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TITLE: TRITIUM MONITORING WITHIN THE REACTOR HALL OF A DT FUSION REACTOR

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TRITIUM MONITORING WITHIN THE REACTOR HALL OF A DT FUSION REACTOR

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ABSTRACT

Monitoring the reactor hall atmosphere of DT-fueled fusion reactors will probably be performed with conventional ion chamber and proportional counter instruments modified as necessary to deal with the background radiation. Background includes external neutron and gamma radiation and internal beta-gamma radiation from the activated atmosphere. Although locating instruments in remote areas of the reactor hall and adding local shielding and electronic compensation may be feasible, placing the instruments in accessible low-background areas outside of the reactor hall and doing remote sampling is preferable and solves most of the radiation problems. The remaining problem of the activated atmosphere may be solved by recently developed instruments in conjunction with the use of semi-permeable membranes currently under development and evaluation.

INTRODUCTION

Fusion power reactors fueled by D-T gas mixtures will have large quantities of tritium in the reactor and support buildings. For instance in the STARFIRE conceptual reactor, the total inventory consists of approximately 11 kg of tritium (Table 1).

Active monitoring for tritium leaks into secondary containments or into room atmospheres is essential both for safety and environmental reasons and for correction or control of the problem before (further) damage is done and/or additional tritium is released. Monitoring for atmospheric tritium in support buildings with normal background radiation can be accomplished with conventional instrumentation. In the areas with high radiation background levels such as the hot cell(s) and reactor hall, special approaches or instrumentation are needed.

Table 1. STARFIRE Tritium Inventory[1]

Tritium System	Vulnerable[a] (g)	Non-vulnerable[a] (g)
Solid Breeder Blanket	—	~10,000
Blanket Purge Stream	0.2	—
Blanket Tritium Recovery	281	—
Vacuum Pumps	69	—
Fueling	58	—
Fuel Processing	—	154
Storage	—	1071
Total	398	~11,225

MONITORING INSTRUMENTS

Most tritium room air monitors are of two types: flow-through ion chamber instruments and flow-through proportional counters. Ion chamber monitors are generally more common except in countries with more stringent concentration limits or monitoring requirements (as in Germany, for instance). The normal sensitivity of an ion chamber monitor is 1-5 $\mu Ci/m^3$[a] and depends somewhat on the size of the chamber and the time constant and other properties of the electronics. Although most such monitors employ flow-through ion chambers which for air monitoring require the use of a pump, in many cases the pump may be dispensed with and the chamber designed with "open" (perforated) walls. An example of such an open-walled chamber is the one shown in Fig. 1 designed for glovebox monitoring at the Tritium Systems Test Assembly at the Los Alamos National Laboratory.

The proportional counter instrument, on the other hand, cannot function without pumps since the sampled atmosphere must be mixed with a counting gas (usually methane or natural gas) before entering the counter. It is inherently more sensitive than the ion chamber monitor by a factor of 10-100 or more depending on the

[a] This may be compared to the Derived Air Concentration of 20 $\mu Ci/m^3$ for tritiated water vapor recently published by the International Commission Radiation Protection in ICRP-30 (Part 1, 1979).

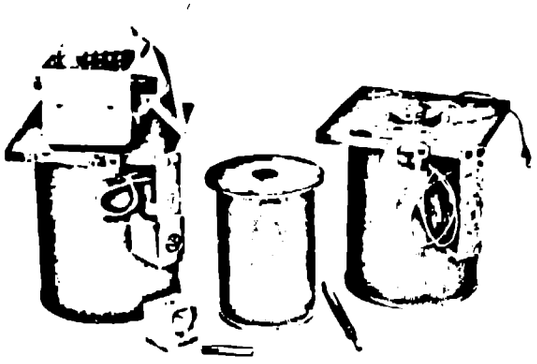

Fig. 1. Open-walled tritium ion chambers used at TSTA for glovebox monitoring. A remotely actvated gamma check source unit for routine instrument checking is shown attached to the assembled chamber, which is protected by a felt dust cover.

counting time, but its upper range is limited to a tritium concentration of ~1 mCi/m^3, which in many cases restricts its usefulness. The ion chamber has no such limitation.

