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The Monitoring System of the Tritium Research Laboratory, Sandia Laboratories, Livermore, CA

W. R. Wall, R. S. Hafner, D. L. Westfall, R. D. Ristau

Sandia Laboratories

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THE MONITORING SYSTEM OF THE TRITIUM RESEARCH LABORATORY, SANDIA LABORATORIES, LIVERMORE, CALIFORNIA

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ABSTRACT

Automated tritium monitoring is now in use at the Tritium Research Laboratory (TRL). Betatec 100 tritium monitors, along with several Sandia-designed accessories, have been combined with a PDP 11/40 computer to automatically read and record tritium concentrations of room air, containment. and cleanup systems. Each individual monitoring system, in addition to a local display in the area of interest, has a visible/audible display in the control room. Each system is then channeled into the PDP 11/40 computer, providing immediate assessment of the status of the entire laboratory from a central location. Measurement capability ranges from $\mu Ci/m^3$ levels for room air monitoring to kCi/m^3 levels for glove box and cleanup systems monitoring.

In this report the overall monitoring system and its capabilities are discussed, with detailed descriptions given of monitors and their components.

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SANDIA LABORATORIES, LIVERMORE, CALIFORNIA

I. Introduction

The Tritium Research Laboratory (TRL) is used for experimental work with isotopes of hydrogen and their compounds. It was designed to conform to the Department of Energy philosophy, which is to limit the release of any radioactive material to a level "as low as reasonably achievable." In order to meet this goal the philosophy of operation at the TRL is "containment and cleanup."

In order to contain any accidental release, all experimental work with tritium takes place in sealed glove boxes. These glove boxes are connected to two cleanup systems: the Gas Purification System (GPS) and the Vacuum Effluent Recovery System (VERS).

The monitoring system of the TRL was designed to ensure the safe and effective use of these systems, and to provide personnel and environmental protection. The system includes a monitoring capability from kCi/m^3 levels for glove box and cleanup system monitoring, to $\mu Ci/m^3$ levels for room air and stack effluent monitoring. Each tritium monitor is interfaced to the TRL control computer, which continuously scans each of the tritium monitors, assesses any hazards based upon the monitor readings, and takes the appropriate action according to the hazard involved.

The monitoring system operates automatically. Action taken by the computer is determined by the location of the monitor and by the monitoring subsystem involved (Figure 1). The monitoring subsystems are: (1) Room Air Monitoring, (2) Glove Box Monitoring, (3) GPS Monitoring, (4) VERS Monitoring, and (5) Stack Effluent Monitoring.

This report is divided into five major sections. In Section II a general description of the various monitoring systems is given. Section III is a component description--electrical and mechanical--of the monitors. Section IV gives the component makeup of the basic systems and their subsystems. The TRL control computer and guard alarm interface are discussed in Section V.

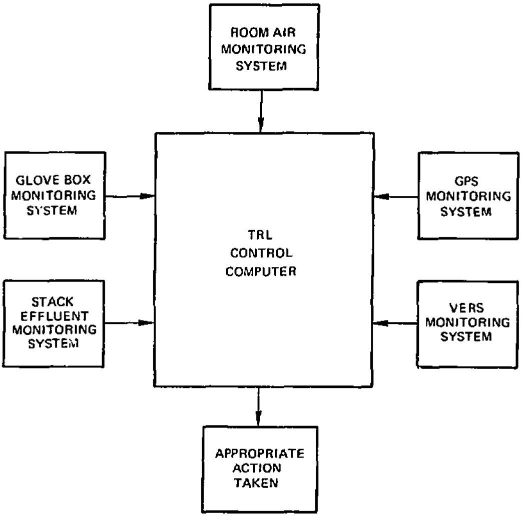


Figure 1. Schematic of the Overall Tritium Monitoring System

II. Monitoring-System General Description

A. Room Air Monitoring

In order to protect personnel working in the TRL the tritium monitors used must be capable of measuring the maximum permissible concentration (MPC) of tritium in its two predominant forms, tritium gas (T_2) and tritiated water vapor (HTO). For a 40-hour week, the MPC for T_2 is 2 mCi/m^3. The MPC for HTO, for a 40-hour week, is 5 $\mu Ci/m^3$. Thus the room air tritium monitors in the TRL are designed to read from 1 $\mu Ci/m^3$ to 20 Ci/m^3, and monitor the room air continuously.

Each room has been provided with a selectable, multi-inlet system, which helps reduce the need for portable monitors. In order to reduce the response time of the monitor (1) the diameter of the inlet lines has been kept small (nominally 1/4"), (2) these lines have been kept as short as possible, and (3) the entire detection system has been mounted in the room of interest.

Each room has two readout devices (visible/audible displays), one mounted in the room and one at the entrance to the room, providing the users with the current status of their laboratory. Each room air monitor, as well as all other tritium monitors, also has a visible/audible display located in the control room, which provides the TRL operations staff with the capability of immediate assessment of the status of the entire laboratory.

B. Glove Box Monitoring

The sealed glove boxes in which the experimental work with tritium takes place are 4 feet wide, 8 feet high, and 8 feet long. Each has been equipped with viewing windows, glove ports, access doors, pass-through port, heat exchanger, vacuum pumps, pressure controls, fire alarm, and a tritium monitor.

The atmosphere of each glove box is continuously monitored, and in the event the tritium concentration exceeds a pre-determined limit, valves connecting the glove box to the GPS will be opened and the glove box atmosphere will be processed by the GPS.

The range of the tritium monitor selected for use for glove box monitoring is based upon (1) the potential for gram amounts of tritium being involved in a given experiment and (2) the allowable leak rates of experimental equipment within the box. Glove box tritium monitors are capable of reading from 1 mCi/m^3 to 20 kCi/m^3.

