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RECENT RESULTS AT THE TRITIUM SYSTEMS TEST ASSEMBLY*

by

J. L. Anderson and J. R. Bartlit

INTRODUCTION

The Tritium Systems Test Assembly (TSTA) project at Los Alamos is charged with developing and demonstrating the tritium technology required for the magnetic fusion energy program. Since June 1987 the project has been operated by Los Alamos National Laboratory under the joint funding of the U.S. Department of Energy (DOE) and the Japan Atomic Energy Research Institute (JAERI). At TSTA the technology under development includes reactor exhaust gas processing technology and safety systems. This project is not currently investigating the processing of tritium extracted from a breeding blanket. The processing of tritium extracted from a breeding blanket is a possible upgrade to TSTA. This possible upgrade is the subject of an ongoing study among Los Alamos, JAERI and the Argonne National Laboratory (ANL). This upgrade, the Breeding Blanket Interface (BBI) is being investigated with consideration of installing such an upgraded process systems at TSTA in the 1990-1992 time frame.

The exhaust gas processing system at TSTA is designed to demonstrate full-scale exhaust gas processing for a fusion machine of a size currently being designed for ITER. That is, the exhaust gas processing loop Fig. 1, is designed to process tritium at the rate of about 1 kg per day. Of course, deuterium is also a major component of the exhaust gas. Current gas processing uses a total gas stream comprised of ~ 65% deuterium, 35% tritium, 1-2% reactive impurities (currently nitrogen and methane) with the remaining gas hydrogen and helium. This gas is processed through the loop of Figure 1 at about 6 liters per minute. The tritium inventory required to process through this loop at this rate is about 110 g. The main process loop at TSTA has been operating at this flow rate since July 1987¹.

In addition to the operation of the main process loop, a number of nonloop experiments are underway at TSTA. This paper will update the status of both loop and nonloop studies at Los Alamos.

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LOOP OPERATIONS

In February 1988 the TSTA loop was operated around-the-clock for six days. The main objectives of this experiment was to investigate the steady state operation of the cryogenic distillation columns of the isotope separation system², and to use the cryogenic front end³ of the fuel cleanup system, Fig. 2, to continuously remove impurities (0.9% by volume nitrogen and 0.1% by volume methane) and to demonstrate on-line regeneration of saturated molecular sieve beds and recovery of the hydrogen isotopes from the impurities. For 36 hours during this run, the impurity mixture was injected into the flowing gas loop. The molecular sieve beds, operated at 77K, effectively removed the impurities to less than a few parts-per-million (the limit of detectability by the gas chromatographic analytical techniques used at TSTA). When the gas analysis indicated the impurity front reached a point at about 75% of the length of the molecular sieve, gas flow was switched to a second bed at 77K (see Fig. 2) and the first bed was heated and regenerated. The recovered impurities were oxidized in the catalytic reactor CR2 in Fig. 2. The resulting water, containing any tritium from the methane, was collected on the molecular sieve bed freezer at 160 K. After collecting all of the water the freezer was warmed, the water vapor passed over the hot uranium in Hot Metal Bed 4 where uranium oxide was formed. The hydrogen isotopes were fed back into the main process loop, as shown in Figure 2. Using this impurity mixture, we thereby demonstrated continuous impurity removal and on-line regeneration of a saturated molecular sieve bed, followed by recovery of the hydrogen isotopes contained in the impurities. This was an important demonstration, as the hydrogen species in impurities in an actual reactor exhaust gas stream will be primarily deuterium and tritium. Therefore, it is imperative that these hydrogens be recovered and recycled. The successful operation of the cryogenic distillation system during this experiment has been previously described by Sherman et al.⁴ A brief summary of these results include several days of steady-state operation, thus allowing the measurement of concentration profiles of hydrogen isotopes along the length of the columns. This data can then be used to compare actual performance of the columns with that predicted by design codes. A sample of about 10 g of ultrapure tritium was collected from the reboiler of the T Column, Figure 3, during this run. The purity of the tritium, as measured in the final collection volume was >99.98% with the only detectable impurity being deuterium. This demonstrated the adequacy of the TSTA isotope separation system design to prepare tritium of a purity required to fuel the Tokamak Fusion Test Reactor (TFTR) at Princeton.