Both instruments are sensitive to external penetrating radiation, which results in signals which could be mistaken for tritium. For instance the ion chamber monitor's response to gamma radiation is ~100 $\mu Ci/m^3$ per mR/h. Eliminating or minimizing the effects of high radiation backgrounds can be accomplished by local shielding, by remote sampling, or by the use of additional chambers to provide the subtracting current or counts. In the case of ion chamber monitors, compensation usually takes the form of a closed chamber placed next to or concentric with the measuring chamber. Subtraction, which is never perfect, depends on the radiation field spectrum and geometry at the chamber location. Compensation that varies from 95% to 105% is considered excellent. Subtraction with proportional counters is accomplished with guard chambers placed on either side of the counting volume. Using pulse height and rise-time discrimination and coincidence/anticoincidence counting, the sensitivity of the counting chamber to penetrating radiation is greatly reduced and compensation more easily accomplished. As in the case of ion chambers, subtraction is also dependent on the radiation spectrum and geometry.

Neither of the two instrument types in its basic configuration differentiates between molecular tritium (HT) and tritiated water vapor (HTO). This discrimination is oftentimes desirable since the relative hazard of HTO to the molecular form is of the order of 25 000. However, several laboratories in the United States and Canada[2-5] have developed prototype ion chamber and proportional counter instruments that can perform this differentiation. Semi-permeable membranes, which take advantage of th much greater permeability of water vapor ove that of hydrogen gas, are used to make the separation. Major disadvantages of membranes are long response and clearing times, being of minutes to tens of minutes.

To further complicate the problem of monitoring the reactor hall, the atmosphere will have high concentrations of radioactive gases. Assuming there is an inner shield surrounding the reactor, the concentrations within and outside of the shield will, of course, be substantially different and will depend on whether there is mixing of the atmospheres of the two volumes. For purposes of illustration, the maximum average concentrations of ^{16}N, ^{13}N, and ^{41}Ar expected within the (original) shield and remaining reactor hall (test cell) of the Tokamak Fusion Test Reactor (TFTR) (where the atmosphere is air), assuming no ventilation, are given in Table 2. At a next generation reactor like an INTOR or STARFIRE, the concentrations will be higher--at least within the shield.

Proportional counter instruments with the design features mentioned earlier, by virtue of their geometry and circuitry, are also suitable for subtracting the counts produced by high-energy-beta emitting gases in the sampled atmosphere. However, the subtraction, which, as in the case of external radiation, is electronically programmed into the counting circuit, is different for different beta-emitters or for background radiation, for that matter. The

Table 2. Maximum Concentrations of Activated Gases Within Test Cell at TFTR ($\mu Ci/m^3$)

Location	Plasma Pulse Rate	^{16}N	^{13}N	^{41}Ar
Within Inner Shield	1 shot	2.0×10^{6}	1.5×10^{4}	3.3
	100 shots/8 h	2.0×10^{6}	5.2×10^{4}	100
Test Cell Outside Shield	1 shot	390	2.2	7.2×10^{-3}
	100 shots/8 h	390	7.4	2.2×10^{-1}

relative amounts of each radioactive gas would have to remain constant for compensation to be effective over a period of time.

An ion chamber instrument which uses two concentric, coaxial chambers for current subtraction has recently been developed at the Los Alamos for monitoring tritium in the presence of activated gases.[6] The inner, measuring chamber and the outer, compensating chamber are separated by a common wall made of 6.3 μm-thick double-aluminized Mylar supported over a copper screen. The Mylar stops the tritium betas but allows those of higher energy to penetrate to the outer chamber where the subtraction current is produced. Each chamber feeds its own electrometer and current balancing is performed after the electrometer stages. Measurements made at Los Alamos and at the RTNS-2 facility at the Lawrence Livermore National Laboratory confirmed its predicted detection limit (for tritium) of less than $\sqrt{C}$ μCi/m^3 where C is the concentration of the contaminant gas in μCi/m^3. Its maximum sensitivity is that of conventional ion chamber instruments. Figure 2 is a photograph of the chamber assembly of the prototype instrument. Similar instruments are expected to be used for monitoring the TFTR test cell after tritium is introduced.

It is possible that semi-permeable membranes which can be used for HTO-HT discrimination may also be used for HTO-HT/activated air discrimination or even HTO-HT-activated air discrimination by adding a catalyst and an additional chamber. How useful membranes become for this application depends on the relative permeabilities of HTO, N_2 (or $_{41}NO_x$, the probable chemical form of ^{13}N) and ^{41}Ar. Preliminary permeability measurements appear to be encouraging but more work needs to be done.

