IX - RADIOACTIVE WASTE SYSTEMS

IX - RADIOACTIVE WASTE SYSTEMS (Cont'd.)

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IX - RADIOACTIVE WASTE SYSTEMS

1.0 SUMMARY DESCRIPTION

The radioactive waste systems collect, treat, and dispose of radioactive and potentially radioactive wastes in a controlled and safe manner such that the operation and availability of the station is not limited. The radioactive waste system includes equipment, instrumentation, and operating procedures which ensure that radioactive wastes may be safely processed and disposed of within the limits set forth in 10CFR20, 10CFR50, Appendix I, and 40CFR190.

The radioactive input to the Radwaste systems is due primarily to 1) activation products resulting from irradiation of the reactor water and impurities therein (principally metallic corrosion products) and 2) fission products resulting from defective fuel cladding or tramp uranium contamination within the reactor system.

Radioactive wastes resulting from station operation are classified as liquid, gaseous, and solid. The following definitions apply to radioactive wastes:

1. Liquid Radioactive Wastes - Liquids directly from the reactor process and auxiliary systems or liquids which can become contaminated due to contact with these liquids from reactor process systems.

2. Gaseous Radioactive Wastes - Offgases from the Main Condenser evacuation and Turbine Gland Sealing Systems and ventilation system exhausts from buildings having the potential for containing radioactive materials. Gaseous radioactive wastes include noble gases, radioiodine, particulates, Carbon-14 and tritium.

3. Solid Radioactive Wastes - Solids from the reactor or auxiliary systems, solids in contact with reactor or auxiliary systems operations or those materials processed through the radwaste system.

2.0 LIQUID RADWASTE SYSTEM

The Liquid Radwaste (LRW) System includes an augmented treatment subsystem which is no longer in use. The LRW System (non-augmented) is described below.

2.1 Safety Objective

The safety objective of the LRW System is to provide those means necessary to maintain control over plant liquid radioactive effluents.

2.2 Safety Design Basis

The LRW System is designed to prevent the inadvertent release of liquid radioactive material from the exclusion area of the plant so that resulting radiation exposures are within the limits of 10CFR20, 10CFR50, Appendix I, and 10CFR100.

2.3 Power Generation Objective

The power generation objective of the LRW System is that the operation or availability of the plant is not limited.

2.4 Power Generation Design Basis

The LRW System is designed so that liquid radwastes are discharged from the plant within the limits specified in 10CFR20, 10CFR50, Appendix I, and 40CFR190, and the operation or availability of the plant is not limited. The LRW System collects, treats, and returns processed radioactive liquid waste to the plant for reuse. Treated radioactive wastes not suitable for reuse are discharged from the plant as releases or packaged for offsite processing or disposal.

2.5 Liquid Radwaste System (Non-Augmented)

2.5.1 Description

The LRW System for CNS was designed to accept process wastes from two nuclear units. Since CNS is only a single unit, it is larger than would normally be necessary. The LRW System collects, processes, stores, and disposes of all radioactive liquid wastes.

Included in the LRW System are the following components/systems:

a. Piping and equipment drains carrying potentially radioactive wastes;

b. Floor drain systems in areas which may contain potentially radioactive wastes;

c. Tanks, piping, pumps, process equipment, instrumentation and auxiliaries necessary to collect, process, store, and dispose of potentially radioactive wastes; and

d. Tanks and sumps used to collect potentially radioactive wastes.

Equipment was selected, arranged, and shielded to permit operation, inspection, and maintenance with acceptable personnel doses. For example, tanks and processing equipment which are expected to contain significant radiation sources, are located behind shielding, and similarly sumps, pumps, valves, and instruments are located in radiologically controlled access rooms or shielded spaces. In addition, the radwaste equipment was selected to minimize the need for maintenance. The radwaste system equipment configurations are given in Burns and Roe Drawings 2032 Sheets 1-5, 2033 Sheets 1-4, 2079 Sheets 1 and 2, and 2080. Operation of the waste system is essentially manual start-automatic stop.

The LRW System is divided into several subsystems so that the liquid wastes from various sources can be kept segregated and processed separately. Cross connections between the subsystems provide additional flexibility for processing of the wastes by alternate methods. The liquid radwastes are classified, collected, and treated as either high purity, low purity, or chemical. The terms "high" purity and "low" purity refer to chemistry purity conductivity and not radioactivity.

2.5.2 High Purity Wastes (Waste Collector Subsystem)

High purity (low conductivity) liquid wastes are collected in the Waste Collector Tank from the following sources:

Waste Collector Tank

1. Drywell Equipment Drain Sump
2. Reactor Building Equipment Drain Sump
3. Radwaste Building Equipment Drain Sump
4. Turbine Building Equipment Drain Sump
5. Startup Discharge from Reactor Water Cleanup (RWCU) Pumps
6. Draining of RHR System
7. Decantate from RWCU Phase Separators
8. Decantate from Condensate Phase Separators
9. Fuel pool system
10. Decantate from Waste Sludge Tank[18]
11. Chemical Waste Sample Tank[22]
12. Distillate Tank[22]
13. Radwaste Building Sample Rack IE
14. Waste Sample Tanks
15. Elevated Release Point Sump(Z sumps)

These wastes have low conductivity with variable radioactive concentrations dependent on their area of collection. The average high purity waste collected is 16,000 gallons/day with an average activity level of 1×10^{-4} μCi/ml.

During treatment, the high purity wastes are filtered in the Waste Collector Filter and then demineralized in the deep bed Waste Demineralizer. The expected decontamination factor (DF) for combined filtration and demineralization is at least 1,000. After processing, the waste is pumped to the Waste Sample Tanks where it is sampled.

If the analysis of the sample reveals water of high conductivity or high turbidity, the waste is recycled to the Waste Collector Tank for reprocessing. If the analysis of the sample reveals purity of the waste is acceptable, the waste is sent to the Condensate Storage Tank (CST). However, if the CST inventory does not permit additional water, the waste may be sent to the Waste Surge Tank or the waste can be discharged to the river, provided a minimum of one Circulating Water Pump is in operation. The flow capacity is 270 GPM.

The backwash resins from the demineralizer are sent to the Spent Resin Tank. The resins are then pumped to a high integrity container where they are dewatered using the NuPac dewatering system.

The backwash filter material from the Waste Collector Filter is sent to the Waste Sludge Tank. Solids treatment of the contents of this tank is similar to that for the resins. However, the tank contains a mixture of backwashes from the Waste Collector and Floor Drain Filters and fuel pool demineralizer sludges.

2.5.3 Low Purity Wastes (Floor Drain Subsystem)

Low purity (high conductivity) liquid wastes are collected in the Floor Drain Collector Tank from the following sources:

Floor Drain Collector Tank

1. Drywell Floor Drain Sump
2. Reactor Building Floor Drain Sumps
3. Radwaste Building Floor Drain Sumps
4. Turbine Building Floor Drain Sump
5. Chemical Waste Tank
6. Laboratory Drain Tanks
7. Elevated Release Point Sump (alternate flow path only)
8. Augmented Radwaste Building Floor Drain Sump
9. Decantate from Waste Sludge Tank (only when Waste Collector Tank is full)[18]

These wastes generally have low radioactivity concentrations, therefore, processing consists of filtration and subsequent transfer to the Floor Drain Sample Tank for sampling and analysis.

If the analysis of the sample reveals that the purity of the waste is sufficient to transfer to the High Purity Waste System then the waste is transferred to the Waste Collector Tank, if the inventory of the High Purity Waste System is such as to permit the additional volume. If the purity of the waste precludes processing to the Waste Collector Subsystem, but has low enough radioactivity concentration and acceptable purity for discharge, the waste is discharged to the river, provided a minimum of one Circulating Water Pump is in operation. If the waste cannot be processed to the Waste Collector Subsystem or the river, it is recycled back to the Floor Drain Collector Tank for further processing.

Because no radium-226 or radium-228 of plant origin will be present, and because the potential concentration of iodine-129 is very low, the discharge concentration limit for otherwise unidentified mixture of radioisotopes will not exceed the limit of 10^{-7} μCi/ml above background. If other radioisotopes are shown not to be present in significant concentrations, or if analyses are made, discharge limits may meet maximum permissible concentrations.

