired performance of the charcoal delay beds.

Streams in the GWMS are monitored for both hydrogen and oxygen content so that a flammable mixture does not accumulate. An explosive mixture of hydrogen and oxygen in the GWMS is prevented by maintaining an oxygen concentration less than 4 percent by volume. To dilute this gas further, it is mixed with the compound building ventilation flow before it is discharged to the environment. This feature complies with 10 CFR 50, Appendix A, GDC 3 (Reference 16) and the guidance in NRC RG 1.189 (Reference 22).

The design parameters for the GWMS are listed in Tables 11.3-3 and 11.3-4. The GWMS has the capability to process gases associated with the design basis source term.

The GWMS is designed so that releases of radioactive gases are below the concentration limits in 10 CFR 20, Appendix B (Reference 3). The GWMS design allows the Technical Specifications for the release of gaseous effluents to be met and to keep offsite doses to the public within the specified limits.

Annual average airborne releases of radionuclides from the plant are determined using the PWR-GALE Code, NUREG-0017 (Reference 1), and the design basis source term presented in Section 11.1. The expected annual quantity of released radioactive material, averaged over the 60-year life of the plant, and the expected doses to individuals at or beyond the site boundary are calculated in accordance with the guidance provided in NUREG-0017 (Reference 1). The principal parameters used in calculating the annual releases of radioactive materials in gaseous effluents using this guidance are provided in Tables 11.3-1 and 11.3-6.

The GWMS uses equipment that is commonly used in the nuclear power industry. The performances are proven and documented. The equipment is sized to process waste gases using design source term and design conditions that bound normal operation including

AOOs. The equipment is also housed in the compound building with sufficient shielding such that the average annual dose at the site boundary from direct radiation from the gaseous sources does not exceed the limits of 10 CFR 50, Appendix I (Reference 4). Charcoal beds significantly reduce the concentration of radioactive iodine in the effluent stream. Noble gases can also be delayed in the charcoal beds to allow decay prior to release.

GWMS equipment is designed, located, and shielded to comply with the guidance of NRC RG 8.8 (Reference 15), thus maintaining occupational doses ALARA.

The GWMS includes radiation monitoring to continuously measure the radioactivity in the effluent stream prior to release into the environment to comply with the requirements of GDC 60 (Reference 11) and 64 (Reference 13). Additional and redundant radiation monitors are provided in the building ventilation system to verify the radiation level. Upon detection of radiation levels above the setpoint, the monitor activates an alarm and sends signals to close the GWMS discharge valves.

The GWMS is designed so that the interconnection between plant systems precludes the contamination of non-radioactive systems and uncontrolled releases of radioactivity to the environment to meet the requirements of IE Bulletin 80-10 (Reference 18). At least two isolation valves are located between the clean and contaminated systems to minimize the potential for contamination of clean systems. This feature meets the requirements of 10 CFR 20.1406 (Reference 23).

11.3.1.5 Radioactive Source Terms in the GRS

As shown in Figure 11.3-1, the input sources to the GRS are the vent gases from the reactor drain tank (RDT), volume control tank (VCT), equipment drain tank (EDT), and gas stripper. The expected radioactive sources for each component of the GRS are calculated using the radioactive concentrations of the inflows to GRS from the CVCS components, which are determined based on the expected reactor coolant radionuclide concentrations provided in Table 11.1-9.

The mixed specific activities of sources to the GRS are then calculated by weighting each source contribution corresponding to its partial flow fractions. Activity build-up on the

charcoal beds is modeled, assuming the holdup times for noble gases that are presented in Table 11.2-2.

Buildup activity in the charcoal guard bed is calculated assuming that the inflow activities are trapped in the resin bed entirely. For the buildup activities in i^{th} charcoal delay bed, the following differential equation is used:

$$\frac{dA_i}{dt} = Q_{i-1} - Q_i - \lambda A_i$$

$$Q_i = Q_{i-1} \cdot e^{-\lambda T_H}$$

Where:

A_i	=	buildup activity in the i^{th} charcoal delay bed (Bq)
Q_i	=	flow rate of radioactivity (Bq/hr)
T_H	=	holdup time per each charcoal bed (hr)
λ	=	decay constant (hr^{-1})

Table 11.3-10 provides the expected radioactive inventories of the each GRS component.

The method to determine radwaste classification for GRS components is the same as the method described for the LWMS (refer to Subsection 11.2.1.4).

11.3.1.6 Site-Specific Cost-Benefit Analysis

The GWMS is designed to be used for any site.

NRC RG 1.110 (Reference 24) provides compliance with 10 CFR 50, Appendix I (Reference 4), numerical guidelines for offsite radiation doses as a result of gaseous or airborne radioactive effluents during normal operations including AOOs. The cost-benefit analysis, as required by 10 CFR 50, Appendix I (Reference 4), Section II, Paragraph D, demonstrates that the addition of items of reasonably demonstrated technology is not favorable or cost beneficial.

The COL applicant is to perform a site-specific cost-benefit analysis to demonstrate compliance with NRC RG 1.110 (Reference 24) (COL 11.3(2)).

11.3.1.7 Mobile or Temporary Equipment

The GWMS is designed with permanently installed equipment. The GWMS does not include the use of mobile or temporary equipment.

11.3.2 GRS Description

The process flow diagram (PFD) of the GRS is provided in Figure 11.3-1, and an equipment list for the GRS is provided in Table 11.3-4. The COL applicant is to provide the piping instrumentation diagram (P&ID) (COL 11.3(3)).

Gaseous waste contains radioactive krypton and xenon, which are fission products that originate from fuel and tramp uranium on fuel surfaces. The GRS receives fission gases through the gas surge header and uses charcoal delay beds to delay discharge and allow decay prior to release. The primary input sources to the gas surge header are the gas stripper, VCT, RDT, and EDT in the chemical and volume control system (CVCS). The gases consist primarily of hydrogen and nitrogen with trace quantities of fission gases and oxygen. The removal of fission gases by the gas stripper maintains the fission gas concentration at a low level in the reactor coolant. This minimizes the escape of radioactive gases during maintenance on the reactor coolant system (RCS) and minimizes releases resulting from leakage of reactor coolant.

The GRS consists of one header drain tank, two waste gas dryers, one chiller, two charcoal guard beds, four charcoal delay beds, one high-efficiency particulate air (HEPA) filter and the associated piping, valves, and instrumentation.

The GRS is designed to accommodate the normal letdown flow rate of 80 gpm, which converts to a displaced cover gas flow of 11 scfm. This flow rate is within the design GRS capacity of 22 scfm. During a pressurizer relief operation, the cover gas flow could increase for a short period. The surge cover gas is directed to the gas surge header for moderation and buffering of flow. The gas surge results in a higher velocity through the charcoal bed, even though it is buffered by the gas surge header. There is no buffering

function in GRS header drain tank. The charcoal blowout can be prevented by the screen installed on the bottom of the GRS delay bed. The HEPA filter is used to remove any charcoal fines escaped from the delay beds.

The GRS uses charcoal at ambient temperature to delay the passage of radioactive gases. When operating at design conditions, the mass of charcoal provided in the absorber beds is sufficient to provide a delay of 45 days for xenon and a delay of 3.5 days for krypton. The waste gas dryer controls the inlet gas moisture and temperature to achieve the desired performance of the charcoal delay beds.

The condensed liquid in the gas surge header in the auxiliary building and in the GRS inlet piping in the compound building is collected in the GRS header drain tank. The tank is also used to collect condensate from the waste gas dryer.

Downstream of the gas surge header, two 100 percent capacity trains are used to reduce the process stream relative humidity to improve and protect the performance of the charcoal delay beds. Each train comprises one waste gas dryer and one charcoal guard bed.

The waste gas dryer cools the waste gases below 7.8 °C (46 °F) and removes the condensate before the gas enters the guard beds. The GRS chiller provides the cooling water when the plant chilled-water system is unavailable. Humidity sensors downstream of the waste gas dryer are provided to detect unacceptable moisture content.

The charcoal guard bed is provided upstream of the charcoal delay beds. The guard bed protects the main charcoal delay bed from moisture. Humidity sensors are installed upstream and downstream of the charcoal guard bed to monitor the charcoal wetting condition. Temperature sensors are installed at the guard beds and delay beds. The short-lived radionuclides are delayed, and iodine is held up for decay in the charcoal guard beds. Nitrogen purge is available to dry the charcoal beds in the event of excessive moisture contamination. Two guard beds and four charcoal delay beds containing a total of 9,798 kg (21,600 lb) of charcoal are used for xenon and krypton delay. The beds are located in a shielded vault.

