MLM-3265(OP)

Second Topical Meeting on Tritium Technology in Fission, Fusion, and Isotopic Applications, Dayton, Ohio, 30 April – 2 May 1985; also Fusion Technology, Special Supplement, September 1985

DEVELOPMENT OF AN INTEGRATED MONITORING SYSTEM FOR A NEW TRITIUM FACILITY AT MOUND

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ABSTRACT

A stand-alone system was developed for monitoring process support services and tritium levels in gloveboxes, room air, room exhaust ducts, and stack exhaust. Sixty tritium monitors were built and interfaced to a Health Physics control room where all tritium levels are displayed and abnormal conditions appear as alarms on large display boards. The control room was designed for full remote control of all monitors, with the exception of those for gloveboxes, as well as for control and alarm display of many other functions, including the purge rate for glovebox atmosphere and the selection of room air discharge to stack or to a tritium cleanup system. The monitoring system is interfaced to a data gathering computer and an automatic dialing alarm system.

INTRODUCTION

Four objectives governed the development of an integrated monitoring system at Mound. These were: (1) a stand-alone system using a computer only for data gathering; (2) the remote control of monitors and the display of all tritium concentrations in a control room; (3) simple maintenance-free monitors of a common design with interchangeable components; and (4) a response time constant of one second for control functions and safety.

To meet these objectives, ion chambers, electrometers, alarms, and controls were designed and developed. New design concepts were stressed by minimizing the influence of existing monitoring system designs.[1-6]

ION CHAMBER AND ELECTROMETER DEVELOPMENT

The classical ion chamber uses a small cylindrical counting electrode varying in diameter from 1/16 to 3/8 in. Linearity and accuracy decrease rapidly due primarily to ion recombination. In our studies, a 1/8-in. electrode shows loss of linearity at a tritium concentration of 8 mCi/m^3 and a 1/4-in. rod at 20 mCi/m^3. To provide reasonable accuracy, most commercial monitors use a series of ranges accompanied by electrical compensation.

To achieve the desired accuracy and simplicity, it appeared that linearity improvement and elimination of range changes were important development goals. An empirical study of different counting electrode configurations in a nominal 2-liter chamber showed that the design in Fig. 1, a four-fin electrode, provided the best linearity and could eliminate range change requirements.

The electrode consists of four stainless steel fins (each 4½ in. long and 1¼ in. wide) a ¼-in. diameter rod in the center and a ½-in. air gap between the fins and the center rod. The fins provide the linearity to high levels of tritium, and the rod/air gap provides linearity at the low microcurie levels. If continuous fins in the form of a cross were used, the linearity will deteriorate below 200 $\mu Ci/m^3$ because of an abnormal increase in current. If only an air gap were used between the fins, the opposite occurs with an abnormal decrease in current below 200 $\mu Ci/m^3$.

Hence, the electrode in Fig. 1 provides linearity from 1 $\mu Ci/m^3$ to 0.5 Ci/m^3 with an accuracy of ±3%. The collection efficiency of this electrode is also much higher. If a factor of one is assigned to the fin electrode for a known quantity of tritium, a typical ¼-in. rod electrode yields an efficiency of only 0.7. The mechanism behind this improved linearity is apparently very complex. The linearity may be linked to the uniform voltage field created within the chamber by the fin system. It is currently under study and results are to be published.

*Mound is operated by Monsanto Research Corporation for the U. S. Department of Energy under Contract No. DE-AC04-76DP00053.