The average "dirty waste" (i.e., Low Purity Wastes from the Floor Drain Sumps) volume collected from the Floor Drain System is 7,000 gallons/day.

In the treatment process the wastes are filtered in the Floor Drain Collection Filter with a flow capacity of 65 gpm and an expected DF of 10 for filtration.[1]

2.5.4 Chemical Wastes

Chemical wastes are collected in the Chemical Waste Tank and Laboratory Drain Tanks from the following sources.

1. Shop decontamination solutions
2. Laboratory drains
3. Reactor Building and Radwaste Building decontamination drains

4. RWCU, Waste, and Condensate Precoat Tank drains

The chemical wastes are normally comprised of laboratory drains. Infrequently (every several years) decontamination solutions may be present due to equipment decontamination for maintenance. The MPF floor drains provide some of this solution due to decontamination of equipment in the machine shop. The maximum activity and volumes are due to the decontamination solutions.[16]

Chemical wastes are of such high conductivity (ionic content) as to preclude treatment by ion exchange. The wastes are neutralized, if necessary, using caustic or sulfuric acid as the neutralizing medium. These wastes are sent to the Floor Drain Collector Tank and processed by the Low Purity Waste System for disposal to the river. The flow rate for the Laboratory Drain Tanks to the Floor Drain Collector Tank is 38 gpm. The Chemical Waste Tank wastes are transferred to the Floor Drain Collector Tank at a rate of 50 gpm. A DF of 10 is expected in passing through the Floor Drain Collector Filter. After being shown suitable for disposal, the waste is diluted into the Circulating Water Discharge Canal at a rate to be within the unidentified mixture concentration limit of 10CFR20.[1]

If the radioactivity content of the waste precludes disposal to the river, the chemical wastes are processed through the floor drain demineralizer system or processed using an approved vendor method. See USAR IX-2.5.

Corrosion of laboratory drains through the normal use of acids is minimized by recirculating unused portions of samples to waste at the sample station. In effect this retains the sample in the system until it is satisfactorily neutralized. Reactor water, Condensate and Feedwater samples which do not need to be neutralized are routed to the High Purity Waste Subsystem where the water is recovered for reuse.

2.6 Augmented Liquid Radwaste (LRW) System[25]

The function of the Augmented Liquid Radwaste System to supplement the Liquid Radwaste System in processing wastes from the Floor Drain Collector Filter, the Floor Drain Collector Tank, the Chemical Waste Tank, and the Lab Drain Tanks. However, CNS no longer uses this system to process liquid radwaste.[27] Nevertheless, the equipment remains in place as shown in Burns and Roe Drawing 2079, Sheets 1 and 2.

2.7 Safety Evaluation

2.7.1 LRW (Non-Augmented)

The Radwaste Building is located on the north side of the Reactor Building, about 600 feet from the Missouri River. All of the liquid radwaste storage and collection tanks contained in this structure are located below ground level. The liquid radwaste storage and collection tanks with capacities greater than 500 gallons are of Class I design. The attached liquid process piping is of Class I design up to the first isolation valve. The Reactor Water Clean-up (RWCU) phase separator tanks, which are considered a part of the Radwaste System, are located in the Reactor Building. The RWCU phase separator tanks and the attached liquid process piping, up to the first isolation valve, are also of Class I design. Since the Radwaste Building substructure and the liquid radwaste storage and collection tanks are designed to withstand a Class I seismic occurrence, the possibility that radioactive water may escape the tanks, and then the building, and then run out into the ground through cracks is not credible. Additionally, there is a 40 mil plastic waterproofing membrane that completely envelopes the Radwaste Building substructure walls and foundation mat. These structural design features ensure that the safety objective is met.

2.7.2 Augmented LRW

CNS no longer uses this system to process liquid radwaste.[27]

The Augmented Liquid Radwaste System is located in a seismic Class II Radwaste Building extension.

2.8 Power Generation Evaluation

Since the CNS LRW system was designed to accept process wastes from two nuclear units, and CNS only has one nuclear unit, the operation and availability of the plant is not limited.

2.9 Inspection and Testing

The LRW System is normally operating on an "as required" basis during operation of the nuclear plant thereby demonstrating operability without any special inspections or testing.

The LRW System is in scope for License Renewal per 10 CFR 54.4(a)(1) and (a)(2) and was subject to aging management review. Aging effects are managed by the following Aging Management Programs: Bolting Integrity (see USAR Section K-2.1.2), Buried Piping and Tanks Inspection (see USAR Section K-2.1.3), External Surfaces Monitoring (see USAR Section K-2.1.14), Oil Analyses (see USAR Section K-2.1.28), One-Time Inspection (see USAR Section K-2.1.29), Periodic Surveillance and Preventive Maintenance (see USAR Section K-2.1.31), and Selective Leaching (see USAR Section K-2.1.34). There are no Time-Limited Aging Analyses that are applicable.

3.0 SOLID RADWASTE SYSTEM

3.1 Power Generation Objective

The power generation objective of the Solid Radwaste System is to collect, process, package, and provide temporary storage facilities for solid wastes prior to shipment for off-site processing and/or disposal.

3.2 Power Generation Design Basis

1. The system provides collection, processing, packaging, and storage of solid wastes resulting from normal station operations.

2. The system provides a safe and reliable means for handling solid wastes and to minimize radiation exposure to station personnel.

3. The Solid Radwaste System includes equipment, instrumentation, and operating procedures such that the solid radwastes collected and prepared for off-site shipment in shielded casks, if required, will not result in radiation exposures in excess of the limits set in NRC or DOT regulations.

4. Shielded casks are provided as necessary to conform with 10CFR71.

3.3 Description

3.3.1 General (See Burns and Roe Drawing 2298)

The solid waste processing areas are located in the Radwaste and Augmented Radwaste Buildings and process both wet and dry solid wastes. Wet solid wastes include backwash sludge wastes from the Reactor Water Cleanup (RWCU) System, the Condensate Filter Demineralizer System, the Fuel Pool Filter Demineralizers, the Floor Drain Filter, the Waste Collector Filter, and spent resins from the Waste Demineralizer and Floor Drain Demineralizer. Dry solid wastes include rags, paper, equipment parts, solid laboratory wastes, etc., which may be potentially contaminated with radioactive material.

The function of the Solid Radwaste System is to reclaim the liquid phase of the wet solid wastes for reuse within the station and to prepare the solid waste for off-site shipment with minimum exposure of the operators to radiation. Prior to off-site shipment to a licensed burial ground, solid wastes can be temporarily stored on site in shielded areas.

3.3.2 Wet Solid Radwaste

3.3.2.1 Sludge Processing

Expended filter-demineralizer ion exchange resins are removed when necessary by backwashing. RWCU System sludges and Condensate System sludges are collected in Phase Separators where excess backwash water is removed by decantation. The sludge is accumulated for processing, with subsequent radioactivity level decay. The Fuel Pool Filter Demineralizer, Floor Drain Collector Filter and Waste Collector Filter are backwashed to the Waste Sludge Tank.

RWCU sludges, Condensate System sludges, and waste filter and Fuel Pool sludges are kept separate because of the variation in radioactive material content. This approach minimizes shielding requirements during shipping of the solid wastes.

3.3.2.1.1 Reactor Water Cleanup (RWCU) Sludge

The purpose of the Radwaste System for cleanup sludge is to process the highly radioactive backwash waste which is discharged from the RWCU System.

The backwash waste, as discharged from the RWCU Filter Demineralizers, is a relatively dilute slurry (0.5% by weight suspended solids) which is highly radioactive.

The backwash discharge from the RWCU Filter Demineralizers is collected and concentrated in two 4,500 gallon cleanup RWCU Phase Separators which are located below the RWCU Demineralizers in the Reactor Building. Upon sufficient backwash accumulation, the concentrated waste is transferred to the Dewatering System for dewatering.

The RWCU Phase Separators are designed to concentrate the sludge from 0.5 weight % solids to 5% by weight solids by sedimentation and decantation of the supernatant. While the working separator is filling, the other previously filled tank is held isolated to allow additional decay of sludge activity.

After each backwash batch is received by the working separator, it is allowed to settle for a period of time and the decantate is then transferred by pumping to the Waste Collector Tank. When sufficient sludge has accumulated, the working separator is isolated and the sludge is fluidized to a 5% (by weight) slurry and transferred by pumping to the Dewatering System for dewatering. The cleanup phase separators are Class I Seismic. All other equipment is Class II Seismic.

