# 11.3 GASEOUS WASTE MANAGEMENT SYSTEMS

The Gaseous Waste Management System (GWMS) includes systems that process potential sources of airborne radioactive releases during normal operation and anticipated operational occurrences. The GWMS includes the offgas system and various ventilation systems. These systems reduce radioactive gaseous releases from the plant by filtration or delay, which allows decay of radioactive materials prior to release.

The offgas system collects and delays the release of non-condensable radioactive gases removed from the main condenser by the air ejectors during normal plant operation. Plant ventilation systems process airborne radioactive releases from other plant sources, such as equipment leakage, maintenance activities, and the steam seal system as detailed in Section 9.4.

## 11.3.1 DESIGN BASES

The objectives and criteria, which form the bases for the design of the GWMS, are as follows:

a. The GWMS is designed to control and monitor the release of radioactive materials in gaseous effluents in accordance with GDC 60 and 64.

b. The GWMS is designed to limit offsite doses from routine station releases to less than the limits specified in 10CFR20, and to operate within the dose objectives established in 10CFR50, Appendix I.

c. The GWMS is designed to keep exposures to plant personnel ALARA while those personnel are conducting normal plant operation and maintenance activities.

d. The design basis and expected source terms correspond to fuel defects that result in a noble gas release rate of 100,000 and 50,000 μCi/sec, respectively, after a 30-minute delay.

e. The assumptions and parameters used for evaluating expected gaseous radioactive releases are based upon NUREG 0016, Revision 1 (Reference 11.3-4) and are listed in Tables 11.2-8, 11.3-2, and 11.3-4.

f. Filtration units in the ventilation systems are designed, operated, and maintained in accordance with the design bases presented in Section 9.4. Table 11.3-4 provides a listing of the filter trains that are used to control gaseous releases.

g. Continuous monitoring is provided for those pathways with significant potential for airborne radioactive releases.

h. A description of the major equipment items in the offgas system is provided in Table 11.3-5. The seismic and quality group classifications of the GWMS components, piping and structures housing them are listed in Section 3.2. The differences in "as-built" configuration of the Unit 2 portion of GWMS piping in regard to quality group "D" classification and stem leak-off connection to valves are shown in Dwgs. M-2169, Sh. 1 and M-2171, Sh. 1.

i. Conservative analyses, similar to those presented in Reference 11.3-1, demonstrate that equipment failure cannot result in doses exceeding acceptable guidelines; thus, neither the offgas system nor the buildings housing the equipment are required to meet Seismic Category I requirements. However, the offgas system is contained in the Turbine and Radwaste buildings, and the offgas vent is routed through the Reactor Building. The Reactor Building is Seismic Category I as described in Section 3.2. Turbine and Radwaste building structural walls are part of the total structural system and were analzyed to withstand a safe shutdown earthquake.

j. The GWMS is designed with sufficient capacity and redundancy to accommodate anticipated processing requirements during normal operation including anticipated operational occurrences.

k. Instrumentation is provided in the offgas system to detect abnormal concentrations of hydrogen and other system malfunctions.

l. The pressure boundary of the offgas system, consisting of piping and major components, is designed to either withstand the effects of multiple hydrogen detonations or to preclude the existence of a detonable gas mixture.

## 11.3.2 SYSTEM DESCRIPTIONS

### 11.3.2.1 Offgas System

Non-condensable radioactive offgas is removed from the main condenser by the mechanical vacuum pump (MVP), during startup and hot shutdown or by the steam jet air ejector (SJAE) during plant operation. The offgas consists of activation gases, fission product gases, radiolytic hydrogen and oxygen, and condenser air in-leakage. The SJAE offgas normally contains activation gases, principally N-16, O-19, and N-13. The N-16 and O-19 have short half-lives

and are readily decayed. The N-13 isotope, with a 10-minute half-life, is present in small amounts that is further reduced by delay provided in the design of the offgas system. The SJAE offgas will also contain various isotopes of the radioactive noble gases, xenon and krypton, that are precursors of biologically significant Sr-89, Sr-90, Ba-140, and Cs-137. The concentration of these noble gases depends on the amount of tramp uranium in the coolant and on the cladding surfaces and the number and size of fuel cladding leaks.

The common offgas recombiner system receives up to a 5 scfm low flow purge air from the service air system when the common offgas recombiner is in standby. The purpose of the low flow purge air is to dilute hydrogen in the common offgas recombiner and move it into the aligned Unit 1 or Unit 2 ambient temperature charcoal offgas system.

The offgas system is designed to reduce the radioactivity in the offgas to permissible levels for release under all site atmospheric conditions. The system utilizes catalytic recombination for volume reduction and control of hydrogen concentration. Selective adsorption of fission product gases on activated carbon is used to provide time for delay of short-lived radioisotopes before release.

The building layout and equipment location of the offgas system components is shown on Dwgs. M-220, Sh. 1, M-230, Sh. 1, M-272, Sh. 1, M-273, Sh. 1, and M-274, Sh. 1.

#### 11.3.2.1.1 Process Flow Description

Figure 11.3-1 is the process flow diagram for the offgas system. The process data for startup and normal operating conditions are contained in Table 11.3-8. The P&IDs are shown as Dwgs:

| | | | |
|---|---|---|---|
| M-169, Sh. 1 | M-169, Sh. 2 | M-169, Sh. 3 | M-169, Sh. 4 |
| M-2169, Sh. 1 | M-2169, Sh. 2 | M-2171, Sh. 1 | M-2171, Sh. 2. |
| M-171, Sh. 1 | M-171, Sh. 2 | | |

During startup or shutdown of a unit, the MVP is used to draw or maintain a vacuum on the main condenser as described in Section 10.4.2. The MVP discharge bypasses the offgas recombiner and treatment systems and enters the turbine building exhaust vent downstream of the filter units. Any activity in the MVP discharge mixes with the turbine building vent flow and is monitored by the vent sampling system. The MVP is typically used to maintain vacuum prior to and during reactor heat-up to support condensate de-aeration and flushing of the condensate and feedwater systems. Operation of the vacuum pump is limited to 5% power in order to avoid the formation of explosive gas mixtures in the pump, water separator and discharge piping.

When sufficient steam pressure is available, the offgas system (which requires steam for the recombiner preheater) and the two-stage SJAE train, consisting of 4 parallel primary stage air ejectors and one secondary stage ejector, are placed into service using main steam. Alternatively, clean steam from the auxiliary boilers may be used to drive the SJAE and the recombiner system to minimize the operation of the MVP and the release of fission gases to the turbine building vent.

The non-condensable gases in the main turbine condenser are removed by the SJAE and discharged to the offgas recombiner system. For an in-service recombiner Steam is used to dilute hydrogen in the offgas to less than the flammability limit in air from the discharge of the secondary steam jet through the recombiner to the recombiner condenser. Additional dilution steam is provided by a bypass loop around the ejector nozzle to the discharge. This arrangement allows adjusting the total steam flow for dilution without sacrificing SJAE performance. Piping and components from the dilution steam injection point to the recombiner condenser inlet are electrically heat traced to prevent condensation of the dilution steam, particularly during cold start-up.

For the common offgas recombiner system in standby, low flow purge air is used to dilute hydrogen in the common offgas recombiner system to less than the flammability limit in air. The low flow purge air dilutes hydrogen from the common offgas recombiner skid inlet through to the aligned Unit 1 or Unit 2 ambient temperature charcoal offgas system.

There are three offgas recombiner systems, one for each unit and a common system that can be used by either unit when necessary. The purpose of the recombiner system is to reduce the offgas volume and to eliminate the potential for an explosion. To support the operation of Hydrogen Water Chemistry, oxygen is injected upstream of the recombiner system at a flow rate of approximately one half the hydrogen injection rate (Reference Subsection 9.5.9 for a description of the system). In the recombiner, hydrogen reacts with oxygen in a controlled manner within a catalyst bed. The hydrogen concentration is reduced to less than 1% concentration by volume on a dry basis of 5 scfm air flow and less than 0.5% concentration for an air flow of at least 10 scfm. When the common offgas recombiner is in standby, the hydrogen concentration is reduced to less than 1% concentration by volume by use of the low flow purge air.

The offgas first passes through the recombiner preheater in order to minimize the moisture content prior to entering the catalyst bed. The recombination process takes place inside the recombiner vessel that is electrically preheated during standby by strip heaters on the outside. The reaction temperature is approximately 800°F.

The water vapor in the offgas leaving the recombiner vessel is removed in the recombiner condenser where the offgas is cooled. A motive steam jet then boosts the saturated gas stream pressure from below to slightly above atmospheric pressure.

The reduced pressure main, or auxiliary, motive steam used in the motive jet is removed from the offgas stream in the motive steam jet condenser. The offgas then passes through a delay pipe from the recombiner system in the turbine building to the ambient temperature charcoal offgas system in the radwaste building.

The pressure differential between the condensers in the recombiner systems and the main condenser is sufficient to drain the condensate without additional motive force to the main condenser, while the delay pipe is drained by level controlled valves to the turbine building radwaste sump.

The delay line consists of approximately 689 ft. of 8 in. diameter and 60 ft. of 16 in. diameter piping. At a nominal flow rate of 21.8 scfm, this pipe provides for 12.9 minutes of decay of the radioactive isotopes in the offgas stream prior to entering the adsorption train.