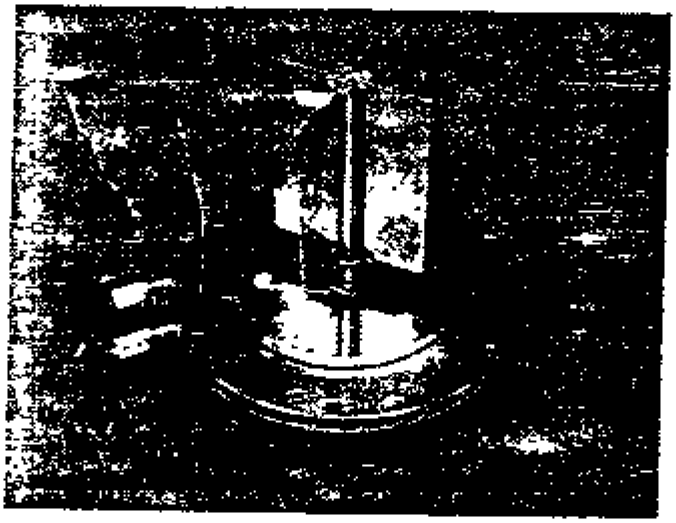

Fig. 1 – Open ion chamber showing fin counting electrode.

With the wide range of linearity available, only one range change is necessary for displaying 1 μCi/m³ to 20 Ci/m³ on a 4½ digit digital panel meter. The two ranges employ two high-megohm resistors with 1000:1 ratio. When the tritium concentration (voltage) reaches a level of 20,000 μCi/m³, the lower resistance resistor (e.g., 10^{9} Ω) which is suspended in air is mechanically pulled by a solenoid into contact with the counting electrode and in parallel to the high value first range resistor (e.g., 10^{12} Ω). This range changing technique eliminates any leakage paths which may occur with conventional switching methods. Thus, the accuracy of the first range is maintained.

Potential problems of electrometer instability and zero drift due to humidity changes and current leakage paths were minimized by redesigning the interface to the counting electrode. Connections to the electrode were restricted to the gate of the field effect transistor (FET) and the high impedance load resistor. A feedback of nearly 100% allows the counting electrode to operate at the same zero potential as the base plate in which the Torlon insulator for the electrode is mounted. Because of these features, the electrometer is unaffected by 99% relative humidity and current leakage from the electrode is greatly reduced.

The resulting electrometer, operating with a 24-volt electrode potential, can withstand abrupt pressure changes in the ion chamber from vacuum to two atmospheres without failure of the input FET. Measurement accuracy and linearity are maintained down to a pressure of 150 torr.

The time constant (response to 66% of a step change in input signal of tritium) for these electrometers is less than one second. Because of the short time constant and sensitivity, background noise (cosmic, alpha, thermal, and electrical) may appear as small short-term spikes on the digital display. A discriminator was developed to remove from the output of the electrometer noise signals having random frequency periods of less than 2.2 s. As a result, the time constant of the monitor was increased to 6.0 s. Because noise only affects concentration readings below 15 μCi/m³, it was desirable to restore the fast response for higher levels of tritium. Hence, a comparator circuit was added to sense when the electrometer output due to tritium exceeds a maximum voltage level for unwanted noise so that the discriminator function can be automatically turned off. Hence, the electrometer output can return to a 1 s time response. The rate of rise of the input signal (the concentration of tritium) will affect the overall time constant. More specifically, a 20,000 μCi/m³ step function in concentration may have a time constant of 2 s, while 70 μCi/m³ will have 6 s.

TYPICAL MONITOR

The electronics console is shown in Fig. 2. Although this unit could satisfy most monitoring needs, it was used primarily for glovebox monitoring since remote control was used for all other monitoring in this project. The Lexan-faced console, which can be rack or table mounted, requires a space of only 7 in. in height.

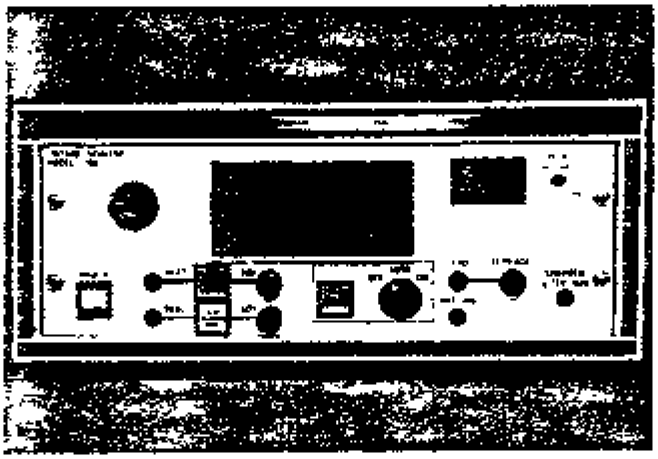

Fig. 2 – Monitoring console.

