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OVERVIEW OF TRITIUM PROCESSING DEVELOPMENT
AT THE TRITIUM SYSTEMS TEST ASSEMBLY

by

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ABSTRACT

The Tritium Systems Test Assembly (TSTA) at the Los Alamos National Laboratory has been operating with tritium since June 1984. Presently there are some 50 g of tritium in the main processing loop. This 50 g has been sufficient to do a number of experiments involving the cryogenic distillation isotope separation system and to integrate the fuel cleanup system into the main fuel processing loop. In January 1986 two major experiments were conducted. During these experiments the fuel cleanup system was integrated, through the transfer pumping system, with the isotope separation system, thus permitting testing on the integrated fuel processing loop. This integration of these systems leaves only the main vacuum system to be integrated into the TSTA fuel processing loop. In September 1986 another major tritium experiment was performed in which the integrated loop was operated, the tritium inventory increased to 50 g and additional measurements on the performance of the distillation system were taken. In the period June 1984 through September 1986 the TSTA system has processed well over 10^8 Ci of tritium. Total tritium emissions to the environment over this period have been less than 15 Ci. Personnel exposures during this period have totaled less than 100 person-mRem. To date, the development of tritium technology at TSTA has proceeded in progressive and orderly steps. In two years of operation with tritium, no major design flaws have been uncovered.

INTRODUCTION

The Tritium Systems Test Assembly (TSTA) at Los Alamos is charged with developing the tritium technology required to fuel a fusion reactor. This technology includes vacuum systems for exhausting unburned D,T from the reactor; purification systems for removing chemical impurities from this exhaust gas; isotopic separation systems for separating HD, D₂, T₂, and DT; circulation and transfer pumps; and the evaluation, but not development, of tritium pellet injectors. A second major task at TSTA is the development and evaluation of safety and environmental systems associated with the tritium handling facilities at a fusion reactor. This includes development of new tritium monitors; room air detritiation systems; gaseous effluent detritiation systems; secondary and tertiary containment techniques; and techniques for performing routine and emergency maintenance on tritium contaminated systems.

Tritium experiments were initiated in June 1984 when 10 g of tritium was introduced into the cryogenic distillation isotope separation system. Since June 1984 the system has processed approximately 10⁸ Ci of tritium.

The success of these operations is at least partially demonstrated by the fact that in the 19 month period from June 1984 through August 1986, tritium emissions to the environment have been less than 7 Ci as elemental tritium and less than 6 Ci as tritium oxide. This is a record unmatched by any other major tritium facility. Personnel exposures during this period have totaled less than 100 person-mRem. Experiments performed during this period include the tests on the isotope separation system,¹ tritium testing of a palladium alloy membrane diffuser,² evaluation of a ceramic electrolysis cell for decomposing tritiated water,² and tests to study the contamination and decontamination of surfaces exposed to elemental tritium and tritium oxide.³

RECENT OPERATIONS

In January 1986 two major experiments involving the isotope separation system were performed. The isotope separation system is a cryogenic, fractional distillation system.⁴ This system takes 20-24 hours to cool from room temperature to liquid hydrogen temperature (20K), to liquify the hydrogen and to establish near equilibrium conditions in each of the four columns.

Also, when shutting down the system, it takes several hours to warm the columns, vaporize the hydrogen isotopes and transfer all of the hydrogen gas to the uranium beds for long-term storage as uranium hydrides. For this reason, a major experiment takes several days to conduct. During these periods, the TSTA must continuously be staffed by a minimum of two experienced, knowledgeable people. Within the limitations of our staffing level, as dictated by budget constraints, it is difficult to operate frequently for extended periods of time. Because we are thus limited in how frequently we can schedule these major runs, we must carefully plan the experiments to be performed during these periods.

