9.0 GENERAL

9.1 PURPOSE AND DEFINITION

A monitoring system consists of:

- One or more remote monitors or detectors
- Centrally located cabinet(s) or console(s) where data from the monitors are received and displayed
- Interconnecting cables, power supplies, pumps, alarms, recorders, display panels, relays, and auxiliary components

9.1.1 Radiation Monitoring System

In a typical light water reactor (LWR) the Radiation Monitoring System (RMS) comprises three major groups. These are:

- Process Radiation Monitoring System (PRMS)
- Area Radiation Monitoring System (ARMS)
- Post-accident Monitoring System

The ARMS provides surveillance of radiation levels in selected areas of the plant. The Post-accident Monitors are designed to provide extended range on the plant monitoring capabilities to address off-normal radiological conditions. While the Process RMS is closely associated with the plant Area Radiation Monitoring System and the Post-accident Monitoring System, this manual focuses on the two major subdivisions of the PRMS that monitor either in-plant radioactive fluid streams or radioactive effluent discharges to the environment.

9.1.2 Process Radiation Monitoring System

The PRMS monitors process liquid and gas flows and liquid and airborne effluent. The Process Radiation Monitors:

- Give early warning of a possible plant malfunction
- Warn operating personnel of increasing radiation/radioactivity
- Prevent inadvertent release of radioactivity to the environment.

The PRMS provides surveillance of selected fluid streams containing radioactivity and provide data that is used to control in-plant handling of such streams. Therefore, they have important implications to radwaste management. A process monitor may be either an in-line or off-line unit.

The number, location and specific design of a PRMS vary from plant to plant, but the basic function and design features are common to all LWR.

Many of the sampling/monitoring channels of the RMS have local readout and control, but the main RMS panels are located in the Control Room.

PRMS are discussed in more detail for PWRs and BWRs in sections 9.4 and 9.7 respectively. The differences between in-plant process monitors and effluent monitors is primarily associated with their specific application, thus they share design characteristics and have common components.

9.1.3 Radiological Effluent Monitors

A radiological effluent monitor is a device that:

- Removes a representative sample from the effluent stream
- Detects and quantitatively measures the radioactive material present in the sample
- Discharges the sampled medium back to the effluent stream
- Transmits the data to a central point

The design functions of a radiological effluent monitor at a LWR are:

- Detection and measurement of radioactive material released in gaseous or liquid effluent streams
- Generation of a signal for alarm or actuation of other systems to terminate or modify the flow or nature of the effluent stream upon detection of high radioactivity

A system of radiological effluent monitors for a nuclear power reactor usually consists of several remote monitors connected by cable to a central console or cabinet where the data for each monitor are processed and recorded.

9.2 REGULATORY BASIS FOR EFFLUENT MONITORING

Standards governing the release of radioactive liquids and gases from LWR are established in 10 CFR 50, Appendix I.

Compliance with these standards is enforced through the Radiological Environmental Technical Specifications (RETS) for each such facility. The RETS are a site-specific application of generic Technical Specifications (Tech Specs) for either a BWR or a PWR. The generic radiological Tech Specs are based on NUREG 0133, NUREG 0472, or NUREG 0473. They specify the environmental surveillance for the reactor type, including those pertaining to radiological effluent monitoring instrumentation.

In 1989, the NRC changed the format of the RETS (and the ODCM). These changes are set forth in NRC Generic Letter 89-01. Until then the RETS were part of the facility Tech Specs, which are included as an appendix to the facility license. Under the revised format the programmatic or general features are retained in the Tech Specs and the procedural details are part of the ODCM (see Chapter 8). The portion of the RETS that is transferred to the ODCM is now called Standard Radiological Effluent Controls (SREC).

Table 9.2-1 lists the radioactive liquid effluent monitoring instruments required by BWR RETS and Table 9.2-2 lists the radioactive gaseous effluent monitoring instruments required by BWR RETS. Similar RETS requirements apply for PWR process and effluent monitoring systems.

In addition, Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident" extends the number and range of radiological monitors.

9.3 GENERAL DESIGN TYPES OF RADIOACTIVITY SAMPLER/MONITORS

A typical RMS uses four general types of sampler/monitor units. They are:

- Off-line liquid
- Off-line gas (& particulate)
- In-line gas (& particulate)
- In-line liquid

In-line liquid detectors are used only occasionally in PWRs, but are common in BWR Radiation Monitoring Systems.

The RMS normally utilizes beta or gamma scintillation detectors. In general, off-line liquid units use gamma scintillation detectors and the gas/particulate monitors use beta scintillation detectors. The gamma scintillation detectors are sodium iodide crystals optically coupled to photomultiplier tubes. The beta detectors are normally beta sensitive plastic optically coupled to a photomultiplier tube. The output signal from the detector is transmitted to a ratemeter and a multi-pen recorder in a Control Room instrument panel. Frequently a local ratemeter is also available.

9.3.1 Off-line Liquid Monitors

Liquid monitors measure the gross gamma activity level of dissolved and suspended radionuclides in the liquid effluent or liquid process stream. This monitor consists of several major subassemblies, which include:

- Cabinet assembly
- Sampler assembly
- Gamma detector assembly
- Check source assembly
- Electronic unit assembly
- Plumbing and valving

The sampler assembly consists of a chamber and a lead shield. The sample chamber is constructed from Type 316 stainless steel with all wetted surfaces passivated and mirror polished. The chamber may be spherical, hemispheric, or bucket-shaped with a capacity in the range of several liters. There is typically a cylindrical well depressed into the sample chamber for the detector. This recessed well allows the liquid stream to effectively surround the detector, which is outside the chamber.

Effluents typically enter the chamber at the bottom, fill the chamber, then exit from the top; however, other configurations are also in use. The unit can be backflushed with clean water by reversing the flow.

The detector is a standard gamma scintillation assembly. The electronics are system specific and range from analog logarithmic rate meters to microprocessor based digital units.

9.3.2 Off-line Gas Monitors

The off-line gas monitors are equipped with pumping systems that transport the sample from the collection point to the detector. These units are housed in seismically designed cabinets and generally are located in a centralized area of the primary auxiliary building; although some units are located elsewhere, i.e., the containment area. While some units are limited to sampling and monitoring the gas, others also collect and monitor radioiodine and airborne particulates.

9.3.3 In-line Liquid Monitors

The in-line liquid monitors are usually a scintillation detector inserted into an in-line well in the system piping. The well is a special fixture sunk into the pipe. Otherwise, it is comparable to off-line units.

The advantages of an in-line monitor are:

- The detector is continuously observing a representative sample
- Rapid response to activity changes

The disadvantage of an in-line monitor is that the detector must be sturdy enough to endure turbulent flow, which reduces detection sensitivity.

9.3.4 In-line Gas Monitors

Two types of in-line gas monitors exist. The first is simply a detector attached to or near a line and oriented to ensure the proper view of the system to be monitored. The other is similar to in-line liquid monitors. It is sometimes used on smaller lines, such as the containment purge exhaust line.

9.4 PWR RADIATION MONITORING SYSTEM

PWRs are designed to restrict any radioactive liquid or gaseous waste releases to the auxiliary and containment building effluent and ventilation systems. However, as a precautionary measure, additional monitoring capability provides surveillance of releases via other potential pathways such as a primary-to-secondary leakage. Gaseous release pathways are shown in Figure 9.4-1.

Table 9.4-1 lists the monitor location, type of detector, sensitivity ranges, and any automatic actions for PWR process and effluent monitors.

9.4.1 Liquid Effluent Monitors

All effluents from liquid radioactive waste pathways from a PWR are normally released in batch mode at controlled rates and mixed with station circulating water (or cooling tower blowdown); therefore a single monitoring point after mixing is required to confirm compliance with station release limits and administrative discharge requirements.

9.4.2 Airborne Radioactive Effluent Monitors

Off-line gas channels monitor radioactive gas from:

- Auxiliary Building Vent (2 locations)
- Leak Collection Area
- Waste Gas Decay Tank Vaults Vent
- Waste Gas Decay Tank

The following channels monitor radioiodine and airborne particulates in addition to noble gases:

- Gaseous Waste Monitor
- Ventilation Vent Monitor
- Elevated Release Monitor (Plant Vent)
- Containment Monitor
- Multi-sample Monitor

The latter provides surveillance in a number of areas of the plant by sequentially drawing samples from various selected points located throughout.

9.4.3 Gaseous Waste System

This channel of the RMS monitors the radioactivity releases through the plant vent, especially during venting of the gas decay tanks. The detector is used to principally monitor noble gases and its output is transmitted to the Control Room. It features automatic isolation, when required.

9.4.4 Containment Particulate and Gaseous Monitor

The containment monitor is comprised of two channels:

- Containment particulate monitor
- Containment gas monitor

These channels continuously withdraw an isokinetic sample of the air within the containment. The sample passes through a moving filter paper. The amount of radioactivity is determined by scanning the radioactive material as it deposits. After passing through the filter paper, the sample passes through a charcoal cartridge to remove the radioiodine prior to entering a sealed system that forms a fixed shielded volume for noble gases. After mixing and measurement in this volume, the gas is returned to the containment.

The particulate monitor includes a moving filter (Figure 9.4-2) and an iodine collection cartridge. The moving filter sampler is shielded by two inches of lead. The system operates by passing the effluent through the moving filter, which has a 99% collection efficiency for particulates greater than 0.3 microns diameter. The paper can be advanced either in a step-program mode or continuously. The rate of paper movement for continuous monitoring is around 1 inch per hour. The deposited activity is monitored by a beta phosphor optically coupled to a ten-stage photomultiplier. The output signal is routed to an integral preamplifier with a high dynamic range and voltage gain prior to transmitting it to a ratemeter in the Control Room.

Typically a cesium-137 check source is provided to check detector response. This check source can be activated from the main Control Room RMS cabinet.

After passing through the moving paper filter the sample stream goes through a removable stainless steel filter holder housing a charcoal filter for iodine collection. Charcoal cartridges are periodically replaced. The removed cartridge is analyzed in the counting laboratory for iodine-131.

Next the sample is drawn through the gas monitor. In this channel the gas monitor is enclosed in a shield assembly. The gas collection volume contains a stainless steel liner. The detector for this monitoring channel is a sodium iodide crystal with a ten-stage photomultiplier and a preamplifier assembly.