There are no dials to read; all controls on the front of the panel (alarm levels, zero, system test, etc.) are read from the same digital panel meter which displays the tritium concentration. The appropriate pushbutton is depressed to obtain the setting of a control. Special friction shaft locks are used on all controls to prevent accidental change of the settings. Independent low- and high-level alarms can be set anywhere in the range of 1-20,000 μCi.

All displays of tritium concentrations are expressed in microcuries per cubic meter. When range change occurs, a deadfront (black until lighted) red display of "x 10^3" appears adjacent to the DPM, indicating that the DPM reading must be multiplied by 1000.

A system or instrument test from the front panel allows the user to test the performance of the entire monitor (ion chamber, electrometer, alarms, and display). When the test button is depressed, a reference voltage equivalent to a predetermined tritium concentration (e.g., 12,300 ± 300 $\mu Ci/m^3$) is applied to the input of the electrometer.

Upon recovery from a power outage, an automatic deactivation circuit disables the alarms of the monitor for a period of 90 s. This allows the monitor to come to equilibrium after power-up and prevents alarming. The same alarm deactivation feature is also a part of the "zero test" check of the electrometer. In addition, it also allows the "system test" to be made without alarm activation by depressing the "zero test" pushbutton prior to the system test. During this time delay, the DPM still displays current tritium concentrations.

Airflow through the ion chamber is measured continuously by a thermistor and can be read from the DPM by means of a pushbutton switch on the front panel. The bridge measuring circuit consists of a measuring thermistor in the ¼-in. diameter exhaust port of the chamber and a reference thermistor within the chamber. Both are heated at the same bias level. The difference in cooling rate of the two thermistors causes a bridge offset voltage which is displayed as liters/minute airflow.

The control room (Fig. 3) was designed to enable the Health Physicist to easily ascertain the radiological environment of the facility, as well as the condition of important support services. From this room, the operator has remote control of all monitors with the exception of glovebox monitors. It contains concentration and alarm displays, airflow control, glovebox purge control, a data gathering computer, and an automatic dialing alarm system for after-hours protection of the facility. The room, as well as all monitors, are supplied emergency power within 6 s of a power outage.

The high-rise section of the general control console (Fig. 4) contains 60 digital panel meters for displaying the tritium concentrations. For ease of identification, displays are color-coded in groups according to use. Below the DPMs, a control panel for 38 monitors contains all the controls normally found on the rack-mounted console shown earlier in Fig. 2. The control console contains its own power supplies, backup power supplies, relays, and controls for sending alarms to all areas of the facility. All AC and DC circuits are isolated in individual conduits and compartments.

Fig. 3 – Control room.

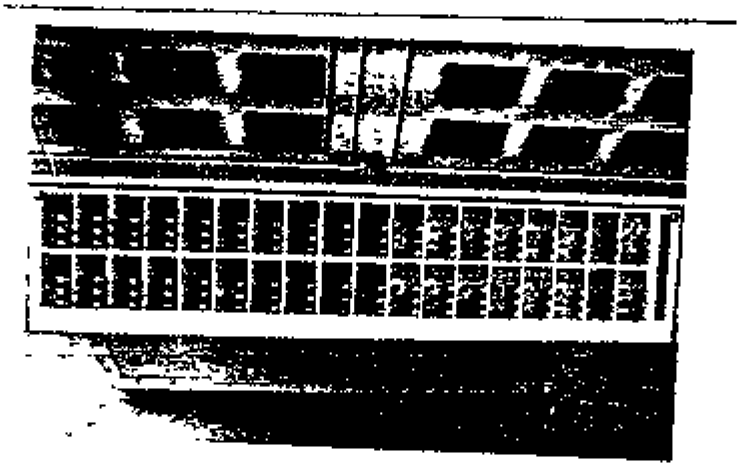

Fig. 4 – General control console.