The first run in January 1986 was the first major experiment since June 1984. Following the June 1984 run, several small, but significant modifications were made to the isotope separation system and to the associated plumbing. Because of this long down-time between experiments, it required even longer than the planned 24 hours to bring the distillation system on-line. Once on-line, several significant accomplishments were attained. During this run the tritium inventory in the isotope separation system was increased from ~10 g (10^5 Ci) to ~30 g (300,000 Ci). Hydrogen and deuterium gas was removed from the distillation system and replaced by tritium over a period of two days as the tritium inventory was increased to the 30 g level. This demonstrated the ability to replace and to change the gas mixture to the isotope separation system. During this experiment, the isotope separation system was operated in a recycle mode. In this mode, products from the four columns are mixed together and this mix fed as input to the first column.

At the end of this week, the isotope separation system was shut down and the new deuterium-tritium gas mixture was quantitatively transferred to the uranium storage beds. One week later a second major experiment was conducted, again involving the isotope separation system. This time we were able to bring the distillation system on-line quickly (less than 24 hours) and to re-establish the stable operating mode reached during the first week. Once this state was established, the chemical impurity removal system, (the fuel cleanup system) was interfaced with the isotope separation system. This integration of these two major systems plus the associated transfer pumping system was a major advance in the TSTA program. During this test the D,T gas mixture

was circulated through the fuel cleanup system, using the TSTA developed, all-metal transfer pumping system, into the cryogenic distillation system. The D,T gas used during this test was free of chemical impurities so the fuel cleanup system was not used to remove impurities. The major goal of this test was the integration of the fuel cleanup-transfer pump-isotope separation systems.

In addition to the integrated operation of this loop with a 30 g tritium inventory, several other technical goals were achieved in the January operations. Within the cryogenic distillation columns, the axial composition profiles of hydrogen isotopes were measured. We also began to accumulate a data base on how flow rates, pressure differential and hydrogen isotope ratios affect the interactions among the four columns.

In September 1986, a third major experimental campaign resulted in the increase of the tritium inventory in the loop to 50 g. In this experiment we again operated the integrated fuel cleanup, transfer pump, isotope separation system in the recycle mode. During this experiment the molecular sieve front-end portion of the fuel cleanup from the tritium which was added to the system to increase the inventory to the 50 g level. The impurities removed were primarily N_2 but some traces of other compounds of carbon, nitrogen and oxygen were successfully removed by the fuel cleanup system. Also during this experiment we prepared and collected approximately 5 g of high purity (>99%) tritium. Small quantities of tritium of purity greater than 99.9% were also collected.

The distillation system was designed for an equilibrium tritium inventory of about 90 g. Until we have introduced that complete inventory we will not be able to demonstrate completely the ultimate performance of this system for separating hydrogen isotopes. However, the total data collected through September 1986 definitely indicate that the distillation system will perform well within the design specifications. These specifications are to produce four hydrogen streams:

- 1) A HD stream free of tritium
- 2) A pure D_2 stream (>99.96% D_2)
- 3) A 1:1 mix DT stream (>99.99% DT)
- 4) A pure T_2 stream (>99% T_2)

while operating at the maximum flow rate of 360 g moles per day of a deuterium tritium gas mixture. This corresponds to a tritium flow of about 1 kg per day through the loop. This is essentially a full scale system for an INTOR-size fusion machine (1.5 GWe).

Other major accomplishments during the January experiment include the demonstration of easy start-up and rapid, safe shutdown of the system. Start-up for the first week of operation was admittedly slow, but the system had undergone significant modifications between June 1984 and January 1986. Start-up for the second experiment in January 1986 went very smoothly. At the conclusion of each of the runs in January the deuterium-tritium mixture was vaporized and the gas mixture transferred quickly to the uranium storage beds where the hydrogen isotopes are stored as solid uranium hydrides. These tests confirmed the reversible operation of our uranium storage beds.⁵

After the eight month shutdown between January and September, we were able to start up the system very quickly for the September experiments. This indicates that as the TSTA staff becomes more familiar with the system, the operations will become more routine.

