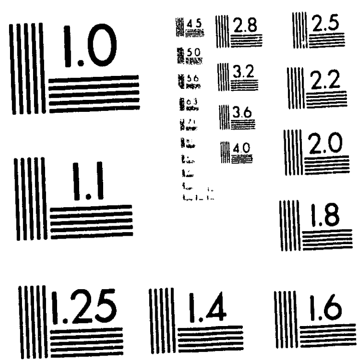
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Initial Testing of the Tritium Systems at the Tokamak Fusion Test Reactor*

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ABSTRACT

The Tokamak Fusion Test Reactor (TFTR) at Princeton will start its D-T experiments in late 1993, introducing and operating the tokamak with tritium in order to begin the study of burning plasma physics in D-T. Trace tritium injection experiments, using small amounts of tritium will begin in the fall of 1993. In preparation for these experiments, a series of tests with low concentrations of tritium in deuterium have been performed as an initial qualification of the tritium systems. These tests began in April 1993. This paper describes the initial testing of the equipment in the TFTR tritium facility.

INTRODUCTION

The tritium facility at TFTR, in Fig. 1, consists of:

- The Tritium Storage and Delivery System (TSDS) is enclosed in three gloveboxes, the Tritium Receiving and Analytical, the Tritium Storage and Delivery and the Vacuum Pumping gloveboxes. The purpose of this system is to receive, analyze and store tritium and to deliver tritium to the injection systems on the tokamak.

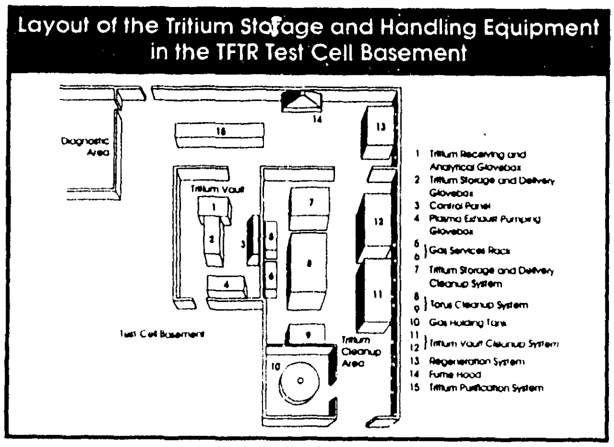

Fig. 1 TFTR Tritium Area Layout

- The Torus Cleanup System (TCS) is a 24 std. l/s cleanup system which receives the gas from the various vacuum systems on the tokamak, and processes this gas to remove and collect the tritium contained in this gas. This system catalytically oxidizes the tritium and the resultant tritiated water is collected on molecular sieve beds for off-site shipment.

- The Tritium Vault Cleanup System (TVCS) is a 472 std. l/s cleanup system capable of processing the atmosphere in the various rooms of the tritium facility in the event of a tritium release into these areas.

- The Tritium Storage and Delivery Cleanup System (TSDCS) is a 4.7 std. l/s cleanup system for maintaining a dry, inert, tritium free atmosphere in the TSDS glovebox. The glovebox atmosphere is also maintained oxygen free by use of a copper getter bed to remove oxygen.
- The Tritium Regeneration System (TRS) is used during regeneration of the oxygen getter bed and the molecular sieve drier beds in the cleanup systems. This is accomplished in the TRS by circulating a high temperature regeneration gas through the fixed molecular sieve beds, and by reducing the copper oxide by circulating a high temperature hydrogen stream through the oxygen getter bed.

These systems have been described previously [1]. They were designed and fabricated in the late 1970's, installed in 1982 and have been in non-tritium operation since 1990. Except for the TRS, they have now been tested with hydrogen and/or tritium during the Tritium Systems Tests at TFTR.