After exiting this line, the gas is cooled to approximately 40°F by a refrigerated chiller unit to condense and remove moisture. The offgas flow is reheated to approximately 65°F to provide a dehumidified (dew point of 40°F) air flow to the activated carbon absorber train. This is necessary to maintain the carbon moisture content ≤ 5%. Moisture and temperature instrumentation measure the process conditions downstream of the chiller to monitor the performance of the water removal assemblies and to guard against degraded activated carbon performance that might result from either an increase in the moisture content or temperature of the gas.

Prior to entering the main activated carbon vessels, the process stream passes through a sacrificial guard bed. The principal function of this guard bed is to protect the main carbon beds against moisture and other contaminants when the dehumidification section is inoperable. Each guard bed has been sized to absorb the moisture that might result from a failure of the chiller over a period of approximately 40 hours. This design feature, in conjunction with the moisture and temperature instrumentation, provides protection against the contamination of the activated carbon adsorber bed. Differential pressure indication is provided.

After passing through the guard bed, the gas enters the main activated carbon adsorption bed. This bed, operating in a controlled temperature vault, selectively adsorbs and delays the xenon and krypton from the bulk carrier gas. This delay on the activated carbon permits the radioactive xenon and krypton isotopes to decay in place. Upon exiting the adsorber beds, the process stream passes through a HEPA outlet filter, where radioactive particulate matter and

activated carbon fines are retained. Taps are provided to take effluent samples, if desired, to determine the efficiency of the adsorber system.

The process stream is then directed to the turbine building ventilation exhaust duct where it is diluted, with a minimum of 42,000 scfm of air, prior to being released from the top of the reactor building.

Table 11.3-1 provides the estimated annual expected isotopic activity released from the GWMS based upon assumptions and parameters given in Tables 11.2-8, 11.3-2, 11.3-4 and NUREG 0016, Revision 1.

11.3.2.1.2 Activated Carbon Holdup Time

After passing through the recombiner section, the off gas stream consists primarily of the air in-leakage from the main condenser and the air from the common offgas recombiner low flow purge.

From NUREG 0016, Revision 1, the xenon and krypton holdup times are closely approximated by the following equation:

$$T = 0.26 \frac{MK}{F} \quad \text{(Equation 11.3-1)}$$

$$= 43.1 \frac{MK}{P^*}$$

*NUREG 0016, Revision 1, recommends the use of 0.0062 scfm/MWt when assessing routine radioactive releases and doses (per Equation 11.3-1).

Where:

- T = holdup time (hours)
- K = dynamic adsorption coefficient ($cm^3$/gm)
- M = mass of activated carbon adsorber ($10^3$ lbs)
- P = thermal power level ($MW_t$)
- F = offgas flowrate ($cm^3$/min)

The Sixth Edition of the Heat Exchange Institute Standards for Steam Surface Condensers (Reference 11.3-3, paragraph 5.16(c)(2)) indicates that with certain conditions of stable operation and suitable construction, non-condensable gases should not exceed 6 scfm per shell

for large condensers. The Susquehanna SES has three shells per condenser resulting in an anticipated in-leakage of 18 scfm. Dynamic adsorption coefficients used to determine the holdup times are discussed in NUREG 0016 and are a function of carbon type, temperature, and moisture content. The values used in the analysis are based on the manufacturer demonstrated values of 516 $cm^3$/gm for xenon and 36 $cm^3$/gm for krypton. The offgas treatment system contains 74 tons of activated carbon, excluding the guard beds. With the above dynamic adsorption coefficients and a combination condenser air in leakage and low flow purge air rate of approximately 21.8 scfm, the system provides holdup times of 39 days for xenon and 2.7 days for krypton.

#### 11.3.2.1.3 Detonation Resistance

The SSES offgas treatment system is designed to either withstand multiple hydrogen detonations or to preclude the existence of a detonable gas mixture. The system has been analyzed utilizing a conservative design method as a guideline (Reference 11.3-5) for calculating equipment and piping wall thickness capable of withstanding multiple internal hydrogen detonations such that the system pressure boundary will be useable without repair or subsequent inspection.

The basic methodology used in the design of detonation resistant BWR offgas systems is described in American National Standard, ANSI/ANS-55.4, 1979, Appendix C and assumes the absence of simultaneous secondary events such as earthquakes. A refinement of this ANSI methodology was utilized in assessing the detonation resistance of the SSES offgas system.

In addition, gases removed from the SJAE condenser by the second-stage ejector and discharged to the off gas system are mixed with the motive steam to eliminate the possibility of an explosion in the line between the SJAE discharge and the recombiner condenser for the in-service recombiner system. A bypass piping loop around the second stage air ejector provides additional steam to dilute the hydrogen concentration and maintain the recombiner discharge temperature within limits. For the common offgas recombiner system in standby, the low flow purge air, when in service, assists in eliminating the possibility of an explosion in the common offgas recombiner system. Consequently, a detonable mixture of gases will not exist between the dilution steam injection point and the recombiner condenser. Controls close the first stage air ejector suction valves if the second stage SJAE plus bypass steam flow decreases by approximately 15% below the operating set point.

The offgas hydrogen analyzers, pre-treatment radiation monitors and other instrumentation, which is not safety related, may fail following a detonation within the off gas pressure boundary. However, failure of this equipment poses no personnel or public safety hazard. The offgas

system detonation resistance was reviewed by the USNRC as documented in License Amendment(s) 179 for Unit 1 and 152 for Unit 2.

#### 11.3.2.2 Component Description

##### 11.3.2.2.1 Recombiner System

Three recombiner assemblies are located in the turbine building in a shielded area below the main condenser steam jet air ejectors. Each recombiner assembly consists of the following major components: a recombiner, preheater, recombiner vessel, recombiner condenser, motive steam jet, motive steam jet condenser, and a condensate cooler.

One recombiner assembly is primarily designated for the service of each nuclear unit and the third assembly is a common standby to both units. Each recombiner assembly is sized to accommodate the design flow from one nuclear unit. The piping and valve manifold upstream of the recombiner assemblies permit the transfer of the offgas stream between a unit designated assembly and the common standby recombiner assembly.

The materials of construction, design pressures and temperatures, and the design codes for the components associated with the recombiner assemblies are listed in Table 11.3-5.

##### 11.3.2.2.2 Activated Carbon Adsorber System

After entering the common inlet header, the gas mixture from each unit can be directed to either of two parallel equipment sub-trains each consisting of a water removal/temperature reduction assembly, and a activated carbon guard bed. The utilized activated carbon adsorption train of each offgas treatment system is primarily designated for the service of the associated nuclear unit. Each adsorption train consists of five activated carbon adsorber beds in series. The trains and sub-trains are isolable at both the inlet and outlet by remotely operated valves. The following subsections describe the various equipment that is associated with each system.

##### 11.3.2.2.3 Inlet HEPA Filter

The activated carbon adsorber system inlet HEPA filter vessels do not contain filter elements.

##### 11.3.2.2.4 Water Removal/Temperature Reduction Assembly

The water removal/temperature reduction assembly is used to cool and dehumidify the offgas to an operating temperature of approximately 65°F and a 40°F dewpoint in order to assure a maximum of 5% moisture is achieved in the activated carbon adsorbers. The offgas flow is first directed through a precooler which was originally designed to use reactor building closed cooling water as the cooling medium. Due to the acceptably low temperature of the offgas, the reactor building closed cooling water has been isolated from the precooler. This heat exchanger is built in accordance with TEMA Standard Class C, Type BEU.

A chiller is used to reduce the offgas stream temperature to approximately 40°F in order to condense and remove moisture. A refrigerant flows in the tube side and the offgas in the shell side. Water cooled refrigeration condensing units are provided for each chiller. This design eliminates the problems generally associated with a system circulating chilled glycol, such as leakage between the sides of the heat exchanger and leakage of glycol solution from pump seals. Also, the direct expansion refrigeration approach eliminates the use of circulation pumps, increasing system reliability. The refrigeration condensing units are located away from the precooler/chiller assembly in a low radiation area.

The condensate from the chiller is collected in a drain pot on the chiller. Since the accumulation rate of condensate is expected to be very small, an on-off type level control has been incorporated into the design. The condensate is directed back to the main condenser. Malfunction of the level control system may result in some of the offgas returning to the main condenser, thereby preventing an uncontrolled release into the radwaste building.

The offgas sides of the precooler and the chiller have been constructed of stainless steel to reduce the amount of corrosion products that might increase maintenance personnel doses or decrease system reliability.

#### 11.3.2.2.5 Guard Beds

The offgas stream leaving the water removal assembly is reheated to approximately 65°F by electric heat tracing prior to entering the guard bed. The moisture content is then measured in order to monitor the performance of the water removal equipment. If the moisture content exceeds a preset level, an alarm is initiated in both the main control room and the local radwaste building control room.

The guard bed is provided to protect the main carbon beds against moisture and other contaminants when the dehumidification section is inoperable. Moisture in the main carbon adsorber beds would reduce the delay time for fission gases. The guard bed contains approximately 1280 lbs. of activated carbon. The guard bed is sized to absorb moisture that could result from a failure of the chiller over a period of approximately 40 hours. A low-pressure

air drying/purge system has been provided to dry the guard bed should it become contaminated with water. However, the drying system is no longer used, because of the risk of carbon fires. The carbon in the guard beds is removed and replaced if an unacceptable pressure drop occurs.

The moisture monitor at the discharge of each guard bed will indicate when the guard bed is approaching saturation and corrective measures can be taken prior to any contamination of the main activated carbon adsorber bed.

The carbon steel guard bed vessel is designed to the code requirements of ASME Section VIII, Division 1. The materials of construction, the design pressure and temperature of these vessels are listed in Table 11.3-5.