C. <u>Gas Purification System Monitoring</u>

The GPS is capable of reducing the tritium concentration in a glove box to less than one part per billion (less than 2.5 mCi/m^3). As the atmosphere of the glove box is circulated through the GPS, the tritium is oxidized on a catalyst bed. This tritiated water is then collected on a series of molecular sieve dryers.

Range selection of the monitors used on the GPS is based on tritium concentrations which may be present at different points throughout the system. The influent comes from a glove box; therefore, the GPS inlet monitor is identical to a glove box monitor, with a range from 1 mCi/m^3 to 20 kCi/m^3. This monitor serves a dual purpose: first, it provides an input to a totalizer which records the total amount of tritium processed by the GPS; second, it serves as a cross check of the appropriate glove box monitor.

There are four other monitors associated with the GPS. These are: the monitor between dryers 2 and 3 and the GPS exhaust monitor, both with a range from 1 $\mu Ci/m^3$ to 20 Ci/m^3; the monitor between dryers 1 and 2, with a range from 10 $\mu Ci/m^3$ to 200 Ci/m^3; and the dryer regeneration system monitor, with a range from 1 mCi/m^3 to 20 kCi/m^3.

D. Vacuum Effluent Recovery System Monitoring

The VERS collects the effluent from all vacuum systems in the TRL. These gases are collected in a tank and the tritium concentration is monitored. Activity below the cleanup capability is exhausted to the stack. Activity above this concentration is processed through the VERS, which removes tritium by the same process, and to the same level, as the GPS.

There are four tritium monitors associated with the VERS. Monitors at the 10-ft^3 monitoring tank, the non-contaminated hold tank, and the VERS exhaust each have a range from 1 $\mu Ci/m^3$ to 20 Ci/m^3. The contaminated hold tank monitor has a range from 10 $\mu Ci/m^3$ to 200 Ci/m^3.

E. Stack Effluent Monitoring

The tritium concentration in the stack effluent is monitored using two monitors with overlapping ranges. Each of these monitors provides an input to a totalizer which records the total amount of tritium exhausted up the stack. The range of the low-level stack effluent monitor is from 1 $\mu Ci/m^3$ to 20 Ci/m^3. The range of the high-level stack effluent monitor is from 100 $\mu Ci/m^3$ to 2 kCi/m^3.

III. Component Description

The monitoring system can be described in terms of its electronic and mechanical components. All of the electronic and the majority of the mechanical components in the monitors throughout the TRL are interchangeable with minor modifications. Along with each component, the appropriate modifications will be described.

A. Electronic Components

1. Basic Tritium Monitor -- The tritium monitors are Overhoff and Associates, Betatec 100 tritium monitors, designed and built to Sandia specifications. Each is an auto-ranging instrument, capable of reading from 1 to 1999 units on each of five ranges (overall range: 1 to 1.99×10^7 units per instrument). Each monitor consists of an ion chamber with vibrating-reed electrometer and a meter module with a digital readout (Figure 2).

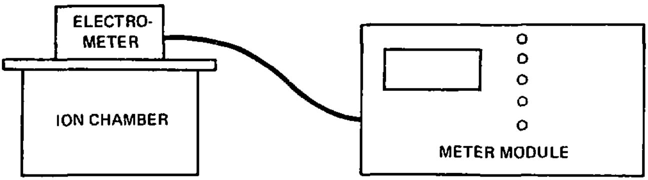


Figure 2. Schematic of a Basic Tritium Monitor

2. Ion Chamber -- The ion chamber provides a known volume in which tritium concentration is measured. The three ion-chamber configurations used in the TRL are (Figure 3):

1) Dual two-litre ion chambers, for low-level monitoring, including room air and low-level stack effluent. Measurable concentration is 1 $\mu Ci/m^3$ to 20 Ci/m^3.

2) Single two-litre ion chambers, for intermediate-level monitoring at two levels, including high-level stack effluent, and portions of the GPS and VERS. Measurable concentrations are 10 $\mu Ci/m^3$ to 200 Ci/m^3, and 100 $\mu Ci/m^3$ to 2 kCi/m^3.

3) Dual 20-cm^3 ion chambers, for high-level monitoring, including portions of the GPS and all glove boxes. Measurable concentration is 1 mCi/m^3 to 20 kCi/m^3.

All ion chambers, regardless of configuration, must meet a leak rate-specification of 10^{-6} std cm^3/sec. This allows any ion chamber to be used on any tritium monitoring system in the TRL.

3. Electrometers -- A vibrating-reed electrometer is mounted on each ion chamber. The electrometer provides a voltage to the meter module as a function of the tritium concentration in the ion chamber. (The current required in a dual, two-litre ion chamber for a reading of 1 $\mu Ci/m^3$ is 2 x 10^{-15} amperes.) All electrometers are interchangeable, except for their feedback resistors. These resistors provide the desired range selection, and are matched to the ion chamber configuration.