3.3.2.1.1.1 Equipment Description

Cleanup Phase Separators

These tanks are of stainless steel construction and designed and fabricated in accordance with API-650 for atmospheric design pressure at 250°F. Each tank has a capacity of 4,500 gallons.

Sludge Pumps

This pump has a capacity of 200 gpm at 300 feet TDH.

Decant Pump

This pump has a capacity of 50 gpm at 30 feet TDH.

3.3.2.1.2 Condensate Filter Demineralizer Sludge

The purpose of this system is to process the radioactive backwash waste which is discharged from the Condensate Filter Demineralizer System.

The backwash waste as discharged from each of seven Condensate Demineralizers is a relatively dilute slurry (0.5% weight suspended solids) which is radioactive.

The backwash discharge from the Condensate Filter Demineralizers is collected in the Condensate Backwash and Transfer Tank which is located below the Condensate Filter Demineralizers in the Radwaste Building. After collection, the waste is transferred by pumping to one of the two Condensate Phase Separators for processing.

The Condensate Phase Separators are designed to concentrate the sludge from 0.5 weight % solids to 5% by weight solids by sedimentation and decantation of the supernatant. While the working separator is filling, the other previously filled tank is held isolated to allow additional decay of sludge activity.

After each backwash batch is received by the working separator, it is allowed to settle for a period of time and the decantate is then transferred by pumping to the Waste Collector Tank. When sufficient sludge has accumulated, the working separator is isolated and the sludge is fluidized to a 5% (by weight) slurry and transferred by pumping to the Dewatering System for dewatering. The Condensate Phase Separators are Class I Seismic. All other equipment is Class II Seismic.

3.3.2.1.2.1 Equipment Description

Condensate Phase Separators

These tanks are of epoxy-coated carbon steel with stainless steel internals and designed and fabricated in accordance with API-650 for atmospheric design pressure at 250°F. Each tank has a capacity of 12,500 gallons.

Sludge Pump

This pump has a capacity of 400 gpm at 125 feet TDH.

Decant Pump

This pump has a capacity of 475 gpm at 50 feet TDH.

Condensate Backwash and Transfer Tank

This tank is made of epoxy-coated carbon steel, designed and fabricated in accordance with API-650 for atmospheric design pressure at 150°F. This tank has a capacity of 12,600 gallons.

Condensate Backwash Transfer Pump

This pump has a capacity of 450 gpm at 30 feet TDH.

3.3.2.1.3 Fuel Pool Filter Demineralizer, Floor Drain Collector Filter, and Waste Collector Filter Sludge

Backwash sludge wastes from the Fuel Pool Filter Demineralizer, Floor Drain Collector Filter, and Waste Collector Filter Demineralizers are drained by gravity to the Waste Sludge Tank which is located in the Radwaste Building. Provisions are incorporated in the Waste Sludge Tanks for the addition of flocculent, if required. These waste sludges are transferred on a batch basis by pumping to the Dewatering System for dewatering. The sludges are a relatively dilute slurry of 0.5 weight % of suspended solids. Piping is also provided to pump the wastes to the Condensate Phase Separators for additional concentration of the sludge for flexibility. All basement tanks are Class I Seismic; all other equipment is Class II Seismic.

3.3.2.1.3.1 Equipment Description

Waste Sludge Tank

This tank is of epoxy-lined carbon steel and designed and fabricated in accordance with API-650 for atmospheric pressure and 140°F. The tank has a capacity of 15,000 gallons.

Waste Sludge Pump

This pump has a capacity of 500 gpm at 125 feet TDH.

3.3.2.2 Spent Resins

Spent resin from the Waste Demineralizer and Floor Drain Demineralizer is sluiced into a 2,000 gallon Spent Resin Tank.

The Waste Demineralizer contains 80 cubic feet of mixed resins which will not be regenerated. Expected spent resin volume is approximately 240 cubic feet per year.

After each spent resin batch is discharged to the Spent Resin Tank, the spent resins will be pumped from the tank to the Centrifuges or the Dewatering System for dewatering. The Spent Resin Tank is Class I Seismic.

3.3.2.3 Wet Solid Radwaste Processing for Disposal

The Resin Dewatering System is available for processing wet solid wastes for disposal. The purpose of this system is to process the waste sludges (see IX-3.3.2.1) and the spent resins (see IX-3.3.2.2). This system concentrates the bulk volume of the wet solid wastes, prepares this concentrated waste for off-site shipment, and reclaims the liquid phase of the wet solid wastes for reuse within the station.

3.3.2.3.1 Resin Dewatering System Description[19]

Wet solid wastes are processed using a Resin Drying (Dewatering) System. This system processes powdered and bead type ion exchange resins and other filter media by removing the excess water from the resins. This is accomplished in a three step process, performed remotely in ventilated, shielded areas to minimize radiation exposure to workers.

First, the liner is filled from the plant's waste tanks using excess water to keep the resin in a slurry and recirculating the waste tank so that a homogeneous mixture is achieved in the liner. During this transfer, the liner will be dewatered so that the available space in the liner is filled with resin to the maximum extent practicable.

Second, the excess water is pumped out of the liner using a positive displacement diaphragm pump.

Third, when all of the pumpable water is removed, the blower is started to recirculate air through the resin. The blower heats the air and as the warm air passes through the resin it entrains and vaporizes moisture in the resin bed. This moist air is pumped through the entrainment separator tank where refrigeration coils condense the water vapor in the air stream and any entrained water is removed. The water is pumped out of the tank using a diaphragm pump. The air is recirculated through the resin until the percent relative humidity of the air stream indicates the resin bed is dry. The system is then shut down, the fillhead removed and the container capped. The container is given a surface-wipe test for determination of surface contamination and then loaded for off-site shipment or transport to storage.

Containers which will be stored temporarily on-site are loaded into Temporary Storage Modules (TSMs) and transferred via truck/crane to the LLRW Storage Facility Pad. The TSMs are concrete cylinders which provide radiation shielding, physical protection, and protection from the elements during the storage period at the Pad. Storage duration at the LLRW Storage Facility Pad is limited to five years in accordance with the guidance provided by Generic Letter 81-38.

The TSMs placed on the Pad for interim storage will eventually be returned to the Augmented Radwaste Building and the waste containers removed. The waste containers will then be placed into shipping casks for off-site shipment. The empty TSMs will be returned to the Pad for storage and reuse, as necessary.

3.3.2.3.1.1 Equipment Description

Fill Head Assembly

This Assembly sits over the liner and serves to direct water/resin slurry in, water out, dry air in, and moist air out of the cask liner. The fillhead is stored in the shipping cask pit.

Piping Assembly

This Assembly contains the water separator which condenses water out of the moist air returning from the fillhead assembly during the drying cycle. The water pump is also located in this assembly and is used to pump free standing water out of the water/resin slurry in the liner.

The piping skid is located on the floor, east of the shipping cask pit, and north of the Drum Handling Control Room north wall. The discharge piping is routed to an existing sump pit located in the Drum Storage Fill Station of the 903’ Radwaste Building.

Blower Assembly

This Assembly is used to pump drying air through the resin being dried in the liner after the free standing water has been pumped out. The air is filtered to remove oils and particulates prior to being directed back to the liner. The skid also contains the HEPA filter for exhaust air during the water/resin slurry fill portion of the cycle.

The blower skid is located on the northeast corner of the Drum Handling Control Room roof.

Chiller Assembly

This assembly consists of a condensing unit with the appropriate refrigeration specialties (i.e., filter/dryer, sight glass, liquid line solenoid valve, thermostatic expansion valve, etc.). The condensing unit provides the cooling refrigerant to the water separator portion of the piping skid assembly.

The chiller is located on the northeast corner of the Drum Handling Control Room roof.

Control Panel

The Control Panel contains process monitoring equipment for remote controlling and monitoring of fill levels, liner temperatures, blower exhaust temperatures, blower inlet temperatures, fillhead position, resin slurry flow control valve, dewatering pump, alarms, water separator inlet air wet bulb temperature, etc. One remote television screen is also included, although it is not attached to the Control Panel.