After passing through the charcoal delay beds, the waste gas flows through a HEPA filter where particulates, including charcoal fines, are removed, and then it is vented to the compound building HVAC system, as shown in Figure 11.3-2.

The GRS operates at pressures slightly above atmospheric, thus limiting the potential for oxygen inleakage. Leakage from the GRS is further limited through the use of welded connections wherever the connections are not restricted for maintenance purposes. Control valves are provided with bellow seals to minimize leakage through the valve stem.

The GRS is designed to prevent the formation or buildup of explosive mixtures of hydrogen and oxygen by monitoring and controlling the concentrations of hydrogen and oxygen through one of the two gas analyzers (continuous monitoring). The concentrations are confirmed by periodic sampling and analysis at several routing locations. When the oxygen concentration is detected to be higher than the predetermined setpoint, nitrogen is injected to dilute the concentration to below the lower flammable limit of 4 percent. Along the gas flow paths, there are process vessels (VCT, RDT, EDT, gas stripper, GRS header drain tanks, and associated piping) that are designed in accordance with ASME VIII (Reference 25) for pressure vessels. Accordingly, design pressures are assigned to contain significant margins above the normal operating pressure, and relief valves are provided for each vessel to protect surges in pressure in the event that an explosion occurs.

The system is designed to alarm locally and in the MCR for operator action. The gas analyzers take continuous samples from various process points and from input sources to the system (e.g., gas stripper, volume control tank, reactor drain tank).

The gas analyzer is set at a high alarm of 2 percent and high-high alarm of 4 percent oxygen. Alarms allow the operating personnel sufficient times for remedial actions to lower concentrations of hydrogen and oxygen. Remedial actions include investigation and eliminating or isolating the source of oxygen intake to the system, or adding nitrogen gas as needed to stabilize and reduce oxygen concentrations within the system to less than the alarm level. Although the GRS design features reduce or eliminate sources of oxygen intake, design features of monitoring and purging are provided against an unexpected buildup of explosive mixtures.

11.3.2.1 Component Description

11.3.2.1.1 Charcoal Delay Beds

The holdup of radioactive gases for decay is accomplished by retention in the charcoal delay beds. The vessels are designed to prevent charcoal carryover. The charcoal delay beds are designed to allow the replacement of the charcoal. Operation is performed at ambient temperature. Piping connections are arranged to make it possible to bypass any charcoal delay bed. In addition, nitrogen gas can be introduced to each charcoal delay bed in order to flush or dry the charcoal. Two charcoal guard beds are provided upstream of the delay beds to protect the delay beds from excessive moisture. If the guard bed is excessively wetted, the guard bed can be bypassed, purged and dried with nitrogen, or reloaded.

11.3.2.1.2 Waste Gas Dryer

One of two waste gas dryers is normally in service to reduce the moisture content of the gases by cooling with chilled water. The cooling water is supplied from the plant chilled-water system or the GRS chiller. The waste gas dryer is designed to take an inlet gas flow of 623 L/min (22 scfm) with an inlet temperature of 48.9 °C (120 °F) and a discharge temperature of 7.8 °C (46 °F).

11.3.2.1.3 GRS Header Drain Tank

All of the condensed liquid in the gas surge header and GRS is collected in the GRS header drain tank. The condensed liquid is drained into the compound building normal sump. The GRS header drain rank is provided with a level control. Tank water level is interlocked with the drain line isolation valve.

11.3.2.1.4 Charcoal Guard Bed

The charcoal guard bed is provided upstream of the charcoal delay beds. The guard bed protects the main charcoal delay bed from moisture. The short-lived radionuclides are also delayed, and iodine is held for decay in the charcoal guard bed.

11.3.2.1.5 HEPA Filter

After passing through charcoal delay beds, the waste gas flows through a HEPA filter where particulates, including charcoal fines, are removed. The waste gas then flows through a check valve to prevent air in-leakage. Efficiency of the HEPA filter is not credited in the PWR-GALE Code calculation. The filter has test ports for in-place testing. Through the check valve, the waste gas flows to the environment after it is diluted with building ventilation air.

11.3.2.2 Design Features

11.3.2.2.1 General Design Features

The following features meet the design criteria:

a. High-activity hydrogenated gaseous waste streams are processed through charcoal delay beds to delay and allow decay of radioactive fission gases prior to release. Decay of fission product gases (xenon and krypton) prior to release significantly reduces offsite exposure levels. Additionally, filtration by the air cleaning unit of the compound building HVAC reduces offsite exposure by reducing radioactive particulates and iodine in plant effluents.

b. The header drain tank is used to collect all condensates from the gaseous waste piping and the waste gas dryer.

c. The charcoal delay process consists only of passive components. A charcoal guard bed is provided upstream of the charcoal delay beds to protect the beds in the unlikely event of excessive moisture input. The moisturized charcoal guard bed can be dried by nitrogen injection.

d. The radioactivity of the processed gaseous waste is monitored prior to discharge to the environment, and the discharge flow is automatically isolated if the preset limit is exceeded. The isolation signal is from the compound building HVAC exhaust.

e. The GWMS is designed to preclude accidental releases of gaseous activity that could result in offsite exposures in excess of acceptable limits.

f. Instrumentation and alarms are provided to preclude the buildup of explosive mixtures of hydrogen and oxygen.

g. Drain lines and valves are sized and sloped to minimize the potential for plugging. Valves are the packless metal diaphragm type and have bellowed sealed stems to minimize leakage.

The GWMS is designed, constructed, and tested to be as leak-tight as practicable. In order to minimize maintenance and corresponding personnel dose while performing maintenance, the following design features are implemented:

a. Components are installed in separately shielded cells to minimize dose while performing maintenance.

b. Only proven and qualified equipment from the nuclear industry is used.

c. Steel piping with butt-welded construction is used to minimize crud traps. Only qualified welders are used.

d. Cubicles containing radioactive liquid are steel-lined or lined with an epoxy coating to minimize the potential for contamination to the groundwater system and to facilitate maintenance and decontamination.

e. Non-radioactive auxiliary subsystems are isolated from the radioactive process streams.

f. Equipment, piping, and instruments are subjected to strict leak-rate testing and inspections.

11.3.2.2.2 Design Features for Minimization of Contamination

The APR1400 is designed with features that meet the requirements of 10 CFR 20.1406 (Reference 23) and NRC RG 4.21 (Reference 19). The basic principles of NRC RG 4.21 (Reference 19) and the methods of control suggested in the regulations are delineated into four design objectives and two operational objectives, which are addressed in Subsection 12.3.1.10. The following description summarizes the primary features of the design and operational objectives for the GWMS.

The GWMS SSCs, including the facility that houses the components, are designed to limit leakage and/or control the spread of contamination. In accordance with NRC RG 4.21 (Reference 19), the GWMS has been evaluated for leakage identification from the SSCs that contain radioactive or potentially radioactive materials, the areas and pathways where probable leakage may occur, and the methods of leakage control incorporated into the design of the system. The leak identification evaluation indicated that the GWMS is designed to facilitate early leak detection and has the capability to assess collected fluids and respond to manage the collected fluids quickly. Thus, unintended contamination to the facility and the environment is minimized and/or prevented by the SSC design, supplemented by operational procedures and programs and inspection and maintenance activities.

Prevention/Minimization of Unintended Contamination

a. The system contains sufficient charcoal material to hold the noble gas nuclides for a period of decay to reduce the release of radioactivity, thus minimizing contamination of the facility and the environment.

b. The system design, including the waste gas dryers and guard beds, are configured into two parallel trains, one operating and one standing by, each with sufficient capacity to remove the moisture to protect the charcoal beds.

c. A HEPA filter is provided downstream of the charcoal beds to prevent the distribution of contaminated charcoal fines.

d. Cubicles in which contaminated materials are stored and processed are epoxy-coated to facilitate cleaning. The GWMS header drain tank is equipped with level instrumentation to detect fluid accumulation and drain the fluid to the radioactive drain system.

e. The system is designed with above-ground piping to the extent practicable. Buried and/or embedded piping is minimized. Piping is sloped to facilitate drainage of condensate to the header drain tank.

f. The system uses valves with leak-tight characteristics, such as the bellows or metal diaphragm types, to minimize leakage.

g. The system uses welded construction to the maximum practicable extent to minimize leakage.