#### 11.3.2.2.6 Main Activated Carbon Adsorber Bed

Each adsorber train contains five tanks of activated carbon which are connected in series. These tanks provide sufficient delay of the radioactive noble gases, xenon and krypton, to permit releases to the environment that will satisfy the requirements of Appendix I to 10CFR50.

The temperature of the activated carbon is kept below 65°F, which is well below its ignition temperature, thus precluding overheating or fire and the consequential release of radioactive materials.

The adsorbers are located in shielded vaults which are maintained at a temperature below 65°F by one of two 100% capacity air conditioning systems that remove the decay heat generated in the adsorbers, any heat introduced by the process stream and through the vault walls.
The back-up air conditioning unit is activated automatically upon failure of the operating unit. Failure of the operating unit actuates a group alarm in the main control room and at a local control panel. In the unlikely event that both air conditioning units are unable to function, the radioactive emissions from the offgas system would increase slightly; however, the releases to the environs would still be well below acceptable limits for the condenser air in-leakage and purge air normally expected.

Channeling in the activated carbon adsorbers is prevented by maintaining a high bed-to-particle diameter ratio (approximately 750). Underhill (Reference 11.3-2) has stated that channeling or wall effects may reduce efficiency of the holdup bed if this ratio is not greater than 12. During installation of the activated carbon, the adsorber vessels may be vibrated from the outside to minimize voids and to increase the bulk density.

There are no provisions for bypassing the activated carbon adsorbers during any mode of operation, except during operation of the mechanical vacuum pump.

The ability of the activated carbon to delay the noble gases can be evaluated by comparing activities measured in samples taken at the outlet of the motive steam jet condenser and at the exit of the outlet HEPA filters.

The carbon steel activated carbon vessels are designed to the code requirements of ASME Section VIII, Division 1. The physical dimensions, materials of construction, design pressure, and design temperature of these vessels are listed in Table 11.3-5.

#### 11.3.2.2.7 Outlet HEPA Filter

After the offgas stream exits the main activated carbon bed, it passes through a HEPA filter where any entrained particulates or activated carbon dust are collected. The removal efficiency of this HEPA filter is 99.97 percent for particulate sizes 0.3 micron and larger. The outlet HEPA filter is sized to accommodate the full design startup flow rate of 300 scfm.

The offgas stream exiting the outlet HEPA filter can be monitored for radioactivity by grab samples. The offgas stream is then directed to the turbine building exhaust duct, where continuous monitoring occurs, and released through the exhaust vent on top of the reactor building.

#### 11.3.2.2.8 Instrumentation and Control

The offgas system is monitored by means of flow, temperature, pressure, and humidity instrumentation, and by hydrogen analyzers to verify specified operation and control, and to ensure that the hydrogen concentration is maintained below the flammable limit. Dwgs. M-169, Sh. 1, M-169, Sh. 2, M-2169, Sh. 1, M-2171, Sh. 1, and M-2171, Sh. 2 show the process parameters that are monitored to alarm in the main control room and the local radwaste control room, as well as whether the parameters are recorded or just indicated.

Dilution steam is provided in a bypass piping loop around the second stage air ejector in order to ensure that a detonable mixture of gases will not exist between the dilution steam injection point and the recombiner condenser and to keep the recombiner vessel outlet temperature below the design maximum. Controls are provided to close the first stage air ejector suction valves if the second stage SJAE plus bypass steam flow decreases by approximately 15%. Pretreatment radiation monitors continuously record and indicate gaseous radioactivity release from the reactor. These monitors provide information in the main control room on the condition

of the fuel cladding and the inlet activity to the recombiner system and the activated carbon adsorbers. These monitors, through the annunciator system, provide redundant high and high-high alarms in the main control room when preset values are exceeded.

Experience with boiling water reactors has shown that the calibration correction factor of the offgas radiation monitors changes with the isotopic content. The isotopic content can change depending on the presence or absence of fuel cladding leaks in the reactor, the nature of the leaks, and the holdup time prior to release. Because of these variations, the monitors are periodically calibrated against grab samples.

Grab samples can be retrieved at the outlet of the motive steam jet condenser, at the test connections of the outlet HEPA filters of the activator carbon adsorber system, and at a connection on the offgas pipe leading to the exhaust vent on the reactor building. The combined second stage SJAE motive and dilution steam flow is measured and recorded by redundant instruments on the local recombiner control panel with low and low-low flow annunciation. Indication and low-low flow annunciation, by a group alarm, is provided on the main control room panel.

The temperature of the recombiner catalyst bed is monitored by three RTDs with each output switchable to one indicator. An alarm is provided to annunciate temperature conditions in excess of the process design value. The inlet temperature to the recombiner is monitored by redundant RTDs and alarms annunciate when the temperature falls below the point where adequate recombination of the radiolytic hydrogen and oxygen would occur. Each recombiner assembly is heat traced. The common standby recombiner assembly is heat traced and monitored to ensure its availability in case the unit designated assembly becomes inoperative.

The recombiner inlet and outlet temperatures are recorded and low, high and high-high alarms annunciate on the local panel while indication and high-high and low temperature alarms are annunciated on the main control room panel. Level controlled valves are used in the drain lines from the recombiner and steam jet condenser shells to the common condensate cooler which, in turn, drains to the main condenser. High condensate level alarms are annunciated at the local control panel, with a group alarm on the main control room panel.

The motive steam jet suction pressure is regulated by a butterfly valve in order to keep the recombiner condenser pressure above the main condenser pressure, thus allowing drainage of the condensate without a motive device.

Two redundant electro-chemical hydrogen analyzers are used to measure the hydrogen content of the offgas process stream at the discharge of each recombiner assembly. The hydrogen concentration from each analyzer is input to a computerized data acquisition system. A high hydrogen concentration alarm annunciates at the local control panel. High-high hydrogen

concentration alarms are provided both at the local and main control room panels while indication is provided locally and on the main control room panel. Each hydrogen analyzer can be independently calibrated with the redundant one in operation.

The hydrogen analyzer systems continuously withdraw samples of the offgas, analyze the hydrogen content, and return the sample gas to the recombiner assembly. Hydrogen level setpoints are established in accordance with program and regulatory requirements. Oxygen analyzers are provided in series with the hydrogen analyzers. The oxygen concentration is an input to the Hydrogen Water Chemistry System, described in subsection 9.5.9.

Offgas system flow measurements are made downstream of the water removal assemblies in the charcoal offgas treatment system with indication and high flow alarm at a local and main control room panel and recording on the local panel only.

#### 11.3.2.2.9 Leakage of Gases from Offgas System

Leakage of radioactive gases from the offgas system is limited by the use of welded construction wherever practicable. Leakage is further limited by the use of process valves that are of diaphragm or bellows stem seal design, or by using double stem packed valves with a bleed-off connection that is either pressurized by instrument air to slightly higher than the system pressure or routed to the main condenser.

The offgas system operates at a maximum of 5 psig during startup. During normal operations, the differential pressure between the system and the atmosphere is small thus limiting the potential for leakage of radioactive gases.

All drains from the various heat exchangers associated with the recombiner and activated carbon adsorber system are directed back to the main turbine condenser. Because of the low elevation, the drains from the delay line are routed through a drain pot with two level control valves in series into the radioactive turbine building sump. This minimizes the potential for offgas escape into the building in case of valve malfunctioning. Alarm and level control instrumentation is also provided.

### 11.3.2.3 Typical Operating Modes

#### 11.3.2.3.1 Standby

During standby mode, the Unit 1 and Unit 2 recombiner systems are isolated from the offgas stream. The assembly steam supply and preheater bleed steam supply valve as well as the

condensate cooler drain valve are open. For the common standby recombiner, the recombiner system discharge valve opens automatically to eliminate potential for pressure buildup due to through seal leakage of the common motive steam jet supply valve. Also for the common standby recombiner, the assembly steam supply and preheater bleed steam supply valves are open and the condensate cooler drain valves are aligned to and from either reactor unit. This, in conjunction with the electrical offgas inlet line heat tracing, keeps the system within a temperature range of 240°F to 270°F, thus preventing condensation when switching the offgas stream from an operating recombiner to the standby one.

Depending on the air in-leakage to the main condenser, this transfer is to be performed within approximately 10 minutes in order to keep the condenser pressure below allowable limits.

Cooling water is normally maintained to the standby recombiner assembly and the refrigeration condenser of the activated carbon adsorber system sub-trains not in operation. The refrigeration system for the chiller is placed in the standby mode and will start upon demand.

While in standby, the low flow purge air is aligned to the common offgas recombiner.

#### 11.3.2.3.2 Prestart

In the prestart mode, the Unit 1 and Unit 2 motive steam jet steam supply valve and the recombiner system discharge valve are open in addition to the valves opened during standby. Motive steam may be from the auxiliary or nuclear boiler. For the common standby recombiner only, the common motive steam jet steam supply valve is open in addition to the valves opened during standby. The motive steam is condensed in the motive steam jet condenser while the recombiner system components are evacuated, ready for offgas admission.

The water removal chiller as well as the activated carbon bed vaults of the ambient temperature charcoal adsorber system must be at the required operating temperature and all valves in the normal operation status.

#### 11.3.2.3.3 Normal Operation

Prior to placing the recombiner system from the prestart into the normal operation mode the following permissives must be present:

- Recombiner inlet temperature not low
- Recombiner outlet temperature not high-high

- Recombiner condenser cooling water flow not low
- Motive steam jet condenser cooling water flow not low

Each permissive is incorporated into the controls of the recombiner system by a two out of two logic allowing opening of the offgas inlet valves to the first stage SJAE upon establishing steam flow through the second stage SJAE and the dilution steam bypass.

