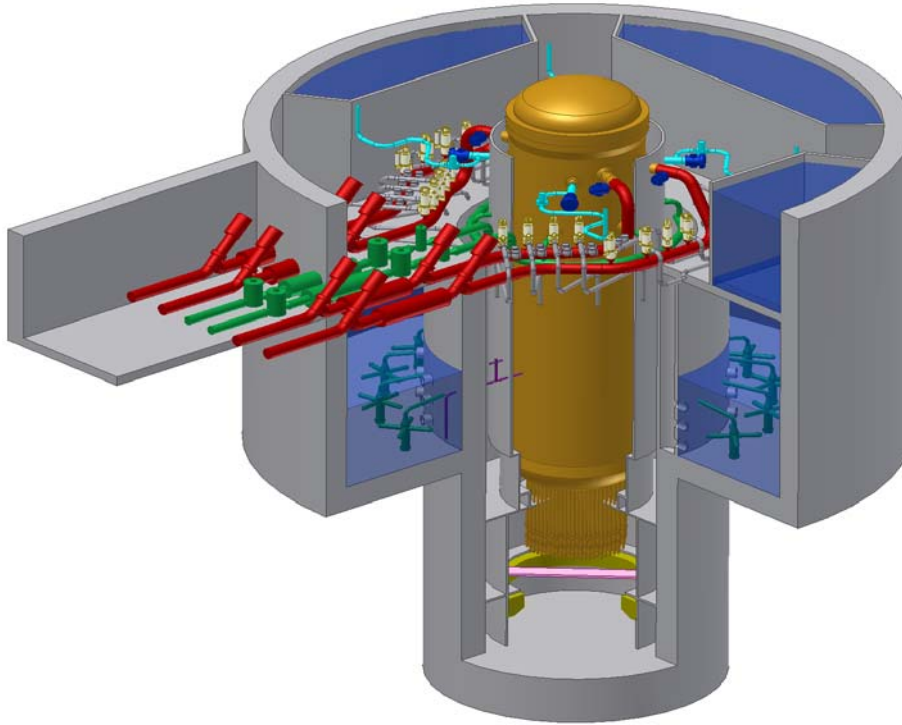




GE Nuclear Energy

**26A6642BH
Revision 01
January 2006**



ESBWR Design Control Document

Tier 2

Chapter 11

Radioactive Waste Management



Contents

| | |
|--|---------|
| 11. Radioactive Waste Management | 11.1-1 |
| 11.1 SOURCE TERMS | 11.1-1 |
| 11.1.1 Fission Products | 11.1-1 |
| 11.1.2 Activation Products | 11.1-3 |
| 11.1.3 Radionuclide Concentration Adjustment | 11.1-4 |
| 11.1.4 Fuel Fission Production Inventory | 11.1-5 |
| 11.1.5 Process Leakage Sources | 11.1-5 |
| 11.1.6 References | 11.1-6 |
| 11.2 LIQUID WASTE MANAGEMENT SYSTEM | 11.2-1 |
| 11.2.1 Design Bases | 11.2-1 |
| 11.2.2 System Description | 11.2-2 |
| 11.2.2.1 Summary Description | 11.2-2 |
| 11.2.2.2 System Operation | 11.2-2 |
| 11.2.2.3 Detailed System Component Description | 11.2-4 |
| 11.2.3 Safety Evaluation — Radioactive Releases | 11.2-6 |
| 11.2.4 Testing and Inspection Requirements | 11.2-7 |
| 11.2.5 Instrumentation Requirements | 11.2-7 |
| 11.2.6 COL Information | 11.2-7 |
| 11.2.7 References | 11.2-7 |
| 11.3 GASEOUS WASTE MANAGEMENT SYSTEM | 11.3-1 |
| 11.3.1 Design Bases | 11.3-1 |
| 11.3.2 Offgas System Description | 11.3-2 |
| 11.3.2.1 Process Design | 11.3-3 |
| 11.3.2.2 Component Design | 11.3-7 |
| 11.3.2.3 Seismic Design | 11.3-10 |
| 11.3.3 Ventilation System | 11.3-11 |
| 11.3.4 Radioactive Releases | 11.3-11 |
| 11.3.5 Testing and Inspection Requirements | 11.3-11 |
| 11.3.6 Instrumentation Requirements | 11.3-11 |
| 11.3.7 Radioactive OffGas System Leak or Failure | 11.3-11 |
| 11.3.7.1 Basis and Assumptions | 11.3-11 |
| 11.3.7.2 Results | 11.3-13 |
| 11.3.8 COL Information | 11.3-13 |
| 11.3.8.1 Offgas System Data | 11.3-13 |
| 11.3.9 References | 11.3-13 |
| 11.4 SOLID WASTE MANAGEMENT SYSTEM | 11.4-1 |
| 11.4.1 Design Bases | 11.4-1 |
| 11.4.2 System Description | 11.4-2 |
| 11.4.2.1 Summary Description | 11.4-2 |
| 11.4.2.2 System Operation | 11.4-2 |
| 11.4.2.3 Detailed System Component Description | 11.4-4 |
| 11.4.3 Safety Evaluation | 11.4-5 |
| 11.4.4 Testing and Inspection Requirements | 11.4-5 |

| | |
|--|---------|
| 11.4.5 Instrumentation Requirements | 11.4-5 |
| 11.4.6 COL Information | 11.4-5 |
| 11.4.7 References | 11.4-5 |
| 11.5 PROCESS RADIATION MONITORING SYSTEM | 11.5-1 |
| 11.5.1 Design Bases | 11.5-1 |
| 11.5.1.1 Design Objectives | 11.5-1 |
| 11.5.2 System Design Bases and Criteria | 11.5-2 |
| 11.5.2.1 Radiation Monitors Required for Safety | 11.5-3 |
| 11.5.2.2 Radiation Monitors Required for Plant Operation | 11.5-3 |
| 11.5.3 Subsystem Description | 11.5-4 |
| 11.5.3.1 Radiation Monitors Required for Safety | 11.5-4 |
| 11.5.3.2 Radiation Monitors Required for Plant Operation | 11.5-7 |
| 11.5.4 Regulatory Evaluation | 11.5-13 |
| 11.5.4.1 Basis for Monitor Location Selection | 11.5-13 |
| 11.5.4.2 Expected Radiation Levels | 11.5-14 |
| 11.5.4.3 Instrumentation | 11.5-14 |
| 11.5.4.4 Setpoints | 11.5-14 |
| 11.5.5 Process Monitoring and Sampling | 11.5-14 |
| 11.5.5.1 Implementation of General Design Criterion 19 | 11.5-14 |
| 11.5.5.2 Implementation of General Design Criterion 60 | 11.5-14 |
| 11.5.5.3 Implementation of General Design Criterion 63 | 11.5-15 |
| 11.5.5.4 Implementation of General Design Criterion 64 | 11.5-15 |
| 11.5.5.5 Basis for Monitor Location Selection | 11.5-16 |
| 11.5.5.6 Expected Radiation Levels | 11.5-16 |
| 11.5.5.7 Instrumentation | 11.5-16 |
| 11.5.5.8 Setpoints | 11.5-16 |
| 11.5.6 Calibration and Maintenance | 11.5-16 |
| 11.5.6.1 Inspection and Tests | 11.5-16 |
| 11.5.6.2 Calibration | 11.5-17 |
| 11.5.6.3 Maintenance | 11.5-18 |
| 11.5.7 COL Information | 11.5-18 |
| 11.5.7.1 RMS Lower Limit of Detection | 11.5-18 |
| 11.5.7.2 Offsite Dose Calculation Manual | 11.5-18 |
| 11.5.7.3 Process and Effluent Monitoring Program | 11.5-18 |
| 11.5.7.4 Site Specific Offsite Dose Calculation | 11.5-18 |
| 11.5.8 References | 11.5-18 |

List of Tables

| | |
|---------------|--|
| Table 11.1-1 | Source Term Design Basis Parameters |
| Table 11.1-2 | Design Basis Noble Radiogas Source Terms in Steam |
| Table 11.1-3 | Calculational Parameters For Source Term Adjustment |
| Table 11.1-4 | Design Basis Iodine Radioisotopes in Reactor Water and Steam |
| Table 11.1-5 | Design Basis Non-volatile Fission Products In Reactor Water |
| Table 11.1-6 | Design Basis N ¹⁶ Concentrations in Reactor Water and Steam |
| Table 11.1-7 | Design Basis Non-coolant Activation Products in Reactor Water |
| Table 11.2-1 | Equipment Codes (from Table 1, RG 1.143) |
| Table 11.2-2a | LWMS Component Capacity (Tanks) |
| Table 11.2-2b | LWMS Component Capacity (Pumps)* |
| Table 11.2-2c | LWMS Component Capacity (Mobile Systems) |
| Table 11.2-3 | Decontamination Factors |
| Table 11.2-4 | Probable Inputs to LWMS from Operational Occurrences |
| Table 11.3-1 | Offgas System Design Parameters |
| Table 11.3-2 | Offgas System Major Equipment Items |
| Table 11.3-3 | Equipment Malfunction Analysis |
| Table 11.3-4 | Offgas System Failure Accident Parameters |
| Table 11.3-5 | Isotopic Source Rates for Design Basis |
| Table 11.3-6 | Releases to the Environment |
| Table 11.3-7 | Offgas System Failure Meteorology and Dose Results |
| Table 11.4-1 | SWMS Component Capacities |
| Table 11.4-2 | Annual Shipped Waste Volumes |
| Table 11.5-1 | Process and Effluent Radiation Monitoring Systems |
| Table 11.5-2 | Process Radiation Monitoring System (Gaseous and Airborne Monitors) |
| Table 11.5-3 | Key to Radiation Monitors Shown on Figure 11.5-1 |
| Table 11.5-4 | Process Radiation Monitoring System (Liquid Monitors) |
| Table 11.5-5 | Radiological Analysis Summary of Liquid Process Samples |
| Table 11.5-6 | Radiological Analysis Summary of Gaseous Process Samples |
| Table 11.5-7 | Radiological Analysis Summary of Liquid Effluent Samples |
| Table 11.5-8 | Radiological Analysis Summary of Gaseous Effluent Samples |

List of Illustrations

Figure 11.2-1. Liquid Waste Management System Process Diagram
Figure 11.3-1. Offgas System
Figure 11.4-1. Solid Waste Management System Process Diagram
Figure 11.5-1. Location of Radiation Monitors

Abbreviations And Acronyms

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| 10 CFR | Title 10, Code of Federal Regulations |
| A/D | Analog-to-Digital |
| AASHTO | American Association of Highway and Transportation Officials |
| AB | Auxiliary Boiler |
| ABS | Auxiliary Boiler System |
| ABWR | Advanced Boiling Water Reactor |
| ac / AC | Alternating Current |
| AC | Air Conditioning |
| ACF | Automatic Control Function |
| ACI | American Concrete Institute |
| ACS | Atmospheric Control System |
| AD | Administration Building |
| ADS | Automatic Depressurization System |
| AEC | Atomic Energy Commission |
| AFIP | Automated Fixed In-Core Probe |
| AGMA | American Gear Manufacturer's Association |
| AHS | Auxiliary Heat Sink |
| AHU | Air Handling Unit |
| AHU | Air Heating Unit |
| AISC | American Institute of Steel Construction |
| AISI | American Iron and Steel Institute |
| AL | Analytical Limit |
| ALARA | As Low As Reasonably Achievable |
| ALWR | Advanced Light Water Reactor |
| ANS | American Nuclear Society |
| ANSI | American National Standards Institute |
| AOO | Anticipated Operational Occurrence |
| AOV | Air Operated Valve |
| API | American Petroleum Institute |
| APLHGR | Average Planar Linear Head Generation Rate |
| APRM | Average Power Range Monitor |
| APR | Automatic Power Regulator |
| APRS | Automatic Power Regulator System |
| ARI | Alternate Rod Insertion |
| ARMS | Area Radiation Monitoring System |
| ASA | American Standards Association |
| ASD | Adjustable Speed Drive |
| ASHRAE | American Society of Heating, Refrigerating, and Air Conditioning Engineers |
| ASME | American Society of Mechanical Engineers |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| AST | Alternate Source Term |
| ASTM | American Society of Testing Methods |
| AT | Unit Auxiliary Transformer |
| ATLM | Automated Thermal Limit Monitor |
| ATWS | Anticipated Transients Without Scram |
| AV | Allowable Value |
| AWS | American Welding Society |
| AWWA | American Water Works Association |
| B&PV | Boiler and Pressure Vessel |
| BAF | Bottom of Active Fuel |
| BHP | Brake Horse Power |
| BOP | Balance of Plant |
| BPU | Bypass Unit |
| BPWS | Banked Position Withdrawal Sequence |
| BRE | Battery Room Exhaust |
| BRL | Background Radiation Level |
| BTP | NRC Branch Technical Position |
| BTU | British Thermal Unit |
| BWR | Boiling Water Reactor |
| BWROG | Boiling Water Reactor Owners Group |
| CAV | Cumulative absolute velocity |
| C&FS | Condensate and Feedwater System |
| C&I | Control and Instrumentation |
| C/C | Cooling and Cleanup |
| CB | Control Building |
| CBGAHVS | Control Building General Area |
| CBHVAC | Control Building HVAC |
| CBHVS | Control Building Heating, Ventilation and Air Conditioning System |
| CCI | Core-Concrete Interaction |
| CDF | Core Damage Frequency |
| CFR | Code of Federal Regulations |
| CIRC | Circulating Water System |
| CIS | Containment Inerting System |
| CIV | Combined Intermediate Valve |
| CLAVS | Clean Area Ventilation Subsystem of Reactor Building HVAC |
| CM | Cold Machine Shop |
| CMS | Containment Monitoring System |
| CMU | Control Room Multiplexing Unit |
| COL | Combined Operating License |
| COLR | Core Operating Limits Report |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| CONAVS | Controlled Area Ventilation Subsystem of Reactor Building HVAC |
| CPR | Critical Power Ratio |
| CPS | Condensate Purification System |
| CPU | Central Processing Unit |
| CR | Control Rod |
| CRD | Control Rod Drive |
| CRDA | Control Rod Drop Accident |
| CRDH | Control Rod Drive Housing |
| CRDHS | Control Rod Drive Hydraulic System |
| CRGT | Control Rod Guide Tube |
| CRHA | Control Room Habitability Area |
| CRHAHVS | Control Room Habitability Area HVAC Sub-system |
| CRT | Cathode Ray Tube |
| CS&TS | Condensate Storage and Transfer System |
| CSDM | Cold Shutdown Margin |
| CS / CST | Condensate Storage Tank |
| CT | Main Cooling Tower |
| CTVCF | Constant Voltage Constant Frequency |
| CUF | Cumulative usage factor |
| CWS | Chilled Water System |
| D-RAP | Design Reliability Assurance Program |
| DAC | Design Acceptance Criteria |
| DAW | Dry Active Waste |
| DBA | Design Basis Accident |
| dc / DC | Direct Current |
| DCD | Design Control Document |
| DCS | Drywell Cooling System |
| DCIS | Distributed Control and Information System |
| DEPSS | Drywell Equipment and Pipe Support Structure |
| DF | Decontamination Factor |
| D/F | Diaphragm Floor |
| DG | Diesel-Generator |
| DHR | Decay Heat Removal |
| DM&C | Digital Measurement and Control |
| DOF | Degree of freedom |
| DOI | Dedicated Operators Interface |
| DOT | Department of Transportation |
| dPT | Differential Pressure Transmitter |
| DPS | Diverse Protection System |
| DPV | Depressurization Valve |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| DR&T | Design Review and Testing |
| DS | Independent Spent Fuel Storage Installation |
| DTM | Digital Trip Module |
| DW | Drywell |
| EB | Electrical Building |
| EBAS | Emergency Breathing Air System |
| EBHV | Electrical Building HVAC |
| ECCS | Emergency Core Cooling System |
| E-DCIS | Essential DCIS (Distributed Control and Information System) |
| EDO | Environmental Qualification Document |
| EFDS | Equipment and Floor Drainage System |
| EFPY | Effective full power years |
| EFU | Emergency Filter Unit |
| EHC | Electrohydraulic Control (Pressure Regulator) |
| ENS | Emergency Notification System |
| EOC | Emergency Operations Center |
| EOC | End of Cycle |
| EOF | Emergency Operations Facility |
| EOP | Emergency Operating Procedures |
| EPDS | Electric Power Distribution System |
| EPG | Emergency Procedure Guidelines |
| EPRI | Electric Power Research Institute |
| EQ | Environmental Qualification |
| ERICP | Emergency Rod Insertion Control Panel |
| ERIP | Emergency Rod Insertion Panel |
| ESF | Engineered Safety Feature |
| ETS | Emergency Trip System |
| FAC | Flow-Accelerated Corrosion |
| FAPCS | Fuel and Auxiliary Pools Cooling System |
| FATT | Fracture Appearance Transition Temperature |
| FB | Fuel Building |
| FBHV | Fuel Building HVAC |
| FCI | Fuel-Coolant Interaction |
| FCM | File Control Module |
| FCS | Flammability Control System |
| FCU | Fan Cooling Unit |
| FDDI | Fiber Distributed Data Interface |
| FFT | Fast Fourier Transform |
| FFWTR | Final Feedwater Temperature Reduction |
| FHA | Fire Hazards Analysis |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| FIV | Flow-Induced Vibration |
| FMCRD | Fine Motion Control Rod Drive |
| FMEA | Failure Modes and Effects Analysis |
| FPS | Fire Protection System |
| FO | Diesel Fuel Oil Storage Tank |
| FOAKE | First-of-a-Kind Engineering |
| FPE | Fire Pump Enclosure |
| FTDC | Fault-Tolerant Digital Controller |
| FTS | Fuel Transfer System |
| FW | Feedwater |
| FWCS | Feedwater Control System |
| FWS | Fire Water Storage Tank |
| GCS | Generator Cooling System |
| GDC | General Design Criteria |
| GDSCS | Gravity-Driven Cooling System |
| GE | General Electric Company |
| GE-NE | GE Nuclear Energy |
| GEN | Main Generator System |
| GETAB | General Electric Thermal Analysis Basis |
| GL | Generic Letter |
| GM | Geiger-Mueller Counter |
| GM-B | Beta-Sensitive GM Detector |
| GSIC | Gamma-Sensitive Ion Chamber |
| GSOS | Generator Sealing Oil System |
| GWSR | Ganged Withdrawal Sequence Restriction |
| HAZ | Heat-Affected Zone |
| HCU | Hydraulic Control Unit |
| HCW | High Conductivity Waste |
| HDVS | Heater Drain and Vent System |
| HEI | Heat Exchange Institute |
| HELB | High Energy Line Break |
| HEP | Human error probability |
| HEPA | High Efficiency Particulate Air/Absolute |
| HFE | Human Factors Engineering |
| HFF | Hollow Fiber Filter |
| HGCS | Hydrogen Gas Cooling System |
| HIC | High Integrity Container |
| HID | High Intensity Discharge |
| HIS | Hydraulic Institute Standards |
| HM | Hot Machine Shop & Storage |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| HP | High Pressure |
| HPNSS | High Pressure Nitrogen Supply System |
| HPT | High-pressure turbine |
| HRA | Human Reliability Assessment |
| HSI | Human-System Interface |
| HSSS | Hardware/Software System Specification |
| HVAC | Heating, Ventilation and Air Conditioning |
| HVS | High Velocity Separator |
| HWC | Hydrogen Water Chemistry |
| HWCS | Hydrogen Water Chemistry System |
| HWS | Hot Water System |
| HX | Heat Exchanger |
| I&C | Instrumentation and Control |
| I/O | Input/Output |
| IAS | Instrument Air System |
| IASCC | Irradiation Assisted Stress Corrosion Cracking |
| IBC | International Building Code |
| IC | Ion Chamber |
| IC | Isolation Condenser |
| ICD | Interface Control Diagram |
| ICS | Isolation Condenser System |
| IE | Inspection and Enforcement |
| IEB | Inspection and Enforcement Bulletin |
| IED | Instrument and Electrical Diagram |
| IEEE | Institute of Electrical and Electronic Engineers |
| IFTS | Inclined Fuel Transfer System |
| IGSCC | Intergranular Stress Corrosion Cracking |
| IIS | Iron Injection System |
| ILRT | Integrated Leak Rate Test |
| IOP | Integrated Operating Procedure |
| IMC | Induction Motor Controller |
| IMCC | Induction Motor Controller Cabinet |
| IRM | Intermediate Range Monitor |
| ISA | Instrument Society of America |
| ISI | In-Service Inspection |
| ISLT | In-Service Leak Test |
| ISM | Independent Support Motion |
| ISMA | Independent Support Motion Response Spectrum Analysis |
| ISO | International Standards Organization |
| ITA | Inspections, Tests or Analyses |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| ITAAC | Inspections, Tests, Analyses and Acceptance Criteria |
| ITA | Initial Test Program |
| LAPP | Loss of Alternate Preferred Power |
| LCO | Limiting Conditions for Operation |
| LCW | Low Conductivity Waste |
| LD | Logic Diagram |
| LDA | Lay down Area |
| LD&IS | Leak Detection and Isolation System |
| LERF | Large early release frequency |
| LFCV | Low Flow Control Valve |
| LHGR | Linear Heat Generation Rate |
| LLRT | Local Leak Rate Test |
| LMU | Local Multiplexer Unit |
| LO | Dirty/Clean Lube Oil Storage Tank |
| LOCA | Loss-of-Coolant-Accident |
| LOFW | Loss-of-feedwater |
| LOOP | Loss of Offsite Power |
| LOPP | Loss of Preferred Power |
| LP | Low Pressure |
| LPCI | Low Pressure Coolant Injection |
| LPCRD | Locking Piston Control Rod Drive |
| LPMS | Loose Parts Monitoring System |
| LPRM | Local Power Range Monitor |
| LPSP | Low Power Setpoint |
| LWMS | Liquid Waste Management System |
| MAAP | Modular Accident Analysis Program |
| MAPLHGR | Maximum Average Planar Linear Head Generation Rate |
| MAPRAT | Maximum Average Planar Ratio |
| MBB | Motor Built-In Brake |
| MCC | Motor Control Center |
| MCES | Main Condenser Evacuation System |
| MCPR | Minimum Critical Power Ratio |
| MCR | Main Control Room |
| MCRP | Main Control Room Panel |
| MELB | Moderate Energy Line Break |
| MLHGR | Maximum Linear Heat Generation Rate |
| MMI | Man-Machine Interface |
| MMIS | Man-Machine Interface Systems |
| MOV | Motor-Operated Valve |
| MPC | Maximum Permissible Concentration |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| MPL | Master Parts List |
| MS | Main Steam |
| MSIV | Main Steam Isolation Valve |
| MSL | Main Steamline |
| MSLB | Main Steamline Break |
| MSLBA | Main Steamline Break Accident |
| MSR | Moisture Separator Reheater |
| MSV | Mean Square Voltage |
| MT | Main Transformer |
| MTTR | Mean Time To Repair |
| MVP | Mechanical Vacuum Pump |
| MWS | Makeup Water System |
| NBR | Nuclear Boiler Rated |
| NBS | Nuclear Boiler System |
| NCIG | Nuclear Construction Issues Group |
| NDE | Nondestructive Examination |
| NE-DCIS | Non-Essential Distributed Control and Information System |
| NDRC | National Defense Research Committee |
| NDT | Nil Ductility Temperature |
| NFPA | National Fire Protection Association |
| NIST | National Institute of Standard Technology |
| NICWS | Nuclear Island Chilled Water Subsystem |
| NMS | Neutron Monitoring System |
| NOV | Nitrogen Operated Valve |
| NPHS | Normal Power Heat Sink |
| NPSH | Net Positive Suction Head |
| NRC | Nuclear Regulatory Commission |
| NRHX | Non-Regenerative Heat Exchanger |
| NS | Non-seismic |
| NSSS | Nuclear Steam Supply System |
| NT | Nitrogen Storage Tank |
| NTSP | Nominal Trip Setpoint |
| O&M | Operation and Maintenance |
| O-RAP | Operational Reliability Assurance Program |
| OBCV | Overboard Control Valve |
| OBE | Operating Basis Earthquake |
| OGS | Offgas System |
| OHLHS | Overhead Heavy Load Handling System |
| OIS | Oxygen Injection System |
| OLMCPR | Operating Limit Minimum Critical Power Ratio |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| OLU | Output Logic Unit |
| OOS | Out-of-service |
| ORNL | Oak Ridge National Laboratory |
| OSC | Operational Support Center |
| OSHA | Occupational Safety and Health Administration |
| OSI | Open Systems Interconnect |
| P&ID | Piping and Instrumentation Diagram |
| PA/PL | Page/Party-Line |
| PABX | Private Automatic Branch (Telephone) Exchange |
| PAM | Post Accident Monitoring |
| PAR | Passive Autocatalytic Recombiner |
| PAS | Plant Automation System |
| PASS | Post Accident Sampling Subsystem of Containment Monitoring System |
| PCC | Passive Containment Cooling |
| PCCS | Passive Containment Cooling System |
| PCT | Peak cladding temperature |
| PCV | Primary Containment Vessel |
| PFD | Process Flow Diagram |
| PGA | Peak Ground Acceleration |
| PGCS | Power Generation and Control Subsystem of Plant Automation System |
| PH | Pump House |
| PL | Parking Lot |
| PM | Preventive Maintenance |
| PMCS | Performance Monitoring and Control Subsystem of NE-DCIS |
| PMF | Probable Maximum Flood |
| PMP | Probable Maximum Precipitation |
| PQCL | Product Quality Check List |
| PRA | Probabilistic Risk Assessment |
| PRMS | Process Radiation Monitoring System |
| PRNM | Power Range Neutron Monitoring |
| PS | Plant Stack |
| PSD | Power Spectra Density |
| PSS | Process Sampling System |
| PSWS | Plant Service Water System |
| PT | Pressure Transmitter |
| PWR | Pressurized Water Reactor |
| QA | Quality Assurance |
| RACS | Rod Action Control Subsystem |
| RAM | Reliability, Availability and Maintainability |
| RAPI | Rod Action and Position Information |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| RAT | Reserve Auxiliary Transformer |
| RB | Reactor Building |
| RBC | Rod Brake Controller |
| RBCC | Rod Brake Controller Cabinet |
| RBCWS | Reactor Building Chilled Water Subsystem |
| RBHV | Reactor Building HVAC |
| RBS | Rod Block Setpoint |
| RBV | Reactor Building Vibration |
| RC&IS | Rod Control and Information System |
| RCC | Remote Communication Cabinet |
| RCCV | Reinforced Concrete Containment Vessel |
| RCCWS | Reactor Component Cooling Water System |
| RCPB | Reactor Coolant Pressure Boundary |
| RCS | Reactor Coolant System |
| RDA | Rod Drop Accident |
| RDC | Resolver-to-Digital Converter |
| REPAVS | Refueling and Pool Area Ventilation Subsystem of Fuel Building HVAC |
| RFP | Reactor Feed Pump |
| RG | Regulatory Guide |
| RHR | Residual heat removal (function) |
| RHX | Regenerative Heat Exchanger |
| RMS | Root Mean Square |
| RMS | Radiation Monitoring Subsystem |
| RMU | Remote Multiplexer Unit |
| RO | Reverse Osmosis |
| ROM | Read-only Memory |
| RPS | Reactor Protection System |
| RPV | Reactor Pressure Vessel |
| RRPS | Reference Rod Pull Sequence |
| RSM | Rod Server Module |
| RSPC | Rod Server Processing Channel |
| RSS | Remote Shutdown System |
| RSSM | Reed Switch Sensor Module |
| RSW | Reactor Shield Wall |
| RTIF | Reactor Trip and Isolation Function(s) |
| RT _{NDT} | Reference Temperature of Nil-Ductility Transition |
| RTP | Reactor Thermal Power |
| RW | Radwaste Building |
| RWBCR | Radwaste Building Control Room |
| RWBGA | Radwaste Building General Area |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| RWBHVAC | Radwaste Building HVAC |
| RWCU/SDC | Reactor Water Cleanup/Shutdown Cooling |
| RWE | Rod Withdrawal Error |
| RWM | Rod Worth Minimizer |
| SA | Severe Accident |
| SAR | Safety Analysis Report |
| SB | Service Building |
| S/C | Digital Gamma-Sensitive GM Detector |
| SC | Suppression Chamber |
| S/D | Scintillation Detector |
| S/DRSRO | Single/Dual Rod Sequence Restriction Override |
| S/N | Signal-to-Noise |
| S/P | Suppression Pool |
| SAS | Service Air System |
| SB&PC | Steam Bypass and Pressure Control System |
| SBO | Station Blackout |
| SBWR | Simplified Boiling Water Reactor |
| SCEW | System Component Evaluation Work |
| SCRRI | Selected Control Rod Run-in |
| SDC | Shutdown Cooling |
| SDM | Shutdown Margin |
| SDS | System Design Specification |
| SEOA | Sealed Emergency Operating Area |
| SER | Safety Evaluation Report |
| SF | Service Water Building |
| SFP | Spent fuel pool |
| SIL | Service Information Letter |
| SIT | Structural Integrity Test |
| SIU | Signal Interface Unit |
| SJAE | Steam Jet Air Ejector |
| SLC | Standby Liquid Control |
| SLCS | Standby Liquid Control System |
| SLMCPR | Safety Limit Minimum Critical Power Ratio |
| SMU | SSLC Multiplexing Unit |
| SOV | Solenoid Operated Valve |
| SP | Setpoint |
| SPC | Suppression Pool Cooling |
| SPDS | Safety Parameter Display System |
| SPTMS | Suppression Pool Temperature Monitoring Subsystem of Containment Monitoring System |
| SR | Surveillance Requirement |