The sampling is performed by a positive displacement pumping system.

9.4.5 Auxiliary Building Ventilation

The PWR auxiliary building ventilation includes:

- Refueling pool area
- Radwaste processing areas
- Laboratory and sampling areas

In general, samples are drawn by off-line gas monitors and monitored by a scintillation (or proportional) counter.

9.5 PROCESS MONITORS

The use of process radioactivity monitors is site specific; therefore, any list is at best indicative of the general use of process monitors for surveillance of fluid system streams.

In PWRs process monitors are used to monitor:

- Component cooling water system
- Steam generator blowdown
- Condenser air ejector exhaust
- Cooling water from generator blowdown heat exchange
- Reactor coolant letdown system
- Recirculation spray heat exchanger
- Exhaust from various areas of the plant
- Containment air particulate radioactivity
- Containment noble gas activity
- Waste gas decay tanks
- Failed fuel

In general these monitors read out and alarm in the Control Room.

The monitor on the component cooling water system warns of small leaks from the reactor coolant system to the component cooling water system. Changes in the component cooling system surge tank are adequate for detection of large leaks.

Steam generator blowdown monitors serve two functions:

- Monitor effluents that steam generators blowdown directly to the environment
- Monitor process liquids to detect leaks in the steam generator tubes.

The air ejector exhaust monitor also serves two functions:

- Monitor effluent that air ejectors exhaust to the environment
- Detection and alarm for leaking steam generator tubes. This unit monitors for radioactive noble gases.

The cooling water from the steam generator blowdown heat exchanger is monitored for leaks using a liquid monitor.

The reactor coolant letdown system monitor is used to detect failed fuel by measuring iodine-135 activity.

9.6 AIRBORNE RADIOACTIVITY MONITORS

This description of airborne radioactivity monitors used for ventilation exhaust is divided into discussion of:

- Sample collection
- Sample transport
- Particulate radioactivity monitoring
- Radioiodine monitoring and sampling
- Noble gas monitors
- Pumps and flow control
- Electronic assembly

9.6.1 Sample Collection

Gaseous or liquid samples are collected by similar methods. These samples must be representative of the fluid stream being sampled.

In the case of gases, this means that suspended particles from 0.3 micron to 10 micron are sampled and collected by isokinetic sampling. Figure 9.6-1 shows the placement of an isokinetic nozzle in a vent duct. Figures 9.6-2 through 9.6-5 provide examples of various sample nozzles. Sample nozzle design requirements are specified in ANSI N13.1 (1969). These nozzles are also suitable for sampling liquids provided they are reinforced to withstand the hydraulic conditions.

9.6.2 Sample Transport

Once the sample is collected by the sample nozzle, it is transported to the monitor or sample collector, usually by piping. Drawing the fluid through sampling lines can distort the sample by loss of particles from:

- Settling by gravity
- Temperature induced deposition
- Brownian diffusion
- Turbulent deposition
- Reaction with sample line surfaces

These losses are controlled by:

- Heat tracing and insulating lines
- Reducing sample line length
- Avoiding bends less than five times the pipe radius
- Control of sample velocity in lines

9.6.3 Particulate Radiation Monitor

There are two general types of particulate samplers - fixed and moving filters. The particulate monitor is the first monitor to see the air sample. The particulate filter removes particles that interfere with iodine and noble gas monitoring downstream.

Figure 9.6-6 shows the internal portion of a particulate monitor. Figure 9.6-7 shows a particulate filter holder. The particulate detector consists of a fixed-filter assembly and lead plug on the front end of the shield. A scintillation detector and lead plug are on the opposite end.

The sample enters the shield, passes through the replaceable filter, and exits the shield. The filter collects >99% of the particulates over 0.3 micron. In operation, the filter is viewed by a beta scintillator. A check source is provided to periodically confirm proper operation of the detector. In some cases, the filter paper is collected for laboratory analysis rather than being monitored by a field detector. In either case the filter accumulates activity and must be removed periodically. The buildup time must be considered in establishing any alarm set points. Particulate monitors are intended to monitor activity over a range from 10^{-11} to 10^{-6} µCi/cc.

When digital systems are used, they can be set to monitor the change in rate of activity buildup.

The moving filter monitors are sometimes used for containment air monitors. Continuous air samples are collected from the containment atmosphere near the reactor containment fan cooler. The samples are drawn outside of the containment in closed sealed systems and monitored by a scintillation detector and a movable filter detector assembly before passing through a noble gas monitor. The only advantage of a moving filter is the more rapid response to changes in activity; however, it is more complex mechanically.

9.6.4 Iodine Monitor

An iodine monitor is also shown in Figures 9.6-1, 9.6-6, and 9.6-8. The iodine detector consists of a charcoal cartridge assembly and lead plug on the front end of the shield and a sodium iodide scintillation detector assembly and lead plug on the opposite end. The sample enters the shield, passes through the replaceable charcoal cartridge and exits the shield. The charcoal cartridge absorbs iodine and is easily changed. In some units it is directly monitored by the detector; in others, it is periodically collected for laboratory analysis (or both).

Background subtraction can be provided by monitoring adjacent detector window(s). The design range of typical iodine monitors is 10^{-11} to 10^{-6} µCi/cc. But noble gases are also trapped by the charcoal and severely interfere with the monitor operation. Silver zeolite filters can be used in lieu of the charcoal when required. Silver zeolite is effective for radioiodine but allows the noble gases to pass through.

9.6.5 Noble Gas Monitors

Off-line radioactive noble gas monitors are shown in Figures 9.6-1 and 9.6-6.

The gas detector consists of a lead plug on the front end of the shield and a scintillation detector on the other end or centered in the shielded volume. The design range of off-line noble gas monitors is generally in the range of 10^{-6} to 10^{-1} μCi/cc.

9.6.6 Pumps and Flow Control

Several types of pumps are used to move the samples through the system. These include lobe and carbon vane pumps. An automatic flow system is use to maintain the flow at a prescribed known rate. The flow control system usually consists of a mass flow indicator/transmitter, a motor operated flow control valve, and a flow comparator.

The mass flow indicator/transmitter is located between the sampler and the flow control valve. It measures the flow rate in standard units and compensates for variable temperature and density. The signal is transmitted to the flow comparator that controls the flow control valve. Actual flow depends on the required sensitivity, but is between 1 and 3 scfm. Both high and low flow activate alarms.

9.6.7 Electronics Assembly

Each channel contains a completely integrated modular assembly that includes:

- Level amplifiers
- Log level amplifiers
- Power supplies
- Test-calibration circuitry
- Remote actuated radiation check source
- Radiation rate meter
- Indicating light and alarms
- Bi-stable circuits

The level amplifiers increase the detector signal to provide a discriminated output to the log level amplifier. The log level amplifier accepts the shaped pulse and converts the pulse rate to a logarithmic analog signal and amplifies the resulting output for suitable indication and recording.

The power supply furnishes the positive and negative voltages for transistor circuits, relays, alarms, lights, and detector high voltage.

The test-calibration circuits provide a precalibrated signal for a channel check and a solenoid operated radiation check source to confirm channel operation.

The rate meters provide channel reading and level signal for recorders.
The use of microcomputers in later systems provides much more capability and sophistication than described above.

9.7 BWR RADIATION MONITORING SYSTEM

BWR liquid radioactive wastes originate from:

- Plant sumps
- Operation of reactor support systems
- Radioactive liquid waste processing system

The radioactive liquid release pathways are shown in Figure 9.7-1. In general all liquid wastes are collected, processed, and routed to either condensate storage for reuse or to the discharge canal. Discharges are generally in batch modes at controlled rates.

The radioactive gaseous release pathways are shown in Figure 9.7-2. Table 9.7-1 lists the channels of the BWR radioactive gaseous waste RMS and their general features.

A number of radiation monitors and monitoring systems provide surveillance on process liquid and gas streams that could serve as discharge routes for radioactive material or control fluid transfer within a BWR. These include:

- Process Liquid RMS
- Main Steam Line RMS
- Air Ejector Off Gas RMS
- Stack-Gas RMS
- Process Ventilation RMS
- Plant Ventilation Exhaust RMS

Typically, the normal RMS is supplemented by accident range instrumentation.

9.7.1 Process Liquid RMS

The Process Liquid RMS indicates:

- Radioactivity in liquid plant effluent greater than operational limits
- System malfunctions in the liquid process streams.

The Process Liquid RMS typically consists of five independent channels to monitor and record the radioactivity level of:

- Reactor Building Closed Cooling Water System
- Station Service Water System
- Residual Heat Removal System Service Cooling Water System (redundant)
- Radioactive waste liquid effluent

Each process liquid radioactivity monitoring channel is identical, and is either an in-line or off-line unit as described previously in this chapter

Table 9.7-2 provides an overview of monitored systems including liquid channels.

There are few fundamental differences between BWRs in the channels or the systems they serve. Some plants do not have the valve operability permissives. These plants use the Liquid Radwaste System RMS for alarm and monitoring functions only.

9.7.2 Main Steam Line RMS

The main steam lines are located in the steam tunnel downstream of the outer isolation valves between the nuclear system and the turbine. The Main Steam Line RMS:

- Monitors the main steam line for gross release of fission products
- Initiates appropriate action to limit fuel damage and contain fission product release upon indication of fuel failure.

The Main Steam Line RMS is designed to give prompt indication of a gross release of fission products and is capable of detecting a gross release of fission products from the fuel under any anticipated operating combination of main steam lines. Upon detection of a gross release of fission products from the fuel, it initiates:

- Prompt reactor shutdown
- Closure of the main steam isolation valves
- Closure of the condenser mechanical vacuum pump line valve
- Termination of operation of the condenser mechanical vacuum pump
- Other action to contain fission products released from the fuel.

The main steam line radiation monitoring system consists of:

- Gamma sensitive ionization chambers
- Multi-decade radiation monitor rate meter
- Printer recorders
- Trip auxiliary unit

It interacts with:

- Reactor Protection System (RPS)
- Group Isolation Circuits
- Mechanical vacuum pump breaker and valving
- Condenser air tray valving
- Off gas system stack isolation valve.

Four instrumentation channels monitor the gross gamma radiation from the main steam lines. The detectors are physically located near the main steam lines just downstream of the outboard main steam line isolation valves in the space between the primary containment and the secondary containment walls. The detectors are geometrically arranged so that the system is capable of detecting significant increases in radiation level for a number of main steam lines in operation. Their location along the main steam lines enables the earliest practical detection of gross fuel failure.