The Control Panel and television screen are located along the east wall of the Drum Handling Control Room.

3.3.3 Dry Solid Radwaste

Two methods are presently available for processing dry, solid, radioactively contaminated waste. The preferred method is incineration, compaction, and smelting through services procured from an off-site vendor(s) due to the cost of waste disposal. However, hydraulic compaction is an alternative.

The preferred method of processing dry, solid, radioactively contaminated waste begins with its collection in large Sea Land containers at the site. The waste is not compacted or processed in any way prior to shipment to an off-site vendor. The vendor will sort all waste into three streams for processing: incineration, compaction and smelting. The majority of the waste will be incinerated and packaged. Any non-incinerable waste may be compacted using a super-compactor. Any metallic waste may be smelted into blocks for use as shielding at Department of Energy facilities. The slag from the smelting process is incorporated into the packaging for the incinerated waste.

The last method of processing dry radioactive waste (DAW) is with the hydraulic compactor. The hydraulic compactor includes the hydraulic pump with motor, hydraulic oil storage, high efficiency filter, fan and accessories. The hydraulic compactor is designed to compress the wastes in a 55 gallon drum at 50 psi over the open area of the drum. During compression, ventilation air is pulled across the top of the drum through high efficiency filters by a fan. The filled 55 gallon drums are transferred to a temporary storage area.

3.3.4 Miscellaneous Solid Wastes

Some solid materials that are not processed by the radwaste system are stored in the spent fuel pool until offsite storage or disposal. Examples are control blades, neutron detectors, and vacuum filters. (See Section X-3.5.1 for further discussion).

3.3.5 Independent Spent Fuel Storage Installation (ISFSI)

The ISFSI augments the Spent Fuel Pool as a means for storage of spent fuel, pursuant to 10 CFR 72.210.

3.4 Power Generation Evaluation

Operation of the Solid Radwaste System is by semi-remote means, and the shielding design in the system working areas minimizes radiation dose to personnel and allows the processing of waste to be within 10CFR20 limits.

3.5 Inspection and Testing

Those Solid Radwaste System used on a routine basis do not require specific testing to assure proper operation. Those Solid Radwaste Systems not used on a routine basis are tested prior to use to assure proper operation.

4.0 GASEOUS RADWASTE SYSTEM

This section describes the Gaseous Radwaste System which includes the Off-Gas (OG) System and Augmented Off-Gas (AOG) System.

4.1 Power Generation Objective

The Off-Gas System collects and processes gaseous radioactive wastes from the Main Condenser Steam Jet Air Ejectors (SJAEs), the startup Mechanical Vacuum Pumps, the Gland Steam Condensers, and other minor sources, and controls their release to the atmosphere through the Elevated Release Point (ERP) in such a way that the operation and availability of the station is not limited.

4.2 Power Generation Design Basis

1. The Gaseous Radwaste System is designed so that gaseous and particulate radwastes are processed and discharged such that operation and availability of the station are not limited.

2. The Gaseous Radwaste System is designed to minimize the possible explosion hazard of the hydrogen and oxygen present.

3. The Gaseous Radwaste System is designed to include equipment, instrumentation, and operating procedures such that the gaseous radwastes discharged from the ERP to the environment will not exceed the limits set forth in the ALARA requirements of 10CFR50, Appendix I.

4. The Gaseous Radwaste System is designed to provide isolation on high off-gas radioactivity level.

5. The Gaseous Radwaste System is designed to maintain its integrity for all expected operating conditions by conservative process design.

6. The off-gas liquid drain line must function to drain excess liquid from the system and drain at a rate not in excess of the capacity of one Z Sump pump.

4.3 Off-Gas System (Non-Augmented)

4.3.1 Description

4.3.1.1 General

The Off-Gas System (Burns and Roe Drawing 2009) includes the subsystems that process and dispose of the gases from the Main Condenser Air Ejectors, the startup Mechanical Vacuum Pumps, and the Gland Steam Condensers. The processed gases are routed to the ERP for dilution and elevated release to the atmosphere. The Air Ejector discharge and the ERP are continuously monitored by radiation monitors. See USAR VII-12.

Expected activity levels of activation gases leaving the reactor steam nozzles during normal operation with no fuel leaks are identified in Table IX-4-1. The corresponding activity arriving at the turbine and air ejector are less due to decay in transit and the fact that part of the N-13, N-16, and most of the 0-19 isotopes remain with the condensate and do not follow the noncondensibles. Other radioactive gases which may also be present are H-3, N-17, Ar-37, and Ar-41. These are present in amounts low enough to be deemed insignificant by comparison with the N-13. Of the activity arriving in the primary steam at the turbine, a fraction will go to the Gland Seal Off-Gas subsystem.

Gases routed to the ERP include air ejector and gland seal off-gases, and gases from the Standby Gas Treatment System (see USAR V-3.3.4 for additional information concerning SGT System). Dilution air input to the ERP is provided to reduce the hydrogen in the Air Ejector off-gases to a concentration of less than four percent (4%) by volume. Dilution air is supplied by one of two full capacity fans in the Off-Gas Filter Building located near the ERP. The ERP is designed such that prompt mixing of all gas inlet streams occurs in the base to provide additional dilution of hydrogen and to allow location of the sample point as near to the base as possible. The ERP drainage is routed to the Liquid Radwaste System via loop seals.

The Gaseous Radwaste System is adequately shielded to minimize the dose received by station personnel.

TABLE IX-4-1

GASEOUS RADWASTE SYSTEM DATA

Basis for System Design

A. Rate of evolution in steam from reactor steam nozzle.

Isotope	Half-Life	Evolution Rate (μCi/sec)
N-13	10 min.	2.0×10^3
N-16	7.4 sec.	1.0×10^7
O-19	29 sec.	7.0×10^3

B. Flow rates of dry gases at air ejector at 130°F and 1 atm.

Hydrogen (From Reactor Water Decomposition)	108 ft^3/min.
Oxygen (From Reactor Water Decomposition)	54 ft^3/min.
Air (In-leakage to Turbine Condenser)	45 ft^3/min.(1)
Water Vapor (To Saturate)	34 ft^3/min.
Activated and Noble Gases	Negligible
TOTAL GASES	241 ft^3/min.

(1) At 130°F and 15.7 psia.

C. ERP release rate of N-13 = 300 μCi/sec with 30 minute holdup.

4.3.1.2 Air Ejector Off-Gas Subsystem

The Air Ejector Off-Gas Subsystem consists of a 30 minute hold-up line, high efficiency filters, isolation valves, dilution fans, and the ERP. During normal operation, the Air Ejector off-gas is the major contributor to the activity in the station off-gas release. The Air Ejector off-gases entering this system are noncondensibles from the Main Condenser. These noncondensibles consist essentially of hydrogen and oxygen formed in the reactor by radiolytic decomposition of water, air in-leakage to the Main Condenser, water vapor, and fission gases which are negligible in terms of volume.

Fission gases may arise from minor amounts of tramp uranium on the surface of the fuel element or from imperfections or perforations which might develop in the fuel cladding. The release rate of activation gases is proportional to the thermal output of the reactor and to the hold-up time provided in the system prior to release at the ERP.

For normal station operation, the Air Ejector Off-Gas Subsystem provides a total hold-up time of 30 minutes, based on normal air in-leakage. This time period provides for decay of short lived Xe or Kr to solid daughters to permit retention of these particulates by filters prior to off-gas vent pipe release. In addition, this holdup provides sufficient time for an operator to take appropriate action in the event that the noble gas release rate (due to fuel leaks) exceeds the instantaneous permissible release rate. The 30 minute hold-up requirement and the flow rates given in Table IX-4-1 are the basis for sizing the Air Ejector Off-Gas Subsystem.

Valves are placed in each of the Air Ejector Off-Gas Subsystems, which are automatically closed on an isolation signal from both air ejector process radiation monitors. A signal from both channels is required to close these valves by means of a time delay of 15 minutes when the short term release rate limit is reached.

The system, from the Air Ejector outlet to the Dilution Fan outlet, is designed for a pressure of 350 psi to contain a possible explosion resulting from the hydrogen and oxygen present. The Off-Gas Filter System which is located in the Off-Gas Filter Building, consists of two parallel trains, with each train containing a moisture separator, two full-flow, high-efficiency, particulate air (HEPA) filters, and a filter retainer plate. Each train is sized for 100% Air Ejector Off-Gas Capacity (one operating, one spare unit).