| <u>Term</u> | <u>Definition</u> |
|--------------------|--|
| SRM | Source Range Monitor |
| SRNM | Startup Range Neutron Monitor |
| SRO | Senior Reactor Operator |
| SRP | Standard Review Plan |
| SRS | Software Requirements Specification |
| SRSRO | Single Rod Sequence Restriction Override |
| SRSS | Sum of the squares |
| SRV | Safety Relief Valve |
| SRVDL | Safety relief valve discharge line |
| SSAR | Standard Safety Analysis Report |
| SSC(s) | Structure, System and Component(s) |
| SSE | Safe Shutdown Earthquake |
| SSLC | Safety System Logic and Control |
| SSPC | Steel Structures Painting Council |
| ST | Spare Transformer |
| STP | Sewage Treatment Plant |
| STRAP | Scram Time Recording and Analysis Panel |
| STRP | Scram Time Recording Panel |
| SV | Safety Valve |
| SWH | Static water head |
| SWMS | Solid Waste Management System |
| SY | Switch Yard |
| TAF | Top of Active Fuel |
| TASS | Turbine Auxiliary Steam System |
| TB | Turbine Building |
| TBCE | Turbine Building Compartment Exhaust |
| TEAS | Turbine Building Air Supply |
| TBE | Turbine Building Exhaust |
| TBLOE | Turbine Building Lube Oil Area Exhaust |
| TBS | Turbine Bypass System |
| TBHV | Turbine Building HVAC |
| TBV | Turbine Bypass Valve |
| TC | Training Center |
| TCCWS | Turbine Component Cooling Water System |
| TCS | Turbine Control System |
| TCV | Turbine Control Valve |
| TDH | Total Developed Head |
| TEMA | Tubular Exchanger Manufacturers' Association |
| TFSP | Turbine first stage pressure |
| TG | Turbine Generator |

| <u>Term</u> | <u>Definition</u> |
|--------------------|---|
| TGSS | Turbine Gland Seal System |
| THA | Time-history accelerograph |
| TLOS | Turbine Lubricating Oil System |
| TLU | Trip Logic Unit |
| TMI | Three Mile Island |
| TMSS | Turbine Main Steam System |
| TRM | Technical Requirements Manual |
| TS | Technical Specification(s) |
| TSC | Technical Support Center |
| TSI | Turbine Supervisory Instrument |
| TSV | Turbine Stop Valve |
| UBC | Uniform Building Code |
| UHS | Ultimate heat sink |
| UL | Underwriter's Laboratories Inc. |
| UPS | Uninterruptible Power Supply |
| USE | Upper Shelf Energy |
| USM | Uniform Support Motion |
| USMA | Uniform support motion response spectrum analysis |
| USNRC | United States Nuclear Regulatory Commission |
| USS | United States Standard |
| UV | Ultraviolet |
| V&V | Verification and Validation |
| Vac / VAC | Volts Alternating Current |
| Vdc / VDC | Volts Direct Current |
| VDU | Video Display Unit |
| VW | Vent Wall |
| VWO | Valves Wide Open |
| WD | Wash Down Bays |
| WH | Warehouse |
| WS | Water Storage |
| WT | Water Treatment |
| WW | Wetwell |
| XMFR | Transformer |
| ZPA | Zero period acceleration |

11. RADIOACTIVE WASTE MANAGEMENT

11.1 SOURCE TERMS

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

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

The various radionuclides included in the design basis term have been categorized as fission products or activation products and tabulated in the subsections that follow. The lists do not necessarily include all radionuclides that may be detectable or theoretically predicted to be present.

Those that have been included are considered to be potentially significant with respect to one or more of the following criteria:

- plant equipment design,
- shielding design,
- understanding system operation and performance,
- measurement practicability.

The values provided in this section are not valid for calculation of environmental releases. Ratio factors are given in Table 11.1-1 and are discussed in Chapter 12.2.2.

11.1.1 Fission Products

Noble Radiogas Fission Products

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

The design basis noble gas source term mixture is from Reference 11.1-1, and the total of the release rates of the 13 noble gases from the vessel. The noble radiogas source term rate after 30-minute decay has been used as a conventional measure of the fuel leakage rate, because it is

conveniently measurable and was consistent with the nominal 30-minute offgas holdup system used on a number of early plants. A design basis noble gas release rate of 3,700 MBq/sec (100,000 μ Ci/sec) at 30 minutes decay has historically been used for the design of the gaseous waste treatment systems in BWR plants (Reference 11.1-2) with satisfactory results. It was selected on the basis of operating experience with consideration given to several judgmental factors, including the implications to environmental releases, system contamination, and building air contamination. The design basis noble radiogas source terms are presented in Table 11.1-2.

Radioiodine Fission Products

For many years, design basis radioiodine source terms for BWRs have been specified to be consistent with an I^{131} leak rate of 26 MBq/sec (700 μ Ci/sec) from the fuel (Reference 11.1-2). Experience indicated that I^{131} leakage rates this high would be approached only during operation with substantial fuel cladding defects. It would not be anticipated that full power operation would continue for any significant period of time with fuel cladding defects as severe as might be indicated by I^{131} leakage in excess of 26 MBq/sec (700 μ Ci/sec).

The design basis reactor water radioiodine concentrations are based on the relative mix of radioiodines in reactor water predicted by the data of Reference 11.1-1 with magnitudes increased such that the I^{131} concentration is consistent with the Table 11.1-1 release rate from the fuel based upon shortened fuel. This provides a substantial margin relative to the expected I^{131} release rate shown in Table 11.1-1. Reference 11.1-1 specifies expected concentrations of the 5 principal radioiodines in reactor water for a reference BWR design and provides bases for adjusting the concentrations for plants with relevant plant parameters that do not match those of the reference plant. The concentration adjustment factors were calculated as described in Subsection 12.2.2 using the plant parameters in Table 11.1-3. The scale factor required to increase the concentration of I^{131} from the concentration calculated using Reference 11.1-1 to the design basis value is shown in Table 11.1-1. The design basis concentrations are presented in Table 11.1-4.

The ratio of concentration in reactor steam to concentration in reactor water (carryover ratio) is taken to be 0.02 for radioiodines (Reference 11.1-1). Consequently, the design basis concentrations of radioiodines in steam are defined by multiplying the values of Table 11.1-4 by the factor 0.02.

Other Fission Products

This category includes all fission products other than noble gases and iodines and also includes transuranic nuclides. Some of the fission products are noble gas daughter products that are produced in the steam and condensate system. The only transuranic which is detectable in significant concentrations is Np^{239} . Concentrations of those radionuclides that are typically observable in the coolant are provided in Reference 11.1-1 for a Reference BWR plant. The Reference plant concentrations are adjusted to obtain estimates for the ESBWR plant by using the procedure described in Subsection 11.1.3 and appropriate data from Table 11.1-3. In order to assure conservative design basis concentrations for the ESBWR, the results were increased by the same factor used to obtain design basis radioiodine concentrations. The design basis reactor water concentrations are presented in Table 11.1-5. The ratio of concentration in steam to concentration in water (carryover) for these nuclides is expected to be less than 0.001. The

design basis concentrations in steam are obtained by multiplying the values in Table 11.1-5 by 0.001.

11.1.2 Activation Products

Coolant Activation Products

The coolant activation product of primary importance in BWRs is N^{16} . ANSI/ANS-18.1 (Reference 11.1-1) specifies a concentration of 1.85 MBq/gm (50 μ Ci/gm) in steam leaving the reactor vessel for plants without Hydrogen Water Chemistry (HWC). Plants with HWC are specified at 9.25 MBq/gm (250 μ Ci/gm). This HWC concentration is used as the design basis N^{16} concentration in steam for ESBWR. This is treated as essentially independent of reactor design because both the production rate of N^{16} and the steam flow rate from the vessel are assumed to vary in direct proportion to reactor thermal power. It should be noted that a portion of the source term traditionally identified as " N^{16} " actually represents C^{15} . To the extent that C^{15} is present, it is no more than about ~ 0.55 MBq/gm (15 μ Ci/gm). Historically, gross gamma dose rate measurements made to confirm the magnitude of the N^{16} concentration have included responses to gamma rays from C^{15} . Use of the combined " N^{16} " source term in shielding design introduces additional conservatism because the C^{15} component has a 2.45 second half-life, and therefore decays more rapidly with transport time through the system than N^{16} , which has a 7.1 second half-life.

The design basis N^{16} concentrations in steam and reactor water are shown in Table 11.1-6. Reference 11.1-1 gives the reactor water concentration at the recirculation system. Because the ESBWR does not have an external recirculation loop, the reactor water concentration has been decay-corrected to the reactor core exit to obtain an estimated value shown in Table 11.1-1.

Noncoolant Activation Products

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

Tritium

Tritium is produced by activation of naturally occurring deuterium in the primary coolant and, to a lesser extent, as a fission product in the fuel (Reference 11.1-2). The tritium is primarily present as tritiated oxide (HTO). Because tritium has a long half-life (12 years) and is not affected by cleanup processes in the system, the concentration is controlled by the rate of loss of water from the system by evaporation or leakage. All plant process water and steam have a common tritium concentration. The concentration reached depends on the actual water loss rate; however, References 11.1-1 and 11.1-3 both specify a typical concentration of 370 Bq/gm (0.01 μ Ci/gm) that is stated in Reference 11.1-3 to be based on BWR experience adjusted to account for liquid recycle. This value is taken to be applicable for the ESBWR.

Argon-41

Argon-41 is produced in the reactor coolant as a consequence of neutron activation of naturally occurring Argon-40 in air that is entrained in the feedwater. The Argon-41 gas is carried out of the vessel with the steam and stripped from the system with the non-condensables in the main condenser. Observed Argon-41 levels are highly variable due to the variability in air in-leakage rates into the system. Reference 11.1-3 specifies an Argon-41 release rate from the vessel of 1.5 MBq/sec (40 μ Ci/sec) for a 3400 MW Reference BWR. This value bounded the available experimental database. Based on adjusting to the ESBWR thermal power, a design basis Argon-41 release rate specified for the ESBWR is shown in Table 11.1-1.

11.1.3 Radionuclide Concentration Adjustment

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

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

$$C = \frac{S}{M(\lambda + R)} \quad (11.1-1)$$

where:

C = radionuclide concentration

S = radionuclide input rate to coolant

M = reactor water mass

λ = radionuclide decay constant

R = sum of removal rates of the radionuclide from the system.

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

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

where the subscript "r" refers to the Reference Plant, P is the reactor thermal power and M, λ , and R are as defined above.

The removal rate from the system is the sum of the removal rates due to the Reactor Water Cleanup System and the condensate demineralizer and is given by:

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

where:

F_c = cleanup system flow rate

E_c = fraction of radionuclide removed in cleanup demineralizer

F_s = steam flow rate

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

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

E_s = fraction of radionuclide removed in condensate demineralizer.

The Reference Plant and ESBWR plant parameters and the nuclide-dependent removal rate parameters used for the ESBWR are shown in Table 11.1-3. The nuclide-dependent parameters are the same as those used for the Reference Plant except for the fraction circulated through the condensate demineralizer.

11.1.4 Fuel Fission Production Inventory

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

11.1.5 Process Leakage Sources

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

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

As a consequence of normal steam and water leakage into the drywell, equilibrium drywell concentrations exist during normal operation. Purging of this activity from the drywell to the environment occurs via the drywell purge system, which can be routed and processed through a charcoal filtration system and makes minor contributions to total plant releases.

Airborne release data from BWR building ventilation systems and the main condenser mechanical vacuum pump have been compiled and evaluated in Reference 11.1-4, which contains data obtained by utility personnel and from special in-plant studies of operating BWR plants by independent organizations and by GE Nuclear Energy. Releases due to process leakage are reflected in the airborne release estimates discussed in Section 12.2..2.

11.1.6 References

- 11.1-1 ANSI/ANS, "American National Standard Radioactive Term for Normal Operation of Light Water Reactors," ANSI/ANS-18.1-1999.
- 11.1-2 General Electric Company, "Technical Derivation of BWR 1971 Design Basis Radioactive Material Source Terms," NEDO-10871, March 1973.
- 11.1-3 USNRC, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors," NUREG-0016, Revision 1, January 1979.
- 11.1-4 General Electric Company, "Airborne Releases From BWRs for Environmental Impact Evaluations," NEDO-21159, March 1976.

Table 11.1-1
Source Term Design Basis Parameters

| Parameter | Value |
|--|---|
| Total of the release rates of the 13 noble gases (30minute decay reference, t30) | 3700 MBq/sec (100,000 μ Ci/sec) |
| Normal operational noble gas release rate (t30) | 740 MBq/sec (20,000 μ Ci/sec) |
| Design basis I-131 radioiodine core release rate | 26 MBq/sec (700 μ Ci/sec) |
| Expected I-131 radioiodine core release rate | 3.7 MBq/sec (100- μ Ci/sec) |
| I ¹³¹ concentration scale factor | 5 |
| Reactor core exit N ¹⁶ concentration | 1.85 MBq/gm (50 μ Ci/gm) w/o HWC 9.25 MBq/gm (250 μ Ci/gm) w/HWC |
| Design Basis Argon ⁴¹ release rate | 2.0 MBq/sec (53 μ Ci/sec) |

Table 11.1-2
Design Basis Noble Radiogas Source Terms in Steam

| Isotope | Decay Constant (per hour) | Steam Concentration | | Source Term at t=30min | |
|----------------|--------------------------------------|----------------------------|--------------------------------|-----------------------------------|---------------------------------|
| | | (MBq/gm) | (μCi/gm) | (MBq/sec) | (μCi/sec) |
| Kr-83m | 3.73E-1 | 5.4E-05 | 1.5E-03 | 1.1E+02 | 2.9E+03 |
| Kr-85m | 1.55E-1 | 9.1E-05 | 2.5E-03 | 2.0E+02 | 5.5E+03 |
| Kr-85 | 7.37E-6 | 3.6E-07 | 9.8E-06 | 8.9E-01 | 2.4E+01 |
| Kr-87 | 5.47E-1 | 3.0E-04 | 8.1E-03 | 5.6E+02 | 1.5E+04 |
| Kr-88 | 2.48E-1 | 3.0E-04 | 8.1E-03 | 6.5E+02 | 1.7E+04 |
| Kr-89 | 1.32E+1 | 1.9E-03 | 5.2E-02 | 6.4E+00 | 1.7E+02 |
| Xe-131m | 2.41E-3 | 3.0E-07 | 8.1E-06 | 7.3E-01 | 2.0E+01 |
| Xe-133m | 1.30E-2 | 4.5E-06 | 1.2E-04 | 1.1E+01 | 2.9E+02 |
| Xe-133 | 5.46E-3 | 1.3E-04 | 3.4E-03 | 3.1E+02 | 8.4E+03 |
| Xe-135m | 2.72E+0 | 4.0E-04 | 1.1E-02 | 2.5E+02 | 6.8E+03 |
| Xe-135 | 7.56E-2 | 3.5E-04 | 9.4E-03 | 8.1E+02 | 2.2E+04 |
| Xe-137 | 1.08E+1 | 2.4E-03 | 6.4E-02 | 2.6E+01 | 6.9E+02 |
| Xe-138 | 2.93E+0 | 1.4E-03 | 3.7E-02 | 7.7E+02 | 2.1E+04 |
| Totals | | 7.3E-03 | 2.0E-01 | 3.7E+03 | 1.0E+05 |

Table 11.1-3
Calculational Parameters For Source Term Adjustment

| A. Plant Parameters for Source Term Adjustment | | | |
|---|-----------------|---------|------------|
| Parameter | Reference Plant | ESBWR | |
| Thermal Power, MWt | 3400 | 4500 | |
| Reactor Water Mass, kg | 1.7E+5 | 6.74E+5 | |
| Cleanup System Flow Rate, kg/hr | 5.8E+4 | 1.93E+5 | |
| Steam Flow Rate, kg/hr | 6.8E+6 | 1.93E+7 | |
| Ratio of Condensate Demineralizer Flow Rate to Steam Flow Rate. | 1 | 1 | |
| B. Removal Parameters for Source Term Adjustment | | | |
| Parameter | Iodines | Rb, Cs | All Others |
| Fraction removed by cleanup system | 0.9 | 0.5 | 0.9 |
| Fraction removed by condensate demineralizers | 0.9 | 0.5 | 0.9 |
| Ratio of concentration in steam and reactor water | 0.02 | 0.001 | 0.001 |
| Fraction of radionuclides in steam treated by condensate demineralizer. | 1 | 1 | 1 |

Table 11.1-4
Design Basis Iodine Radioisotopes in Reactor Water and Steam

| Decay Constant | | Water Concentration | | Steam Concentration | |
|-----------------------|------------|----------------------------|----------------|----------------------------|----------------|
| Isotope | (per hour) | (MBq/gm) | (μ Ci/gm) | (MBq/gm) | (μ Ci/gm) |
| I-131 | 3.59E-3 | 3.9E-04 | 1.1E-02 | 7.9E-06 | 2.1E-04 |
| I-132 | 3.03E-1 | 3.7E-03 | 9.9E-02 | 7.4E-05 | 2.0E-03 |
| I-133 | 3.33E-2 | 2.7E-03 | 7.2E-02 | 5.3E-05 | 1.4E-03 |
| I-134 | 7.91E-1 | 6.8E-03 | 1.8E-01 | 1.4E-04 | 3.7E-03 |
| I-135 | 1.05E-1 | 3.8E-03 | 1.0E-01 | 7.6E-05 | 2.1E-03 |

Table 11.1-5
Design Basis Non-volatile Fission Products In Reactor Water

| Isotope* | Decay Constant | Concentration | |
|-----------------|-----------------------|----------------------|----------------|
| | (per hour) | (MBq/gm) | (μ Ci/gm) |
| Rb-89 | 2.74E+0 | 6.9E-04 | 1.9E-02 |
| Sr-89 | 5.55E-4 | 1.7E-05 | 4.5E-04 |
| Sr-90 | 2.81E-6 | 1.2E-06 | 3.1E-05 |
| Y-90 | 2.81E-6 | 1.2E-06 | 3.1E-05 |
| Sr-91 | 7.31E-2 | 6.4E-04 | 1.7E-02 |
| Sr-92 | 2.56E-1 | 1.5E-03 | 4.1E-02 |
| Y-91 | 4.93E-4 | 6.6E-06 | 1.8E-04 |
| Y-92 | 1.96E-1 | 9.3E-04 | 2.5E-02 |
| Y-93 | 6.80E-2 | 6.4E-04 | 1.7E-02 |
| Zr-95/Nb-95 | 4.41E-4 | 1.3E-06 | 3.6E-05 |
| Mo-99/Tc-99m | 1.05E-2 | 3.3E-04 | 8.9E-03 |
| Ru-103/Rh-103m | 7.29E-4 | 3.3E-06 | 8.9E-05 |
| Ru-106/Rh-106 | 7.83E-5 | 5.0E-07 | 1.3E-05 |
| Te -129m | 8.65E-4 | 6.6E-06 | 1.8E-04 |
| Te-131m | 2.31E-2 | 1.6E-05 | 4.4E-04 |
| Te-132 | 8.89E-3 | 1.6E-06 | 4.5E-05 |
| Cs-134 | 3.84E-5 | 4.5E-06 | 1.2E-04 |
| Cs-136 | 2.22E-3 | 3.0E-06 | 8.0E-05 |
| Cs-137/Ba-137m | 2.63E-6 | 1.2E-05 | 3.2E-04 |
| Cs-138 | 1.29E+0 | 1.4E-03 | 3.8E-02 |
| Ba-140/La-140 | 2.26E-3 | 6.6E-05 | 1.8E-03 |
| Ce-141 | 8.88E-4 | 5.0E-06 | 1.3E-04 |
| Ce-144/Pr-144 | 1.02E-4 | 5.0E-07 | 1.3E-05 |
| Np-239 | 1.24E-2 | 1.3E-03 | 3.6E-02 |

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

Table 11.1-6
Design Basis N¹⁶ Concentrations in Reactor Water and Steam

| Isotope | Half-Life | Steam Concentration* | | Reactor Water Concentration** | |
|----------------|------------------|-----------------------------|----------------|--------------------------------------|----------------|
| | | (MBq/gm) | (μ Ci/gm) | (MBq/gm) | (μ Ci/gm) |
| N-16 | 7.13 sec | 1.85 | 50 | 2.2 | 60 |

* During operation with hydrogen water chemistry, increase this value by a factor of five.