ALARMS AND ALARM STATUS DISPLAY

All monitors have low- and high-level alarms with audible outputs and visual displays. In the control room, an alarm status display board, one-half deadfront for discrete alarms and one-half with a floor layout of the facility, shows the identity and location of all process support services and two-level tritium alarms (Fig. 5). One common audible is used in the control room, thus requiring the operator to look on the black deadfront display for a flashing visual alarm. Low-level alarms appear as discrete yellow lights and high-level as red lights. Room alarms appear as flashing room numbers on the floor layout. Gloveboxes in each room are outlined on the floor layout and small red LEDs identify which gloveboxes are in the high-alarm state.

High-level alarms of room and duct monitors activate a flashing DO NOT ENTER sign at the entrance of the affected room. This sign is extinguished only after the tritium levels drop below the high-alarm set point. For safety reasons, the high-level (Klaxon) alarms and the high-level stack alarm, which activates bells in all areas, can be acknowledged only from the control room.

ROOM MONITORS

Each room in the new facility has one or more independent room monitor stations suspended from the ceiling as shown in Fig. 6. The station consists of a deadfront enclosure, with two digital panel meters to display tritium concentration readings in two opposite directions. The station, which has no external controls,

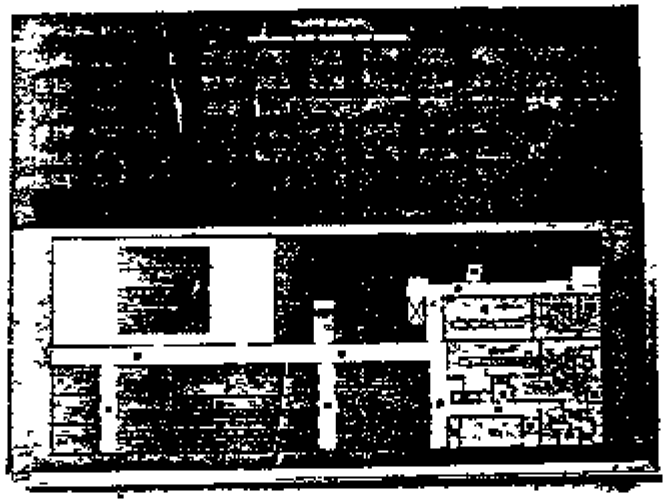

Fig. 5 - Alarm status display board.

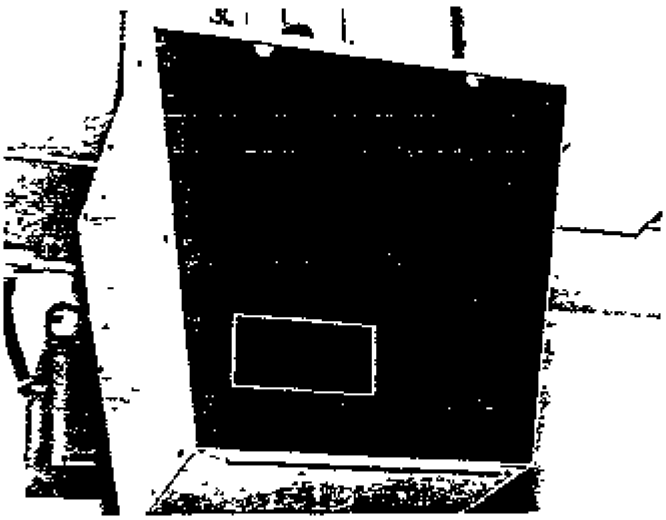

Fig. 6 - Room display enclosure.

contains the ion chamber, its electrometer, a rotameter, filter, low-level visual and audible alarms for room and duct monitors. Yellow visual alarms appear on both sides of the deadfront enclosure indicating either ROOM or DUCT alarms since both use the same low-level audible alarm and both can be acknowledged at the monitor enclosure. All control components and DC power supplies are located in the control room.