Upon possible explosion upstream of filters, the failed filter retainer plate is capable of stopping all filter pieces larger than 0.15 x 0.15 mm in cross-section and shall sustain explosion pressure from either direction. Both filter units are located below grade in a shielded pit; appropriate valving is provided to permit isolating either filter unit. The internal construction of each unit is designed to permit remote removal of the unit within its container.

The Off-Gas Dilution Fans supply dilution air to reduce the hydrogen concentration in the ERP and maintain suitable exit velocities at the top of the ERP. Either one of the two fans provides the required dilution air flow (one normally operating and one spare). The two fans are electrically interlocked. Loss of either fan is annunciated in the Main Control Room. Both fans are on an emergency power source. Check valves are located to prevent bypass of air. The Off-Gas Dilution Fans are located in the Off-Gas Filter Building, in a room radiation shielded from all adjoining areas. Dilution flow is added to the flow of Off-Gas before the Off-Gas pipe enters the floor of the Off-Gas Filter Building to travel underground to the ERP. Dilution flow piping has been designed to contain an explosion (Off-Gas flow is within extra heavy or schedule 40 pipe) and to completely seal off an inoperative dilution run. Standard weight pipe, incorporating a check valve and a butterfly valve, is maintained up to the dilution fan outlet plenum.[20]

A positive pressure of approximately 1 in. w.g. exists. System operation is normal with the slight backpressure on the air ejectors because they will function with a backpressure in excess of 1 psi. A flow orifice has been located downstream of where the dilution flow enters to provide a low pressure for the Off-Gas inlet and to provide monitoring of the dilution flow.[25]

To provide an indirect indication of hydrogen leakage into the Off-Gas Building, a red light that is connected to the CAM unit has been installed inside the northwest window of the building. This light will illuminate if high activity is present in the Off-Gas Building. An increase in activity would also indicate the presence of hydrogen because they both are a result of off-gas leakage.

The Air Ejector Off-Gas pipe meets the requirements of ANSI B31.1.0 Section I and Case N-12. The Air Ejector Off-Gas pipe wall is designed for pressures per NACA-TN-3935.

4.3.1.3 Gland Seal Off-Gas Subsystem

The Gland Seal Off-Gas Subsystem collects gases from the Gland Steam Condenser and the Mechanical Vacuum Pumps and passes them through holdup piping prior to release to the stack. Gland Seal off-gases and gases from the Mechanical Vacuum Pumps (used during each startup) are routed to the stack via the Gland Seal Holdup Line which is separate from the Air Ejector Holdup Line.

The Gland Seal Off-Gas Subsystem provides a one minute holdup time to allow decay of N-16. The holdup time is provided by a long 48 inch diameter pipe between the Gland Seal Exhausters and the ERP.

Operating pressure is atmospheric; however, design pressure for explosion possibilities is 900 psig. Hydrogen and oxygen are well below explosive limits. No filters, shut-off valves, or radiation monitors are required. The Mechanical Vacuum Pumps are manually stopped by remote manual switch. Upon a Main Steam Line (MSL) Radiation Monitor isolation signal, the Mechanical Vacuum Pumps trip and the inlet and outlet valves to the Mechanical Vacuum Pumps close.

The Gland Seal Off-Gas pipe meets the requirements of ANSI B31.1.0, Section I, and Code Case N-12.

4.4 Augmented Off-Gas (AOG) System[25]

4.4.1 System Parameters

It is the function of the AOG System to further delay the radioactive gases in the off-gas stream, reducing the activity level, prior to venting to the atmosphere. This system satisfies the as low as practicable requirements of 10CFR50, Appendix I. The off-gas stream enters the AOG System after passage through the 48 inch delay pipe at the flow rates shown in Table IX-4-2.

The AOG System is designed to handle off-gas flow from the plant during operation with maximum air in-leakage at 130°F. The system design parameters are as follows:

4.4.1.1	Sizing:	The equipment is installed in two parallel trains, each with 100% capacity, except for the charcoal beds which can be operated in the following arrangements: 6 beds in parallel or 6 beds in series up to 50 scfm, or 5 beds in series up to 30 scfm.
4.4.1.2	Decontamination Factor (DF):	1,000 minimum, based on 6 charcoal beds, 30 scfm flow, and the 30-minute activity level of 100,000 μCi/sec. Decontamination factors for alternate charcoal bed configurations and flow rates are calculated in NEDC 10-052.[28].
4.4.1.3	Operation:	Continuous Remote control capability Reduced flow operation capability
4.4.1.4	Safety and Reliability:	Redundancy Failsafe control systems Safety monitoring and alarm systems Elimination of potential leakage of radioactive elements Elimination of potential hydrogen explosion 350 psig Design Pressure
4.4.1.5	Mechanical Design:	40 year useful life expectancy. 1. Initially designed as follows: a. Process side radioactive components per ASME Code, Section III, Class 3. b. Nonradioactive components per ASME Code, Section VIII, Division 1. c. Seismic Class IIS. 2. After implementation of Minor Design Change 83-034[15] design is as follows: a. Piping and equipment pressure parts as per USAR Appendix A. b. Other components per USNRC Regulatory Guide 1.143, Rev. 1, October 1979.
4.4.1.6	Configuration:	Skid-mounted equipment modules and individual components

TABLE IX-4-2

NONCONDENSIBLE GAS FLOW RATES (LB/HR) ENTERING AUGMENTED OFF-GAS TREATMENT SYSTEM

Component	Startup	Normal In-leakage at 130°F	Maximum In-Leakage at 130°F
Air	1,150.0	138.0	181.8
Hydrogen	1.6	31.8	31.8
Oxygen	12.8	254.0	254.0
Water	132.0	91.8	91.8
Total	1,296.4	515.6	559.4

4.4.2 Process Design

The processes required to satisfy the system parameters are basically 30 minute delay, dilution, recombination, dehumidification, and long term delay, as shown below:

Off-gas ↓

30 minute delay → Dilution → Recombination → Dehumidification → Long term delay

↑ Decontaminated Stream

After the off-gas stream passes through the 30 minute delay pipe and existing filters, the SJAE dilutes the off-gas stream raising pressure to the required system inlet pressure. In the recombination process, the hydrogen and oxygen are recombined stoichiometrically. Dehumidification consists of moisture removal prior to long term delay to reduce the dewpoint of the gas to a very low level. Long term delay for the decay of the noble gas isotopes is achieved in a series of charcoal beds. These processes are shown in detail on the flow diagram, Cosmodyne Drawing 6000302, Sheets 1 and 2, and are described in detail in the following paragraphs.

4.4.2.1 Hydrogen Dilution

The Off-Gas stream, after a 30 minute delay in an existing delay pipe, enters the AOG System. The normal hydrogen concentration is much greater than the lower hydrogen flammability limit of 4.1% and requires dilution of the Off-Gas stream to reduce hydrogen concentration to a safe level. The dilution requirements are based on minimum bleed air flow, which results in the highest concentration of hydrogen as the worst-case condition (Table IX-4-3).

The Off-Gas stream is diluted with steam prior to entering the Recombiner. The Recombiner trains utilize nuclear plant steam to eliminate the recycle loop as a potential source of catalyst migration to undiluted portions of the Off-Gas process. This process of dilution is described below.

Up to 7000 lbm/hr of steam is utilized for Off-Gas dilution. 2400 lbm/hr of this steam is provided by motive steam to the third stage ejector. The remaining steam is provided at the suction of the third stage ejector via a pressure reducing nozzle. Both of these sources of dilution steam are supplied from plant nuclear steam. The action of throttling the high pressure nuclear plant steam into the low pressure AOG stream superheats the stream, therein, assuring that the gas temperature entering the Recombiner is well above saturation temperature to prevent condensation of moisture on the Recombiner catalyst bed.