Adequate and Early Leak Detection

a. The system is designed with gas analyzers and a radiation monitor to provide reasonable assurance of the integrity of the SSCs, including piping, and to provide alarms to warn operators of explosive gas concentrations.

b. The system is designed with adequate space around all components to enable prompt evaluation and response to leakage detection.

Reduction of Cross Contamination, Decontamination, and Waste Generation

a. The SSCs are designed with life-cycle planning through the use of nuclear–industry-proven equipment and materials that are compatible with the chemical, physical, and radiological environment, thus minimizing cross contamination and waste generation.

b. The process piping containing contaminated fluid is sloped to facilitate flow and reduce fluid traps, thus reducing decontamination and waste generation. Decontamination fluid is collected and routed to the LWMS for processing and release.

c. Utility connections are designed with a minimum of two barriers to prevent contamination of non-radioactive systems from radioactive systems.

Decommissioning Planning

a. The SSCs are designed for the full service life and are fabricated, to the maximum extent practicable, as individual assemblies for easy removal.

b. The SSCs are designed with decontamination capabilities using low-pressure nitrogen. Design features such as welding techniques and surface finishes are included to minimize the need for decontamination and minimize waste generation.

c. The GWMS is designed with minimum embedded or buried piping. The drain gas header between buildings is equipped with piping sleeves with leakage directed back to the compound building for collection, thus preventing the spread of contamination.

Operations and Documentation

a. The GWMS is designed for remote and automated operations. The system is equipped with instruments to actuate the drain valve from the header drain tank.

b. The COL applicant is to prepare the operational procedures and maintenance programs related to leak detection and contamination control (COL 11.3(4)). Procedures and maintenance programs are to be completed before fuel is loaded for commissioning.

c. The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations (COL 11.3(5)). Documentation requirements are included as a COL information item.

Site Radiological Environmental Monitoring

a. The GWMS is part of the plant and is included in the site process control program and the site radiological environmental monitoring program for monitoring of

facility and environmental contamination. The site radiological environmental monitoring program includes sampling and analysis of effluent to be released, meteorological conditions, hydrogeological parameters, and potential migration pathways of radioactive contaminants. The COL applicant is to prepare the site process control program and the site radiological environmental monitoring program (COL 11.3(6)).

11.3.3 Radioactive Effluent Releases

11.3.3.1 Radioactive Effluent Releases and Dose Calculation in Normal Operation

Radioactive gaseous effluents generated from normal operation, including anticipated operational occurrences, are treated and released through the GWMS. The GWMS is designed to treat radioactive gaseous effluents to meet the concentration limits of 10 CFR 20, Appendix B (Reference 3), and dose limits of 10 CFR 50, Appendix I (Reference 4). The treated gaseous effluents are released through the auxiliary building, reactor containment building, compound building, and turbine generator building HVAC vents. Figure 11.3-3 provides information on the release points of gaseous effluents including height, dimensions, effluent temperature, effluent flow rates, exit velocity, and size and shape of flow orifices.

The gaseous releases from plant sources during normal operation, including AOOs, are calculated by using the PWR-GALE Code, which conforms to the methodology of NUREG-0017 (Reference 1). The input data for calculating gaseous releases are presented in Table 11.2-2. The χ/Q value at the exclusion area boundary (EAB) is assumed to be 2.0×10^{-5} sec/m^3 for the calculation of gamma dose in air, beta dose in air, dose to total body, dose from ground, and does due to inhalation. The χ/Q value at the offsite food production area is assumed to be 1.0×10^{-5} sec/m^3 for the calculation of dose from food intake. The D/Q value at the site boundary is 2.0×10^{-7}/m^2. Expected annual gaseous effluent releases are presented in Table 11.3-1. The design basis effluent concentrations are calculated using Eq. 11.3-1 and are then compared against the concentrations of 10 CFR 20, Appendix B (Reference 3). The sum of ratios of concentrations for the design basis fuel defect is 0.162 as presented in Table 11.3-6. This value is less than 1.0, which indicates that the releases meet the regulatory limit.

The equation for calculating design basis radionuclide concentration of the gaseous effluent is as follows:

$$C_i = CF \cdot Q_i \cdot MF_i \cdot \frac{\chi}{Q} \quad \text{(Eq. 11.3-1)}$$

Where:

C_i = design basis gaseous effluent concentration for the i^{th} isotope, Bq/L

CF = conversion factor (= 3.17×10^{-8} yr/sec)

Q_i = annual expected release rate of nuclide i evaluated by PWR-GALE Code (Bq/yr)

MF_i = multiplication factor for the i^{th} isotope $\left(= \frac{RCS(i)_{DAMSAM}}{RCS(i)_{ANSI/ANS18.1}}\right)$
(ratio of 1 % fuel defect design basis nuclide concentration to ANSI/ANS-18.1-1999 expected concentration)

χ/Q = maximum directional annual average atmospheric dispersion factor at restricted area boundary, sec/m^3

The maximum individual doses at the exclusion area boundary are calculated by using the GASPAR II Code (Reference 26). Parameters used in the GASPAR II Code (Reference 26) are presented in Table 11.3-5. Calculated doses are shown in Table 11.3-7. The annual beta air dose is 0.0794 mGy, and the annual gamma air dose is 0.00613 mGy, which are less than the limits of 0.2 mGy and 0.1 mGy, respectively, as presented in 10 CFR 50, Appendix I. The dose to the total body is 0.00379 mSv/yr, dose to skin is 0.0557 mSv/yr, and the maximum dose to any organ (child bone) is 0.145 mSv/yr. These doses are less than the limitations of 0.05 mSv/yr, 0.15 mSv/yr, and 0.15 mSv/yr, respectively, as presented in 10 CFR 50, Appendix I (Reference 4).

The COL applicant is to perform a site-specific dose calculation following NRC RG 1.109 (Reference 27) and NRC RG 1.111 (Reference 28) and compare the doses from the gaseous effluents with the numerical design objectives of 10 CFR 50, Appendix I (Reference 4) and the compliance requirements of 10 CFR 20.1302 (Reference 29). The COL applicant is also to perform the dose calculation using the total gaseous effluents from the site for comparison with the requirements of 40 CFR 190 (Reference 30) (COL 11.3(7)).

11.3.3.2 Radioactive Effluent Releases and Dose Calculation Due to Gaseous Waste Management System Leak or Failure

The GRS, as described in Subsection 11.3.1, is designed to collect, monitor, and process radioactive waste gases that originate in the RCS and are processed by holdup for decay prior to release. The GRS uses ambient-temperature charcoal adsorption beds to provide sufficient holdup for decay of noble gases.

The release event is described as an unexpected and uncontrolled release of radioactive xenon and krypton gases from the GRS resulting from an inadvertent bypass of the main decay portion of the charcoal delay beds. Isolating or terminating the release is assumed to take as long as 2 hours.

The bases for calculating the maximum offsite concentration of the gaseous effluent resulting from a leak or failure of the GRS are as follows:

a. The design basis gaseous effluent source term is based on the design basis RCS equilibrium concentration resulting from fission product leakage into the RCS based on 1 percent fuel defect in accordance with the NRC Standard Review Plan BTP 11-5 (Reference 14). The BTP 11-5 method adds the accidentally induced charcoal unit bypass leakage to the source term for normal operation. The accidental release source contributions are calculated based on the design basis RCS equilibrium concentration.

b. The short-term, 2-hour accident atmospheric dispersion factor is assumed to be 1.0×10^{-3} sec/m^3. This is consistent with the dispersion factors provided in Section 2.3.

c. The annual gaseous effluent releases and the accidental event gaseous effluent releases without decay are calculated by using the PWR-GALE Code, and the calculated values are multiplied by isotope-specific multiplication factors. This multiplication factor is determined by dividing the design basis RCS equilibrium concentration calculated using the DAMSAM Code (Reference 31), which is presented in Table 11.1-2, by the RCS expected concentration, which is presented in Table 11.1-9 for each isotope.

d. For isotopes of which design basis RCS equilibrium concentration, calculated by is less than the expected concentration, the expected concentration is used for conservatism.

e. Particulates and iodines are assumed to be removed by pretreatment equipment. Therefore, only the total effective dose equivalent (TEDE) from external exposure to noble gases is calculated in this analysis.