A house vacuum system provides the airflow through the room ion chambers by maintaining a -35 in. of water exhaust pressure at each monitor. The exhaust pressure and pump are continuously monitored. Any abnormal conditions are displayed on the alarm board in the control room.

GLOVEBOX MONITORS

Because glovebox monitors are an intimate part of the process operations, the monitor is located in the work area and is under the control of the process operators. To monitor tritium levels in the glovebox, its inert atmosphere is purged at 2 L/min through an ion chamber to an effluent removal system (ERS) for recovery of the tritium.

The function of the monitor is twofold: to provide a high purge rate for a rise in tritium levels and to indicate when a process operation or equipment is a source of tritium release. The ion chamber is mounted outside the glovebox, and the gas sample is continuously pulled through the chamber by the negative operating pressure of the ERS. Tritium concentrations, alarms, and purge control signals are interfaced to the control room for display and data gathering purposes.

By means of a three-way switch (OFF, AUTO, ON) at the monitor, the high purge can be controlled manually. The high-level alarm will activate the high-flow purge if the purge control is in the AUTO position. To ensure that the ERS gas handling capacity is not exceeded, the purge control signal from each glovebox passes through a control board in the control room (right side of Fig. 7) allowing the control room operator to override the purge signal by means of a three-way switch (ON, REMOTE, OFF). In the remote position, the lab technician or monitor has control of the purge rate. The negative pressure and flow rate to the ERS are constantly monitored on LED bargraphs and, at the discretion of the control room operator, the purging can be stopped or started on any of 30 glovebox systems.

DUCT MONITORS

Exhaust ducts from each room contain monitors which serve two purposes: (1) backup for the room monitors, and (2) activation of a tritium emergency cleanup system (ECS). Exhaust air is diverted from the stack to the ECS in the event of a tritium spill.

Duct monitors use a flow-through wire mesh ion chamber installed in the duct or behind the intake grill of the room exhaust duct. These single range monitors (1-20,000 $\mu Ci/m^3$) have a time constant of 1 s. The ion chamber consists of a 3/8-in. counting electrode enclosed in a stainless steel mesh cylinder. To reduce noise and stabilize readings, a felt bonnet is is installed over the chamber for trapping dust and ionized particulate. Aside from using a single electrode, being single range, and having no outer (ion) chamber, duct monitors do not differ electronically from room or glovebox monitors.

ECS/STACK AIRFLOW CONTROL

From a desk console, the destination of the exhaust air from each room may be controlled. The console allows the exhaust of any room to be manually switched to STACK, ECS, or AUTO. In the AUTO position, the exhaust routing to the ECS or stack is under control of the duct monitor. Diverting a room to the ECS places the

Fig. 7 – Emergency cleanup system and stack airflow display board.

room supply and exhaust in a closed-loop with the ECS for cleanup of room air. In addition, the duct valves for any room may be tested periodically without activating the ECS; a room may be completely isolated from supply and exhaust; and more than one room may be processed through the ECS.

The status of the ECS and the exhaust destination of air from every room are displayed on a deadfront alarm display board in the control room as shown in the left half of Fig. 7. When a high alarm signal comes from the duct monitor or a similar signal is supplied manually from the control console, the ECS is activated as are four air-operated duct valves, two closing the supply and exhaust to the stack and two opening the supply and exhaust to the ECS. Four respective microswitches close, indicating new valve positions. The NORMAL STATUS light is extinguished, the ECS OPERATING light is lit, and four discrete valve lights are displayed on the alarm board showing the room identification and valve positions. The control console also sends out a latching signal so that, even though the tritium levels drop below the alarm set point, the cleanup system and valves remain activated until the ECS is manually reset.