** Valid at core exit.

Table 11.1-7
Design Basis Non-coolant Activation Products in Reactor Water

| Decay Constant | | Concentration | |
|-----------------------|------------|----------------------|----------------|
| Isotope | (per hour) | (MBq/gm) | (μ Ci/gm) |
| Na-24 | 4.63E-2 | 3.2E-04 | 8.7E-03 |
| P-32 | 2.02E-3 | 6.6E-06 | 1.8E-04 |
| Cr-51 | 1.04E-3 | 5.0E-04 | 1.3E-02 |
| Mn-54 | 9.53E-5 | 5.8E-06 | 1.6E-04 |
| Mn-56 | 2.69E-1 | 3.8E-03 | 1.0E-01 |
| Fe-55 | 3.04E-5 | 1.7E-04 | 4.5E-03 |
| Fe-59 | 6.33E-4 | 5.0E-06 | 1.3E-04 |
| Co-58 | 4.05E-4 | 1.7E-05 | 4.5E-04 |
| Co-60 | 1.50E-5 | 3.3E-05 | 8.9E-04 |
| Ni-63 | 7.90E-7 | 1.7E-07 | 4.5E-06 |
| Cu-64 | 5.42E-2 | 4.8E-04 | 1.3E-02 |
| Zn-65 | 1.18E-4 | 1.7E-04 | 4.5E-03 |
| Ag-110M | 1.16E-4 | 1.7E-07 | 4.5E-06 |
| W-187 | 2.90E-2 | 4.9E-05 | 1.3E-03 |

11.2 LIQUID WASTE MANAGEMENT SYSTEM

The ESBWR Liquid Waste Management System (LWMS) is designed to control, collect, process, handle, store, and dispose of liquid radioactive waste generated as the result of normal operation, including anticipated operational occurrences.

The LWMS is housed in the radwaste building and consists of the following four subsystems:

- equipment (low conductivity) drain subsystem;
- floor (high conductivity) drain subsystem;
- chemical drain subsystem;
- detergent drain subsystem;

A LWMS Process Diagram depicting all four subsystems is provided in Figure 11.2-1. A conceptual radwaste building general arrangement is provided in Figures 1.2-21 thru 1.2-25. The LWMS equipment codes and component capacities are provided in Tables 11.2-1, 11.2-2a, 11.2-2b, and 11.2-2c, respectively. The normal and maximum daily inputs, and process decontamination factors for the LWMS subsystems are provided in Tables 11.2-3 and 11.2-4, respectively.

The equipment and floor drainage collection system, a major input source to the LWMS, is described in Subsection 9.3.3.

Process and effluent radiological monitoring and sampling systems are described in Section 11.5.

11.2.1 Design Bases

Safety Design Bases

The LWMS has no safety-related function.

Power Generation Design Bases

- The LWMS has the capability to process the maximum anticipated quantities of liquid waste without impairing the operation or availability of the plant during both normal and expected occurrence conditions, satisfying the requirements of 10 CFR 20 and 10 CFR 50 (see Table 11.2-4 for time to process maximum inputs).
- Alternate process subsystem cross-ties and adequate storage volumes are included in the LWMS design to provide for operational and anticipated surge waste volumes.
- The LWMS is designed so that no potentially radioactive liquids can be discharged to the environment unless they have first been monitored and diluted as required. Off-site radiation exposures on an annual average basis are within the limits of 10 CFR 20 and 10 CFR 50.
- The LWMS is designed to meet the requirements of General Design Criterion (GDC) 60 and Regulatory Guide 1.143.
- The LWMS is designed to keep the exposure to plant personnel “as low as reasonably achievable” (ALARA) during normal operation and plant maintenance, in accordance with Regulatory Guide 8.8.

- The seismic category, quality group classification, and corresponding codes and standards that apply to the design of the LWMS are discussed in Section 3.2.
- All atmospheric liquid radwaste tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each collection tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.
- An evaluation is included in Chapter 12 to show that the proposed systems are capable of controlling releases of radioactive materials within the numerical design objectives of Appendix I to 10 CFR 50.
- An evaluation is included in Chapter 12 to show that the proposed systems have sufficient capacity, redundancy, and flexibility to meet the concentration limits of 10 CFR 20 during periods of equipment downtime and during operation at design basis fuel leakage.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.2.2 System Description

11.2.2.1 Summary Description

The LWMS collects, monitors, processes, stores, and disposes of potentially radioactive liquid waste collected throughout the plant.

The equipment and floor drainage systems are described in Section 9.3.

Potentially radioactive liquid wastes are collected in tanks located in the radwaste building. System components are designed and arranged in shielded enclosures to minimize exposure to plant personnel during operation, inspection, and maintenance. Tanks, processing equipment, pumps, valves, and instruments that may contain radioactivity are located in controlled access areas.

The LWMS normally operates on a batch basis. Provisions for sampling at important process points are included. Protection against accidental discharge is provided by detection and alarm of abnormal conditions and by administrative controls.

The LWMS is divided into several subsystems, so that the liquid wastes from various sources can be segregated and processed separately, based on the most economical and efficient process for each specific type of impurity and chemical content. Cross-connections between subsystems provide additional flexibility in processing the wastes by alternate methods and provide redundancy if one subsystem is inoperative.

11.2.2.2 System Operation

The LWMS consists of the following four process subsystems:

Equipment (Low Conductivity) Drain Subsystem

The equipment drain collection tanks receive low conductivity inputs from various sources within the plant. These waste inputs have a high chemical purity and are processed on a batch basis. The equipment drain subsystem consists of three collection tanks and collection pumps, a

mobile based Hollow Fiber Filter (HFF) and Deep-Bed Ion Exchanger system including organic material pre-treatment equipment, an intermediate tank/pump, and two sample tanks and sample pumps. One collection tank is normally used as a surge tank that can collect waste from the low conductivity waste and/or high conductivity waste. Cross-connections with the floor drain subsystem allows processing through the mobile system for floor drain treatment.

Mobile based chemical addition equipment is provided to add chemical agent(s) for recovering the performance of the HFF System. The equipment provides for addition of chemical agent(s) for the Reverse Osmosis System (RO) in the floor drain subsystem.

A strainer or filter is provided downstream of the last ion exchanger in series to collect any crud and resin fines that may be present.

The process effluents are collected in one of the two sample tanks for chemical and radioactivity analysis. If acceptable, the tank contents are returned to the condensate storage tank for plant reuse. A recycle line from the sample tanks allows the sampled effluents that do not meet water quality requirements to be pumped back to an Equipment (Low Conductivity) Drain Collection Tank or Floor (High Conductivity) Drain Collection Tank for additional processing. If the plant condensate inventory is high, the sampled process effluent may be discharged.

The HFF is backwashed periodically to maintain filtration capacity. Backwash waste is discharged to a low activity phase separator. Spent deep-bed ion exchanger resin is discharged to a low activity spent resin holdup tank as a slurry.

Floor (High Conductivity) Drain Subsystem

The floor drain collection tanks receive high conductivity waste inputs from various floor drain sumps in the reactor building, turbine building, and radwaste building. The floor drain collection tanks also receive waste input from chemical drain collection tank.

The floor drain subsystem consists of two floor drain collection tanks and collection pumps, a mobile based Reverse Osmosis (RO) and Deep-Bed Ion Exchanger System including suspended solid pre-treatment equipment, an intermediate tank/pump and two sample tanks and sample pumps. The waste collected in the floor drain collection tanks are processed on a batch basis. Cross-connections with the equipment drain subsystem also allow for processing through that subsystem.

Additional collection capacity is also provided by one additional equipment drain collection tank that is shared with the equipment drain subsystem.

A strainer or filter is provided downstream of the last ion exchanger in series to collect any crud and resin fines that may be present.

The floor drain sample tanks collect the process effluent, so that a sample may be taken for chemical and radioactivity analysis before discharging or recycling. The discharge path depends on the water quality, dilution stream availability and plant water inventory. Off-standard quality effluent can be recycled to floor drain collection tanks or equipment drain collection tanks. If the treatment effluent meets water quality standards and if the water inventory permits it to be recycled, the processed floor drain effluent can be recycled to the condensate storage tank or discharged off-site.

The liquid waste is concentrated in the RO system and is periodically discharged to a concentrated waste tank. Spent deep-bed ion exchanger resin is discharged to a low activity spent resin holdup tank as a slurry.

The capability exists to accept used condensate polishing resin in a Condensate Resin Holdup Tank. The used condensate polishing resin from Condensate Purification System is transferred to the Condensate Resin Holdup Tank prior to use in the pre-treatment deep-bed ion exchanger in the floor drain subsystem.

Chemical Drain Subsystem

The chemical waste collected in the chemical drain collection tank consists of laboratory wastes and decontamination solutions. After accumulating in the chemical drain collection tank, chemical agents may be added to the chemical drain by mobile-based chemical pre-treatment equipment if necessary and the pre-treated chemical drain is transferred to floor drain collection tanks for further processing. Chemical pre-treatment operation is typically a neutralization process. A sample is then taken and if discharge standards are met, then the waste may be discharged off-site. A cross-connection with the detergent drain subsystem is also provided.

Detergent Drain Subsystem

Waste water containing detergent from the controlled laundry and personnel decontamination facilities and decontamination waste water from the reactor building or turbine building throughout the plant is collected in the detergent drain collection tanks. The detergent drain subsystem consists of two detergent drain collection tanks and collection pumps, a mobile-based detergent drain filter and charcoal filter system including organic material pre-treatment equipment, an intermediate tank/pump, and two sample tanks and sample pumps. The detergent wastes are processed through a suspended solid removal process and organic material removal process and collected in sample tanks. A sample is then taken and if discharge standards are met, then the waste is discharged off-site. Off-standard quality water can either be recycled for further processing to the detergent collection tank or to the floor drain collection tank. A cross-connection with the chemical drain collection subsystem is also provided.

11.2.2.3 Detailed System Component Description

The LWMS consists of permanently installed tanks, pumps, pipes, valves, and instruments, and mobile systems for waste processing. Mobile systems provide an operational flexibility and maintainability to support plant operation. The major components of the LWMS are as follows:

Pumps

Two types of pumps are utilized in the LWMS.

The LWMS process pumps are centrifugal pumps constructed of materials suitable for their intended service.

Neutralization chemicals in the LWMS are added with reciprocating positive displacement pumps (or functionally similar pumps). These pumps are constructed of materials suitable for their intended service.

Tanks

Tanks are sized to accommodate the expected volumes of waste generated in the upstream systems that feed waste into the LWMS for processing. The tanks are constructed of stainless steel to provide a low corrosion rate during normal operation. They are provided with mixing eductors and/or air spargers. The capability exists to sample all LWMS collection and sample tanks. All LWMS tanks are vented through a filtration unit and eventually discharged into the plant vent. The LWMS tanks are designed in accordance with the equipment codes listed in Table 11.2-1.

All atmospheric liquid radwaste tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each collection tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.

Mobile Systems

Mobile Systems for equipment drain processing

The equipment drain mobile system utilizes non-precoat type Hollow Fiber Filter (HFF) for removing suspended solid and radioactive particulate material and charcoal filters for organic material removal. Backwash operation for HFF is performed when the differential pressure of HFF exceeds a preset limit. HFF backwash waste is discharged to a low activity phase separator. A charcoal filter is located upstream of HFF for the purpose of removing organic material, which may cause fouling of the HFF. Spent charcoal is packaged directly into the container when the differential pressure exceeds a preset limit or waste quality of the effluent from the charcoal filter exceeds a preset value.

The equipment drain ion exchangers following the HFF are of the mixed-bed type. Exhausted resins are sluiced to the low activity spent resin holdup tank when some chosen effluent purity parameter (such as conductivity) exceeds a preset limit or upon high differential pressure. Fine mesh strainers with backwashing connections are provided in the ion exchange vessel discharge and in the downstream piping to prevent resin fines from being carried over to the sampling tanks.

The mobile system is skid-mounted and is designed and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to keep operational flexibility.

Mobile Systems for floor drain and chemical drain processing

Floor drain and chemical drain wastes are more complex to process than equipment drains. The floor drain mobile system utilizes pre-filtration equipment for removing suspended solids and organic impurities, Reverse Osmosis System (RO) for removing ionic impurities, and finally deep-bed ion exchangers for polishing.

The pre-filtrated liquid waste is collected into the feed tank of the RO System. The feed tank serves as a front-end supply tank to the process. The liquid waste is transferred to the RO unit via a booster pump. The RO unit uses membrane tubes that are made of a semi-permeable material. When pressure is applied to the feed side of the membrane, the solution passes through the membrane (permeates) and the solids and high molecular wastes are rejected. The rejected

solids and ionic impurities are returned to the feed tank and the final permeate is polished by deep-bed ion exchangers. The floor drain ion exchangers following the RO are of the mixed-bed type. Exhausted resins are sluiced to the spent resin tank when some chosen effluent purity parameter (such as conductivity) exceeds a preset limit or upon high differential pressure. Fine mesh strainers with backwashing connections are provided in the ion exchange vessel discharge and in the downstream piping to prevent resin fines from being carried over to the sampling tanks.

The chemical drain pre-treatment unit performs a pre-conditioning of chemical waste, such as pH adjustment, prior to processing in the RO system.

The mobile system is of a skid-mounted design and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to ensure operational flexibility.

Mobile Systems for detergent drain processing

The detergent drain mobile system typically utilizes a charcoal filter to remove organics and a cartridge type filter to remove suspended solids. When the differential pressure of the filter exceeds a preset value, the filter media is exchanged and the spent filter media is packaged as active solid waste.

The mobile system is of a skid-mounted design and configured for relatively easy installation and process reconfiguration. In-plant supply and return connections from permanently installed equipment to the mobile system are provided to ensure operational flexibility.

The mobile systems are located in the Liquid Waste Treatment System bay to allow truck access and mobile system skid loading and unloading. Modular shield walls are provided in the Radwaste Building to allow shield walls to be constructed to minimize exposure to personnel during operation and routine maintenance.

11.2.3 Safety Evaluation — Radioactive Releases

Safety Evaluation

The LWMS has no safety-related function. Failure of the system does not compromise any safety-related system or component nor does it prevent shutdown of the plant. No interface with the Class 1E electrical system exists.

Radioactive Releases

During liquid processing by the LWMS, radioactive contaminants are removed and the bulk of the liquid is purified and either returned to the condensate storage tank or discharged to the environment. The radioactivity removed from the liquid waste is concentrated in filter media ion exchange resins and concentrated waste. The decontamination factors (DFs) that are listed in Table 11.2-3 are in accordance with NUREG-0016, but are considered conservative values. The filter sludge, ion exchange resins and concentrated waste are sent to the Solid Waste Management System (SWMS) for further processing. If the liquid meets the purity requirements it is returned to the plant for condensate makeup. If the liquid is discharged, the activity concentration is consistent with the discharge criteria of 10 CFR 20 and dose commitment in 10 CFR 50, Appendix I.

The parameters and assumptions used to calculate releases of radioactive materials in liquid effluents and their bases are provided in Chapter 12.

Expected releases of radioactive materials by radionuclides in liquid effluents resulting from normal operation, including anticipated operational occurrences and from design basis fuel leakage are provided in Chapter 12.

A tabulation of the releases by radionuclides can be found in Chapter 12. The tabulation is for the total system and for each and includes indication of the effluent concentrations. The calculated concentrations in the effluents were within the concentration limits of 10 CFR 20; the doses resulting from the effluents are within the numerical design objectives of Appendix I to 10 CFR 50 and the dose limits of 10 CFR 20 as set forth in Chapter 12.

Dilution Factors

Refer to Section 12.2 for dilution factors used in evaluating the release of liquid effluents.

11.2.4 Testing and Inspection Requirements

The LWMS is given a pre-operational test as discussed in Chapter 14. Thereafter, portions of the systems are tested as needed.

During initial testing of the system, the pumps and mobile systems are performance tested to demonstrate conformance with design flows and process capabilities. An integrity test is performed on the system upon completion.

Provisions are made for periodic inspection of major components to ensure capability and integrity of the systems. Local display devices are provided to indicate all vital parameters required in routine testing and inspection.

11.2.5 Instrumentation Requirements

The LWMS is operated and monitored from the Radwaste Building Control Room. Major system parameters, i.e., tank levels, process flow rates, filter and ion exchanger differential pressure, ion exchanger effluent conductivity, etc., are indicated and alarmed as required to provide operational information and performance assessment. A continuous radiation detector is provided to monitor the discharge of radioactivity to the environs. Key system alarms are repeated in the main control room.

Requirements for sampling are set forth in Subsection 9.3.2.

11.2.6 COL Information

None.

11.2.7 References

None.

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

| Equipment | Design and Fabrication | Materials¹ | Welder Qualification and Procedures | Inspection and Testing |
|--|---|---|--|--|
| Pressure Vessels | ASME Code Section VIII, Div. 1 or Div.2 | ASME Code Section II | ASME Code Section IX | ASME Code Section VIII, Div. 1 or Div.2 |
| Atmospheric Tanks | ASME Code ² Section III, Class 3, or API 650, or AWWA D-100 | ASME Code ³ Section II | ASME Code Section IX | ASME Code ² Section III, Class 3; or API 650, or AWWA D-100 |
| 0-15 psig Tanks | ASME Code ² Section III, Class 3, or API 620 | ASME Code ³ Section II | ASME Code Section IX | ASME Code ² Section III, Class 3 or API 620 |
| Heat Exchangers | ASME Code Section VIII, Div. 1 or Div.2 and TEMA | ASME Code Section II | ASME Code Section IX | ASME Code Section VIII, Div. 1 or Div.2 |
| Piping and Valves | ANSI B31.3 | ASTM and ASME Code Section II | ASME Code Section IX | ANSI B31.3 |
| Pumps | API 610; API 674 ; API 675 ; or ASME BPVC Section VIII, Div.1 or Div.2 or Manufacturer's Standards ⁴ | ASTM A571-84 (1997) or ASME Code Section II or Manufacturer's Standards | ASME Code Section IX (as required) | ASME Code ² Section III, Class 3; or Hydraulic Institute |
| Flexible Hoses and Hose Connections for MRWP | ANSI/ANS-40.37 | ANSI/ANS-40.37 | ANSI/ANS-40.37 | ANSI/ANS-40.37 |

Notes:

- (1) Manufacturer's material certificates of compliance with material specifications may be provided in lieu of certified material.
- (2) ASME Code stamp, material traceability, and the quality assurance criteria of Appendix B to 10 CFR 50 are not required. Therefore, these components are not classified as ASME Code Section III, Class 3.
- (3) Fiberglass-reinforced plastic tanks may be used in accordance with appropriate articles of Section 10 of the ASME Boiler and Pressure Vessel Code for applications at ambient temperature.
- (4) Manufacturer's standard for the intended service. Hydrotesting should be at 1.5 times the design pressure.

* Per RG 1.143, all materials are in accordance of ASME Section II.

Table 11.2-2a
LWMS Component Capacity (Tanks)*

| Component | Type** | Quantity | Nominal Capacity*** Liter (Gal) per Tank |
|----------------------------------|-----------------------|-----------------|---|
| Equipment Drain Collection Tanks | Vertical, Cylindrical | 3 | 140,000 (36,988) |
| Equipment Drain Sample Tanks | Vertical, Cylindrical | 2 | 140,000 (36,988) |
| Floor Drain Collection Tanks | Vertical, Cylindrical | 2 | 130,000 (34,346) |
| Floor Drain Sample Tanks | Vertical, Cylindrical | 2 | 130,000 (34,346) |
| Chemical Drain Collection Tank | Vertical, Cylindrical | 1 | 4,000 (1,057) |
| Detergent Drain Collection Tanks | Vertical, Cylindrical | 2 | 15,000 (3,963) |
| Detergent Drain Sample Tanks | Vertical, Cylindrical | 2 | 15,000 (3,963) |

* Per RG 1.143, all materials are in accordance of ASME Section II.

** Per RG 1.143, tank design and fabrication are in accordance with ASME Section III, Class 3; API 620; API 650 or AWWA D-100, depending on design requirements.

*** Nominal capacity refers to the total tank capacity.

Table 11.2-2b
LWMS Component Capacity (Pumps)*

| Component | Type | Quantity | Nominal Capacity* Liters/Hour (gpm) |
|----------------------------------|-------------------------|-----------------|--|
| Equipment Drain Collection Pumps | Horizontal, Centrifugal | 3 | 60,000 (264) |
| Equipment Drain Sample Pumps | Horizontal, Centrifugal | 2 | 60,000 (264) |
| Floor Drain Collection Pumps | Horizontal, Centrifugal | 2 | 55,000 (242) |
| Floor Drain Sample Pumps | Horizontal, Centrifugal | 2 | 55,000 (242) |
| Chemical Drain Collection Pumps | Horizontal, Centrifugal | 2 | 6,000 (26.4) |
| Detergent Drain Collection Pumps | Horizontal, Centrifugal | 2 | 12,000 (52.8) |
| Detergent Drain Sample Pumps | Horizontal, Centrifugal | 2 | 12,000 (52.8) |

* Pump capacity refers to the minimum required capacity.

Table 11.2-2c
LWMS Component Capacity (Mobile Systems)

| Component* | Type | Quantity** | Nominal Cap. |
|--|---|------------|-------------------|
| Mobile Systems for Equipment Drain Processing Equipment Drain Pre-Filter Equipment Drain Filter Equipment Drain Ion Exchangers Equipment Drain Chemical Injection Unit Equipment Drain Intermediate Tank Equipment Drain Intermediate Pump | Charcoal Filter or others Hollow Fiber Filter Mixed Bed Type - Vertical, Cylindrical Horizontal, Centrifugal | 1 | 20,000L/h (88gpm) |
| Mobile Systems for Floor Drain Processing Floor Drain Pre-Filters Floor Drain Reverse Osmosis (RO) unit Floor Drain Ion Exchangers Floor Drain Intermediate Tank Floor Drain Intermediate Pump | Cartridge Type Reverse Osmosis (RO) Mixed Bed Type Vertical, Cylindrical Horizontal, Centrifugal | 1 | 15,000L/h (66gpm) |
| Mobile Systems for Chemical Drain Processing Chemical Drain Neutralization Unit | - | 1 | - |
| Mobile Systems for Detergent Drain Processing Detergent Drain Organic Pre-Treatment Detergent Drain Pre-Filter Detergent Drain Charcoal Filter | Charcoal or others Cartridge Type Charcoal Filter | 1 | 2,000L/h (8.8gpm) |

* Typical components are shown for each mobile system.

** This column shows mobile system quantity for each subsystem, not each component quantity.

Table 11.2-3
Decontamination Factors

| Subsystems* | Filter | Reverse Osmosis | Ion-Exchanger | Total DF |
|---|---------------|------------------------|----------------------|-----------------|
| Equipment (low conductivity) | | | | |
| Drain Subsystem: | | | | |
| Halogens | 1 | - | 100 (10)** | 1,000 |
| Cs, Rb | 1 | - | 10 (10)** | 100 |
| Other nuclides | 1 | - | 100 (10)** | 1,000 |
| Floor (high conductivity) | | | | |
| Drain Subsystem: | | | | |
| Halogens | 1 | 10 | 100 (10)** | 10,000 |
| Cs, Rb | 1 | 10 | 2 (10)** | 200 |
| Other nuclides | 1 | 10 | 100 (10)** | 10,000 |
| A DF of 1 is used for tritium. | | | | |
| Chemical Drain Subsystem: | | | | |
| Chemical drain is processed in Floor Drain Subsystem. | | | | |
| Detergent Drain Subsystem: | | | | |
| A DF of 1 is used for the detergent drain filter for all radionuclides. | | | | |

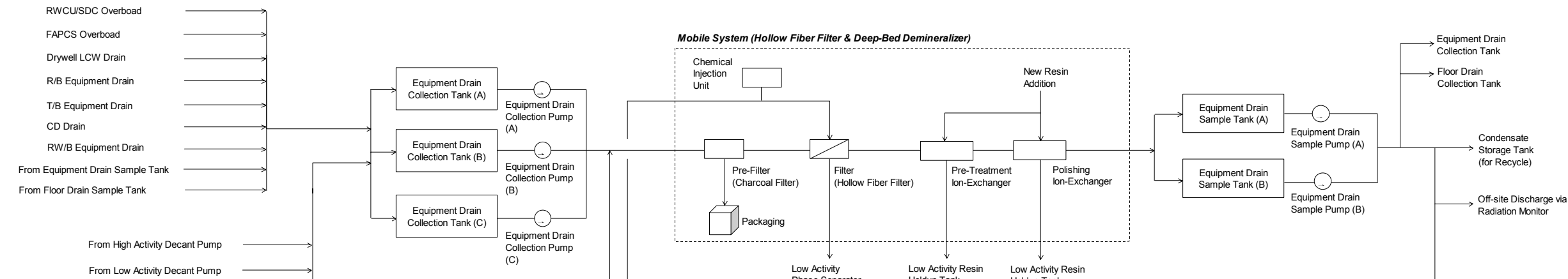
* From NUREG-0016 Revision 1, Table 1-5.