Each channel consists of a gamma sensitive ionization chamber and related instrumentation channel components. The detector is mounted so it is exposed to gross gamma radiation within the main steam line. The detector feeds to a radiation monitor and recorder. This monitor has two upscale trips, one downscale trip, and a trip indicating an inoperative instrument.

9.7.3 Air Ejector Off Gas RMS

The Air Ejector Off Gas RMS is comprised of the:

- Off Gas RMS
- Off Gas Linear RMS
- Charcoal Bed Outlet RMS

The air ejector Off Gas RMS indicates approach to limits for the release of radioactive materials to the environs and initiates control of the off gas to ensure compliance with the limits.

The components of the off gas radiation monitoring system are divided in two identical channels consisting of:

- Gamma sensitive ionization chambers
- Multi-decade radiation monitor rate meter
- Printer (pen) recorders.

There are differences in types of detectors and sample location from plant to plant. These differences relate to the type of off gas system being used.

The system interacts with:

- Off Gas System
- RPS electrical busses
- Instrument bus

9.7.3.1 Off Gas RMS

The Off Gas RMS facilitates determination of the region of the core with leaky elements. This system continuously monitors the main condenser off gas for gamma radiation. The off gas samples are collected prior to treatment by the off gas treatment system. It functions to:

- Indicate when limits for the release of radioactive material to the environs are approached
- Initiate appropriate control of the off gas so that release limits are not exceeded.

The non-condensable gases are drawn from the main condenser by the steam jet-air ejector and are discharged to the off gas system piping. The radioactivity of the gas is measured by two detectors (typically ionization detectors) located in the off gas six-hour holdup volume. This measurement indicates and records continuously in the Control Room.

The relative location of the detectors in the off gas flow path is sensitive to short-lived radioactivity levels of nitrogen-16 and oxygen-19 in the main steam line that are normally relatively high, but quickly decay. To obtain a more accurate indication of the activity levels of radionuclides that affect the gas effluent through the stack release point, the air ejector off gas sample is monitored after a transportation delay of at least two minutes. The system monitors and records radiation levels, alarms off-normal conditions, and initiates auto isolation (after a time delay) of the Off Gas System if off normal conditions threaten release of the activity to the plant stack in such quantities that the release of activity to the plant stack could exceed the stack release limits. The radiation level of fission gases monitored by this channel is an indication of the general level of fuel cladding defects.

The heart of the system function is the off gas isolation capability. The isolation is affected through a logic channel that initiates a 15 minute time delay for corrective action by an operator after which it:

- Closes the Off Gas Isolation Valve
- Closes the Off Gas Line Drain Valves
- Isolates the Off Gas Pressurized Drain Tank from its pump

This channel includes an off gas vial sample panel where particulate and radioiodine samples are collected for laboratory analysis.

There are differences in the types of detectors and sample locations from one BWR to another. These differences relate primarily to the type of off gas system at the facility.

9.7.3.2 Off Gas Linear RMS

The Off Gas Linear RMS provides continuous gamma flux monitoring over a 9.5 decade range and is used as a diagnostic instrument that facilitates determination of the location of leaking fuel elements in a particular section of the reactor core. There are no alarms or trips associated with the Off Gas Linear RMS, but provides visual indication of the flux level. Fuel element failure raises the off gas gamma radiation levels. If fuel element failure is suspected, the control rods are moved in a programmed sequence. This causes localized changes in reactor core reactivity and in the rate of emission of radioactive noble gases from the leaking fuel element. The change in radiation level with control rod movement enables a determination of the approximate location of the leaking fuel.

9.7.3.3 Charcoal Bed Outlet RMS

The Charcoal Bed Outlet RMS monitors and records the radiation level of the off gas effluent from the charcoal bed outlet. It also provides alarms on off-normal conditions.

The Charcoal Bed Outlet RMS continuously monitors the radiation level of the gases vented to the plant stack by sampling a small portion of the bulk gas volume. The sample is extracted from the off gas flow immediately downstream of the off gas system charcoal beds. Gas flow through this system is ensured by the ram effect of the gas on the probe tips and by suction created by the vacuum pump. The gases are actively drawn into the system, past the process radiation sampler, which contains two redundant shielded scintillation detectors in series, and are returned to the inlet of the off gas system charcoal beds.

In its passage through the monitoring system, the larger airborne particulates and volatile radioiodine are removed by particulate and halogen (charcoal or silver zeolite) filters respectively before entry into the sampling chambers. The rate of gas flow is constantly measured and controlled by the pump and flow control assembly with a rotameter. A clogged filter or a defective vacuum pump annunciates an alarm. Off gas samples entering the sample panel are first heated to reduce the moisture condensate ahead of the particulate and halogen filter assembly. The temperature of the heater is regulated by a thermostat imbedded in the downstream end of the heater.

The halogen filter removes the radioiodine and must be changed periodically; therefore, this filter is mounted in a removable holder that can be opened without disassembly of the piping.

Immediately following the sample filter is a purge system, which allows switching from a gas sample to a purging atmosphere. The purging system consists of a three-way solenoid valve and an operate purge switch. During normal operation the switch is in the operate position keeping the solenoid valve energized and aligned to sample the off gas stream. Moving the switch to the purge position de-energizes the solenoid to block the off gas sample pipe and filtered air from the atmosphere is admitted to the test chambers. Process radiation samplers follow the purging valves. These are steel containers that house the scintillation detectors, the check source, and the piping necessary to route the off gas sample by the detectors. Installed radioactive check sources provide a means to confirm detection and calibration of the RMS.

The rate of gas flow through the system is constantly measured by a rotameter and controlled by the pump and a flow assembly, which consists of a vacuum pump, a pneumatically operated flow regulating valve, and filters. The flow rate is determined by the pumping effort of the vacuum pump, the opening of the pneumatically operated flow valve, and the condition of the filter. It establishes the pressure differential across the sample system.

Other deviations in the flow rate, which could be from filter holding or holing, affect the magnitude of the pressure differential and are sensed by the pneumatically operated flow regulating valve. The flow regulating valve responds by changing the size of the opening and, in turn, the flow rate through the system to compensate for the initial change in the line restriction to restore the flow rate to its set level.

A filter holder on the discharge of the vacuum pump is usually empty, but can be used to collect particulate samples when desired.

The Charcoal Bed Outlet RMS is designed to replace the Off Gas RMS and provide an isolation trip at the outlet of the charcoal beds in place of the current timer activated off gas isolation valve trip. The replacement was predicated on an off gas system back fit to reduce stack releases. The back fit added hydrogen recombiners and the charcoal beds as well as most other portions of the Off Gas System (except the air ejectors on the holdup volume, the particulate filters, and the stack). The addition of this equipment reduces the off gas flow rate substantially. This reduction in flow changes the holdup volume time from thirty minutes to over six hours. This additional volume permits the reaction time to be extended beyond 15 minutes before isolation of the off gas system is required. Moreover, the point of concern shifts to the outlet of the charcoal bed rather than the 30-minute holdup line.

The differences from one BWR to another in the Charcoal Bed Outlet RMS are minor if the BWR has an ambient temperature recombiner and charcoal adsorber off gas system.

9.7.4 Stack Gas RMS

The Stack Gas RMS indicates and records the emission rate of radioactive airborne material from the stack and alarms at a pre-established limit. The system generates alarms when the radiation level is too high or unrealistically low, but has no isolation functions. The components of the Stack-Gas RMS are the same as in the Charcoal Bed Outlet RMS. The only difference is the sample point. The Stack-Gas RMS draws a sample from an isokinetic probe located sufficiently high in the plant stack to ensure a representative sample of the release and returns the analyzed sample to the stack. This location provides monitoring of the effluent from:

- RECHAR system
- Steam packing exhausters
- Main condenser mechanical vacuum pump
- Standby Gas Treatment System Blower

9.7.5 Process Ventilation RMS

The Process Ventilation RMS monitors air and effluent from the:

- Control Room
- Reactor Building
- Refueling Floor

It is subdivided into the Secondary Containment Ventilation and the Control Room Ventilation RMS. The Secondary Containment RMS is further divided into Reactor Building Ventilation and Refueling Floor Zone subsystems. Because the Control Room is not a source of radioactive effluent, this part of the system is not discussed.

9.7.6 Secondary Containment Ventilation RMS

The secondary containment ventilation RMS monitors and continuously records radio-activity in the exhaust of the Reactor Building Ventilation System and the Refueling Zone. It includes two sets of exhaust system monitors. GM detectors are located on the refueling floor next to the fuel pool to monitor the refueling zone ventilation exhaust. The other set of GM detectors are located in the reactor zone ventilation exhaust. All other components are located in the main Control Room. It features high radioactivity alarms that:

- Isolate the affected ventilation system
- Provide an alternate flow path for secondary containment ventilation via the Standby Gas Treatment system.

The Secondary Containment Ventilation RMS channel and design features are usually similar at BWRs. The number of channels varies with secondary containment ventilation design schemes, which are influenced by space and area limitations and whether it is a multiple unit facility. Furthermore, their specific design is affected by progression in technology, i.e., later BWRs would tend to have solid state and digital systems rather than analog instrumentation.

Each secondary containment ventilation RMS channel has two trips. The upscale trip indicates high radioactivity and the downscale trip implies instrument trouble. If there is one upscale or two downscale trips, the affected zone is shutdown and the Standby Gas Treatment System is started. The High Radiation Signal is also sent to the Primary Containment and Reactor Vessel Isolation Control System to close the various primary containment purge and exhaust paths.

The refueling zone ventilation RMS monitors the airborne radioactivity in that area. A high radioactivity alarm shuts downs the Refueling Zone Ventilation System and activates the Standby Gas Treatment System.

The Reactor Building RMS monitors airborne radioactivity from the reactor zone that passes through Reactor Building Ventilation System exhaust duct. It alarms if the radioactivity level reaches a pre-established point.

When a high level alarm is reached, the monitoring system:

- Shuts down the Reactor Ventilation System
- Isolates the Reactor Building
- Activates the Standby Gas Treatment System
- Closes the primary containment purge and vent valves.

