STACK AND AREA TRITIUM MONITORING SYSTEMS FOR THE TOKAMAK FUSION TEST REACTOR (TFTR)*

Glenn G. Pearson, Lewis D. Meixler, Robert A. P. Sissingh, Princeton University Plasma Physics Laboratory, Princeton, New Jersey 08543--The TFTR Tritium Stack and Area Monitoring Systems have been developed to provide the required level of reliability in a cost effective manner consistent with the mission of the Tritium Handling System on TFTR. Personnel protection, environmental responsibility, and tritium containing system integrity have been the considerations in system design.

During the Deuterium-Tritium (D-T) experiments on TFTR, tritium will be used for the first time as one of the fuels. All of the tritium bearing systems will have potentially releasable inventories. Although the tritium inventories (total on-site inventory is limited to 50,000 Ci) are low, the consequences of a release may still be significant. For that reason, a thorough TFTR tritium monitoring program has been initiated. Three systems will be monitored:

Process monitors are used on the tritium systems to provide inventory verification. (These monitors are not part of this discussion.)

Area monitors provide surveillance of the air in various rooms at TFTR. Area monitors are the primary line of defense against an accidental release of tritium into the TFTR building. A monitor alarm at the Caution level serves as an operator alert, which will be investigated. Should an area monitor go into a High or High-High alarm state, immediate and automatic corrective action would be taken. HVAC dampers would close, fans would be shutdown, and appropriate tritium cleanup action would be initiated.

Stack monitors monitor the air at the TFTR test site that is exhausted through the HVAC systems, from the room exhaust stacks and the tritium systems process vents. Stack monitors are a second line of defense, and upon a stack alarm, immediate and automatic action would be taken. HVAC dampers would close, fans would be shutdown, and appropriate tritium cleanup action would be initiated. In addition to an alarm function, the stack monitors provide a record of effluent released. This information is available on a real time basis.

The philosophies for the implementation of the Stack and Area Tritium Monitoring Systems at TFTR are to use hardwired controls wherever personnel protection is involved, and to take advantage of modern intelligent controllers to provide a distributed system to support the functions of tracking, displaying, and archiving concentration levels of tritium for all of the monitored areas and stacks.

Background

One of the goals of TFTR since its inception has been the introduction of a mixture of deuterium and tritium as fuel. Specific areas were set aside for

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TFTR Tritium Monitor Descriptions

<u>Type</u>	<u>Salient Features</u>	<u>Location/Service</u>
1.	Simple, detects gross tritium, fixed units have dual chambers for gamma compensation.	Area Monitors, both fixed and portable: fixed units tied to hardwired fan & damper control
2.	Differentiating, able to differentiate between tritium and activated air, coaxial ionization chamber. Requires additional electronics to perform its function. Not gamma compensated.	TFTR Stack/hard-wired fan & damper control/account tritium inventory
3.	Differentiating, able to differentiate between tritium and activated air, coaxial ionization chamber. Requires additional electronics to perform its function. Gamma compensated/ via an additional chamber.	TFTR Test Cell/ hardwired fan & damper control
4.	Discriminating, special membrane, able to discriminate between elemental tritium, tritium oxide and Activated air. The design of this monitor gives it an inherent response time of approximately 20 minutes.	TFTR Stack/ not tied to fan & damper control
5.	Discriminating, passive, uses three drying traps, a catalyst, and an air mover to discriminate between HTO, T ₂ O, and activated air. Not a "real-time" system.	TFTR Stack/ environmental sampler

Figure 1: Types of Monitors

Tritium handling equipment. These areas would contain equipment to not only handle the normal storage, delivery and recovery of tritium, but also such cleanup equipment as deemed prudent (or as stipulated by DOE) to scavenge tritium from each of the rooms containing tritium bearing equipment, in the unlikely event of an accidental release of tritium into one or more of these rooms.

Special Requirements For Magnetic Fusion Facilities

Real-time tritium area and effluent monitors for fusion reactors must respond in sufficient time upon detection of tritium to allow an effective and acceptable response. Personnel and environmental safety are the first concerns. Closely coupled with that concern is the need to scrupulously manage the tritium inventory. Area and stack (effluent) monitors play an important part in tracking and inventory control. In addition, monitors which sample the air from the Test Cell which houses TFTR must also be able to distinguish between tritium and other radioactive gases (activated air: ^{41}Ar , ^{13}N , ^{16}N). They must be able to operate in elevated magnetic fields from TFTR and to operate in moderate gamma and neutron fluxes. In all, four types of real-time tritium monitors were found to be the optimum mix at TFTR. Each of the four types depends on the use of an ionization chamber and an electrometer to detect the betas emitted by tritium.