4. Meter Modules -- The information from the ion chamber and electrometer is supplied to the meter module (Figure 4). The meter module provides visual display information, electronic information for accessories, and power supply

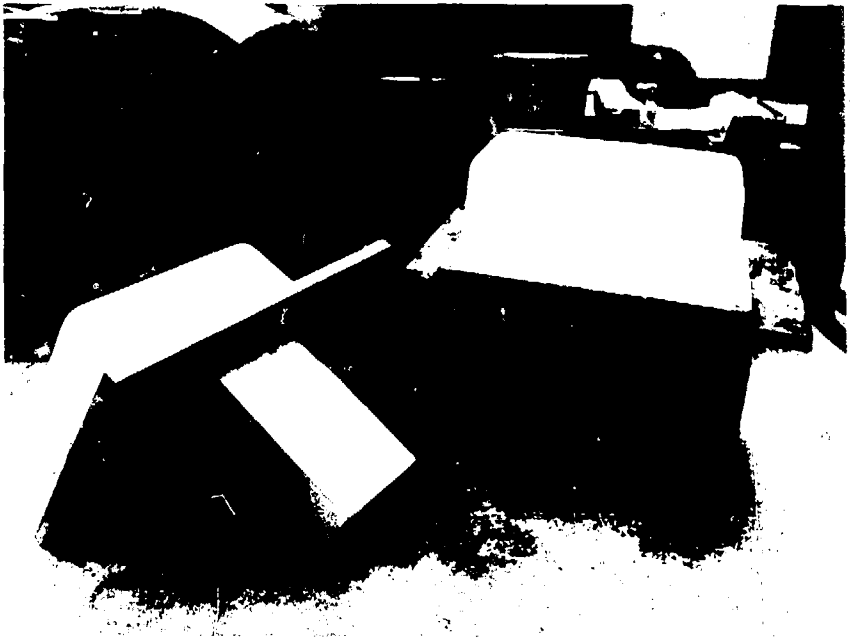
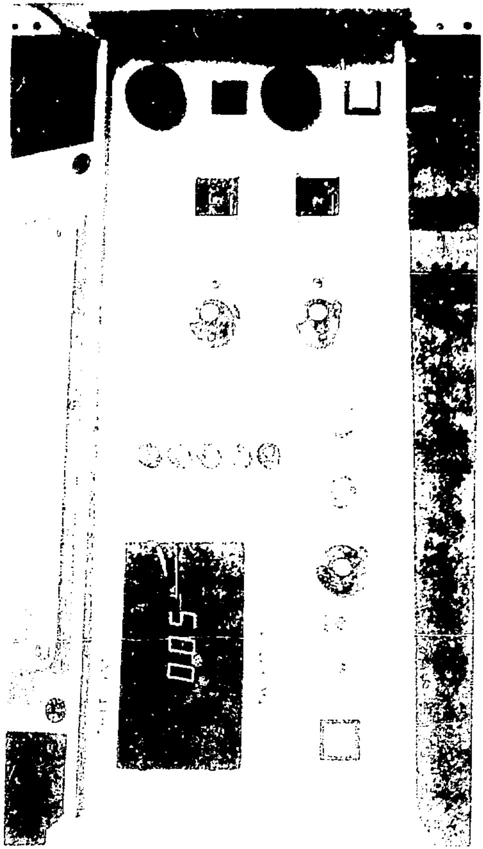


Figure 3. Dual Two-Litre and Dual 20-cm^3 Ion Chambers



voltages for the ion chamber, electrometer, and some accessories. The meter modules are interchangeable electrically, but the units/multiplier information must be changed to provide the desired range indication for each monitor. This is done by changing the stick-on decals to the left and right of the range indicator lamps.

The front panel of the meter module is divided into two sections: the display section and the alarm section. The display section provides a direct readout of the tritium concentration in the appropriate units. The units/multiplier information, located to the left and right of the illuminated range lamp, is applied directly to the reading displayed on the digital panel meter.

The alarm section provides each tritium monitor with a low and high alarm. These alarms can be set at any level throughout the entire range of the instrument, and are completely independent of each other.

5. Remote Displays -- The remote display (Figure 5) is a Sandia-designed accessory to the basic tritium monitor, and is used only with the room-air tritium monitoring system. It is normally located at the entrance to the room of interest, providing the users with the capability of assessing potential hazards prior to entering their laboratory. The remote display contains the necessary visual and audio components of the meter module, each in the same relative position as its counterpart.

6. Console Displays -- The console display (Figure 6) is another Sandia-designed accessory to the tritium monitor, and is the method of visual/functional display in the control room. In addition, it is the primary method of interfacing between the basic tritium monitor and the TRL control computer.

Like the remote display, the console display also contains the necessary visual and audio components in the same relative position as its counterpart