In the mass spectrometry laboratory Halon fire control, using heat sensors, is employed. The Halon system is interlocked with the monitor to prevent LCS or valve activation if Halon is dumped, because, after passing through a catalyst, Halon can be very corrosive to the equipment. Tests with 20% Halon-80% air showed no effect on tritium monitoring response or accuracy.

STACK MONITORING

Two real-time monitors and a glycol bubbler collection monitor are used for sampling exhaust air. For day-to-day operations and alarming functionings, a low-level single range monitor 0.1-2000 $\mu Ci/m^3$ is used. A standard dual range monitor serves as backup in the event of a large release or malfunction of the low-level monitor. Airflow through the stack duct is measured by a continuous reading airflow device (Annubar). The data are transmitted to the control room for display and also to an accumulator which uses the airflow and concentration from the low-level monitor to provide a cumulative effluent readout on a wall display board. The rate of effluent ($\mu Ci/min$) is also displayed.

When using a fast time constant and sensitivity to 0.1 $\mu Ci/m^3$, background noise from ionized gases, radon, and cosmic radiation can cause abnormal cumulative effluent measurements. Hence, the output of a second identical monitor which samples only intake air from a "cold" corridor is connected in opposite polarity to the measuring chamber. The resultant signal is received by the accumulator. Although noise interferences may not occur simultaneously, the integrated compensation over a period of several hours reduces the error significantly to ±10%.

Because of its sensitivity and differentiating capability for HT and HTO, a glycol bubbler is used for reporting effluents discharged to the environment.[7,8] The basic bubbler was redesigned to use a mass flow controller to regulate the gas flow through two series of glycol bubblers separated by a palladium sponge catalyst bed held at 500°C. HTO is trapped in the first series, and HT converted to HTO is held up in the second series. The tritium in the vials is measured by liquid scintillation counting. Calibration of the bubbler showed a recovery (measurement) accuracy within ±1% of the standard measured by proportional counting and traceable to the Bureau of Standards. As installed in the exhaust duct to the stack, accuracy within ±7% was obtained when two curie releases were made in a fumehood more than 500 ft away from the stack.

AUTOMATIC DIALING SYSTEM

After normal working hours, service and tritium alarms will activate an automatic dialing alarm system which uses existing telephone lines for notifying plant security. The alarm conditions are vocalized by a synthesized voice. Security then calls the responsible personnel to investigate and correct the problem. This system, which is microprocessor controlled, is capable of monitoring 64 alarm channels. Having a 24-hr battery backup, it also notifies security of a power outage.

Following an acknowledgement of the call, the system vocalizes a sign-off and hangs up. The system then enters a delay to allow adequate time for corrective action. The delay time is keyboard programmable from 1-99 hr. If the delay elapses and the problem still exists, the system begins dialing again at 2-min intervals until acknowledged.

There are circumstances when certain alarm conditions are acceptable or cannot be corrected within the normal work day. To prevent these "false" alarms from activating the alarm dialing system, a latching alarm interface was designed to lock out daytime alarms but allow night alarms to activate the system.

The advantages of the system include complete control by monitoring personnel, easy change of telephone numbers from a keypad, and ascertainment of alarm status from offsite.

COMPUTER INTERFACE

Because facility guidelines required a stand-alone monitoring system, a computer serves only as a passive device for data gathering. The computer samples 60 monitors and 66 alarms and records tritium levels, alarms, etc., for archival purposes. All channels are sampled every 10 s. If tritium levels do not exceed a predetermined trigger value, the recording frequency is every 1800 s. When a trigger valve has been exceeded, e.g., 3 $\mu Ci/m^3$ for room monitors, all sampling data for that channel are recorded until the tritium level drops below the trigger point.

SUMMARY

No significant use or maintenance problems have been encountered with this system. One year of operation with 60 monitors indicates a failure rate per monitor of less than one in nine years of operation. Most of the failures occur during the first six months. In addition, the system is simple enough that new personnel can be indoctrinated within minutes on the use of the monitors, the control functions, and the interpretation of results.

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