The equation used to calculate the dose consequences for failures in the GRS, which is consistent with BTP 11-5 (Reference 14), is as follows:

$$D = \sum_{i} K(i) \cdot Q(i) \cdot \chi/Q$$

Where:

D	=	total effective dose equivalent, mSv
K(i)	=	dose conversion factor given in USEPA Federal Guidance Report No. 12 (Reference 32) for the ith isotope, $mSv \cdot m^3/Bq \cdot sec$
χ/Q	=	short-term accident atmospheric dispersion factor for 2 hours at exclusion area boundary (EAB), sec/m^3
Q(i)	=	noble gas release rate of the ith isotope for 2 hours calculated using the following equation, Bq $Q(i) = [R(i)_n + R(i)_a] \cdot MF(i)$
$R(i)_n$	=	gaseous effluent release rate due to normal operation for 2 hours, Bq
$R(i)_a$	=	gaseous effluent release rate due to GRS system failure for 2 hours, Bq

Dose consequence is calculated using RADTRAD Code (Reference 33). As presented in Table 11.3-9, the calculated TEDE at the EAB is 0.0316 mSv, which is less than the acceptance criterion of 1 mSv specified in the Standard Review Plan, Section 11.3 (Reference 5).

The COL applicant is to perform an analysis using site-specific meteorological data to demonstrate that the potential airborne concentration resulting from GRS failure meets the requirements of 10 CFR 20, Appendix B, Table 2 (Reference 3) (COL 11.3(8)).

11.3.3.3 Offsite Dose Calculation Manual

The offsite dose calculation manual is prepared using NEI's generic offsite dose calculation manual (ODCM) template, NEI 07-09A. The COL applicant is to prepare an offsite dose calculation manual (ODCM) according to NEI 07-09A (Reference 34) (COL 11.3(9)).

11.3.4 Process Vent Subsystem

The process vent portion of the GWMS is designed to collect the low-activity aerated gas streams from the potentially contaminated HVAC vent headers in the containment building, auxiliary building, turbine generator building, and compound building. The process vents, except the condenser vacuum system vent, are monitored, filtered, and released through the building HVAC systems. The condenser vacuum system is monitored and then discharged without filtration.

Building HVAC systems are described in Section 9.4. Figure 11.3-2 is a simplified process flow diagram.

For non-safety building HVAC systems, initial performance tests are performed to verify the operability of the components, instrumentation, and control equipment. Non-safety-related ventilation systems are tested in accordance with NRC RG 1.140 (Reference 10). Periodic visual inspections and preventive maintenance are conducted according to normal industry practices. Safety-related ventilation systems are tested in accordance with NRC RG 1.52 (Reference 9) and as required by the Technical Specifications.

11.3.5 Testing and Inspection Requirements

The GWMS does not have a safety-related function, and inservice inspection of the components is, therefore, not required.

The GWMS is pneumatically pressure tested in conformance with Regulatory Position C.4.4 of NRC RG 1.143 (Reference 2). Testing of piping systems is performed in accordance with the applicable codes and standards as described in Table 11.3-2.

Inspections and tests are conducted for the periodic evaluation of system operability and performance in accordance with NRC RG 1.143 (Reference 2).

11.3.5.1 Instrumentation Testing Requirements

Periodic tests and calibrations are performed on the analyzers and instrumentation channels during normal operation. These tests and calibrations provide confidence that projected gaseous effluent releases are ALARA, and that the explosive gas mixture concentration is less than the flammability limit.

The discharge isolation valves are designed to close upon the receipt of a high-radiation signal. This function can be verified by simulating the high-radiation signal to the discharge valves so they close automatically. Simulating the high-radiation alarm signal confirms the proper operation of the discharge valve closure.

11.3.5.2 Preoperational Inspection

After installation, but prior to initial system operation, the GWMS is tested to verify pressure integrity, design flow conditions, and instrumentation and control operability. Periodically during operation, tests of the GWMS automatic functions and alarms are performed, and instrumentation is checked. Gauges and instrumentations are calibrated at proper time intervals.

11.3.6 Instrumentation Requirements

Table 11.3-8 provides a list of instrumentation for the GWMS. Instrumentation in contact with process streams is designed to minimize the potential for explosion. Manual override capability of automatic controls is provided where necessary to maintain system operability. For the equipment operated manually, remote manual hand switches with status lights are provided for all frequently operated valves and components. The description of the radiation monitoring system interfaces with the MCR is provided in Section 11.5.

11.3.7 Combined License Information

COL 11.3(1) The COL applicant is to confirm the implementation milestones for the coating program in the GWMS.

COL 11.3(2) The COL applicant is to perform a site-specific cost-benefit analysis to demonstrate compliance with NRC RG 1.110.

COL 11.3(3) The COL applicant is to provide the piping instrumentation diagram (P&ID).

COL 11.3(4) The COL applicant is to prepare the operational procedures and maintenance programs related to leak detection and contamination control.

COL 11.3(5) The COL applicant is to maintain complete documentation of system design, construction, design modifications, field changes, and operations.

COL 11.3(6) The COL applicant is to prepare the site process control program and the site radiological environmental monitoring program.

COL 11.3(7) The COL applicant is to calculate doses to members of the public following the guidance of NRC RG 1.109 and NRC RG 1.111, using site-specific parameters, and is to compare the doses from gaseous effluents with the numerical design objectives of 10 CFR 50, Appendix I, and in compliance with requirements of 10 CFR 20.1302 and 40 CFR 190.

COL 11.3(8) The COL applicant is to perform an analysis using site-specific meteorological data to demonstrate that the potential airborne concentration resulting from a GWMS failure meets 10 CFR 20, Appendix B, Table 2.

COL 11.3(9) The COL applicant is to prepare an offsite dose calculation manual (ODCM) according to NEI 07-09A.

11.3.8 References

1. NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors," 1985.

2. NRC RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, 2001.

3. 10 CFR 20, Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage."

4. 10 CFR 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents."

5. Standard Review Plan, Section 11.3, "Gaseous Waste Management System," NUREG-0800, U.S. Nuclear Regulatory Commission, March 2007.

6. NRC RG 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," Rev. 1, U.S. Nuclear Regulatory Commission, March 2007.

7. ANSI/ANS 18.1-1999, "Radioactive Source Term for Normal Operation of Light-Water Reactors," 1999.

8. ANSI/ANS 55.4, "Gaseous Radioactive Waste Processing System for Light Water Reactor Plants," 1993.

9. NRC RG 1.52, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants," U.S. Nuclear Regulatory Commission, June 2001.

10. NRC RG 1.140, "Design, Testing, and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light Water Cooled Nuclear Power Plants," U.S. Nuclear Regulatory Commission, June 2001.

11. General Design Criterion 60, “Control of Releases of Radioactive Materials to the Environment,” 10 CFR 50, Appendix A.

12. General Design Criterion 61, “Fuel Storage and Handling and Radioactivity Control,” 10 CFR 50, Appendix A.

13. General Design Criterion 64, “Monitoring Radioactivity Releases,” 10 CFR 50, Appendix A.

14. Branch Technical Position (BTP) 11-5, “Postulated Radioactive Release Due to Waste System Leak or Failure,” March 2007.

15. NRC RG 8.8, “Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable,” U.S. Nuclear Regulatory Commission, 1978.

16. 10 CFR 50, Appendix A, “General Design Criteria for Nuclear Power Plants.”

17. NRC RG 1.54, “Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants,” Rev. 2, U.S. Nuclear Regulatory Commission, October 2010.

18. IE Bulletin No. 80-10, “Contamination of Nonradioactive System and Resulting Potential for Unmonitored, Uncontrolled Release of Radioactivity to Environment,” U.S. Nuclear Regulatory Commission, May 6, 1980.

19. NRC RG 4.21, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning,” U.S. Nuclear Regulatory Commission, June 2008.

20. ASME Section II, “Material Specification.”

21. NRC RG 1.33, “Quality Assurance Program Requirements (Operation),” U.S. Nuclear Regulatory Commission, February 1978.

22. NRC RG 1.189, “Fire Protection for Nuclear Power Plants,” Rev. 2, U.S. Nuclear Regulatory Commission, October 2009.

23. 10 CFR 20.1406, “Minimization of Contamination.”

24. NRC RG 1.110, “Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors,” U.S. Nuclear Regulatory Commission, March 1976.

25. ASME Section VIII, "Rules for Construction of Pressure Vessels"

26. NUREG/CR-4653, GASPAR II Technical Reference and User Guide, U.S. Nuclear Regulatory Commission, Washington, DC, March 1987.