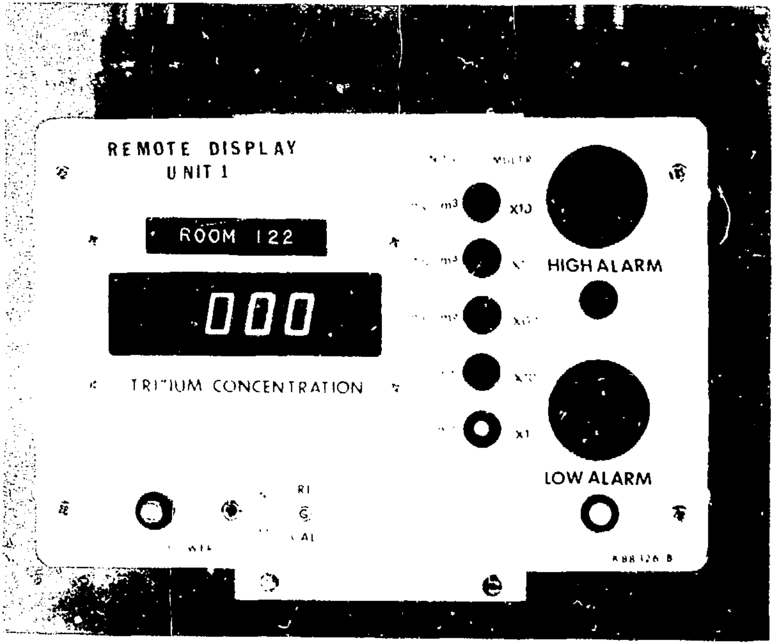


Figure 5. A Remote Display Module

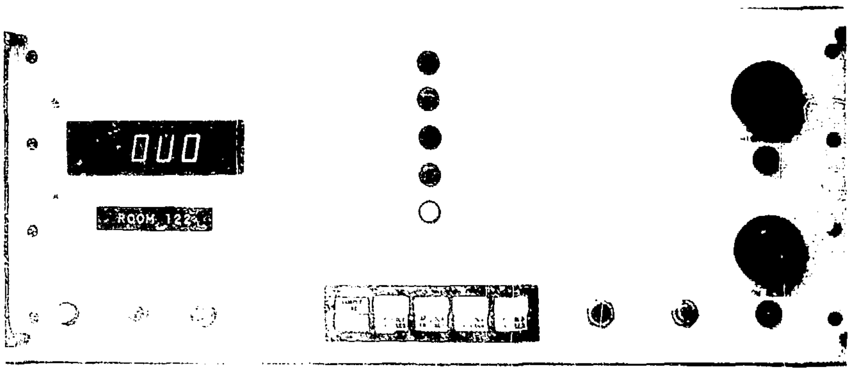


Figure 6. A Console Display Module

on the meter module. Unlike the remote displays, console displays are used on most of the tritium monitoring systems in the TRL. Interchangeability requires only the changing of the stick-on decals for the appropriate units/multiplier information, and the appropriate switch-module configuration.

A five-unit switch module is located in the lower, center portion of the console-display front panel. For room air monitors, four switches control the four solenoid valves on the room air sample manifold (see Section IIIB, Mechanical Components). The fifth switch controls the use of a backup room air tritium monitor, located on the room air calibration manifold.

For glove box monitors, only one switch is used. This switch controls the use of a backup glove box monitor, located on the glove box calibration manifold.

GPS and VERS console displays have no switches installed. A blank switch plate is installed in all unused portions of the switch modules.

7. Totalizers -- There are two totalizer units used in the monitoring system of the TRL. These Sandia-designed accessories work as a system (Figure 7) to record the total amount of tritium released in the stack effluent and processed by the GPS. A digital clock, a scanner, and a printer complete this totalizer system.

Tritium totals on each totalizer are provided by the integrator and accumulator readouts. The former is the total tritium released or processed during the current integration interval. The latter is the total tritium released or processed since the system was last reset to zero. At the end of each integration interval, each readout and the time of day is scanned, and these readings are printed. Each totalizer has been provided with a low- and high-level alarm, which will be activated if the tritium totals exceed the respective pre-set level during the integration interval.

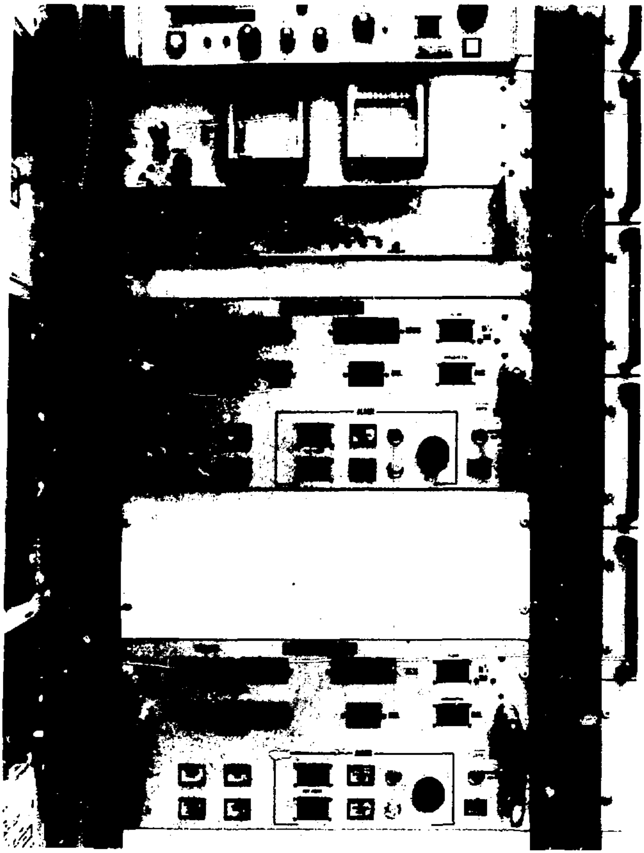


Figure 7. The Totalizer System

8. Hallway Manifold System Flush Control -- The hallway manifold system (HMS) flush control unit (Figure 8) is a Sandia-designed accessory to the room air and stack effluent monitoring systems. It is located in the control room and provides the capability of purging the room air exhaust and the room air calibration manifolds (see Mechanical Components) with compressed air or nitrogen. In addition, the HMS flush control unit provides an alarm input to the guard alarm interface unit (see Section IVB) in the event of low air flow in either the room air exhaust, room air calibration, or stack effluent sampling manifolds.

9. Glove Box Flush Control -- The glove box flush valve control unit (Figure 8) is a Sandia-designed accessory to the glove box monitoring system and is located in the control room. Its function is to provide: (1) automatic purging of the glove box air sample lines and calibration manifold whenever the glove box calibration monitor is not sampling a glove box; (2) an alarm input to the guard alarm interface in the event of low air flow in the glove box calibration manifold; and (3) automatic re-routing of the glove box calibration monitor sample to the VERS in the event the tritium concentration exceeds a pre-determined level.

There are two additional electronic components of the overall monitoring system: the TRL control computer and the guard alarm interface. Each will be discussed under the computer section (IV) of this report.