** For two ion exchangers in series, the DF for the second unit is given in parenthesis

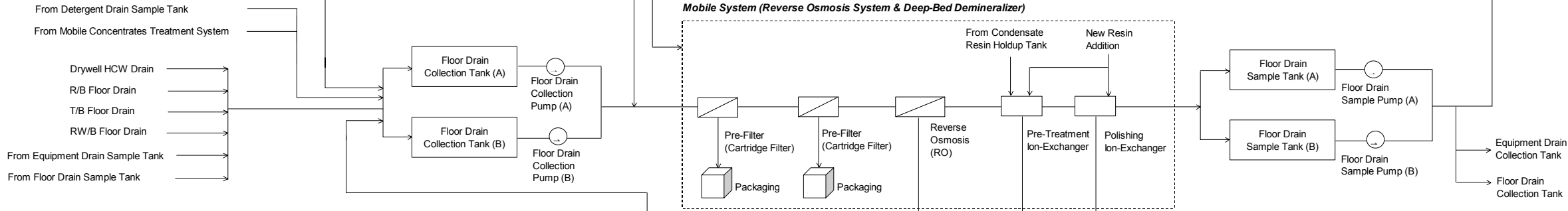
Table 11.2-4
Probable Inputs to LWMS from Operational Occurrences

| Subsystem | Normal Liters/Day (Gal/Day) | Maximum Liters/Day (Gal/Day) | Time Needed to Process Maximum Input (Hr) |
|---|-----------------------------------|------------------------------------|---|
| Equipment (low conductivity) Drain Subsystem | 65,000 (17,173) | 125,000 (33,025) | 6.3 |
| Floor (high conductivity) Drain Subsystem | 11,000 (2,906) | 100,000 (26,420) | 6.7 |
| Chemical Drain Subsystem | 3,000 (793) | 3,000 (793) | 0.2 |
| Detergent Drain Subsystem | 4,000 (1,057) | 12,000 (3,170) | 6.0 |

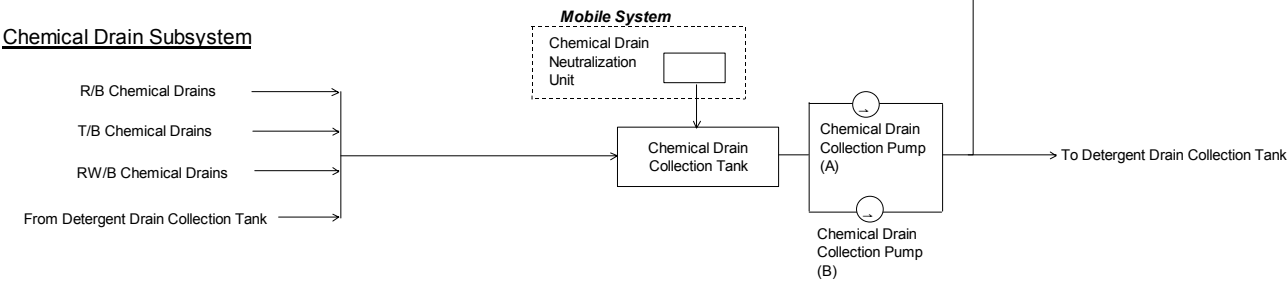
Equipment (Low Conductivity) Drain Subsystem



Floor (High Conductivity) Drain Subsystem



Chemical Drain Subsystem



Abbreviations:
RWCUSDC - Reactor Water Cleanup/Shutdown Cooling System
FAPCS - Fuel and Auxiliary Pools Cooling System
LCW - Low Conductivity Waste
HCW - High Conductivity Waste
CD - Condensate Demineralizer

Detergent Drain Subsystem

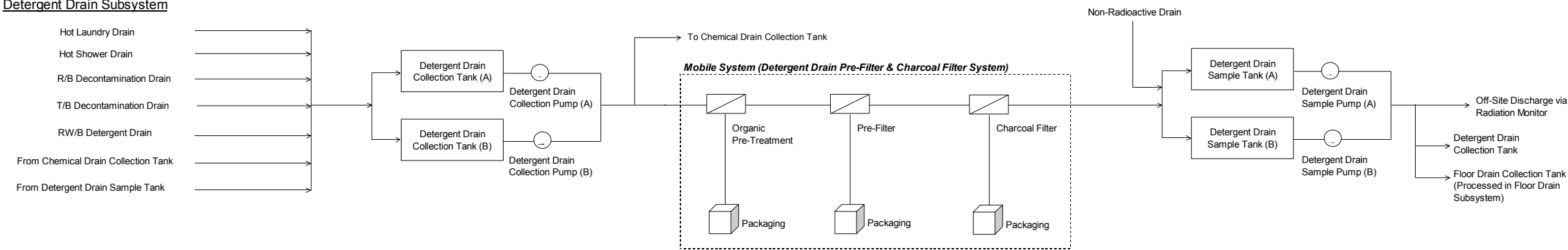


Figure 11.2-1. Liquid Waste Management System Process Diagram

11.3 GASEOUS WASTE MANAGEMENT SYSTEM

11.3.1 Design Bases

The objective of the gaseous waste management system is to process and control the release of gaseous radioactive effluents to the site environs so as to maintain the exposure of persons in unrestricted areas to radioactive gaseous effluents as low as reasonably achievable according to 10 CFR 50, Appendix I (Reference 11.3-1). This is accomplished while maintaining occupational exposure as low as reasonably achievable and without limiting plant operation or availability.

The two main sources of plant gaseous radioactive effluents are the building ventilation systems, which are discussed in Section 9.4, and the power cycle offgas system (Offgas System) that is described and reviewed in this section.

The Offgas System (OGS) provides for holdup, and thereby, decay of radioactive gases in the offgas from the main condenser evacuation system (Subsection 10.4.2) and consists of process equipment along with monitoring instrumentation and control components.

The OGS minimizes and controls the release of radioactive material into the atmosphere by delaying release of the offgas process stream initially containing radioactive isotopes of krypton, xenon, iodine, nitrogen, and oxygen. This delay, using activated charcoal absorber beds, is sufficient to achieve adequate decay before the process offgas stream becomes discharged from the plant.

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

The gaseous effluent treatment systems are designed to limit the dose to off-site persons from routine station releases to significantly less than the limits specified in 10 CFR 20 (Reference 11.3-2) and to operate within the relevant limits specified in the plant-specific Technical Specifications.

As a conservative design basis for the OGS, an average annual noble radiogas source term (based on 30 minute decay) is assumed. The OGS System Design Parameters are shown in Table 11.3-1. The system is mechanically capable of processing three times the source term without affecting delay time of the noble gases. Also listed is the isotopic distribution at $t = 0$. Table 11.3-5 shows the xenon time delays with an assumed air in-leakage.

Using the isotopic activities at the discharge of the OGS, the decontamination factor for each noble gas isotope can be determined. Section 11.1 presents source terms for normal operational and anticipated occurrence releases to the primary coolant. Tables in this section, if not designated otherwise, are based upon a design basis annual average offgas release rate (measured after 30 minutes decay from the core) of noble gases and I^{131} as shown in Table 11.3-1 and 12.2-15. For normal expected conditions, the leak rates and doses are expected to be less than one-fifth of the design basis numbers.

The average annual exposure at the site boundary during normal operation from all gaseous sources is not expected to exceed the dose objectives of 10 CFR 50, Appendix I, in terms of actual doses to actual persons (Refer to Section 12.2). The radiation dose design basis for the

treated offgas is to provide sufficient holdup until the required fraction of the radionuclides has decayed with the daughter products retained by the charcoal.

The gaseous waste management system equipment is selected, arranged, and shielded to maintain occupational exposure as low as reasonably achievable in accordance with Nuclear Regulatory Commission Regulatory Guide 8.8.

The gaseous waste management system is designed to the requirements of the General Design Criteria 60 and 64.

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

The OGS is also designed to the requirements indicated in DCD section 3.2.

11.3.2 Offgas System Description

Process Functions

Major process functions of the OGS include the following:

- recombination of radiolytic hydrogen and oxygen into water to reduce the gas volume to be treated and the explosion potential in downstream process components;
- two-stage condensation of bulk water vapor first using condensate and then chilled water as the coolant reducing the gaseous waste stream temperature to the value shown in Table 11.3-1;
- dynamic adsorption of krypton and xenon isotopes on charcoal at the approximate temperature shown in Table 11.3-1;
- monitoring of offgas radioactivity levels and hydrogen gas content;
- release of processed offgas to the atmosphere; and
- discharge of liquids to the condenser and Liquid Waste Management System.

Process Equipment

Major process equipment of the OGS consists of the following:

- recombiners, including a preheater section, a catalyst section, and a condenser section;
- cooler-condensers;
- dryers
- activated charcoal adsorbers;
- monitoring instrumentation; and
- process instrumentation and controls.

Process Facility

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

Power cycle condensate is used as the coolant for the offgas condensers. The pressure of condensate supplied to the offgas condenser should not exceed the design pressure of the condenser, and power cycle condensate isolation valves should be normally open to both recombiner condensers.

The gaseous waste stream is then cooled in the cooler condenser. Chilled water is provided at the temperature shown in Table 11.3-1. The cooler condenser is located immediately above the offgas condenser and is designed to allow the condensed moisture from the gaseous waste stream to drain back into the offgas condenser, from which it is sent to the main turbine condenser.

The gaseous waste stream is heated to the value shown in Table 11.3-1 by ambient heating in the charcoal vault.

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

Releases

The significant gaseous wastes discharged to the OGS during normal plant operation are radiolytic hydrogen and oxygen, power cycle injected gasses and air in-leakage, and radioactive isotopes of krypton, xenon, iodine, nitrogen, and oxygen. The radiation dose from gaseous discharge is primarily external rather than ingestion or inhalation. When releasing gases from the plant, the plume or cloud is the source of radiation to the ground. The maximum radiation corresponds to the zone of maximum ground concentration. This, in turn, is a function of wind velocity and direction, the presence of building obstructions in the wake and other meteorological conditions in the area. From the foregoing considerations, a release rate from the plant stack or vent can be established such that the maximum radiation dose to any area in the environs is not exceeded.

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

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

The criterion for release of gaseous wastes to the atmosphere, excluding accident sequences, is that maximum external radiation dosage to the environment be maintained below the maximum dose objectives of Appendix I to 10 CFR 50 in terms of actual doses to actual off-site persons. An instantaneous release rate, established by 10 CFR 20, of several times the annual average permissible release rate limit is permitted as long as the annual average is not exceeded. Every reasonable effort has been made to keep radiation exposures and release of radioactive materials “as low as reasonably achievable” (ALARA). The OGS discharge is routed to the plant stack.

11.3.2.1 Process Design

Primary design features are shown on the simplified offgas diagram (Figure 11.3-1).

The steam jet air ejectors (SJAE) are described in DCD Subsection 10.4.2

Preheating

Recombiner preheaters preheat gases to provide for efficient catalytic recombiner operation and to ensure the absence of liquid water that suppresses the activity of the recombiner catalyst. Maximum preheater temperature does not exceed the value shown in Table 11.3-1 should gas flow be reduced or stopped. This is accomplished by using extraction steam as shown in Figure 10.1-2 - Rated Heat Balance. During startup, steam at this pressure, is available before the process offgas is routed through the preheater section to the recombiner catalyst section. Electrical preheaters are not exposed directly to the offgas.. Each preheater section connects to an independent final stage air ejector to permit separate steam heating of both recombiners during startup or drying one recombiner while the other is in operation. For reliability, preheater steam is nuclear steam. The preheater is sized to handle a dilution steam load of 115% of rated flow in addition to allowing for 5% plugged tubes.

Hydrogen/Oxygen Recombination

Minimum performance criteria for the catalytic recombiners are as follows:

- In normal full power operation the hydrogen in the recombiner effluent does not exceed 0.1% by volume on a moisture-free basis, at the defined minimum air flow shown in Table 11.3-1.
- During startup or other reduced power operations (between 1 and 50% of reactor rated power), the hydrogen in the recombiner effluent does not exceed 1.0% by volume on a moisture free basis at the defined minimum air flow.
- An intentional air bleed equal to minimum air flow is introduced into the system upstream of the operating recombiner when the turbine condenser air in-leakage falls below the defined minimum air flow. The out-of-service recombiner catalyst is heated to the value shown in Table 11.3-1 by dilution steam injection and preheat steam before admitting process gas (containing hydrogen) to the recombiner. Three temperature sensing elements are provided in each catalyst bed and are located to measure the temperature profile from inlet to outlet.

Condensing

The offgas condensers cool the recombiner effluent gas to the maximum temperatures for normal operation and startup operation shown in Table 11.3-1. The condenser includes baffles to reduce moisture entrainment in the offgas. The unit is sized to handle a dilution steam load of 115% of rated flow, in addition to allowing for 5% plugged tubes. The drain line is capable of draining the entire process condensate, including the 15% excess plus 2.5 l/s (40 gpm), from the unit at both startup and normal operating conditions, taking into account the possibility of condensate flashing in the return line to the main condenser. The drain line also incorporates a flow element so that higher flows caused by tube leakage can be easily identified, and a passive loop seal with a block valve operable from the main control room. A gas sample tap is provided downstream of and near the offgas condensers to permit gas sampling.

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

Adsorption

The activated charcoal uses “arbitrary” adsorption coefficient K_{arb} values for krypton and xenon. Separate K_{arb} laboratory determinations of krypton and xenon are made for each manufacturer's lot unless the manufacturer can supply proof convincing to the purchaser that other lots of the same production run immediately adjacent to the lot tested are equivalent to the lot tested with respect to krypton and xenon adsorption. Other adsorption tests (e.g., dynamic coefficients) may be acceptable, provided their equivalence to K_{arb} tests for this purpose can be demonstrated. Charcoal particle size, moisture content and minimum charcoal ignition temperature in air are shown in Table 11.3-1.

Properties of activated charcoal used in the adsorber vessels are an optimization of the following:

- high adsorption for krypton and xenon;
- high physical stability;
- high surface area;
- low pressure drop;
- low moisture absorption;
- high ignition temperature; and
- dust-free structure.

The Kr and Xe holdup time is closely approximated by the following equation:

$$t = \frac{K_d M}{V} \quad (11.3-1)$$

where

- t = holdup time of a given gas
- K_d = dynamic adsorption coefficient for the given gas
- M = weight of charcoal
- V = flow rate of the carrier gas

in consistent units.

Dynamic adsorption coefficient values for xenon and krypton were reported by Browning (Reference 11.3-7). GE Nuclear Energy has performed pilot plant tests at the Vallecitos Laboratory and the results were reported at the 12th AEC Air Cleaning Conference (Reference 11.3-8).

Noble Gas Mixture

The fission product noble gas composition used as the nominal design basis is defined in Section 11.1. During normal operation with no fuel leaks, release rate of noble gases (after 30 minute decay) may occur because of minute quantities of uranium contamination. The system is also capable of safe mechanical operation at release rates that may occur in the event of gross fuel failures.

Air Supply

Carrier gas is the air leakage from the main condenser after the radiolytic hydrogen and oxygen are removed by the recombiner. The air in-leakage design basis is conservatively assumed to be the total value shown in Table 11.3-1.

An air bleed supply is provided for dilution of residual hydrogen at air in-leakages below the minimum value shown in Table 11.3-1, for valve stem sealing, for recombiner startup, for blocking during maintenance, for instrument operation, for providing an air flow through the standby recombiner when processing offgas, and for purging gas mixtures from process and instrument lines prior to maintenance. These normal air purge flow rates are not used while the system processes reactor offgas. The air is supplied from a compressor that does not use oil for lubrication of the compressor cylinder, as oil compromises the performance of the catalytic recombiners and charcoal adsorbers. During both startup and normal operation, air is bled to the standby recombiner train just downstream of the final SJAE suction valve for train purging after switchover. Flow indicators are provided on all air bleed lines to assure that proper air flow is being delivered to the process line or equipment. The air supply is protected from back flow of process gas by two check valves in series or by a check valve and a pressure control valve in series.

Range-ability

The process can accommodate reactor operation from 0 to 100% of full power. In normal operation, radiolytic gas production varies linearly with thermal power. The process can accommodate the airflow range shown in Table 11.3-1 for the full range of reactor power operation.

In addition, the process can mechanically accommodate a startup higher airflow upon initiation of the steam jet air ejectors. This startup airflow results from evacuation of the turbine condensing equipment while the reactor is in the range of about 3% to 7% of rated power.

Redundancy

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

Design provisions are incorporated which preclude the uncontrolled release of radioactivity to the environment as a result of any single equipment failure short of the equipment failure accident described in Subsection 11.3.7. An analysis of single equipment piece malfunctions is provided in Table 11.3-3.

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

- The system design minimizes ignition sources so that a hydrogen detonation is highly unlikely even in the event of a recombiner failure.
- The system pressure boundary is detonation-resistant in addition to the measure taken to avoid a possible detonation.

- All discharge paths to the environment are monitored. The normal effluent path is monitored by the Process Radiation Monitoring System and the equipment areas are monitored by the Area Radiation Monitoring System.
- Dilution steam flow to the steam jet air ejector is monitored and alarmed, and the valving is required to be such that loss of dilution steam cannot occur without coincident closure of the process gas suction valve(s) so that the process gas is sufficiently diluted if it is flowing at all.

Charcoal Adsorber Bypass

A piping and valving arrangement is provided, which allows isolation and bypass of the charcoal adsorber vessel most likely to catch fire or become wetted with water, while continuing to process the offgas flow through the remaining adsorber vessels. A nitrogen purge can be injected upstream of the vault entrance so that further combustion is prevented and the charcoal is cooled below its ignition temperature. Capability is provided to employ all or a portion of the charcoal adsorber vessels (either guard bed or charcoal beds) to treat the offgas flow during normal or off-standard process operating conditions. Capability is also provided to completely bypass all charcoal adsorber vessels during plant startup and/or when fuel performance allows.

The main purpose of this bypass is to protect the charcoal during preoperational and startup testing when gas activity is zero or very low and when moisture is most likely to enter the charcoal beds. The bypass valve arrangement is such that no single valve failure or valve misoperation would allow total charcoal bypass. The bypass mode of charcoal operation is not normal for power operation. However, it may be used if the resulting activity release is acceptable.

Valves

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

Nitrogen and Air Purge

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

11.3.2.2 Component Design

For portions of the system that may contain an explosive mixture, the design provides for ignition sources to be minimized and the system to be able to sustain an explosion without loss of integrity.

Calculation methods for translation of detonation pressures into wall thickness are summarized in the ANSI-55.4 (Reference 11.3-6). Equipment are designed and constructed in accordance with the requirements of Table 11.3-2.

Materials

Per Regulatory Guide 1.143, Regulatory Position 1.1.2, materials for pressure-retaining components of process systems¹ are selected from those covered by the material specifications listed in Section II, Part A of the ASME Boiler and Pressure Vessel Code, except that malleable, wrought or cast-iron materials, and plastic pipe are not allowed in this application. The components satisfy all of the mandatory requirements of the material specifications with regard to manufacture, examination, repair, testing, identification, and certification.

Pressure Relief

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

Equipment Room Ventilation Control

The equipment rooms are under negative ventilation control. The equipment in the equipment rooms is qualified for the environmental conditions it is expected to see.

Differential pressure between general areas and equipment cells is sufficient to maintain a flow of air from clean areas into potentially contaminated areas. In addition, the TBHV is capable of removing sufficient heat from the process piping, equipment, motors, and instrumentation so as to maintain the environmental temperatures as established. All equipment cell and charcoal vault ventilation air is discharged without passing through occupied areas to the Turbine Building compartment exhaust system and the plant vent stack, where effluent radiation monitoring is performed.

Leakage

The leakage criteria apply from the steam jet air ejector through the OGS, including all process equipment and piping in between as shown on Figure 11.3-1. Leakage from the process through purge or tap lines to external atmospheric pressure is sufficiently low so it is undetectable by “soap bubble” test. This requirement does not apply to in-line process valves.

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

Vents and Drains

Offgas System drains, depending on source, are routed to either the condenser hotwell or to the radwaste system. All piping is provided with high point vents and low point drains to permit system drainage following the hydrostatic test. A water drain is provided on the process lines

¹ “Process System” refers to that portion of the OGS that normally processes SJAE Offgas.

just upstream of the charcoal tanks. The process line to and from the charcoal adsorbers is sloped so that there are no intervening low spots to act as water traps.

Valves

No valves controlling the flow of process gas are located in the charcoal adsorber vault. For all valves exposed to process offgas, valve seats are designed to avoid sparks.

All valves exposed to process gas have bellows stem seals, double stem seals or equivalent.

Recombiners

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

Each recombiner is part of an integrated preheater-recombiner-condenser pressure vessel assembly. The preheater section uses nuclear quality steam to heat the offgas process stream gases to at least the minimum values shown in Table 11.3-1 before it reaches the catalyst in the recombiner section. The recombined hydrogen and oxygen, in the form of super-heated steam, which leaves the recombiner section, is then condensed (by power cycle condensate) to liquid water in the condenser section of the assembly, while the noncondensable gases are cooled to temperatures below the maximum value shown in Table 11.3-1. The condensed water in the condenser section is drained to a loop seal that is connected to the main condenser hotwell. Condensed preheater section steam is drained to the above loop seal that is connected to the hotwell.

No flow paths exist whereby unrecombined offgas can bypass the recombiners .

Charcoal Adsorber Vessels

The charcoal adsorber vessels are to be cylindrical tanks installed vertically.

Channeling in the charcoal adsorbers is prevented by supplying an effective flow distributor on the inlet and by a high bed-to-particle diameter ratio. Temperature elements are installed along the charcoal adsorber vessels in sufficient quantity to monitor the temperature profile along the flow path during operation.

Charcoal Adsorber Vault

The temperature within the charcoal adsorber vault is maintained and controlled by appropriate connection(s) to the Turbine Building HVAC System. The decay heat is sufficiently small that, even in the no-flow condition, there is no significant loss of adsorbed noble gases because of temperature rise in the adsorbers.

The charcoal adsorber vault itself is designed for the temperature range shown in Table 11.3-1 because it may be necessary to heat a vessel or the vault to the maximum temperature (by the use of portable heaters) to facilitate drying the charcoal. A smoke detector is installed in the exhaust ventilation duct from the charcoal adsorber vault to detect and provide alarm to the operator as a charcoal fire within the vessel(s) usually results in the burning of the exterior paint surface.

Construction of Process Systems

Pressure-retaining components of process systems employ welded construction to the maximum practicable extent. Process piping systems include the first root valve on sample and instrument lines.

Moisture Separator

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

Maintenance Access

The system equipment is generally not accessible for maintenance during system operation. All equipment is accessible during the plant outages. The following are exceptions:

- The redundant offgas recombiner trains are located in separate rooms to allow maintenance access to the standby train when processing offgas in the operable train.
- Control valving and hydrogen analyzers are accessible for maintenance during the out-of-services portion of their cycle.
- Charcoal vault air conditioning and ventilation equipment are accessible for maintenance during plant operation.

The OGS is designed, constructed, and tested to be as leak tight as practicable.

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

- redundant components for all active, in-process equipment pieces located in separate shielded cells;
- no rotating equipment in the radioactive process stream;
- block valves with air bleed pressurization for maintenance which may be required during plant operation; and
- shielding of nonradioactive auxiliary subsystems from the radioactive process stream.

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

- extremely stringent leak rate requirements placed upon all equipment, piping and instruments and enforced by requiring as-installed helium leak tests of the entire process system;
- use of welded joints wherever practicable;
- specification of valve types with extremely low leak rate characteristics (i.e., bellows seal, double stem seal, or equal);
- routing of most drains through loop seals to the main condenser; and
- specification of stringent seat-leak characteristics for valves and lines discharging to the environment through other systems.

11.3.2.3 Seismic Design

Offgas System equipment and piping are classified Seismic Category NS.

11.3.3 Ventilation System

Radioactive gases are present in the power plant buildings as a result of process leakage and steam discharges. The process leakage is the source of the radioactive gases in the air discharged through the ventilation system. The design of the ventilation system is described in Section 9.4. The radiation activity levels from the ventilation systems are treated in Section 12.2. The ventilation flow rates are shown in Section 9.4.

11.3.4 Radioactive Releases

Refer to Subsection 12.2 for radioactive release information from the OGS.

11.3.5 Testing and Inspection Requirements

Because the gaseous radioactive waste system has no safety function, no inservice inspection of the components is required.

Preoperational and startup testing, which includes hydrostatic testing of system components and piping; helium leak testing; and verification of air ejector pressure and flow, preheater operation (recombiner inlet temperature), catalyst temperature, and offgas condenser operation; is accomplished as described within Section 14.2.

During normal operation, the hydrogen analyzers, process components, and monitoring instrument channels are periodically tested and calibrated to ensure that the explosive gas mixture is below the flammability limit and projected doses from gaseous effluent releases are kept as low as reasonably achievable and below regulatory limits.

11.3.6 Instrumentation Requirements

Control and monitoring of the OGS process equipment is performed both locally and remotely from the main control room. Generally, system control is from the main control room. Instrument components are installed wherever possible in accessible areas to facilitate operation and maintenance. Only instrument sensing elements are permitted behind shield walls.

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

The flow rate of the offgases is continuously monitored. This flow rate, in conjunction with activity concentrations as measured by the monitor downstream of the recombiners and the monitor downstream of the charcoal adsorbers, permits monitoring fission gases from the reactor, calculation of offgas discharge to the vent, and calculation of the charcoal adsorber system performance.

11.3.7 Radioactive OffGas System Leak or Failure

11.3.7.1 Basis and Assumptions

The radiological consequences for an Offgas System accident as specified in Standard Review Plan 11.3, Branch Technical Position ESTB 11-5 are presented. The branch technical position

assumptions were used except as detailed below to evaluate this accident. The accident parameters are shown in Table 11.3-4. The results are presented in Tables 11.3-6 and 11.3-7 and show the ESBWR design to be compliant with the requirements of the Branch Technical Position.