27. NRC RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I," U.S. Nuclear Regulatory Commission, 1977.

28. NRC RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous effluents in Routine Releases from Light-Water-Cooled Reactors," Rev. 1, U.S. Nuclear Regulatory Commission, July 1977.

29. 10 CFR 20.1302, "Compliance with Dose Limits for Individual Members of the Public."

30. 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

31. DAMSAM, "A Digital Computer Program to Calculate Primary and Secondary Activity Transients," Combustion Engineering, Inc.

32. USEPA Federal Guidance Report No. 12, "External Exposure to Radionuclides in Air, Water, and Soil," 1993.

33. NUREG/CR, "RADTRAD: A Simplified Model for RADionuclide Transport and Removal and Dose Estimation," June 1999.

34. NEI 07-09A, "Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM) Program Description." Rev.0, March 2009.

Table 11.3-1 (1 of 2)

Expected Gaseous Radioactive Effluents During Normal Operation Including AOOs (Bq/yr)

Nuclide	Waste Gas System	Building Ventilation				Air Ejector Exhaust	Total
		Fuel Handling	Reactor	Auxiliary	Turbine		
I-131	0.00E+00	1.07E+07	3.15E+07	2.59E+07	0.00E+00	0.00E+00	6.66E+07
I-132	0.00E+00	3.03E+08	7.40E+08	7.40E+08	0.00E+00	0.00E+00	1.78E+09
I-133	0.00E+00	1.37E+08	3.70E+08	3.29E+08	0.00E+00	0.00E+00	8.51E+08
I-134	0.00E+00	4.81E+08	1.22E+09	1.22E+09	0.00E+00	0.00E+00	2.92E+09
I-135	0.00E+00	2.81E+08	7.40E+08	6.66E+08	0.00E+00	0.00E+00	1.70E+09
Kr-85m	0.00E+00	0.00E+00	2.59E+11	0.00E+00	0.00E+00	0.00E+00	2.59E+11
Kr-85	6.66E+13	0.00E+00	1.15E+14	9.25E+11	0.00E+00	4.44E+11	1.81E+14
Kr-87	0.00E+00	0.00E+00	7.40E+10	0.00E+00	0.00E+00	0.00E+00	7.40E+10
Kr-88	0.00E+00	0.00E+00	1.85E+11	0.00E+00	0.00E+00	0.00E+00	1.85E+11
Xe-131m	3.63E+12	0.00E+00	7.77E+13	7.03E+11	0.00E+00	3.33E+11	8.14E+13
Xe-133m	0.00E+00	0.00E+00	4.81E+12	7.40E+10	0.00E+00	0.00E+00	4.81E+12
Xe-133	0.00E+00	0.00E+00	2.59E+12	0.00E+00	0.00E+00	0.00E+00	2.59E+12
Xe-135m	0.00E+00	0.00E+00	1.48E+11	1.11E+11	0.00E+00	3.70E+10	2.96E+11
Xe-135	0.00E+00	0.00E+00	1.85E+12	3.70E+10	0.00E+00	0.00E+00	1.89E+12
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+11	1.11E+11
Xe-138	0.00E+00	0.00E+00	7.40E+10	3.70E+10	0.00E+00	0.00E+00	1.11E+11
Cr-51	5.18E+03	6.66E+04	3.40E+06	1.18E+05	0.00E+00	0.00E+00	3.59E+06
Mn-54	7.77E+02	1.11E+05	1.96E+06	2.89E+04	0.00E+00	0.00E+00	2.11E+06
Co-57	0.00E+00	0.00E+00	3.03E+05	0.00E+00	0.00E+00	0.00E+00	3.03E+05
Co-58	3.22E+03	7.77E+06	9.25E+06	7.03E+05	0.00E+00	0.00E+00	1.78E+07
Co-60	5.18E+03	3.03E+06	9.62E+05	1.89E+05	0.00E+00	0.00E+00	4.07E+06
Fe-59	6.66E+02	0.00E+00	9.99E+05	1.85E+04	0.00E+00	0.00E+00	1.04E+06
Sr-89	1.63E+04	7.77E+05	4.81E+06	2.78E+05	0.00E+00	0.00E+00	5.92E+06
Sr-90	6.29E+03	2.96E+05	1.92E+06	1.07E+05	0.00E+00	0.00E+00	2.33E+06
Zr-95	1.78E+03	1.33E+03	0.00E+00	3.70E+05	0.00E+00	0.00E+00	3.70E+05

Table 11.3-1 (2 of 2)

Nuclide	Waste Gas System	Building Ventilation				Air Ejector Exhaust	Total
		Fuel Handling	Reactor	Auxiliary	Turbine		
Nb-95	1.37E+03	8.88E+05	6.66E+05	1.11E+04	0.00E+00	0.00E+00	1.55E+06
Ru-103	1.18E+03	1.41E+04	5.92E+05	8.51E+03	0.00E+00	0.00E+00	6.29E+05
Ru-106	9.99E+02	2.55E+04	0.00E+00	2.22E+03	0.00E+00	0.00E+00	2.89E+04
Sb-125	0.00E+00	2.11E+04	0.00E+00	1.44E+03	0.00E+00	0.00E+00	2.26E+04
Cs-134	1.22E+04	6.29E+05	9.25E+05	2.00E+05	0.00E+00	0.00E+00	1.78E+06
Cs-136	1.96E+03	0.00E+00	1.18E+06	1.78E+04	0.00E+00	0.00E+00	1.22E+06
Cs-137	2.85E+04	9.99E+05	2.04E+06	2.66E+05	0.00E+00	0.00E+00	3.33E+06
Ba-140	8.51E+03	0.00E+00	0.00E+00	1.48E+05	0.00E+00	0.00E+00	1.55E+05
Ce-141	8.14E+02	1.63E+02	4.81E+05	9.62E+03	0.00E+00	0.00E+00	4.81E+05
H-3							5.92E+12
C-14							2.70E+11
Ar-41							1.26E+12

Table 11.3-2

Equipment Codes and Standards for Radwaste Equipment
(from NRC RG 1.143, Table 1)

Equipment	Design and Fabrication	Material	Welder Qualifications and Procedures	Inspection and Testing
Pressure Vessels	ASME Sec. VIII, Div. 1 or Div. 2	ASME Sec. II	ASME Sec. IX	ASME Sec. VIII, Div. 1 or Div. 2
Piping and Valves	ASME B31.3	ASME Sec. II	ASME Sec. IX	ASME B31.3
Filters	ASME Sec. VIII, Div. 1	ASME Sec. II	ASME Sec. IX	ASME Sec. VIII, Div. 1

Table 11.3-3

System Design Parameters

Design Parameter	Design Value
Xenon delay	45 days
Dynamic adsorption coefficient Kd for Xe	263 cc/g
Dynamic adsorption coefficient Kd for Kr	18.7 cc/g
Maximum gaseous waste stream temp, °C (°F)	60 (140)
Charcoal temperature, °C (°F)	10 to 40 (50 to 104)
Plant Chilled Water Temperature, °C (°F)	5.8 (42.5)
CCW temperature, °C (°F)	43.3 (110)
Minimum activated charcoal ignition temperature, °C (°F)	156.1 (313)
Gas flow range L/min (scfm)	0 to 28.3 (0 to 1.2)
Charcoal bed vault temperature range, °C (°F)	10 to 40 (50 to 104)
Charcoal particle size	6-12 mesh (USS) with 90 to 100 percent retention
Charcoal moisture content	2.0 percent maximum

Table 11.3-4 (1 of 2)

GWMS Major Equipment Design Information

Tanks	
Equipment name Quantity (each) Design capacity, L (ft^3) Design pressure, kg/cm^2 (psig) Design temperature, °C (°F) [[Material]] Radwaste safety class	Header drain tank 1 566 (20) 10.5 (150) 93.3 (200) Stainless steel RW-IIa
Equipment name Quantity (each) Total mass of charcoal, kg (lbm) Design flow, L/min (scfm) Design pressure, kg/cm^2 (psig) Design temperature, °C (°F) [[Material]] Radwaste safety class	Charcoal guard bed (GRS package) 2 272 (600) 623 (22) 10.5 (150) 93.3 (200) Stainless steel RW-IIa
Equipment name Quantity (each) Total mass of charcoal, kg (lbm) Design flow, L/min (scfm) Design pressure, kg/cm^2 (psig) Design temperature, °C (°F) [[Material]] Radwaste safety class	Charcoal delay bed (GRS package) 4 9,525 (21,000) 57 (2) 10.5 (150) 93.3 (200) Carbon steel RW-IIa
Equipment name Quantity (each) Size, µm Efficiency, % Design flow, L/min (scfm) Design pressure, kg/cm^2 (psig) Design temperature, °C (°F) [[Material]] Radwaste safety class	HEPA filter (GRS package) 1 0.3 99.97 (1) 2548 (90) 10.5 (150) 93.3 (200) Stainless steel RW-IIa

Table 11.3-4 (2 of 2)

Heat Exchanger	
Equipment name	Waste gas dryer (GRS package)
Quantity (each)	2
Design flow, L/min (scfm)	623 (22)
Outlet temperature, °C (°F)	7.8 (46)
Design pressure, kg/cm^2 (psig)	10.5 (150)
Design temperature, °C (°F)	93.3 (200)
[[Material]]	Stainless steel
Radwaste Safety Class	RW-IIa

(1) Efficiency of this HEPA filter is not credited in the PWR-GALE Code calculation.