TRITIUM SYSTEMS TESTS

In April 1993 an Operational Readiness Review approved the introduction of up to 1000 Curies (Ci) of tritium at TFTR to be used to conduct the Tritium Systems Tests. This is a series of tests to leak check the systems with tritium, perform functional testing of the equipment with tritium, allow the operating staff to gain "hands-on" tritium experience and to begin to establish a data base of operations of the facility with tritium. A series of Integrated Systems Test Procedures (ISTPs) were written and approved for conducting the Tritium Systems Tests. These ISTPs were: ISTP-191 "Receiving, Unloading, and Inventory of Tritium for Tritium Systems Test"; ISTP-192, "Tritium Manipulation in the Tritium Storage and Delivery System"; ISTP-193, "Tritium Manipulation Between the Tritium Storage and Delivery System and the Tritium Storage and Delivery Cleanup System"; and ISTP-194, "Tritium Manipulation in the Torus Cleanup System".

In anticipation of the tritium tests, the cleanup systems, TCS, TSDCS and TVCS, had undergone testing with hydrogen to measure the cleanup efficiency (Decontamination Factor) for removing elemental hydrogen isotopes from a gas stream. These hydrogen tests were performed using a gas chromatograph as an analytical tool for detecting elemental hydrogen in the input and output streams of the cleanup systems. These tests yielded results showing that all of the cleanup systems had Decontamination Factors in excess of the design requirement of 1000.

In these hydrogen tests, a known amount of hydrogen gas was injected in front of the catalytic recombiner on the respective cleanup systems. Elemental hydrogen was measured on the outlet of recombiner and moisture was measured on the outlet of the drier beds. Analysis of the elemental hydrogen was by gas chromatography. Staff from the Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory participated in the tests and provided the gas chromatography equipment and expertise.

Detailed test procedures were prepared, in accordance with established administrative procedures and DOE Orders, to control the movement of the tritium in the Tritium Systems Tests. All of the tritium systems had been leak tested previously with a helium mass spectrometer type leak detector and confirmed to have no single leak to the atmosphere >10^{-6} scc/s. Tritium leak checking, using a monitor as the detector, has a higher sensitivity than helium for leak checking.

ISTP-191:

A container with a gas mixture of 10 liters of deuterium containing ~100 Ci of tritium was prepared at the Tritium Systems Test Assembly (TSTA) at the Los Alamos National Laboratory, and was shipped to TFTR for these tests. This gas mixture was used to perform a series of Integrated Systems Test Procedures (ISTPs) at TFTR. The tritium container was moved into the Tritium Receiving Glovebox and ISTP-191 was conducted. The gas (~0.5% tritium) was analyzed and transferred to the uranium bed-1 (UBED-1) in the TSDS. At TFTR the analysis of tritium generally is performed by mass spectrometry, beta scintillation, metal gettering techniques and ion chamber measurements. An Extrel quadrupole mass spectrometer (QMS) is operated in low resolution mode in conjunction with a SAES™ metal getter appendage pump and EG&G Mound Labs Model MD-200 Beta Scintillator detector (BS). Calibrations of the QMS are made using pure gases and appropriate calibrated gas mixes. Total gas quantity is determined by PVT measurements.

ISTP-192:

A block diagram of the TSDS, indicating major components, is shown in Fig. 2. UBED-1 was then heated to produce a pressure of about 2400 Torr of the test gas above the UBED. This gas was then used to perform ISTP-192. Section by section, adjacent portions of TSDS were opened up to this gas while maintaining the gas pressure above 1500 Torr. Leak testing of this system was conducted using the glovebox monitor (Overhoff Technology Corporation) with a sensitivity of 1 µCi/m^3 with its inlet connected to a stainless steel probe through plastic tubing as described in [2]. Each valve bonnet, gasket flange, and welded joint was "sniffed" to detect any tritium leaks. The total quantity of test gas available was insufficient to pressurize more than half the TSDS at one time. The test was, therefore, halted temporarily to cool the uranium bed and reabsorb the tritium for pressurizing the second half of the system. In all, only one valve bonnet was observed to be leaking ; the bonnet nut was tightened and no further leak was detected. At no time did the test pressure in any open section drop below 1500 Torr. No leaks, other than the one mentioned above were detected. The glovebox monitor showed that the integrated loss from the system did not raise the glovebox background level significantly.

