Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

TITLE: CONTINUED STUDIES OF CO-PUMPING OF DEUTERIUM AND HELIUM
ON A SINGLE, 4K ACTIVATED CHARCOAL PANEL

Received by OST

OCT 0 4 1990

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SUBMITTED TO:

Ninth Topical Meeting on the Technology of Fusion Energy
Oak Brook, IL, October 7-11, 1990

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**CONTINUED STUDIES OF CO-PUMPING
OF DEUTERIUM AND HELIUM ON A SINGLE,
4K ACTIVATED CHARCOAL PANEL**

by

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September 1990

TEST APPARATUS

The Tritium Systems Test Assembly (TSTA) was set up, in part, to evaluate components that were developed for operation in the fusion fuel cycle, specifically to assess the effects of tritium on their performance and life. Pursuant to this objective, the program procured three cryopumps which were each candidates for use in the fuel cycle. The pumps were configured as compound pumps; that is the pumps had the capability of separately accumulating the hydrogen isotopes (deuterium and tritium) and the helium. This arrangement had two purposes. The separately captured gases could be roughed to separate sections of the fuel cleanup and recovery elements of the cycle, and clogging of the sorber included in the pump to capture helium could be prevented. The issue of clogging of the sorber was addressed in 1989 (Ref. 1) in a test program at TSTA. The reference noted also that a TSTA study negated the need for helium separation.

The short program undertaken in 1989 to evaluate the feasibility of co-pumping deuterium and tritium (DT) and helium on a charcoal sorbent showed that the charcoal will indeed simultaneously pump the gases. Of interest also was the fact that the total accumulation of helium (capacity) was virtually identical in constant throughput runs in which the D_2 /He ratio was changed between runs. The test program described here was undertaken to evaluate further the co-pumping capabilities of the charcoal sorbent.

A cryopump supplied by LLNL, one of the three provided for TSTA, and fitted with a charcoal/binder surface devised by Grumman was the test item for these tests and last years tests. The pump (Fig. 1) featured a set of concentric cylindrical arrays. the largest,

outer array was a liquid helium-cooled panel whose inner surface was coated with activated charcoal. In board of that is an opaque chevron array which is normally cooled with liquid helium to pump DT for DT/helium separation. The inner cylindrical array is a liquid ntirogen-cooled louvered thermal shield. For the subject test the chevron temperature was not actively cooled and its temperature allowed to "float" between that of the charcoal and the louver, so that all gases were pumped by the charcoal.

The vacuum system (Fig. 2) as part of the TSTA is capable of handling tritium, although that gas was not used in this test series. The test (LLNL) pump's 40-cm bottom flange mounts on a 40 cm gate valve and duct leading to a 1 m³ tank simulating the torus. The second (by BNL) of the three pumps initially procured, installed for evaluation or for roughing of the test pump, was not used. Regenerated gases were pumped by the turbomolecular pump shown.

TEST METHOD

The LLNL pump was prepared for testing by baking the charcoal at approximately 120°C for 24 hours while desorbed gases were pumped with the turbopump. Pressures were maintained in the 10⁻⁴ torr range during bakeout. Seventy-two hours prior to the first run, liquid nitrogen was added to the shields. The sorbing and condensing surfaces of the pump ("compound" configuration) were allowed to cool to near-liquid nitrogen temperature by thermal radiation to the 77 K shields, and then to 4 K for testing. Following the tests, gaseous conduction of regenerated gases allowed the cryopump to warm to room

temperature overnight. Regeneration of the condensing and sorbing surfaces was achieved by passing heated helium gas through the panels until a temperature rise of 100 K was noted.

Pumping speeds were determined by establishing a steady feed rate of the desired test gas and recording pressure within the torus. Speed was calculated from the relationship:

$$S = Q/P$$

where S is the speed in liters per second. Q is the feed rate in torr liters per second and P is the pressure in torr. The base pressure of the pump was several decades lower than the test pressures and was ignored in the determination of pump speed. Pressure was measured by nude Bayard-Alpert gages mounted in the torus. In-situ calibration of the gages with the test gases was performed before the measurements described herein.

For runs in which all test gases were to be pumped on the charcoal surface, the condensing surfaces of the pump were pre-chilled to approximately 70 K by passing cold helium gas through the panel (cryosorber only configuration). During the test these surfaces tended to float at this temperature.

Figure 3 shows, grouped by the two test types, the tests performed. For co-pumping tests, deuterium and helium at constant throughputs and at the mixture ratios shown were pumped from the torus until impending runaway was evident. In the pre-load tests,

deuterium was pumped until the prescribed amount, stated in torr-liter per cm^2 of charcoal frontal area, accumulated in the test pump, at which time helium alone was fed at a constant rate until impending runaway.