9.7.7 Plant Ventilation Exhaust RMS

The Plant Ventilation Exhaust RMS monitors and records the release of airborne and gaseous radioactive materials from plant to the environs. It consists of three subsystems:

- Reactor and Turbine Building Ventilation Exhaust RMS
- Radwaste Building Ventilation Exhaust RMS
- Turbine Building Ventilation Exhaust RMS

The first monitors a composite sample from the normal ventilation exhaust of the turbine building, reactor zone, and refueling zone. The second monitors the normal ventilation exhaust from the radwaste building. The third monitors the upper atmosphere of the turbine building near the turbine building roof ventilation intakes.

Each of these subsystems consists of an assembly that monitors activity of:

- Total gas
- Radioiodine
- Airborne particulates

High activity or monitor malfunction is alarmed in the main Control Room.

Each individual subsystem includes a built-in check source for each monitor. The components of the subsystems are the same except for the sampling points. Samples are drawn through isokinetic probes in a single tube manifold from the respective exhaust duct(s). The sample first passes though a steeped paper type particulate filter that is continuously monitored by a beta scintillation detector. Next, the filtered sample passes through a fixed carbon (or silver zeolite) filter that is continuously monitored by a gamma scintillation detector. The sample stream then passes though a gas counting chamber that uses a beta detector to monitor for noble gases. Subsequently, it is exhausted by a rotary lobe compressor through a muffler to the environment.

In general, the Plant Ventilation Exhaust RMS does not differ from BWR to BWR except as related to differences in site specific ventilation system design.

Table 9.2-1 RETS Requirements for Radioactive Liquid Effluent Monitoring Instrumentation at BWRs

Gross Radioactivity Monitors Providing Alarm and Automatic Termination of Release

- Liquid Radwaste Effluent Line

Gross Beta or Gamma Radioactivity Monitoring Providing Alarm, But Not Automatic Termination of Release

- Service Water System Effluent Line
- Component Cooling Water System Effluent Line

Flow Rate Measurement Devices

- Liquid Radwaste Effluent Line
- Discharge Canal

Radioactivity Recorders

- Liquid Radwaste Effluent Line

Table 9.2-2 RETS Requirements for Radioactive Airborne Effluent Monitoring Instrumentation at BWRs

Main Condenser Off-Gas Treatment System Effluent Monitoring

- Noble Gas Activity Monitor (with alarm and automatic termination of release)
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Main Condenser Off-Gas Treatment System Explosive Gas Monitoring System

- Hydrogen Monitor
- Hydrogen or Oxygen Monitor.

Reactor Building Ventilation/ Purge Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Main Stack Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Turbine Building Ventilation Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Auxiliary Building Ventilation System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Fuel Building Area Ventilation Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Radwaste Area Ventilation Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Turbine Gland Seal Condenser Vent and Mechanical Vacuum Pump Exhaust Monitoring System

- Noble Gas Activity Monitor
- Iodine Sampler
- Particulate Sampler
- Effluent System Flow Rate Measuring Device
- Sampler Flow Rate Measuring Device.

Condenser Air Ejector Radioactivity Monitor

- Noble Gas Activity Monitor (prior to input to holdup system).