TABLE IX-4-3

STREAM COMPOSITION AFTER DILUTION

	VOLUME		MASS	
COMPONENT	% by Vol.	Rate Lb-mol/hr	% by Wt.	Rate lb/hr.
Hydrogen (H_x)	3.96	15.77	0.45	31.80
Oxygen (O_x)	1.98	7.88	3.61	254.00
Air	0.23	0.93	0.38	26.97
Steam (H_2O)	93.82	373.30	95.55	6,719.40
Total	100.00	397.90	100.00	7,032.20

4.4.2.2 Recombination

The recombination process is carried out in a single stage Catalytic Recombiner. Prior to entering the Recombiner, the AOG stream must have hydrogen concentration lower than 4% for safety and must be preheated above the saturation temperature. As explained previously, the stream entering the Recombiner is sufficiently diluted and is also preheated to about 250°F-320°F during normal operation. This dilution is also sufficient for minimum bleed air flow of 6.0 scfm; in this worst case condition, the hydrogen concentration is still only 3.96%.

It is important that the Recombiner catalyst remain dry at all times to preserve its reactivity; therefore, to prevent condensation of moisture on the catalyst bed during startup, a steam-heated preheater is used to raise the temperature of the AOG stream from 250°F to 320°F. Since the SJAE is not operating prior to startup, service air provides the motive force. The Recombiner is also preheated prior to startup by an external electric heater. The SJAE will be running, and service air may be used for additional off-gas flow.

In the Recombiner, most of the hydrogen and oxygen present in the inlet stream are catalytically combined, reducing the hydrogen concentration from 4% on a wet basis to 1% maximum, dry basis. The heat of reaction, with the formation of water vapor, raises the temperature of the gas stream as it passes through the Recombiner catalyst bed. With inlet temperature maintained at 320°F, the temperature of the effluent gas stream will equal [preheater outlet temperature]+[%H2 Into Recombiner x 125°F]. Example: preheater temperature of 320°F plus Recombiner H2 concentration of 2%, Recombiner outlet temperature equals [320°F]+[2%x125°F] = 570°F.[17]

The hot effluent consists principally of steam, with air and very small quantities of radioactive gases (krypton and xenon). On leaving the Recombiner, the AOG stream flows to a Post-Recombiner Condenser.

4.4.2.3 Dehumidification

The steam in the Post-Recombiner Condenser is desuperheated, condensed, and cooled to approximately 150°F. Condensate at 120°F (maximum) is used as the cooling medium. The AOG stream is further cooled, then flows to a water separator where the condensed liquid is separated from the gas stream and cycled back to the Hotwell.

The effluent AOG gas from the water separator is cooled further to approximately 40°F in a cooler-condenser. A Glycol Cooler System provides the necessary refrigeration. Condensate is removed in a Moisture Separator and is sent to the Chemical Drain Sump.

4.4.2.4 Drying

The AOG stream is then dried to approximately -60°F dewpoint by passing it through an adsorbent bed of a Cyclic Dryer System. The Cyclic Dryer System contains two dryer beds, each of which has the capacity of adsorbing water contained in the AOG stream at maximum flow rate for 24 hours. The two dryer beds are alternately placed in service every 24 hours, at which time the exhausted dryer bed is regenerated. For regeneration, a portion of the AOG stream is withdrawn upstream of the Dryer System, is heated by an electric heater, and fed to the exhausted dryer bed. This gas stream is returned to the inlet of the AOG System by the Third Stage SJAE. The regeneration accomplished in this manner is a closed loop operation, eliminating the possibility of accidental release of residual gases to the atmosphere.

4.4.2.5 Hydrogen Analyzers

Hydrogen analyzers are installed at the downstream end of the AOG System. Also, the Recombiners are equipped with temperature sensors and alarms. This instrumentation system will indicate any anomalies in the hydrogen concentration and permit corrective action as required.

4.4.2.6 Long Term Delay

For decay of radioactive isotopes, the AOG stream is passed through a series of charcoal adsorber beds. A lower than ambient operating temperature of 0°F is selected since the adsorption coefficients, K, of krypton and xenon increase with decrease in temperature. Experiments were conducted by Oak Ridge using tracer gases to determine K values at various temperatures. Also, the contractor conducted its own experiments utilizing argon as a sweep gas and krypton, xenon, and carbon dioxide as the constituents. Based on this and other published data, adsorption coefficients of 75 and 1,500 cc/gm are selected for krypton and xenon, respectively.

A quantity of 33.3 tons of charcoal at 0°F temperature will delay krypton isotopes for 44.5 hours and xenon isotopes for 37 days. This is based on 30 scfm flow rate at 0°F temperature and about 0.5 psig pressure. These specified delays will reduce the effluent activity to less than 100 μCi/sec. Table IX-4-4 shows the activity profile for the system based upon 0.1 Ci/sec input to the AOG System. A maximum flow of 50 scfm was assessed per calculation NEDC 04-056.

TABLE IX-4-4

ACTIVITY PROFILE

ISOTOPE	ACTIVITY AFTER 30-MINUTE DELAY (µCi/sec)	30 SCFM ACTIVITY OF CHARCOAL BED EFFLUENT (NOTE 1 & 3) 6 BEDS (5 BEDS) (µCi/sec)	40 SCFM ACTIVITY OF CHARCOAL BED EFFLUENT (NOTE 2 & 3) 6 BEDS (µCi/sec)	50 SCFM ACTIVITY OF CHARCOAL BED EFFLUENT (NOTE 2 & 3) 6 BEDS (µCi/sec)
Kr-89	180	0, (0)	0	0
Kr-87	15,000	0, (0)	0	0
Kr-83m	2,900	0, (0)	0.01	0.149
Kr-88	18,000	.3, (2.1)	4.74	25.5
Kr-85m	5,600	5.1, (18.1)	29.54	86.2
Kr-85	20	20, (20.0)	20	20
Xe-137	670	0, (0)	0	0
Xe-135m	6,900	0, (0)	0	0
Xe-138	21,000	0, (0)	0	0
Xe-135	22,000	0, (0)	0	0
Xe-133m	280	.003, (0.016)	0.07	0.362
Xe-133	8,200	64.3, (138.3)	214.73	450
Xe-131m	15	1.8, (2.5)	3.03	4.19
N-13	1,500	0, (0)	0	0
TOTAL	102,265	91.5, (181)	272.1	586.6

Notes

1. The 6 bed values are based on the original Cosmodyne Contract. The 5 bed values are based on NEDC 10-052.[28]

2. The 6 bed values are based on NEDC 04-056.

3. Charcoal bed arrangements which correspond to the listed release rates are validated in NEDC 10-052.[28]

In the safety evaluation of the AOG System, the NRC estimated that approximately 900 Ci/yr of the noble gases and negligible iodines would be released from the Condenser Off-Gas System. The estimates of Table IX-4-4, corresponding to an annual release of approximately 2300 Ci, are based upon a higher condenser inleakage rate and conditions yielding 100,000 μCi/sec Off-Gas activity after a 30-minute holdup for a 3400 MWt reactor. The NRC estimate was normalized for a 2486 MWt reactor.

The NRC calculated the DDE at the site boundary to be 0.35 mrem/year and the potential dose to a child's thyroid from drinking milk from the nearest farm with cows to be 5.8 mrem/year.[14]

The activity of F-18 is not considered in calculating the effluent activity, since it is expected that fluoride will be removed from the Off-Gas stream along with condensed steam prior to entering the AOG System.

The six Charcoal Beds, each containing approximately 11,000 pounds of charcoal, are arranged to operate in series, in parallel, and with a bypass of first vessel. To meet the values specified in Table IX-4-4 the charcoal beds must be operated in one of the following configurations: 6 beds in parallel (up to 40 scfm), 6 beds in series (up to 50 scfm), or 5 beds in series up to 30 scfm.[28] Following the Charcoal Beds, the air stream is filtered to remove charcoal dust and/or solid daughter particles.

4.4.3 Seismic Analysis

Original design for seismic loading the Off-Gas System is based on Class IIS and:

Horizontal Coefficient	0.10 g
Vertical	0 g

Seismic design analysis, based on analytical models for each skid, provided qualification for the structural design in lieu of testing. The analytical approach utilized the multidegree-of-freedom model.

In this procedure, each structural system (skid) was mathematically modeled using a sufficient number of mass points to ensure adequate representation of motion throughout all parts of the skid. This technique utilized modal participation factors to determine the multidegree-of-freedom modal response. (See Section XII 2.3.5.2).