B. Mechanical Components

1. Central Pumping Station -- Air samples are drawn into the various manifolds by the central pumping station (Figure 9). Half of the central pumping station consists of dual sample pumps which draw samples through the room air exhaust, the room air calibration, and the stack effluent sampling

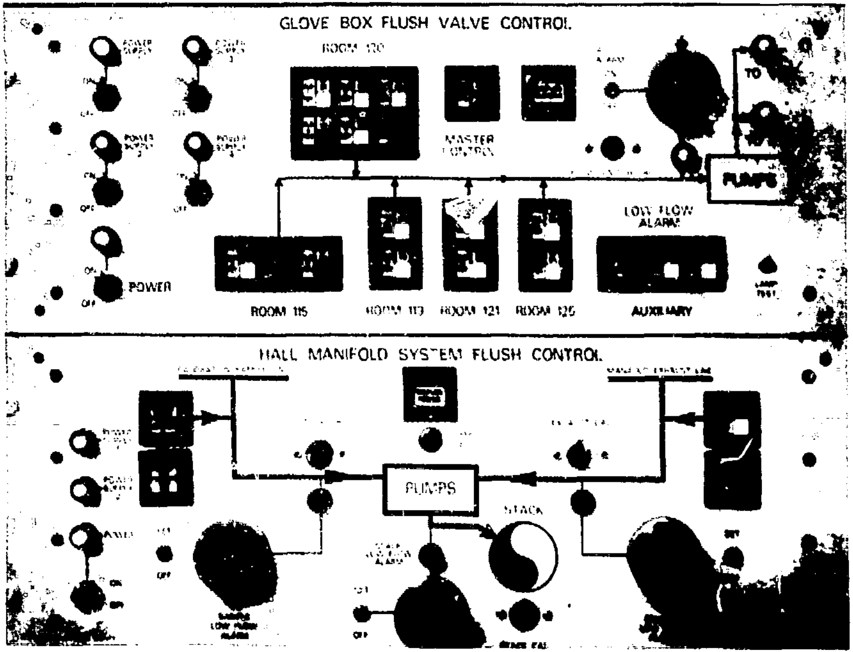


Figure 8. Glove Box Flush-Valve Control and Hall-Manifold System Flush Control

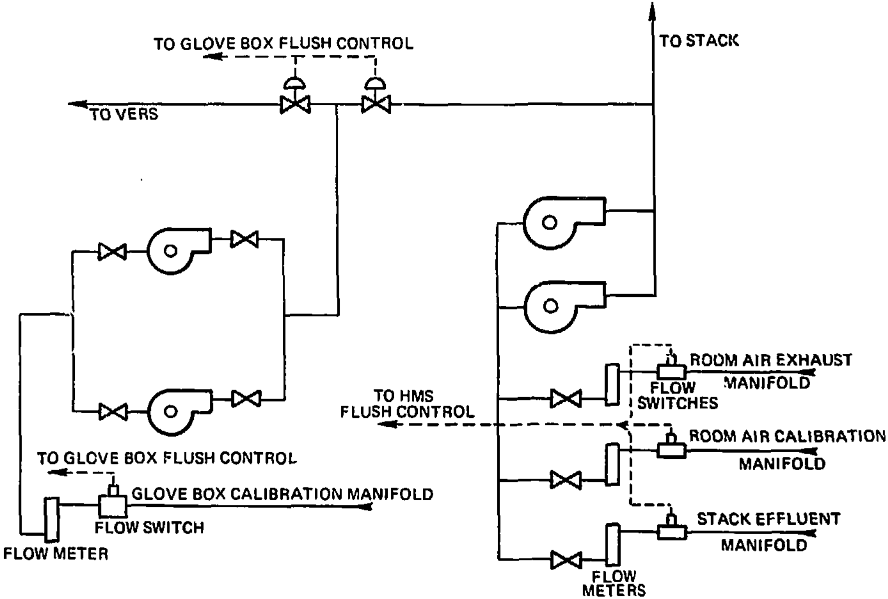


Figure 9. Schematic of the Central Pumping Station

manifolds. There is a shut-off valve, a flowmeter, and a flow switch in each of these lines. These flow switches provide low-flow alarm inputs to the HMS flush control unit. Each of the sample pumps has a rated capacity of 125 litre/min; all are exhausted to the stack.

The other half of the central pumping station consists of dual sample pumps, which draw their samples into the glove box calibration manifold. This manifold is also equipped with shut-off valves, a flowmeter, and a flow switch. This flow switch provides the low-flow alarm input to the glove box flush valve control unit. The sample pumps have a secondarily contained head, and have a rated capacity of 11 litre/min. They are normally exhausted to the stack. Solenoid valves in the exhaust line, controlled by the glove box flush valve control unit, divert the exhaust into the VERS whenever the tritium concentration exceeds a pre-set limit.

2. Room Air Sample Manifold -- Each room in the TRL is equipped with a room air sample manifold. This sample manifold is a selectable, four-way inlet system for the ion chamber. At the inlet of each line there is a hose connection and an in-line particulate filter. At each inlet to the sample manifold there is a normally open solenoid valve. These valves can be selectively closed by activating the switches on the appropriate console display, located in the control room.

Under normal conditions, all four valves are open, allowing the monitor to measure a representative sample of the room air tritium concentration. During potentially hazardous conditions, valves may be closed to select a portion of the room to be monitored. Should even more localized monitoring be desired, a piece of flexible, plastic tubing attached to a hose connection, with the other three valves closed, will allow the room air tritium monitor to be used as a "sniffer."

3. Room Air Exhaust and Calibration Manifolds -- Room air is drawn into the sample manifold and through the ion chamber. The exhaust from the ion chamber is drawn through the hallway manifold selector (a three-way solenoid valve), which is normally open to the room air exhaust manifold. The air samples from all room air tritium monitors are drawn through this manifold, by the central pumping station.

Changing the hallway manifold selector, which is accomplished by operating one of the switches in the switch module on the appropriate console display, re-routes the sample into the room air calibration manifold. The room air calibration tritium monitor is mounted on this manifold, allowing a cross check of each room air tritium monitor reading against a single unit. It also provides a method of backing up any of the room air monitors, whenever maintenance on a monitor is required. Samples are drawn into this manifold by the central pumping station.