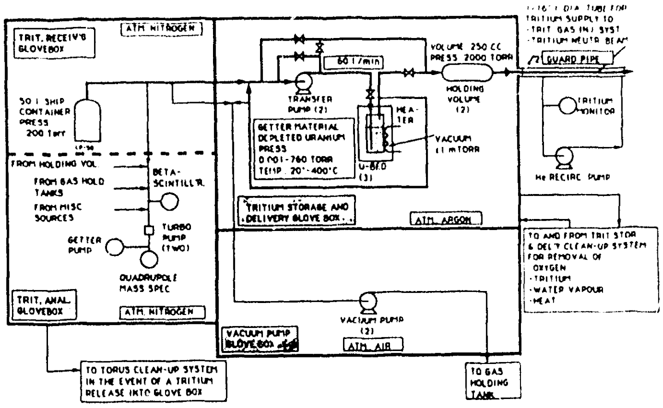

Fig. 2 TFTR Tritium Storage and Delivery System

ISTP-193:

Once the TSDS process was tested, the glovebox itself was tested with the 0.5% tritium gas using ISTP-193. Here, tritium gas was trapped at a known volume and pressure between two valves and later swept into the glovebox with helium gas. A total of 26 mCi were transferred to the glovebox in this manner. A small fan was used to achieve homogeneity in the glovebox atmosphere. The tritium concentration in the glovebox was measured at 13,600 µCi/m^3 by the glovebox monitor. The glovebox was placed in a static condition (isolated from the cleanup system) at atmospheric pressure for leak testing. Sniffing of all glove ports, windows, and glovebox joints indicated no leakage detectable with a handheld Scintrex tritium monitor with a sensitivity of 1 µCi/m^3. Subsequently, glovebox pressure was raised to slightly above atmospheric pressure with argon. No leaks were detected at this pressure.

This tritium was then used as a source of elemental (DT) tritium for leak testing the Tritium Storage and Delivery Cleanup System (TSDCS), Fig. 3. The TSDCS was connected to the TSDS glovebox to circulate the glovebox atmosphere while maintaining the platinum catalyst in the recombiner at less than 35° C. This precaution was taken to permit elemental tritium to reach the discharge side of the molecular sieve drier beds in the TSDCS. Recirculation of this gas back to the TSDS glovebox showed an equilibrium level of about 34 µCi/m^3 in the glovebox (about twice the background level). No leaks greater than 10 µCi/m^3 above background were detected using the handheld Scintrex monitor to sniff all TSDCS flanges, valve bonnets, gaskets and welds. This test procedure was then repeated to provide a source of tritium for testing TSDCS with a hot recombiner (~175° C). Glovebox tritium concentration, as a function of time, is shown in Fig. 4. No tritium was observed at the discharge of TSDCS, so a decontamination factor was calculated to be over 4000, consistent with results obtained when TSDCS was tested with hydrogen.

ISTP-194:

The Torus Cleanup System (TCS) was then tested using ISTP-194. Approximately 800 mCi of tritium were transferred from UBED-1 in the TSDS to the Gas Holding Tank in the TCS, Fig. 5. The handheld monitor was used to sniff all flanges, welds and valve bonnets during the transfer operation, and during GHT sampling and analysis operations. No leaks were detected. Approximately 200 mCi were then introduced into the TCS and recirculated while maintaining the recombiner catalyst cold. Once elemental tritium levels at the TCS discharge point exceeded dischargeable levels, the addition of tritium was

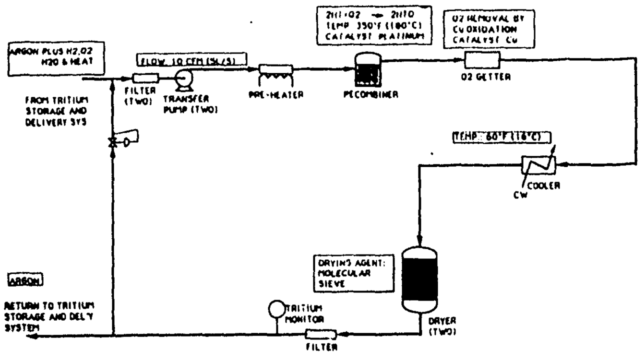

Fig. 3 Tritium Storage and Delivery Cleanup System

stopped and leak checking of the TCS was initiated, while maintaining the recirculating flow through the TCS. Again, no leaks were detected. Finally, upon completion of the leak checking, the TCS recombiner temperature was raised and the recirculating tritium was cleaned up. The three phases of this test are clearly shown in Fig. 6: initial buildup due to introduction of tritium; slow decay due to equilibration and plating out within TCS; and finally, very rapid cleanup once the recombiner temperature approached 175°C. Subsequent cleanup of approximately 580 mCi at a recombiner temperature of about 500°C showed no tritium in the TCS outlet, consistent with the results obtained during testing with a nominal 1% hydrogen in nitrogen mixture. This implies a decontamination factor well over 1000.