Closing of the first stage SJAE offgas inlet valves occurs when any of the above permissives trip or there are two out of two trip signals of dilution steam (2nd stage SJAE motive & bypass) flow low-low.

The recombiner system inlet valve closes upon a recombiner condenser outlet temperature high-high which in turn automatically opens a bypass valve recycling the SJAE discharge back to the main condenser. This allows switchover to the standby recombiner without interrupting the SJAE motive steam flow within the period determined by the rise of the main condenser pressure.

#### 11.3.2.3.4 Startup

The offgas system can be started with the main condenser ≤ 8 in HgA with initial vacuum having been drawn by the MVP. The system requires a main condenser vacuum of at least 8 in HgA established to provide a motive force for returning condensate to the main condenser and prevent back flooding the recombiner systems. To prevent hydrogen buildup downstream, recombiner vessel temperature should be 240°F to 270°F before offgas flow is admitted to the vessel. Operation of both activated carbon absorber sub-trains is required for startup or anytime offgas flow is > 150 scfm. After startup, the flow rate of non-condensables exhausted by the SJAE in conjunction with the low flow purge air (if the common recombiner is in standby) should stabilize, primarily as a function of reactor power level and condenser in-leakage.

#### 11.3.2.3.5 Equipment Malfunction

Malfunction analysis, indicating the consequences and design precautions taken to accommodate failure of various components of the offgas system, is presented in Table 11.3-6.

### 11.3.2.4 Other Radioactive Gas Sources

There are three general areas that contain gaseous radioactive sources: the primary and secondary containment, the turbine building, and the radwaste building. The description of the ventilation systems for these buildings is presented in Section 9.4. The building volumes, flow rates, sources, and other information required to calculate the airborne concentrations of radioactive materials and doses are discussed in Subsections 12.2.2, 12.3.3, and 12.4.

11.3.2.4.1 Primary and Secondary Containment

Gaseous radioactive effluents can emanate from several sources. Leakage into the drywell and wetwell of the primary containment will be contained until containment atmosphere is purged in preparation for maintenance. Purged gases are processed through the activated carbon filters of the SGTS prior to release to the plant environs.

As indicated in Section 9.4, the two reactor buildings and the common refueling floor area have been designated as HVAC Zones I, II and III, respectively. Each of these zones has been divided into equipment compartment areas, where radioactive leakage may be expected, and other areas that contain non-radioactive equipment, accessways, and the refueling floor. The exhaust air from the equipment compartment where radioactive leakage may occur is discharged through exhaust systems containing six-inch deep activated carbon filters. The air from the other areas is usually released unfiltered; however, if high concentrations do occur, the air can be re-circulated and a small fraction discharged through the SGTS until the high concentration condition can be corrected.

In the Appendix I evaluation it was assumed that radioactive releases from the reactor building are processed through the activated carbon and HEPA filters before release to the atmosphere. There may be small quantities of radioactivity released unfiltered from the refueling floor area and the spent fuel pool, especially during the early stages of refueling. However, the quantities of iodine and particulates released from this source are expected to be much less than the releases from equipment leakage, equipment maintenance, drywell purge, and the vessel head lifting operation, all of which are filtered. Considering the uncertainties in the calculation of the reactor building releases and the conservative assumptions use in estimating releases, it is expected that the actual releases from the reactor building to the atmosphere should be lower than the estimates presented in this evaluation.

The main steam relief valves are vented to the suppression pool. The activity released from the actuation of these relief valves will be contained in the primary containment until its atmosphere is purged through the SGTS. Effects of releases to the Suppression Pool are bounded by the effects of the closure of all Main Steam Isolation Valves concurrent with a stuck-open Main Steam Safety Relief Valve. The analyses of these events and their effects are described in Sections 15.1.4 and 15.2.4.

11.3.2.4.2 Radwaste Building

Leakage into the radwaste building atmosphere will be processed through a pre-filter and HEPA filter. In addition, an activated carbon filtration system processes the exhausts from the major radwaste system tanks.

11.3.2.4.3 Turbine Building

As indicated in Subsection 9.4.4, the turbine building ventilation system contains a filtration system with HEPA and six inch deep activated carbon filters. Building air from those areas of the turbine building where equipment leakage and airborne activity could be expected is processed through the filtration system before it is released through the turbine building vent exhaust to the atmosphere. Air from non-contaminated areas is released through the turbine building vent exhaust without filtration.

The process valve stem leakage collection system is used for the collection of stem packing leakage from steam valves in the turbine building. Leakage from these valves is directed to the main turbine condenser and processed through the offgas system prior to being released to the environs.

Valves in the turbine building were originally provided with valve stem packing leakoff connections. Research and testing has shown that improved packing provides an effective seal to prevent leakage into the Turbine Building. As a result, these leakoff connections are in the process of being removed and packing configurations changed, as appropriate, to conform with the new requirements. As part of this effort, leakoff isolation valves and piping will be removed (or abandoned in place) and the leakoff collection header piping will be removed or abandoned in place.

In the past, the steam packing exhaust has presented a source of gaseous radioactive releases in some BWR plants. However, at this station, an auxiliary source of clean steam is provided for gland seal purposes from the steam seal evaporator. Therefore, essentially no activity is released from this system. Subsection 10.4.3 provides a detailed description of the gland seal steam system.

During the startup of each unit, air is removed from the main turbine condenser by a mechanical vacuum pump. This vacuum pump discharges to the turbine building ventilation exhaust system. A radiation detector continuously monitors the effluent from the turbine building exhaust system and an alarm is actuated upon the detection of a high radiation level.

## 11.3.3 RADIOACTIVE RELEASES

An evaluation of the gaseous radioactive releases was performed to show compliance with the ALARA guidelines. The assumptions used in this evaluation are summarized in Tables 11.2-8, 11.3-2, and 11.3-4 for gaseous releases. Expected radioactive releases from the major buildings, prior to treatment, are presented in Table 12.2-30. The calculated annual expected gaseous radioactive releases per unit are given in Table 11.3-1. Expected average annual radionuclide concentrations are compared to 10CFR20 limits in Table 11.3-11.

The building vent locations, shape, effluent flow rate, and heat input are given on Figure 11.3-4.

Actual plant operations are expected to differ from the assumptions used in the analysis. Air leakage into the condenser and other portions of the steam cycle under vacuum will vary due to aging and degradation of piping, valves and seals. Age and variations in moisture loading may affect the activated carbon dynamic adsorption coefficients. Fission product leakage from the reactor is expected to be much lower than assumed for the great majority of the plant operating time. These variations will be monitored, and Susquehanna will be operated such that the yearly routine releases will be kept ALARA, consistent with the dose guidelines of Appendix I to 10CFR50. The activity released from the various vents will be monitored to ensure that the airborne concentrations at offsite locations will be below the limits of 10CFR20 for unrestricted areas.

## 11.3.4 ESTIMATED DOSES

Dose calculations to assure compliance with Appendix I to 10 CFR Part 50 based on the expected gaseous source term referenced above were performed in accordance with USNRC Regulatory Guide 1.109 by use of the USNRC computer code "GASPAR". Input data for these calculations are given in Table 11.3-7. The doses resulting from gaseous effluents are a small fraction of the 10CFR20 limits and are within 10CFR50, Appendix I design objectives. A comparison of the estimated releases with the Appendix I design objectives is presented in Table 11.3-10.

## 11.3.5 REFERENCES

11.3-1 NEDO-10734, "A General Justification for Classification of Effluent Treatment System Equipment as Group D" (February 1973).

11.3-2 "Design of Fission Gas Holdup Systems," Proceedings of the 11th AEC Air Cleaning Conference, D. Underhill et al (1970).

11.3-3 "Standards for Steam Surface Condensers," Sixth Edition, Heat Exchange Institute, N.Y., N.Y. (1970).

11.3-4 NUREG 0016, Revision 1, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWR-Gale Code)," U.S. Nuclear Regulatory Commission (January 1979).

11.3-5 NEDE-11146, "Pressure Integrity Design for New Off-Gas Systems," GE Nuclear Energy, July 1971.