The system is designed to be both detonation and seismic resistant and meets all criteria of Regulatory Guide 1.143. As such, the failure of a single active component leading to a direct release of radioactive gases to the environment is highly unlikely. Therefore, inadvertent operator action with bypass of the delay charcoal beds is analyzed for compliance to ESTB 11-5. A top-level diagram of the ESBWR Offgas System can be found in Figure 11.3-1 that shows the ESBWR charcoal beds consist of ten charcoal tanks. The first and second, or guard tanks contain charcoal followed by a flow split into two lines, each line of which leads through four massive tanks, each containing charcoal. Bypass valves exist to direct flow around (1) one guard tank, (2) two series of follow-on tanks, or (3) one guard bed and the two series of follow-on tanks. To bypass either pathway (1) or (2) above requires the operator to enter a computer command with a required permissive. To bypass all tanks requires the operator to key in the command with two separate permissives. Because the bypass of all tanks would require both inadvertent operation upon the operator (keying in the wrong command) plus getting two specific permissives for three incorrect decisions, it is assumed not likely to occur. Downstream of the charcoal beds shown on Figure 11.3-1 are a series of two redundant radiation monitoring instruments and an air-operated isolation valve. Upon receiving a Hi signal, the system alarms the control room, where a Hi-Hi signal automatically initiates a "treat" mode, causing flow to process through the charcoal tanks, and override switch settings. Therefore, bypass of the charcoal beds during periods with significant radioactive flow through the Offgas System are limited and/or automatically terminated by actuation of the downstream sensors.

To evaluate the potential radiological consequences of an inadvertent bypass of the charcoal beds, it was assumed that operator error or computer error has led to the bypass of the eight follow-on beds in addition to the failure of the automated air-operated downstream isolation valve. It is also assumed that during this period, the plant is running at, and continues to run at, the maximum permissible offgas release rate based upon the assumption of 100 $\mu\text{Ci/sec/MWt}$ as stipulated in Standard Review Plan 11.3 evaluated to a decay time of 30 minutes from the vessel exit nozzle. Even with the failure of the downstream isolation valve, it is not anticipated or assumed that the isolation instrumentation would fail, but would instead alarm the control room with a high radiation alarm, causing the operator to manually isolate the Offgas System (i.e., close suction valves) within 1 hour of the alarm.

Therefore, this analysis differs from the branch technical position on the following points:

- There is no motive force to remove any significant inventory from the eight follow-on charcoal tanks while in bypass and, therefore, no activity from these tanks is included in the final release calculations.
- With redundant instrumentation, it is expected that operator intervention to either shut off the bypass or isolate the Offgas System is predicted to occur within 1 hour. Therefore, the total flow from the system is evaluated for 1 hour and not the 2-hour period stipulated in Branch Technical Position ESTB 11-5.

11.3.7.2 Results

The DBA evaluation assumptions are given in Table 11.3--4, the isotopic flows and releases in Table 11.3-5 and Table 11.3-6, and the meteorology and dose results in Table 11.3-7.

The dose results are given in Table 11.37 and are within the limiting 25 mSv (2.5 Rem) whole body dose for an infrequent event or the 5 mSv (0.5 Rem) frequent event limitation of Branch Technical Position ESTB 11-5.

11.3.8 COL Information

11.3.8.1 Offgas System Data

Offgas System design parameters, major equipment items as well as other system data, as shown in tables 11.3-2, are to be defined by the COL applicant.

11.3.9 References

- 11.3-1 Code of Federal Regulations 10 CFR 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions to Meet the 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water Cooled Nuclear Power Reactors."
- 11.3-2 Code of Federal Regulations 10 CFR 20, "Standards for Protection Against Radiation."
- 11.3-3 Nuclear Regulatory Commission (NRC), Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."
- 11.3-4 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII - Division 1.
- 11.3-5 American Institute of Steel Construction (AISC), Manual of Steel Construction
- 11.3-6 American National Standards Institute, "Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants," ANSI/ANS-55.4.
- 11.3-7 W.E. Browning, et al., "Removal of Fission Product Gases from Reactor Offgas Streams by Absorption," June 11, 1959, Oak Ridge National Laboratory (ORNL) CF59-6-47.
- 11.3-8 D.P. Seigwarth, "Measurement of Dynamic Absorption Coefficients for Noble Gases on Activated Carbon," Proceedings of the 12th AEC Air Cleaning Conference.
- 11.3-9 Dwight Underhill, et al., "Design of Fission Gas Holdup Systems, Proceedings of the Eleventh AEC Air Cleaning Conference," 1970, p. 217.
- 11.3-10 General Electric Co., "Radiological Accident Evaluation - The CONAC03 Code," NEDO-21143-1, December 1981.

Table 11.3-1
Offgas System Design Parameters*

| Design Parameter | Design Value |
|---|---|
| Design Basis annual average noble radiogas release rate | 3700 MBq/s (100,000 μ Ci/s) |
| Assumed air in-leakage | 51 m ³ /h (30 scfm) |
| Xenon delay | 60- day |
| Maximum gaseous waste stream temperature | 67 °C (153 °F) |
| Charcoal temperature (approximate) | 35 °C (95 °F) |
| Maximum cooler condenser temperature | 18 °C (65 °F) |
| Chilled water temperature | 7°C (45°F) |
| Gaseous waste stream temperature | 35 °C (95 °F) |
| Nominal recombiner preheater temperature | 177 °C (351 °F) |
| Maximum recombiner preheater temperature | 210 °C (410 °F) |
| Out-of-service hydrogen/oxygen catalytic recombiner minimum temperature | 121 °C (250°F) |
| Minimum activated charcoal ignition temperature | 156 °C (313 °F) |
| Minimum air bleed supply rate | 0.17 m ³ /min (6 scfm) |
| Air bleed to standby recombiner train at startup and normal operation | 0.17 m ³ /min (6 scfm) |
| Radiolytic gas flow range | 0 to 8.6 m ³ /min (302 scfm) |
| Charcoal adsorber vault temperature range | 29 °C (84 °F) to 40 °C (104 °F) |
| Charcoal particle size | 8 – 16 mesh (USS) with less than 0.5% under 20 mesh |
| Charcoal moisture content | < 5% by weight |
| Major offgas activity maximum permissible concentration (MPC) | 5.9E+6 Bq/cm ³ |

* For additional information on radioactive releases, refer to Subsection 11.1 or 12.2.

Table 11.3-2
Offgas System Major Equipment Items

| | |
|--|-------------------------------|
| Recombiner (Item D005, 2 required, contains preheater, catalyst, and condenser sections) ** | |
| Carbon steel shell | |
| Design pressure: | 2.41 MPa gauge (350 psig) |
| Design temperature: | 232 °C(450 °F) |
| Code of construction: | ASME Section VIII, Division 1 |
| Preheater Section | Shell and tube heat exchanger |
| Tubes: | stainless steel |
| Tube-side design temperature: | 302 °C(575 °F) |
| Tube-side design pressure: | 8.6 MPa gauge (1250 psig) |
| Design temperature: | 232 °C (450 °F) |
| Catalyst section | |
| Catalyst support: | stainless steel |
| Design temperature: | 482 °C (900 °F) |
| Catalyst: | precious metal on metal base |
| Offgas condenser section | Shell and tube heat exchanger |
| Tubes: | stainless steel |
| Tube-side design pressure: | 2.41 MPa gauge (350 psig) |
| Design temperature: | 482 °C (900 °F) |
| Cooler Condenser (Item B010, 2 required)** | |
| Shell and tube heat exchanger, carbon steel vessel | |
| Shell-side design pressure: | 2.41 MPa gauge (350 psig) |
| Shell-side design temperature: | 121 °C (250 °F) |
| Tubes: | stainless steel |
| Tube-side design pressure: | 1 MPa gauge (145 psig) |
| Code of construction: | TEMA Class C |
| Charcoal Adsorbers (Items D012A and D012B-J) | |
| Carbon steel vessels filled with activated charcoal | |
| Design pressure: | 2.41 MPa gauge (350 psig) |
| Design temperature: | 121 °C (250 °F) |
| Code of construction: | ASME Section VIII, Division 1 |

** Potential variation in parameters may be considered in COL phase (see subsection 11.3.8.1 for COL Information).

Table 11.3-3
Equipment Malfunction Analysis

| Equipment Item | Malfunction | Result(s) | Design Precautions |
|------------------------|--|--|--|
| Steam jet air ejectors | Low flow of motive high pressure steam | If the hydrogen and oxygen concentrations exceed 4 vol %, the recombiner's temperature rise is excessive. | Automatic system isolation on low steam flow. |
| | | Inadequate steam flow causes overheating and may result in exceeding the design temperature of the recombiner vessel. | Steam flow to be held at constant maximum flow regardless of plant power level. |
| | Wear of steam supply nozzle of ejector | Increased steam flow to recombiner could reduce degree of recombination at low power levels. High discharge temperature from recombiner condenser could result because of inadequate condenser capacity. | Temperature alarms on preheater exit (catalyst inlet). Downstream H ₂ analyzer alarms. High temperature alarms on exit from recombiner. |
| Recombiner preheater | Steam leak | Steam consumption would increase. | Spare recombiner train. |
| | Low-pressure steam supply | Recombiner performance could fall off at low-power level, and hydrogen content of recombiner gas discharge could increase eventually to a combustible mixture. | Low temperature alarms on preheater exit (catalyst inlet). Downstream H ₂ analyzer alarm. |
| Recombiner catalyst | Catalyst gradually deactivates | Temperature profile changes through catalyst. Eventually excess H ₂ would be detected by H ₂ analyzer or by offgas flowmeter. Eventually the gas could become combustible. | Temperature probes in catalyst bed and H ₂ analyzer provided. Spare recombiner train. |
| | Catalyst gets wet at start | H ₂ -O ₂ recombination fails. Eventually the gas downstream of the recombiner could become combustible. | Condensate drains, temperature probes in recombiner. Air bleed system at startup. Spare recombiner. Hydrogen analyzer. |

Table 11.3-3
Equipment Malfunction Analysis

| Equipment Item | Malfunction | Result(s) | Design Precautions |
|--|--------------------------------|--|--|
| Recombiner condenser | Cooling water leak | The coolant (reactor condensate) would leak to the process gas (shell) side. This would be detected by drain flow increase. Moderate leakage would be of no concern from a process standpoint. (The process condensate drains to the hotwell.) | Drain high flow alarm. Redundant recombiner. |
| Cooler condenser | Corrosion of tubes | Water would leak into process (shell) side and be sent to main condenser hotwell. | Stainless-steel tubes specified. Conductivity cell in condenser drain. |
| Moisture separator in cooler condenser | Corrosion of wire mesh element | Increased moisture would be retained in process gas routed to charcoal over a long period. | Stainless steel mesh specified. Spare cooler condenser provided. Levels in pre-charcoal drain. |
| Charcoal adsorbers | Charcoal gets wet | Charcoal performance deteriorates gradually as moisture deposits. Holdup times for krypton and xenon would decrease, and plant emissions would increase. Provisions made for drying charcoal as required during annual outage. | High instrumented, mechanically simple gas dehumidification system. |
| System | Internal detonation | Release of radioactivity if pressure boundary fails | Main process equipment and piping are designed to contain a detonation. |
| | | Internal damage to the recombiner and its heat exchanger | Redundant recombiner, damaged internals can be repaired. |
| | | Damage to instrumentation sensors | Redundant, damaged sensors can be replaced. |
| System | Earthquake damage | Release of radioactivity | Dose consequences are within the design guidance of BTP ETSB 11-5. |

Table 11.3-4
Offgas System Failure Accident Parameters

| | |
|---|--|
| I. Data and Assumptions Used to Estimate Source Terms | |
| a. Power Level | 4,500 MWt |
| b. Offgas Release Rate | 1.67E+4 MBq/s ¹ (4.5E+5 µCi/s) |
| c. Duration of Release | 1h |
| II. Dispersion and Dose Data | |
| a. Meteorology | Table 11.3-7 |
| b. Dose Methodology | Reference 11.3-10 |
| c. Dose Conversion Assumptions | Reference 11.3-10, RG 1.109 |
| d. Activity Releases | Table 11.3-6 |
| e. Dose Evaluations | Table 11.3-7 |

¹Isotopic rates refer to a 30-minute decay time.

Table 11.3-5
Isotopic Source Rates for Design Basis*

| Isotope | t=0 | | t=30 min | |
|----------|---------|---------|----------|---------|
| | MBq/s | Ci/s | MBq/s | Ci/s |
| Kr-83m | 1.30E+2 | 3.53E-3 | 1.08E+2 | 2.93E-3 |
| Kr-85m | 2.22E+2 | 5.99E-3 | 2.05E+2 | 5.54E-3 |
| Kr-85 | 8.88E-1 | 2.40E-5 | 8.88E-1 | 2.40E-5 |
| Kr-87 | 7.30E+2 | 1.97E-2 | 5.55E+2 | 1.50E-2 |
| Kr-88 | 7.33E+2 | 1.98E-2 | 6.48E+2 | 1.75E-2 |
| Kr-89 | 4.43E+3 | 1.20E-1 | 6.44E+0 | 1.74E-4 |
| Total Kr | | | | 4.12E-2 |
| Xe-131m | 7.30E-1 | 1.97E-5 | 7.29E-1 | 1.97E-5 |
| Xe-133m | 1.09E+1 | 2.94E-4 | 1.08E+1 | 2.92E-4 |
| Xe-133 | 3.10E+2 | 8.38E-3 | 3.09E+2 | 8.36E-3 |
| Xe-135m | 9.42E+2 | 2.55E-2 | 2.50E+2 | 6.77E-3 |
| Xe-135 | 8.42E+2 | 2.27E-2 | 8.10E+2 | 2.19E-2 |
| Xe-137 | 5.89E+3 | 1.59E-1 | 2.56E+1 | 6.93E-4 |
| Xe-138 | 3.33E+3 | 8.99E-2 | 7.70E+2 | 2.08E-2 |
| Total Xe | | | | 5.88E-2 |
| Kr+Xe | | | | 1.00E-1 |

* Only the major isotopic constituents are identified.

Table 11.3-6
Releases to the Environment

| Isotope | Release Rate | | Releases | |
|----------|--------------|---------|----------|---------|
| | MBq/s | Ci/s | MBq | Ci |
| Kr-83m | 4.88E+2 | 1.32E-2 | 1.76E+6 | 4.74E+1 |
| Kr-85m | 9.22E+2 | 2.49E-2 | 3.32E+6 | 8.98E+1 |
| Kr-85 | 4.00E 0 | 1.08E-4 | 1.44E+4 | 3.88E-1 |
| Kr-87 | 2.50E+3 | 6.75E-2 | 9.60E+6 | 2.42E+2 |
| Kr-88 | 2.91E+3 | 7.87E-2 | 1.05E+7 | 2.84E+2 |
| Kr-89 | 2.90E+1 | 7.83E-4 | 1.04E+5 | 2.82E 0 |
| Total Kr | 6.85E+3 | 1.85E-1 | 2.46E+7 | 6.66E+2 |
| | | | | |
| Xe-131m | 3.28E 0 | 8.86E-5 | 1.18E+4 | 3.20E-1 |
| Xe-133m | 4.86E+1 | 1.31E-3 | 1.75E+5 | 4.74E 0 |
| Xe-133 | 1.39E+3 | 3.76E-2 | 5.02E+6 | 1.35E+1 |
| Xe-135m | 1.13E+3 | 3.05E-2 | 4.06E+6 | 1.10E+2 |
| Xe-135 | 3.65E+3 | 9.85E-2 | 1.31E+7 | 3.54E+2 |
| Xe-137 | 1.15E+2 | 3.12E-3 | 4.16E+5 | 1.12E+1 |
| Xe-138 | 3.46E+3 | 9.36E-2 | 1.25E+7 | 3.36E+2 |
| Total Xe | 9.80E+3 | 2.65E-1 | 3.52E+7 | 9.54E+2 |
| Kr+Xe | 1.67E+4 | 4.50E-1 | 6.00E+7 | 1.62E+3 |

Table 11.3-7
Offgas System Failure Meteorology and Dose Results

| Meteorology | Whole Body Dose |
|--------------------------|------------------------|
| 1.0 E-3 s/m ³ | 3.1 E-3 Sv |

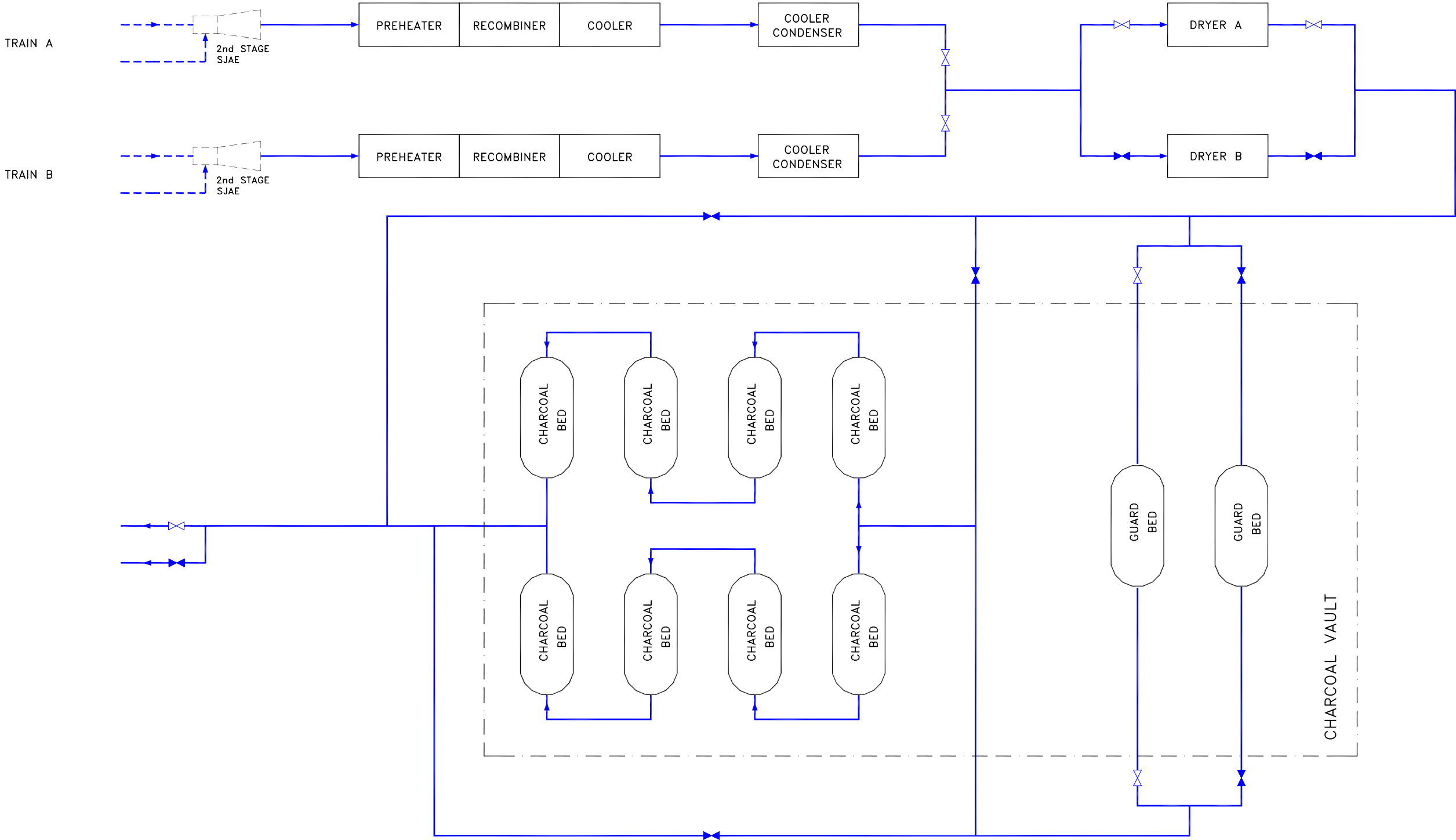


Figure 11.3-1. Offgas System

11.4 SOLID WASTE MANAGEMENT SYSTEM

The Solid Waste Management System (SWMS) is designed to control, collect, handle, process, package, and temporarily store wet and dry solid radioactive waste prior to shipment. This waste is generated as a result of normal operation and anticipated operational occurrences.

The SWMS is located in the radwaste building. It consists of the following four subsystems:

- wet solid waste collection subsystem;
- mobile wet solid waste processing subsystem;
- dry solid waste accumulation and conditioning subsystem;
- container storage subsystem;

The SWMS Process Diagram depicting all four subsystems is provided in Figure 11.4-1. A conceptual radwaste building general arrangement drawing is provided in Figures 1.2-21 thru 1.2-25. The SWMS component capacities are provided in Table 11.4-1. The estimated annual shipped waste volumes generated from the SWMS subsystems are provided in Table 11.4-2. The SWMS has the capability to process wastes at rates higher than shown in Table 11.4-2. The isotopic inventory of the as-shipped waste is provided by waste type in Chapter 12.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.4.1 Design Bases

Safety Design Bases

The SWMS has no safety-related function.

Power Generation Design Bases

The SWMS is designed to provide collection, processing, packaging, and storage of bead resin, filter backwash, and dry solid waste resulting from normal operations.

- The SWMS is designed to meet the requirements of Regulatory Guide 1.143.
- The SWMS is designed to keep the exposure to plant personnel “as low as reasonably achievable” (ALARA) during normal operation and plant maintenance, in accordance with Regulatory Guide 8.8.
- The SWMS is designed to package solid waste in DOT-approved containers for off-site shipment and burial.
- The SWMS is designed to prevent the release of significant quantities of radioactive materials to the environment so as to keep the overall exposure to the public well within 10 CFR 20 limits and in accordance with the limits specified in 10 CFR 50.
- The SWMS is designed to package the wet and dry types of radioactive solid waste for off-site shipment and burial, in accordance with the requirements of applicable NRC and DOT regulations, including 10 CFR 61, 10 CFR 71 and 49 CFR 170 through 178. This results in radiation exposures to individuals and the general population well within the limits of 10 CFR 20 and 10 CFR 50.

- The seismic and quality group classification and corresponding codes and standards that apply to the design of the SWMS components and piping, and the structures housing the SWMS are discussed in Section 3.2.
- On-site storage space for 6-month's volume of packaged waste is provided in the radwaste building.
- All atmospheric collection and storage tanks are provided with an overflow connection at least the size of the largest inlet connection. The overflow is connected below the tank vent and above the high level alarm setpoint. Each tank room is designed to contain the maximum liquid inventory in the event that the tank ruptures.

Process and effluent radiological monitoring systems are described in Section 11.5.

11.4.2 System Description

11.4.2.1 Summary Description

The SWMS controls, collects, handles, processes, packages, and temporarily stores solid waste generated by the plant prior to shipping the waste offsite. The SWMS processes the filter backwash sludges and bead resins generated by the Liquid Waste Management System (LWMS), Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDC), Fuel and Auxiliary Pools Cooling System (FAPCS) and the Condensate Purification System. Contaminated solids such as high efficiency particulate air (HEPA) and cartridge filters, rags, plastic, paper, clothing, tools, and equipment are also disposed of in the SWMS.

The SWMS is capable of receiving, processing, dewatering the solid radioactive waste inputs for permanent off-site disposal. There is no liquid plant discharge from the SWMS.

11.4.2.2 System Operation

The SWMS consists of four process subsystems:

Wet Solid Waste Collection Subsystem

The wet solid waste collection subsystem collects the spent bead resin slurry, filter and tank sludge slurry and concentrated waste into the one of the five tanks in accordance with the waste characteristics.

Spent bead resin sluiced from the RWCU, FAPCS, Condensate Purification System and LWMS are transferred to three spent resin tanks for radioactive decay and storage. Spent resin tanks are categorized as follows:

- High Activity Resin Holdup Tank for receiving RWCU and FAPCS spent bead resin,
- Low Activity Resin Holdup Tank for receiving LWMS spent bead resin,
- Condensate Resin Holdup Tank for receiving Condensate Purification System spent bead resin.

The capability exists to keep the higher activity resins, the lower activity resins and condensate resins in separate tanks. Excess water from a holdup tank is sent to the equipment drain collection tank or floor drain collection tank by a decant pump.

When sufficient bead resins have been collected in the high/low activity resin holdup tank, they are mixed via the high/low activity resin circulation pump and sent to the mobile wet solid waste processing subsystem via the high/low activity resin transfer pump. When sufficient bead resins have been collected in the condensate resin holdup tank, they are mixed via the condensate resin circulation pump and sent to the LWMS pre-treatment ion-exchanger for reuse or the mobile wet solid waste processing subsystem via the condensate resin transfer pump.

Two Low Activity Phase Separators receive suspended solid slurries from the Condensate Purification System, mobile filtration system of the LWMS and high integrity containers (HIC) effluent. The suspended solids are allowed to settle and the residual water is transferred by the low activity decant pump to the equipment drain collection tanks or floor drain collection tanks for further processing. When sufficient sludges have been collected in the tank, the sludges are mixed by the low activity resin circulation pump and sent to the mobile wet solid waste processing subsystem by the low activity resin transfer pump.

During transfer operations of the spent bead resins and the sludges, the suspended solids are kept suspended by a circulation pump to prevent them from agglomerating and possibly clogging lines.

One Concentrated Waste Tank receives concentrated waste from the mobile reverse osmosis system of the LWMS. When sufficient concentrated waste has been collected in the tank, the concentrated waste is sent to the mobile wet waste processing subsystem by a mixing/transfer pump.

Mobile Wet Solid Waste Processing Subsystem

The mobile wet solid waste processing subsystem consists of a dewatering station for high activity spent resin, a dewatering station for low activity spent resin and sludge and a dewatering station (or dryer) for concentrated waste. An empty HIC is lifted off of a transport trailer and placed in each empty dewatering station. The tractor/trailer may then be released. The HIC closure lid is removed and placed in a laydown area. Spent cartridge filters may be placed in the HIC at this point, if not shipped in separate containers.