4. Glove Box Calibration Manifold -- Provisions have been made to draw a sample from a glove box and measure the tritium concentration in another backup monitor. At the glove box, there is a normally closed solenoid valve in an additional sample line. This valve can be opened by activating the switch on the appropriate glove box console display. The sample is then drawn from the glove box into the glove box calibration manifold and tritium monitor by the central pumping station.

All three of the above manifolds are located in the main hallway and run the length of the TRL. Because of their length and their potential for the buildup of tritium contamination, provisions have been made to flush these lines. Solenoid valves have been installed in the room air exhaust and calibration manifolds. These valves are controlled by the HMS flush control unit, located in the control room. By activating the appropriate switches, the room air exhaust or the room air calibration manifold will be continuously flushed with nitrogen or compressed air.

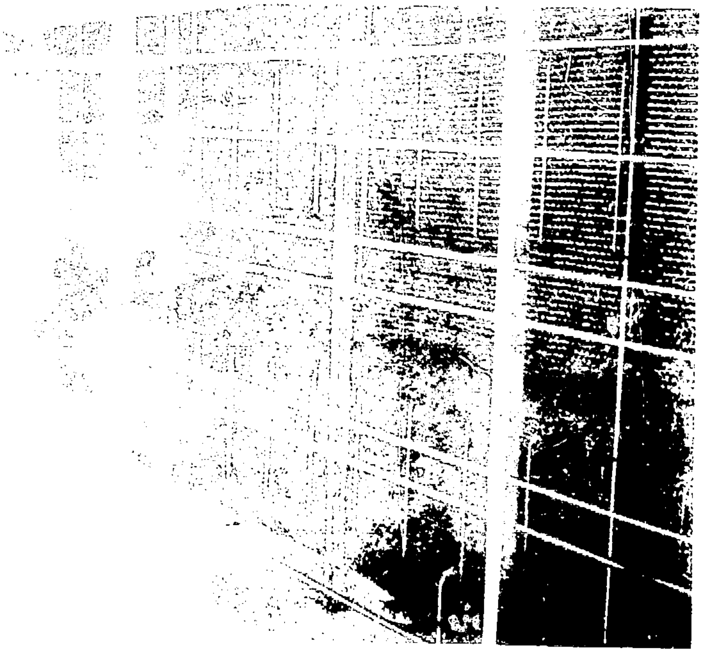
A similar system has been installed for the glove box calibration manifold. Solenoid valves in this line, however, are activated by the glove box flush valve control unit, also located in the control room.

5. Stack-Effluent Sample Manifold -- The stack-effluent tritium monitors draw their sample from a sample array (Figure 10) located in the TRL building exhaust duct. Since the sample point is upstream of the building exhaust fans, this sample array was designed to provide a representative sample of the TRL exhaust air by using a multi-point sample system, located just downstream of a laminar flow unit. The sample is drawn directly from the exhaust duct by the central pumping station, and is returned to the exhaust duct downstream of the sample array.

6. Pump Modules -- For glove box, GPS, and VERS monitoring, the sample is drawn by a pump module (Figure 11). A pump module consists of an ion chamber, pump, flow meter, inlet and outlet shut-off valves, and interconnecting tubing. Any ion chamber can be mounted in a pump module; however, the interconnecting tubing may have to be re-routed because of differences in the two-litre and dual 20-cm^3 ion chambers.

The pump itself, which is identical to the pumps used on the glove box portion of the central pumping station, has a secondarily contained head. This secondary containment is to minimize the potential for a tritium release into a room in the event of a pump-head failure.

Pump modules are mounted as close to the desired sample point as possible. For glove box monitoring, the pump draws a sample through a hose connection and an in-line particulate filter, located just inside the glove



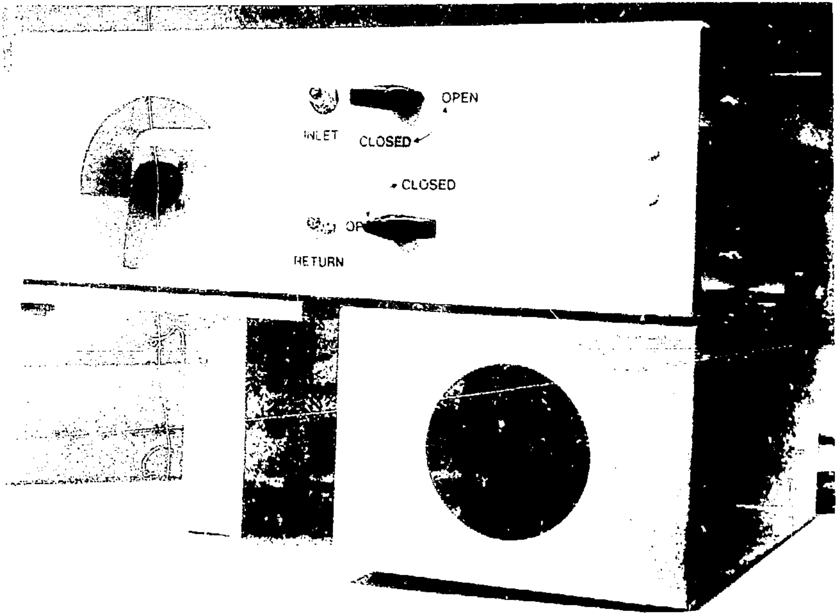


Figure 11. [illegible]

box. Flow is then through the pump module and back to the glove box. For GPS and VERS monitoring, the pump draws a sample directly from the line of interest, and returns it to the line downstream of the sample point.

IV. Monitoring System Description

Each of the above components has been combined in various configurations to form the individual monitoring systems. When the appropriate individual monitoring systems are combined, they make up one of the basic monitoring systems. The following are the basic monitoring systems and their sub-systems, with a component listing for each.