Table 11.3-1

ANNUAL GASEOUS RELEASES PER UNIT

Annual Building or Component Release[1] (Curie per Year)

| Nuclide | Turbine Building | Reactor[2] Building | Radwaste Building | Steam Jet Air Ejector | Mechanical Vacuum Pump | Total Annual Release |
|---|---|---|---|---|---|---|
| H-3 | 6.0E+00 | 8.6E+01[3] | *[4] | * | * | 9.2E+01 |
| C-14 | * | * | * | 9.5E+00 | * | 9.5E+00 |
| Ar-41 | * | 1.5E+01 | * | 8.7E+01 | * | 1.0E+02 |
| Kr-83m | * | * | * | * | * | * |
| Kr-85m | 5.00E+00 | 4.0E+00 | * | 3.0E+02 | * | 3.1E+02 |
| Kr-85 | * | * | * | 2.6E+02 | * | 2.6E+02 |
| Kr-87 | 1.2E+01 | 2.0E+00 | * | * | * | 1.4E+01 |
| Kr-88 | 1.8E+01 | 4.0E+00 | * | 4.1E+01 | * | 6.3E+01 |
| Kr-89 | 1.2E+02 | 2.0E+00 | 2.9E+01 | * | * | 1.5E+02 |
| Xe-131m | * | * | * | 5.9E+01 | * | 5.9E+01 |
| Xe-133m | | | | 6.0E+00 | | 6.0E+00 |
| Xe-133 | 3.0E+01 | 1.1E+02 | 2.2E+02 | 6.7E+03 | 1.3E+03 | 8.4E+03 |
| Xe-135m | 8.0E+01 | 6.0E+01 | 5.3E+02 | * | * | 6.7E+02 |
| Xe-135 | 6.6E+01 | 1.3E+02 | 2.8E+02 | * | 5.0E+02 | 9.7E+02 |
| Xe-137 | 2.0E+02 | 1.9E+02 | 8.3E+01 | * | * | 4.7E+02 |
| Xe-138 | 2.0E+02 | 8.0E+00 | 2.0E+00 | * | * | 2.1E+02 |
| I-131 | 3.4E-04 | 8.9E-05 | 3.1E-03 | * | 1.3E-01 | 1.3E-01 |
| I-133 | 5.0E-03 | 1.3E-03 | 4.4E-02 | * | 1.4E+00 | 1.5E+00 |
| Cr-51 | 1.8E-06 | 1.1E-05 | 7.0E-06 | * | 1.0E-06 | 2.1E-05 |
| Mn-54 | 1.2E-06 | 1.4E-05 | 4.0E-05 | * | * | 5.5E-05 |
| Fe-59 | 2.0E-07 | 3.9E-06 | 3.0E-06 | * | * | 7.1E-06 |
| Co-58 | 2.0E-06 | 3.0E-06 | 2.0E-06 | * | * | 7.0E-06 |
| Co-60 | 2.0E-06 | 5.0E-05 | 7.0E-05 | * | 5.6E-07 | 1.2E-04 |
| Zn-65 | 1.2E-05 | 5.0E-05 | 3.0E-06 | * | 3.4E-07 | 6.5E-05 |
| Sr-89 | 1.2E-05 | 5.0E-07 | * | * | * | 1.3E-05 |
| Sr-90 | 4.0E-08 | 1.0E-07 | * | * | * | 1.4E-07 |
| Zr-95 | 8.0E-08 | 1.0E-05 | 8.0E-06 | * | * | 1.8E-05 |
| Nb-95 | 1.2E-08 | 1.0E-04 | 4.0E-08 | * | * | 1.0E-04 |
| Mo-99 | 4.0E-06 | 6.6E-04 | 3.0E-08 | * | * | 6.6E-04 |

Table 11.3-1

ANNUAL GASEOUS RELEASES PER UNIT

| Annual Building or Component Release[1] (Curie per Year) | | | | | | |
|---|---|---|---|---|---|---|
| Nuclide | Turbine Building | Reactor[2] Building | Radwaste Building | Steam Jet Air Ejector | Mechanical Vacuum Pump | Total Annual Release |
| Ru-103 | 1.0E-07 | 4.2E-05 | 1.0E-08 | * | * | 4.2E-05 |
| Ag-110m | * | 2.4E-08 | * | * | * | 2.4E-08 |
| Sb-124 | 2.0E-07 | 5.0E-07 | 7.0E-07 | * | * | 1.4E-06 |
| Cs-134 | 4.0E-07 | 4.7E-05 | 2.4E-05 | * | 3.2E-06 | 7.5E-05 |
| Cs-136 | 2.0E-07 | 5.0E-06 | * | * | 1.9E-06 | 7.1E-06 |
| Cs-137 | 2.0E-06 | 6.0E-05 | 4.0E-05 | * | 8.9E-06 | 1.1E-04 |
| Ba-140 | 2.0E-05 | 2.2E-04 | 4.0E-08 | * | 1.1E-05 | 2.5E-04 |
| Ce-141 | 2.0E-05 | 9.0E-06 | 7.0E-08 | * | * | 2.9E-05 |

Notes:

1. Based on NUREG-0016, Revision 1, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors", (BWR - GALE Code), Section 2.2.4.

2. All of Reactor Building tritium is assumed to be released in the Refueling Area.

3. 8.6E+01 = $8.6 \times 10^{1}$

4. * indicates a negligible quantity or less than 1 Ci/yr per unit for Noble gases.

# TABLE 11.3-2

## ASSUMPTIONS AND PARAMETERS USED FOR EVALUATION OF GASEOUS RELEASES

| | |
|---|---|
| 1. Reactor coolant and main steam radionuclide concentrations | Table 11.2-9 |
| 2. Radionuclide releases from buildings before treatment (from NUREG 16) | Table 12.2-30 |
| 3. Radionuclide input (I-131) into the main condenser offgas treatment (from NUREG 16) (Ci/yr/unit) | 6 |
| 4. Charcoal Delay System parameters | |
| a) Mass of charcoal, M, ($10^3$lb) | 148 |
| b) Operating/dew point temperatures (°F) | 60-65/40 |
| c) Dynanmic adsorption coefficient, K, ($cm^3$/gm) for Xe/Kr | 516/36 |
| d) Power Level P ($MW_t$) | 4032 |
| e) e) Charcoal holdup time T (hrs) | $43.1\frac{MK}{P}$ |
| 5. Gland seal system flow rate lb/hr | 25,000 |
| Activity level | Clean steam |
| 6. Offgas holdup time before the charcoal delay system (hr) | 0.12 |
| 7. Filtration systems on building ventilation | Table 11.3-4 |

## Table 11.3-4

## Filter Trains Used To Control Gaseous Effluents

| Filter | Rated Capacity (CFM)(1) | Filter Components* | Charcoal Thickness (in.) | Iodine Removal Efficiency(2) (%) |
|---|---|---|---|---|
| Containment/Auxiliary Building | | | | |
| Unit 1 – Zone I, below refueling floor | 16,000 | P-H-C-H | 6 | 99 |
| Unit 2 – Zone II, below refueling floor | 16,000 | P-H-C-H | 6 | 99 |
| Units 1 & 2 – Zone III, refueling floor | 4,000 | P-H-C-H | 6 | 99 |
| Drywell purge – through SGTS | 10,500 | M-P-H-C-H | 8 | 99 |
| Turbine Building | | | | |
| | 20,000 | P-H-C | 6 | 99 |
| Radwaste Building | | | | |
| | 30,000 | P-H | 0 | 0 |
| Tank exhaust filter | 1,000 | P-H-C-H | 2 | 70 |
| Control Structure | | | | |
| Sample Room exhaust | 1,500 | P-H-C | 2 | 70 |
| Radiation chemical lab | 1,500 | P-H-C | 2 | 70 |
| Radiation chemical lab | 1,500 | P-H-C | 2 | 70 |
| Decontamination area exhaust | 1,500 | P-H-C | 2 | 70 |

* M – Moisture separator
P – Prefilter
H – HEPA
C - Charcoal

**NOTES:**

1. Flow rates are rated capacities per filter train. For system design basis flow rates, see FSAR Section 9.4.
2. Removal efficiencies for ESF system activated carbon adsorber units are per RG 1.52, Revision 2 and per RG 1.140, Revision 1 for non-ESF systems.

# TABLE 11.3-5

## OFF GAS SYSTEM MAJOR EQUIPMENT DESCRIPTION
(Design Codes and Standards are provided in Table 3.2-1)

| Equipment | Equipment Numbers | Type | Qty. | Material | Capacity | Size | Design Pressure/ Temp. PSIG/°F |
|---|---|---|---|---|---|---|---|
| | | | | Recombiner System | | | |
| Preheater | 0E/1E/2E-136 | Shell and Straight tubes, BEM | 3 | Shell, Channel: CS Tubes, Sheet: SS | 271,246 Btu/hr (4) | 21 0 sq. ft. | Shell Side: 450/450 Tube Side: 300/450 |
| Recombiner Vessel | 0S/1S/2S-125 | Vertical Cyl. | 3 | SS; Pourable metal substrate precious metal catalyst | Approximately 39 cf Catalyst | 60" Dia., 74" High | 300/950 |
| Catalyst Bed | ---- | GE23A6222 | 3 | Pourable metal substrate precious metal catalyst | Normal Operation: Inlet: 239,340 SCFH total, <4.0 vol.% $H_2$ Outlet: 1 Vol % $H_2$ based on 5 SCFM Dry Air | 55.25" Dia., 28" Deep | Maximum Operating Outlet: 830°F |
| Recombiner Condenser | 0E/1E/2E-137 | Shell and U-tubes, BEU | 3 | Shell, Tubes Sheet: SS; Channel: CS | $14.6x10^6$ Btu/hr(4) | 970 sq. ft. | Shell Side: 300/950 Tube Side: 150/150 |
| Condensate Cooler | 0E/1E/2E-152 | Shell and U-tubes, BEU | 3 | Shell, channel: CS; Tubes, Sheet: SS | $580x10^3$ Btu/hr(4) | 138 sq. ft. | Shell Side: 300/250 Tube Side: 150/150 |
| Motive Steam Jet | 0E/1E/2E-133 | | 3 | SS | Startup: Suction: 300 SCFM Air 123 SCFM Steam Disch: 300 SCFM Air 1189 SCFM Steam | Suct: 6", Disch: 4", Motive 2 ½" | Body: 300/200 Steam Chest: 600/500 |
| Motive Steam Jet Condenser | 0E/1E/2E-134 | Shell and U-tubes, BEU | 3 | Shell, channel: CS; Tubes, Sheet: SS | $3.53x10^6$ Btu/hr | 960 sq. ft. | Shell Side: 300/300 Tube Side: 150/150 |
| Delay Piping | GBC-106, GBC-206 | | 3 | CS | | 8" / 16" | 300/850 |
| Inlet HEPA Filter Housing[1] | 1F301A,B 2F301A,B | NA (Note 1) | 4 | CS (Housing) | NA (Note 1) | Housing: 10" Dia x 36" High | 450/200 |
| Precooler (Note 3) | 1E/2E-302A,B | Shell and U-tubes | 4 | Shell Side: SS Tube Side: SS | 86,930 Btu/hr | 41.3 sq. ft. | Shell Side: 150/150 Tube Side: 695/200 |
| Chiller Vessel | 1E/2E-303A,B | Shell and Helical Coils | 4 | Shell Side: SS Tube Side: SS | 41,000 Btu/hr | 115 Sq. ft. | Shell Side: 520/200 Tube Side: 150/125 |
| Refrigeration Compressor; | 1K/2K-321 A,B 1E/2E-301 A,B | Reciprocating Semi Hermetric | 4 | CI / Freon 12 | 41,000 Btu/hr. | 3 HP | 350/150 |