Table 11.3-5

Input Parameters for the GASPAR II Code

Parameter	Value
Midpoint of plant life (years)	30
Distance to site boundary (m)	700
Fraction of the year that leafy vegetables are grown	1.0
Fraction of the year that milk cows are grown	1.0
Fraction of the maximum individual’s vegetable intake that is from his own garden	0.76
Fraction of milk-cow feed intake that is from pasture while on pasture.	1.0
Average absolute humidity over the growing season(g/m^3)	8.0
Fraction of the year that beef cattle are on pasture	1.0
Fraction of beef-cattle feed intake that is from pasture while the cattle are on pasture	1.0
Source term multiplier to be applied to each radionuclide release	1.0
Source terms	See Table 11.3-1
Milk Pathway Considered	Goat
χ/Q at EAB (sec/m^3)	2.0E-05
χ/Q at food production area (sec/m^3)	1.0E-05
D/Q (m^{-2})	2.0E-07
Other parameters	NRC RG 1.109

Table 11.3-6 (1 of 2)

Design Basis Gaseous Effluent Concentration at the Site Boundary

Nuclide	Design Basis Release[(1)] (Bq/yr)	Effluent Concentration (Bq/m^3)	10 CFR 20 Appendix B Limits (Bq/m^3)	Ratio
H-3	2.08E+13	1.32E+01	3.70E+03	3.56E-03
C-14	2.70E+11	1.71E-01	1.11E+04	1.54E-05
Ar-41	1.26E+12	7.98E-01	3.70E+02	2.16E-03
I-131	3.62E+09	5.15E-02	7.40E+00	6.96E-03
I-132	6.00E+09	1.30E-02	7.40E+02	1.76E-05
I-133	2.17E+10	7.32E-02	3.70E+01	1.98E-03
I-134	3.87E+09	8.14E-03	2.22E+03	3.67E-06
I-135	1.33E+10	3.90E-02	2.22E+02	1.76E-04
Kr-85m	1.32E+12	8.11E+00	3.70E+03	2.19E-03
Kr-85	3.04E+12	1.15E+02	2.59E+04	4.44E-03
Kr-87	3.91E+11	2.13E+00	7.40E+02	2.88E-03
Kr-88	1.33E+12	1.27E+01	3.33E+02	3.82E-02
Xe-131m	8.14E+13	1.15E+01	7.40E+04	1.55E-04
Xe-133m	4.81E+12	3.05E+00	2.22E+04	1.37E-04
Xe-133	2.37E+13	1.31E+03	1.85E+04	7.09E-02
Xe-135m	1.42E+12	8.74E-01	1.48E+03	5.91E-04
Xe-135	7.79E+12	6.09E+01	2.59E+03	2.35E-02
Xe-137	4.93E+11	3.04E-01	-	-
Xe-138	4.93E+11	5.98E-01	7.40E+02	8.08E-04
Cr-51	1.55E+07	9.85E-06	1.11E+03	8.88E-09
Mn-54	2.11E+06	1.34E-06	3.70E+01	3.61E-08
Co-57	3.03E+05	1.92E-07	3.33E+01	5.78E-09
Co-58	1.78E+07	1.13E-05	3.70E+01	3.04E-07
Co-60	4.07E+06	2.58E-06	1.85E+00	1.39E-06
Fe-59	1.04E+06	6.57E-07	1.85E+01	3.55E-08

Table 11.3-6 (2 of 2)

Nuclide	Design Basis Release(1) (Bq/yr)	Effluent Concentration (Bq/m^3)	10 CFR 20 Appendix B Limits (Bq/m^3)	Ratio
Sr-89	1.34E+08	8.51E-05	7.40E+00	1.15E-05
Sr-90	4.21E+07	2.67E-05	2.22E-01	1.20E-04
Zr-95	5.57E+05	3.53E-07	1.48E+01	2.39E-08
Nb-95	2.77E+06	1.76E-06	7.40E+01	2.38E-08
Ru-103	6.29E+05	3.99E-07	3.33E+01	1.20E-08
Ru-106	2.89E+04	1.83E-08	7.40E-01	2.47E-08
Sb-125	2.26E+04	1.43E-08	2.59E+01	5.52E-10
Cs-134	7.89E+07	9.60E-03	7.40E+00	1.30E-03
Cs-136	6.00E+07	3.80E-05	3.33E+01	1.14E-06
Cs-137	1.29E+08	1.45E-02	7.40E+00	1.96E-03
Ba-140	1.55E+05	9.85E-08	7.40E+01	1.33E-09
Ce-141	4.81E+05	3.05E-07	2.96E+01	1.03E-08
			SUM	1.62E-01

(1) The design basis release rates are adjusted from the expected values in Table 11.3-1 using multiplication factors, which are the ratios of design basis RCS concentrations to expected concentrations. If a multiplication factor is less than 1, a value of 1 is used for conservatism.

Table 11.3-7 (1 of 3)

Maximum Offsite Individual Dose Resulting
from Normal Plant Gaseous Releases

Type of Dose	Estimated Dose
Annual beta air dose (mGy/yr)	7.94E-02
Annual gamma air dose (mGy/yr)	6.13E-03
Dose to total body (mSv/yr)	3.79E-03
Dose to skin (mSv/yr)	5.57E-02

Table 11.3-7 (2 of 3)

	Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Plume	3.47E-03							5.53E-02
Ground	3.19E-04	3.19E-04	3.19E-04	3.19E-04	3.19E-04	3.19E-04	3.19E-04	3.74E-04
Vegetable								
Adult		5.03E-03	2.46E-02	4.97E-03	4.92E-03	1.15E-02	4.86E-03	
Teen		7.75E-03	3.88E-02	7.72E-03	7.64E-03	1.57E-02	7.56E-03	
Child		1.77E-02	9.19E-02	1.78E-02	1.77E-02	3.28E-02	1.76E-02	
Meat								
Adult		1.70E-03	7.84E-03	1.66E-03	1.66E-03	1.93E-03	1.65E-03	
Teen		1.40E-03	6.61E-03	1.38E-03	1.37E-03	1.57E-03	1.37E-03	
Child		2.55E-03	1.24E-02	2.55E-03	2.54E-03	2.85E-03	2.54E-03	
Goat milk								
Adult		2.18E-03	9.07E-03	2.43E-03	2.29E-03	1.23E-02	2.18E-03	
Teen		3.77E-03	1.66E-02	4.21E-03	3.97E-03	1.99E-02	3.78E-03	
Child		8.67E-03	4.06E-02	9.46E-03	9.04E-03	4.11E-02	8.71E-03	
Infant		1.75E-02	7.82E-02	1.92E-02	1.82E-02	9.64E-02	1.77E-02	
Inhalation								
Adult		7.54E-04	7.54E-04	7.54E-04	7.54E-04	7.54E-04	7.54E-04	
Teen		7.54E-04	7.54E-04	7.54E-04	7.54E-04	7.54E-04	7.54E-04	

Table 11.3-7 (3 of 3)

	Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Child		6.53E-04	2.05E-05	6.58E-04	6.62E-04	1.64E-03	6.66E-04	
Infant		3.75E-04	1.06E-05	3.81E-04	3.81E-04	1.27E-03	3.85E-04	
Total								
Adult	3.79E-03	9.96E-03	4.18E-02	1.01E-02	9.93E-03	2.74E-02	9.75E-03	5.57E-02
Teen	3.79E-03	1.40E-02	6.23E-02	1.44E-02	1.40E-02	3.90E-02	1.38E-02	5.57E-02
Child	3.79E-03	2.99E-02	1.45E-01	3.08E-02	3.03E-02	7.87E-02	2.98E-02	5.57E-02
Infant	3.79E-03	1.82E-02	7.85E-02	1.99E-02	1.89E-02	9.80E-02	1.84E-02	5.57E-02

Table 11.3-8

Instrument Indication and Alarm Information Page

Equipment	Parameter	Record	Indicate	Alarm		Auto Control
				High	Low	
Waste gas dryer	Outlet cooling water					
	Temperature		×			
	Effluent gas temperature		×	×		
Gas drying or moisture removal	Outlet gas moisture content	×		×		
Charcoal guard bed	Bed temperature		×	×		
Charcoal delay beds	Inlet gas moisture		×	×		
	Inlet gas temperature		×	×		
	Outlet gas temperature		×	×		
System gas analyzers	H_2 concentration (% volume)	×	×			
	O_2 concentration (% volume)	×	×	×		×
System discharge line	Radiation	×	×	×		×
System	Gas flow rate – inlet	×	×			
	Gas flow rate – outlet	×	×			

× = required

Table 11.3-9

Gaseous Waste Management System Failure Doses

GRSF Activity Release Path	GRSF Dose (mSv) Receptor Location	
	EAB	LPZ
Tank Release to Environment	3.16E-02	6.950E-03
Allowable Dose Limit	1.00E+00	1.00E+00

Table 11.3-10

Expected Radioactive Source Terms for GRS Components

Nuclide	Inlet (Bq/cm^3)	Buildup Activity on Charcoal Bed (Bq)				Outlet (Bq/cm^3)
		1st Delay Bed	2nd Delay Bed	3rd Delay Bed	4th Delay Bed	
Kr-85m	1.83E+04	2.09E+11	8.12E+09	3.15E+08	1.22E+07	4.17E-02
Kr-85	1.38E+06	5.30E+13	5.30E+13	5.30E+13	5.30E+13	1.38E+06
Kr-87	1.92E+04	6.47E+10	6.92E+05	7.39E+00	7.90E-05	2.51E-16
Kr-88	2.02E+04	1.51E+11	8.94E+08	5.30E+06	3.15E+04	2.50E-05
Xe-131m	1.00E+06	3.65E+14	1.90E+14	9.85E+13	5.11E+13	7.31E+04
Xe-133m	8.31E+04	1.12E+13	3.19E+11	9.07E+09	2.58E+08	5.42E-02
Xe-133	3.66E+04	9.43E+12	2.13E+12	4.82E+11	1.09E+11	9.56E+01
Xe-135m	1.46E+05	9.83E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-135	7.67E+04	1.85E+12	2.11E+03	2.41E-06	2.75E-15	1.30E-31
Xe-137	3.82E+04	6.45E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	6.92E+04	4.33E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Br-84	2.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	3.08E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-132	8.39E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-133	3.86E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-134	1.43E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-135	7.87E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NOTES

1. THIS VALVE IS SET TO MAINTAIN LOW NITROGEN PURGE TO THE DISCHARGE LINE TO PREVENT AIR FROM GOING INTO THE GRS PACKAGE DURING LOW-LOW OR NO FLOW PERIOD. (COOD : E4)

2. GAS SURGE HEADER IN THE COMPOUND BUILDING TO HAVE ONLY ONE LOW POINT WHICH IS TO BE AT THE INLET TEE TO THE GRS HEADER DRAIN TANK. (COOR : A5)