In May and June 1988, the exhaust gas processing loop was again operated for five days around-the clock. During this test, the final subsystem was integrated into the loop. This is the vacuum facility (VAC). The vacuum facility at TSTA is based on the use of compound cryopumps⁵. The compound cryopump tested in this loop operation was designed and constructed by Brookhaven National Laboratory (BNL) and uses activated charcoal as the cryosorption surface. Tests during this experiment demonstrated the ability to pump DT gas as well as DT with up to 10% He on this pump. Tests to demonstrate separate regeneration of the cryocondensation (hydrogen) panel and the cryosorption (helium) panel were performed. The results of

the regeneration tests are not completely definitive. The regeneration gas from the cryocondensation surface was indeed pure DT with no detectable He; however, the helium regenerated from the cryosorption surface contained some 10% DT. It is not yet known whether this is a basic design problem with the compound pump, or if the contamination of the helium with DT occurred during the regeneration cycle. Additional tests will have to be performed.

NON LOOP EXPERIMENTS

A. Pellet Injector Tests

The Oak Ridge National Laboratory (ORNL) has built a single shot, proof-of-principle tritium pellet injector. This injector has been installed at TSTA for tritium testing⁶. It must be emphasized that the role of TSTA in these tests was to provide a facility, expertise, and tritium to accommodate the ORNL experimental program. P. W. Fisher, ORNL, is the Principal Investigator for this project. In tests at TSTA during May-August 1988, some 80 tritium pellets were made and accelerated to velocities up to 1400 m/s. This series of tests was the first production and acceleration of tritium pellets. Details of these tests are reported by Fisher⁷.

B. Vacuum Facility Tests

In addition to the operation of the VAC facility as part of the integrated TSTA loop, a number of pumping/regeneration tests were performed on two compound cryopumps at TSTA. The BNL pump used during the integrated loop run was testing with a variety of deuterium-helium gas mixtures. The pumping speed and capacity were measured as a function of gas feed rate with several gas mixtures from pure deuterium to deuterium - 25% helium.

The second pump, designed and fabricated by Lawrence Livermore National Laboratory (LLNL) was initially an argon frost pump⁵. However, this pump has now been modified by LLNL to remove the argon frost capability and replaced by a cryosorption panel of activated charcoal. This pump has not been used in any integrated loop pumping tests, but a series of tests pumping deuterium-tritium-helium and deuterium-helium mixtures have been conducted. The tests then serve as a basis for comparing the operation of the two pumps. Briefly, the results obtained in these tests, conducted by H. Yoshida, JAERI and C. R. Walthers, LLNL, are summarized below.

- The pumping speeds for the two pumps for pumping D-T, as measured in the vacuum chamber (torus mockup), were similar despite large differences between the pumps in the

areas of the cryopumping surfaces (i.e. these tests were conductance limited due to the experimental setup). The pumping surfaces are:

	<u>BNL (cm²)</u>	<u>LLNL (cm²)</u>
DT Condensing chevron	2400	9000
He sorbing panel (charcoal)	1300	11000

- The BNL pumping speeds (in loop operation) were in the range of 2-10% of the full plasma exhaust gas flow rate for an ITER-size reactor.
- Impurity effects on the pumping speed for D-T and D₂ were investigated with 1% N₂ and 1-25% He. Little effect was seen.
- A Monte Carlo simulation code to evaluate the BNL pump performance was developed. Detailed analysis of the test results are ongoing.

CONCLUSIONS

The recent series of tests, both loop operations and nonloop experiments continue to build on the tritium technology data base for fusion. The exhaust gas processing loop in operation at TSTA has been shown to be adequate to process the exhaust gas from an ITER size machine. There are possibilities for upgrading and improving the technologies employed in this loop, especially in the fuel cleanup system. The LANL-JAERI team at TSTA will continue to evaluate these possibilities. In 1990 an upgraded fuel cleanup system, based on a palladium-silver alloy membrane diffuser and a ceramic electrolysis cell⁸ will be installed and tested at TSTA. This new system offers the possibility of an improved system for removing impurities without the generation of solid waste products (uranium oxide). A final decision as to which system is best is still several years in the future. The important conclusion to be drawn from the present experiments at TSTA is that an exhaust gas processing system adequate for ITER has been demonstrated.

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This paper is a summary of work performed by the TSTA staff including personnel from the Los Alamos National Laboratory and the Japan Atomic Energy Research Institute. Detailed discussions of much of this work will be covered in future publications by the staff. Our appreciation for the dedicated, hard work of the staff is expressed.

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Figure 1. Schematic diagram of the fusion fuel cycle.

TSTA FUEL CLEANUP SYSTEM

Figure 2. TSTA Fuel Cleanup System

Figure 3. Flow Paths for Isotope Separation System