## TABLE 11.3-5

### OFF GAS SYSTEM MAJOR EQUIPMENT DESCRIPTION
(Design Codes and Standards are provided in Table 3.2-1)

| Equipment | Equipment Numbers | Type | Qty. | Material | Capacity | Size | Design Pressure/ Temp. PSIG/°F |
|---|---|---|---|---|---|---|---|
| Condenser | | | | | | | |
| Guard Bed Vessel | 1T/2T-305 A,B | Vertical Cyl. | 4 | CS | 0.64/tons of activated charcoal | 30" dia. X 122" high | 410/150 |
| Charcoal Adsorber Vessel | 1T/2T-306 thru 310 | Vertical Cyl. | 10 | CS | 14.8 tons | 96" dia. X 254" high | 375/150 |
| Charcoal Bed | ---- | PSPEC H1026 | 10 | Activated Carbon | Adsorpt.coeff. (cc/gm) (Note 2) Xe: 516 KR: 36 | PSPEC H-1026 | PSPEC H-1026 |
| Outlet HEPA Filter | 1F/2F-302 | Pleated Cartridge | 2 | Element: Glass Fiber<br>Housing: CS<br>Frame: SS | 45 SCFM at rated capacity | Housing: 14" dia., 36" high<br>Cartr.: 10 5/8" dia., 8" high | 310/150 |

Notes:

1. HEPA filter element has been permanently removed from inlet filter housing.
2. Kd at 20°C, 5% moisture in carbon.
3. Precooler is not used.
4. Valves given for the capacity of the pre-heater, recombiner condenser, and condensate cooler represent the component heat load at rated power level operating under normal water chemistry.

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| 1. Second Stage SJAE air-operated Bypass Dilution Steam Flow Control Valves | Fail closed | Dilution of hydrogen in offgas could be insufficient | Redundant flow control valves regulated by redundant flow measuring and controlling instrumentation are provided with local and main control room low flow alarms and system shutdown logics. The second valve would open on failure of the first valve to maintain flow. Low second-stage steam supply flow would trip local alarms, and low-low flow would also isolate the SJAE offgas suction valves and would trip a low-low steam flow alarm in the control room. If dilution flow and SJAE suction cannot be restored, rising main condenser backpressure will trip the turbine, followed by a reactor scram. Offgas would remain in the offgas system and main condenser, and no uncontrolled leakage would result. |
| | | High recombiner temperature due to exothermic recombination of higher hydrogen concentration, possible pressure boundary damage | Control of inlet hydrogen concentration with SJAE bypass dilution steam should limit the available reaction exotherm, and thereby limit the recombiner process and outlet temperatures. Recombiner process or discharge temperature high would alarm locally and by a group trouble alarm in the control room, and discharge temperature is indicated in the control room. Recombiner discharge temperature high-high would alarm both locally and in the control room, and would cause an offgas isolation (closure of SJAE offgas suction isolation valves). Reopening the isolation valves would require the operator to correct the condition or align the common standby recombiner. Offgas would remain within the offgas system and main condenser with no uncontrolled release. |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| 2. Piping between SJAE and Recombiner Assembly | Pipe rupture | Release of offgas mixture to turbine building basement | This event has been analyzed as a Limiting Fault. See FSAR Section 15.7. Radiation monitors would alarm and operators would close the SJAE inlet (offgas isolation) valves. The release would be processed through the turbine building ventilation-filtration system. |
| 3. Recombiner Preheater | Steam leak | Would further dilute process offgas and be condensed in the recombiner condenser. Steam consumption and condensate flow would increase. | Any significant leakage would result in a pressure rise in the offgas stream upstream of the preheater, and would trip a local high pressure alarm and control room group trouble alarm. The excess steam would be condensed out in the recombiner condenser until the leakage was in excess of the condenser drain capacity. Local drain pot high level would then alarm and trip a control room group trouble alarm. |
| 4. Recombiners | Catalyst gradually deactivates | The temperature profile would change through the catalyst. Eventually excess hydrogen would occur in the recombiner discharge. | Temperature probes are installed in the recombiner beds and exit of each recombiner. The hydrogen analyzer would indicate high hydrogen concentrations and provide a recording to compare to previous performance. If catalyst degraded significantly, a high hydrogen concentration alarm might trip, and would trip a control room group trouble alarm. A further increase in hydrogen concentration would trip a control room alarm and the SJAE offgas inlet valves would close. |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| | Catalyst gets wet | Hydrogen recombination would fall off and higher hydrogen concentrations would occur downstream. Eventually the gas mixture could become combustible. | Temperature probes are installed in the recombiner beds and exit of each recombiner. The hydrogen analyzer would indicate high hydrogen concentrations and provide a recording to compare to previous performance. If catalyst degraded significantly, a high hydrogen concentration alarm might trip, and would trip a control room group trouble alarm. A further increase in hydrogen concentration would trip a control room alarm and the SJAE offgas inlet valves would close. |
| | | | The second stage SJAE motive and bypass dilution steam ensures the steam concentration remains above the hydrogen ignition limit between the SJAE and the recombiner condenser inlet, and the offgas system downstream of the recombiner condenser inlet will withstand an internal hydrogen ignition. |
| 5. Recombiner condenser, motive steam jet condenser, Condensate cooler. | Cooling water leak | Cooling water leak to the shell side of a condenser or cooler. | Moderate amounts of coolant leakage would be directed back to the main condenser. If leakage exceeded the capacity of the level control valves and drains, a high level alarm at the local and a group trouble alarm at the main control room panel would indicate this excessive leakage. Long period leakage would produce a low level in the gaseous radwaste recombiner closed cooling water head tank which would annunciate in the main control room. The offgas could then be transferred to the common standby recombiner assembly. |
| | Drain level control fails closed | Condensate would build up in the affected condenser and pressure drop would increase. | The level control and level alarms are separate instrumentation. The local high level alarm and main control room group trouble alarm would indicate the high level condition. |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| | Drain level control fails open | Gas would recycle to the main condenser, increase the load on the SJAE, increase main condenser pressure, and if left uncorrected, would eventually cause a turbine trip and reactor scram. | Valves are of the spring loaded fail closed type. Drains are routed to the main condenser thus eliminating any leakage offgas to the building. |
| | Loss of condenser cooling water | The dilution steam and the recombined hydrogen and oxygen would remain in the system as steam and increase the pressure in the recombiner assembly. | A separate offgas recombiner closed cooling water system is provided for each recombiner assembly. If the loss of cooling water is limited to a single recombiner assembly, common standby recombiner can be started. If there is a total loss of cooling water to all assemblies, the plant would be shut down. |
| | | | Low cooling water flow to either condenser would produce alarms and an offgas isolation (closure of SJAE offgas suction isolation valves). Reopening would require the operator to correct the condition or align the common standby recombiner. |
| | | | The immediate effect of a cooling water loss would be pressure increase immediately downstream of the recombiner condenser. As the pressure increases, a pressure switch would trip a time delayed local and group alarm in the main control room. A temperature rise in the recombiner condenser outlet would trip a high alarm and upon further increase, to high-high would cause a recombiner shutdown (close the offgas and motive steam inlet valves to the assembly and open the offgas recycle valve to the main condenser), permitting the SJAE's to remain in operation. |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| | | | Offgas would remain within the offgas system and main condenser with no uncontrolled release. |
| | | Steam would pass the motive steam jet condenser and partially condense in the delay pipe. The remainder would partially reach the charcoal offgas treatment system. | An alarm would be triggered locally and on a group annunciator in the main control room indicating high motive steam jet condenser outlet temperature. See below for effects of excess moisture reaching the charcoal offgas treatment system. |
| | Loss of condensate cooler cooling water | Flashing in drain line to main condenser could reduce drain flow below required capacity. | High condensate inlet or outlet temperature would trip a local alarm and control room group trouble alarm. Cooling water is controlled by a single manual valve. Unless the malfunction were a line blockage, any malfunction which caused a loss of cooling water would therefore also include loss of cooling water to the entire recombiner, followed by recombiner isolation and operator action to align the common standby recombiner. |
| 6. Holdup piping between the Recombiner Assembly and Charcoal Adsorber portions of the Offgas System. | Excessive corrosion of line | Leakage of gaseous and liquid radioactive products into the piping tunnel. | Area radiation monitors in the turbine and radwaste buildings. The piping tunnel is provided with floor drains which would direct leakage to the liquid radwaste system. |
| 7. Holdup piping drains | Level valve fails to open. | Accumulation of condensate in pipe. | Level control instrumentation with a high level annunciator in the main control room. The manual bypass valve can be opened around the two redundant level valves. |
| | Level valve fails to close. | Offgas leakage to turbine building sump | Valves are spring loaded fail-closed types. Two valves in series are provided. The area radiation monitor would alarm. |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| 8.Inlet HEPA filters<br><br>NOTE: The ambient temperature charcoal offgas system inlet HEPA filter vessels no longer contain filter elements, and the inlet filter differential pressure alarms have been removed. | | | |
| 9. Pre-cooler<br><br>NOTE: Cooling water to the precooler has been isolated, the precooler is no longer used, and the precooler cooling water low flow alarm has been disabled. | | | |
| | Cooling water leak | None. Cooling water has been isolated. | Cooling water has been isolated. |
| | Loss of cooling water | None. Operating experience found that the precooler is not required. | None required. |
| 10. Chiller refrigeration machines. | Complete loss of a chiller | The moisture content of the process stream would increase and contaminate the guard bed. | Two chiller-guard bed pretreatment subtrains are provided per unit, with chiller shell local high temperature alarm, control room group trouble alarm, and local and control room temperature indication. The operator would transfer the offgas stream to the other charcoal pretreatment subtrain. Moisture instrumentation is provided for the inlet and outlet of each guard bed, with local indication and alarms and a group trouble alarm in the control room. High moisture content at the inlet of the guard bed is alarmed in the main control room. The guard bed is sized to absorb moisture that would result from failure of a chiller for 48 hours during normal operations. |
| | Refrigerant tubes leaking | Refrigerant and lubricating oil would contaminate the guard bed and refrigerant might contaminate the charcoal adsorber beds. | Refrigerant would pass through both guard and adsorber beds with only a temporary minor reduction in adsorber capacity and without significant long-term effects. Lubricating oil would be trapped in the guard bed. The total charge of |