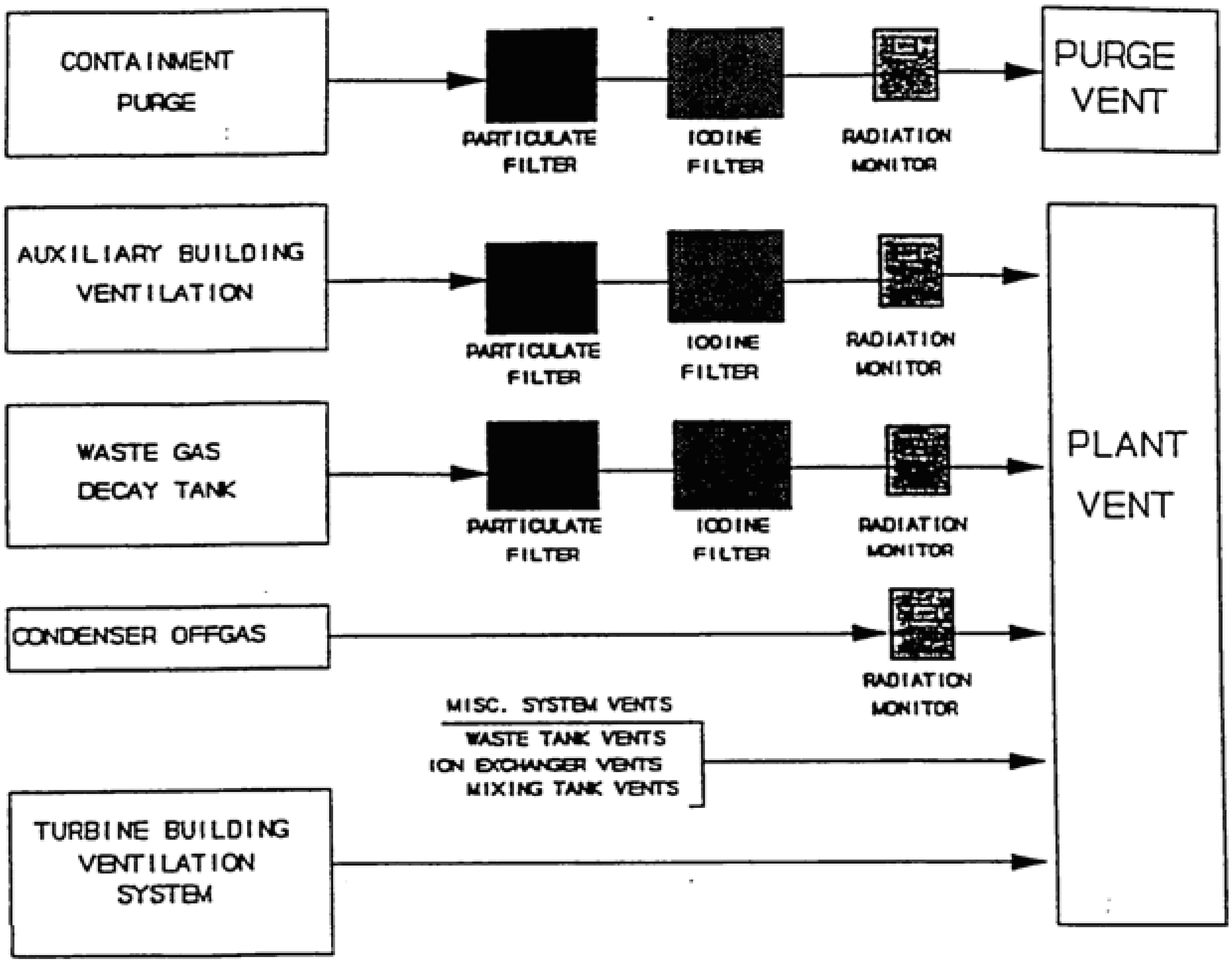

Figure 9.4-1 Gaseous Effluent Pathways from a PWR

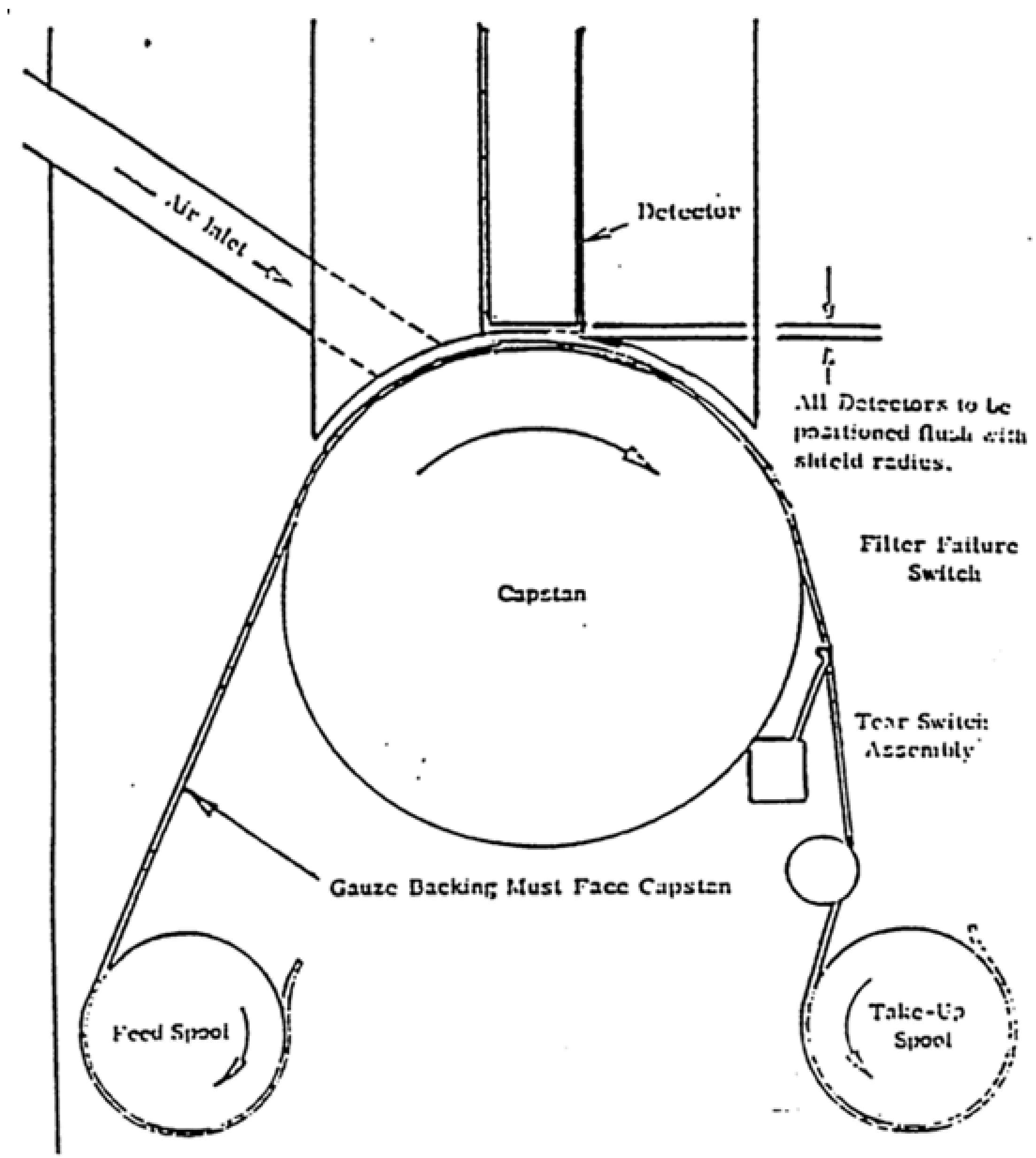

Figure 9.4-2 Moving Filter Particulate Monitor

Table 9.4-1. Listing of PWR Effluent Monitors

Location	Detector Type	Automatic Action	
Containment Air Particulate*	γ scintillation	10-9 to 10-6 µCi/cc	Isolates containment purge and exhaust if running. Isolates relief and vacuum lines. Shifts containment fan coolers to accident mode.
Containment Noble Gas Monitor	β scintillation	10-6 to 10-3 µCi/cc	Same as above
Purge Exhaust Monitor *	APD, G-M Tube,	10-6 to 10-2 µCi/cc	Isolate containment purge supply and exhaust valves if running.
Auxiliary Building Ventilation *	β and γ scintillations	10-6 to 10-2 µCi/cc	Initiates auxiliary building isolation. Diverts to gas treatment system.
Plant Vent Stack Monitor *	G-M Tube	10-6 to 10-2 µCi/cc	Alarm function only
Main Control Room Intake Air Particulate	γ scintillation	10-6 to 10-2 µCi/cc	Isolates main control room ventilation
Condenser Air Ejector Gas	G-M Tube		Alarm function only
Steam Generator Blowdown Liquid *	γ scintillation	10-5 to 10-2 µCi/cc	Alarm function only
Component Cooling Water System *	γ scintillation	105 to 10-2 µCi/cc	Closes CCW surge tank vent exchanger
Service Water Effluent Discharge	γ scintillation	10-6 to 10-2 µCi/cc	Alarm function only
Waste Disposal System Liquid Discharge *	γ scintillation, G-M Tube	10-6 to 10-2 µCi/cc	Closes effluent discharge to the environment
Gas Decay Tank Effluent Discharge	β scintillation, G-M Tube	10-6 to 10-3 µCi/cc	Closes effluent discharge to the environment
Seismic Class I Pipe Tunnel *	β&γ scintillation	10-11 to 10-6 µCi/cc	

* Typically required by Technical Specifications.