During selected co-pumping runs the throughput of deuterium and helium was interrupted periodically for 15 minutes and the reference pressure recorded as a measure of isotherm conditions for the mixtures on charcoal. A similar test of helium pumped on the charcoal (Ref. 2) showed that pressure had approached a stable value in 15 minutes. Note that the data taken here as well as other data in this subject test series are specific to the pump configuration tested.

DISCUSSION OF RESULTS

The tests described here were undertaken to evaluate further the results from two runs of the previous years (Ref. 1) program. When deuterium and helium were co-pumped by liquid helium-cooled charcoal these results were observed: Helium pumping speed was lower compared to pump speed in runs using no deuterium, and the quantity of helium sorbed, up to impending thermal runaway, was independent of the deuterium/helium throughput mixture ratio (for the two ratios tested). Two methods were used here: (1) Preload tests--deuterium was pumped until a predetermined accumulation was reached, then helium was pumped and (2) Co-pump tests--deuterium and helium were co-pumped at various mixture ratios. Runs were ended when the reference pressure rose noticeably.

The results of the two test types showed marked similarities: helium pumping speed is reduced in the presence of deuterium and the capacity of charcoal for helium is relatively

unaffected by the accumulated deuterium amount, except in runs where the deuterium amount introduced throughput to the pump was low.

Figures 4 shows the effect of the presence of deuterium on helium pumping capacity for runs in which the deuterium preload ranged from zero to 10 torr-liter/m² of charcoal surface frontal area. Helium capacity reduced markedly from the zero preload (reference) run in which the helium capacity was 1.4 torr liter/cm². However, for runs in which the deuterium preload was approximately 1 torr liter/cm² or greater, the helium capacity, for the range of conditions tested, was relatively constant at about 0.6 torr liter/cm². Helium pumping speed (Fig. 5) was reduced as the amount of preload was increased. For the run in which the deuterium preload was 10 torr liter/cm², helium speed was 75% of its value obtained in the reference run.

Figure 4 also shows the effect that co-pumping helium and deuterium has on charcoal capacity for helium. Over the range of helium-deuterium mixtures tested from zero to 95% helium, helium capacity again reduced as the presence of deuterium was increased. Helium capacity was 0.7 torr liter/cm² for the 67/33 helium-deuterium mixture ratio run compared to the reference (no deuterium) capacity of 1.4 torr liter/cm². However, the capacity reduction as a function of mixture ratio lessened as the ratio was decreased from 67/33 to 5/95. Helium capacity after a 5/95 helium-deuterium mixture ratio run (Ref. 1) was 0.4 torr liter/cm².

A clear conclusion cannot be drawn from the results beyond the fact the charcoal

cooled to liquid helium temperature can pump helium effectively in the presence of deuterium, in spite of the fact that the deuterium is exposed to temperature-pressure conditions at which it is expected to condense and solidify. It appears that the deuterium is being sorbed by the charcoal and that the helium is competing with the deuterium for sites in the charcoal matrix.

CONCLUSIONS AND RECOMMENDATIONS

Based upon results to date and pending tritium compatibility tests under way at TSTA, activated coconut charcoal seems ideally suited for single panel pumping of DT-helium fusion reactor exhaust. The results would have more value if the surface coverage of charcoal in the LLNL pump could be measured. Measurements may be possible by inference from testing on disks in the TSTA charcoal/tritium exposure cryostat. Knowledge of the desorption characteristics of the charcoal has not been taken during these tests because there is no means of precisely controlling temperature on the LLNL cryopanel. It is recommended that cryosorber materials being developed in the ITER program be obtained for side-by-side testing against charcoal in the tritium exposure cryostat as they become available.

Figure 1. Cryopump arrangement (Thermal Shielding Not Shown)

Figure 2. Flow paths for D_2 /He Pumping Tests

CO-PUMPING OF HELIUM AND DEUTERIUM

<u>Date</u>	<u>Test Gas</u>	<u>Helium Capacity</u> <u>torr liter/cm²</u>
05/17/90	95/5 D ₂ /He	.4
05/31/90	75/25 D ₂ /He	.5
06/01/90	50/50 D ₂ /He	.6
06/01/90	33/67 D ₂ /He	.7

HELIUM PUMPING WITH DEUTERIUM PRELOAD

<u>Date</u>	<u>D₂ Preload</u> <u>torr liter/cm²</u>	<u>Helium Capacity</u> <u>torr liter/cm²</u>
05/24/90	0	1.9
05/30/90	0	1.3
05/31/90	0	1.3
05/29/90	0.5	0.70
05/25/90	1	0.55
05/29/90	2	0.58
05/18/90	5	0.45
05/21/90	5	0.65
05/23/90	5	0.6
05/22/90	10	0.7

Figure 3. Test Run Log

4K CHARCOAL CRYOSORBER

Figure 4

IS 1290 2/00

4K CHARCOAL CRYOSORBER

Figure 5

END

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