TABLE 11.3-6

OFFGAS SYSTEM EQUIPMENT MALFUNCTION ANALYSIS

| Equipment Item | Malfunction | Consequences | Design Precautions |
|---|---|---|---|
| | | | lubricating oil per chiller does not exceed the guard bed capture capacity. Two chiller-guard bed pretreatment trains are provided per unit. The operator would transfer the offgas stream to the other pretreatment subtrain on eventual loss of the chiller. |
| | | Loss of cooling capacity would cause increased moisture content of the process stream. | Same as loss of a chiller, above, but might be less rapid. |
| 11. Main Activated Charcoal Adsorbers | Activated carbon gets wet | Adsorption performance would deteriorate gradually as activated carbon gets wet. Holdup times would decrease and plant gaseous releases would increase. | Sacrificial guard bed would absorb moisture. Guard bed outlet local moisture indication and alarms with control room group trouble alarm. The guard bed is sized to absorb moisture that would result from failure of a chiller for 48 hours during normal operations. |
| 12. Charcoal vault air conditioning units (Radwaste Building Chilled Water System, and Offgas System Area Cooling Coils and Fans) | Mechanical failure | If the ambient temperature increases, delay efficiency of the charcoal beds decreases. Increased emission could occur depending on the fuel leakage rate. | A spare air conditioning unit is provided. (Only ventilation is required in winter.) |
| 13. Outlet HEPA filter | Hole in filter element | Filter bypass | Differential pressure instrumentation and filter test connections are provided. The activated carbon media in the guard beds and main adsorber beds should also be a good filter at low air velocity. |

TABLE 11.3-7

INPUT DATA FOR ATMOSPHERIC DOSE CALCULATIONS

| CRITICAL RECEPTION | SITE BOUNDARY LOCATIONS | | VEGATABLE GARDEN | RESIDENCE | DAIRY FARM |
|---|---|---|---|---|---|
| Location | Nearest Site Boundary X/Q | Maximum X/Q Site Boundary | Maximum D/Q Garden / Maximum X/Q Residence | Maximum D/Q Residence | Maximum D/Q Dairy |
| Critical Sector | SSW | WSW | WSW | NE | WSW |
| Distance from vents-miles(meters) | 0.39 (628) | 1.22 (1963) | 1.3 (2093) | 0.9 (1448) | 1.7 (2735) |
| Transit Time (sec) | 175 | 357 | 381 | 596 | 498 |
| X/Q (normal) – (sec/$m^3$) | 1.16E-05 | 1.25E-05 | 1.14E-05 | 2.86.E-06 | 7.75E-06 |
| X/QD (decayed) (sec/$m^3$) | 1.16E-05 | 1.24E-05 | 1.13E-05 | 2.85.E-06 | 7.66E-06 |
| X/QDD (decayed) + depleted (sec/$m^3$) | 1.08E-05 | 1.07E-05 | 9.70E-06 | 2.51E-06 | 6.48E-06 |
| DEP Deposition (1/$m^2$) | 5.03E-08 | 1.60E-08 | 1.43E-08 | 1.81E-08 | 9.36E-09 |
| Occupancy (hr/yr) | 8766 | 8766 | 8766 | 8766 | 8766 |

## TABLE 11.3-8

## OFFGAS SYSTEM FLOWS
(Refer to Fig. 11.3-1)

| | | | Design Normal Operation (40 SCFM Air) | | | | Start-up (300 SCFM Air; Cond. Pressure 5" Hg** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stream No. | Press. Psia | Temp. °F | $H_2$ % Vol.Conc. | PPH/SCFM $H_2O$ | PPH/SCFM Non-Cond. | PPH/SCFM Total | Press. Psia | Temp. °F | $H_2$ % * Vol.Conc. | PPH/SCFM $H_2O$ | PPH/SCFM Non-Concens. | PPH/SCFM Total |
| 2nd Stage SJAE Outlet | 16.7 | 272 | <4.0 | 10700/3712 | 635/277 | 11335/3989 | 15.7 | 270 | -- | 10700/3712 | 1395/300 | 12095/4012 |
| Recomb. Inlet | 14.2 | 272 | <4.0 | 10700/3712 | 635/277 | 11335/3989 | 13.8 | 270 | -- | 10700/3712 | 1395/300 | 12095/4012 |
| Recomb. Outlet | 10.6 | 830 | 0.0015 | 11150/3949 | 186/40 | 11335/3989 | 9.9 | 720 | -- | 10700/3712 | 1395/300 | 12095/4012 |
| Recomb. Cond. Outlet | 10.4 | 140 | 0.09 | 40/14 | 186/40 | 226/54 | 9.7 | 140 | -- | 352/123 | 1395/300 | 1747/423 |
| Motive Steam Jet Outlet | 15.2 | 274 | 0.004 | 3080/1080 | 186/40 | 3226/1120 | 18.6 | 239 | -- | 3392/1189 | 1395/300 | 4787/1489 |
| Motive Jet Cond. Outlet | 15.2 | 140 | 0.1 | 27 / 9 | 186/40 | 213/49 | 18.5 | 140 | -- | 158/55 | 1395/300 | 1553/355 |
| Precooler Inlet | 15.1 | 140 | 0.1 | 27/9 | 186/40 | 213/49 | 17.7 | 140 | -- | 80/28 | 698/150 | 778/178 |
| Chiller Inlet | 15.1 | 110 | 0.11 | 11/4 | 186/40 | 197/44 | 17.4 | 114 | -- | 38/13 | 698/150 | 736/13 |
| Chiller Outlet | 15.0 | 40 | 0.125 | 1/0.3 | 186/40 | 187/40 | 16.7 | 85 | -- | 10/4 | 698/150 | 708/154 |
| Guard Bed Inlet | 15.0 | 65 | 0.125 | 1/0.3 | 186/40 | 187/40 | 16.7 | 85 | -- | 10/4 | 698/150 | 708/154 |
| Chiller Inlet | 14.9 | 65 | 0.125 | 1/0.3 | 186/40 | 187/40 | 15.8 | 65 | -- | 10/4 | 698/150 | 708/154 |
| Adsorber Chiller | 14.8 | 65 | 0.125 | 1/0.3 | 186/40 | 187/40 | 15.0 | 65 | -- | 10/4 | 698/150 | 708/154 |
| Post-Filter Outlet | 14.7 | 65 | 0.125 | 1/0.3 | 186/40 | 187/40 | 14.7 | 65 | -- | 10/4 | 698/150 | 708/154 |

* During cold start-up a negligible amount of hydrogen is introduced into the main condenser.