Next, the fill head is positioned over the HIC using a crane. The fill head includes a closed circuit television camera for remote viewing of the fill operation. The HIC is then filled with each kind of wet solid waste. The capability to obtain samples during the fill operation is provided.

Excess water is removed from the HIC and sent by a resin pump to the high activity resin holdup tank or a low activity phase separator that is in the receiving mode by a resin pump. Sufficient water is removed to ensure there is very little or no free standing water left in the HIC. Drying of the HIC contents may also be performed with heated air.

The fill head is then removed and placed in a laydown area. The closure head is then placed on the HIC. The HIC is vented just prior to being shipped off-site for disposal to ensure that pressure is not building up. Radiation shielding is provided around the HIC stations.

The estimated annual shipped waste volumes from processing wet solid wastes are presented in Table 11.4-2.

Dry Solid Waste Accumulation and Conditioning Subsystem

Dry solid wastes consist of air filters, miscellaneous paper, rags, etc., from contaminated areas; contaminated clothing, tools, and equipment parts that cannot be effectively decontaminated; and solid laboratory wastes. The activity of much of this waste is low enough to permit handling by contact. These wastes are collected in containers located in appropriate areas throughout the plant, as dictated by the volume of wastes generated during operation and maintenance. The filled containers are sealed and moved to controlled-access enclosed areas for temporary storage.

Most dry waste is expected to be sufficiently low in activity to permit temporary storage in unshielded, cordoned-off areas. Dry active waste will be sorted and packaged in a suitably sized container that meets DOT requirements for shipment to either an off-site processor or for ultimate disposal. The dry active waste is separated into three categories: non-contaminated wastes (clean), contaminated metal wastes, and the other wastes, i.e., clothing, plastics, HEPA filters, components, etc.

In some cases, large pieces of miscellaneous waste are packed into larger boxes. Because of its low activity, this waste can be stored until enough is accumulated to permit economical transportation to an off-site burial ground for final disposal.

The capability exists to bring a shipping container into the truck bay during periods of peak waste generation. Bagged dry active waste can be directly loaded into the shipping container for burial or processing in off-site facilities. A truck scale is provided to ensure optimum shipping/disposal weight of the shipping container.

Cartridge filters that are not placed in HICs are placed in suitability-sized containers meeting DOT requirements.

The estimated shipped waste volumes from processing dry active wastes are presented in Table 11.4-2.

Container Storage Subsystem

On-site storage space for 6-months volume of packaged waste is provided. Packaged waste includes HICs, shielded filter containers and 55-gallon (200-liter) drums as necessary.

11.4.2.3 Detailed System Component Description

The major components of the SWMS are as follows:

Pumps

Two types of pumps are utilized in the SWMS.

The SWMS process pumps are centrifugal pumps constructed of materials suitable for the intended service.

Air-operated, double-diaphragm type pumps are utilized in dewatering stations.

Tanks

Tanks are sized to accommodate a sufficient volume of waste sludges or bead resin to fill a HIC. The SWMS tanks are sized for normal plant waste volumes with sufficient excess capacity to accommodate equipment downtime and expected maximum volumes that may occur. The tanks are constructed of stainless steel to provide a low corrosion rate during normal operation. They

are provided with mixing eductors and/or air spargers. The capability exists to sample all SWMS tanks. All SWMS tanks are vented through a filtration unit and the exhausted air is eventually discharged into the plant vent. The SWMS tanks are designed in accordance with ASME Section III, Class 3; API 620; API 650 or AWWA D-100.

The vent and overflow nozzles of the spent resin tank are equipped with fine mesh screens to minimize spread of particulate contamination to the radwaste tank vent system.

Piping

Piping used for hydraulic transport of slurries such as ion exchange resins, filter backwash (sludge), and waste tank sludge are specifically designed to assure trouble-free operation. Pipe flow velocities are sufficient to maintain a flow regime appropriate to the slurry being transported (ion exchange resins, filter backwash, or tank sludge). An adequate water/solids ratio is maintained throughout the transfer. Slurry piping is provided with automatic flushing with a sufficient water volume to flush the pipe clean after each use, e.g., at least two pipe volumes.

11.4.3 Safety Evaluation

The SWMS has no safety-related function. There is no liquid plant discharge from the SWMS. Failure of the subsystem does not compromise any safety-related system or component nor does it prevent shutdown of the plant. No interface with the Class 1E electrical system exists.

11.4.4 Testing and Inspection Requirements

The SWMS is given a pre-operational test as discussed in Chapter 14. Thereafter, portions of the subsystems are tested as needed.

During initial testing of the system, the pumps and the other equipment will be performance tested to demonstrate conformance with design flows and process capabilities. An integrity test is performed on the system upon completion.

Provisions are made for periodic inspection of major components to ensure capability and integrity of the subsystems.

11.4.5 Instrumentation Requirements

The SWMS is operated and monitored from the radwaste control room or local operating stations within the facility. Major system parameters, i.e., tank levels, process flow rates, etc., are indicated (recorded and alarmed as required) to provide operational information and performance assessment. Key system alarms are repeated in the main control room.

11.4.6 COL Information

None.

11.4.7 References

None.

Table 11.4-1
SWMS Component Capacities

| Equipment Description | Type | Quantity | Nominal Capacity* Liter (Gal) |
|--------------------------------------|-------------------------|----------|----------------------------------|
| Tanks | | | |
| High Activity Resin Holdup Tank | Vertical, Cylindrical | 1 | 70,000 (18,494) |
| Low Activity Resin Holdup Tank | Vertical, Cylindrical | 1 | 70,000 (18,494) |
| Condensate Resin Holdup Tank | Vertical, Cylindrical | 1 | 70,000 (18,494) |
| Low Activity Phase Separator | Vertical, Cylindrical | 2 | 55,000 (14,531) |
| Concentrated Waste Tank | Vertical, Cylindrical | 1 | 60,000 (15,852) |
| Pumps | | | |
| High Activity Decant Pump | Horizontal, Centrifugal | 2 | 333L/min (88gpm) |
| Low Activity Decant Pump | Horizontal, Centrifugal | 2 | 333L/min (88gpm) |
| High Activity Resin Circulation Pump | Horizontal, Centrifugal | 2 | 3,330L/min (881gpm) |
| Low Activity Resin Circulation Pump | Horizontal, Centrifugal | 1 | 3,330L/min (881gpm) |
| Condensate Resin Circulation Pump | Horizontal, Centrifugal | 1 | 3,330L/min (881gpm) |
| High Activity Resin Transfer Pump | Horizontal, Centrifugal | 2 | 379L/min (100gpm) |
| Low Activity Resin Transfer Pump | Horizontal, Centrifugal | 1 | 379L/min (100gpm) |
| Condensate Resin Transfer Pump | Horizontal, Centrifugal | 1 | 379L/min (100gpm) |
| Concentrated Waste Pump | Horizontal, Centrifugal | 2 | 1,333L/min (352gpm) |
| Mobile Process Equipment | | | |
| Dewatering Equipment Fill Head | N/A | 3 | - |
| HIC Return Pump | Diaphragm | 3 | 379L/min (100gpm) |
| Dryer (optional) | Drum Dryer | 1 | |
| Sorting Table | N/A | 1 | N/A |

* For tanks, nominal capacity refers to the total tank capacity. Nominal capacity for pumps is in liters/min (gallons/min)

Table 11.4-2
Annual Shipped Waste Volumes

| Waste Type | Estimated Annual Waste Generation m ³ /yr (ft ³ /yr) | Estimated Shipped Volume* m ³ /yr (ft ³ /yr) |
|---|--|--|
| Dry Active Solids (DAW): | | |
| Combustible waste: | 225 (7,951) | 225 (7,951) |
| Compactable waste: | 38 (1,343) | 38 (1,343) |
| Other waste: | 100 (3,534) | 100 (3,534) |
| DAW Total | 363 (12,827) | 363 (12,827) |
| Wet Solid Wastes: | | |
| RWCU Spent Bead Resin: | 7.6 (269) | 7.6 (269) |
| FAPCS Spent Bead Resin: | 8.0 (283) | 8.0 (283) |
| Condensate Purification System Spent Bead Resin: | 33.8 (1,194) | 33.8 (1,194) |
| LWMS Spent Bead Resin: | 5.4 (191) | 5.4 (191) |
| Condensate Purification System Filter Sludge: | 5.2 (184) | 5.2 (184) |
| LWMS Filter Sludge: | 0.8 (28.3) | 0.8 (28.3) |
| LWMS Concentrated Waste: | 50 (1,767) | 25 (883) |
| Wet Solid Waste Total | 111 (3,922) | 85.8 (3,032) |

* Note the goal value is a long term average of resins and sludges in the dewatered condition and all other wastes packaged for shipment. The values for resins and sludges in the above table are volumes packaged for shipment.

Wet Solid Waste Collection Subsystem

Mobile Wet Solid Waste Processing Subsystem

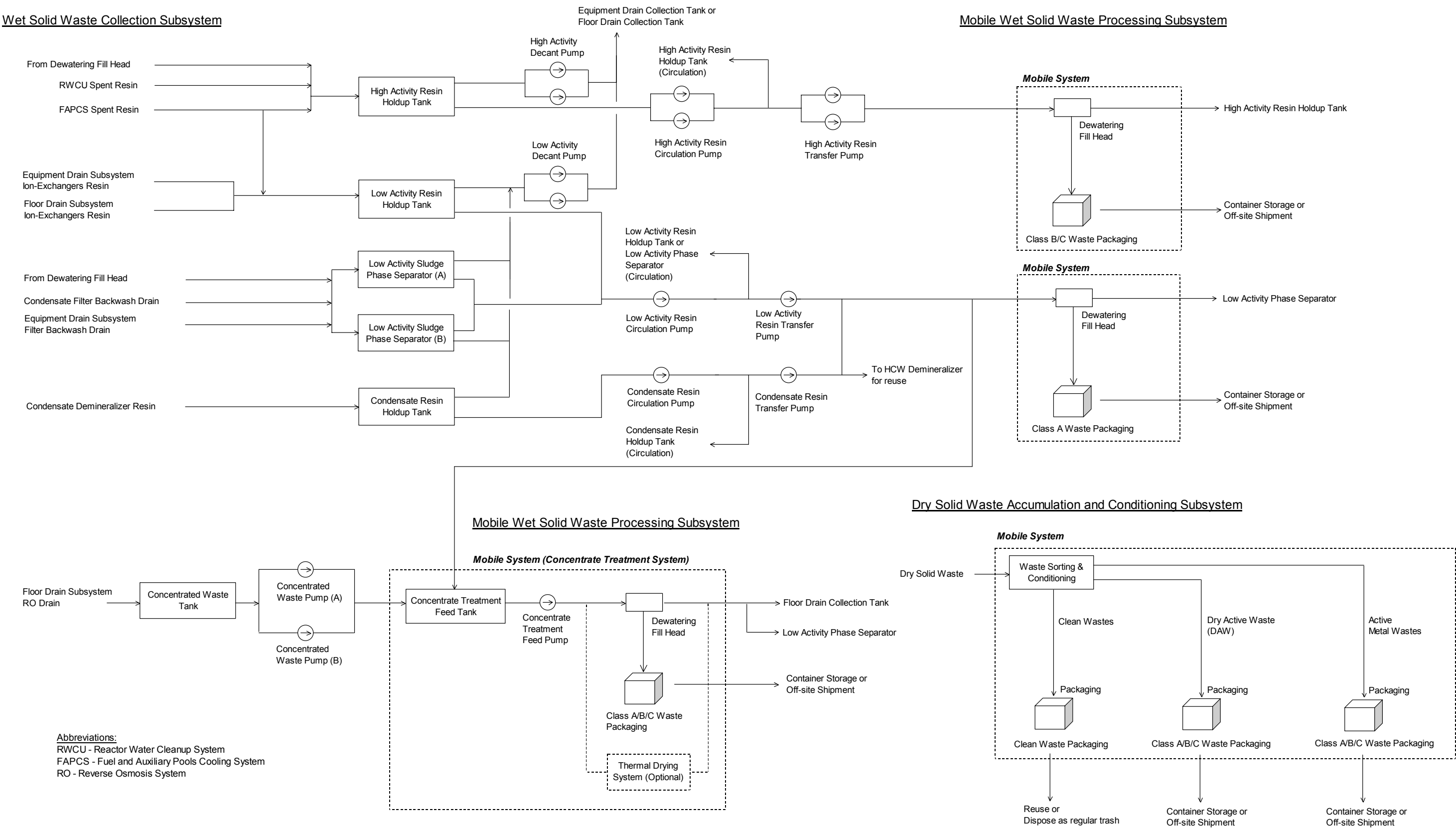


Figure 11.4-1. Solid Waste Management System Process Diagram

11.5 PROCESS RADIATION MONITORING SYSTEM

The Process Radiation Monitoring System (PRMS) is provided to allow determination of the content of radioactive material in various gaseous and liquid process and effluent streams. The design objective and criteria are based on the following requirements:

- Radiation instrumentation required for safety and protection.
- Radiation instrumentation required for monitoring and plant operation.

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

This system provides continuous monitoring and display of the radiation measurements during normal, abnormal, and accident conditions.

11.5.1 Design Bases

11.5.1.1 Design Objectives

11.5.1.1.1 Radiation Monitors Required for Safety and Protection

The main purpose of these radiation monitoring subsystems is to initiate appropriate protective action to limit the potential release of radioactive materials to the environment if predetermined radiation levels are exceeded in major process/effluent streams. Another objective is to provide plant personnel with indication and alarm of the radiation levels in the major process/effluent streams.

The following PRMS subsystems provide signals that initiate automatic safety functions:

- Reactor Building Heating, Ventilating, and Air Conditioning (HVAC) exhaust Radiation Monitoring Subsystem (RMS)
- Refuel Handling Area HVAC exhaust RMS
- Control Building air intake HVAC RMS
- Drywell sumps Low Conductivity Waste/High Conductivity Waste (LCW/HCW) Discharge RMS
- Isolation Condenser Vent Exhaust RMS
- Fuel Building Main Area HVAC RMS
- Containment Purge Exhaust RMS

11.5.1.1.2 Radiation Monitors Required for Plant Operation

The main purpose of these radiation monitoring subsystems is to provide plant personnel with measurements of the content of radioactive material in important gaseous and liquid effluent and process streams. Additional objectives are to initiate discharge valve isolation on the offgas or liquid radwaste systems if predetermined release rates are exceeded, and to provide for sampling at certain radiation monitor locations to allow determination of specific radionuclide content.

The following PRMS subsystems are provided to meet the above design objectives:

- Monitoring Gaseous Effluent Streams
 - Plant Stack RMS
 - Turbine Building Normal Ventilation Air HVAC RMS
 - Turbine Building Compartment Area Air HVAC RMS
 - Radwaste Building Ventilation Exhaust RMS
 - Main Turbine Gland Seal Steam Condenser Exhaust RMS
 - Fuel Building Combined Ventilation Exhaust RMS
 - Turbine Building Combined Ventilation Exhaust RMS
 - Fuel Building Ventilation Exhaust Air Handling Unit (AHU) RMS
- Monitoring Liquid Effluent Streams
 - Liquid Radwaste Discharge RMS
- Monitoring Gaseous Process Streams
 - Main Steamline RMS
 - Offgas Pre-treatment RMS
 - Offgas Post-treatment RMS
 - Charcoal vault ventilation RMS
 - Drywell Fission Product RMS
- Monitoring Liquid Process Streams
 - Reactor Component Cooling Water Intersystem Leakage RMS
- Monitoring Gaseous Intake Streams
 - Technical Support Center HVAC Air Intake RMS

11.5.2 System Design Bases and Criteria

The instrumentation used in the subsystems of the PRMS is designed to be in conformance with the relevant requirements and guidelines of:

- 10 CFR 20.1302, 10 CFR 20 Appendix B, 10 CFR 50.34a, 10 CFR 50.36a
- 10 CFR 50, Appendix A, General Design Criteria (GDC) 19, 60, 63, and 64
- 10 CFR 50 Appendix I
- Regulatory Guides (RG) 1.21, 1.45, 1.97, 4.15
- Standard Review Plan 11.5 (Draft Rev. 4) of NUREG-0800.
- NUREG-0737, Item II.F.1, Attachments 1 and 2.

- ANSI/HPS N13.1-1999
- ANSI N42.18-1980

The system design provides radiation monitoring during normal reactor operations, anticipated operational occurrences, and post-accident conditions.

The safety-related process radiation monitoring subsystems are classified Safety Class 2, Seismic Category I. These subsystems conform to the quality assurance requirements of 10 CFR 50 Appendix B.

11.5.2.1 Radiation Monitors Required for Safety

The design criteria for the safety-related functions as defined in Subsection 11.5.1.1 include the following functional requirements:

- Withstand the effect of natural phenomena (e.g., earthquakes) without loss of capability to perform their functions;
- Perform the intended safety functions in the environment resulting from normal and abnormal conditions (e.g., loss of HVAC and isolation events);
- Meet the reliability, testability, independence, and failure mode requirements of engineered safety features;
- Provide continuous output of radiation levels to the main control room;
- Permit checking of the operational availability of each channel during reactor operation with provisions for calibration function and instrument checks;
- Ensure an extremely high probability of accomplishing safety functions in the event of anticipated operational occurrences;
- Initiate protective action when operational limits are exceeded;
- Annunciate the high radiation levels in the main control room to alert operating personnel of abnormal conditions;
- Insofar as practical, provide self-monitoring of the radiation monitors to the extent that power failure or equipment failure causes annunciation in the main control room and initiation of the required protective action;
- Register full-scale output if radiation detection exceeds full scale;
- Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions, per Regulatory Guide (RG) 1.97;
- Use redundant divisional channels that satisfy the separation and single failure criteria, for the initiation of safety functions.

11.5.2.2 Radiation Monitors Required for Plant Operation

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

- Provide continuous indication of radiation levels in the main control room;

- Annunciate the high radiation levels in the main control room to alert operating personnel to the abnormal conditions;
- Insofar as practical, provide self-diagnosis of the radiation monitors to the extent that power failure or equipment failure causes annunciation in the main control room and isolation of the effluents paths as required;
- Monitor a representative sample of the bulk stream or volume;
- Incorporate provisions for calibration and functional checks;
- Use instrumentation compatible with anticipated radiation levels and ranges expected under normal, abnormal and accident conditions (Regulatory Guide 1.97);
- Register full-scale output if radiation detection exceeds full scale.

11.5.3 Subsystem Description

11.5.3.1 Radiation Monitors Required for Safety

The design description of each radiological monitoring and sampling function as identified in Subsection 11.5.1 is provided in this section under its designated name. The types of instrumentation, together with pertinent parameters for each subsystem, are presented in Tables 11.5-1 and 11.5-2.

11.5.3.1.1 Reactor Building HVAC Exhaust Radiation Monitoring Subsystem (RMS)

This subsystem monitors the gross radiation level in the exhaust duct of the Reactor Building ventilation system from the Reactor Building Exhaust duct and the Refueling Area Air Exhaust duct. A high activity level in the ductwork could be due to fission gases from a leak or an accident.

The subsystem consists of four redundant instrument channels. Each channel consists of a gamma-sensitive detector and a Main Control Room (MCR) radiation monitor.

The detectors are located adjacent to the exhaust ducting upstream of the ventilating system isolation valves and monitor the RB HVAC exhausts. The detectors are physically located upstream of the ventilation exhaust duct isolation dampers such that closure of the dampers can be accomplished prior to exceeding radioactive effluent limits imposed by 10 CFR 50, Appendix I.

Any two-out-of-four channel trips result in the closure of the Reactor Building ventilating exhaust ventilation dampers and stoppage of the RB HVAC exhaust fans.

Trip circuits initiate their respective alarms in the MCR.

The range of channel measurement and display is as shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to the amount associated with a refueling accident and the subsequent ventilation flow into the Reactor Building Ventilation.

11.5.3.1.2 Refuel Handling Area HVAC Exhaust RMS

This subsystem monitors the gross radiation level in the refuel handling area ventilation exhaust duct. The system consists of four channels that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor.

This subsystem performs the same trip functions as those described in Subsection 11.5.3.1.1 for the Reactor Building HVAC exhaust radiation monitoring.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to the amount associated with a refueling accident and the subsequent flow into the Reactor Building Ventilation system.

11.5.3.1.3 Control Building Air Intake HVAC RMS

The Control Building Air Intake HVAC radiation monitoring subsystem is provided to detect the gross radiation level in the normal outdoor air intake supply and automatically initiates closure of the outdoor air intake and the exhaust dampers, and startup of the emergency air filtration system. The emergency air filtration system fans are started and refuel area exhaust fans stopped on high radiation.

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

The radiation monitors for each of the Control Building Air Intake HVAC subsystems consist of four redundant channels to monitor the air intake to the building.

The monitors meet the requirements for Class 1E components to provide appropriate reliability. The system warns of the presence of significant air contamination in inlet air and provides isolation of the Control Building intake air ducts.

Each radiation channel consists of a gamma sensitive detector and a radiation monitor that is located in the MCR.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to cover normal operation and be sensitive enough to initiate isolation of the MCR prior to exceeding the 10 CFR 50 Appendix A GDC 19 guidelines of 0.05 Sieverts whole body or its equivalent to any part of the body.

11.5.3.1.4 Drywell Sumps LCW/HCW Discharge RMS

This subsystem monitors the gross radiation level in the liquid waste transferred in the drain line from the drywell low conductivity waste (LCW) and high conductivity waste (HCW) sumps to the Radwaste System. One monitoring channel is provided in each sump drain line. Each channel uses a gamma sensitive radiation detector that is located near the drain line from the sump just downstream from the outboard isolation valve. The output from each detector is fed to radiation monitors in the MCR for display and annunciation.

Automatic isolation of the two sump discharge pipes occurs if high radiation levels are detected during liquid waste transfers.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for expected radioactivity concentrations due to

accident source terms in these sumps and address the TMI concern about unmonitored transfer of wastes from the containment to the radwaste facility.

11.5.3.1.5 Isolation Condenser Vent Exhaust RMS

This subsystem monitors the gross radiation from the exhaust of the air from the atmospheric pool area above each isolation condenser. The subsystem consists of sixteen channels (four per isolation condenser vent) that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor.

This subsystem initiates isolation of the affected isolation condenser by closure of isolation valves in the steam line to the condenser and in the condensate return line from the condenser.

The detectors monitor radioactivity in the isolation condenser discharge pool area exhaust that might have resulted from a tubing break or a defective condenser.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage from normal operation up to, and several decades beyond, for radioactivity released prior to exceeding limits of 10 CFR 20. Under normal operation, there is no radioactivity expected to be exhausted from this path since there shouldn't be any leakage into the pool area.

11.5.3.1.6 Fuel Building Main Area HVAC RMS

This subsystem monitors the gross radiation level in the Fuel Building Main Area HVAC exhaust duct. The system consists of four channels that are physically and electrically independent of each other. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor. The subsystem monitors the radiation level of the air exiting the spent fuel pool and the associated fuel handling areas as well as the rooms with the fuel pool cooling and cleanup equipment.

This subsystem provides inputs to logic that results in the energization of the Fuel Building Area HVAC fans and a trip of the Fuel Building Main Area HVAC.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide sufficient coverage for radioactivity released during normal operation up to, and including several decades beyond, the amount associated with a refueling accident and the subsequent air flow into the Fuel Building HVAC.

11.5.3.1.7 Containment Purge Exhaust (RMS)

This subsystem monitors the gross radiation level in the exhaust duct leading from the primary containment.

The subsystem consists of four redundant instrument channels. Each channel consists of a gamma-sensitive detector and a MCR radiation monitor.

The detectors are located adjacent to the exhaust ducting upstream of the ventilating system isolation valves. The detectors are physically located upstream of the ventilation exhaust duct isolation dampers such that closure of the dampers can be accomplished prior to exceeding radioactive effluent limits.

Any two-out-of-four channel trips will result in the closure of the Reactor Building HVAC isolation dampers and stoppage of the RB HVAC exhaust fans.

All trip circuits will initiate their respective alarms in the MCR.

The range of channel measurement and display will be as shown in Table 11.5-1 and Table 11.5-2.

11.5.3.2 Radiation Monitors Required for Plant Operation

See Table 11.5-3 and Figure 11.5-1 for diagrammatic information concerning the placement of the PRM subsystems.

Information on these monitors is presented in Table 11.5-2.

11.5.3.2.1 Main Steamline (MSL) RMS

This subsystem monitors the gross gamma radiation level of the steam transported by the Main Steamlines in the MSL tunnel. The normal radiation level is produced primarily by coolant activation gases plus smaller quantities of fission gases being transported with the steam.

The MSL radiation monitors consist of four redundant instrument channels. Each channel consists of a local gamma detector and a radiation monitor located in the main control room.

The detectors are physically located near the Main Steamlines just downstream of the outboard Main Steamline isolation valves (MSIVs) in the steam tunnel. These detectors are arranged so that they are capable of detecting significant increases in radiation level with any number of the Main Steamlines in operation.

The subsystem initiates shutdown of the main turbine condenser mechanical vacuum pump (MVP) and MVP line discharge valve closure upon detection of high radiation. Channel trips are annunciated in the MCR. Although the subsystem is qualified as safety, its function is non-safety.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide detection from normal background radiation at zero percent reactor power up to, and including, gross releases of fission products from reactor fuel into the reactor vessel and its subsequent transport to the Main Steamlines.