TRITIUM INVENTORY

As a final test, all of the tritium on the uranium beds in the TSDS was desorbed and sent to the Gas Holding Tank (GHT) in the TCS. A total of about 117 Ci were transferred at this time. The measurement of tritium in the GHT (about 7.6 m^3) was by a Femto-tech™ model 2524PP/U24 tritium monitor in a sample recirculating loop. This monitor had been calibrated, by Los Alamos National Laboratory, at concentrations from 1 to 20 Ci/m^3. The measured concentration in the GHT during this test was about 13.5 Ci/m^3. This gas in the GHT was processed through the TCS, collecting the tritiated water on the fixed molecular sieve beds in the TCS. No leaks were detected while processing this higher concentration gas. No tritium was detected at the outlet of the molecular sieve beds. Thus both the leak tightness and the functionality of the TCS were demonstrated during this test.

When the 117 Ci of tritium were transferred from the TSDS to the Gas Holding Tank in the TCS a problem was encountered. Intially, the tritium monitor on the GHT measured much less than 117 Ci. Several activities were initiated to determine the cause for this discrepancy. First, the tritium monitor on the GHT was suspect. A spare, identical monitor was available. This monitor was sent to LANL for calibration with tritium gas in the range 1-20 Ci/m^3. Second, all of the vacuum piping between the uranium beds and the GHT was purged with nitrogen to the GHT. Also, the decision was made to sample and analyze oil in the vacuum pump used to pump the test gas into the GHT. During the maintenance operation to sample the pump oil some 11 Ci of tritium were released to the plant stack, and a small amount (< 1 Ci) was released into the tritium vault. The tritium in the vault actuated the alarm

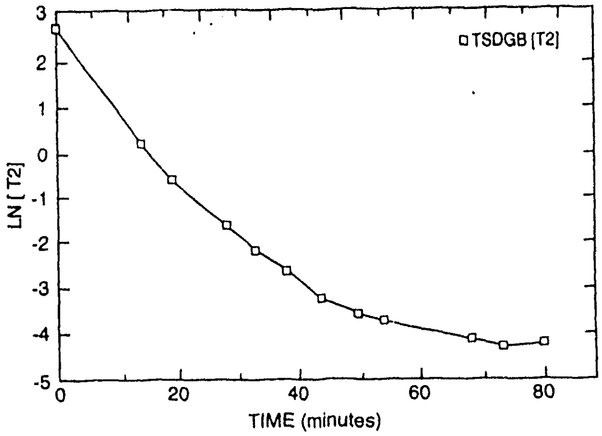

Fig. 4 TSDGB Cleanup, initial tritium load was 26 mCi.