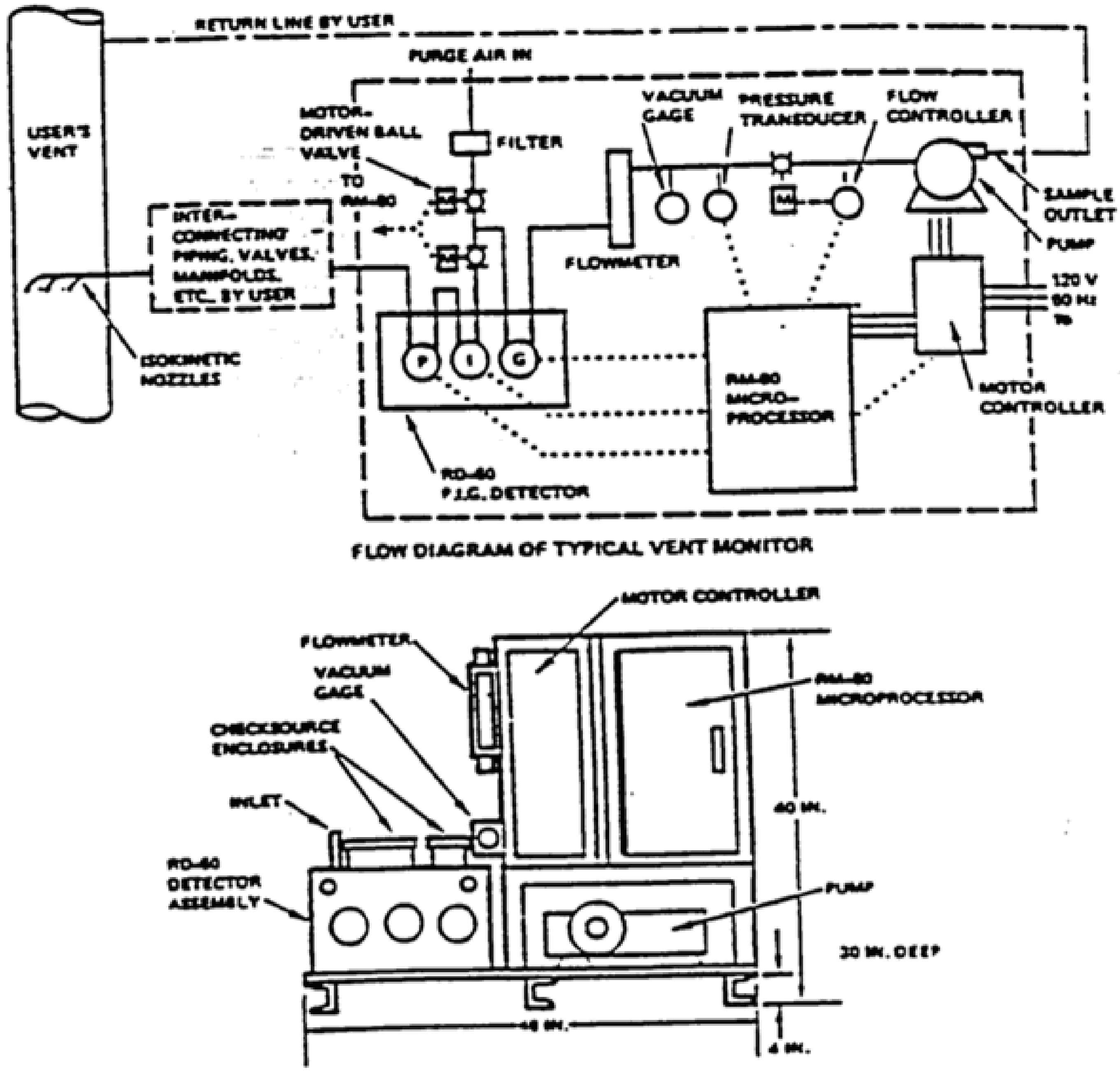

Figure 9.6-1 Typical Vent Sampler/Monitor

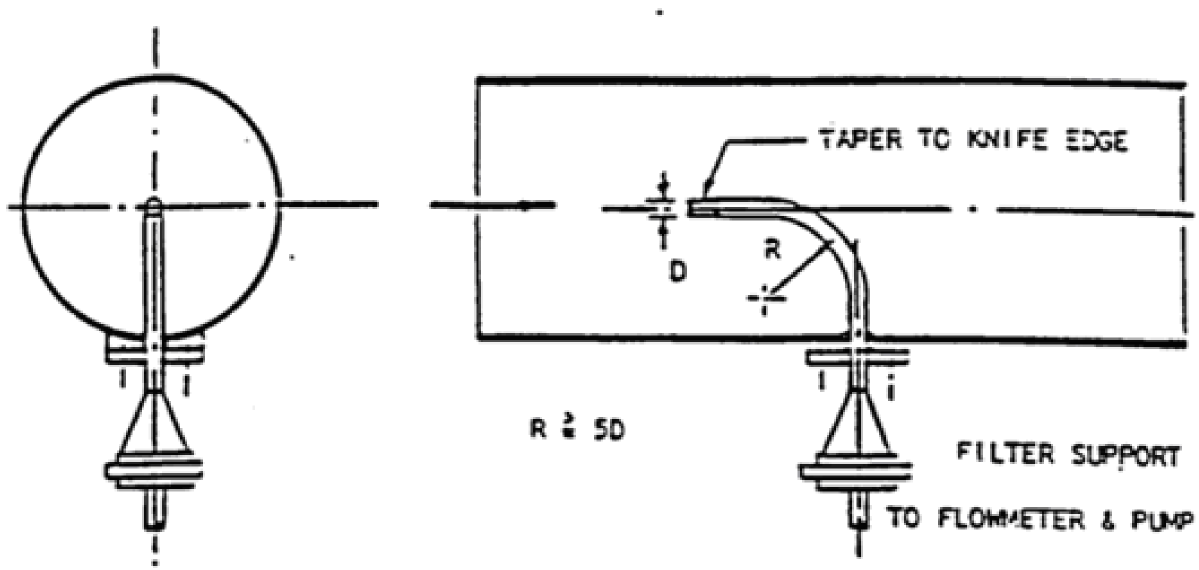

Figure 9.6-2 Single Circular Probe Sampler

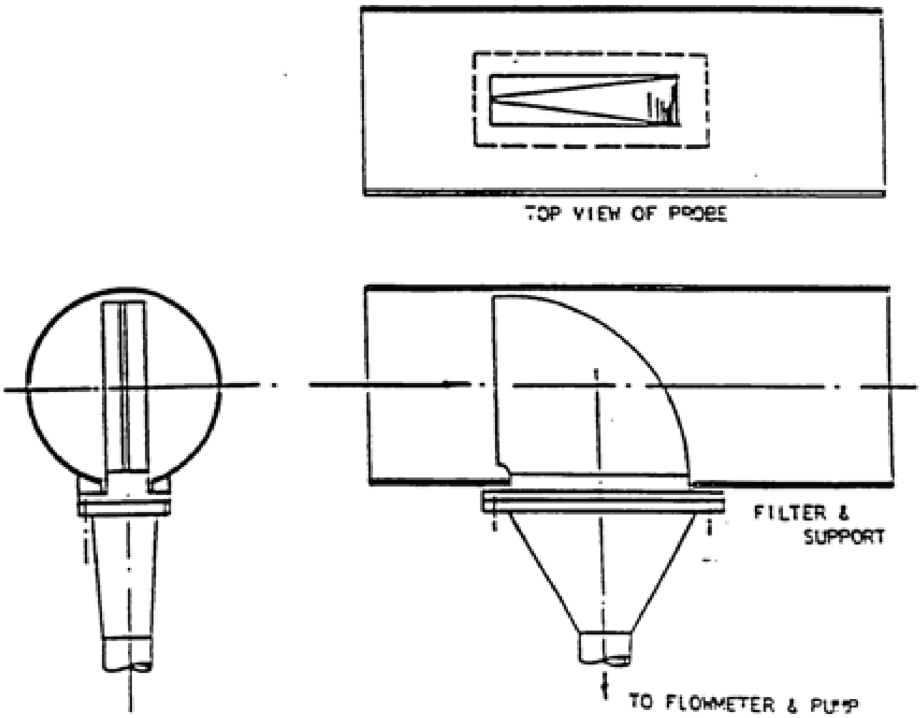

Figure 9.6-3 Rectangular Slot Probe Sampler

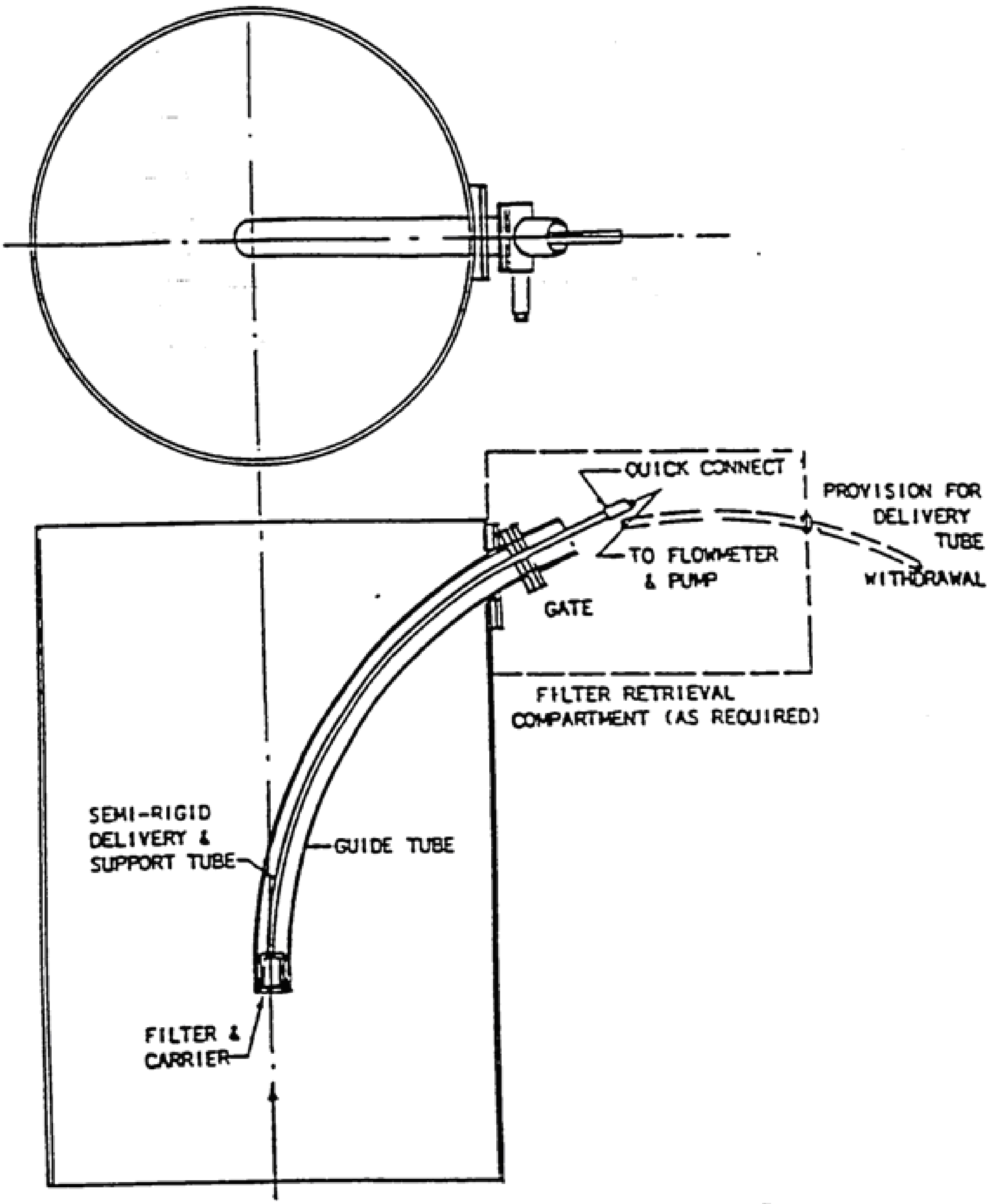

Figure 9.6-4 Single Probe Retrievable Filter Gas Stream Sampler

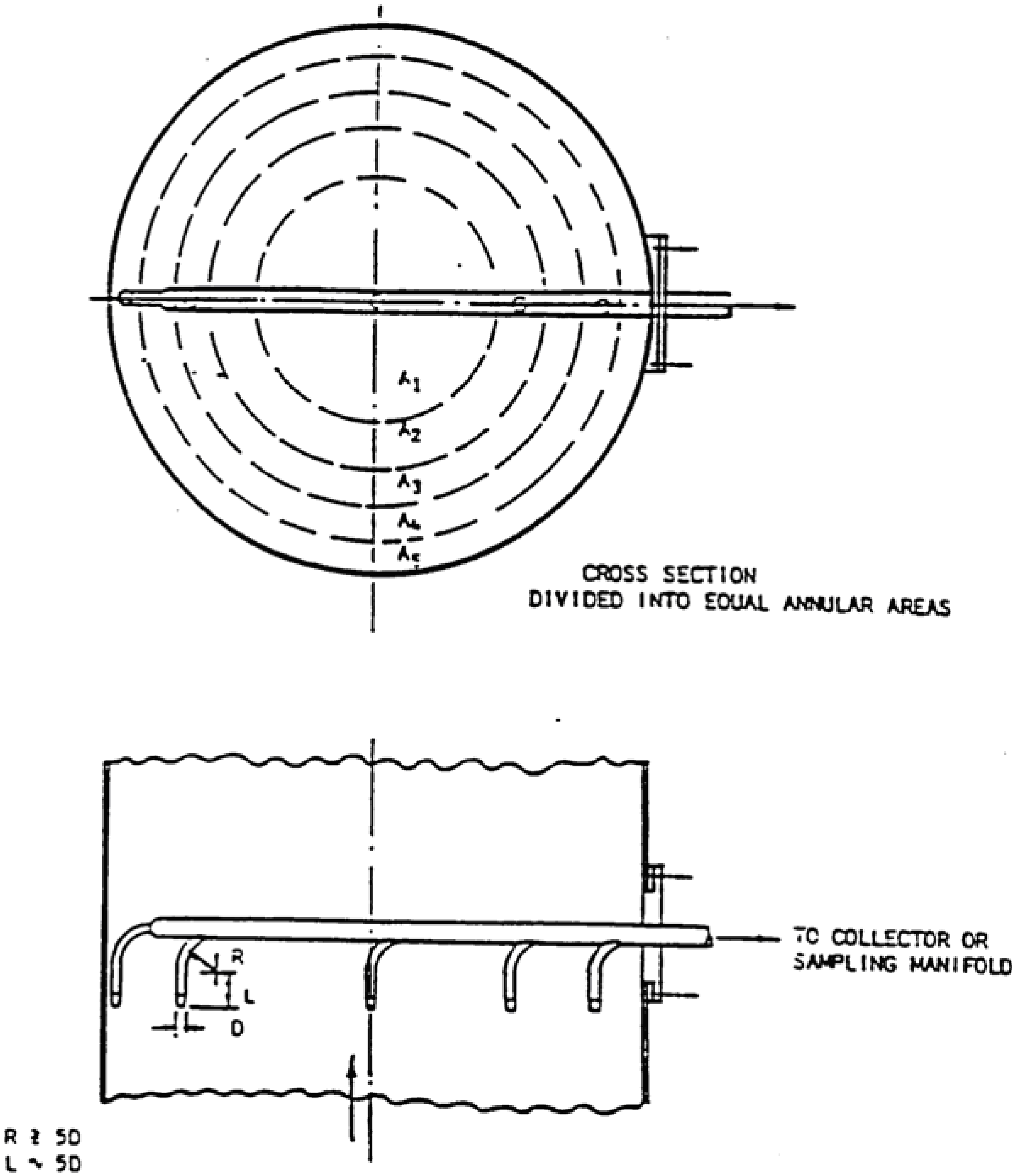

Figure 9.6-5 Multiprobe Sampler for Large Duct or Stack

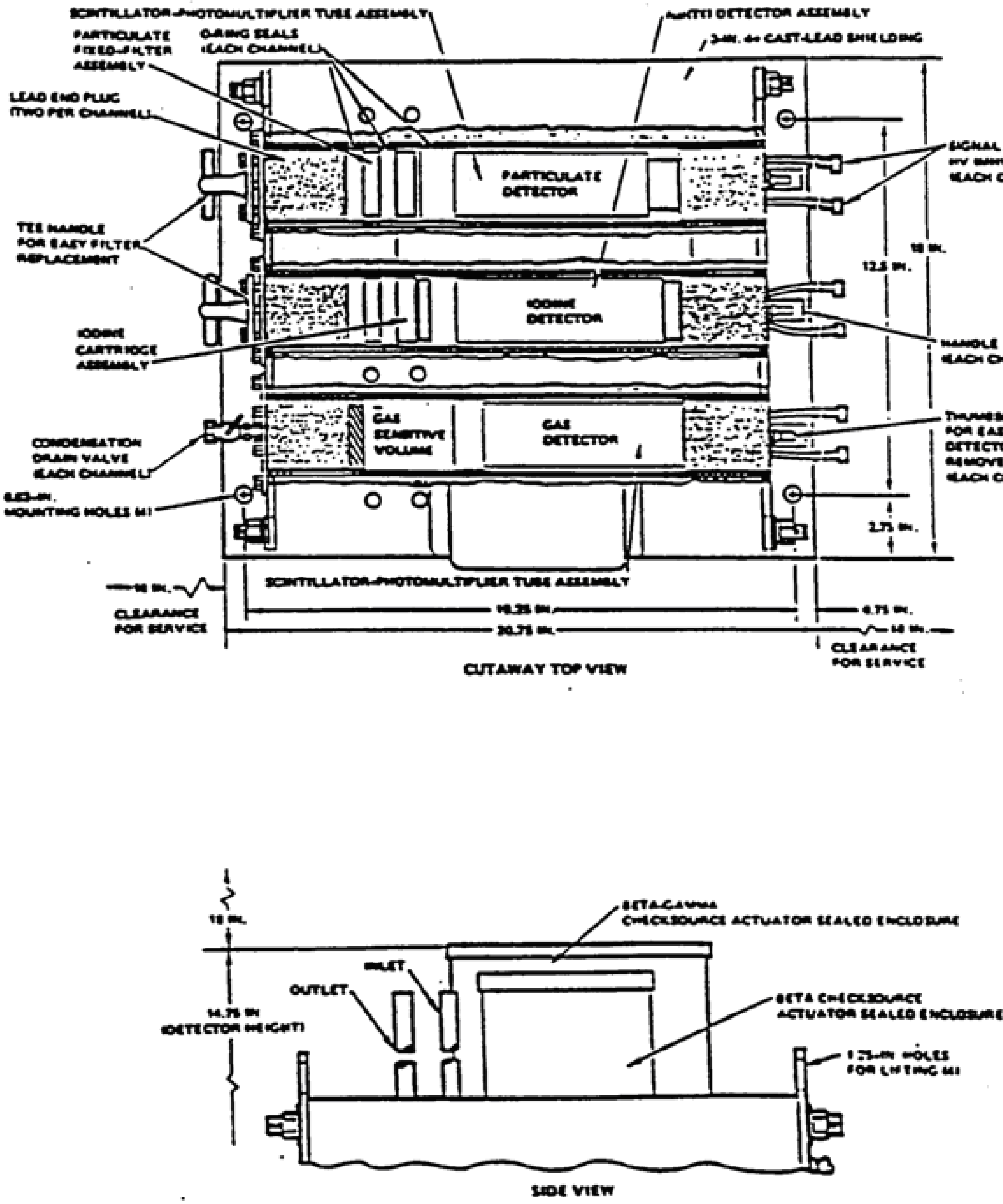

Figure 9.6-6 Cutaway Views of Fixed Filter Airborne Radioactivity Monitor

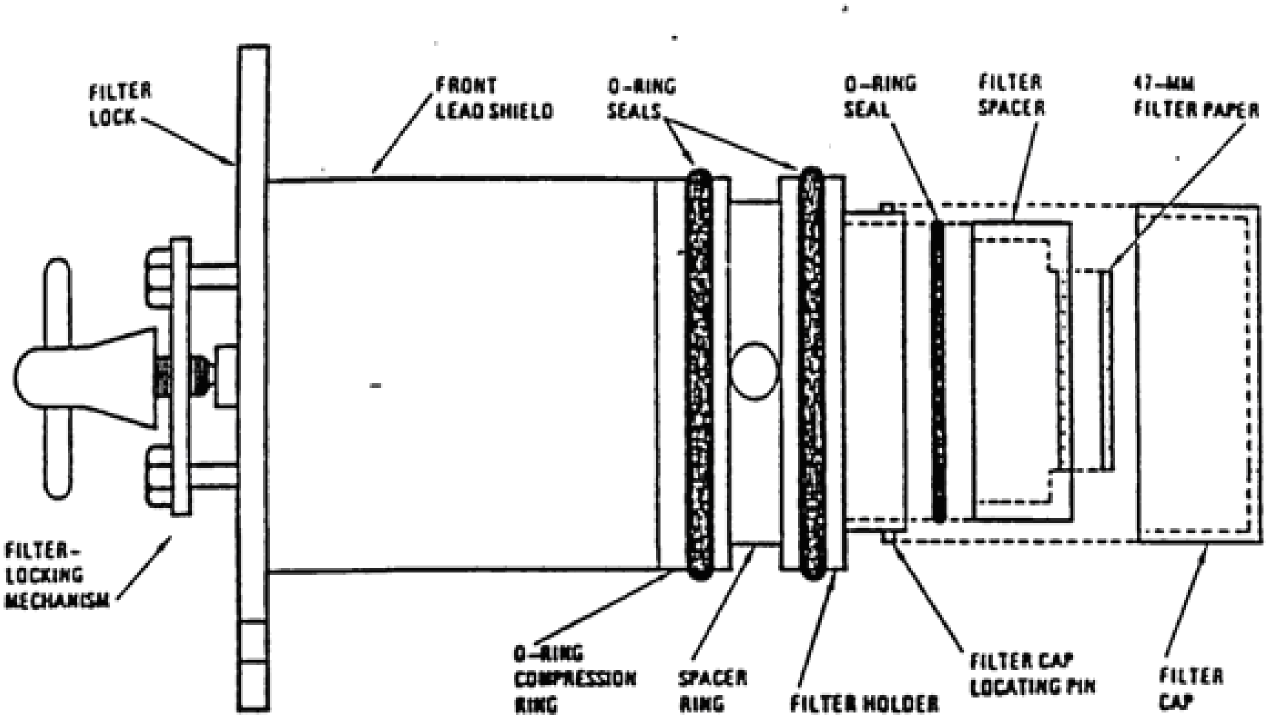

Figure 9.6-7 Particulate Filter Replacement Assembly

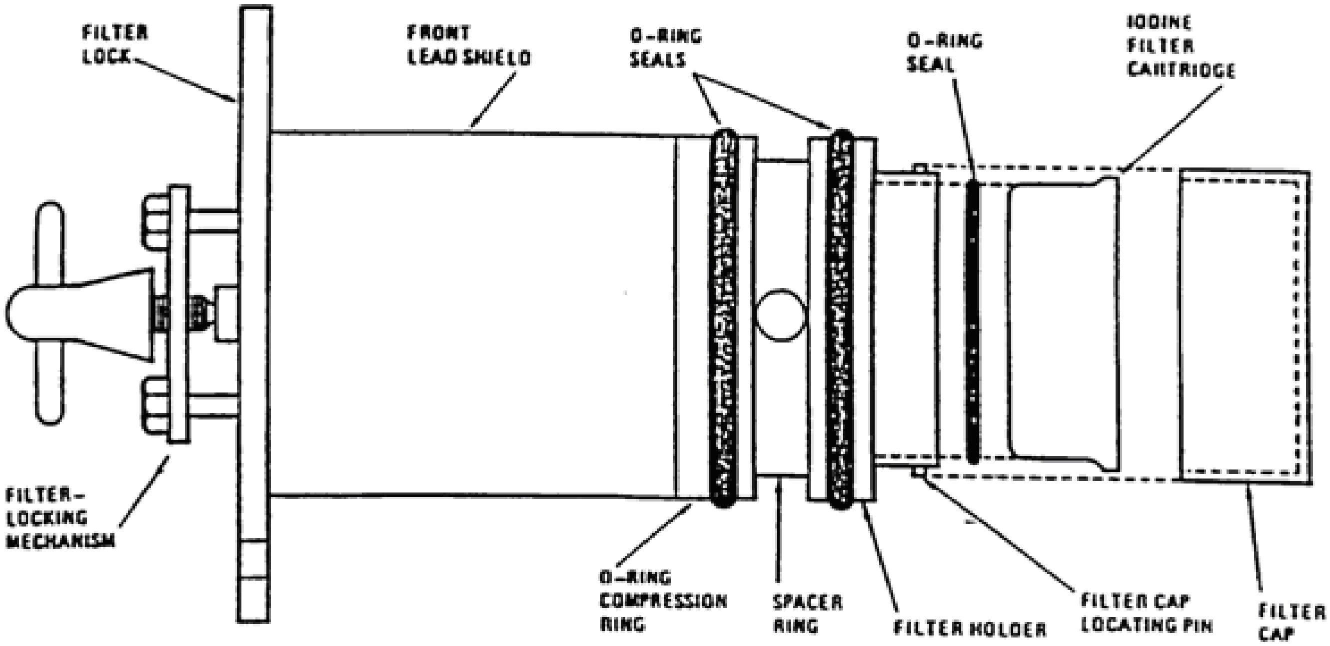

Figure 9.6-8 Iodine Filter Cartridge Replacement Assembly

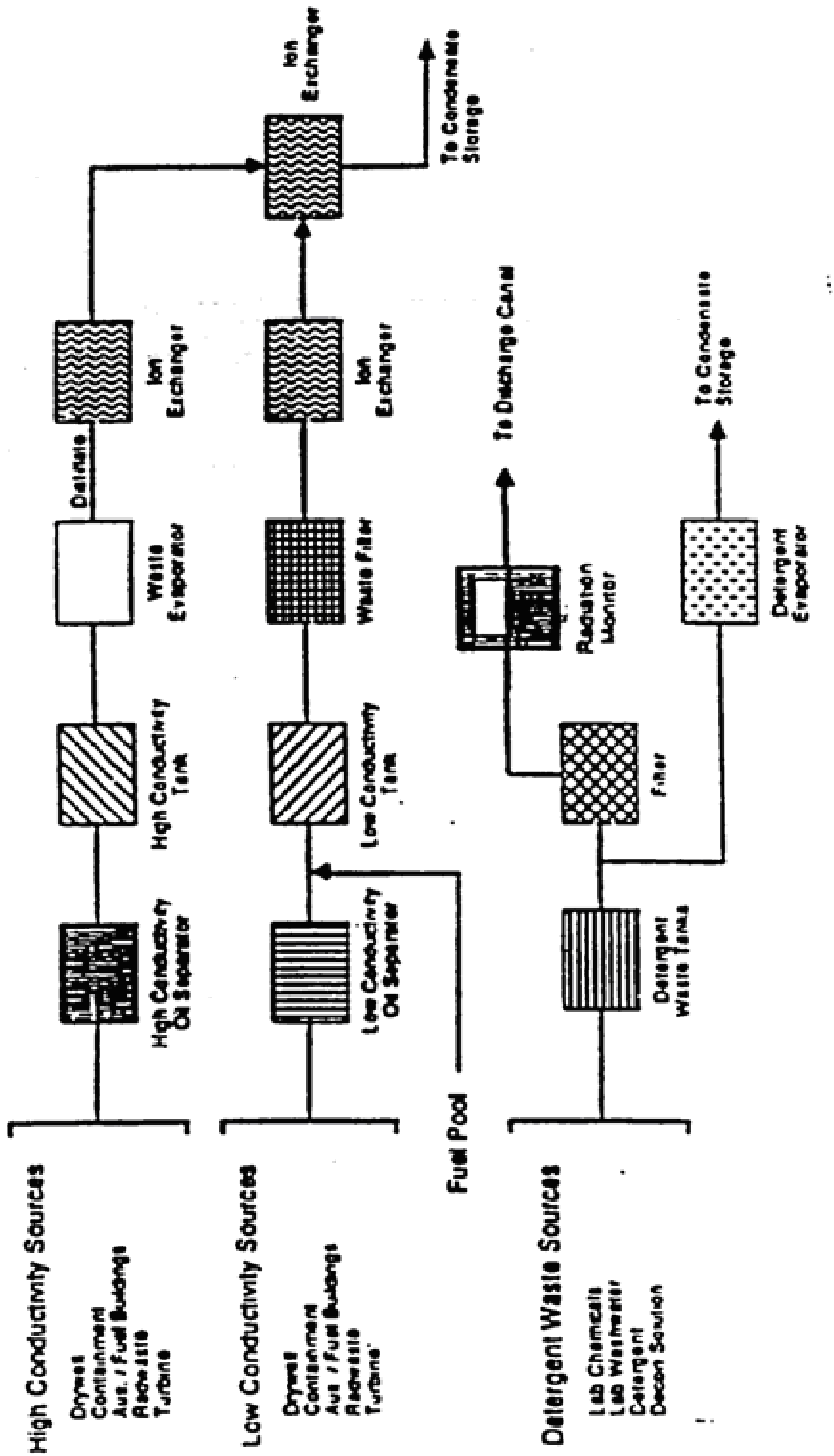

Figure 9.7-1 BWR Radioactive Liquid Release Pathways

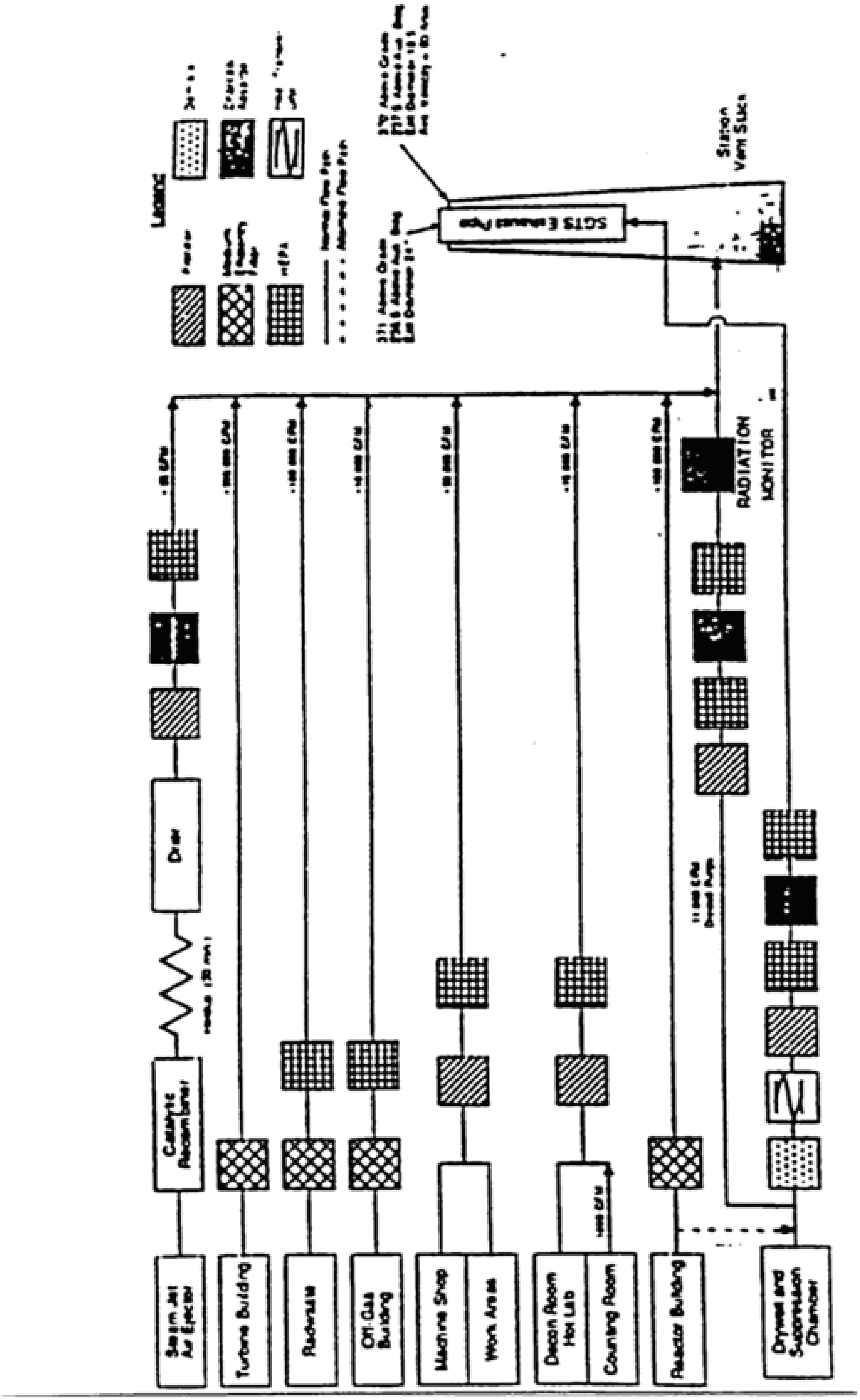

Figure 9.7-2 BWR Radioactive Airborne Release Pathways

Table 9.7-1 BWR Process and Effluent Radiation Monitoring System (Gaseous and Particulate)

Monitored Process	Channels	Type	Range	Configuration	Location
Plant Vent Elevated Discharge	1	Particulate, Iodine, GM	$10 - 10^6$ cpm	Off-line	Sample Line
Radwaste Building Ventilation Exhaust	8	GM	0.01 - 100 mR/hr	Off-line	Exhaust ducts
Auxiliary Building HVAC	2	GM	0.01 - 100 mR/hr	Off-line	Exhaust duct upstream of intake ventilation isolation valve
Containment Ventilation	1	GM	0.01 - 100 mR/hr		
Containment HVAC	4	GM	0.01 - 100 mR/hr	Local area	Exhaust duct upstream of exhaust ventilation isolation valve