INSERT FIGURE 1 HERE

Monitors

One liter gamma compensated (compensated to 5 mRad/hr) canne and concentric type ionization chambers provide the backbone of the TFTR Tritium Monitoring System. These devices are used for area and stack monitoring. Each of the eight stacks has been provided with a real-time monitor, designed to differentiate between activated air and tritium. In addition, the combined stack flows are monitored for activated air (AA), tritium oxide (HTO) and elemental tritium (HT). Both active (real-time) and passive monitors are used.

Area monitors on the other hand are real time monitors exclusively monitoring for tritium. They are unable to differentiate between activated air and tritium, nor are they able to discriminate between HTO and HT. Testing has shown shielding to be required for the approximately 100 gauss fields in the TFTR test cell basement during experiments.

Area Monitors (Type 1)

Area monitors (except for Test Cell) were fabricated by Nuclear Measurements Corporation (NMC) to Princeton University, Plasma Physics Laboratory (PPPL) specifications. These monitors are contained in a single chassis. Mu metal was used to shield the solid state electrometer, ionization chamber, and associated electronics. The prototype was tested in the presence of dynamic (115 gauss) and static (150 gauss) magnetic fields while a known quantity of tritium was circulated through it. The worst case effect, found during dynamic magnetic testing, was a 7-10% increase in activity. Magnetic field strength at tritium monitor locations in the test cell basement is approximately 100 gauss during TFTR operations, hence only magnetically shielded tritium monitors will be used in this area.

Differentiating Monitors (Types 2 & 3)

Differentiating monitors are required in the stack and in the test cell in order to distinguish tritium from activated air. In the stack, control of environmental releases is the concern. In the test cell, one must be able to distinguish the relatively large amounts of activated air during DT operation from tritium. To accomplish both these tasks, monitors based on a Los Alamos National Laboratory (LANL) design have been fabricated by Overhoff Technology Corporation. The heart of this instrument is a cylindrical flow through ion chamber positioned within a larger outer cylindrical chamber. Sampled air is passed through the inner part of the coaxial chamber (which is constructed of a square mesh copper screen covered with 0.064-mm double - aluminized mylar). In this detector, high energy betas (> 1.0 Mev) from activated air easily pass through the inner mylar walled chamber to the outer chamber, while weak tritium betas (≤ 18 keV) remain within the confines of the inner chamber. In this configuration, outer chamber current subtraction from inner chamber currents effectively provides tritium concentrations and activated air concentrations in the sample stream.

Discriminating Monitor (Type 4)

Tritium oxide (HTO , T_2O) results in four orders of magnitude more dose equivalent than elemental tritium (T_2). In order to separate the two forms of tritium a discriminating monitor was built at LANL¹ which will monitor a combined sample from each of the eight stacks. Discrimination is achieved by a detector which allows tritiated water vapor to pass through a membrane, while restricting the passage of elemental tritium. Following the separation of tritium oxide and the elemental forms of tritium, each specimen is counted in separate 1 liter ionization chambers. Response time for this monitor is on the order of 20 minutes.

Discriminating Monitor (Type 5)

In addition to type 4, the combined stack effluent is monitored by a passive tritium sampler, the PPPL Differential Atmospheric Tritium Sampler (DATS). The DATS was designed and fabricated at PPPL. It is an environmental sampler, designed to operate continuously for up to two weeks without AC power. The sampler consists of drying traps, catalyst and an air mover. Two of the traps collect HTO, and the third collects HT. Tritium is recovered from the samples by first baking out under vacuum and then cryogenically condensing the distillate. Obviously this is not a "Real-time" monitor, but it is capable of providing a record of HT and HTO release over an extended period of time without an external source of power.²

Accountability

The stack monitoring system is designed to run continuously whenever there is tritium in the facility, generating continuous data information for each of the eight primary stacks which service the TFTR facility. Airflow information and concentration levels are input to a commercially available, microprocessor-based, distributed control system designed for plant control. The system has been purchased with standard software and operating system. PPPL will write the necessary application-specific software. Among the important tasks this system will perform are the calculation of release concentrations of tritium, the archiving of release information, and the remote display of radiation concentrations and integrated release.

