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A NEW TRITIUM MONITOR FOR THE
TOKAMAK FUSION TEST REACTOR

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ABSTRACT

At DT-fueled fusion reactors, there will be a need for tritium monitors that can simultaneously measure in real time the concentrations of HTO, HT and the activated air produced by fusion neutrons. Such a monitor has been developed, tested and delivered to the Princeton Plasma Physics Laboratory for use at the Tokamak Fusion Test Reactor (TFTR). It uses semipermeable membranes to achieve the removal of HTO from the sampled air for monitoring and a catalyst to convert the HT to HTO, also for removal and monitoring. The remaining air, devoid of tritium, is routed to a third detector for monitoring the activated air. The sensitivities are those that would be expected from tritium instruments employing conventional flow-through ionization chambers: $1-3 \mu\text{Ci}/\text{m}^3$. Its discriminating ability is approximately 10^{-3} for any of the three components (HTO, HT and activated air) in any of the other two channels. For instance, the concentration of HT in the HTO channel is 10^{-3} times its original concentration in the sampled air. This will meet the needs of TFTR.

INTRODUCTION

During operation of a DT-fueled fusion reactor, the reactor hall atmosphere, assumed to be air, will have high concentrations of ^{16}N , ^{13}N and ^{41}Ar . This radioactive air would normally interfere with efforts to monitor for tritium releases using conventional tritium instruments. Flow-through ionization chamber instruments, the type most often used in the United States for tritium monitoring, cannot differentiate among various radioactive gases, including elemental tritium (written HT here) and its oxide form (written HTO here). To solve part of the problem, that of monitoring tritium and the activated air simultaneously, an instrument was developed at the Los Alamos National Laboratory for eventual use at the

Tokamak Fusion Test Reactor (TFTR).^{1,2} The instrument employs a chamber assembly consisting of two coaxial ionization chambers separated by a thin wall opaque to tritium betas. The inner chamber is the flow-through measuring chamber and the outer chamber is used to obtain the tritium concentration by current subtraction.

However, this technique does not solve the problem of differentiating between the two tritium species: HTO and HT. This is an especially desirable feature at TFTR, where tritium is expected to be introduced in 1988. The TFTR has a room cleanup system (basically a scrubber) which removes most of the HTO but none of the HT. Thus a release of tritium, which may include both tritium species, would be only partly cleaned up before stacking. The decision to stack the remaining tritium will need to be made on the basis of the amount of tritium remaining in each form. The importance of differentiating between these two species is due to their different radiological hazard in air. The most recent estimate by the ICRP³ is that HTO is 2.5×10^4 times as hazardous as HT.

Several laboratories have explored the possibility of using semipermeable membranes to separate HTO from the sampled air for monitoring and thus to be able to measure the concentrations of both species simultaneously in the same instrument.⁴⁻⁶

This technique lends itself to an extension which can be used to measure not only the HTO and HT concentrations but that of the activated air as well. The modification involves the addition of a catalyst to promote the oxidation of the HT to HTO and additional membrane chambers to remove the HTO thus formed.

With the support of the Princeton Plasma Physics Laboratory, such an instrument was developed, tested and delivered to TFTR.

MASTER

END

However, before tritium is introduced, it will be used to monitor only the concentration of activated air formed by DD neutrons.

DESCRIPTION OF THE INSTRUMENT

The key element in such a discriminating monitor is the semipermeable membrane, which must have a high permeability for HTO relative to those for HT and the components of activated air. The membrane material chosen is Dupont Nafion, a copolymer of tetrafluoroethylene and other monomers. It is available as capillary tubing which is assembled in bundle form by Perma Pure Products, Inc.^b in an impermeable shell for commercial drying applications. In this report, we will refer to these units as dryers although in the present application, the sampled air is not dried but remains at the moisture level that is maintained at TFTR: viz, 40% relative humidity.

In operation, the sampled air is directed on the outside of the capillary tubing (when sam-

pling for HTO) or through the tubing itself (when removing the remaining HTO) (Fig. 1). A counterflowing stream of clean, moist air flows on the other side of the capillary membrane to remove the HTO. The sizes of the dryers used in the instrument as well as the actual flow rates were determined experimentally.

Fig. 1 Schematic drawing of a tube dryer. The air streams may be interchanged when sampling for HTO.

A simplified flow diagram with the instrument's main mechanical components is given in Fig. 2.

Fig. 2 Simplified drawing of the flows through the mechanical components of the instrument.