Control building HVAC	6	GM	0.01 - 100 mR/hr	Off-line	Intake duct upstream of intake ventilation isolation valve.
Fuel Building HVAC	4	GM	0.01 - 100 mR/hr	Off-line	Sample line
Off-Gas Vent Exhaust	1	Particulate, Iodine, GM	$10^4 - 10^6$ cpm	Off-line	Sample line
Off-Gas Post-Treatment	2	Particulate, Iodine, GM	$10^1 - 10^6$ cpm	Off-line	Sample line
Off-Gas Pretreatment Gas	1	GM	$10^0 - 10^6$ mR/hr	Adj. to sample chamber	Sample line
Main Steamline	4	γ Ion Chamber	$1 - 10^6$ mR/hr	Adjacent to sample line	Immediately downstream of plant main steam line isolation valve
Shield Annulus HVAC	2	GM	0.01 - 100 mR/hr	Off-line	Exhaust duct upstream of exhaust vent isolation valve.
Containment Space (refueling mode)	4	GM	0.01 - 100 mR/hr	Local area	Locally in upper containment.
Standby Gas Treatment	2	GM	0.01 - 100 mR/hr	Off-line	SBGTS exhaust air duct downstream of exhaust and heat removal.
Carbon Bed Vault	1	GM	$10^o - 10^6$ mR/hr	Off-line	Carbon bed vault.
CRD Maintenance Area	1	GM	0.01 - 100 mR/hr	Off-line	Exhaust duct.
Battery Room Exhaust	1	GM	0.01 - 100 mR/hr	Off-line	Exhaust duct .
Radwaste Building	1	GM	0.01 - 100 mR/hr	Off-line	Exhaust duct.

Table 9.7-2 BWR Radioactive Liquid Radiation Monitoring Systems

Monitored Process	No. of Channels	Detector Type	Sample Line or detector Location	Channel Range	Warning Alarm	
Main steamline	4	γ ion chamber	Immediately downstream of main steamline isolation valve.	1 - 10^6 mR/hr	A*,B	TS
Auxiliary building HVAC	2	GM	Exhaust duct upstream of intake ventilation isolation valve	0.01 to 100 mR/hr	A,B	TS