MAINTENANCE TECHNIQUES DEMONSTRATED

A major accomplishment at TSTA since the start of tritium experiments in June 1984 has been the demonstration of techniques for doing maintenance and equipment change-out on tritium contaminated components. In the time between the June 1984 and the first run in January 1986, extensive modifications and maintenance were performed on these systems. Similarly, in the period between the two runs in January 1986 and immediately following the second run, extensive maintenance was performed on the system. This maintenance included replacement of some components, repair of a faulty weld joint, addition of new piping and components to the tritium contaminated system, and major modifications to the gloveboxes which provide secondary containment for these systems.

All of this maintenance and modification was performed without any major release of tritium to the facility or to the environment (<1 Ci total) and with no measurable exposure of operating personnel to tritium. This was accomplished by carefully purging and evacuating any line before starting the maintenance operation, by the use of gloveboxes as secondary containment, and by

extensive use of the flexible ventilation duct (elephant trunk) to control air flow around the contaminated components under maintenance, Fig. 1. Frequently a glovebox window had to be removed to provide adequate access to the component in question. In these cases the elephant trunk is used to provide adequate air flow by attaching the trunk to a glove port in a different area of the glovebox. This then pulls air in the box where the window is removed, across the work area, and out through the elephant trunk, thus converting the glovebox to a fume hood, Fig. 2. On very large components which might not be enclosed in a glovebox, a plastic tent or shroud can be erected around the components, again using the elephant trunk to provide an adequate air flow. The operating personnel may use self-contained breathing air units or in extreme cases, may be suited up in plastic suits with supplied breathing air.



Fig. 1. The Flexible Ventilation duct (Elephant Trunk) at TSTA.

The experience at TSTA has demonstrated that these techniques are perfectly suitable for performing maintenance on tritium-contaminated equipment. The exhaust gas from the elephant trunk is continuously monitored during operation. In future fusion facilities, if high tritium levels are detected in the gas, the stream can be routed to an air detritiation system. If the tritium levels are low (as we have observed at TSTA), this exhaust gas can be released directly to the atmosphere through the facility stack. The practical experience at TSTA in 1986 has clearly demonstrated that these techniques can and will work.



Fig. 2. The Elephant Trunk attached to a glovebox, thus converting the glovebox to a fume hood. Also shown is a Health Physics Technician providing monitoring help during a maintenance operation.

FUTURE PLANS AT TSTA

In the coming few months, a number of major experiments are anticipated at TSTA. We will continue to evaluate the efficiency of the fuel cleanup system for removing and decomposing impurities⁷ in the D,T gas stream. These tests can be done using the transfer pumping and fuel cleanup system, but will not require the isotope separation system. At the completion of these tests, a series of major experiments using the integrated process loop will be performed. During these tests the tritium inventory in the loop will be increased to about 100 g and the performance of the distillation system will be thoroughly investigated. We will also begin to do integrated operation of the fuel clean-up transfer pump-isotope separation systems at the design flow rates and with impurity injection in the D,T gas feed to the fuel cleanup system. Once these series of tests have been completed, we will work to integrate the vacuum system into the process loop and proceed to evaluate the compound cryopumps with tritium. Ultimately we will plan to operate this integrated loop for long periods of time to build up a data base on system efficiency, component reliability and system availability. This data base will then be available to designers of future fusion machines such as the Compact Ignition Tokamak (CIT), the Fusion Engineering Reactor (FER) in Japan, and the Engineering Test Reactor (ETR) now being considered on the international front.

To date the development of tritium technology at TSTA has proceeded in progressive and orderly steps. In two years operations with tritium, no major design flaws have been uncovered. In addition to operating and evaluating the existing components at TSTA, we are continuing to work on the development of new and improved components. By maintaining close contact with other tritium technology projects within the US DOE (Sandia Laboratories, Mound Laboratory, Savannah River, other Los Alamos tritium projects, and the Tokamak Fusion Test Reactor, TFTR, at Princeton) and with the developing fusion tritium programs in Japan, Canada, and Europe, we have stayed at the forefront of tritium technology. As the only integrated loop testing facility in the fusion program we have an opportunity and an obligation to develop avenues for the exchange of data, ideas, and operating experience among these parties. This is a responsibility we consider to be among our most important assignments.

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