Operation During Loss of AC Power or Seismic Event

The tritium monitoring systems are designed to continue operation under adverse conditions such as loss of ac power and seismic events. The primary ac supply for the tritium monitors is from a 480 volt ring bus which is backed by a diesel generator which starts automatically 30 seconds after the loss of ac power. In the event of a total power failure, the tritium monitors are backed by individual Uninterruptible Power Supplies (UPS) for a minimum of two hours.

Stack and Area tritium monitors were subjected to rigorous testing by an independent testing laboratory to establish that they would remain operational through and after the Most Intense Earthquake (MIE) predicted for the TFTR area.³ Stack sample/flow skids were evaluated by a qualified expert.

Figure 2: TFTR Test Cell Monitoring System

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Normal Operation

Area tritium monitors have been placed in each of the tritium containing rooms at the TFTR facility. Eight stack tritium monitors have been placed on each of the seven exhaust stacks associated with these rooms and on the process exhaust line. The alarm outputs of the area monitors are interlocked with the fans and tritium seal dampers associated with each area, and with the Tritium Vault Cleanup System (TVCS). The associated stack monitor serves a backup function for the area monitor, and in addition provides a means of tracking release through the stack in real time. The analog signal outputs of the monitors and of the stack sample-flow system are sent to a distributed control and monitoring system (D3-CS) for computation and archiving of release. Three independently adjustable alarm thresholds known as Caution, High, and High-High have been designed into each monitor. Caution Level alarms are annunciated but initiate no hardware response. Both High and High-High alarms are annunciated and initiate a hardware response. Health Physics recommends a Derived Air Concentration (DAC) for HTO to be the setpoint for High alarms. Figure 2, "TFTR TEST CELL MONITORING SYSTEM", contains the block diagram of the entire tritium monitoring system for the TFTR test cell. Two area monitors located outside the test cell shielding wall are connected to air sampling lines in the test cell. Two stacks, one negative pressure at 7,500 cfm and the other the main return at 35,000 cfm are monitored. The Alarm outputs of the two area monitors and the stack monitor for the main return are logically "anded" with the HVAC Permissive. Loss of permissive causes the primary HVAC fans for the test cell to stop and, close and seal HVAC dampers. Because of the volume of the Test Cell (1,000,000 cubic feet) and the unlikelihood of a release in the Test Cell, it is not serviced by the TVCS, which has a capacity of 1000 cfm. The negative pressure fan for the Test Cell will continue to run to prevent an uncontrolled release. The stack monitoring system will detect and record any release. Driers have been placed in the negative pressure stack to remove any HTO from the effluent stream.

Details of the entire TFTR Tritium and Stack Monitoring System may be found in the PPPL document, OPR-SPEC-TR-22.⁴

Failsafe Operation

Failsafe interlocks have been designed into the Heating, Ventilation, and Air Conditioning system (HVAC). Fans and dampers are interlocked to avoid over or under-pressurization of HVAC ductwork. A loss of permissive from an area or stack monitor is interpreted as an alarm condition. Hardwired outputs of the area and stack monitors fail in the alarm state upon total loss of power.

DoE Order Compliance

The monitoring requirements for occupational workers are stated in DOE Order 5480.11, "Radiation Protection for Occupational Workers", 12-21-88. The order states that ambient air monitoring is required for any area where the air has the potential to exceed 10% of a Derived Air Concentration. Area tritium monitors have been provided for all areas which house tritium bearing equipment. These rooms are maintained at a negative pressure relative to the rest of the facility.

Monitoring requirements for the general public and the environment are stated in DOE Order 5400.5, "Radiation Protection of the Public and the Environment". The order states that the 10 mrem/year site boundary limit will not be exceeded. DOE Order 6430.1A, "General Design Criteria", state that activated air monitoring shall be provided for fusion facilities where applicable. This requirement has been met at TFTR by monitoring both at the local level in the TFTR test cell and at the stacks for the experimental areas.

The TFTR test cell monitors are of the differentiating type(type 3-fig 1), capable of distinguishing between actual tritium and the activated air produced by the high neutron flux produced by TFTR during DT pulsing. As noted in figure 1, the type 3 monitor requires an additional chamber for gamma compensation.

The concentration of tritium and activated air released through the stacks is measured and recorded by individual real-time tritium/activated-air monitors. Total effluent release data is collected and archived by the distributed control system, and may be displayed for any period of time.

Conclusions

The TFTR Tritium Monitoring System has been designed to provide tritium concentrations for personnel and environmental protection. A variety of monitors have been employed to this end. Real time area and stack monitors are tied to HVAC control systems, and passive samplers provide a continuous effluent monitoring without ac power. The challenge of TFTR's radiological and electrical environment has been met.

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