Control building HVAC	6	GM	ntake duct upstream of intake ventilation isolation valve	0.01 to 100 mR/hr	A,B	TS
Fuel building HVAC	4	GM	Sample line	0.01 to 100 mR/hr	C	TS
Shield annulus HVAC	2	GM	Exhaust duct upstream of exhaust vent valve isolation valve	0.01 to 100 mR/hr	A,B	TS
Standby gas	2	GM	SBGTS exhaust air duct downstream of exhaust and heat removal fans and dampers	0.01 to 100 mR/hr	A,B	TS
Containment space (refueling)	4	GM	Locally in upper containment	0.01 to 100 mR/hr	A,B	TS
Liquid radwaste effluent	1	Scint.	Sample line	10 to 10^6 cpm	A,B	TS
Closed cooling water system	1	Scint .	Sample line	10 to 10^6 cpm	A	N/A
Essential service water sys., RHR	2	Scint .	Sample line	10 to 10^6 cpm	A	N/A
Offgas post-treatment	2	GM	Sample line	10 to 10^6 cpm	D	TS
Offgas pre-treatment	1	GM	Sample line	1 to 10^6 mR/hr	B	N/A
Carbon bed vault	1	GM	Carbon bed vault	1 to 10^6 mR/hr	B	N/A
Plant vent discharge	1	GM	Sample line	10 to 10^6 cpm	A	TS
Radwaste building vent	8	GM	Exhaust ducts	0.01 to 100 mR/hr	C	TS
Offgas vent	1	GM	Sample line	10 to 10^6 cpm	A,B	TS
Service water	1	Scint.	Sample Line	10 to 10^6 cpm	A	TS
Battery room exhaust	1	GM	Exhaust duct	0.01 to 100 mR/hr	A	N/A
CRD maintenance area	1	GM	Exhaust duct	0,01 to 100 mR/hr	A	N/A
Radwaste bldg. control room	1	GM	Exhaust duct	0.01 to 100 mR/hr	A	N/A

Legend
* Full power
A: Above background
B: Below trip point
C: At quarterly TS level
D: Technical Specification Report Level
TS: Technical Specification
N/A Not applicable