A. Room Air Monitoring System

A typical room air monitoring system (Figure 12) consists of (1) a room air sampler, a dual two-litre ion chamber with electrometer, and a meter module, all located in the room of interest; (2) a remote display and a hallway manifold selector, located just outside the room of interest; and (3) a console display with the appropriate switch module configuration, located in the control room. The console display provides the input to the computer.

In addition, the room air monitoring system includes the room air exhaust manifold, the central pumping station, and the room air portion of the hallway manifold system flush control unit. The room air calibration monitoring sub-system consists of (1) the room air calibration manifold and central pumping station; (2) a dual two-litre ion chamber with electrometer, located on the room air calibration manifold; and (3) the meter module and room air calibration manifold portion of the hallway manifold system flush valve controller, both located in the control room. The computer input from this sub-system is provided directly from the meter module.

B. Glove Box Monitoring System

A typical glove box monitoring system (Figure 13) consists of (1) a pump module with dual 20-cm^3 ion chamber, electrometer, and a meter module,

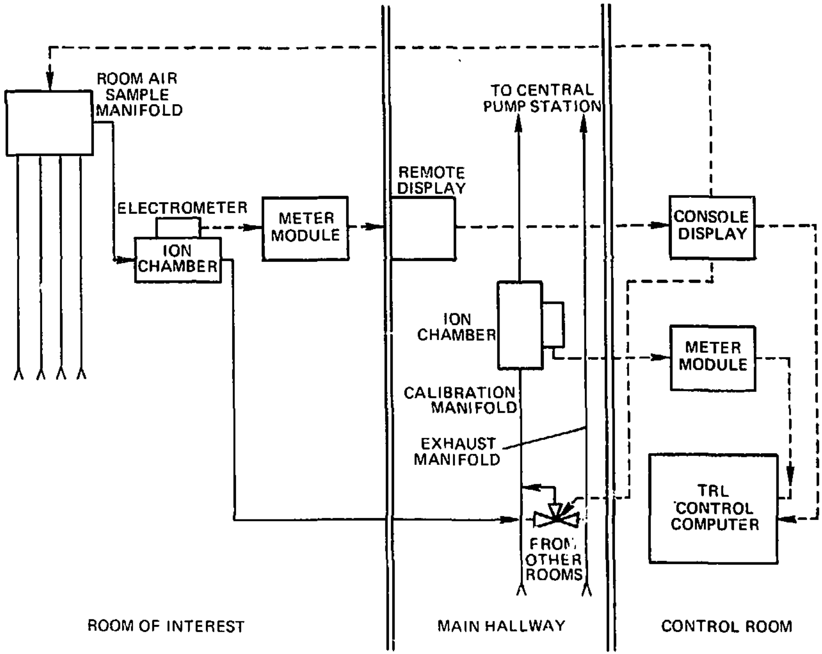


Figure 12. Schematic of the Room Air Monitoring System

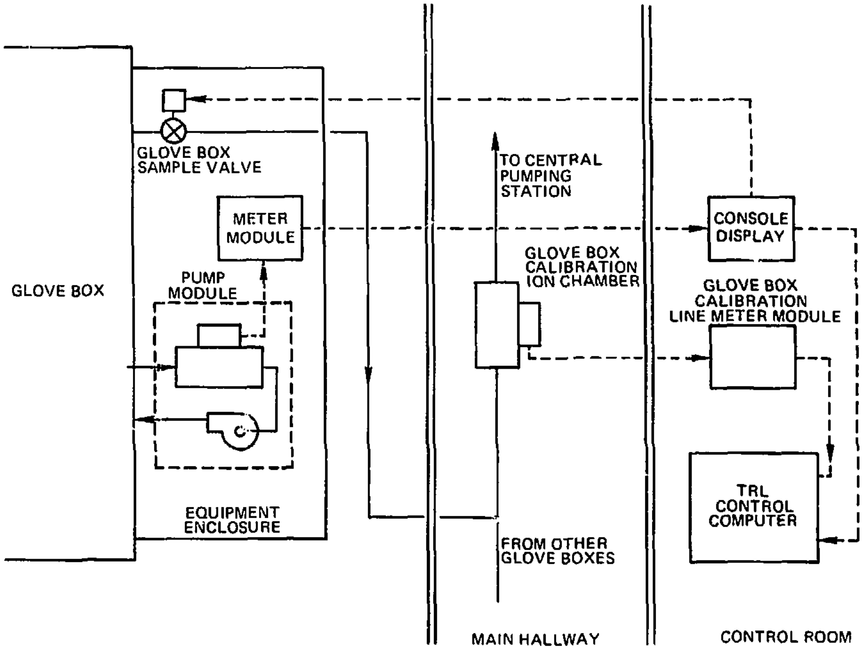


Figure 13. Schematic of the Glove Box Monitoring System

mounted in the glove box equipment housing; and (2) a console display, located in the control room. The console display provides the input to the computer.

The glove box calibration monitoring sub-system consists of (1) the solenoid valve at the glove box of interest; (2) the glove box calibration manifold; (3) a single two-litre ion chamber, located on the glove box calibration manifold; and (4) the meter module and the glove box flush valve control unit, located in the control room. The computer input is provided directly from the meter module.

C. GPS and VERS Monitoring System

A typical GPS or VERS monitoring system consists of (1) a pump module with the appropriate ion chamber and electrometer located as close to the desired sample point as possible; (2) a meter module, located in an electronic equipment rack at the entrance to the cleanup systems equipment room; and (3) a console display, located in the control room. For GPS and VERS monitors, the console display provides the input to the computer. The GPS inlet tritium monitor provides an additional input to the totalizer system.