** During cold start-up both charcoal adsorber trains are used when flow rate exceeds 150 SCFM.

Table 11.3-10

COMPARISON OF INDIVIDUAL DOSES FROM EXPECTED GASEOUS EFFLUENT RELEASES WITH 10CFR50, APPENDIX I DESIGN OBJECTIVES

| | **10CFR50 Appendix I Design Objectives (Per Unit)** | **Expected Annual Dose (Per Unit)** |
|---|---|---|
| Noble Gas Effluents (at the site boundary) | | |
| Gamma Air Dose[(1)] (mrad) | ≤ 10 | 3.0 |
| Beta Air Dose[(1)] (mrad) | ≤ 20 | 5.1 |
| Total Body of Individual (mrem) | ≤ 5 | 1.9 |
| Skin of Individual (mrem/yr) | ≤ 15 | 4.6 |
| Radioiodines and Particulates | | |
| Dose to any Organ Infant Thyroid (Dairy) (mRem) | ≤ 15 | 14.5 |
| Dose to any Organ Child Thyroid (Garden) (mRem) | ≤ 15 | 11.9 |

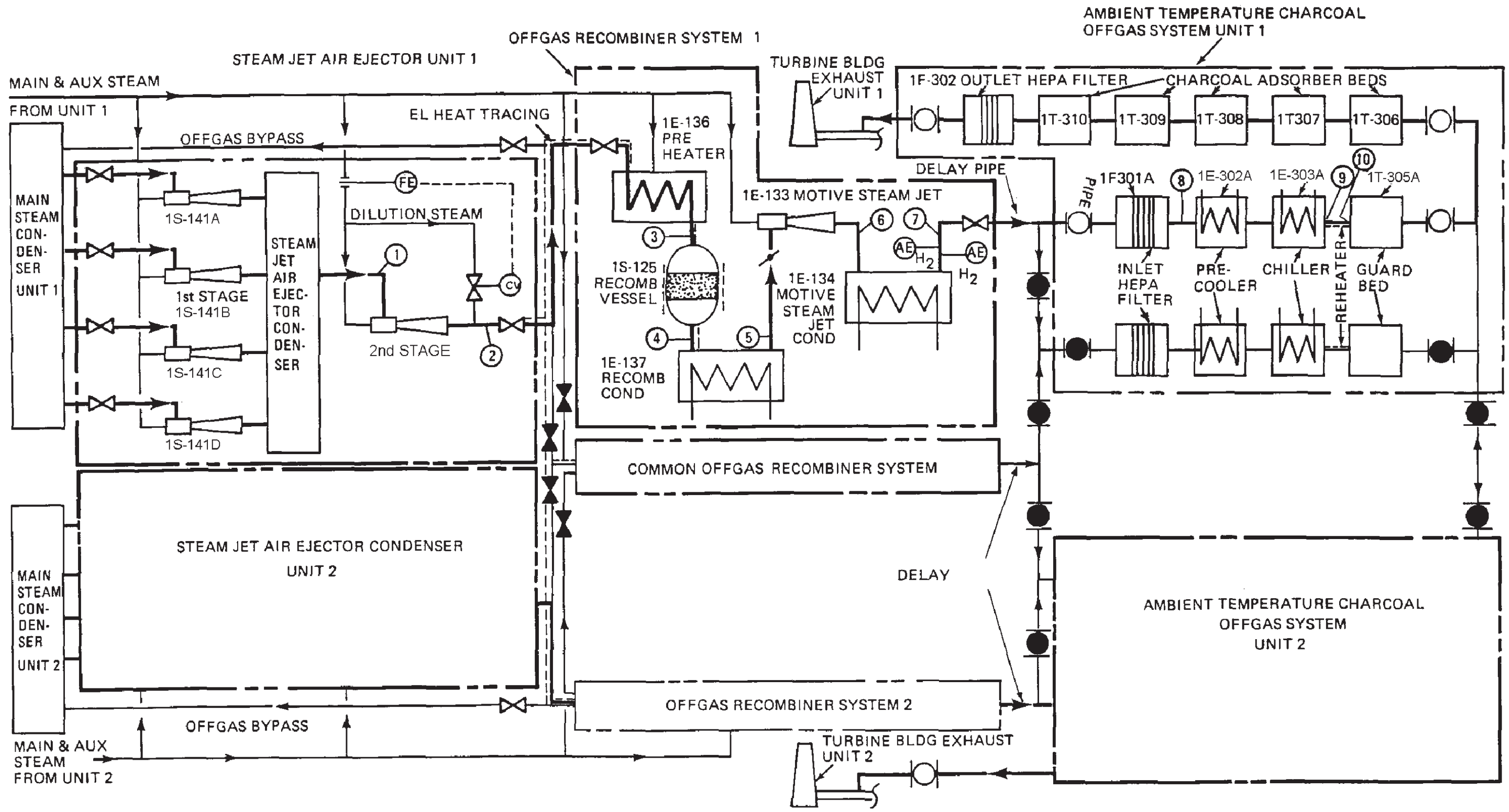
Table 11.3-11

COMPARISON OF EXPECTED RADIONUCLIDE CONCENTRATIONS IN THE ENVIRONMENT FROM ROUTINE ATMOSPHERIC RELEASES TO 10CFR20 LIMITS

LOCATION: WSW SITE BOUNDARY

| Isotope | Expected Annual Average Concentration from Two Units (μCi/ml) | 10CFR20 Appendix B,Table II, Column 1 Effluent Concentration Limit (μCi/ml) | Fraction of Effluent Concentration Limit |
|---|---|---|---|
| I-131 | 1.06E-13(-13) | 2.00E-10 | 5.30E-04 |
| I-133 | 1.15E-12 | 1.00E-09 | 1.15E-03 |
| Ar-41 | 8.08E-11 | 1.00E-08 | 8.08E-03 |
| Kr-83M | - | 5.00E-05 | - |
| Kr-85M | 2.44E-10 | 1.00E-07 | 2.44E-03 |
| Kr-85 | 2.06E-10 | 7.00E-07 | 2.94E-04 |
| Kr-87 | 1.13E-11 | 2.00E-08 | 5.62E-04 |
| Kr-88 | 5.02E-11 | 9.00E-09 | 5.56E-03 |
| Kr-89 | 1.17E-10 | 1.00E-09 | 1.17E-01 |
| Xe-131M | 4.68E-11 | 2.00E-06 | 2.34E-05 |
| Xe-133M | 4.76E-12 | 6.00E-07 | 7.92E-06 |
| Xe-133 | 6.62E-09 | 5.00E-07 | 1.33E-02 |
| Xe-135M | 5.32E-10 | 4.00E-08 | 1.33E-02 |
| Xe-135 | 7.74E-10 | 7.00E-08 | 1.11E-02 |
| Xe-137 | 3.72E-10 | 1.00E-09 | 3.72E-01 |
| Xe-138 | 1.66E-10 | 2.00E-08 | 8.32E-03 |
| Cr-51 | 1.65E-17 | 3.00E-08 | 5.50E-10 |
| Mn-54 | 4.38E-17 | 1.00E-09 | 4.38E-08 |
| Co-58 | 5.54E-18 | 1.00E-09 | 5.54E-09 |
| Fe-59 | 5.62E-18 | 5.00E-10 | 1.13E-08 |
| Co-60 | 9.72E-17 | 5.00E-11 | 1.94E-06 |
| Zn-65 | 5.18E-17 | 4.00E-10 | 1.29E-07 |
| Sr-89 | 9.90E-18 | 2.00E-10 | 4.96E-08 |
| Sr-90 | 1.11E-19 | 6.00E-12 | 1.85E-08 |
| Nb-95 | 7.94E-17 | 2.00E-09 | 3.96E-08 |
| Zr-95 | 1.43E-17 | 4.00E-10 | 6.58E-08 |
| Mo-99 | 5.26E-16 | 2.00E-09 | 2.64E-07 |
| Ru-103 | 3.34E-17 | 9.00E-10 | 3.70E-08 |
| Ag-110M | 1.90E-20 | 1.00E-10 | 1.90E-10 |
| Sb-124 | 1.11E-18 | 3.00E-10 | 3.70E-09 |
| Cs-134 | 5.92E-17 | 2.00E-10 | 2.96E-07 |
| Cs-136 | 5.62E-18 | 9.00E-10 | 6.26E-09 |
| Cs-137 | 8.80E-17 | 2.00E-10 | 4.40E-07 |
| Ba-140 | 1.99E-16 | 2.00E-09 | 9.96E-08 |
| Ce-141 | 2.30E-17 | 8.00E-10 | 2.88E-08 |
| H-3 | 7.30E-11 | 1.00E-07 | 7.30E-04 |
| C-14 | 7.54E-12 | 3.00E-09 | 2.52E-04 |
| Site ECL Fraction | | | 5.57E-01 |

NOTES: (1) 1.19e-13 = $1.19 \times 10^{-13}$

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| |
|---|
| SUSQUEHANNA STEAM ELECTRIC STATION<br>UNITS 1 & 2<br>FINAL SAFETY ANALYSIS REPORT |
| OFFGAS SYSTEM<br>PROCESS FLOW DIAGRAM<br><br>FIGURE 11.3-1, Rev 54 |

AutoCAD: Figure Fsar 11_3_1.dwg

THIS FIGURE HAS BEEN
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|---|
| Figure 11.3-2A-1 replaced by dwg.<br>M-169, Sh. 1<br><br>FIGURE 11.3-2A-1, Rev. 57 |

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Figure 11.3-2A-2 replaced by dwg.
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FIGURE 11.3-2A-2, Rev. 57

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FIGURE 11.3-2A-3, Rev. 56

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| Figure 11.3-2A-4 replaced by dwg.<br>M-169, Sh. 4<br><br>FIGURE 11.3-2A-4, Rev. 56 |

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Figure 11.3-2C-1 replaced by dwg.
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FIGURE 11.3-2C-1, Rev. 57

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| --- |
| Figure 11.3-2C-2 replaced by dwg.<br>M-2169, Sh. 2<br><br>FIGURE 11.3-2C-2, Rev. 56 |

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| Figure 11.3-2D-1 replaced by dwg.<br>M-2171, Sh. 1<br><br>FIGURE 11.3-2D-1, Rev. 56 |

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Figure 11.3-2D-2 replaced by dwg.
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FIGURE 11.3-2D-2, Rev. 55

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| Figure 11.3-3-1 replaced by dwg.<br>M-171, Sh. 1<br><br>FIGURE 11.3-3-1, Rev. 56 |

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Figure 11.3-3-2 replaced by dwg.
M-171, Sh. 2

FIGURE 11.3-3-2, Rev. 55

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Security-Related Information
Figure Withheld Under 10 CFR 2.390

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| --- |
| RELEASE POINT<br>LOCATIONS & DETAILS<br><br>FIGURE 11.3-4 |