Following implementation of MDC 83-034[15] seismic analyses are to be performed in accordance with the criteria specified in Regulatory Guide 1.143, Rev. 1, October, 1979.

4.4.4 Fabrication

The AOG System original design and fabrication was conducted in accordance with the following standards:

Pressure Vessels:	ASME Section III, Class 3
Heat Exchangers:	ASME Section III, Class 3, TEMA R
Process Piping:	ASME Section III, Class 3 & ANSI
Pumps and Valves:	ASME Section III, Class 3 (NPVC)
Materials:	ASTM
Electrical & Instruments:	NEC, NEMA, IEEE, IES
Metal Treatment:	SSPC

Those components which are not in direct contact with the radioactive stream were designed and fabricated in accordance with ASME Code Section VIII, Division 1.

Welding materials are in accordance with the requirements of the American Welding Society (AWS) specifications.

Quality group classification and quality assurance provisions are in accordance with criteria specified in USAR Appendix A for piping and equipment pressure parts, and per USNRC Regulatory Guide 1.143, Rev. 1, October, 1979, for other components.[15]

4.4.5 Instrumentation and Control

A continuous indication of system operating conditions is displayed in the AOG Control Room. The system operates automatically and by remote control; temperatures, pressures, humidity, hydrogen concentration, and flow rates are continuously monitored to ensure correct operation and proper control function. Radioactivity is monitored at the ERP. Instrumentation related to critical parameters is connected to an alarm system allowing abnormal conditions to be promptly observed and remedied. Comparison of the alarm signal(s) and the various indicators will accurately pinpoint the source of the trouble.

The system is also operated by a logic network of interlocked controls which maintain proper flow paths at all times. This is particularly important in controlling flow through one or the other dual equipment trains and in operation of the Cyclic Dryer Subsystems.

4.5 Power Generation Evaluation

4.5.1 Off-Gas (OG) System

The 30 minute holdup time provides for the radioactive decay of the short-lived activation and fission gases and thereby reduces the stack release rate. The short-lived fission gases decay to solid daughter products and are removed on the high efficiency filters which have a manufacturers design capability to remove 99.97% of particulates greater than 0.3 microns in size.

The routine release to the environment of noncondensible coolant activation products and noble gas fission products for gland seal leakage is given in Table IX-4-5. This data was developed based on a diffusion mixture of noble gases which would result in a release rate of 0.1 Curies/sec after 30 minutes holdup. The equilibrium activity level for particulate daughter products of decay of the noble gases is given in Table IX-4-6.[9] Data in Tables IX-4-5 and IX-4-6 does not take into consideration the operation of the AOG System (see USAR Section 4.4).

The Air Ejector Off-Gas System is monitored and controlled to ensure that the radiation dose limits at the site boundary as prescribed by 10CFR20 are not exceeded. Duplicate continuous radiation monitors record the radiation level in the off-gases and alarms in the Main Control Room on high radiation. Radiation monitors are also provided in the ERP for detection of ERP activity release. Radiation levels at the Air Ejector in excess of the allowable "instantaneous" release rate alarms in the Main Control Room and after a 15 minute delay isolates the Off-Gas System. The time delay is provided to permit corrective action to be taken by the operator when possible to avoid station shutdown.

TABLE IX-4-5

MAXIMUM EXPECTED ACTIVITY RELEASE TO THE ENVIRONMENT FROM GLAND SEAL LEAKAGE**

Isotope	Half Life	Release Rate (μCi/sec)
N-17	4.14 sec.	1 (-4)*
N-16	7.35 sec.	4 (1)
O-19	29 sec.	2 (0)
N-13	10 min.	2 (0)
Ar 41	1.83 hr.	6 (-3)
Ar 37	34.3 day	1 (-7)
H 3	12.26 yr.	8 (-4)
Total Activation Gases		5 (1)
Short Lived	---	4 (1)
Kr 89	3.2 min.	1 (2)
Xe 137	3.8 min.	2 (2)
Xe 135m	15 min.	4 (1)
Xe 138	17 min.	1 (2)
Kr 87	1.3 hr.	2 (1)
Kr 83m	1.86 hr.	2 (0)
Kr 88	2.8 hr.	2 (1)
Kr 85m	4.4 hr.	8 (0)
Xe 135	9.2 hr.	1 (1)
Xe 133m	2.3 day	3 (-1)
Xe 133	5.27 day	6 (0)
Xe 131m	12.0 day	3 (-2)
Kr 85	10.4 yr.	9 (-3)
Total Nobel Gases		6 (2)
Total Activation and Noble Gases		6 (2)

* Numbers in parentheses represent powers of 10 (i.e., read 1 (-4) as 1×10^{-4})

** Based on 0.1 Ci/sec at ERP

TABLE IX-4-6

PARTICULATES BUILDUP IN ENVIRONMENT*

Isotope	Half Life	Equilibrium Activity Level (Curies)
Rb 87	5 x 10^{10}y	0.14
Rb 88	17.8m	0.29
Rb 89	15.4m	0.028
Sr 89	52d	0.028
Cs 135	3 x 10^{6}y	0.53
Cs 137	30y	0.066
Ba 137m	2.55m	0.060
Cs 138	32.2m	0.15

* Based on 0.1 Ci/sec at ERP

The ERP allows atmospheric dispersion of the effluent to reduce direct radiation dose rates. ERP release rate limits are established per the CNS ODAM.

Shielding for the Off-Gas System equipment is provided as necessary to maintain safe radiation dose levels for personnel.

The Off-Gas Filters are designed with a copper ground strap to prevent static electricity from igniting any hydrogen that passes through them.[10]

The Z-sump vent is designed to vent gases to the ERP to prevent possible sump pressurization due to loss of the system loop seal.[11]

The ERP is provided with an automatic heat tracing system to prevent freezing of water vapor at the release opening, thus preventing ice blockage and a possible hydrogen explosion.[12] To insure that a representative sample is obtained for the ERP monitor, the sampling line between the ERP and the Off-Gas Filter Building is heat traced to minimize sample plate-out. If the dilution flow should cease, valves will isolate the Off-Gas System flow.[13]

A differential pressure (dP) can occur between the Off-Gas hold-up and the Z Sump. This operational condition can result in liquid being held up in the line. In order to mitigate this condition that would interfere with post-accident Z Sump operation, the Off-Gas liquid drain line has a 1-1/4 inch flow restrictor to ensure that the drain rate is less than the capacity of one Z Sump pump. In addition, a dP equalization line and dP pressure monitoring instrumentation are provided for Operations to minimize the potential for the undesirable dP conditions.[23]

4.5.2 Augmented Off-Gas (AOG) System

The AOG System is designed for a continuous safe and reliable operating life of 40 years. The system is designed to operate reliably within safe limits under all normal and maximum operating conditions.

In addition, the system will withstand the effects of various types of failure conditions. Table IX-4-7 is a failure mode and effect analysis which indicates the potential consequences of failures in various parts of the system and notes the precautions incorporated in the system design which will accommodate or compensate for these various failure conditions.

4.6 Inspection and Testing

The Off-Gas System is operated continuously during station operation.

The Off-Gas System is in scope for License Renewal per 10 CFR 54.4(a)(1) and (a)(2) and was subject to aging management review. Aging effects are managed by the following Aging Management Programs: Bolting Integrity (see USAR Section K-2.1.2), Buried Piping and Tanks Inspection (see USAR Section K-2.1.3), External Surfaces Monitoring (see USAR Section K-2.1.14), Oil Analyses (see USAR Section K-2.1.28), One-Time Inspection (see USAR Section K-2.1.29), Periodic Surveillance and Preventive Maintenance (see USAR Section K-2.1.31), and Selective Leaching (see USAR Section K-2.1.34). There are no Time-Limited Aging Analyses that are applicable.