D. Stack Effluent Monitoring System

The stack effluent monitoring system (Figure 14) consists of (1) the multi-point sample system, located inside the ventilation exhaust duct; (2) a dual two-litre and a single two-litre ion chamber with electrometer, located on the stack effluent sample manifold; (3) the central pumping station; and (4) meter modules for both monitors, located in the control room. Computer inputs are provided directly from each meter module. Both meter modules provide an additional input into the totalizer system.

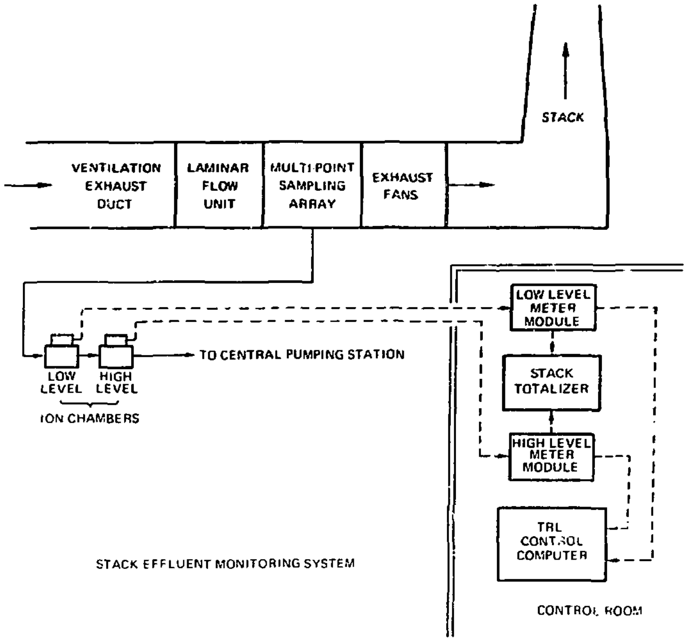


Figure 14. Schematic of the Stack Effluent Monitoring System

V. TRL Computer System

A. TRL Control Computer

The control computer is a Digital Equipment Corporation PDP 11/40 computer. The computer and its peripherals, which include two disc drives, a keyboard printer, a video terminal, and an external real-time clock, are located in the control room.

The computer continuously scans each of the tritium monitors and VERS pressure readings, and records the data. It also scans each of the glove boxes for pressure alarms, fire alarms, and the correct GPS inlet and outlet valve positions. Whenever a high glove box tritium level exists, the computer selects the correct cleanup gases for the glove box, selects the appropriate GPS dryers, starts the GPS, connects the glove box to the GPS, and runs the GPS until the tritium level is sufficiently reduced.

Whenever the computer finds an alarm condition, it prints a message on the keyboard printer indicating the alarm and its time of occurrence. It also sends an alarm to the guard alarm interface unit.

B. Guard Alarm Interface

The guard alarm interface unit (Figure 15) is a Sandia-designed accessory to the overall TRL monitoring system. Its function is to provide an alarm in the control room whenever an abnormal condition occurs in any of the several building systems. In addition, the interface will relay the alarm to Security Headquarters after normal working hours.

The interface is divided into seven alarm sections, the first four of which are presently active. In order of highest priority, they are: emergency, danger, hazard, and operational alarms. Each section has a series of lamps indicating the cause of the alarm. Additional lamps indicate the

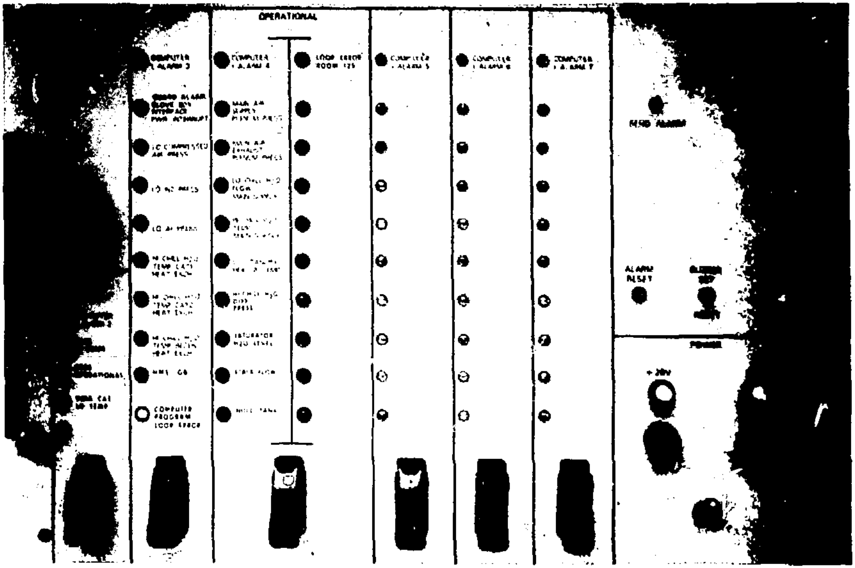


Figure 15. The Guard Alarm Interface

condition in which the interface is functioning. When in the "send alarm" condition, all alarm occurrences will be sent to Security Headquarters. When in the "do not send alarm" condition, only the emergency alarms and one hazard alarm will be sent.

An alarm may be generated by the computer or any of several TRL systems such as the GPS, VERS, or portions of the tritium monitoring system. An alarm may also be generated by any of several building systems, such as the ventilation, chilled water, or electrical power distribution system. Whenever the alarm is generated, the interface unit will illuminate the appropriate lamp, and sound a local alarm in the control room.

If the alarm occurs during normal working hours, the control room operator will notify the appropriate personnel. If the alarm occurs after normal working hours, the guard alarm interface unit relays the alarm to Security Headquarters, and Security will notify the appropriate personnel.