11.5.3.2.2 Offgas Pre-treatment RMS

This subsystem monitors radioactivity in the main turbine condenser Offgas after it has passed through the Offgas condenser and moisture separator/cooler. The monitor detects the gross radiation level that is attributable to the fission gases that are produced in the reactor and then transported with steam through the turbine to the main turbine condenser.

A continuous sample is extracted from the Offgas pipe, then passed through a sample chamber and a sample panel before being returned to the suction side of the steam jet air ejector (SJAЕ). The sample chamber is a stainless steel pipe that is internally polished to minimize plate-out. It can be purged with room air to check detector response to background radiation. Sample line flow is measured and indicated on the sample panel. A gamma-sensitive detector, positioned on the sample chamber, is connected to a local radiation monitor.

The radiation level reading can be directly correlated to the concentration of the noble gases in the sample chamber by obtaining a grab sample at the sample panel. The sample is then removed and the sample is analyzed with a multichannel gamma pulse height analyzer to determine the concentration of the various noble gas radionuclides. A correlation between the observed activity and the monitor reading permits calibration of the monitor.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. The range is selected to provide indication over an offgas release rate of approximately 3.7 Mega-Bequerels per second (MBq/s) up to approximately 3.7E5 MBq/s (after a 30 minute decay).

11.5.3.2.3 Offgas Post-treatment RMS

This subsystem monitors radioactivity for halogens, particulates and noble gas releases during normal and accident conditions in the Offgas piping downstream of the Offgas System charcoal adsorbers and upstream of the Offgas System discharge valve. A continuous sample is extracted from the Offgas System piping, passed through two Offgas post-treatment samplers for monitoring and sampling, and returned to the Offgas System piping. Sampling is done in accordance with ANSI 13.1-1999. Automatic compensation for variation in stack flow is provided to maintain the sample panel flow proportional to the main flow. Two local radiation monitors, connected to gamma-beta sensitive radiation detectors, analyze and visually display the measured radiation level.

The sample panel shielded chambers can be purged with room air to check detector response to background radiation. Sample line flow is measured and indicated on the sample panel.. A remotely- operated check source for each detector assembly is used to check operability of the channel.

Each radiation monitor has trip circuits that actuate corresponding main control room annunciators.

The trip outputs are used to initiate closure of the Offgas System discharge and Charcoal Bed bypass valves. The trip setpoint is set so that valve closure is initiated prior to exceeding 10 CFR 20.1203 limits. A channel trip is also used to initiate alignment of the Offgas System flow valves to achieve treatment through the charcoal vault.

Provisions for grab sample collection are provided and can be used for isotopic analysis and monitor calibration.

Tritium sampling is also provided by the subsystem.

Abnormal flow, measured at the sample panel, is annunciated in the MCR.

The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2. The ranges are selected to cover an Offgas release rate of 3.7E5 Bq/s to 3.7E4 MBq/s. The lower range limit is based on the approximate value of an expected release rate for Kryptons and Xenons in the Offgas System. The upper range limit is set by the plant release limit, which in turn is set by plant unique factors such as site size, and meteorology.

The subsystem provides data for reports of gaseous releases of radioactive materials in accordance with Regulatory Guide 1.21.

11.5.3.2.4 Charcoal Vault Ventilation RMS

The ventilation of the charcoal vault is monitored for gross gamma radiation level, in order to look for leakage from the charcoal tanks. A single instrument channel is used. The channel includes a gamma sensitive detector and a radiation monitor. The detector is located outside the charcoal vault on the HVAC exhaust line from the vault. The radiation monitor is located locally.

The range of channel measurement and display is shown in Table 11.5-1 and Table 11.5-2. This range is selected to span normal radiation background to beyond a point where it would have successfully indicated leakage from the charcoal vault into the ventilation/refrigeration duct. Under normal operation, the charcoal vault ventilation air flow should not have radioactivity in it.

11.5.3.2.5 Turbine Building Combined Ventilation Exhaust RMS

This subsystem monitors the Turbine Building Combined Ventilation exhaust for halogens, particulates and noble gas releases during normal and accident conditions.

A representative sample is continuously extracted and passed through the sample panel for monitoring and sampling, and then returned to the Turbine Building Combined Ventilation Exhaust stream. Sampling is done in accordance with ANSI 13.1-1999. Automatic compensation for variation in flow is provided to maintain the sample panel flow proportional to the main flow.

The radiation detector assembly consists of shielded gas chambers that house gamma-beta sensitive detectors and check sources. A local radiation monitor analyzes and visually displays the measured radiation level. The subsystem has provisions for purging the sample panel with room air to check detector response to background radiation level reading.

Each sample chamber is equipped with a check source to test detector response, thus checking operability of the radiation channel.

The radiation monitor initiates trips for alarm indications on high radiation. Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

Provisions for grab sample collection are provided and can be used for isotopic analysis and monitor calibration.

Tritium sampling is also provided by the subsystem.

The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2. These ranges are selected to provide indication of isotopic effluent concentrations provided in 10 CFR 20. The subsystem provides data for reports of airborne releases of radioactive materials in accordance with Regulatory Guide 1.21.

11.5.3.2.6 Liquid Radwaste Discharge RMS

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

Liquid waste can be discharged from the sample tanks containing liquids that have been processed through one or more treatment systems such as filtration, and ion exchange. During

the discharge, the liquid is extracted from the liquid radwaste discharge process pipe, passed through a liquid sample panel that contains a detection assembly for radiation monitoring, and returned to the process pipe. The detection assembly consists of a detector mounted in a shielded sample chamber equipped with a check source. A local radiation monitor analyzes and visually displays the measured gross radiation level.

The sample panel chamber can be drained and flushed to allow assessment of background buildup. Sample line flow is measured and indicated on the sample panel. A check source can be used to check operability of the channel.

The radiation monitor has trip circuits that are used to stop the discharge to the environment.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2. The liquid radwaste discharge radiation monitor provides data for reports of liquid releases of radioactive materials in accordance with Regulatory Guide 1.21. This monitor is used to demonstrate compliance with the liquid effluent release concentration limits of 10 CFR 20.

11.5.3.2.7 Reactor Component Cooling Water Intersystem Leakage RMS

This subsystem consists of two channels. Each channel monitors for intersystem radiation leakage into the respective RCCWS loop and, as such, addresses the guidelines of RG 1.45.

Each channel consists of a detector that is located on the downstream side of each RCCWS heat exchanger exit pipe. Each channel provides individual channel trips on high radiation level and downscale/inoperative indication for annunciation in the MCR.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2.

11.5.3.2.8 Radwaste Building Ventilation Exhaust RMS

This subsystem monitors the Radwaste Building ventilation exhaust for halogens, particulates and noble gas during normal and accident conditions. Each instrument channel consists of a local detector and a radiation monitor. The radiation monitor provides upscale and inoperative trips. Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

A sample, continuously extracted, passes through the panel and returns to the exhaust. Sampling is done in accordance with ANSI 13.1-1999. Automatic compensation for variation in process flow is provided to maintain the sample panel flow proportional to the main flow.

Provisions for grab sample collection are provided and can be used for isotopic analysis and monitor calibration.

The subsystem has provisions for purging the sample panel with room air to check detector response to the background radiation level reading.

Tritium sampling is also provided by the subsystem.

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

The trip signals are annunciated in the Radwaste Building control room and in the MCR. The ranges of channel display are shown in Table 11.5-1 and Table 11.5-2. The subsystem provides data for reports of airborne releases of radioactive materials in accordance with Regulatory Guide 1.21.

11.5.3.2.9 Turbine Building Compartment Area Air HVAC RMS

This subsystem monitors the air in the compartment area HVAC in the Turbine Building for gross radiation levels. The monitoring is provided by two channels. Each channel uses a gamma sensitive detector located internal to the monitored exhaust duct. The outputs from the detectors are fed into radiation monitors for display and annunciation. Each monitor provides alarm trips in the MCR on high radiation and when a monitor is inoperative.

The range of channel display is shown in Table 11.5-1 and Table 11.5-2.

11.5.3.2.10 Turbine Building Normal Ventilation Air HVAC RMS

This subsystem monitors the normal ventilation air HVAC from the clean area in the Turbine Building for gross radiation levels. The monitoring is provided by two channels. Each channel uses a gamma sensitive detector located internal to the monitored exhaust duct. The outputs from the detectors are fed into radiation monitors for display and annunciation. Each monitor provides alarm trips in the MCR on high radiation and when a monitor is inoperative.

The range of channel display will be as shown in Table 11.5-1 and Table 11.5-2.

11.5.3.2.11 Main Turbine Gland Seal Steam Condenser Exhaust RMS

This subsystem monitors the releases to the Turbine Building Combined Ventilation exhaust from the main turbine gland seal condenser system. The releases are continuously sampled and monitored for noble gases. The output signal is displayed in the MCR. The channel has an upscale alarm and an inoperative alarm.

A grab sample of the flow path can be extracted for laboratory analysis. Samples of halogens and particulates can be collected on filters for periodic analysis.

The subsystem will have provision for purging the sample panel with room air to check detector response to the background radiation level reading.

Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

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

The range of channel display is shown in Table 11.5-1 and Table 11.5-2.

11.5.3.2.12 Drywell Fission Product RMS

This subsystem, consisting of two channels, continuously monitors noble gases and particulates in the drywell air space under normal operating conditions. These measurements are used to demonstrate compliance with RG 1.45 for leak detection.

Each radiation monitor provides upscale and inoperative alarms that are indicated in the MCR. Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

The range for the particulate of channel display is given in Table 11.5-1 and Table 11.5-2. This lower limit of detectability is sufficient to indicate the equivalent of 3.785 liters per minute (lpm) leak rate (normal reactor water) within 60 minutes.

The range for the gaseous of channel display is given in Table 11.5-1 and Table 11.5-2. This lower limit of detectability is sufficient to indicate the equivalent of 3.785 lpm leak rate (normal reactor water) within 60 minutes.

A grab sample can be extracted for laboratory analysis. Samples of halogens and particulates can be collected on filters for periodic analysis.

The subsystem will have provision for purging the sample panel with room air to check detector response to the background radiation level reading.

11.5.3.2.13 Technical Support Center (TSC) HVAC Air Intake RMS

This subsystem continuously monitors the intake air ventilation duct of the Technical Support Center with a single gamma sensitive radiation monitor. Upon detection of radioactivity, the Air Handling Unit (AHU) outdoor air damper for the TSC is closed and the filter train fan is started.

This monitor provides upscale and inoperative alarms that are alarmed in the MCR.

The range of channel measurement and display is given in Table 11.5-1 and Table 11.5-2. The range is selected to cover the normal radiation background up to, and several decades beyond, the dose rate given in 10 CFR 50 Appendix A GDC 19. Under normal conditions, no radioactivity is expected to be entering the TSC HVAC intake.

11.5.3.2.14 Plant Stack RMS

The Plant Stack RMS will be used to monitor particulate, iodine and gaseous concentrations in the main stack effluent for both normal and accident plant conditions. It will be composed of three sampling channels that are designed to meet the requirements of both 10 CFR 20.1203 for effluent releases and Regulatory Guide 1.97 for accident effluent releases.

The dynamic range is selected to demonstrate compliance with RG 1.21 and 1.97 normal and post accident releases. In addition, the capability of the subsystem is such that if multiple indications are needed, sufficient decade overlap, via different instruments, is provided for measurement and display.

Provisions for grab sample collection are provided and can be used for isotopic analysis and monitor calibration.

Provisions for monitoring tritium will also be provided.

A sample, continuously extracted from the stack, passes through the panel and returns to the stack exhaust. Sampling is done in accordance with ANSI 13.1-1999. Automatic compensation for variation in stack flow is provided to maintain the sample panel flow proportional to the main flow. The subsystem will have provisions for purging the sample panel with room air to check detector response to the background radiation level reading.

Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

The Plant Stack RMS is non-safety-related. The stack is sampled continuously for the full range of concentrations between normal conditions and those postulated in Regulatory Guide 1.97. The Plant Stack radiation monitor is a post-accident monitor and meets the guidelines of Regulatory Guide 1.97 and NUREG-0737. The plant vent radiation monitor also provides data for plant effluent release reports identified in Regulatory Guide 1.21.

11.5.3.2.15 Fuel Building Ventilation Exhaust Air Handling Unit (AHU) RMS

The Fuel Building Ventilation Exhaust AHU RMS consists of a total of four channels that monitor the radiation level of the air entering the Fuel Handling Ventilation (FHV) unit area exhaust AHUs. Two channels provide the monitoring. Each channel uses a gamma sensitive detector located internal to the monitored exhaust duct. The outputs from the detectors are fed into radiation monitors for display and annunciation. Each monitor provides alarm trips in the MCR on high radiation and when a monitor is inoperative.

The Fuel Building Ventilation Exhaust AHU RMS is nonsafety-related.

11.5.3.2.16 Fuel Building Combined Ventilation Exhaust RMS

The Fuel Building Combined Ventilation exhaust RMS will continuously monitor halogens, particulates and noble gas releases transported from the Fuel Building to the plant stack under both normal and accident conditions.

A sample, continuously extracted from the Fuel Building HVAC duct, passes through a sample panel and is returned to the main exhaust. Sampling is done in accordance with ANSI 13.1-1999. Automatic compensation for variation in HVAC flow is provided in order to maintain the sample panel flow proportional to the main flow. The subsystem will have provision for purging the sample panel with room air to check detector response to the background radiation level reading.

Also, abnormal flow, measured at the sample panel, is annunciated in the MCR.

Provisions for grab sample collection are provided and can be used for isotopic analysis and monitor calibration.

A tritium monitoring device will be associated with this subsystem.

The displayed range is selected to cover normally expected concentrations of radioactivity in Fuel Building HVAC exhaust air, up to and beyond, radionuclide concentrations indicated in 10 CFR 20.

The Fuel Building Combined Ventilation Exhaust RMS is non-safety-related.

11.5.4 Regulatory Evaluation

The system design for radiation monitoring is in conformance with the relevant requirements and criteria that are stipulated in the codes and standards that are identified in Subsection 11.5.2. Radiation monitoring is provided during reactor operation and under post-accident conditions. Specifically, the following requirements are evaluated for compliance:

11.5.4.1 Basis for Monitor Location Selection

The detector locations are selected, per RG 1.21 and Standard Review Plan 11.5, to monitor all the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences. The radioactivity levels in liquid and gaseous effluent releases are monitored, measured, displayed and recorded.

11.5.4.2 Expected Radiation Levels

Expected radiation levels are provided in Tables 11.5-1 and 11.5-2.

11.5.4.3 Instrumentation

Grab samples are analyzed to identify and quantify the specific radionuclides in effluents. The results from the sample analysis are used to establish relationships between the gross gamma monitor readings and concentrations or release rates of radionuclides in continuous effluent releases. Tables 11.5-4 through 11.5-7 provide summary information concerning the frequency, analysis, sensitivity and purpose for both liquid and gaseous process and effluent extracted samples that are analyzed in the health physics laboratory.

11.5.4.4 Setpoints

The trip setpoints for certain safety-related radiation monitors are specified in the Offsite Dose Calculation Manual required by plant Technical Specifications. Trip setpoints for nonsafety-related radiation monitors are specified in the plant Operating Procedures.

11.5.5 Process Monitoring and Sampling

11.5.5.1 Implementation of General Design Criterion 19

The Main Control Building is provided with detectors that sense radiation in the intake air supply to the control building and provide warning and initiate actions to protect operating personnel for access and occupancy of the control room under accident conditions.

In addition, the Technical Support Center ventilation air intake is provided with radiation detection to initiate actions to protect personnel.

11.5.5.2 Implementation of General Design Criterion 60

All potentially significant radioactive discharge paths are equipped with a control system to automatically isolate the effluent on indication of a high radiation level. The subsystems providing these features include:

- Offgas Post-treatment RMS
- Reactor Building HVAC Exhaust RMS
- Refuel Handling Area HVAC Exhaust RMS
- Drywell Sump LCW/HCW Discharge RMS
- Liquid Radwaste Discharge RMS
- Fuel Building Main Area HVAC RMS
- Isolation Condenser Vent Exhaust RMS
- Main Steamline RMS
- Containment Purge Exhaust RMS

11.5.5.3 Implementation of General Design Criterion 63

Fuel storage and radioactive waste systems and their associated handling areas are monitored for excessive radiation levels. The subsystems monitoring these areas include:

- Offgas Pre-treatment RMS
- Offgas Post-treatment RMS
- Radwaste Building Ventilation Exhaust RMS
- Fuel Building Ventilation Exhaust AHU RMS
- Fuel Building Combined Ventilation Exhaust RMS
- Charcoal Vault Ventilation RMS
- Fuel Building Main Area HVAC RMS
- Refuel Handling Area Exhaust RMS
- Reactor Building HVAC Exhaust RMS

11.5.5.4 Implementation of General Design Criterion 64

Radiation levels in the reactor containment atmosphere, spaces containing components for the recirculation of loss-of-coolant accident fluids, effluent discharge paths and important process streams are monitored for radioactivity. The subsystems monitoring these paths and areas include:

- Reactor Building HVAC Exhaust RMS
- Refuel Handling Area HVAC Exhaust RMS
- Drywell Sumps LCW/HCW Discharge RMS
- Isolation Condenser Vent Exhaust RMS
- Fuel Building Main Area HVAC RMS
- Main Steamline RMS
- Offgas Pre-treatment and Offgas Post-treatment RMS
- Charcoal Vault Ventilation RMS
- Reactor Component Cooling Water Intersystem Leakage RMS
- Turbine Building Combined Ventilation Exhaust RMS
- Radwaste Building Ventilation Exhaust RMS
- Turbine Building Combined Ventilation Exhaust RMS
- Main Turbine Gland Seal Steam Condenser Exhaust RMS
- Drywell Fission Products RMS
- Fuel Building Combined Ventilation Exhaust RMS

- Fuel Building Ventilation Exhaust AHU RMS
- Turbine Building Normal Ventilation Air HVAC RMS
- Turbine Building Compartment Area Air HVAC RMS
- Plant Stack RMS
- Containment Purge Exhaust RMS

11.5.5.5 Basis for Monitor Location Selection

The detector locations are selected to monitor the major and potentially significant paths for release of radioactive material during normal reactor operation including anticipated operational occurrences, thus meeting the intent of RG 1.21 and SRP 11.5. Monitoring of each major path provides measurements that are representative of releases to demonstrate compliance with 10 CFR 20 Appendix B limits.

11.5.5.6 Expected Radiation Levels

Expected radiation levels are listed in Tables 11.5-1 and 11.5-2.

11.5.5.7 Instrumentation

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

11.5.5.8 Setpoints

The trip setpoints for the certain safety-related radiation monitors are specified in the Offsite Dose Calculation Manual required by plant Technical Specifications. Trip setpoints for non-safety-related radiation monitors are specified in the plant operating procedures.

11.5.6 Calibration and Maintenance

11.5.6.1 Inspection and Tests

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

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

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

- Main Steamline
- Reactor Building HVAC Exhaust
- Refuel Handling Area HVAC Exhaust
- Control Building Air Intake HVAC
- Fuel Building Main Area HVAC
- Isolation Condenser Vent Exhaust
- Turbine Building Normal Ventilation Air HVAC
- Turbine Building Compartment Area Air HVAC
- Charcoal Vault Ventilation
- Drywell Sump LCW/HCW Discharge
- Technical Support Center HVAC Air Intake
- Offgas Pre-treatment
- Fuel Building Ventilation Exhaust AHU
- Containment Purge Exhaust HVAC

The following monitors include built-in check sources:

- Offgas Post-treatment
- Liquid Radwaste Discharge
- Radwaste Building Ventilation Exhaust
- Main Turbine Gland Seal Steam Condenser Exhaust
- Turbine Building Combined Ventilation Exhaust
- Drywell Fission Product
- Reactor Component Cooling Water Intersystem Leakage
- Fuel Building Combined Ventilation Exhaust
- Plant Stack

11.5.6.2 Calibration

Calibration of radiation monitors is performed using certified commercial radionuclide sources traceable to the National Institute of Standards and Technology. Each continuous monitor is calibrated during plant operation or during the refueling outage if the detector is not readily accessible. Calibration can also be performed on the applicable instrument by using liquid or gaseous radionuclide standards or by analyzing particulate iodine or gaseous grab samples with laboratory instruments.

11.5.6.3 Maintenance

Control and routine maintenance and cleaning operations of the sampling systems is conducted from either the front or the top of the skid or panel. Lifting eyes or other devices are provided for hoisting the units, to facilitate replacement if it is ever required.

Instrument modules are design to facilitate calibration checks and troubleshooting. Accessibility for power supply adjustments is provided.

Sampling racks and electronic modules are serviced and maintained on an annual basis or in accordance with the operational instructions to ensure reliable operation. Such maintenance includes servicing and replacement of defective components and adjustments, as required, after performing a test or calibration check. If any work is performed that would affect the calibration of the instrument, a re-calibration is performed following the maintenance operation.

11.5.7 COL Information

11.5.7.1 RMS Lower Limit of Detection

The derivation of each Subsystem's Lower Limit of Detection is to be determined by the COL applicant based on site specific conditions and operating characteristics of each installed effluent radiation monitoring subsystem.

11.5.7.2 Offsite Dose Calculation Manual

The COL applicant will also develop an offsite dose calculation manual (ODCM) that contains the methodology and parameters used for calculation of offsite doses resulting from gaseous and liquid effluents. The applicant will address operational setpoints for the radiation monitors and address programs for monitoring and controlling the release of radioactive material to the environment, which eliminates the potential for unmonitored and uncontrolled release. The ODCM will include planned discharge flow rates.

11.5.7.3 Process and Effluent Monitoring Program

In addition, the COL applicant is responsible for the site-specific program aspects of the process and effluent monitoring and sampling per ANSI N13.1 and Regulatory Guides 1.21 and 4.15.

11.5.7.4 Site Specific Offsite Dose Calculation

The COL applicant is responsible for addressing 10 CFR 50, Appendix I guidelines for maximally exposed offsite individual doses and population doses via liquid and gaseous effluents.

11.5.8 References

- 11.5-1 10 CFR 20.1302, "Compliance with Dose Limits for Individual Members of the Public."
- 11.5-2 10 CFR 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents-Nuclear Power Plants."
- 11.5-3 10 CFR 50.34(f)(2)(xvii) and 10 CFR 50.34(f)(2)(xxvii).

- 11.5-4 10 CFR 50.36a, "Technical Specifications on Effluents from Nuclear Power Reactors."
- 11.5-5 10 CFR Part 50, Appendix A, General Design Criterion 60, "Control of Releases of Radioactive Materials to the Environment."
- 11.5-6 10 CFR Part 50, Appendix A, General Design Criterion 63, "Monitoring Fuel and Waste Storage."
- 11.5-7 10 CFR Part 50, Appendix A, General Design Criterion 64, "Monitoring Radioactivity Releases."
- 11.5-8 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents."
- 11.5-9 Regulatory Guide 1.21, "Measuring and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants."
- 11.5-10 Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident."
- 11.5-11 Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operation) - Effluent Streams and the Environment."
- 11.5-12 ANSI N13.1-1999, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities."
- 11.5-13 ANSI N13.10-1974, "Specification and Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents" (1974).
- 11.5-14 NUREG-0737, "Clarification of TMI Action Plan Requirements" (1980).