TABLE IX-4-7
System Failure Analysis

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
1. Steam Jet Air Ejector	A. Reduction of steam Supply pressure or Flow	* Hydrogen concentration increase * Process stream temperature drop * Motive force reduction * Reduction in preheating	* Line pressure, temperature and flow indicators and alarms * Design for hydrogen detonation * Standby equipment	* Open OG-AOV-254AV, Close AOG-AOV-901AV * Flow balance of steam input for temperature and dilution * Start-up blower and/or existing blowers to maintain flow
	B. Corrosion	* External leakage	* Stainless steel nozzles * Corrosion allowance for carbon steel * Standby equipment	* Upon indication of external leakage (plant monitoring equipment, switch to standby equipment to allow repair
2. Preheater	A. Corrosion of tubes	* Inleak of steam to off-gas – additional dilution and load on condenser	* Safety factor in tube design * Stainless steel tubing * Standby equipment * Design capacity of condenser and water separator drains allows some compensation * Temperature monitor/alarm of condenser discharge * Liquid level alarm on water separator	* If alarm conditions are reached, switch to standby equipment

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
2. Preheater (Continued)	B. Reduction or loss of steam supply	* Low Recombiner inlet temperature	* Temperature monitoring/alarms on Recombiner, inlet And output * High H2 alarm Recombiner Performance) * Standby equipment	* Flow balance of steam input for partial temperature compensation * Upon alarmed condition, switch to standby equipment
3. Recombiner	A. Catalyst deactivates through long-term use, poisoning or wetting	* Increased H2 concentration * Reduced temperature profile through Recombiner	* Inlet temperature control to prevent wetting * Temperature profile monitoring/alarms * H2 concentration alarms * Design allowance by catalyst mfgr. to preclude iodine poisoning * Standby equipment	* Upon alarmed condition switch to standby equipment; replace or reactivate catalyst
4. Post-Recombiner Condenser	A. Corrosion of tubes	* Water inleak to off-gas causing condenser flooding	* Safety factor in tube design * Stainless steel tubing * Liquid level monitor/alarm on Water Seperator * Standby equipment	* Switch to standby equipment to allow repair, plugging or replacement of tubes

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
4. Post-Recombiner Condenser (Continued)	B. Reduction or loss of coolant (plant condensate)	* Insufficient cooling/ condensation	* Condensate discharge temperature monitoring/alarm	* Open OG-A0V-254AV, Close AOG-A0V-901AV * Will require correction of plant condensate system
	C. Overtemperature of coolant	* Insufficient cooling/ condensation	* Temperature-controlled flow of coolant supply * Condenser discharge monitor/alarm	* Decrease flow rate of high temperature coolant * Alarm indicates need for correction in plant condensate system
5. Water Separator	A. Corrosion of wire mesh	* Increased moisture in process gas	* Stainless steel wire mesh * Cooler-Condenser capacity (downstream)	* Cooler-condenser design will accommodate this amount of excess moisture * Standby equipment allows repair during regular inspection and maintenance
	B. Clogging of drain top	* Build-up of water level	* Liquid level monitor/alarm * Drain trap bypass * Standby equipment	* Water will be bypassed to condensate drain * Upon alarm condition (uncorrected), switch to a standby equipment

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
6. Cooler-Condenser	A. Corrosion of tubes	* Glycol solution leakage into process stream; discharged with condensate	* Safety factor in tube design * Stainless steel tubing * Liquid level gage on glycol tank * Level switch on Moisture Separator * Standby Cooler-Condenser	* Switch to standby cooler * Plug defective tube(s) * Replace defective tubes
	B. Ice on tubes (low glycol temperature)	* Increased plugging and pressure drop on shell side	* Temperature controls and alarms on glycol solution * Standby systems * Temperature control and alarm on process stream	* Reset glycol temperature controls * Switch to standby glycol unit * Switch to standby cooler condenser
	C. High discharge gas temperature (insufficient glycol cooling)	* High humidity discharge gas * Inadequate Dryer operation	* High temperature alarm on process stream * Temperature controls and alarms for glycol solution * Standby systems	* Reset glycol temperature controls * Switch to standby glycol unit * Switch to standby cooler
7. Glycol Cooler, Condenser	A. Loss of one glycol cooling unit	* High temperature of Cooler-Condenser Discharge	* High temperature alarm * Standby glycol cooler	* Switch to standby glycol cooler
	B. Loss of both glycol units	* High gas dewpoint * Impaired dryer function	* High temperature alarm * High humidity (Dryer) alarm	* Repair coolers

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
8. Cooler-Condenser Moisture-Separator	A. Corrosion of wire mesh B. Clogging of water drain	* Increased moisture in process gas * Possible impairment of dryer function	* Stainless steel wire mesh * High humidity alarm * Standby equipment * Level switch alarm	* Switch to standby system if drying process deteriorates
9. Dryer Heater	A. Electrical failure or control failure-under-temperature	* Loss of heating, resulting in insufficient dryer regeneration * Eventual saturation of beds, loss of drying capacity	* Excess heating capacity available in case of element failure * Alarm system for high humidity condition * Standby equipment	* Switch to standby equipment
	B. Control failure-over-temperature	* Process gas becomes too hot for Dryer Chiller capacity	* High temperature alarm * High humidity alarm * Standby equipment	* Switch to standby equipment
10. Cyclic Dryers	A. Bed saturation-moisture break-through	* Moisture freezeout in Gas Cooler, increasing ΔP * -20°F dewpoint gas reaching Charcoal Bed	* High humidity alarm * High Gas Cooler discharge alarm * Standby equipment * Gas Cooler bypass	* Switch to standby Dryer * Bypass Gas Cooler temporarily for thaw
	B. Cycling control failure	* Saturation of Drying Bed	* High humidity alarm * Standby system	* Switch to standby equipment
11. Gas Cooler	A. Corrosion of tube	* Leakage of glycol solution into process stream	* Stainless steel tubing * High humidity alarm * Gas Cooler bypass	* Bypass Gas Cooler; thaw; return to operation

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
11. Gas Cooler (Continued)	B. Ice on tube	* Increased plugging and ΔP	* Stainless steel tubing * High humidity alarm * Gas Cooler bypass * Temperature alarm	* Bypass Gas Cooler; thaw; return to operation
	C. High discharge temperature	* Increased heat load in Charcoal Beds	* Standby Glycol Cooler * High temperature alarm	* Switch to standby Glycol Cooler
12. Charcoal Adsorbers	A. Moisture (ice) on charcoal	* Deterioration of performance as ice buildup increases	* Highly instrumented Gas Dryer System with redundant equipment * Gas Cooler (freeze-out moisture) * Bypass of two Charcoal Beds without significant deterioration of performance * Charcoal Bed flexible flow arrangement	* Change flow pattern appropriately * Switch to standby Dryer System
	B. High operating temperature	* Reduced performance level	* Temperature alarm * Standby Glycol Cooler * Charcoal Bed flexible flow arrangement	* Change flow pattern appropriately * Switch to standby Glycol Cooler

TABLE IX-4-7
System Failure Analysis (Cont'd.)

EQUIPMENT ITEM	FAILURE OR MALFUNCTION	EFFECT ON SYSTEM	DESIGN PRECAUTIONS	CORRECTIVE ACTION
13. Glycol Cooler, Charcoal Tanks	A. Loss of one glycol cooling unit	* High temperature of Dryer Chiller discharge	* High temperature alarm * Standby Glycol Cooler	* Switch to standby Glycol Cooler
	B. Loss of both glycol units	* Impaired adsorption function	* High temperature alarm	* Repair coolers
14. Afterfilter	A. Clogging of filter	* Reduced flow * Backpressure in system	* Line pressure monitors/alarms * ΔP across filter monitored/alarmed * Standby equipment	* Switch to standby equipment for filter cleaning/repair
	B. Rupture of filter element	* Release of particulates	* ΔP across filter monitored/alarmed * Standby equipment	* Switch to standby equipment for filter cleaning/repair

5.0 REFERENCES FOR CHAPTER IX

1. Q/A 9.6, Amend. 13.
2. Not used.
3. Not used.
4. Not used.
5. Not used.
6. Not used.
7. Not used.
8. Not used.
9. Q/A 9.5, Amend. 9.
10. MDC 76-37.
11. MDC 74-147.
12. MDC 76-10.
13. MDC 76-6.
14. SER, pp. 20-21 of Supplement 1.
15. MDC 83-034, Amend. 1, AOG Reclassification.
16. MDC 84-115.
17. MDC 82-086.
18. MDC 83-12
19. DC 87-17
20. MDC 76-4.
21. Deleted.
22. MDC 84-265
23. MP 97-100
24. Q/A 9.7, Amend. 13
25. MDC 76-8
26. Deleted.
27. T.S. Amendment 89
28. NEDC 10-052