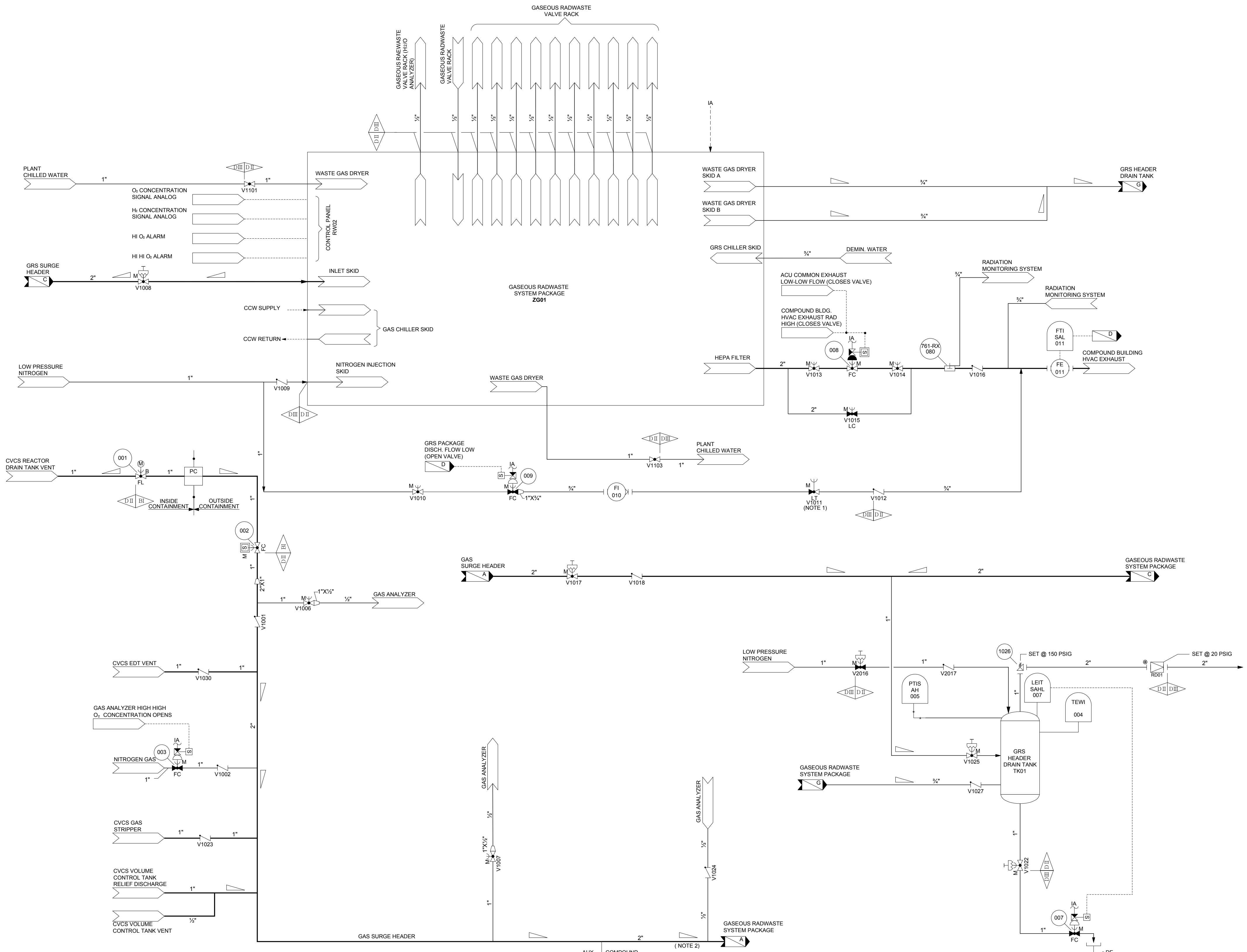


Figure 11.3-1 Gaseous Radwaste System Flow Diagram

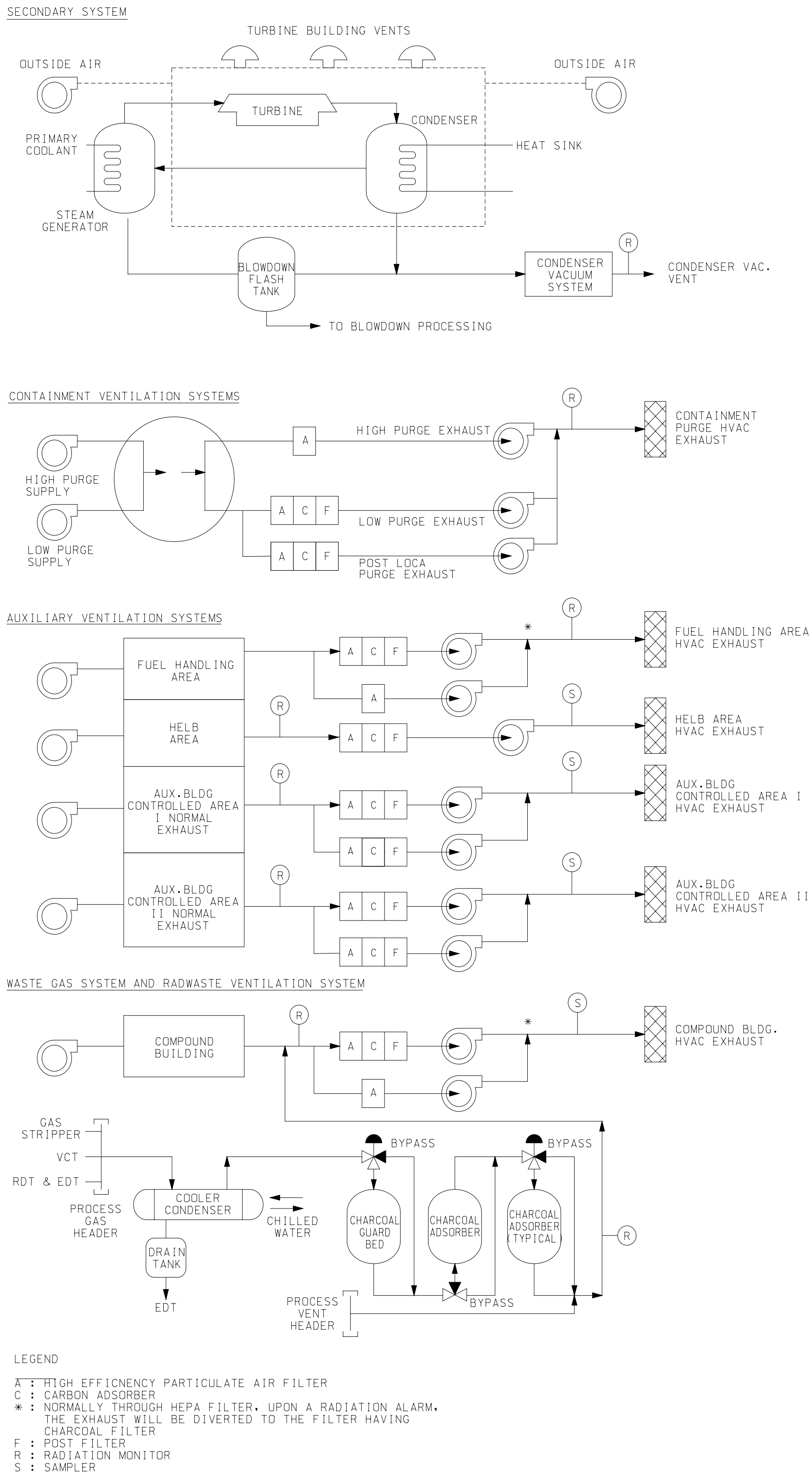
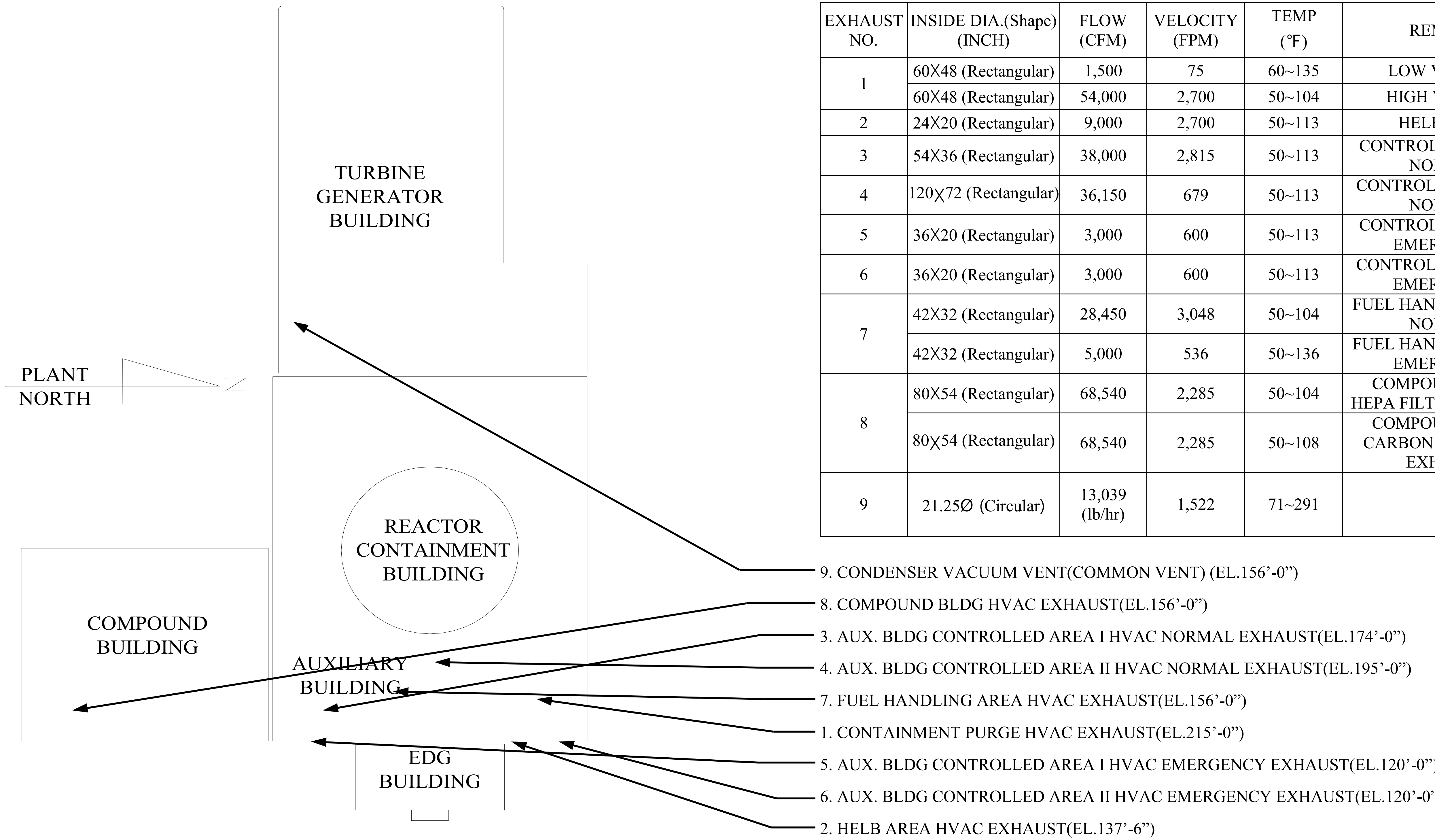


Figure 11.3-2 Simplified Airborne Pathway Release Assessment Process



EXHAUST NO.	INSIDE DIA.(Shape) (INCH)	FLOW (CFM)	VELOCITY (FPM)	TEMP (°F)	REMARK
1	60X48 (Rectangular)	1,500	75	60~135	LOW VOLUME
	60X48 (Rectangular)	54,000	2,700	50~104	HIGH VOLUME
2	24X20 (Rectangular)	9,000	2,700	50~113	HELB AREA
3	54X36 (Rectangular)	38,000	2,815	50~113	CONTROLLED AREA I NORMAL
4	120X72 (Rectangular)	36,150	679	50~113	CONTROLLED AREA II NORMAL
5	36X20 (Rectangular)	3,000	600	50~113	CONTROLLED AREA I EMERGENCY
6	36X20 (Rectangular)	3,000	600	50~113	CONTROLLED AREA II EMERGENCY
7	42X32 (Rectangular)	28,450	3,048	50~104	FUEL HANDLING AREA NORMAL
	42X32 (Rectangular)	5,000	536	50~136	FUEL HANDLING AREA EMERGENCY
8	80X54 (Rectangular)	68,540	2,285	50~104	COMPOUND BLDG HEPA FILTER EXHAUST
	80X54 (Rectangular)	68,540	2,285	50~108	COMPOUND BLDG CARBON ADSORBER EXHAUST
9	21.25Ø (Circular)	13,039 (lb/hr)	1,522	71~291	

Figure 11.3-3 Gaseous Effluent Release Points and Exhaust Parameters