Table 11.5-1

Process and Effluent Radiation Monitoring Systems

| Monitored Process | No. of Channels | Sample Line or Detector Location | Displayed Channel Range |
|---|-----------------|--|---|
| A. Safety-Related Monitors | | | |
| Reactor Building HVAC Exhaust | 4 | Exhaust duct upstream of exhaust ventilation isolation valve | 1E-4 to 1E0 mSv/h |
| Refuel Handling Area HVAC Exhaust | 4 | Exhaust duct upstream of exhaust ventilation isolation valve | 1E-4 to 1E0 mSv/h |
| Control Building Air Intake HVAC | 8 | Intake duct upstream of intake ventilation isolation valve | 1E-4 to 1E0 mSv/h |
| Drywell Sumps LCW/HCW Discharge | 2 | Drain line from LCW & HCW sumps | 1E-2 to 1E4 mSv/h |
| Fuel Building Main Area HVAC | 4 | Exhaust duct upstream of exhaust ventilation isolation valve | 1E-4 to 1E0 mSv/h |
| Isolation Condenser Vent Exhaust | 16 | Exhaust of air space surrounding isolation condensers | 1E-4 to 1E0 mSv/h |
| Containment Purge Exhaust | 4 | Exhaust duct upstream of exhaust ventilation isolation valve | 1E-4 to 1E0 mSv/h |
| B. Monitors Required for Plant Operation | | | |
| Main Steamline | 4 | Immediately downstream of plant Main Steamline isolation valve | 1E-2 to 1E4 mSv/h |
| Plant Stack | 3 | On Stack exhaust | 1E -3 to 1E 10 MBq/m ³ (gaseous) 1E -6 to 1E 7 MBq/m ³ (particulate & halogen) |
| Turbine Building Normal Ventilation Air HVAC | 2 | Exhaust duct from Turbine Building Normal ventilation | 1E-4 to 1E0 mSv/h |

Table 11.5-1
Process and Effluent Radiation Monitoring Systems

| Monitored Process | No. of Channels | Sample Line or Detector Location | Displayed Channel Range |
|---|------------------------|---|---|
| Turbine Building Compartment Area Air HVAC | 2 | Exhaust duct from Compartment area | 1E-4 to 1E0 mSv/h |
| Turbine Building Combined Ventilation Exhaust | 3 | On Turbine Building combined exhaust line | 1E-3 to 1E3 MBq/m ³ (gaseous) 1E-7 to 1E-1 MBq/m ³ (particulate and iodine) |
| Radwaste Building Ventilation Exhaust | 3 | On Radwaste Building exhaust line | 1E-3 to 1E3 MBq/m ³ (gaseous) 1E-7 to 1E-1 MBq/m ³ (particulate) 1E-7 to 1E-1 MBq/m ³ (iodine) |
| Main Turbine Gland Seal Steam Condenser Exhaust | 1 | Sample line from exhaust from Gland Seal condenser | 1E-3 to 1E3 MBq/m ³ |
| Liquid Radwaste Discharge | 1 | Sample line from combined liquid Radwaste effluent path | 1E-3 to 1E3 MBq/m ³ |
| Offgas Pre-treatment | 1 | Sample line after Offgas cooler/condenser | 1E-2 to 1E4 mSv/h |
| Offgas Post-treatment Skid A | 2 | Sample line after Charcoal treatment beds | 1E0 to 1E7 MBq/m ³ (gaseous) 1E-7 to 1E1 MBq/m ³ (particulate) 1E-7 to 1E1 MBq/m ³ (iodine) |
| Offgas Post-treatment Skid B | 1 | Sample Line after Charcoal treatment beds | 1E0 to 1E7 MBq/m ³ (gaseous) |
| Charcoal Vault Ventilation | 1 | On charcoal vault HVAC exhaust line | 1E-2 to 1E4 mSv/h |

Table 11.5-1

Process and Effluent Radiation Monitoring Systems

| Monitored Process | No. of Channels | Sample Line or Detector Location | Displayed Channel Range |
|--|-----------------|---|---|
| Reactor Component Cooling Water Intersystem Leakage | 2 | Each RCCW heat exchanger line exit | 1E-1 to 1E5 MBq/m ³ |
| Technical Support Center HVAC Air Intake | 1 | Intake HVAC duct | 1E4 to 1E0 mSv/h |
| Drywell Fission Product (Particulate) | 1 | Sample line from drywell atmosphere | 1E-7 to 1E-1 MBq/m ³ |
| Drywell Fission Product (Gaseous) | 1 | Sample line from drywell atmosphere | 1E-1 to 1E4 MBq/m ³ |
| Turbine Building Combined Ventilation Exhaust | 3 | Sample line from drywell atmosphere | 1E-3 to 1E3 MBq/m ³ (gaseous) 1E-7 to 1E-1 MBq/m ³ (particulate) 1E-7 to 1E-1 MBq/m ³ (iodine) |
| Fuel Building Ventilation Exhaust AHU | 2 | On HVAC duct leaving Fuel Building AHU's | 1E-4 to 1E0 mSv/h |
| Fuel Building Combined Ventilation Exhaust | 3 | Sample Line from HVAC exhaust leaving Fuel Building | 1E-3 to 1E3 MBq/m ³ (gaseous) 1E-7 to 1E-1 MBq/m ³ (particulate) 1E-7 to 1E-1 MBq/m ³ (iodine) |
| MBq/m ³ = mega-becquerel per cubic meter; mSv/h = milli-Sieverts per hour | | | |

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

| Radiation Monitor | Configuration | Dynamic Detection Range * | Principal Radionuclides Measured | Expected Activity ** | Alarms and Trips |
|-----------------------------------|--|--|---------------------------------------|----------------------|------------------------------------|
| A. Safety-Related Monitors | | | | | |
| Main Steamline | Offline (adjacent to Main Steamlines) | $\approx 1.4\text{E } 2 \text{ to } 1.4\text{E } 8$ MBq/m ³ | N-16, O-19 & Coolant activation gases | ** | DNOSC INOP High High-High |
| Reactor Building HVAC Exhaust | Inline (adjacent and external to HVAC duct) | $\approx 1.5\text{E } 3 \text{ to } 1.5\text{E } 7$ MBq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |
| Refuel Handling Area HVAC Exhaust | Inline (adjacent and external to HVAC duct) | $\approx 7.3\text{E}2 \text{ to } 7.3\text{E}6$ Bq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |
| Control Building Air Intake HVAC | Inline (adjacent and external to HVAC air intake duct) | $\approx 8\text{E}1 \text{ to } 8\text{E } 5$ MBq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |
| Fuel Building Main Area HVAC | Inline (adjacent and external to HVAC duct) | $\approx 7.4\text{E } 1 \text{ to } 7.4\text{E } 5$ MBq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |
| Isolation Condenser Vent Exhaust | Inline (adjacent to vent duct) | $\approx 1.5\text{E } 3 \text{ to } 1.5\text{E } 7$ MBq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |
| Containment Purge Exhaust | Inline (adjacent and external to HVAC duct) | $\approx 1.5\text{E } 3 \text{ to } 1.5\text{E } 7$ MBq/m ³ | Xe-133 | ** | DNOSC/INOP High High-High |

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

| Radiation Monitor | Configuration | Dynamic Detection Range * | Principal Radionuclides Measured | Expected Activity ** | Alarms and Trips |
|---|--|--|--|--------------------------|---|
| B. Monitors Required for Plant Operation | | | | | |
| Offgas Post-treatment | Offline | $\approx 8 \text{ E-3 to } 8 \text{ E } 3 \text{ MBq/m}^3$ $\approx 2.6 \text{ E } -3 \text{ to } 2.6 \text{ E} 3 \text{ MBq/m}^3$ $\approx 3.7 \text{ E } -7 \text{ to } 3.7 \text{ E } -1 \text{ Bq/m}^3$ $\approx 7.4 \text{ E } -7 \text{ to } 7.4 \text{ E } -1$ | Xe-133 Kr-85 Cs-137 I-131 | ** ** ** ** | Abnormal Flow DNSC/INOP High High-High High-High-High |
| Offgas Pre-treatment | Offline (adjacent to sample chamber) | $\approx 1.7 \text{ E } 2 \text{ to } 1.7 \text{ E } 8 \text{ MBq/m}^3$ $\approx 1.0 \text{ E } 2 \text{ to } 1.0 \text{ E } 8 \text{ MBq/m}^3$ | Xe-138 Kr-88 | ** ** | DNSC/INOP High High-High |
| Main Turbine Gland Seal Steam Condenser Exhaust | Offline | $\approx 8 \text{ E } -3 \text{ to } 8 \text{ E } 3 \text{ MBq/m}^3$ $\approx 2.6 \text{ E } -3 \text{ to } 2.6 \text{ E } 3 \text{ MBq/m}^3$ | Xe-133 Kr-85 | ** ** | Abnormal Flow DNSC/INOP High High-High |
| Charcoal Vault Ventilation | Inline (adjacent and internal to HVACduct) | $\approx 5.1 \text{ E } 2 \text{ to } 5.1 \text{ E } 8 \text{ MBq/m}^3$ $\approx 1 \text{ E } 2 \text{ to } 1 \text{ E } 8 \text{ MBq/m}^3$ | Xe-133 Kr-85 | ** ** | DNSC/INOP High |
| Turbine Building Normal Ventilation Air HVAC | Inline (adjacent and internal to HVACduct) | $\approx 1 \text{ E } -4 \text{ to } 1 \text{ E } 0 \text{ mSv/h}$ | Co-60 | ** ** | DNSC/INOP High |
| Turbine Building Compartment Area Air HVAC | Inline (adjacent and internal to HVACduct) | $\approx 1 \text{ E } -4 \text{ to } 1 \text{ E } 0 \text{ mSv/h}$ | Co-60 | ** ** | DNSC/INOP High |
| Turbine Building Combined Ventilation Exhaust | Offline | $\approx 8 \text{ E } -3 \text{ to } 8 \text{ E } 3 \text{ MBq/m}^3$ $\approx 2.6 \text{ E } -3 \text{ to } 2.6 \text{ E } 3 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7 \text{ to } 7.4 \text{ E } -1 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7 \text{ to } 7.4 \text{ E } -1 \text{ MBq/m}^3$ | Xe-133 Kr-85 Cs-137 I-131 | ** ** ** ** | Abnormal Flow DNSC/INOP High High-High |

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

| Radiation Monitor | Configuration | Dynamic Detection Range * | Principal Radionuclides Measured | Expected Activity ** | Alarms and Trips |
|--|----------------------------------|--|------------------------------------|----------------------|---|
| Plant Stack | Offline | $\approx 1 \text{ E } -3$ to $1 \text{ E } 10 \text{ MBq/m}^3$ $\approx 1 \text{ E } -3$ to $1 \text{ E } 10 \text{ MBq/m}^3$ $\approx 1 \text{ E } -6$ to $1 \text{ E } 7 \text{ MBq/m}^3$ $\approx 1 \text{ E } -6$ to $1 \text{ E } 7 \text{ MBq/m}^3$ | Xe-133 Kr-85 Cs-137 I-131 | ** ** ** ** | Abnormal Flow DNSC/INOP High High-High |
| Drywell Fission Product | Offline | $\approx 8.1\text{E}-8$ to $8.1\text{E}-2 \text{ MBq/m}^3$ $\approx 2.6\text{E}-7$ to $2.6 \text{ E } -1 \text{ MBq/m}^3$ (particulate) | Cs-137 Co-60 | ** ** | Abnormal Flow DNSC/INOP High High-High |
| Drywell Fission Product | Offline | $\approx 8.1\text{E}-3$ to $8.1\text{E}3 \text{ MBq/m}^3$ $\approx 2.6\text{E}-3$ to $2.6\text{E}3 \text{ MBq/m}^3$ (gaseous) | Xe-133 Kr-85 | ** ** | DNSC/INOP High High-High |
| Radwaste Building Ventilation Exhaust | Offline | $\approx 8 \text{ E } -3$ to $8 \text{ E } 3 \text{ MBq/m}^3$ $\approx 2.6\text{E}-3$ to $2.6 \text{ E } 3 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7$ to $7.4 \text{ E } -1 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7$ to $7.4\text{E}-1 \text{ MBq/m}^3$ | Xe-133 Kr-85 Cs-137 I-131 | ** ** ** ** | Abnormal Flow DNSC/INOP High High-High |
| Fuel Building Combined Ventilation Exhaust | Offline | $\approx 8 \text{ E } -3$ to $8 \text{ E } 3 \text{ MBq/m}^3$ $\approx 2.6 \text{ E } -3$ to $2.6 \text{ E } 3 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7$ to $7.4 \text{ E } -1 \text{ MBq/m}^3$ $\approx 7.4 \text{ E } -7$ to $7.4 \text{ E } -1 \text{ MBq/m}^3$ | Xe-133 Kr-85 Cs-137 I-131 | ** ** ** ** | Abnormal Flow DNSC/INOP High High-High |
| Fuel Building Ventilation Exhaust AHU | Inline and internal to HVAC duct | $\approx 5.5\text{E}0$ to $5.5 \text{ E } 4 \text{ MBq/m}^3$ $\approx 1\text{E}2$ to $1\text{E}6 \text{ MBq/m}^3$ | Xe-133 Kr-85 | 0** 0** | DNSC/INOP High |

Table 11.5-2

Process Radiation Monitoring System (Gaseous and Airborne Monitors)

| Radiation Monitor | Configuration | Dynamic Detection Range * | Principal Radionuclides Measured | Expected Activity ** | Alarms and Trips |
|--|---|---|----------------------------------|----------------------|--------------------------------|
| Technical Support Center HVAC Air Intake | Inline and internal to HVAC intake duct | $\approx 8 \text{ E}0$ to $8\text{E}4 \text{ MBq/m}^3$ $\approx 1.7\text{E}2$ to $1.7\text{E} 6 \text{ MBq/m}^3$ | Xe-133 Kr-85 | ** ** | DNSC/INOP High High-High |
| Bq/ m ³ = Becquerels per cubic meter, MB/m ³ = Mega Becquerels per cubic meter; DNSC/INOP = downscale/inoperative; Abnormal Flow = High or Low flow in the sampling system outside system limits | | | | | |

- * Dynamic detection ranges are estimated and will be adjusted according to plant unique configurations and radiation background.
- ** Activity levels are expected to be at the subsystem's lower limit of detection (LLD). The derivation of each LLD is to be determined by the COL applicant based on site specific conditions and operating characteristics of each installed effluent radiation monitoring subsystem. See Section 12.2 for expected activity of various processes and effluents.

Table 11.5-3
Key to Radiation Monitors Shown on Figure 11.5-1

| ID on Figure 11.5-1 | Description |
|--------------------------------|---|
| 1 | Main Steamline |
| 2 | Reactor Building HVAC Exhaust |
| 3 | Refuel Handling Area HVAC Exhaust |
| 4A, 4B | Control Building Air Intake HVAC |
| 5 | Turbine Building Normal Ventilation Air HVAC |
| 6 | Turbine Building Compartment Area Air HVAC |
| 7 | Offgas Pre-treatment |
| 8 | Charcoal Vault Ventilation |
| 9 | Offgas Post-treatment |
| 10 | Turbine Building Combined Ventilation Exhaust |
| 11 | Liquid Radwaste Discharge |
| 12 | Drywell Sump LCW/HCW Discharge |
| 13 | Plant Stack |
| 14 | Main Turbine Gland Seal Steam Condenser Exhaust |
| 15 | Reactor Component Cooling Water Intersystem Leakage |
| 16 | Drywell Fission Product |
| 17 | Radwaste Building Ventilation Exhaust |
| 18 | Fuel Building Combined Ventilation Exhaust |
| 19 | Isolation Condenser Vent Exhaust |
| 20 | Technical Support Center HVAC Air Intake |
| 21 | Fuel Building Main Area HVAC |
| 22 | Fuel Building Ventilation Exhaust AHU |
| 23 | Containment Purge Exhaust |

Table 11.5-4

Process Radiation Monitoring System (Liquid Monitors)

| Radiation Monitor | Configuration | Dynamic Detection Range * | Principal Radionuclides Measured | Expected Activity ** | Alarms & Trips |
|---|--|--|---|-----------------------------|---|
| Liquid Radwaste Discharge | Offline | $\approx 2.1\text{E}3$ to $2.1\text{E}3$ MBq/m ³ $\approx 1.9\text{E}-2$ to $1.9\text{E}4$ MBq/m ³ | Cs-137 Co-60 | ** ** | Abnormal Flow DNSC/INOP High High-High |
| Reactor Component Cooling Water Intersystem Leakage | Offline (mounted external to RCCW piping) | $\approx 4.3\text{E}-3$ to $4.3\text{E}3$ MBq/m ³ $\approx 3.6\text{E}-3$ to $3.6\text{E}3$ MBq/m ³ | Cs-137 Co-60 | ** ** | DNSC/INOP High |
| Drywell Sump LCW/HCW Discharge | Inline (mounted external to and adjacent to HCW and LCW discharge pipes outside the drywell) | $\approx 4\text{E}4$ to $4\text{E}10$ MBq/m ³ $\approx 8\text{E}0$ to $8\text{E}6$ MBq/m ³ | Cs-137 Co-60 | ** ** | DNSC/INOP High High-High |
| MBq/m ³ = Mega Becquerels per cubic meter; DNSC/INOP = downscale/inoperative | | | | | |

- * Dynamic detection ranges are estimated and will be adjusted according to plant unique configurations and radiation background.
- ** Activity levels are expected to be at the subsystem's lower limit of detection (LLD). The derivation of each LLD is to be determined by the COL applicant based on site specific conditions and operating characteristics of each installed effluent radiation monitoring subsystem. See Section 12.2 for expected activity of various processes and effluents.

Table 11.5-5
Radiological Analysis Summary of Liquid Process Samples

| Sample Description | Grab Sample Frequency | Analysis | Sensitivity (MBq/m ³) | Purpose |
|--|-----------------------|--------------------------|-----------------------------------|---|
| 1 Reactor Coolant | | | | |
| Filtrate | Daily | Gross gamma | 3.7×10^{-2} | Evaluate reactor water activity |
| Crud | Daily | Gross gamma | 3.7×10^{-2} | Evaluate crud activity |
| Filtrate | Weekly * | I-131, I-133 | 3.7×10^{-3} | Evaluate fuel cladding integrity |
| Crud and filtrate | Weekly | Gamma spectrum | 1.85×10^{-3} | Determine radionuclides present in system |
| 2. Reactor Water Cleanup / Shutdown Cooling System | Biweekly | Gross gamma | 3.7×10^{-2} | Evaluate cleanup efficiency |
| 3. Condensate Demineralizer | | | | |
| Influent | Monthly | Gross gamma | 3.7×10^{-2} | Evaluate leakage |
| Effluent | Monthly | Gross gamma | 3.7×10^{-2} | Evaluate demineralizer performance |
| 4. Condensate Storage Tank | Weekly | Gross β - γ | 3.7×10^{-2} | Evaluate water radioactivity |
| 5. FAPCS – Filter/Demineralizer | | | | |
| Inlet & Outlet | Periodically | Gross β - γ | 3.7×10^{-2} | Evaluate system performance |
| 6. LCW Collection (3) and Sample Tank (2) | Periodically | Gross β - γ | 3.7×10^{-2} | Evaluate system performance |
| 7. HCW Collection (2) and Sample Tank (2) | Periodically | Gross β - γ | 3.7×10^{-2} | Evaluate system performance |
| 8. Detergent Drain Subsystem | Periodically | Gross β - γ | 3.7×10^{-2} | Evaluate system performance |

Table 11.5-5**Radiological Analysis Summary of Liquid Process Samples**

| Sample Description | Grab Sample Frequency | Analysis | Sensitivity (MBq/m³) | Purpose |
|---|------------------------------|--------------------------|--|------------------------------|
| Collection (2) and Sample Tank (2) | | | | |
| 9. Reactor Component Cooling Water System | Weekly | Gross β - γ | 3.7×10^{-2} | Evaluate intersystem leakage |

* Performed more frequently if increase noted on daily gamma count.

Table 11.5-6

Radiological Analysis Summary of Gaseous Process Samples

| Sample Description | Sample Frequency | Analysis | Sensitivity (MBq/m ³) | Purpose |
|--|---------------------------------|-------------------------------------|--|--|
| 1. Containment Atmosphere (drywell) | Periodically and prior to entry | Gross α - β Tritium | 3.7×10^{-7} 3.7×10^{-2} | Determine need for respiratory equipment |
| 2. Offgas Pre-treatment Sample | Monthly | Gamma spectrum | 3.7×10^{-6} | Determine Offgas activity |
| 3. Offgas Post-treatment Sample | Weekly | Gross β | 3.7×10^{-7} | Determine Offgas System cleanup efficiency |
| | | I-131 | 3.7×10^{-6} | |
| | | Gamma spectrum Tritium | 3.7×10^{-6} 3.7×10^{-2} | |
| 4. Main Turbine Gland Seal Steam Condenser Exhaust 2 | Weekly | Gross β | 3.7×10^{-7} | Determine effectiveness of gland sealing |
| | | I-131 | 3.7×10^{-6} | |
| | | Gamma spectrum Tritium | 3.7×10^{-6} 3.7×10^{-2} | |

Table 11.5-7

Radiological Analysis Summary of Liquid Effluent Samples

| Sample Description | Sample Frequency | Analysis | Sensitivity (MBq/m ³) | Purpose |
|--|------------------|---------------------|-----------------------------------|---------------------------|
| | | | | |
| 1. Liquid Radwaste Effluent Discharge* | Weekly ** | Ba/La-140 and I-131 | 1.85×10^{-3} | Effluent discharge record |
| Composite of all discharges | Monthly | Gamma Spectrum | 18.5×10^{-3} | |
| | | Tritium | 3.7×10^{-1} | |
| | | Gross alpha | 3.7×10^{-3} | |
| | | Dissolved gas | 3.7×10^{-1} | |
| | Quarterly | Sr-89 and Sr-90 | 1.85×10^{-3} | |

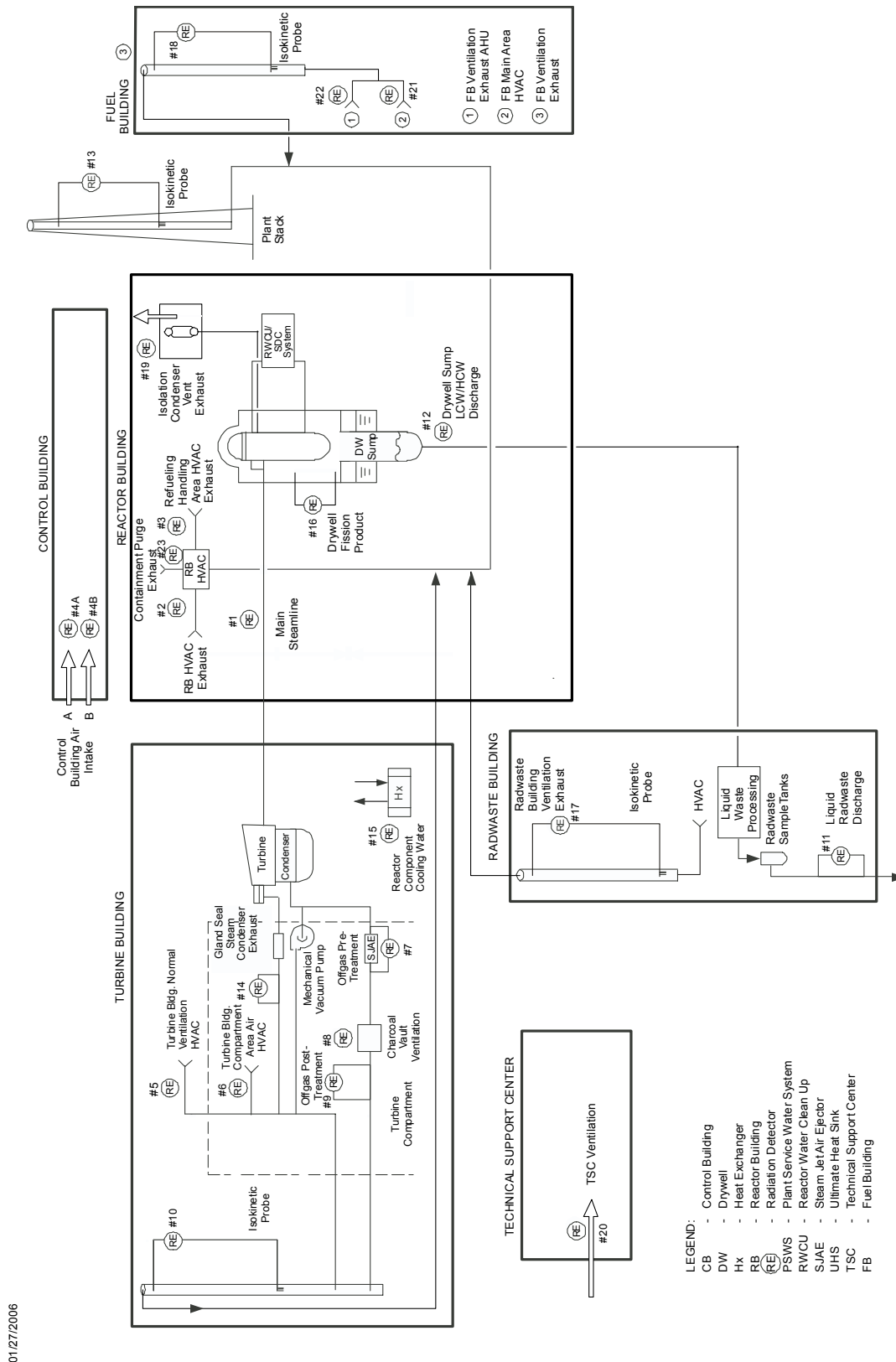
* ESBWR Radwaste is processed on a batch basis. If a tank is to be discharged, analysis will be performed on each batch. If a tank is not to be discharged, analysis will be performed periodically to evaluate equipment performance.

** The ESBWR Liquid Waste Management System (LWMS) is designed to recycle 100% of the liquid radwaste (zero liquid release). The LWMS system has provisions for off-site discharge. If liquid radwaste is discharged, the sampling and analysis will be done per the requirements of RG 1.21.

Table 11.5-8
Radiological Analysis Summary of Gaseous Effluent Samples

| Sample Description | Sample Frequency* | Analysis | Sensitivity (MBq/m ³) | Purpose |
|--|-------------------|-----------------|-----------------------------------|-----------------|
| 1. Turbine Building Combined Ventilation Exhaust | Weekly | Gross β | 3.7×10^{-7} | Effluent record |
| | | I-131 | 3.7×10^{-6} | |
| | | Ba/La-140 | 3.7×10^{-5} | |
| | Monthly | Gamma spectrum | 3.7×10^{-6} | |
| | | I-133 and I-135 | 3.7×10^{-6} | |
| | | Tritium | 3.7×10^{-2} | |
| | | Gross alpha | 3.7×10^{-7} | |
| | Quarterly | Sr-89 and Sr-90 | 3.7×10^{-7} | |
| 2. Plant Stack | As above | As above | As above | Effluent record |
| 3. | | | | |
| 3. Radwaste Building Ventilation Exhaust | As above | As above | As above | Effluent record |
| 4. Fuel Building Combined Ventilation Exhaust | As above | As above | As above | Effluent record |

* All frequencies of sampling will be in accordance with RG 1.21.



01/27/2006

Figure 11.5-1. Location of Radiation Monitors