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The sampled air, directed through the instrument at 3 lpm, passes through the first dryer on the outside of the Nafion bundle. This is a 50-tube dryer approximately 35-cm long. A clean counterflowing air stream flows through the capillary tubing and into a 1-l ionization chamber where the concentration of HTO achieved is 95% of the initial concentration. Since only part of the HTO is removed in the first dryer, a second dryer is used to complete the removal. Two separate dryers are used because the flow rates appropriate to the two tasks are not compatible. In the second dryer, a 53-cm-long, 200-tube unit, the sampled air goes through the capillary tubing and the counterflowing purge air, at 20 lpm, flows on the outside of the capillary bundle.

After passing through the first two dryers, where little HT or activated air is removed, the sampled air goes through a precious metal catalyst (on stainless steel ribbon) heated to approximately 250°C. There the HT is converted to HTO, which is then partly removed in the 3rd dryer (for monitoring), and finally completely removed in the 4th dryer. The air devoid of tritium is then directed to the third 1-l ionization chamber, where the activated air concentration is measured.

A photograph of the front of the 155-cm instrument rack is shown in Fig. 3 and one of

Fig. 3 Photograph of the front of the Instrument showing the electronic chassis and flow control panel.

the rear of the rack with its sides and door removed is shown in Fig. 4.

Fig. 4 Photograph of the rear of the Instrument. The tube dryers are mounted on the left and right walls of the cabinet. Below the electronic chassis are the three ionization chambers, catalyst chamber (insulation removed), variable transformer (to control the catalyst temperature), and pumps (at the bottom).

The electronic package, located in the chassis at the top of the rack, was built by Overhoff and Associates, Inc.³ to meet our specifications. It consists of three electrometer channels, each with a range of 1-10⁷ $\mu\text{Ci}/\text{m}^3$ (when coupled to the 1-l chambers),

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covered by two digital ranges. With an electronic time constant of 15 s, its sensitivity is approximately $2 \mu\text{Ci}/\text{m}^3$. The two tritium channels are supplied with adjustable alarms. Connectors at the rear of the instrument have been provided for computer data acquisition, remote readouts and recorders.

PERFORMANCE

The performance of the instrument is largely dependent on the permeation of HTO through the Nafion membrane relative to that of other gases. Although some of the permeabilities have been measured by others, tests were made at Los Alamos of the permeation of HTO, HT and ^{85}Kr and of ^{13}N at the Rotating Target Neutron Source facility at the Lawrence Livermore National Laboratory. Krypton-85 was used instead of ^{41}Ar because of the difficulty of obtaining argon in sufficiently high concentrations. However, there is no reason to believe that the permeability of krypton would be significantly different from that of argon. Although the concentration of ^{13}N ($T_{1/2} = 7\text{s}$) in the reactor hall is expected to be higher than that of ^{13}N immediately following a DT burn, its concentration quickly decays to a value lower than that of ^{13}N before the sampled air reaches the instrument. Nitrogen-13, believed to be in the form of $^{13}\text{NO}_x$, is expected to be the dominant radioactive gas in the instrument's activated air channel.

The permeation tests mentioned above helped determine the flow rates and dryer sizes necessary to achieve satisfactory separation. As a result of these measurements, the discriminating ability of the instrument has been calculated. The results are:

HT in the HTO channel*: $\sim 2 \times 10^{-4}$
 HT in the activated air channel: $\sim 10^{-3}$
 HTO in activated air channel: $< 10^{-4}$
 ^{85}Kr in the HT channel: $\sim 10^{-3}$
 ^{85}Kr in the HT or HTO channel: $< 10^{-3}$
 $^{13}\text{NO}_x$ in the HT or HTO channel: $\sim 10^{-3}$

These results are entirely satisfactory for present use at TFTR. One disadvantage of the use of semipermeable membranes is the long transport time of HTO through the material. With the Nafion dryers, response times for tritium of ~ 6 min (1% of final equilibrium value) and 20 min (50% of final value) have been measured. These times may be decreased with other

membranes, especially thinner ones but at the possible expense of the instrument's discriminating ability. To these times must be added the time (1-2 min) for the sampled air to reach the instrument located 50 m from the reactor hall and the mechanical time constant associated with the flow rate (1 lpm) through each tritium ionization chamber (overall volume 2 l). Quick response is necessary when action must be taken immediately following a release. For this, a different instrument such as the one mentioned earlier but which does not discriminate between HTO and HT, may be suitable. Following a release that is being contained in the building and possibly cleaned up, monitors with response times of minutes should be quite acceptable.

CONCLUSION

The discriminating monitor described has met the requirements of TFTR with regard to sensitivity, range, discriminating ability and response time. Although faster response times would be desirable, it is not necessary in an instrument that will be monitoring reactor hall or stack concentrations that can change only very slowly with time.

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*Read as "the concentration HT in the HTO channel divided by the concentration of HT in the inlet air," etc.