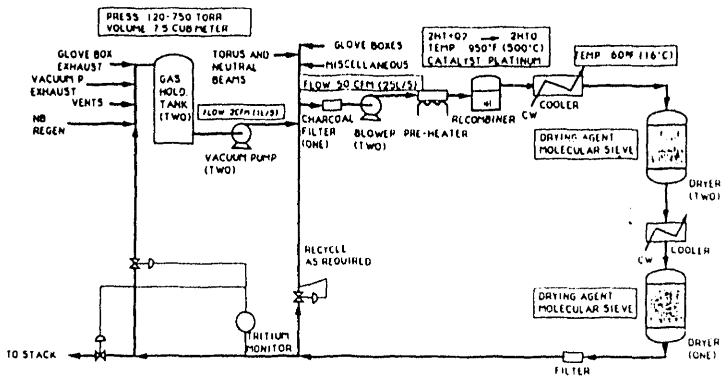

Fig. 5 Torus Cleanup System

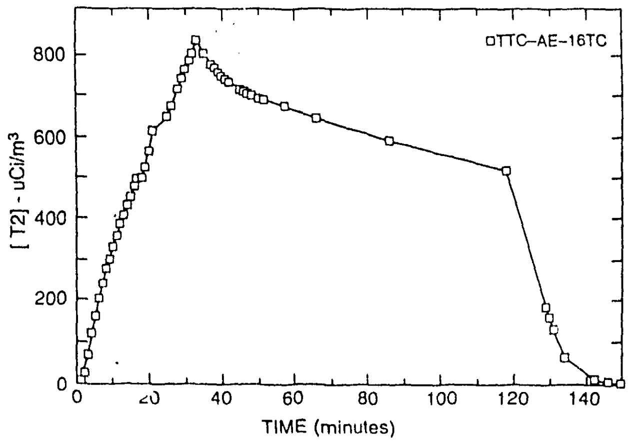

Fig. 6 Tritium concentration at outlet of TCS during ISTP-194

on the area (room) monitor and this activated the Tritium Vault Cleanup System (TVCS). The TVCS quickly cleaned the vault atmosphere, removing the tritium by oxidation to form tritiated water and collecting the tritiated water on molecular sieve. This was an unplanned test of the TVCS, but in fact demonstrated that the system works as designed.

Upon completion of the calibration of the second monitor at Los Alamos, this monitor was installed on the GHT and used to analyze the contents. Measurements taken with the calibrated monitor proved that all of the tritium was indeed in the GHT and that the original monitor installed on the GHT had not been functioning properly.

At the conclusion of these tests, a summary of the tritium inventory data was generated. Table 1 summarizes the inventory data. These data show that all of the tritium introduced into the TSDS from the original shipping container has been identified and measured at the end of the experiment. The ~6 Ci identified as Process Holdup has not been measured, but is inferred by difference. The DOE level of accountability for tritium is to the nearest 0.01 g (100 Ci). These data show that the measurements at TFTR are at a much higher sensitivity than required by DOE for inventory control.

Table I
INVENTORY SUMMARY
Tritium Systems Test

	CURIES
Recieved from LANL	125.8
Transferred to Tritium System	121.6
Residual Gas Left in Shipping Container	4.2
Current Location of Tritium Used In Tritium Systems Test:	
	CURIES
Torus Cleanup System	82.3
Gas Holding Tank A	20.6
Gas Holding Tank B	0.6
Residual on U-Bed 1	0.4
Stack Release	11.0
Process Holdup (not measured)	6.7
Total Ending Tritium	121.6 Curies

CONCLUSIONS

The Tritium Systems Tests on the TFTR tritium systems have been completed successfully. No major leaks or equipment failures were detected in the primary tritium systems. One relatively small leak was corrected by tightening a valve bonnet nut. During a maintenance operation, a small (11 Ci) tritium release occurred. This resulted in activation of the Tritium Vault Cleanup System. Testing the TVCS had not been an objective of these tests, however, this event demonstrated that the TVCS does operate and function as designed.

These tests were conducted with slightly over 100 Ci of tritium. At the end of the test, we were able to account for all of the tritium, thus demonstrating measurement capability well in excess of that required by current DOE requirements for inventory control. Through these tests the operating staff at TFTR have gained valuable "hands-on" tritium experience. With this series of tests successfully completed, the tritium staff at TFTR is now ready to proceed with expanding the tritium boundary up to and into the tokamak and into the vacuum systems.

ACKNOWLEDGMENTS

Many TFTR engineers, scientists, technicians and Tritium Operators helped in the planning and execution of these tests. Without their dedicated and tireless contribution, we would not have been able to conduct this work. We are also appreciative of the help of Dr. Scott Willms, LANL, in conducting the hydrogren tests on the cleanup systems and Mr Dick Olsher and his staff at LANL for calibrating our Femto-tech monitor.

This work was supported by US DOE Contract #DE-AC02-76-CHO-3073.

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PUBLICATION TITLE/DATE: IEEE Meeting, Hyannis, Massachusetts, Oct. 11-15, 1993

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