MONITORING THE REACTOR HALL

A tritium monitor located in a reactor hall would have to face an interesting radiation environment: direct and secondary neutron and gamma/bremsstrahlung radiation, gamma radiation from activated equipment and building structures and beta/gamma radiation from activated gases. Certainly the atmosphere within the inner shield would have to be monitored remotely. Although it might be possible to locate at least the instrument chambers within the reactor hall outside of the inner shield and then provide local shielding and compensation as necessary, from a logistics point of view it would certainly be preferable to locate all of the tritium instruments outside of the reactor hall in a low radiation area where instruments may be checked, calibrated, replaced, or repaired as required without concern about the reactor's operation or the radiation in the reactor hall. All monitoring of the reactor hall atmosphere would then be done remotely with long hoses. The added sampling delay of ~1 min for a 30-60 m sampling line has a built-in benefit which would otherwise probably have to be incorporated into the external plumbing of some of the instruments. The delay would allow the concentration of ^{16}N to decay to a value below that of ^{13}N before it reaches the measuring chamber, thereby increasing the sensitivity of a compensating tritium monitor by a factor of 10 or more. In the case of TFTR, for instance, the concentric ion chamber monitor with a minimum sensitivity of $\sqrt{C}$ μCi/m^3 could detect a release within the inner shield (volume of 370 m^3) of less than 90 mCi.

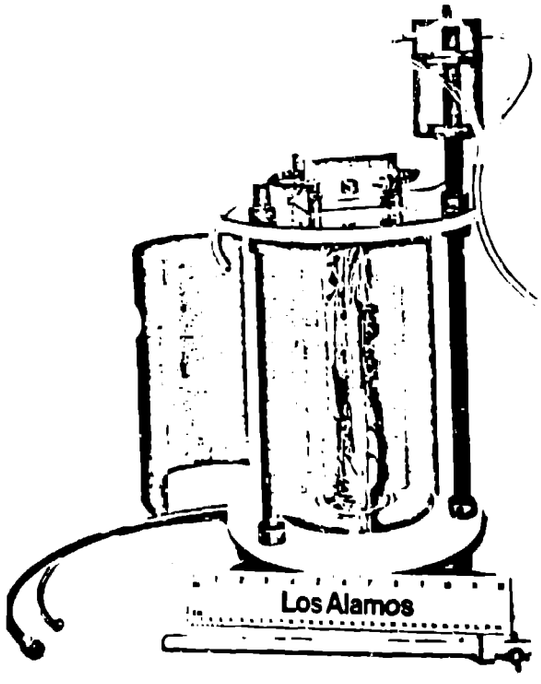

Fig. 2. Prototype chamber assembly developed at LANL for monitoring tritium in the presence of activated air. Sampled air is introduced and removed through the hollow central electrode (bottom).

It is expected that the reactor hall atmosphere will be monitored by ion-chamber-type instruments using the compensating type for the volume within the inner shield and the non-compensating type outside. If semi-permeable membranes can be used to advantage with activated gases, as I feel they can be, they may then be incorporated with these instruments to further improve their sensitivity and to allow simultaneous discrimination of HTO and HT.

The exhaust air that must be stacked to maintain negative pressure in the reactor hall could be monitored with a proportional counter instrument using membranes to separate the tritium from the activated air and the HT from the HTO, if desired. It is expected that a passive HTO-HT-discriminating stack bubbler would also be used so that the active stack monitor's ability to discriminate between HTO and HT is probably not very important.

PASSIVE MONITORING

Although the emphasis in this paper has been directed toward real-time monitoring, a word should be said about passive monitoring. Passive monitoring usually consists of taking grab samples of moisture in the air by freezing or bubbling and analyzing the collected moisture for HTO using a liquid scintillation spectrometer. To measure the HT, a catalyst is incorporated in the sampling line to convert it to HTO prior to collection. Except for losses in sampling hoses or tubing, the measurement is very accurate and could be used to check or calibrate active instruments while actually in use. Vapor losses in long lines can be minimized by either heating the sampling tubing or having a bubbler within the reactor hall and remotely sampling the liquid. Passive analysis of the collected moisture allows for relatively simple chemical and/or electronic techniques to achieve the desired separation of the tritium from any radioactive contaminants that may have become entrapped.

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